CONTENTS

CONTENTS

Welcome Message

As the General Chair and Co-chair of the conference, it is our great pleasure to cordially invite you to the 16th International Meeting on Information Display (IMID 2016), to be held at the ICC Jeju, Jeju island, Korea from August 23 to 26, 2016.

On behalf of the Organizing Committee of the IMID 2016, we would like to welcome all participants, including the Invited Speakers, Exhibitors, and all guests to the conference.

The IMID has been held every year since 2001 and organized by the Korean Information Display Society (KIDS), the Society for Information Display (SID) and the Korea Display Industry Association (KDIA). The IMID has become a premier conference with more than 1,800 attendees every year, where many academic, industry, and business leaders meet, publish R&D results and share knowledge of information displays.

We truly speak with confidence that IMID 2016 provides the opportunity for you to share experience, challenges, and innovative solutions with colleagues from around the world.

Our IMID 2016 Committee, composed of experts from the major information display organizations in the world, will prepare various programs focused on recent achievements in the field and outlining trends in the operations of future missions.

In the IMID 2016, 3 keynote addresses, technical oral and poster presentations, workshops, industrial forum, special exhibition and special tour will provide great opportunities to share the most up-to-date scientific discoveries and innovative ideas..Your contributions of papers and presentations as well as active participation in the conference will make the events even more fruitful.

The committees are especially pleased that IMID 2016 will be held in the world-renowned resort island of Jeju, an oval-shaped volcanic island characterized by mild oceanic climate throughout the year. The island has been designated by UNESCO as a Global Geopark in 2010 for its unique geological features and scenic beauty for the world to preserve.

For every attendee, the IMID 2016 will be not only a great opportunity to enrich their professional network, but also an excellent occasion to visit and enjoy Jeju Island, one of UNESCO's World Natural Heritage sites.

Great weather, a site of superb scenic beauty and delicious cuisine, together with friendly and warm faces await you.

We assure you that this conference will be an academically enriching, socially enjoyable, and memorable experience for all the delegated and their guests.

Thank you.

Sincerely,

Jong Sun Choi
The General Chair of IMID2016
President of KIDS

Jun Souk
The General Co-Chair of IMID 2016
Director of SID Korea Chapter

Program Overview

• Workshop

09:30~15:30, Tuesday, August 23, 2016 / 3F, Room A (Halla Hall A)

Advances Towards Interactive Displays and Immersive Visual Experiences
Dr. Achin Bhowmik (Intel Corp., U.S.A)

A Window to Virtual, Mixed, or Augmented Reality
Dr. Joo Hwan Kim (NVIDIA, U.S.A)

Basics & Technical Challenges of Flexible Displays
Prof. Ki-Yong Lee (Hanyang Univ., Korea)

Nanocarbon Hybrid Electrodes for Touch, Flexible and Wearable Electronics
Dr. Geon-Woong Lee (KERI, Korea)

From Evaporable to Solution-Processable State-of-the-Art Materials: Challenges and Opportunities
Dr. Remi Anemian (Merck KGaA, Germany)

Recent Progress of Amorphous Oxide Semiconductors: Defects and New Materials
Prof. Toshio Kamiya (Tokyo Inst. of Tech., Japan)

• Industrial Forum

09:00~15:00, Tuesday, August 23, 2016 / 3F, Room B (Halla Hall B)

Time	Title	Speaker
08:30~09:00	Registration	
09:00~09:30	Things for expanding OLED opportunities from the current market situation	Choong Hoon Yi (UBI Research)
09:30~10:00	Living Under OLEDs: A Designer's Journey & Case Study	Leslie M. North (Aurora Lighting Design, Inc.)
10:00~10:20	Coffee Break	
10:20~10:50	Advanced Materials for Next Generation OLEDs	Michiko Nagato (KONICA MINOLTA, INC.)
10:50~11:20	EPD for new display applications	Yung-Sheng Chang (Eink)
11:20~11:50	Evolution of Automotive Display	YasuoSasao, (ALPS)
11:50~13:30	Networking Luncheon	
13:30~14:00	[KEY NOTES] Introduction of display technology for VR/AR	JongSeo Lee (Samsung Display Co., Ltd.)
14:00~14:30	[KEY NOTES] Plastic-OLED market projection and application in automotive display	SanghyunAhn (LG Display Co., Ltd.)
14:30~15:00	[KEY NOTES] Future Prospects of OLED display technology	Tetsuo Urabe (Sony Corporation)
15:30 ~	Opening Ceremony	

Keynote Addresses

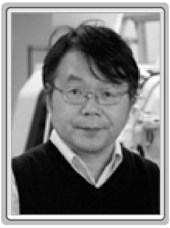
16:00~17:30, Tuesday, August 23, 2016 / Tamna Hall A (5F)

Keynote I: 16:00~16:30
Dr. Bernhard Straub
(Daimler AG, Germany)

Automotive Displays in the field of Consumer Electronic and Vehicle Integration

Keynote II: 16:30~17:00
Dr. Sung-Chul Kim
(Samsung Display Co., Ltd., Korea)

AMOLED, Future Displays and Technologies



Keynote III: 17:00~17:30
Prof. Hideo Hosono
(Tokyo Institute of Technology, Japan)

Materials Issue for Large-Sized OLEDs Driven by Oxide TFTs

Young Leaders Conference

16:30~18:00, Wednesday, August 24, 2016 / 3F Room E (#302)

Young Leaders Conference (YLC) is open to students who would like to share and discuss their research results. After oral presentations, outstanding presenters among all YLC applicants will be selected by committees from Samsung Display, LG Display, and Merck based upon their research originality and technical significance. In addition, Best Presentation Award will be given right after the session. Student presenters who apply for KIDS award are automatically candidates for the YLC presenters.

Social Events

Opening Ceremony	15:30~16:00, Tuesday, August 23, 2016 / Tamna Hall A (5F) Keynote Addresses will be followed after Opening Ceremony. Do not miss!
Opening Party	17:45~19:45, Tuesday, August 23, 2016 / Ocean View (5F) Enjoy out Opening Party! A free drink will be distributed to participants at the entrance.
Banquet	19:00~21:00, Thursday, August 25, 2016 / Woojeong Hall, Booyoung Hotel (B2F) Participants are required to present the 'Banquet Ticket' at the entrance. Great food and great performance will be there!
Special Tour	14:30~18:00, Thursday, August 25, 2016 Tour fee will be paid by cash (USD 10 or KRW 10,000) On-Site Registration desk. All tours include entrance fee as per itinerary and touring with the service of an English speaking guide. All tours are based on the estimated price and tour courses could be changed later due to the local circumstances. • ST-1 Seongsan Ilchulbong Peak (Itinerary : ICC Jeju – Seongsan Ilchulbong Peak – ICC Jeju) • ST-2 Oedolgae (Olle Trail) + Olle Market (Itinerary : ICC Jeju - Oedolgae(Olle Trail) - Olle Market – ICC Jeju) ※ We will start the boarding process at 14:00 as there will be a bus ride to the location of departure

IMID 2016 Awards

- Merck Awards
- Merck Young Scientist Awards
- KIDS Awards (Sponsored by LG Display Co., Ltd.)
- KIDS Awards (Sponsored by Samsung Display Co., Ltd.)

The awardees have been selected from papers submitted to IMID 2016 based upon their originality and the technical significance to information display industry. The awards will be presented at the Opening Party on Tuesday, August 24, 2016 at 5F, Ocean View, ICC Jeju and Banquet on Thursday, August 25, 2016 at B2F, Woojeong Hall, Booyoung Hotel.

- Best Poster Awards

IMID 2016 will present the Best Poster Award to the best poster presenters during the conference. The assessment will be conducted onsite by the judges. The award certificate will be given at the poster sessions by program committee chair of IMID 2016.

IMID 2016 Awarded Papers

Merck Awards

- **Development of Organic Semiconductors for Organic Electronics**
  Prof. Yun-Hi Kim (Gyeongsang Nat'l Univ., Korea)
- **Material Development for High Efficiency OLEDs**
  Prof. Jun Yeob Lee (Sungkyunkwan Univ., Korea)

Merck Young Scientist Award

- **Nanocrystal Quantum Dots for Light Emitting Diodes**
  Dr. Wan Ki Bae (KIST, Korea)

We will feature 'Special Lectures of Merck Awardees' that run in IMID 2016.

- **Session Title:** Special Lectures of Merck Awardees
- **Date:** Aug. 26 (Fri.)
- **Time:** 08:30~10:00
- **Session Room:** Room H (Room 402)

KIDS Awards (Sponsored by Samsung Display Co., Ltd.)

Gold Award

Suppression of Viewing Angle Dependence of Organic Light Emitting Diodes by Introduction of Circular Polarizer with Nanoporous Polymer Film

Nam Su Kim, Beom Pyo, Woo Young Lee, and Min Chul Suh (Kyung Hee Univ., Korea)

Silver Award

Selective Activation of Amorphous IGZO Thin-Film Transistors at 130℃ by Voltage Bias

Heesoo Lee, Ki Soo Chang, Young Jun Tak, Tae Soo Jung, Jeong Woo Park, Won-Gi Kim, Jusung Chung, Chan Bae Jeong, and Hyun Jae Kim (Yonsei Univ., Korea)

Bronze Awards

High-Efficiency CsPbBr3 Perovskite Light-Emitting Diodes and Investigation on Recombination Mechanism

Himchan Cho, Christoph Wolf, Hyung Joong Yun, Jong Seong Bae, and Tae-Woo Lee (POSTECH, Korea)

Highly Efficient Electron Transport Obtained by Doping Cross-linked PCBSD with Graphdiyne in Planar-Heterojunction Perovskite Solar Cells

Meng Li, ZhaoKui Wang, and LiangSheng Liao (FUNSOM, China)

KIDS Awards (Sponsored by LG Display Co., Ltd.)

Gold Award

Ultra-High-Resolution Printing of Flexible Organic Thin-Film Transistors
Xuying Liu, Masayuki Kanehara, Chuan Liu, and Takeo Minari (WPI-MANA, Japan)

Silver Award

Contact Resistance of Polycrystalline Single Layer MoS2 TFT Using Chemical Vapor Deposition Synthesis
Seung-Bum Seo, Gi Woong Shim, Sang Yoon Yang, Jihun Park, Youngjun Woo, and Sung-Yool Choi (KAIST, Korea)

Bronze Awards

Hydrogen Radical Doping Using Hydroxyl Radical Reaction on Highly-Hydrophilic Surface of IGZO Thin-Film Transistors
Hong Jae Kim, Young Jun Tak, Won-Ki Kim, Jeung Woo Kim, Byungha Kang, and Hyun Jae Kim (Yonsei Univ., Korea)

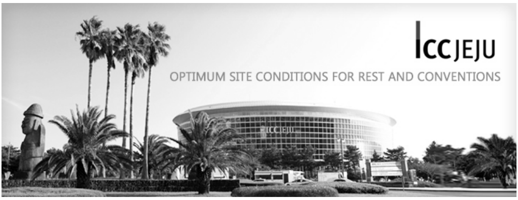
Interfaces and Pattern Resolution of Inkjet-printed Organic Light-Emitting Diode with Novel Hole Transport Layer
Dai Geon Yoon, Beom Seock Kim, Ji Yoon Hong, and Byung Doo Chin (Dankook Univ., Korea)

Light Shutter Using Dye-doped Cholesteric Liquid Crystals with Polymer Network Structure
Byeong-Hun Yu, Seong-Min Ji, Jin-Hun Kim, Jae-Won Huh, and Tae-Hoon Yoon (Pusan Nat`l Univ., Korea)

Useful Information

• Venue

Digital lifestyle has a forming influence on modern society and people are used to be always on and have all kind of information available on their electronic devices.
Accordingly a strong competition in a huge market result in continuously improved high-quality devices, which will be regarded as standard and thus influence the expectations of customers. Furthermore, main stream in consumer electronic devices will push technological development.



IMID 2016 will be held at ICC Jeju. ICC Jeju is an ideal site for our conventions.
ICC Jeju is located in the Jungmun Tourist Complex with the cobalt-blue Northern Pacific stretching on the south and towering Mt. Hallasan in the north. Spreading over an area of more than 5,000㎡, the world-class convention center is a 7-story building.
Artfully blending tourist resources and convention facility, this resort-style convention center is fully equipped for international meetings of any scale and provides professional logistic support for hosting events.

• Registration

Registration fee for the conference includes admission to all Technical Sessions, entrance to the Exhibition and Opening Party as well as a copy of the Conference Program and USB proceedings.

• On-Site Registration Fee

Conference		On-Site Registration
Regular	KIDS / SID Member	USD 640
	Non-Member	USD 740
Student	KIDS / SID Member	USD 150
	Non-Member	USD 170

• Hours of Operation

The registration desk will be available during August 23~26 on the Lobby, 3F at the following times;

Date	Time
Tuesday, August 23	08:30~18:00
Wednesday, August 24	07:30~18:00
Thursday, August 25	07:30~18:00
Friday, August 26	08:00~16:30

• Name Badge

For security purposes, participants must wear their name badges during the conference. If your badge needs any correction, please visit the registration desk for a replacement. There will be staff to check your badge at every gate of scientific rooms and poster session hall.

• Conference Kit

Conference kit will be distributed at the kit desk in the lobby of 3F (right beside the registration desk). After registration, please show your congress kit coupon to receive your kit, which includes a Final Program Book, USB Proceedings, and so on.

• Internet

• Internet Lounge

An internet lounge will be located in the lobby, 3F during the conference. All participants will be able to use computers and the internet from 08:30 to 18:00.

• Wi-Fi

Free Wi-Fi is available for IMID 2016 participants. Please see the SSID and Password for your access.

- SSID: IMID2016
- Password: imid2016kids

• Cloak Room & Lost and Found

You can store your luggage in the cloakroom #301 during August 24~26. All the lost items should be returned to the Cloak Room (3F). Should you lose anything, please report to the cloak room for assistance.

• Tax

Vlaue-added tax (VAT) is levied on most goods and services at a standard rate of 10% and is included in the retail price. In tourist hotels, this 10% tax applies to meals and other services and is added into the bill.

• Tipping

Tipping is not a traditional custom in Korea. A 10% service charge will be added to your bill at all tourist restaurants and hotels. It is also not necessary to tip a taxi driver unless he assists you with luggage or provides an extra service.

• Electricity

The electricity supply commonly used in Korea is the 200-volt 60Hz system. Because most newly built hotels and houses have the 220-volt wiring installed, you are advised to check your electronic equipment beforehand.

• Telephone

Step 1	Determine what time it is in Korea before you call. (9 hours ahead of Greenwich Mean Time.)
Step 2	Dial 001, the international access code.
Step 3	Dial 82, the country code of Korea.
Step 4	Dial the area code of the city you wish to call with 0 removed. [Jeju: 64, Seoul: 2, Daejeon: 42, Busan: 51]
Step 5	Dial the remaining digits.

001(International Access Code) + Country Code + Area Code + Remaining Digits

EX) Calling Secretariat of IMID 2016, Please refer to the following steps; +82-42-472-7460

• Emergency Phone Number

- Medical Emergency: 1339
- Emergencies for Fire, Rescue & Hospital Services: 119
- Police: 112
- First Aid Services: 129

Shuttle Schedule

During the IMID 2016, we run shuttle bus for our participants. So, you can take a shuttle bus in 3F, ICC Jeju Entrance.

Hotel Shuttle of IMID 2016

- Route: Hyatt Regency Jeju ↔ Hotel Hana ↔ Corea Condo ↔ ICC Jeju

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.23 (Tue.)	1st	Departure	Hyatt Regency Jeju	08:30
			Hotel Hana	08:35
			Corea Condo	08:40
		Arrival	ICC Jeju	08:45
	2nd	Departure	Hyatt Regency Jeju	09:00
			Hotel Hana	09:05
			Corea Condo	09:10
		Arrival	ICC Jeju	09:15
	3rd	Departure	ICC Jeju	17:40
			Corea Condo	17:45
			Hotel Hana	17:50
		Arrival	Hyatt Regency Jeju	17:55
	4th	Departure	ICC Jeju	18:10
			Corea Condo	18:15
			Hotel Hana	18:20
		Arrival	Hyatt Regency Jeju	18:25

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.24 (Wed.)	1st	Departure	Hyatt Regency Jeju	07:30
			Hotel Hana	07:35
			Corea Condo	07:40
		Arrival	ICC Jeju	07:45
	2nd	Departure	Hyatt Regency Jeju	08:00
			Hotel Hana	08:05
			Corea Condo	08:10
		Arrival	ICC Jeju	08:15
	3rd	Departure	Hyatt Regency Jeju	18:00
			Hotel Hana	18:05
			Corea Condo	18:10
		Arrival	ICC Jeju	18:15
	4th	Departure	Hyatt Regency Jeju	18:30
			Hotel Hana	18:35
			Corea Condo	18:40
		Arrival	ICC Jeju	18:45

- Route: Hyatt Regency Jeju ↔ Hotel Hana ↔ Corea Condo ↔ ICC Jeju

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.25 (Thu.)	1st	Departure	Hyatt Regency Jeju	07:30
			Hotel Hana	07:35
			Corea Condo	07:40
		Arrival	ICC Jeju	07:45
	2nd	Departure	Hyatt Regency Jeju	08:00
			Hotel Hana	08:05
			Corea Condo	08:10
		Arrival	ICC Jeju	08:15
	3rd	Departure	ICC Jeju	18:00
			Corea Condo	18:05
			Hotel Hana	18:10
		Arrival	Hyatt Regency Jeju	18:15
	4th	Departure	ICC Jeju	18:30
			Corea Condo	18:35
			Hotel Hana	18:40
		Arrival	Hyatt Regency Jeju	18:45

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.26 (Fri.)	1st	Departure	Hyatt Regency Jeju	07:30
			Hotel Hana	07:35
			Corea Condo	07:40
		Arrival	ICC Jeju	07:45
	2nd	Departure	Hyatt Regency Jeju	08:00
			Hotel Hana	08:05
			Corea Condo	08:10
		Arrival	ICC Jeju	08:15
	3rd	Departure	ICC Jeju	16:30
			Corea Condo	16:35
			Hotel Hana	16:40
		Arrival	Hyatt Regency Jeju	16:45
	4th	Departure	ICC Jeju	17:00
			Corea Condo	17:05
			Hotel Hana	17:10
		Arrival	Hyatt Regency Jeju	17:15

Lunch Shuttle of IMID 2016

- Route: ICC Jeju → Yeomiji Botanic Garden → Jungmun Middle School → Seogwipo Sports Center → Jungmun Hotel → ICC Jeju

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.23 (Tue.) Aug.25 (Thu.) Aug.26 (Fri.)	1st	Departure	ICC Jeju	12:00
			Yeomiji Botanic Garden	12:05
			Jungmun Middle School	12:15
			Seogwipo Sports Center	12:15
		Arrival & Departure	ICC Jeju	12:20
	2nd	Departure	Corea Condo	12:30
			Hotel Hana	12:35
			Hyatt Regency Jeju	12:40
			Yeomiji Botanic Garden	12:45
			Jungmun Middle School	12:55
			Seogwipo Sports Center	12:55
		Arrival	ICC Jeju	13:00

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.24 (Wed.)	1st	Departure	ICC Jeju	11:20
		Arrival	Kensington Hotel	11:30
	2nd	Departure	ICC Jeju	12:00
			Yeomiji Botanic Garden	12:05
			Jungmun Middle School	12:15
			Seogwipo Sports Center	12:15
		Arrival & Departure	ICC Jeju	12:20
	3rd	Departure	Corea Condo	12:30
			Hotel Hana	12:35
			Hyatt Regency Jeju	12:40
			Yeomiji Botanic Garden	12:45
			Jungmun Middle School	12:55
			Seogwipo Sports Center	12:55
		Arrival	ICC Jeju	13:00
	4th		Kensington Hotel	13:20
		Arrival	ICC Jeju	13:30

Bareve Hotel own Shuttle of IMID 2016

- Route: Bareve Hotel → ICC Jeju

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.23 (Tue.)	1st	Departure	Bareve Hotel	08:30
		Arrival	ICC Jeju	08:50
	2nd	Departure	Bareve Hotel	09:30
		Arrival	ICC Jeju	09:50
	3rd	Departure	ICC Jeju	17:40
		Arrival	Bareve Hotel	18:00
	4th	Departure	ICC Jeju	19:40
		Arrival	Bareve Hotel	20:00

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.24 (Wed.)	1st	Departure	Bareve Hotel	07:50
		Arrival	ICC Jeju	08:10
	2nd	Departure	Bareve Hotel	08:40
		Arrival	ICC Jeju	09:00
	3rd	Departure	ICC Jeju	16:10
		Arrival	Bareve Hotel	16:30
	4th	Departure	ICC Jeju	18:10
		Arrival	Bareve Hotel	18:30

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug,25 (Thu.)	1st	Departure	Bareve Hotel	07:50
		Arrival	ICC Jeju	08:10
	2nd	Departure	Bareve Hotel	08:40
		Arrival	ICC Jeju	09:00
	3rd	Departure	ICC Jeju	14:40
		Arrival	Bareve Hotel	15:00
	4th	Departure	ICC Jeju	21:20
		Arrival	Bareve Hotel	21:40

Date	Number oftimes	D / A	Classification	Shuttle 1
Aug.26 (Fri.)	1st	Departure	Bareve Hotel	07:50
		Arrival	ICC Jeju	08:10
	2nd	Departure	Bareve Hotel	08:40
		Arrival	ICC Jeju	09:00
	3rd	Departure	ICC Jeju	16:40
		Arrival	Bareve Hotel	17:00

Information on Technical Program

Preview Room

At preview room, oral presentation speaker could check their presentation material. The preview room is # 301. All participants will be able to check the materials from 08:30 to 18:00 on Aug. 24~26. Oral presentation speakers are required to upload the presentation file to the laptop computer in the session room at least 15 minutes prior to the session.

Presentation Time

- Keynote: 30 min.
- Workshops: 50 min.
- Invited Talk: 20 minutes for presentation and 5 minutes for Q&A
- Oral Presentation: 10 minutes for presentation and 5 minutes for Q&A

Poster Sessions

Each paper's presentation code will be shown on the board and adhesive tapes will be provided in the poster session area. All presenters are required to preside at their poster panels during the session for discussion with participants.

	Poster Session I	Poster Session II
Date	Wednesday, August 24	Thursday, August 25
Put-up Time	08:00~12:00	
Presentation Time	13:00~14:30	
Take-down Time	14:30~15:30	

Keynote Addresses

Date : Aug. 23, 2016 Wednesday
Time : 16:00~:17:30
Room : Tamna A (5F)
Chair : Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Keynote I 16:00~16:30

Automotive Displays in the field of Consumer Electronic and Vehicle Integration

Dr. Bernhard Straub (Daimler AG, Germany)

Digital lifestyle has a forming influence on modern society and people are used to be always on and have all kind of information available on their electronic devices. Accordingly a strong competition in a huge market result in continuously improved high-quality devices, which will be regarded as standard and thus influence the expectations of customers. Furthermore, main stream in consumer electronic devices will push technological development. From automotive perspective, vehicle design and integration aspects are important key factors for display development. However there are additional challenges due to automotive conditions. The differentiating facts will be discussed and chances and challenges for display industry will be presented.

Keynote II 16:30~17:00

AMOLED, Future Displays and Technologies

Dr. Sung-Chul Kim (Samsung Display Co., Ltd., Korea)

There was a dramatic improvement in display resolution along with increased size and market of TV and mobile applications has been growing explosively. Recently, paradigm of the market growth is shifting toward innovative designs based on enhanced form factors and the creation of new applications. Displays will be an essential part of our daily lives and it will expand our lives further and further. In this presentation, how much our daily lives will be changed by displays in the future and the technological challenges facing further AMOLED market for realizing a "Smart World" will be addressed.

Keynote Addresses

Date : Aug. 23, 2016 Wednesday
Time : 16:00~:17:30
Room : Tamna A (5F)
Chair : Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Keynote III 17:00~17:30

Materials Issue for Large-Sized OLEDs Driven by Oxide TFTs

Prof. Hideo Hosono (Tokyo Institute of Technology, Japan)

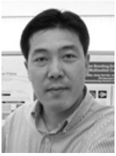
Inverted structure (bottom cathode) organic light emitting diodes have distinct advantages over normal structure in stability and image clarity when oxide thin film transistors (TFTs), a promising backplane to drive large-sized AM-OLEDs, are adapted. A major technical obstacle is the absence of materials suitable for electron injection (EIL) and transport (ETL) layers in production. We report new transparent amorphous oxide semiconductors electron-doped CaO-Al2O3 for EIL and ZnO-based materials for ETL, which have exceptionally low work function of 3.0eV and 3.5eV, respectively, Both are chemically stable and can be deposited at room temperature by sputtering method. Utilization of these materials realizes inverted OLEDs with performance superior to that of normal type devices with currently used LiF/Al. Since the ETL material has high electron mobility (~1cm2/Vs) and forms Ohmic contact with cathode materials (Al or ITO), one can tune an optimize ETL thickness for the maximum light extraction efficiency considering the thickness enough to extirpate the short circuit by through pinholes which is a critical issue for applications. A cost effective production way based on the production processes of liquid crystal displays is proposed.

Workshops

• August 23, 2016 (Tuesday)

Workshops

Chairs : Workshop Ⅰ : Prof. Jae-Hyeung Park (Inha Univ., Korea)
Workshop Ⅱ : Prof. Sung-Kyu Park (Chung Ang Univ., Korea)

Session	Time	Title	
Workshop Ⅰ	9:30~10:20		**Advances Towards Interactive Displays and Immersive Visual Experiences** Dr. Achin Bhowmik (Intel Corp., USA)
	10:20~11:10		**A Window to Virtual, Mixed, or Augmented Reality** Dr. Joo Hwan Kim (NVIDIA, USA)
	11:10~12:00		**Basics & Technical Challenges of Flexible Displays** Prof. Ki-Yong Lee (Hanyang Univ., Korea)
Workshop Ⅱ	13:00~13:50		**Nanocarbon Hybrid Electrodes for Touch, Flexible and Wearable Electronics** Dr. Geon-Woong Lee (KERI, Korea)
	13:50~14:40		**From Evaporable to Solution-Processable State-of-the-Art Materials: Challenges and Opportunities** Dr. Remi Anemian (Merck KGaA, Germany)
	14:40~15:30		**Recent Progress of Amorphous Oxide Semiconductors: Defects and New Materials** Prof. Toshio Kamiya (Tokyo Inst. of Tech., Japan)

1 OLED System & Applications I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:15
Session Chair: Prof. Hong-Bo Sun (Jilin Univ., China)

A1-1 08:30~08:55

Invited Advanced Near-to-Eye Displays and Sensors by OLED Microdisplays

Uwe Vogel, Bernd Richter, Olaf Hild, Philipp Wartenberg, Karsten Fehse, Matthias Schober, Stephan Brenner, Judith Baumgarten, Peter König, Beatrice Beyer, Gerd Bunk, Steffen Ulbricht, Christian Schmidt, Matthias Jahnel, Elisabeth Bodenstein, Stefan Saager, Christoph Metzner, and Volker Kirchhoff (Fraunhofer Inst. for Organic Electronics, Electron Beam and Plasma Tech. FEP, Germany)

OLED-on-Silicon technology has become essential to emissive microdisplays in near-to-eye displays, e.g., upcoming smart glasses. High-resolution OLED micro-patterning, embedded sensors and emission spectra outside the visible enable advanced features. Low-power active-matrix circuitry CMOS backplane architecture broadens the application range. Recent developments will be reported here.

A1-2 08:55~09:10

Uniformity and Crosstalk Simulation on 55-inch AMOLED Panel with 4K Resolution Influenced by TFT Output Characteristics

Reiji Hattori, Chang-Hoon Shim, Chihiro Tsukii (Kyushu Univ., Japan), and Tsuneo Munakata (Jedat Inc., Japan)

The luminous un-uniformity was precisely calculated on 55-inch 4K AMOLED panel considering IR-voltage drop on the power line or cathode electrode in AMOLED depending on the pixel circuits. We classified various kinds of pixel circuits into two types, the absolute voltage programming (AVP) and the relative voltage programming (RVP) methods. In the first method, the data voltage is programmed using the absolute voltage difference between the power line and the data line voltages, while in the second method the gate voltage is applied by the change in gate voltage. As a result, RVP method is necessary for larger sized or high density panel, but the luminous variation still remains even in RVP method, which is due to the imperfection of drain-current saturation. In this paper, two types of TFT characteristics based on TFT models for Spice simulation were employed for the simulation of the pixel current uniformity on a whole panel. The simulation results of the maximum pixel current difference on the 2K and 4K panels depending on top- and bottom-emission, and Model-A and B. The results clearly show that the importance of saturation characteristics of TFT.

1 OLED System & Applications I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:15
Session Chair: Prof. Hong-Bo Sun (Jilin Univ., China)

A1-3 09:10~09:25

TOC (TFT On Color Filter) Process for Polarizer-Free OLED Panel

Ho-young Jeong, Seung-Hee Nam, Kown-shik Park (LG Display Co., Ltd., Korea), and Jin Jang (Kyung Hee Univ., Korea)

The 13.3 inch TOC (TFT On Color filter) OLED panel was developed. Cost reduction, enhancement of brightness and decrease in reflectance could be achieved by applying TOC process that can eliminate polarizer. To embody TOC structure, we developed TFT process with low temperature and peeling-free process between TFT and Color filter.

A1-4 09:25~09:50

Invited New Architectures for OLED Displays: How to Increase Lifetime and Resolution

Michael S. Weaver, Woo-young So, Michael G. Hack, and Julie J. Brown (Universal Display Corp., U.S.A.)

Previously we have presented a novel phosphorescent AMOLED display architecture that enables the fabrication of AMOLED displays using only two low resolution masking steps, and consumes comparable power, and has improved lifetime, as compared to an equivalent RGB side-by-side AMOLED display using three high resolution patterning steps. We have now further improved the design to enable the mask resolution to be only half that of the resultant display in both x and y directions. This new architecture also increases sub-pixel aperture ratios by only requiring one emissive color layer change per pixel, and therefore only one mask tolerance per pixel. The increased fill factors further improve device lifetimes. In this talk we will present further advances on this topic including steps to increase display lifetime and methods to render very high pixel resolutions necessary for virtual reality (VR) applications. Based in part on the architectures discussed above we will also disclose a new architecture which allows the user to selectively limit the amount of deep blue content in the display to mitigate the potential health issues associated with deep blue emission.

1 OLED System & Applications I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:15
Session Chair: Prof. Hong-Bo Sun (Jilin Univ., China)

A1-5 09:50~10:15

Invited Integration Strategy for Flexible and Stretchable Solid State Display

Muhammad Mustafa Hussain, Amir Hanna, Kelvin Chow, and Marlon Diaz (King Abdullah Univ. of Science and Tech., Saudi Arabia)

With the advent of display technology, we are gradually moving toward flexible display system. We anticipate commercially available flexible display technologies by 2020. Therefore, it is obvious we should think about stretchable display as that will allow us adaptively reconfigure the size and the shape of the display. While using naturally stretchable polymeric material we can potentially achieve a stretchable display, however, several critical challenges exist. First, in the past, most stretchable displays failed to mitigate the gaps created between the light emitting diodes. Second, the overall shapes could not have been changed. Therefore, to overcome those two issues, we will show two designs: (i) in a 2D arrangement with spiral configuration to achieve 1000% stretching in silicon based platform [1] and (ii) in a 3D arrangement with robotics platform, stretching in stages. Additionally, in the recent past we have demonstrated that a non-planar 3D wavy architecture of thin film transistors can facilitate higher output current and thus brighter resolution displays. Extensive device fabrication with amorphous oxide semiconductors and further characterizations show the unique advantages associated with this architecture devices in area efficient manner [2-8].

2 Oxide TFT Mobility I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:00
Session Chair: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)

B2-1 08:30~08:55

Invited Superior Electron Transport Properties of ZnON Semiconductors: An Extensive Study on the Materials Characteristics and the Associated Field Effect Devices

Yang Soo Kim and Hyun-Suk Kim (Chungnam Nat'l Univ., Korea)

High mobility zinc oxynitride (ZnON) semiconductors were grown by RF sputtering using mixtures of Ar, N_2, and O_2 gas plasma [1,2]. The RF power and O_2 to N_2 gas flow rate ratio were systematically adjusted to synthesize a set of ZnON films. The electrical properties of the layers were evaluated with respect to their microstructure and chemical composition. The carrier density is suggested to be determined by the anion composition, while the electron mobility results from quite a complex mechanism. First principles calculations indicate that vacant nitrogen sites (V_N) in N-rich ZnON may locally disrupt the electron conduction pathways, which can be restored by the incorporation of oxygen anions therein. The latter are anticipated to result in high electron mobility, of which the exact process parameters can only be found experimentally. Contour plots of Hall mobility and carrier density with respect to the RF power and O_2 to N_2 gas flow rate ratio (see Figure 1) indicate that an optimum region exists where maximum electron mobility is achieved. Using ZnON films grown using the optimum conditions, the fabrication of high performance devices with field effect mobility exceeding 120 cm^2 / Vs is demonstrated, based on simple reactive RF sputtering methods.

2 Oxide TFT Mobility I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:00
Session Chair: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)

B2-2 08:55~09:20

Invited High Mobility Oxide Materials and Their Applications

Yuki Tsuruma, Emi Kawashima, Kazuyoshi Inoue, and Koki Yano (Idemitsu Kosan Co., Ltd., Japan)

We have developed oxide TFT materials such as an amorphous indium–tin–zinc oxide (ITZO) and a polycrystalline indium–gallium oxide (IGO), as shown in Table 1. Both materials have not only high TFT mobilities compared with conventional indium–gallium–zinc oxide (IGZO), but also capabilities for low cost productions through their durability to etchants with a wet etching selectivity [1-4]. The reason why ITZO films have relative high mobility would be due to high intrinsic mobility and low trap density of states (DOS) in the bandgap. The energy gap and electron affinity of SnO_2 are close to those of In_2O_3; thus, the overlap of the In 5s orbital would be maintained, and SnO_2 itself may serve as a conductive path as a Sn 5s orbital [1]. Meanwhile, in Ga_2O_3 of IGZO, the carriers become trapped on the p-states of the Ga atoms. These behavior results in the high Hall mobility of ITZO films compared with that of IGZO films in the same carrier concentration and the low trap density with the same TFT structure in Fig.1. The high mobility of IGO films would be attributed to the In_2O_3 crystalline phase with an edge-sharing octahedral structure [2]. Although In_2O_3 films have difficulty in reduction oxygen vacancies, we have controlled carrier concentration by Ga doping. The uniformity of the mobility over the Gen. 1 substrate (300×350 mm^2) was ±0.86 $cm^2V^{-1}s^{-1}$ in irrespective of their polycrystalline structure [5]. This good uniformity would originate from low grain-boundary potential barriers < 20 meV [3] and indicate no degradation of the mobility at the grain boundary. In this presentation we will show more detail on the conduction mechanism of our high mobility materials and also discuss taking the advantage of these TFT characteristics including their applications.

2 Oxide TFT Mobility I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:00
Session Chair: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)

B2-3

09:20~09:45

Invited What have been clarified for Defects in a-In-Ga-Zn-O and What we can obtain?

Toshio Kamiya, Keisuke Ide, Hideya Kumom, and Hideo Hosono (Tokyo Inst. of Tech., Japan)

This paper will first review the present understanding of defects that have been clarified for amoprhous oxide semiconductors (AOS), and then introduce some new AOS-based materials. We should note that oxygen deficiency may work either electron trap or shallow donor depending on local structures. On the other hand, excess / weakly-bonded oxygen forms an electron trap. These two oxygen-related defects are formed under opposite fabrication conditions. Hydrogen-related defects also have similar double-face behaviors; some hydrogen causes TFT instability while some passivate defects. These understandings let us notice the importance of compensation defects due to oxygen deficiency, weakly-bonded oxygen, and passivation effects of hydrogen, and lead us to new AOS-based materials such as ultrawide bandgap a-Ga_2O_3 and light-emitting thin films.

B2-4

09:45~10:00

Hydrogen Radical Doping Using Hydroxyl Radical Reaction on Highly-Hydrophilic Surface of IGZO Thin-Film Transistors

Hong Jae Kim, Young Jun Tak, Won-Ki Kim, Jeong Woo Park, Byungha Kang, and Hyun Jae Kim (Yonsei Univ., Korea)

Hydrogen has been studied for improvement of electrical performance as carrier supplier in AOSs. However, it has a difficulty to apply to AOSs TFTs because hydrogen bond in AOSs is unstable, and hence cause critical deterioration of instability. In this study, we propose hyrogen radical doping (HRD) method for IGZO film by hydroxyl radical reaction on highly-hydrophilic surface. HRD is new oxide doping method that cann't improve electrical characteristics but also stability of oxide TFT. Highly-hydrophilic surface induced by UV irradiation has a complete wettability property and defective components: metal defects, oxygen vacancies. And then, by dipping in hydrogen peroxide solution, hydroxyl radical (OH*) effectively reacts with defective components in IGZO film by radical chemisorption. Therefore, IGZO film used HRD can decrease defect sites; $V_0^{(2+)}$ + OH* and increase stable metal oxide bond; M^+ + OH*. As a result, IGZO TFT used HRD has superior electrical performances. The mobility increased from 10.9 to 17.5 cm^2/Vs, on-off ratio increased from 1.05 x 10^8 to 3.96 x 10^{10}, SS decreased from 0.44 to 0.31 V/decade, negative Vth shift (NBTS test at 50°C) decreased from 2.4 to 0.4V, and positive Vth shift (PBS test) decreased from 5.0 to 3.4V.

3 AR / VR I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:50
Session Chairs: Prof. Jae-Hyeung Park (Inha Univ., Korea)
Prof. Jang Hyuk Kwon (Kyung Hee Univ., Korea)

C3-1 08:30~08:55

Invited Immersive and Interactive Augmented and Virtual Reality Devices with Intel® RealSense™ Technology

Achintya K. Bhowmik (Intel Corp., U.S.A.)

The recent developments in depth-imaging and 3D computer vision techniques are allowing efficient and real-time acquisition, reconstruction, and understanding of the 3D environment, which are enabling an array of life-like and immersive applications. The miniaturization of the 3D visual sensor hardware modules, development of special-purpose processors for high-performance and low-power computations, and advances in efficient software algorithms are enabling integration of these technologies into small form-factor devices for all-in-one functionalities, accurate real-time 3D-tracking with visual-inertial motion sensing, and natural interactions [1, 2]. In this paper, we present the recent advances in real-time 3D-sensing technologies provided by the Intel® RealSense™ cameras and software libraries. We describe a range of novel systems applications, including a new class of immersive and interactive augmented and virtual reality devices which are blurring the border between the real and the virtual words.

C3-2 08:55~09:20

Invited Holographic Application in AR / VR and SLM(Spatial Light Modulator) Development

Wilbur Wei-Chen Chiang (Selcos Co., Ltd., Korea), Po-Sheng Chiu (Nat'l TsingHua Univ., Taiwan), and Cheng-Huan Chen (Nat'l Chiao Tung Univ., Taiwan)

Improving development of SLM(Spatial Light Modulation) has help to speed up the use of Holographic display in many different area. Better diffraction efficiency, Fast LC response time, wide LC operating temperature range and Large data transfer band width. These factors bring real time, full color holographic display close to real life. There are many advantages with Holographic display. Better light efficiency, program controlled focus distance, larger virtual image, simplified optics design and 3D display. So, there are a lot of people trying to develop the holographic display into real application. Realviewimaging develop holographic display for the interactive medical application.

3 AR / VR I

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:50
Session Chairs: Prof. Jae-Hyeung Park (Inha Univ., Korea)
Prof. Jang Hyuk Kwon (Kyung Hee Univ., Korea)

C3-3 09:20~09:35

High Performances Electrochromic Device for Light Shutter Applications

Yong Cheol Kim, Jin Hwan Park, Ik Jang Ko,Min Jin Kim, Gyeong Woo Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

We have developed a new electrochromic device (ECD) which has very good optical properties as well as fast response time. Especially, we have tried to stabilize ionic state (lactone ring open state) of our black dye by changing solvent and electrolyte materials to improve performances of our ECD. As the results, we could obtain deep black in colored mode which has 5% lower transmittance as compared with reference device. Additionally, rising response time and memory performances were improved significantly. Detailed improved device performances will be discussed in the presentation.

C3-4 09:35~09:50

Light-Guide Optical Element Design for See-Through Glasses

Xue Xiao, Wei Chen, Zhenzhen Li, and Xiaodi Tan (Beijing Inst. of Tech., China)

Eyewear display is a new type of portable mobile devices, which could overlay virtual information on the real world. We have proposed a way to achieve see-through glasses by using an array of notch filters as optical combiners in a light-guide. On the basis of that, a new structure has been developed. The final design offers a field of view of 45 degrees and an exit pupil diameter of 11.55 mm.

4 Printed Transistors and Sensors

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:10
Session Chair: Prof. Chao Jiang (Nat'l Centre for Nanoscience and Tech., China)

D4-1 08:30~08:55

Invited Additive Printing of Flexible Electronics for Sensing

Ping Mei (Palo Alto Research Center, U.S.A.) and Tse Nga Ng (Univ. of California San Diego, U.S.A.)

Active matrix is a versatile structure used for display, sensors, and actuators. However, sensors relying on direct-current (dc) amplitude modulated signals may suffer from drift and noise over long transmission distances across a large matrix. To overcome this limitation, we encoded dc stimuli into digital signals whose alternating current (ac) frequency varies with stimulation intensity. Printed organic ring oscillator circuits, consisting of odd numbers of repeating inverter stages based on complementary field effect transistors, were used to generate the ac modulation. These circuits were integrated by the Zhenan Bao group at Stanford University into a power-efficient skin-inspired mechanoreceptor that transduces pressure into digital signals directly. As force is applied on the sensor, the output frequency ranges from between 0 – 130 Hz to mimic slow-adapting skin mechanoreceptors. The output of the sensors is demonstrated to stimulate optogenetically engineered mouse cortical neurons in-vitro, achieving stimulated pulses in accordance with pressure levels. This work has broad implications for the design and use of large-area organic electronic skins for replacement limbs with neurally integrated touch feedback.

D4-2 08:55~09:20

Invited Megahertz Flexible Low-Voltage Organic Thin-Film Transistors

Hagen Klauk (Max Planck Inst. for Solid State Research, Germany)

Organic thin-film transistors (TFTs) can be fabricated at temperatures of about 100 °C or less and thus not only on glass and polyimide, but also on inexpensive and optically transparent types of plastics, such as polyethylene naphthalate (PEN) and polyethylene terephthalate (PET), and even on paper. In advanced applications, such as integrated display drivers, the TFTs need to control electrical signals of a few volts at frequencies of a few megahertz. This can be achieved by aggressively reducing the lateral transistor dimensions, i.e., the channel length and the gate-to-source and gate-to-drain overlaps. For this purpose, we have developed a process in which the TFTs are patterned using high-resolution silicon stencil masks. With this process, bottom-gate, top-contact organic TFTs with a channel length of 1 μm, effective carrier mobilities of about 1 cm^2/Vs for p-channel TFTs and 0.05 cm^2/Vs for n-channel TFTs, on/off current ratios of 107, and subthreshold swings of about 150 mV/decade can be fabricated on flexible plastic substrates. Owing to small thickness of the gate dielectric (5.3 nm), the TFTs can be operated with voltages of about 3 V. For 11-stage unipolar and complementary ring oscillators based on TFTs with a channel length of 1 μm and a gate overlap of 5 μm, we have measured signal propagation delays per stage as short as 300 ns and 4.2 μs, respectively, both at a supply voltage of 4 V.

4 Printed Transistors and Sensors

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:10
Session Chair: Prof. Chao Jiang (Nat'l Centre for Nanoscience and Tech., China)

D4-3 09:20~09:45

Invited Patterned Top-Contact Fabrication for Short-Channel Organic Transistors

Takafumi Uemura (Osaka Univ., Japan)

In this study, novel fabrication processes for high-mobility organic transistors with photolithography-patterned top electrodes are developed. Though photolithography is a well-established technique to fabricate fine patterns, it is rarely employed in top-contact fabrication for organic thin-film transistors because conventional photoresists seriously damage the organic semiconductor layer. However, recently we have reported a novel photolithography technique using an orthogonal fluorinated photoresist that enables to make fine electrode patterns on the top of organic semiconductors without dissolution of the organic layer. In addition, recently, we have established a novel process to reduce the contact resistance in top-contact geometry by a simple annealing treatment. In the combination of these techniques, small contact resistance of ~50 Ωcm was realized in the top-contact transistors. In addition, organic transistors with high mobility ~4.5 cm^2/Vs and high on/off ratio ~10^9 were achieved in 5-μm channel-length devices. In this presentation, we will describe details of the fine electrode patterning techniques on the top of organic semiconductors, which realizes high-mobility short-channel organic thin-film transistors.

4 Printed Transistors and Sensors

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:10
Session Chair: Prof. Chao Jiang (Nat'l Centre for Nanoscience and Tech., China)

D4-4 09:45~10:10

Invited Small Molecule Organic Field-Effect Transistors for Light Detection and Thin Film Circuits: Effects of Device Structure and Interface Modification

Yingquan Peng (China Jiliang Univ., China), Wenli Lv, Xiao Luo, Yao Li, Lei Sun (Lanzhou Univ., China), Ying Wang, Sunan Xu, Ying Tang, and Yi Wei (China Jiliang Univ., China)

We achieved ultrahigh photoresponsivies of 21 A/W for near infrared and 108 A/W for red light utilizing poly(vinyl alcohol) as gate dielectric for planar heterojunction (PHJ) photosensitive organic field-effect transistors (PhOFET). By optimizing the substrate temperature during film growth and adopting a pentacene inducing layer obove SiO_2, we significantly improved the performance of single layer PbPc (lead phthalocyanine) PhOFETs. We show that by using Ag instead of Au as source/drain electrodes, the perfromance of isotype PHJ-PhOFET can be improved. By depositing a thin Au nanoparticle layer above copper phthalocyanine (CuPc), we achieved a 3 times improvement of charge carrier mobility for CuPc based field-effect transistors. Utilizing thermally evaporated lithium fluoride as the top gate dielectric and fluorinated copper-phthalocyanine (F_{16}CuPc) as the active channel material, a double-gate organic field-effect transistor (DGOFET) with balanced top and bottom channel characteristics was successfully fabricated. For fullerene based n-channel OFETs, remarkably improved device characteristics were achieved via interfacial synergistic modifications. Compared with the reference device without any modifications, the as-fabricated transistor showed a dramatic improvement of saturation mobility from 0.0026 to 0.3078 cm^2/Vs with a maximum on–off current ratio of 10^6 and a minimum subthreshold slope of 1.52 V/decade.

5 Graphene for Display

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:00
Session Chairs: Prof. Chul-Ho Lee (Korea Univ., Korea)
Prof. Gwan-Hyoung Lee (Yonsei Univ., Korea)

E5-1 08:30~08:55

Invited Graphene for Bionic Contact Lens Sensors and Displays

Sangkyu Lee (Seoul Nat'l Univ., Korea) and Byung Hee Hong (LG Electronics Co., Ltd., Korea)

Recently, smart contact lenses including electronic circuits have been developed for various purposes, where the use of flexible and biologically stable electrode materials is essential. Graphene is an atomically thin carbon materials with 2-dimensional hexagonal lattice, showing outstanding electrical and mechanical properties as well as excellent biocompatibility[1-2]. Here we report the graphene-based smart contact lens platform that can be applied to bioinic sensing and displaying for various healthcare applications. The patterned graphene film was transferred on the surface of hemispherical lenses with maintaining its electrical property as a transparent electrode for light emitting diode devices and health care sensors.[3] In addition, the use of graphene benefits from its EMI shielding function due to its ultra-high diamagnetism property that can efficiently absorbs environmental EM waves that may cause cataract in our eyes. We also tested anti-bacterial and moisturizing effect of graphene-coated smart contact lens, which will be attractive as a new bionic platform for wearable technologies in the future.

E5-2 08:55~09:20

Invited Toward Graphene OLED Display

Jaehyun Moon, Jin-Wook Shin, Jun-Han Han, Hyunsu Cho, Byoung-Hwa Kwon, Nam Sung Cho (ETRI, Korea), Kisoo Kim, Seungmin Cho (Hanwha Techwin R&D Center, Korea), and Jeong-Ik Lee (ETRI, Korea)

In this talk, we aim to convince the display community that graphene OLED display is not a pie in the sky but a tangilble reality in the next door. Graphene itself bears outstanding and exotics qualities, suggesting wide ranging applications in electronics, photonics, sensors, energy and biomedical fileds. However, attestion of a reliable performance in a graphene containing device has been a rare event. The problem lies in the feeble quality of graphene in real life. In this talk, we present and discuss technological issues which are strongly relevant to realizing graphene OLED. In particular, we focus on the patterning and integrating issues of graphene into OLEDs. As an actual precursor of graphene AM-OLED display, we developed and fabricated a fully functional graphene pixilated OLED panel. Currently, graphene may be positioned as a component, which has to be integrated into modules and systems to reach commercial level products. Regarding graphene AM-OLED display, the most important element is the establishment of a pervasive method which enables modular integration of graphene into the AM-OLED processing. We believe that our processing scheme is an important leap for graphene AM-OLED display.

5 Graphene for Display

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:00
Session Chairs: Prof. Chul-Ho Lee (Korea Univ., Korea)
Prof. Gwan-Hyoung Lee (Yonsei Univ., Korea)

E5-3 09:20~09:45

Invited Infrared Plasmonics in Graphene

Min Seok Jang (KAIST, Korea)

Graphene is an interesting material for active nanophotonics. Because of its low density of states, the Fermi energy of graphene - and thus the threshold photon energy for interband transitions - is largely tunable via electrostatic gating. More interestingly, the low carrier concentration and the atomic thinness of graphene allows for highly confined plasmonic modes whose properties are also widely tunable as a function of doping density. In my previous works, we investigated the properties of graphene plasmons at mid-infrared frequencies. The plasmon resonances in periodically patterned graphene sheets were observed as peaks in optical extinction spectra. From measurements of resonance frequency changes with nanoresonator width, we showed that the dispersion relation of graphene plasmons are fundamentally different from the conventional noble metal surface plasmons and that the wavelength of graphene plasmons is more than 100 times shorter than the free space wavelength. As a consequence of such extreme field confinement, graphene plasmons strongly interact with substrate phonons, forming hybrid modes called surface phonon plasmon polaritons. Our infrared transmission measurements revealed that the high-field confinement of graphene plasmons allows for classical strong coupling to be observed between graphene plasmons and the polar phonons of a monolayer h-BN sheet. By placing a reflector to block transmission channels and engineering the spacing between the reflector and the graphene resonators, we demonstrated that the absorption in a single layer of graphene resonators can be dynamically tuned from 0 to 25% by electrostatic gating, and possibly reach to 100% with sufficiently high carrier mobility. Kirchhoff's law of thermal radiation, which states the absorptivity and the emissivity of an object is equal, also allows for dynamic control of thermal radiation from heated graphene plasmonic nanoresonators. Graphene plasmonics may offer a unique plat form to dynamically modulate light and heat with unprecedented spatial and temporal resolutions.

5 Graphene for Display

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:00
Session Chairs: Prof. Chul-Ho Lee (Korea Univ., Korea)
Prof. Gwan-Hyoung Lee (Yonsei Univ., Korea)

E5-4 09:45~10:00

Xenon Flash Lamp-Induced Multilayer Graphene Growth

Dae Yong Park and Keon Jae Lee (KAIST, Korea)

In our group, we demonstrated a new synthesis method for high fast fabrication of graphene by flash lamp-induced heat treatment. Because a light duration of our xenon flash lamp is 3 or 15ms, all thermal process containing heating, synthesis and cooling to room temperature will take place within 3 or 15ms. This process is more 4 orders of magnitude faster than conventional CVD method. Xenon flash lamp-induced graphene synthesis method would not only be one of the best ways to mass-production of graphene, but also facilitate graphene-based device applications.

6 Processes & Analysis for Flexible Electronics

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:55
Session Chair: Prof. Han-Ki Kim (Kyung Hee Univ., Korea)

F6-1 08:30~08:45

Formation of Stretchable and Transparent, Large-Area Heaters with Wireless Operations Using Metal Nanofibers

Jiuk Jang, Byung Gwan Hyun, Sangyoon Ji, Eunjin cho, and Jang-Ung Park (UNIST, Korea)

Recently, transparent heaters require good flexibility and stretchability as the parts of wearable electronics since future smart devices have irregular shapes and arbitrary curved surfaces. Although indium tin oxide (ITO) has been widely used as the transparent resistive heater due to its good optoelectronic properties, ITO has limitations for various applications due to its fragility, especially in wearable electronics. In addition, the wireless operating system becomes essential for the wearable electronics as the importance of internet of things (IoT) increases. Here, we demonstrate a large-area transparent and stretchable heater on various substrates based on Joule heating using the random network of the ultra-long Ag nanofibers (AgNFs). Optical transmittance and the sheet resistance of electrode can be controlled by adjusting area fraction of AgNFs random network. AgNFs heater shows high temperature (250 °C) at a low operating voltage (5.5 V) and excellent temperature reliability under large strain (30%). In addition, we integrated wireless operating system with AgNFs heater. Bluetooth module and the micro-controller unit are connected to AgNFs heater so that temperature can be controlled directly. We believe these stretchable and transparent large-area heaters with the wireless operating systems can be embedded into future wearable electronic devices.

F6-2 08:45~09:00

Ink-Jet Printable Transparent QD-LEDs with Anti-Reflection Coating

Sun-Kyo Kim, Seung-Yeol Yang, Yo-Han Choi, and Yong-Seog Kim (Hongik Univ., Korea)

In order to fabricate transparent Patterned-QD-LEDs, a patterned QD layer by ink jet printing method, anti-reflection coating and a transparent electrode using silver nanowire networks was prepared in this study.

6 Processes & Analysis for Flexible Electronics

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:55
Session Chair: Prof. Han-Ki Kim (Kyung Hee Univ., Korea)

F6-3 09:00~09:15

Fabrication of Flexible Transparent Electrode by Using Graphene Flakes and AgNWs Embedded in Polymer Substrate

Ji soo Oh, Jong sik Oh, and Geun young Yeom (Sungkyunkwan Univ., Korea)

Recently, the flexible transparent conductive electrodes (TCEs) have been widely used in electronic devices such as smart-devices, actuators, energy storage, organic light emitting diodes (OLEDs) and so on. Graphene and silver nanowires (AgNWs) are the most common alternative materials applied in flexible TCEs for replacing indium tin oxide (ITO). However, AgNWs still have serious issues such as inherent roughness, easy detachment of NW junctions under tensile force, low work function, and work function mismatches. For graphene, it has also problems including high production cost and long production time obstruct its industrial applicaion. In this study, AgNWs hybridized with graphene flakes (GFs) embedded in a transparent polymer have investigated as a transprent electrode for flexible OLEDs. The results showed that, by hybridizing the GFs with AgNWs, low sheet resistance and high transmittance could be obtained while resolving the problems associated with AgNWs and graphene. The transparent flexible electrodes composed of GFs/AgNWs exhibited favorable physical properties, low sheet resistance with high transmittance, a variable work function from by using GFs doping, an ultra-smooth surface, and a low rate of resistance increase after 100,000 bending cycles. Moreover, the OLED fabricated with the flexible GFs/AgNWs hybrid TCE exhibited preferable properties comparable to those fabricated with a commercial ITO PET film.

F6-4 09:15~09:30

Self-Supplied Nano-Soldering and Exfoliating Metal Nanostructures from Substrates via Surface Oxide Reduction

Ji-Won Seo, Jaeho Ahn, and Jung-Yong Lee (KAIST, Korea)

Here, we suggest a novel post-treatment process of metal nanostrucutures that not only lowers the contact resistance efficiently, but also enhances the environmental stability. By chemical reduction reaction using a vaporized reducing agent, the oxide layers on the metal nanomaterials such as silver naowires (AgNWs), copper nanowires (CuNWs), and silver nanoparticles (AgNPs) are reduced, interlocking the junctions of nanostructure, and ensuring high opto-electrical performance as well as stability of the metal nanostructures. Experimentally, we verified the high opto-electrical performance ($T = 93$ %, $R_{sh} = 17$ Ω/□) and enhanced environmental stability (1.3-fold increment of R_{sh} after 35 days) of AgNWs. Furthermore, byproducts produced during the reduction reaction assist in exfoliating the AgNWs from the substrate and transferring them to other substrates with ease. Transferred AgNWs were applied to fabricate semitransparent organic photovoltaics (SOPVs) in order to show the applicability of the proposed process.

6 Processes & Analysis for Flexible Electronics

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:55
Session Chair: Prof. Han-Ki Kim (Kyung Hee Univ., Korea)

F6-5 09:30~09:55

Invited Characterization of the On-Screen Performance of Curved AMOLEDs

Jyrki Kimmel (Nokia Technologies, Finland)

Over the last few years, products with curved displays have appeared in the consumer electronics markets, in curved televisions, mobile phones, and smart watches. Consequently, there is a need to quantify the on-screen characteristics of curved displays. In a curved display, the appearance of the display will exhibit the effects of viewing angle variation when viewing the curved ends of the display. These effects show as reduced luminance, contrast, and shifting white point, which combine to reduce the ergonomics of the display. This paper summarizes the measurement geometry of curved displays and describes the results obtained previously with AMOLEDs with red-green-blue (RGB) side-by-side geometry. The paper expands from the previous study, concentrating on the effect of curvature of the display on the white point shift as well as on the luminance. The results show that the performance of a curved AMOLED can be predicted from the flat-state measurements, as the main contributing factor to the white point shift and to the decrease of luminance with varying the radius of curvature of the display arises from the viewing angle variation in the central-normal vantage point viewing geometry of the display, when gazing toward the curved ends of the device.

7 Solution Processed OLEDs with High Performance

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:50
Session Chairs: Dr. Takeshi Yamada (Sumitomo, Japan)
Dr. Christopher Brown (Kateeva, Inc., U.S.A.)

G7-1 08:30~08:45

The Effect of Triplet Energy of Hole Transport Layer on the Performances of Solution Processed Blue Phosphorescent Organic Light Emitting Diodes

Pil-Gu Kang and Min Chul Suh (Kyung Hee Univ., Korea)

There have been lots of interests on organic light-emitting diodes (OLEDs) due to their superior image quality resulting from the self-emissive property such as low power consumption, wide viewing angle, wide color gamut, high-speed video rate, etc. However, active matrix organic light emitting diodes (AMOLEDs) have still huge numbers of difficulties to meet the requirements for low-cost, high-resolution, and large-area processing because of the problems originated from the vacuum thermal evaporation technology utilizing shadow masking. Therefore, a solution process has drawn a considerable amount of attention as an alternative for mass production of AMOLEDs because it allows low-cost, large-area processing aforementioned. Also, solution-process OLEDs must consider selecting solvent characteristics. However, the perfect orthogonality in the solubility of the successive solution processed materials is very important to obtain highly efficient OLEDs with complicated multi-layer structure. One of those approaches is to give the perfect cross-linking characteristics to the functional materials we want to maintain from those successive wet process. We used cross-linkable hole transport materials (HTM) in this study. But, in most cases, some part of cross-linkable HTM is not cured completely which makes mixed zone between hole transport layer (HTL) and emission layer (EML). Fig. 1(a) and 1(b) show process of cross-linkable HTL. Fig. 1(c) and 1(d) show degree of crosslinking behavior of some cross-linkable HTL materials. We found that some part of the un-crosslinked materials could be washed out by spin cleaning process. We will report the influence of those spin cleaning process on the device performances including efficiency, driving voltage, impedance, etc.

7 Solution Processed OLEDs with High Performance

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:50
Session Chairs: Dr. Takeshi Yamada (Sumitomo, Japan)
Dr. Christopher Brown (Kateeva, Inc., U.S.A.)

G7-2 08:45~09:10

Invited Solution-Processed Tandem Organic Light-Emitting Devices

Yong-Jin Pu, Takayuki Chiba, Satoru Ohisa, and Junji Kido (Yamagata Univ., Japan)

Organic light-emitting devices (OLEDs) have progressed rapidly due to their great potential for energy saving lighting and TV applications. The tandem OLEDs comprising plural light-emitting-units (LEUs) stacked in series through charge generation layer (CGL) have been produced to achieve the high luminance and long operational lifetime simultaneously.[1] This tandem LEUs structure is actually used now in OLED white lightings. However, it can be made only by vacuum evaporation process due to required multilayer structures, resulting in high cost of the product. Meanwhile, the OLEDs from solution-process have attracted attention for the large area processing and low fabrication cost.[2-4] We report the fabrication of tandem OLEDs comprising two LEUs (1st-LEU and 2nd-LEU) and a CGL between the anode and cathode using only solution-based processes.[5-6] The individual components, 1st-LEU and 2nd-LEU are also fabricated independently. The ZnO/polyethyleneimine bilayer is used as the EIL in 1st-LEU and a molybdic acid derivative is used as the electron acceptor of the CGL. Appropriate choice of solvents during spin coating of each layer ensures that a nine-layered structure is readily fabricated using only solution-based processes. The driving voltage and efficiency of the fabricated tandem OLED are the sums of corresponding values of the component LEUs. These results demonstrate that the solution-processed CGL successfully generated electrons and holes and that the generated electrons and holes were injected into 1st-LEU and 2nd-LEU, respectively, when a voltage was applied, resulting in charge recombinations in each LEU.

7 Solution Processed OLEDs with High Performance

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~09:50
Session Chairs: Dr. Takeshi Yamada (Sumitomo, Japan)
Dr. Christopher Brown (Kateeva, Inc., U.S.A.)

G7-3 09:10~09:35

Invited Universal Charge Generation Layers for Solution Processed Tandem OLEDs

Stefan Höfle, Min Zhang, and Alexander Colsmann (Karlsruhe Inst. of Tech., Germany)

Common tandem OLEDs comprise charge generation layers (CGLs) from high-work function PEDOT:PSS and low-work function ZnO, only allowing the implementation of inverted device architectures (bottom cathode). Any attempt to incorporate a ZnO/PEDOT:PSS CGL into tandem OLEDs with regular architecture (bottom anode) would inevitably lead to a dissolution of ZnO in the acidic PEDOT:PSS. In this work, using metal oxides, we developed novel CGLs that simultaneously form a barrier for subsequently used processing agents and are robust towards the use of acidic components. Therefore, they can be universally employed in various regular and inverted tandem OLED architectures. Since every injected electron-hole pair generates two photons, the luminance and the current efficiency of the tandem OLED at a given device current are doubled (versus a reference single OLED) while the power efficiency remains constant. At a given luminance, the lower operating current in the tandem device reduces electrical stress and improves the device life-time.

G7-4 09:35~09:50

Low Temperature Cross-Linkable Hole-Transporting Materials for Solution-Processed Organic Light-Emitting Diodes

Jaemin Lee, Shahid Ameen, and Changjin Lee (KRICT, Korea)

After the current success of small- and large-sized vacuum-evaporated organic light-emitting diodes (OLEDs), the technological demand for process innovation therefore leads the researchers to devise new materials as well as new processes suitable for such solution-processable OLEDs. Among various kinds of materials, cross-linkable hole-transporting materials (HTMs) are very important to achieve multilayer structure of OLEDs by solution-processing successfully. Although there have been number of results about such cross-linkable HTMs, most of the previous results are adopting relatively high temperature cross-linking condition, and the investigation about temperature effects of cross-linking is relatively rare. In this work, a series of new thermally cross-linkable HTMs have been synthesized and the structure-property relationships of the cross-linkable HTMs have also been systematically investigated. We found out that the optimal cross-linking temperature of the thermally cross-linkable HTMs could be reduced as low as 150°C by controlling the cross-linking functionalities, and accordingly, the resultant OLED device characteristics could also be improved considerably. All of the new materials presented in this work have been applied to basic green phosphorescent OLEDs and the results showed enough potential of our new materials. The detailed chemical and physical properties of the new materials will be discussed in the presentation.

8 High Performance LCDs

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:10
Session Chair: Prof. Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

H8-1 08:30~08:55

Invited A High Image Quality Eco-Display Using Stencil-FSC Methods

Fang-Cheng Lin and Yi-Pai Huang (Nat'l Chiao Tung Univ., Korea)

A field-sequential-color LCD (FSC-LCD) gets rid of color filters to yield a color image by sequentially displaying three high luminance primary-color field-images. It has higher optical throughput, higher resolution, high image saturation and lower power consumption. Hence, FSC-LCDs are promising as next generation eco-displays. However, the main issue limits its commercial application is the color breakup phenomenon. Color breakup is caused by the relative movement between the human eye and the displayed image. The phenomenon degrades the image quality and leads to discomfort in human eyes. This paper introduces Stencil-FSC methods to overcome the color breakup issue.

H8-2 08:55~09:20

Invited Ideal Retarder with Negative Dispersion of Birefringence and Wide Field-of-View

Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

The key functions of the compensation films are wavelength dispersion compensation and viewing angle compensation. For the antireflection film of organic light emitting diode (OLED) displays, both of the functions are essential. To achieve the wavelength-independent compensation property, a retarder whose birefringence is increasing with a longer wavelength of light, i.e., negative dispersion (ND) of birefringence is required. Recently, we demonstrated the ND retarder using 2-dimensional self-organization of smectic liquid crystal and reactive monomers. We also developed various ND retarders with different optical structures which can be used for the compensation film of LCD as well as OLED. Recent progresses of the ND retarders and possible applications will be presented.

8 High Performance LCDs

Date: Aug. 24, 2016 (Wednesday)
Time: 08:30~10:10
Session Chair: Prof. Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

H8-3 09:20~09:45

Invited Polarized Backlights based on Aligned Nanorods: a New Approach for LCDs with High Power Efficiency

Kristiaan Neyts, Michiel Callens, Mohammad Mohammadimasoudi, and Jeroen Beeckman (Ghent Univ., Belgium)

In a Liquid Crystal Display there is a lot of light absorption in the first polarizer and in the color filters. This is because the backlight typically emits unpolarized light and about half of the light is absorbed by the linear polarizer. The white light emitting LEDs are usually based on a blue LED that is combined with a broad-band yellow phosphor and therefore the transmission through the green and the red color filters is relatively low. The absorption in the first polarizer and the color filters can be reduced (and the efficiency increased) by an appropriate design of the backlight. This can be done by using quantum dots that transform blue LED light into red and green narrow band photoluminescence or by using emitters which have a high degree of polarization and align them parallel to the transmission direction of the polarizer. We discuss the use of nanorods that are aligned in an electric field. We show that the emission can have a high degree of polarization.

H8-4 09:45~10:10

Invited Advanced Liquid Crystal Materials for FFS Mode

Chen ChaoYuan,, Wenming Han, Haibin Xu, and Wenyang Ma (Jiangsu Hecheng Display Tech. Co., Ltd., China)

Recently, dramatic increase of the applications with FFS modes, both positive and negative type, due to the wide view angle and the independent color performance with viewing angle [1-4]. However, there are still some room to improve about the response time, transmittance, high driving voltage and contrast ratio, which the liquid crystal plays the very important role. In this study, the advanced liquid crystal materials are developed and show better performance in liquid crystal mixtures such like dielectric anisotropy($\Delta\varepsilon$), optical birefringence(Δn), low temperature solubility, reliability and viscosity[5-6]. On the other hand, the advanced LC singles also show the potential of the solubility, reliability and viscosity in low temperature. Which may help the LC mixture to archive lower viscosity with the same level of dielectric anisotropy compared with commercial LC mixture. Figure 1 shows the $|\Delta\varepsilon|$ versus $\gamma 1$ of the LC mixtures, commercial one and the advanced one from HCCH. The viscosity decreases about 5-30% compared with commercial mixture by employed HCCH advanced single.

9 OLED System & Applications II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:00
Session Chairs: Dr. Uwe Vogel (Fraunhofer FEP, Germany)
Dr. Mike Weaver (UDC, U.S.A.)

A9-1 10:30~10:55

Invited OLED Microarrays as Versatile Light Sources for Biophotonics

Anja Steude, Andrew Morton, Caroline Murawski, and Malte C. Gather (Univ. of St Andrews, U.K.)

Most current research on OLEDs is aimed at applications in information displays and solid-state illumination. However, OLEDs are also highly attractive for applications in biotechnology and biomedicine, in particular due to their low toxicity, their ability to provide patterned illumination with very high spatial resolution as well as due to their fast switching behaviour and high brightness. We have recently demonstrated the use OLEDs to control the behaviour of living cells that are either naturally light sensitive or were rendered light-sensitive through genetic manipulation, a method known as optogenetics. In an initial proof-of-concept experiment, we used OLED microdisplays to control the light-activated locomotion (phototaxis) of the green alga Chlamydomonas reinhardtii [1]. The microdisplays comprise of a silicon chip containing electronics that addresses hundreds of thousands of individual top-emitting OLED pixels deposited directly on the chip. Each display pixel has a size of 6 μm × 9 μm, smaller than a typical cell. More recently, we investigated OLED mediated optogenetic control on both the single cell level [2] and using optogenetic Drosophila larvae [3]. In comparison to naturally occurring light-sensitive systems, optogenetics is often relatively light inefficient and may require optical intensities on the order of mW/mm^2 to achieve robust activation. Somewhat against common expectation, OLEDs can reliably achieve such intensities at acceptable operating voltages when state-of-the-art fluorescent pin stacks are used. References 1 A Steude et al, “Controlling the movement of single live cells with high density arrays of microscopic OLEDs” Advanced Materials 27, 7657-7661 (2015)2 A Steude et al, “Arrays of Microscopic Organic LEDs for High Resolution Optogenetics ChR2 activation with OLED microarrays” Science Advances 2, e1600061 (2016)3 A Morton et al, “High-brightness organic light-emitting diodes for optogenetic control of Drosophila locomotor behaviour” (submitted)

9 OLED System & Applications II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:00
Session Chairs: Dr. Uwe Vogel (Fraunhofer FEP, Germany)
Dr. Mike Weaver (UDC, U.S.A.)

A9-2 10:55~11:10

Micropatterning of OLED Emission by Electron Beam Processing of Single Organic Layers and Complete Devices

Elisabeth Bodenstein, Stefan Saager, Matthias Schober, Christoph Metzner, and Uwe Vogel (Electron Beam and Plasma Tech. FEP, Germany)

The approach presented in this paper describes a method for micropatterning by means of an electron beam process. Thereby the emission area of the OLED can be adjusted to various shapes by processing a single organic layer of the OLED stack or optionally the complete device including the encapsulation. Especially in the latter case the emission modification is completely flexible in application, since it is possible to build the OLED highly productive and completely unpatterned, before the electron beam process is applied (e.g., for signage applications). The electron beam process leads to a locally diminishing of the charge transfer. As a result the luminance output and the current density decrease accordingly. The process is determined by the acceleration voltage of the electrons on the one hand, which defines the penetration depth in the OLED stack. On the other hand the electron dose adjusts the degree of diminishing. With increasing electron dose, the electron beam processed areas appear visually darker. The used method provides the opportunity to modify the emission to various shapes at high-resolution in lateral dimensions and to adjustable intensity profiles (e.g., any grey-level). Furthermore the process is applicable to any kind of OLED, such as top- or bottom-emitting, flexible or rigid.

A9-3 11:10~11:35

Invited Laser Micronanostructuring for High-Performance Organic Optoelectronic Devices

Hong-Bo Sun, Yue-Feng Liu, Yan-Gang Bi, and Jing Feng (Jilin Univ., China)

Organic optoelectronic devices particularly organic light-emitting devices (OLEDs) and organic photovoltaics (OPVs) have been attracting increasing attention owing to their advantages of being thin, lightweight, and portable. High efficiency is a key issue for their commercial applications. While a very low light extraction efficiency of less than 20% is a stumbling block for high efficiency of OLEDs. In the other hands, the organic film has to be very thin due to its short exciton-diffusion length and low carrier mobility, which results in low light absorption efficiency and limited the conversion efficiency of the OPVs. In our work, integration of nanostructures into devices have been demonstrated an effective approach to out-couple waveguide (WG) and surface plasmon–polariton (SPP) modes within OLEDs and improve the light absorption by coupling SPP resonance in OPVs. The nanostructures have been fabricated by holographic lithography and laser ablation. Both experimental and numerical results show obvious enhancement in efficiency of OLEDs and OPVs compared to those of the conventional planar devices.

9 OLED System & Applications II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:00
Session Chairs: Dr. Uwe Vogel (Fraunhofer FEP, Germany)
Dr. Mike Weaver (UDC, U.S.A.)

A9-4 11:35~12:00

Invited Unlocking the Efficiency Potential of Metal Halide Perovskite Light Emitting Devices

Ross A. Kerner, Zhengguo Xiao, and Barry P. Rand (Princeton Univ., U.S.A.)

In this talk, we will discuss our recent work showing that the solution processing of metal halide perovskite thin films displays all of the hallmarks of sol-gel processing. We directly correlate experimental observations with basic sol-gel theory to elucidate the critical steps and specifically target these steps to improve the quality of spin coated thin films, realizing films with roughness on the order of a nm that allow us to demonstrate world-class light emitting devices with red and green external quantum efficiencies of ~10%.

10 Oxide TFT Mobility II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:50
Session Chair: Prof. Jin-Seong Park (Hanyang Univ., Korea)

B10-1 10:30~10:55

Invited Chemical Reaction-Mediated High Mobility Metal Oxide Semiconductor for TFT Application

Yeonwoo Shin, Sang Tae Kim, and Jae Kyeong Jeong (Hanyang Univ., Korea)

Metal oxide semiconductors have attracted attention as an alternative to current silicon-based semiconductors for applications in transparent and/or flexible electronics. Despite this, metal oxide transistors require significant improvements in performance and electrical reliability before they can be applied widely in optoelectronics. One of ways to improve the mobility of electron carriers in metal oxide semiconductor would involve the lattice ordering, which leads to the substantial reduction in the carrier scattering with the semiconductor. Approach that seeks to utilize the crystallization of metal oxide semiconductor has yet to be attempted despite the potential scientific and engineering implication. In this presentation, we explored the metal-induced crystallization of amorphous zinc thin oxide (a-ZTO) semiconductor at a low temperature. The ZTO material was chosen in this study because of its natural abundance compared to more expensive In- and Ga-based oxide components. The fabricated crystalline ZTO TFTs exhibited a high field-effect mobility of 33.5 cm^2/Vs, subthreshold gate swing of 0.40 V/decade, and ION/OFF ratio of > 5 x 10^7. The method in this study is expected to be applied to any type of metal oxide semiconductor.

B10-2 10:55~11:20

Invited Studies on High Mobility Oxide TFTs

Meili Wang, Yun Qiu, Peilin Zhang, Dan Wang (Beijing BOE Display Tech. Co., Ltd., China), and Liangchen Yan (BOE Tech. Froup Co., Ltd., China)

In the past years, we have focused much attentions on various amorphous semicondutor materials, and have made systematically studies on IGZO, ITZO, and ZnON TFTs. The obtained TFT mobility is ~10cm^2/Vs for IGZO TFT, 30cm^2/Vs for ITZO TFT, and 45cm^2/Vs for ZnON TFT, respectively, as showm below. Furthermore, detail investigations have done of the process development and intergration.

10 Oxide TFT Mobility II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:50
Session Chair: Prof. Jin-Seong Park (Hanyang Univ., Korea)

B10-3 11:20~11:35

Wavelength-Dependence of Persistent Photoconductivity in Zinc Oxynitride Thin-Film-Transistors

Hara Kang, Jun Tae Jang, Sungju Choi, Jae-Young Kim, Daehyun Ko, Sung-Jin Choi, Dong Myong Kim, and Dae Hwan Kim (Kookmin Univ., Korea)

Zinc oxynitride (ZnON) thin-film-transistor (TFT) having high mobility up to 110 $cm^2/V{\cdot}s$ is fascinating candidate as the next generation display device in active-matrix organic light-emitting diode and active matrix liquid crystal display panels in order to achieve the advanced display technologies such as 3-dimensional, high-resolution, and large size flat panel display [1-2]. Further, the ZnON TFTs are also suitable for application to optical sensor-embedded display because they have the properties of not only the high photoresponse but also the slight persistent photoconductivity (PPC) [3-4]. In spite of those merits, the wavelength-dependence (photon energy-dependence) of PPC the ZnON TFTs under photo-illumination has been seldom investigated.In this work, we conduct the monochromatic photo-illumination stress with varying the photon energy (Eph) in order to investigate the origin of PPC in the ZnON TFTs. It is observed that the higher photon energy causes not only the higher photocurrent during the illumination but also larger PPC which correlates with the negative threshold voltage shift and the subthreshold slope degradation after the photo-illumination [Fig. 1. (a), (b)]. Consequently, we find that the cause of the PPC is the donor creation near the conduction band edge during the illumination by tracking the subgap density-of-states (DOS) before and after the illumination [Fig. 1. (c)]. Our result is expected to be useful for developing the ZnON TFT-based future display applications.

B10-4 11:35~11:50

Elevated-Metal Metal-Oxide (EMMO) Thin-Film Transistor with Annealing-Induced Source/Drain Regions

Lei Lu, Jiapeng Li, Hoi Sing Kwok, and Man Wong (The Hong Kong Univ. of Science and Tech., Hong Kong)

Described presently is a technology of realizing an elevated-metal metal-oxide (EMMO) thin-film transistor (TFT) with the source/drain (S/D) electrodes raised above the passivation layer. Though functioning also as an etch-stop layer, the passivation layer needs not be patterned as such. Incorporating annealing-induced S/D regions, an EMMO TFT can be fabricated using the same mask-count, while also retaining the same channel-length, as a conventional back-channel etched TFT. EMMO TFT constructed with an indium-gallium-zinc-oxide (IGZO) active layer exhibited superior electrical characteristics. With the back-channel protected during the patterning of the S/D electrodes and the channel defects passivated during a post-metallization anneal in an oxidizing atmosphere, good stability against bias- and illumination-stress was also achieved.

11 AR / VR II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:15
Session Chair: Prof. Yongtaek Hong (Seoul Nat'l Univ., Korea)

C11-1 10:30~10:55

Invited New Insights into Foveated Rendering

Joohwan Kim, Anjul Patney, Marco Salvi, Anton Kaplanyan, Chris Wyman, Nir Benty, Aaron Lefohn, and David Luebke (Nvidia, U.S.A.)

Immersive virtual reality (VR) requires wide field of view (>100 degree in visual angle), high resolution (>60 pixels per one degree in visual angle), low latency (<20ms), and high frame rate (>75Hz). In addition, employing realistic rendering techniques such as global illumination, shadowing, and subsurface scattering significantly increases the rendering cost. All these requirements, which already seem very much challenging, need to be accomplished with small power consumption in order to realize VR devices that are light and portable. Foveated rendering[1,2] dramatically reduces rendering cost by adjusting level-of-detail in rendering according to perceptual thresholds, which vary across the visual field. Fovea is the central region in the retina where the sensitivity to spatial detail is the highest. Sensitivity to spatial detail falls gradually as one moves farther from the fovea in the visual field. For example, grating acuity and vernier acuity drop by 5 and 14-folds respectively at 10 deg of eccentricity compared to the fovea[3]. The performance drop continues further in the eccentricity[4], meaning that foveated rendering can save more rendering cost if the display spans larger in the visual field. Most VR devices host only one observer with wide field of view, providing an ideal environment for foveated rendering. With the help of modern gaze tracking technology, foveated rendering is emerging as the key to efficient content generation and presentation in future VR devices. In this presentation, we overview the related perceptual performances across the visual field as reported in previous literature. Then we describe a series of psychophysical experiments that we performed to find an effective way of foveated rendering. Based on the perceptual findings from our psychophysical studies, we implemented our own foveated rendering algorithm. A verification experiment confirms that our algorithm outperforms existing foveated algorithms in terms of rendering cost.

11 AR / VR II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:15
Session Chair: Prof. Yongtaek Hong (Seoul Nat'l Univ., Korea)

C11-2 10:55~11:20

Invited Redesigning Vision: Achieving Super Human Eyesight by Head Mounted Displays

Kiyoshi Kiyokawa (Osaka Univ., Japan)

We envision the future where head mounted displays (HMDs) become so advanced that our sense of vision canbe redesigned to best accommodate everyday tasks on demand without any visual, temporal and spatialinconsistencies. In this article we introduce a number of our research projects toward this ultimate goal.A wide FOV is beneficial for situation awareness and navigation tasks. We have previously proposed a wideFOV OST HMD, the Hyperboloidal Head Mounted Projective Display (HHMPD). With this design, a horizontalFOV wider than 180° is easily achievable. We have also shown that a large horizontal FOV up to around 130° isbeneficial for search performance in a divided attention task in outdoor AR (Figure 1A) [1].For visual consistency, reproducing realistic depth cues is very important. A varifocal optics and light fielddisplays have been proposed to reproduce accommodation cues. Although occlusion is one of the strongest depthcues, it is difficult to support in an optical manner. We have previously proposed an occlusion-capable OST HMD,the ELMO display, by using a transparent LCD panel as a masking layer. The most advanced ELMO display(ELMO-4) features a parallax-free optics with a built-in real-time depth sensor (Figure 1B) [2].For temporal consistency, prediction filters, frameless rendering, and image shift techniques have been used. Asimilar mechanism is employed in Oculus Rift. We have developed an off-the-shelf, low-latency OST HMD byusing the Oculus Rift DK2 and half-mirror optics (Figure 1C) [3]. An evaluation shows that the system achievesmean temporal error of <1 ms, and median spatial error <0.3° in the viewing angle.For spatial consistency, the eye position with regard to the HMD screen must be measured. Existing manual andautomated methods are either time-consuming or error-prone. We have proposed corneal imaging-basedautomated calibration method (Figure 1D) [4]. Evaluations show that our method is more accurate and stable.Such corneal imaging analysis can be fed back to the system to improve the user experience. We call this new typeof OST display-based AR corneal feedback AR. Its expected features include automated eye pose tracking,automated brightness adjustment, accurate gaze tracking, and gazed object recognition, which we will explore.

11 AR / VR II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:15
Session Chair: Prof. Yongtaek Hong (Seoul Nat'l Univ., Korea)

C11-3 11:20~11:45

Invited Recent Advances in High Brightness Full Color OLED Microdisplay for AR/VR

Tariq A. Ali, Ilyas I. Khayrullin, Evan P. Donoghue, Ihor Wacyk, Kerry Tice, Fridrich Vazan, Laurie Sziklas, and Amal P. Ghosh (eMagin, U.S.A.)

OLED microdisplays are the superior choice for emerging Virtual Reality (VR) and Augmented Reality (AR) application due to their fast response time (which helps prevent nausea), small form factor, low power consumption, high brightness and high contrast [1].eMagin has recently advanced the OLED microdisplay performanceby developing proprietary direct patterning (DP) technology [2]. This includes high brightness for see-through applications and very high resolution allowing wide field of view (FOV) for immersive applications.The combination of eMagin'ssmall form factor microdisplay with advanced optics has resulted in our immersive headset which has much higher resolution and can deliver an emissive, high brightness solution that is far superior to cellphone based VR headsets and provides a more realistic, "screen-door"- free image. By suitable advancements of the OLED stack with directly patterned RGB emitters, the luminance is significantly enhanced with a wide color gamut.Chromaticity coordinates of a new DPWUXGA resolution microdisplayare listed in Table 1 and the corresponding gamut is compared to NTSC 1987 color standards in Fig.1.eMagin's new full-color directly patterned, digital interface microdisplayhas a color pixel pitch of 9.6 micron (~50% fill factor) that is compact in size (0.86" diagonal) with over 7 million pixel elements built on a single crystal silicon backplane. This microdisplayhas achieved more than 3500 cd/m^2 in brightness and has a steep I-V curve, as shown in Fig. 2, resulting in lower power consumption. The luminance versus current density for WUXGA format microdisplay with low voltage DP RGB versus white stack with color filters is shown in Fig. 3

11 AR / VR II

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:15
Session Chair: Prof. Yongtaek Hong (Seoul Nat'l Univ., Korea)

C11-4 11:45~12:00

Motion-to-Photon Latency Analysis for Virtual Reality HMD System

Min-Woo Seo, Song-Woo Choi, Sang-Lyn Lee (Sogang Univ., Korea), Jong-Hwan Park, Eui-Yeol Oh, Jong-Sang Baek (LG Display Co., Ltd., Korea), and Suk-Ju Kang (Sogang Univ., Korea)

This paper proposes a motion-to-photon analysis technique that measures the latency of the core performance of the HMD. The HMD latency causes the human dizziness problem, thereby inevitably solving this problem. We previously presented the measurement system to evaluate the time difference between the user's head movement and the rendered image change [1]. This time difference means a performance index of the motion-to-photon latency. Fig. 1 shows a block diagram of the proposed measurement system [2], [3]. Fig. 2 shows the specific operation based on the proposed measurement system. It uses a servo motor to calculate the motion of the yaw and pitch in a sensor of HMD (Oculus Rift Dk2 HMD). In experiments, we measured the latency in each direction by rotating the HMD through 90°, 180°, and 270° for the different angular velocity. In the experimental results of Table I, the latencies in yaw directions were up to 50.76 ms with the standard deviation of 1.88 ms. The latencies in pitch directions were up to 54.29 ms with the standard deviation of 1.95 ms. Therefore, the proposed system could reliably measure the HMD latency in various directions.

C11-5 12:00~12:15

Image Presenting System for HMD with Focusing on Gazing Point Using Photographed Panorama Light Field

Fuko Takano and Takafumi Koike (Hosei Univ., Japan)

We propose a novel imaging method for head-mounted display (HMD). The method displays a refocused image on a HMD. The refocused image is generated from a trimmed panorama light field image and focused at the center of HMD. When we watch the real world, we perceive clear image at a gazing point. While, we perceive blurry image outside the gazing point in the real world. However, when we watch photographed images on an as-made HMD, these images are focused on some fixed depth position. Thus there is some inconsistency to our eyes, and many people feel a sense of incongruity. By showing an image focused on a center point of the display, we make users gaze at the center point, and this improves immersiveness of HMD. Our goal is developing visually realistic sensation toward a plenoptic display.

12 Organic Thin Film Transistors I

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:10
Session Chairs: Dr. Takafumi Uemura (Osaka Univ., Japan)
Prof. Tse Nga (Tina) Ng (UC San Diego, U.S.A.)

D12-1 10:30~10:55

Invited Molecular Structure Dependent Bias Stress Stability in Organic Thin-Film Transistors

Boseok Kang, Byungho Moon, Hyun Ho Choi, and Kilwon Cho (POSTECH, Korea)

Organic field-effect transistors (OFETs) have attracted special attention in recent decades because of their potential applications for flexible printed electronics. However, although remarkable advances in the performances of organic field-effect transistors in recent years, the OFET device stability (bias stress stability) remains a critical obstacle to their commercial use. Here, we investigated the molecular orientation dependent bias stress stability in n-Type Semiconducting Polymer. The unique electrical properties of an n -type semiconducting polymer, poly[[N , N' -bis(2-octyldodecyl)-naphthalene-1,4,5,8-bis(dicarboximide)-2,6-diyl]- alt -5,5 ' -(2,2 '-bithiophene)] (P(NDI2OD-T2)), are investigated to study the correlation between the microstructures of polymer semiconductor thin films and the bias stress stability in OFETs. Although, the charge carrier mobilities were almost similar regardless of molecular orientation, the bias stress stabilities were different significantly, depending on the molecular orientations of the semiconducting thin films.(Fig 1a) A higher degree of bias stress stability is attained in the P(NDI2OD-T2) FETs prepared with face-on thin-film structures compared to the edge-on thin-film structures. Further experimental evidence by using Photo-Excited-Charge-Collection-Spectroscopy (PECCS) suggests that the aliphatic alkyl chains in edge-on-oriented P(NDI2OD-T2) films present a hurdle to vertical charge transport and induce large numbers of bipolarons during bias stress, in contrast with the face-on structured thin films.(Fig 1 b)We believe that our detailed analysis for the correlation between molecular structure and bias stress stability and charge transport mechanisms in OFETs by using PECCS will reveal the origins of the bias-stress instabilities, and reducing such instabilities will realize practical applications of OFETs in flexible electronics. This work was supported by a grant (Code No. 2011–0031628) from the Center for Advanced Soft Electronics under the Global Frontier Research Program of the Ministry of Science, ICT and Future Planning, Korea.

12 Organic Thin Film Transistors I

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:10
Session Chairs: Dr. Takafumi Uemura (Osaka Univ., Japan)
Prof. Tse Nga (Tina) Ng (UC San Diego, U.S.A.)

D12-2 10:55~11:20

Invited Physical and Compact Modeling of Organic Diodes and Transistors

Gilles Horowitz (Ecole Polytechnique, France)

Owing to their full compatibility with low temperature, all printed fabrication techniques, organic diodes and field-effect transistors carry hopes for the realization of low cost, all flexible electronic circuitry. At this stage, the need for simple, physically based compact models for computer-aided design of such circuits is becoming more ad more desirable. However, most of the currently used models still rest on concepts that have been developed for inorganic materials, including various forms of silicon and oxide semiconductors. In this lecture, we first delineate what differentiates organic semiconductors from their inorganic counterparts. This will next serve as a basis for the presentation of specific physical and compact models for organic diodes and transistors.

D12-3 11:20~11:45

Invited Electrical Transport Mechanisms for Organic Field Effect Transistor based on Monolayer Small Molecule

Chao Jiang and Jiawei Wang (Nat'l Center for Nanoscience and Tech., China)

Due to its high selectivity and sensitivity, organic field–effect transistor (OFET) based sensors have become the most promising one among various of electrical sensors. By optimization of structural and physical-chemical properties at a precision level of molecules, organic sensing devices seek to realize the state of the art in monolayer based device applications. The monolayer Pentacene-based OFET showed tremendous sensitivity for the polar gas molecule such as the ammonia (NH3). A detection limit of the 10 ppm level for NH3 gas has been realized due to the enhancement of charge trapping in the transport channel. In order for clarifying the monolayer sensing mechanism, field-effect mobilities were systematically investigated before and after exposure to a NH3 molecular analyte. A temperature dependent measurement was also carried out to elucidate the carrier transport under even single layer of molecules. The carrier mobilities are found to exhibit an Arrhenius type above 200 K, by contrast, a non-Arrhenius behavior has been observed when measurement temperature is below 180 K. An electric field dependent mobility characterization shows non-Poole-Frenkel type, which shows much different from situation occurred in multiple-layers device, indicating a reduction in the quantity of permitted percolation paths among different layers with increasing of the electric field. A depth understanding of carrier transport within one monolayer may be helpful for optimizing the design of OFETs for better sensor applications.

12 Organic Thin Film Transistors I

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:10
Session Chairs: Dr. Takafumi Uemura (Osaka Univ., Japan)
Prof. Tse Nga (Tina) Ng (UC San Diego, U.S.A.)

D12-4 11:45~12:10

Invited Boosting the Electron Mobility of Solution-Grown Organic Single Crystals via Reducing the Amount of Polar Solvent Residues

Hanying Li (Zhejiang Univ., China)

Enhancing the electron transport to match up with the hole transport developed far ahead is critical for organic electronics. As electron motion is susceptible to extrinsic factors, to seek these factors and to avoid their negative effects become the central challenge. Here, the existence of polar solvent residues in solution-grown single-crystals of 6,13-bis (triisopropylsilylethynyl)-5,7,12,14-tetraazapentacene (TIPS-TAP) is identified as a factor detrimental to electron motion. Field-effect transistors of the crystals exhibit electron mobility boosted up by about 60% after the residues are removed. The average electron mobility reaches up to 8.0 ± 2.2 $cm^2 V^{-1} s^{-1}$ with the highest value of 13.3 $cm^2 V^{-1} s^{-1}$, significantly higher than those obtained previously for the same molecule (1.0-5.0 $cm^2 V^{-1} s^{-1}$). Furthermore, single-crystals of 6, 13-bis(triisopropyl-silylethynyl) pentacene (TIPS-pentacene), a standard p-channel material, conduct electrons in FETs using Au as both source and drain electrodes as the crytals are grown from varied non-polar solvents. In sharp contrast, the electron transport is suppressed in those from polar solvents. Considering that solution processability is believed to be a critical advantage of organic semiconductors for which solvents have been widely used to prepare and anneal thin films and crystals, the solvent issue pointed out in this work will significantly advance the field of organic electronics through harvesting the electron behaviors.

13 Semiconductors for Display

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:40
Session Chair: Prof. Gwan-Hyoung Lee (Yonsei Univ., Korea)

E13-1 10:30~10:55

Invited Emerging Optical Properties of 2D Semiconductors: A Hint for Valleytronics

Hualing Zeng (Univ. of Science and Tech. of China, China), and Xiaodong Cui (The Univ. of Hong Kong, Hong Kong)

The ultimate goal of making atomically thin electronic devices stimulates intensive research in layered materials, in particular the group-VI transition metal dichalcogenides (TMDs). Atomically thin group-VI TMD crystals with 2H stacking order, emerging as a family of intrinsic 2-dimensional (2D) semiconductors with a sizeable bandgap in the visible and near infrared range, satisfy numerous requirements for ultimate electronics and optoelectronics. In addition, the characteristic inversion symmetry breaking presented in monolayer 1H-TMDs leads to non-zero but contrasting Berry curvatures and orbit magnetic moments at K/K' valleys located at the corners of the first Brillouin zone. These features provide an opportunity to manipulate electrons' additional internal degrees of freedom, namely the valley degree of freedom, making monolayer 1H-TMDs a promising candidate for the conceptual valleytronics. In this talk, we show recent advances in optical study on quantum confinement effects, valley dependent optical selection rules, and the interplay of spin and valley degrees of freedoms in this class of atomic 2D semiconductors.

E13-2 10:55~11:10

Wafer-Scale Growth of MoS_2 Thin Films by Atomic Layer Deposition

Jung Joon Pyeon, Soo Hyun Kim, Chong-Yun Kang, and Seong Keun Kim (KIST, Korea)

The wafer-scale synthesis of MoS_2 layers with precise thickness controllability and excellent uniformity is essential for its applications in nanoelectronics industry. Here, we demonstrate the atomic layer deposition (ALD) of MoS_2 films with $Mo(CO)_6$ and H_2S as the Mo and S precursors, respectively. A self-limiting growth behavior is observed in the narrow ALD window of 155 – 175 ˚C. Long H_2S feeding times are necessary to reduce the impurity contents in the films. The as-grown MoS_2 films are amorphous due to the low growth temperature. Post-annealing at high temperatures under H_2S atmosphere efficiently improves the film properties including the crystallinity and the chemical composition. Extremely uniform film growth is achieved even on a 4-inch SiO_2/Si wafer. These results demonstrate that the current ALD process is well adapted for the synthesis of MoS_2 layers for application in industry.

13 Semiconductors for Display

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:40
Session Chair: Prof. Gwan-Hyoung Lee (Yonsei Univ., Korea)

E13-3 11:10~11:25

Contact Resistance of Polycrystalline Single Layer MoS_2 TFT Using Chemical Vapor Deposition Synthesis

Seung-Bum Seo, Gi Woong Shim, Sang Yoon Yang, Jihun Park, Youngjun Woo, and Sung-Yool Choi (KAIST, Korea)

According to the market increase in virtual reality head mounted display and wearable electronics, ultra high resolution issue in display back plane has been increased. Two-dimensional (2D) semiconducting transition metal dichalcogenides (TMDCs) thin film transistor (TFT) has been increased for the next generation channel material. Especially, molybdenum disulfide (MoS_2) has attracted worldwide attention using channel material of the TFT showing high on/off ratio, high mobility.[1] However, MoS_2 TFT performance is limited by contact resistance because MoS_2 TFT is Schottky barrier transistor, which is switched by the tuning of the Schottky barriers at the metal-semiconductor interface.[2] Many study commonly reported that this Schottky barrier can be attributed to the presence of sulfur vacancies, which is related to Fermi level pinning at contact and resulted in contact resistance increase. In order to reduce contact resistance at metal-semiconductor interface, several methods have been reported such as chemically doped source/drain and phase engineering of MoS_2 from semiconducting phase into metallic phase [3]. But, it is uncertain what theirs effect on the contact resistance due to absence resistance network model in 2D semiconductor system.. The purpose of our work is to investigate contact characteristic of the chemically synthesized polycrystalline MoS_2 TFT. We synthesized single layer MoS_2 by using chemical vapor deposition. We observed contact resistance in CVD-MoS_2 film and analyzed contact resistance using simulation with source/drain doping concentration and additional channel resistance at metal to semiconductor junction. From this results, referring former resistance network model of TMD FET, we propose revised resistance distribution model of 2-D semiconductor system. More detailed discussions will be presented.

13 Semiconductors for Display

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:40
Session Chair: Prof. Gwan-Hyoung Lee (Yonsei Univ., Korea)

E13-4 11:25~11:40

Pulsed Laser-Induced N-doped Graphene Growth on SiC Substrate

Tae Hong Im, Dong Hyun Kim, and Keon Jae Lee (KAIST, Korea)

In the carbon material studies, chemically doped graphene has been studied to applicate high performance electronic device. There are several powerful method to grow high performance & quality graphene. For example, representative method would be Chemical Vapor Deposition(CVD)[1], gas phase growth with metal catalyst and Pulsed Laser Deposition(PLD) etc. Each method has own merits and demerits. Gas-phase doping on graphene by CVD requires complicated transfer process which can cause unintentional doping and defects creation. In this work, we report a solid-phase synthesis of N-doped graphene on N-doped silicon carbide (SiC) substrate by pulsed laser (XeCl, 308nm) irradiation. Laser-induced synthesis provides a direct growth of nitrogen doped graphene on an insulating substrate without additional transfer procedure. The XPS analysis demonstrates that the C-N bonding conformation of the N-doped graphene was pyridinic-N type. Also, G band shift in Raman spectra shows that solid-phase doping can provide precise controllability of doping concentration by changing the dopant concentration of the SiC substrate

14 Flexible Electronics

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:35
Session Chair: Dr. Jyrki Kimmel (Nokia, Finland)

F14-1 10:30~10:55

Invited Development of the All-Print Manufacturing Technology of the High Resolution Flexible TFT for Flexible Display

Toshihide Kamata (Nat'l Inst. of Advanced Industrial Science and Tech., Japan), Shinichi Nishi, and Yasuyoshi Mishima (Japan Advanced Printed Electronics Tech. Research Association, Japan)

We have been developing all-print fabrication techniques of flexible circuits for manufacturing of flexible devices. In this paper, we will introduce our newly developed flexible alignment technique, foldable circuits technique and automated continuously operated manufacturing line technology. By applying these techniques, we have succeeded in the development of an all-printed flexible TFT backplane, and demonstrated a flexible display, flexible touch panel and flexible sensors.

F14-2 10:55~11:20

Invited Foldable AMOLED with High Flexibility by Simplified Structure

Yung-Hui Yeh, Jia-Chong Ho, Glory Chen, Chen-Chu Tsai, Chih-Chung Liu, Ming-Hua Yeh, Cheng-Chung Lee, and Janglin Chen (Display Tech. Center/Industrial Tech. Research Inst., Taiwan)

To fulfill the requirements of smart handheld devices, such as thin, light-weight and robust, flexible AMOLEDs are developed. Moreover, since flexible AMOLEDs can be bent, folded or rolled, the smart phone and tablet PC can be converged in the future. An ultrathin foldable AMOLED integrated with touch panel is highly desirable for mobile applications. Based on ITRI's Flexible Universal Plane(FlexUP) technology, we have, in the past, successfully developed the flexible TFT backplane,flexible OLED and, more recently, a front plate including on-cell touch panel and gas barrier. In this paper, we studied several approaches to overcome the flexibility and interference issues with the on-cell touch panel. An ultrathin foldable AMOLED integrated with front plate including on-cell touch sensor and gas barrier modules at 5mm folding radius and folded for 100,000 times has been successfully demonstrated as shown in Fig.1.

14 Flexible Electronics

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~11:35
Session Chair: Dr. Jyrki Kimmel (Nokia, Finland)

F14-3 11:20~11:35

Mo-Re Thin Films for Flexible Display Applications

F. Hauser, T. Jörg, M.J. Cordill, R. Franz (Montanuniversität Leoben, Austria), H. Köstenbauer, J. Winkler (PLANSEE SE, Austria), and C. Mitterer (Montanuniversität Leoben, Austria)

Sputtered Mo films are nowadays widely used as thin films in display applications, e.g., for gate and source/drain metallization and data bus-lines in thin film transistors (TFTs). Within this work a strategy to improve the fracture behavior of brittle Mo thin films by alloying them with Re is explored. A series of Mo-Re thin films with 50 nm thickness onto 50 µm thick polyimide substrates were deposited by magnetron co-sputtering from pure Mo and Re targets. Advanced in-situ characterization methods were subsequently applied to determine the electro-mechanical behavior of the films during deformation. Uniaxial tensile tests were performed under the light microscope to directly observe the fragmentation process in-situ and the electro-mechanical response was evaluated by measuring the change in the electrical resistance during straining. Pure Mo thin films featured straight through-thickness cracks, which are usually observed for brittle films, while the Mo-Re films showed a more wavy crack path, indicating a more ductile behavior. The Mo-Re films exhibited a crack onset strain three times higher than the pure Mo thin films. In summary, alloying of Mo thin films with Re is a promising strategy to improve their fracture behavior which in turn can enable their utilization in flexible displays.

15 OLED Manufacturing by Solution Process

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Yong-Jin Pu (Yamagata Univ., Japan)
Dr. Alexander Closmann (Karlsruhe Inst. of Tech., Germany)

G15-1 10:30~10:55

Invited Latest Development of Polymer Light-Emitting Material for Printed OLED

Takeshi Yamada (Sumitomo Chemical Co., Ltd., Japan)

The basic guidelines of material design for higher efficiency and longer lifetime, and the latest progress of polymer organic light-emitting diode (p-OLED) are discussed.

G15-2 10:55~11:20

Invited Inkjet Technology for OLED Mass Production: TFE to RGB

Christopher T. Brown (Kateeva Inc., U.S.A.)

The YIELDjet platform is the world’s first inkjet printing manufacturing equipment solution developed from the ground up for flexible and large-scale OLEDs. With a novel architecture and breakthrough features, it tackles the volume-manufacturing hurdles that have made flexible and large-size OLEDs economically unviable. They include: Inferior device lifetime, unacceptable particle levels, inconsistent reliability, and poor uptime performance. The YIELDjet platform addresses the obstacles with these advances:

- World’s first production-worthy nitrogen printing environment
- Industry-leading low-particle performance
- Repeatable & reliable uniformity with ultra-wide process window
- Proprietary printing algorithms enabling excellent uniformity with wide process window Thin Film Encapsulation and OLED Printing will be discussed in this presentation.

15 OLED Manufacturing by Solution Process

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Yong-Jin Pu (Yamagata Univ., Japan)
Dr. Alexander Closmann (Karlsruhe Inst. of Tech., Germany)

G15-3 11:20~11:35

Interfaces and Pattern Resolution of Inkjet-Printed Organic Light-Emitting Diode with Novel Hole Transport Layer

Beom Seock Kim, Dai Geon Yoon, Ji Yoon Hong, Chil won Lee, and Byung Doo Chin (Dankook Univ., Korea)

Simple and low-cost processes for a micro-scale patterning are attractive for a development of the organic light emitting diodes (OLEDs) toward commercial large-area application. In this presentation, effects of the combination of solvents and thermal annealing condition on the conformation of interfacial layer structures at the surface of hole transport layer (HTL) were studied. Green emitter inks with solvent mixture were prepared, showing that good film uniformity of printed layers relied on the condition of different boiling point and surface tension of solvent mixture, reducing the so-called coffee ring effect forming at a drying process[1]. During the inkjet process, we have also controlled drop injection density aiming for better drop-to-drop spacing and reduction of line-edge roughness. Drop mixing during the jetting condition as well as drying condition was effective as control parameters for the improved printed pixel uniformity of OLEDs. Printed pattern of organic light emitter, representatively composed of chlorobenzene/ 1,2-dichlorobenzene mixture (using small molecular hosts doped with methyl-substituted iridium complex, $Ir(mppy)_3$) shows the significant reduction of line edge roughness as well as improvement of inkjet device efficiency, nearly comparable to spin-coated ones. Since the HTL possibly dissolves or damaged at the solution-deposition of emitting layer, we studied the phenomena at HTL-light emitting layer interface at the solution processing of device fabrication. Novel cross-linkable HTLs were introduced which were composed of triphenylamine as the cross linking unit and fluorene with various compounds. Our system utilizes dehydration condensation as cross-linking reaction that can be fast with the use of acid promoter[2]. Optimized HTL and device structure were applied for platform of inkjet-printed devices, where pixels up to 100-200 ppi resolution was formed.

15 OLED Manufacturing by Solution Process

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Yong-Jin Pu (Yamagata Univ., Japan)
Dr. Alexander Closmann (Karlsruhe Inst. of Tech., Germany)

G15-4 11:35~11:50

Highly Soluble Fluorinated Imaging Materials for Micropatterned Organic Light-Emitting Diodes

Jongchan Son (Inha Univ., Korea), O Jun Kwon (Univ. of Seoul, Korea), Woo-Won Park, Seok-Heon Jung (Inha Univ., Korea), Byung Jun Jung (Univ. of Seoul), and Jin-Kyun Lee (Inha Univ., Korea)

Construction of micron-scale patterns on organic charge transport layers is an issue for the production of high resolution organic light-emitting diodes (OLEDs). Even though vacuum deposition of small organic functional molecules and deposition through fine metal mask (FMM) is a conventional process to construct pixel patterns, fabrication of high resolution OLEDs with the shadow mask technique seems not so attractive because it is difficult to fabricate micron scale aperture patterns on the metal mask. In addition, low quality pixels are produced by mask sagging. One of the promising candidates to overcome this huddle is Orthogonal photolithography with fluorous solvents and highly fluorinated photoresist (PR) materials. This concept enables lithography on organic layers because fluorous solvents do not interact extensively with non-fluorinated materials, resulting in no chemical erosion or deterioration of organic emitting layers. According to this concept, we synthesized a perfluoroether-tagged calixarene PR (R_F-R2) and a photoacid generator (PAG2) which show a significantly improved solubility in fluorous solvents for PR deposition, pattern develop and stripping. R_F-R2 and PAG2 showed 10 μm resolution patterns on Si wafer as well as tris(4-carbazoyl-9-ylphenyl)amine(TCTA), a hole transporting organic layer(HTL). We examined the performance of green-emitting materials treated with R_F-R2 and PAG2 in fluorous solvents. Finally the imaging materials were applied to the fabrication of patterned OLED pixels built on an organic HTL.

15 OLED Manufacturing by Solution Process

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Yong-Jin Pu (Yamagata Univ., Japan)
Dr. Alexander Closmann (Karlsruhe Inst. of Tech., Germany)

G15-5 11:50~12:05

Slot-Die Coating of Small Molecule Organic Materials Mixed with Chain-Entangled Polymers for Large-Area OLEDs

Dongkyun Shin, Jin-Young Lee, Ki-Young Hong, Su-ho Yoo, and Jongwoon Park (Korea Univ. of Tech. and Education, Korea)

With an attempt to fabricate large-area OLED lighting panels, we investigate slot-die coating of a small molecule (SM) hole transport layer (HTL). It is observed that SM HTL films formed by spin coating exhibit pinhole-like surface, whereas the films by slot-die coating show micro-sized hillocks due to agglomeration. As the plate temperature of the slot coater is increased, smaller hillocks appear more densely. To tackle it, a small amount of a polymer HTL is added into the SM HTL (Hybrid HTL). By the aid of entangled polymer chains, small molecules are prohibited from migrating and thus agglomerations disappear. The peak-to-peak roughness of the slot-coated hybrid HTL films is measured to be about 11.5 nm, which is slightly higher than that (~7 nm) of the polymer HTL film, but much lower than that (~1,071 nm) of the SM HTL film. Similar results are also observed in spin-coated films. It is also addressed that OLED with the hybrid HTL shows higher luminous efficacy, compared to OLED with the SM HTL or the polymer HTL. We have further demonstrated that the dissolution problem occurring between two stacked layers with different solvents during slot-die coating can be suppressed to a great extent using such a combination of materials in hybrid structure.

16 Liquid Crystal Alignments

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Er-Qiang Chen (Peking Univ., China)
Prof. Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

H16-1 10:30~10:55

Invited Stabilized Azo Dye Photo-Alignment Layer for Liquid Crystal Displays

Hoi-Sing Kwok, Man-Chun Tseng, Abhishek Kumar Srivastava, and Vladimir Chigrinov (The Hong Kong Univ. of Science and Tech., Hong Kong)

Diazo dyes form a highly effective class of liquid crystal (LC) photo-alignment materials whose molecules undergo fast orientation or reorientation under exceptionally low irradiation doses and offers very high resolutions with high anchoring energies. These properties make these materials suitable for applications in all-optical LC devices. Moreover, this photo-induced orientation process is very sensitive and requires only low light dosages. In this paper, we describe a process to stabilize these materials for LC manufacturing. Several approaches have been developed, all involving reactive mesogens (RMs) capable of polymerization. The most important approaches are first, passivation of the alignment layer by polymer, second, the azo dye and liquid crystal polymer (LCP) composites, and third approach is based on surface localization of polymer from the bulk on to the azo dye alignment layer. We shall discuss the approach based on the liquid crystal polymer, azo dye composite and lists merits and demerits of the approach. The proposed alignment layer is characterized by VHR ~99.1% and small image sticking coefficient (~1.03), which is comparable to PI rubbing alignment layer. It offers easy processing with high photo and thermal stabilities. Furthermore, the low pre-tilt angle, high anchoring energy and ability of multidomain alignment are suitable for IPS and FFS modes.

H16-2 10:55~11:20

Invited Fast High Contrast Low Power Photoaligned Ferroelectric LCD: New Challenge

Vladimir Chigrinov (Hong Kong Univ. of Science and Tech., Hong Kong)

Ferroelectric liquid crystal (FLC) based on photoalignment is a good candidate for the new generation of display and photonics devices, which are much better in response time, than usually used nematic LC [1,2]. Five new electrooptic modes in FLC: Deformed Helix Ferroelectric (DHF), Electrically Suppressed Helix (ESH) mode, FLC diffraction mode, FLC orientational electro-optic Kerr effect and FLC multi-stable mode were proposed [2]. The photoalignment technology enables to solve the key problems in FLCD applications such as mechanical stability and high quality of the display images. FLC is the most advanced technology for a high resolution, large contrast ratio and low power consumption displays. Fast ESH-FLC devices may successfully compete with nematic LCD currently used for In Plane Switching (IPS) applications in mobile and smart phones and Tablet PC as well as in the new generation of field sequential color (FSC) LCD, which proved to be considerably better in response time, than usually used nematic LC. The new fast responded FLC can be successfully applied in LC photonics devices such as switches, filters, lenses, and sensors [3].

16 Liquid Crystal Alignments

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Er-Qiang Chen (Peking Univ., China)
Prof. Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

H16-3 11:20~11:35

Development of High Performance LCD TV with Dynamic Pre-Tilt Effect

Hokil Oh, Hoon Kim, Su Jeong Kim, and Kichul Shin (Samsung Display Co., Ltd., Korea)

PVA(patterned vertical alignment) mode which have been applied to mass production of large-sized televisions (TVs), provides wide viewing angle and high contrast ratio that comes from multi-domain structure and perfect vertical alignment of LC molecules leading to excellent dark state. However, slow molecular motion in propagation process and stabilization of the LCs in PVA mode leads to slow response time which causes blurring of the moving pictures in LCD TVs. In this report, we propose a new concept of alignment layer, which simultaneously contains both side chain for vertical alignment and the additional side chain with polar end group that responds to the applied electric field. The mechanism of this new alignment layer confirmed that the faster reorientation process of LC molecules from the randomly oriented directors to the aligned directors along the 45° and 135° leads to the fast response time. Here, we call it "dynamic pre-tilt effect". In addition, by utilizing this alignment layer in the new structure of an LCD, the transmittance of the panel can also be improved by increasing the distance between open-areas of pixel and common electrodes without increasing the response time.

H16-4 11:35~11:50

DNA as a Template for Liquid Crystal Displays

Yun Jeong Cha, Min-Jun Gim (KAIST, Korea), Kyunghwan Oh (Yonsei Univ., Korea), and Dong Ki Yoon (KAIST, Korea)

We successfully fabricated two kinds of liquid crystal displays (LCD) based on double strained deoxyribonucleic acid (dsDNA) alignment layer, which include in-plane switching mode- (IPS) and twist nematic (TN) mode-LCDs. As widely known, DNA material is the one of the most abundant materials in nature. And structurally, DNA has the right-handed double helical shape that induce nanogrooves with a very regular period, which can be used as an alignment layer to control the orientation of various kinds of guest materials including biopolymers, nano- and micro-particles and LCs. The LC molecules on of this topographical layer of DNA material align obliquely at a specific angle with respect to the direction of DNA chains, providing an instant and convenient tool for the fabrication of the IPS and TN mode displays compared to the conventional ways such as rubbing and mechanical shearing methods. The electro-optical performance and response time of this device was also investigated. Our result will be of great use in further exploration of the electro-optical properties of the other biomaterials.

16 Liquid Crystal Alignments

Date: Aug. 24, 2016 (Wednesday)
Time: 10:30~12:05
Session Chairs: Prof. Er-Qiang Chen (Peking Univ., China)
Prof. Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

H16-5 11:50~12:05

Generating Optical Vortices via Blue Phase Liquid Crystal Driven by Patterned-Electrodes

Shi-jun Ge, Peng Chen, Wei Hu, and Yan-qing Lu (Nanjing Univ., China)

Optical vortices have great potentials in optical communications, quantum computations, micro-manipulations and so on. We present an approach for generating the optical vortices through blue phase liquid crystal (BPLC). Patterned electrodes, fabricated by micro-lithography process, are utilized to vertically drive the BPLC to form common fork grating and Dammann vortex grating phase profiles. When a voltage is applied on the cell, optical vortices are obtained. Particularly, Dammann vortex grating is designed to generate a series of vortex beams with different topological charges but with equal-energy distribution. Fast switching between Gaussian mode and vortex beams are achieved. Besides, advantages such as electrical tunability and polarization independence are exhibited. These advantages make the devices appealing for optical vortex generation, manipulation and detection.

17 OLED Optics I

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:50
Session Chair: Prof. Kristiaan Neyts (Ghent Univ., Belgium)

A17-1 14:30~14:55

Invited OLED Light Out-Coupling: Transparent Electrode and Dipole Orientation Effects

Chung-Chih Wu, Chun-Yang Lu, Min Jiao, and Wei-Kai Lee (Nat'l Taiwan Univ., Taiwan)

Although current organic light-emitting devices (OLEDs) can offer nearly ~100% internal quantum efficiencies (IQEs), light extraction of internally generated emission in OLEDs remains a critical issue for achieving high external quantum efficiencies (EQEs) for display and lighting technologies. Although various approaches have been reported to enhance optical out-coupling efficiencies of OLED, yet most of them are technically complicated and the extraction efficiency/EQE achieved is still limited. In this contribution, we report that the combination of low-index transparent electrodes and emitters with preferentially horizontal emitting dipoles provides a simple and effective way to achieve very high-EQE OLEDs. Green phosphorescent OLEDs with a high external quantum efficiency of up to ~64% had been demonstrated. The simulation also predicts even higher EQEs are possible with even more strongly oriented emitting dipoles.

A17-2 14:55~15:10

Spontaneously Formed Wrinkles for Spectrum Stabilization and Efficiency Enhancement of Top Emission Organic Light Emitting Diodes on Metallic Foils

JongChan Jeong, Jonghee Lee, Jin-Wook Shin, Jong Tae Lim, ChulWoong Joo, HyunSu Cho, JunHan Han, Joo Yeon Kim, Jeong-Ik Lee, Nam Sung Cho (ETRI, Korea), SungYun Yang (Chungnam Nat'l Univ., Korea) , Jaehyun Moon (ETRI, Korea)

In active-matrix(AM) OLED, TFT back plane, bank layer and OLED are formed on the substrate sequentially. Thus top emitting OLED (TEOLED) are the choice in AM-OLED display. Sputtering method can serevely damage the organic layer. Thus, in forming the top transparent electrode, thermally evaporated thin metal is utilized as the top transparent electrode. Because of the use of metallic transparent electrode in the emission direction and the presence of mircocavity, TEOLED suffer low efficiencies and viewing angle dependent emission spectra. Thereforre, our spontaneously formed wrinkles structure can be a solution to enhance the luminance in all directions. At the same time, measured electroluminiscence spectra show neglible viewing angle dependency.

17 OLED Optics I

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:50
Session Chair: Prof. Kristiaan Neyts (Ghent Univ., Belgium)

A17-3 15:10~15:25

Suppression of Viewing Angle Dependence of Organic Light Emitting Diodes by Introduction of Circular Polarizer with Nanoporous Polymer Film

Nam Su Kim, Beom Pyo, Woo Young Lee, and Min Chul Suh (Kyung Hee Univ., Korea)

The typical out-coupling ratio of the photons from the organic light emitting diodes (OLEDs) is reported to ~20% due to their various loss channels associated with substrate mode, waveguide mode, surface plasmon mode, etc. Thus, we need to improve the device efficiency by using lots of light extraction technologies to compete with LED based AMLCD technologies. Meanwhile, those technologies have been developed to prepare variety of nano-structures to change the light propagating direction. Unfortunately, those technologies can hardly be applicable to the display or lighting applications because they cause lots of problematic issues (e.g. production cost, repeatability, pixel blurring effect, diverse diffraction behavior, etc.). Thus, the major AMOLED panel makers just utilize a microcavity OLED structure to improve the device efficiency. However, those approaches ruin the viewing angle dependence due to a strong resonator behavior. Thus, we have reported our nanoporous polymer films (NPF) could diminish such kind of viewing angle dependence. In this study, we report about the integration of our NPF with circular polarizer and lamination technique to prepare final form of devices. We will also comment about the critical issues to make this kind of films practical in the AMOLED field.

A17-4 15:25~15:50

Invited Outcoupling Enhanced Flexible OLEDs on Nanostructured Plastic Substrates

Jian-Xin Tang and Yan-Qing Li (Soochow Univ., China)

Flexible organic light-emitting diodes (OLEDs) hold great promise for future bendable display and curved lighting applications. One key challenge of high-performance flexible OLEDs is to develop new flexible transparent conductive electrodes with superior mechnical, electrical and optical properties. Herein, we demonstrate a new strategy to achieve a powerful transparent conductive electrode on plastic substrate that combines a quasi-random nanostructured optical coupling layer and an ultrathin metal alloy conduction layer. The optimum electrical conductivity, optical manipulation capability, and high tolerance to mechanical bending are realized in this composite electrode, which is favorable for the fabrication of ITO-free flexible OLEDs with state-of-the-art performance on low-refractive-index plastic substrate. The angularly and spectrally independent boost in light outcoupling of white emission is obtained by minimizing the waveguide mode, metallic electrode-related microcavity effect and surface plasmonic loss due to the integrated quasi-random outcoupling structure in the composite electrode. The resulting white flexible OLED exhibits the high enhancement in efficiency, *e.g.,* external quantum efficiency of 47.2% and power efficiency of 112.4 lm/W. In addition, this composite electrode has a scalable manufacturing potential in large-area flexible electronic systems.

18 Oxide TFT Mobility III

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:00
Session Chairs: Dr. Jong Uk Bae (LG Display Co., Ltd., Korea)
Prof. Jin-Seong Park (Hanyang Univ., Korea)

B18-1 14:30~14:55

Invited High Mobility Oxide TFT for the Application to the High Resolution Active Matrix Display

Sang-Hee Ko Park, Yujin Kim, Kwang-Heum Lee, Geumbi Mun, Guk-Jin Jeon, Jae-Han Ahn (KAIST, Korea), Jae Chul Do, and Wan Woo Park (Advanced Vacuum and Clean Equipment Optimizer, Korea)

Here we report our recent results for the key processes to materialize high mobility oxide TFT in BCE and SA structure. Proper selection of Cu barrier with low temperature processed passivation layer results in highly stable BCE structured Al-ITZO TFT with the mobility higher than 30 $cm^2/V.s$. Depending on the Cu barrier materials, we can control degrees of channel length shortening of BCE TFT to be as little as possible. In case of top gate SA TFT, adopting double gate insulator of alumina/silicon nitride allowed the application of any kind of inter-dielectric layers or passivation. Furthermore, high density plasma sputtering for the deposition of high mobility ITZO layer results in high stability under the current stress. By increasing the density of high mobility active film, we could improve not only the current stress stability, but also the gate bias stress stability

B18-2 14:55~15:20

Invited High Resolution Display Using High Electrical and Reliable Performance Oxide Thin Film Transistors

Jun Hyung Lim, Keunkyu Song, Masataka Kano, Yeonkeon Moon, Hyunsup Lee, Hyung Il Jeon, Junghun Noh, Sang Hee Jang, Byung-Seok Choi, Hye Yong Chu, and Junho Song (Samsung Display Co., Ltd., Korea)

High resolution, good image quality, narrow bezel design, and low fabrication cost are highly desirable characteristics for future display. For implementing such devices, one of the most important issues is fast operation using high mobility thin film transistors (TFTs). Low temperature polysilicon (LTPS) TFTs are suitable for fast operation and these have already undergone extensive research. Despite the successful backplane of applicable displays, they currently suffer from expensive process and large scalable. On the other hand, high mobility oxide semiconductors are considered as a promising alternative to conventional semiconductors such as polysilicon material. Among various candidates, Indium Tin Zinc oxide (ITZO) semiconductors have shown high electrical performance and reliable stability. Here, we demonstrated high resolution display - 8K4K, 872 pixel per inch - applied ITZO TFTs. Furthermore, we performed electrical stress and environmental storage test at 85°C. This proof-of-concept study and our findings are a step toward “high resolution future display applications”.

18 Oxide TFT Mobility III

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:00
Session Chairs: Dr. Jong Uk Bae (LG Display Co., Ltd., Korea)
Prof. Jin-Seong Park (Hanyang Univ., Korea)

B18-3 15:20~15:45

Invited High Mobility Oxide Thin-Film Transistors with In-W-Zn-O Channel

Mamoru Furuta, Daichi Koretomo, Yuta Hashimoto (Kochi Univ. of Tech., Japan), Kenichi Watatani, Miki Miyanaga, and Hideaki Awata (Sumitomo Electric Industries, Ltd., Japan)

Oxide thin-film transistors (TFTs) have received increasing attention for use in next-generation flat panel displays. Compared with conventional amorphous silicon (a-Si:H) TFTs, an InGaZnO (IGZO) TFT has many advantages, such as high field effect mobility (μ_{FE}), steep subthreshold swing (SS), good reliability, and low processing temperature. Although the μ_{FE} of IGZO TFT (~10 cm^2/Vs) is over one order of magnitude higher than that of a-Si:H TFTs, further enhancement of μFE of oxide TFTs makes them competitive to poly-Si TFTs. In this presentation, electrical properties and bias-stress stability of the In-W-Zn-O (IWZO) TFTs with SiOx passivation will be discussed. Bottom-gate and top-contact IWZO TFT was fabricated on th-SiOx/Si substrate. Excellent electrical properties with the μ_{FE} of 34 cm^2/Vs and SS of 0.09 V/dec. were achieved. Threshold voltage shift (ΔV_{th}) was only +0.4 V after positive gate bias stress (V_g=+20 V) of 3,600s. Thus, the IWZO will be a potential candidate for high-mobility oxide TFT.

B18-4 15:45~16:00

The Relation between Phase and Electrical Properties in an $InAlO_X$ Film by Controlling Al doping Concentration for TFT Applications

GeumBi Mun, Hye-In Yeom, Jong-Beom Ko, and Sang-Hee Ko Park (KAIST, Korea)

The Al atom generally plays as a carrier suppressor in oxide semiconductor so that their electrical properties are easily tailored by controlling Al doping concentration. Both the field-effect mobility and carrier concentration commonly decrease because of a percolation effect1 according to increasing the concentration of Al. In contrast, regardless of carrier concentration, the change of phase in $InAlO_X$ (IAO) films by adjusting the Al doping concentration has a huge effect on the characteristics of TFTs. Here, we report that amounts of Al changes the phase of IAO films and the phase has larger effect on the electrical property of IAO TFT than the carrier concentration of IAO films. We will also report the bias-temperature stress in both case of p-IAO and a-IAO TFTs to examine the effect of Al in IAO TFTs.

19 Wearable Electrode

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:25
Session Chair: Prof. Do Hwan Kim (Soongsil Univ., Korea)

C19-1 14:30~14:55

Invited Printable Cu Electrodes for Flexible Thin-Film Electronics

Zijian Zheng (The Hong Kong Polytechnic Univ., Hong Kong)

The ability to fabricate printable Cu electrodes is of great importance to flexible and stretchable electronics, because of the high conductivity, low cost, and ductility of Cu. However, conventional nanoparticle or precursor inks show disadvantage in its high processing temperature, and difficulty to form thin and smooth thin electrodes for flexible applications. To address this challenge, Polymer-Assisted Metal Deposition (PAMD) has been developed in recent years. PAMD is a solution-processing technique that allows ambient fabrication of flexible, foldable, stretchable, compressible, and wearable metal (especially Cu) conductors with very high conductivity, smoothness, and adhesion. PAMD has been demonstrated to be versatile for making high performance flexible thin film electronics including sensors, solar cells, supercapacitors, batteries, and transistors. This talk will start with short introduction of PADM and then focus on the discussion on the latest development of PAMD for high performance transistors and supercapacitors.

C19-2 14:55~15:10

Chip Mounting Technology for Stretchable Electronic System

Hyunjong Kim, Sangwoo Kim, Sungdae Choi, Junghwan Byun, Byeongmoon Lee, Eunho Oh, and Yongtaek Hong (Seoul Nat'l Univ., Korea)

Although there are wide and a lot of researches in progress, it is still a long way until a practically usable stretchable wearable device with complex functions is implemented. In fact, it is required to combine conventional electrical passive or active devices with the electrodes on the elastomeric substrate for early advent of such system in the market. In order to implement such stretchable hybrid device, adhesion property of surface mount device on elastomeric substrate becomes important. We developed a stretchable LED and resistor chip array and enhanced the adhesion property between chip and printed pads after optimizing the adhesive force of three materials. All of adhesive materials have relatively similar electrical properties but have different adhesion properties. Silver ink showed the lowest adhesive strength (average ~70gf) whereas silver epoxy showed the highest adhesive strength (average ~715gf). The damage surface shape of the pads after chip detachment shows that it is important to much strengthen the adhesive force onto the printed electrode pads. Based on the experimental results, it is found that silver epoxy material is a good candidate for surface mounting technology on the elastomeric substrate.

19 Wearable Electrode

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:25
Session Chair: Prof. Do Hwan Kim (Soongsil Univ., Korea)

C19-3 15:10~15:25

Vein-Based Stretchable Transparent Electrodes Fabricated by Polymer-Assisted Metal Deposition

Yaokang Zhang, You Yu, Kan Li, Casey Yan, and Zijian Zheng (The Hong Kong Polytechnic Univ., Hong Kong)

Bio-inspired stretchable and transparent electrodes are fabricated by polymer-assisted metal deposition (PAMD). A satisfactory balance between sheet resistance (~0.9 Ohm/sq) and optical transmittance (~83%) is obtained on these vein-based transprent electrodes (VTEs). Such high performance remains unchanged during cyclic stretching test of 1,000 cycles at a strain of 50%. We further demonstrate the VTEs as high-performance flexible and stretchable interconnects and patterned electrodes that are suitable for optoelectronics.

20 Organic thin film transistors II

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:15
Session Chairs: Prof. Sungjune Jung (POSTECH, Korea)
Dr. Alexey Merkulov (Evonik Resource Efficiency GmbH, Germany)

D20-1 14:30~14:45

Ultra-High-Resolution Printing of Flexible Organic Thin-Film Transistors

Xuying Liu (Nat'l Inst. for Materials Science, Japan), Masayuki Kanehara (Colloidal Ink. Co., Ltd., Japan), Chuan Liu (Sun Yat-sen Univ., China), and Takeo Minari (Nat'l Inst. for Materials Science, Japan)

Shrinking device dimensions to the few-micron scale is the primary step in manufacturing high-resolution electronics. Particularly in the field of high-definition liquid crystal displays, thin-film transistors with channel lengths of no more than 5 mm are typically required. Fully printing of OTFTs currently becomes considerably interesting. Here, we developed an ultra-high-resolution printing technique based on parallel vacuum ultraviolet (PVUV) patterning that can produce high-contrast wettability regions on flexible substrates. We used this technique to selectively deposit a functional ink with a 1-mm feature size, thereby allowing the large-scale fabrication of organic thin-film transistors (OTFTs) with channels as short as 1 μm under ambient atmosphere. Moreover, in short-channel devices, hole injection barriers can be tuned through printing the optimum gate overlaps associated with selectively doping semiconductor/electrode interfaces, resulting in a marked reduction in contact resistance from 20 to 1.5 kΩ cm, and an elevation of charge carrier mobility to a record high of 0.3 cm^2 V^{-1} s^{-1} in a 1-μm-channel device. The results indicate that this technique is promising for the fabrication of large-area, high-resolution, low-cost electronics.

D20-2 14:45~15:00

High Mobility Organic Semiconductors for Scalable Manufacturing of Dynamically Flexible Displays

Simon Ogier, Mike Simms, Shashi Pandya, and Ray Fisher (NeuDrive Limited, U.K.)

Dynamically flexible displays (DFDs) require all components of the display to remain functional during repeated bending cycles of the device. Organic semiconductor (OSC) technology has been shown to be a good candidate for this application due to the inherent flexibility of the organic materials and the low temperature processing enabling a wide range of thin plastic substrate to be chosen for the DFD. NeuDrive Limited is developing of a range of materials suitable for DFDs based on the $FlexOS_{TM}$ OSC small molecule and binder technology. These material sets enable uniform transistor performance with high linear mobility (>4cm^2/Vs) for channel lengths of less than 10 microns.This paper will present the details of the integration of $FlexOS_{TM}$ into a low process temperature compatible pilot line suitable for display backplanes, logic and sensor devices fabricated upon on a range of plastic substrates. Patterning and etch isolation processes to make small width transistor devices demonstrate the potential of this technology to drive a range of display resolutions for reflective or emmissive displays.

20 Organic thin film transistors II

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:15
Session Chairs: Prof. Sungjune Jung (POSTECH, Korea)
Dr. Alexey Merkulov (Evonik Resource Efficiency GmbH, Germany)

D20-3 15:00~15:15

Improvement of Electron Injection in All Solution-Processed N-Type Organic Field-Effect Transistors by Intercalating Inkjet-Printed ZnO Layer

Jeongkyun Roh, Changhee Lee (Seoul Nat'l Univ., Korea), and Hyeok Kim (KITECH, Korea)

The improved injection property of all solution-processed n-type organic field-effect transistors (OFETs) enabled by the inkjet-printed ZnO electron injection layer was demonstrated. Before adopting ZnO as the electron injection layer, ultraviolet photoelectron spectroscopy (UPS) measurement and field-effect transistor analysis were performed to examine the work function and mobility of ZnO, respectively. After confirming the suitability of ZnO in terms of electron injection and transport, we employed the ZnO electron injection layer via inkjet-printing in the all solution-processed n-type OFETs. With the inkjet-printed ZnO electron injection layer, the device exhibited about five-fold increased mobility (0.0058 cm^2/Vs to 0.030 cm^2/Vs), more than two-fold increased charge concentration (2.76×10^{11} cm^{-2} to 6.86×10^{11} cm^{-2}), and reduced device resistance by two orders of magnitude (120 MΩ·cm to 3 MΩ·cm). In addition, the ambipolar behavior of the devices was greatly suppressed by inserting ZnO electron injection layer. Low temperature processed and inkjet-printed ZnO electron injection layer can be one of the great candidates to improve electron injection property of all solution-processed n-type OFETs, and it is also applicable to other organic electronic devices.Figure 1 (a), (b), and (c) show the output characteristics of the device without the ZnO, with the IJP-ZnO, and with the spin-coated ZnO electron injection layer, respectively. As shown in Fig. 1(a), the device without the ZnO electron injection layer showed the poor n-type output characteristic. At the low gate-to-source voltage regime, the device showed a diode-like current-voltage behavior which was caused by the ambipolar characteristic of the device. On the other hands, the device with the IJP-ZnO and spin-coated ZnO electron injection layer showed the ohmic characteristics in the early part, and the devices showed good saturating behaviors. The insertion of ZnO as the electron injection layer was a sophistication with regard to electron injection and transport from the spectrocopic anlaysis and electrical characterisation. ZnO electron injection layer in the all solution-processed OFETs enabled the drastic improvement in the electrical performance of the OFETs.

21 2D Optoelectronics

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:00
Session Chair: Prof. Byung Hee Hong (Seoul Nat'l Univ., Korea)

E21-1 14:30~14:55

Invited Optoelectronics with Two-Dimensional Atomic Crystals

Thomas Mueller (Vienna Univ. of Tech., Austria)

Two-dimensional (2D) atomic crystals, such as e.g. layered transition metal dichalcogenides (TMDs), are currently receiving a lot of attention for applications in (opto-)electronics. Some TMDs are semiconductors with a sizable band gap in the visible, which allows for the construction of electroluminescent devices and lasers. It is thus envisioned that the efficient light emission, combined with the advantages of 2D crystals, such as flexibility, high mechanical stability and low costs of production, could in the future lead to new light sources and, maybe, a new display technology. In this talk I will review our research activities on electrically driven light emission from 2D semiconductors. In particular, I will present electroluminescence studies of TMD p-n junctions, formed by electrostatic doping using a pair of split gate electrodes, as well as emission from van der Waals p-n heterojunctions and TMD-based field-effect transistors. I will conclude with a critical evaluation of the research area and a discussion of remaining challenges.

E21-2 14:55~15:20

Invited Optical and Electro-Optical Properties of 2D Semiconductors

Goki Eda (Nat'l Univ. of Singapore, Singapore)

In this talk, I will highlight the unusual light-matter coupling in some 2D semiconductors and share our recent findings on charge and energy transfer in hetero-bilayers. We show that these transfer dynamics compete at sub-picosecond time scales in these heterostructures. I will also discuss effects arising from exciton-plasmon coupling in 2D semiconductors hybridized with metal nanoparticles. Finally, quantum confined Stark effect and excitonic electroluminescence in van der Waals heterostacks will be discussed.

21 2D Optoelectronics

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:00
Session Chair: Prof. Byung Hee Hong (Seoul Nat'l Univ., Korea)

E21-3 15:20~15:45

Invited Luminescence Properties in Atomically Thin Two-Dimensional Material and its Heterostructure

Kazunari Matsuda (Kyoto Univ., Japan)

Since the discovery of graphene, the very thin materials with a few atomic layer thickness, such as nano-carbon and atomically thin two-dimensional (2D) materials, i.e. carbon nanotube, graphene and transition metal dichalogenide, have attracted a great deal of attention and intensively studied from viewpoint of fundamental physics [1-7] and optical application.[8,9] These are emerging materials as new stages for studying the novel electronic and optical properties, because of characteristic band structures and enhanced Coulomb interaction between carriers. The enhanced Coulomb interaction in atomically thin 2D materials leads to the formation of stable excitons and charged exciton (trion) with extremely large binding energies by optical excitation even at room temperature. It is anticipated that the excitons and trions show various interesting optical phenomena such as significant photoluminescence (PL). We studied the novel optical properties and functionalities of monolayer transition metal dichalcogenide (MX_2:M=Mo, W, X=Se, S, Te) by advanced laser spectroscopic techniques.[4-6] We revealed the drastic change of PL arising exciton and trion by chemical doping [4] and exciton-exciton interactions in monolayer MX_2.[6] Moreover, the novel optical properties and device application in monolayer MX_2 and its heterostructure will be discussed.

E21-4 15:45~16:00

Electro-Optical Switching in a Mixture of Large and Small Sized Graphene-Oxide Liquid Crystal

Rana Tariq Mehmood Ahmad, Seung-Ho Hong, Tian Zi Shen, and Jang Kun Song (Sungkyunkwan Univ., Korea)

Although a conventional liquid crystal display (LCD) has provided the best solutions for usual display applications, recently it seems to face the toughest challenging situation due to the rising of OLED technology. The innovation of display technologies have been always initiated from new functional materials. Aqueous graphene oxide (GO) dispersion has been reported to have extremely large Kerr coefficient, which means it can be useful for extremely low power displays, although the relevant study is in very infantile stage. It has been reported that the field induced birefringence of aqueous GO dispersion can be improved by using high concentration GO with small size. However, the birefringence is still not enough for display applications, and the increase in the field-induced birefringence remains as one of the most challenging issues. In this study, we used a mixture of large size and small size high concentration GO aqueous dispersions (1 wt%) and the field-induced birefringence has significantly improved.

22 Flexible TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:50
Session Chairs: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)
Prof. Jang-Yeong Kwon (Yonsei Univ., Korea)

F22-1 14:30~14:55

Invited Development of Flexible Polymer Complementary Integrated Circuits

Yong-Young Noh (Dongguk Univ., Korea)

Ambipolar p-conjugated polymers may provide inexpensive large-area manufacturing of complementary integrated circuits without requiring micro-patterning of the individual p- and n-channel semiconductors. However, current-generation ambipolar semiconductor-based integrated circuits suffer from higher static power consumption, low operation frequencies, and degraded noise margins compared to complementary logic based on unipolar p- and n-channel organic field-effect transistors (OFETs). Here we demonstrate several approaches to control charge injection and transport property in ambipolar OFETs via development of new conjugated copolymers, optimization of blended gate dielectrics, and engineering of the electrical contacts. By controlling those factors, excellent p-channel (hole mobility > 5 cm^2/Vs) and n-channel (electron mobility > 5 cm^2/Vs) OFET characteristics are demonstrated. Most importantly, in these OFETs the counterpart charge carrier currents are highly suppressed for depletion mode operation (I_{off} < 70 nA when I_{on} > 150 – 200 mA). Thus, high-performance, truly complementary inverters (gain > 50) and ring oscillators (oscillation frequency > 100 KHz) based on a solution-processed ambipolar polymer are demonstrated as well. In addition, various logic circuits such as NAND, NOR, and XOR

22 Flexible TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:50
Session Chairs: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)
Prof. Jang-Yeong Kwon (Yonsei Univ., Korea)

F22-2 14:55~15:10

Selective Activation of Amorphous IGZO Thin-Film Transistors at 130 °C by Voltage Bias

Heesoo Lee (Yonsei Univ., Korea), Ki Soo Chang (KBSI, Korea), Young Jun Tak, Tae Soo Jung, Jeong Woo Park, Won-Gi Kim, Jusung Chung (Yonsei Univ., Korea), Chan Bae Jeong (KBSI, Korea), Tae Sang Kim, Jun Hyung Lim (Samsung Display Co., Ltd., Korea), and Hyun Jae Kim (Yonsei Univ., Korea)

Amorphous In-Ga-Zn-O thin-film transistors (a-IGZO TFTs) have been intensively investigated for applications in next generation displays due to their superior transparency and high field-effect mobility compared with amorphous Si TFTs.[1] Conventional a-IGZO TFTs fabricated by sputtering process have a limitation in requiring additional annealing process over 300 °C after deposition of a-IGZO active layers.[2] This high thermal energy activates a-IGZO TFTs to show desirable semiconducting behavior by forming of chemical bonds and curing of defects from ion bombardment damage. However, the high temperature annealing is a barrier for a-IGZO TFTs to be fabricated on various flexible substrates such as polyethersulphone (PES) and polycarbonate (PC).[3] In this research, we propose a new method to activate sputtered a-IGZO TFTs by applying voltages to electrodes along with annealing at low temperature (130°C). We applied various bias voltages to gate, source, and drain electrodes varied from -100 to +100 V and annealed the sample at 130°C for 1 hour simultaneously. By controlling the bias voltages, the activation effect of applied electric field on samples can be controlled. The sample activated in the optimized condition exhibits superior electrical characteristics comparable to the reference TFTs annealed at 280°C for 1 hour. These results are analyzed electrically and thermodynamically using infrared microthermography. The electrical energy compensates for insufficient thermal energy of low temperature, and we are able to decrease the activation temperature from 280°C to 130°C without degradation of electrical characteristics. Furthermore, electrical and thermal treatment on the active layer at the same time induces local joule heating between source and drain selectively, and this efficient annealing focused on the narrow area does not damage the substrate. Therefore, this study demonstrates the possibility of voltage bias activation at low temperature which could be the first step for future display.

22 Flexible TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:50
Session Chairs: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)
Prof. Jang-Yeong Kwon (Yonsei Univ., Korea)

F22-3 15:10~15:25

Packaging-Completed Flexible NAND-Type Flash Memory Array

Do Hyun Kim and Keon Jae Lee (KAIST, Korea)

Flexible electronics have attracted attention due to their thin, light-weight and less-breaking merits. Especially, brisk researches on Si-based flexible device were conducted to take advantage of its exceptional electrical properties and CMOS process compatibility. To make the Si-based flexible device in practical use, it is important to develop a proper packaging technology for providing signal and power distribution, heat dissipation and mechanical protection. However, flexible packaging for Si-based flexible device which endures harsh repetitive bending conditions requires further investigations. In this study, we report a methodology for fabricating packaging-completed Si-based flexible device. Thin Si-based device was prepared on a temporary substrate through device bonding on glass wafer followed by bottom-Si elimination. Afterwards, the device was interconnected on the flexible printed circuit board (FPCB) through flip-chip bonding utilizing anisotropic conductive film (ACF). Finally, packaging-completed Si-based flexible NAND flash memory was realized showing highly elastic and resilient characteristics under various stress conditions. The interconnections maintained its low resistance during repetitive bending tests. Furthermore, the memory showed reliable memory operation regardless of its bending, demonstrating the usefulness of the method.

22 Flexible TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~15:50
Session Chairs: Prof. Jae Kyeong Jeong (Hanyang Univ., Korea)
Prof. Jang-Yeong Kwon (Yonsei Univ., Korea)

F22-4 15:25~15:50

Invited Controlling the Crystallization of Small Molecule Organic Semiconductors Using Solution Shearing and Their Application to Field-Effect Transistors and Circuits

Steve Park (KAIST, Korea), Gaurav Giri (Univ. of Virgia, U.S.A.), Ioannis (John) Kymissis (Columbia Univ., U.S.A.), Yongtaek Hong (Seoul Nat'l Univ., Korea), and Zhenan Bao (Stanford Univ., U.S.A.)

The electronic properties of solution-processable small molecule organic semiconductors (OSCs) have rapidly improved in recent years. Practical applications of organic electronics as field-effect transistors require sufficient mobility, patterned and precisely registered OSC film within the transistor channel, and device-to-device uniformity over a large area, a task that remains a significant challenge. Here we present solution shearing as a promising technique to achieve such a task. In solution shearing, organic solution is sandwiched between a heated substrate and a shearing blade. When the evaporation rate of the solvent at the meniscus matches that of the shearing rate, the crystals can be grown along the direction of shearing, resulting in aligned crystalline films. To further enhance crystallinity, the substrate can be patterned with solvent wetting and dewetting regions to limit nucleation events and impede lateral crystal growth, resulting in highly aligned crystals with mobility as high as 2.7 cm^2/Vs. Furthermore, we have developed a novel technique known as CONNECT, which utilizes a non-wetting substrate with wetting electrodes to generate self-patterned and self-registered films within the channel with low device-to-device variability. We have successfully built a 2-bit half adder circuit, demonstrating the practical applicability of our technique for large-scale circuit fabrication.

23 Soluble OLED Materials

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:10
Session Chair: Dr. Stefan Höfle (Karlsruhe Inst. of Tech., Germany)

G23-1 14:30~14:55

Invited Novel Solution-Processable Materials for Efficient Long-Lived Phosphorescent OLEDs

Anna Hayer, Philipp Stoessel, Christian Ehrenreich, Nils Koenen, Florian Maier-Flaig, Holger Heil, Peter Levermore, Beate Burkhart, Katja Stegmaier, Edgar Böhm, and Herwig Buchholz (Merck KGaA, Germany)

Though huge progress in soluble small molecule materials development has already been made by transferring knowledge from evaporable OLED materials[1], there is still room for improvement. In this paper, we focus on three newly developed series of red and green phosphorescent emitters and further show the positive impact on device performnace obtained by using novel adapted host and hole transport materials. We show that the materials presented here are suitable for ink-jet printing with wide process window, good uniformity and high performance. In order to address soluble red efficiency, two series of novel phosphorescent red emitters are developed that show high photoluminescence quantum efficiency (PLQE) and narrow spectra. Several colour-tuned derivatives of each series are obtained. Fig. 1 shows that both new series are clearly superior to the previous generation in both full width at half maximum (FWHM) and PLQE. Fig. 2 shows example results with emitters from all 3 generations: The PLQE increase in the emitters can be translated into significantly higher device efficiencies.

G23-2 14:55~15:20

Invited Solution-Processed Multi-layer OLEDs Utilizing Photo-Crosslinkable Azide-Containing Hole-Transporting Polymers

Joon Woo Park, Hyeong Jun Kim, and Bumjoon J. Kim (KAIST, Korea)

A novel framework of azide containing photo-crosslinkable, conducting copolymer is reported as a hole-transporting layer (HTL) material for efficient solution-processed, multi-layer, organic light emitting diodes (OLEDs). We have reported a general methodology for synthesizing photo-crosslinkable hole transporting conducting polymers by copolymerizing small amount of azido-styrene monomers (3 – 10 wt%) during the polymerization of HTL materials. Incorporated azido-styrene successfully photo-crosslinked with a low power of UV irradiation (254 nm, 2 mW/cm^2) at a short exposure time (less than 5 min), enabling fabrication of multi-layer structured OLED with solution processing. Ir(ppy) 3 based OLED device containing photo-crosslinkable poly(triphenylamine)(X-PTAA) as a hole-transporting /electron-blocking layer exhibits much enhanced performance compared to that of controlled device without X-PTPA. Furthermore, micro-patterned OLEDs with the photo-crosslinkable X-PTPA can be fabricated through standard photolithography (Figure 1a). The versatility of this approach is also demonstrated by introducing the same azide moiety into other hole-transporting materials such as poly(carbazole)(X-PBC).

23 Soluble OLED Materials

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:10
Session Chair: Dr. Stefan Höfle (Karlsruhe Inst. of Tech., Germany)

G23-3 15:20~15:45

Invited Highly Efficient Injection Layer for Solution Processed OLED

Jun Liu, Yang Wang, Zhiyuan Min, Xinkai Wu, and Gufeng He (Shanghai Jiao Tong Univ., China)

Solution processed organic light-emitting dioded (OLED) is considered to be advantageous in reducing the manufacturing cost. However, to achieve highly efficient and stable s-OLEDs, interface engineering between electrodes and organic semiconductor is a major concern. For hole injection, a low temperature solution-processed MoO_3 (s-MoO_3) thin film with a facile method for organic optoelectronic devices is developed. The film is extremely smooth with root mean square (RMS) roughness of 0.318 nm, which is a significant advance for fabricating devices. X-ray photoelectron spectroscopy (XPS) measurement shows that the s-MoO_3 possesses few Mo^{5+} states with a Mo:O stoichiometry of 2.99, demonstrating a nearly ideal MoO_3 stoichiometry at low annealing temperature. On the other hand, a three-dimensional metal-organic framework (MOF) based on ZnO is developed as a highly efficient and air-stable solution-processed electron injection layer (s-EIL). The MOF film can be readily obtained by annealing a spin-coated precursor film at 120 °C in air, which is facilely prepared by the reaction of ZnO powder with formic acid and ammonia water. With this as EIL, both electron-only device and OLED exhibit significantly enhanced electrical property and air stability, compared to that with vacuum evaporated Cs_2CO_3 as EIL. The enhanced electron injection property is attributed to its reduced work function compared to bare ITO.

23 Soluble OLED Materials

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:10
Session Chair: Dr. Stefan Höfle (Karlsruhe Inst. of Tech., Germany)

G23-4 15:45~16:10

Invited Development of Quantum Dots as Electroluminescent Material for Solution Processable Display Applications

Sung Hoon Jo (KETI, Korea), Sungoh Lim (Dankook Univ., Korea), Min suk Oh, Jiwan Kim, and Chul Jong Han (KETI, Korea)

Quantum dots are alternative electroluminescent material which can substitute organic or organometallic EML with its high stability, easy production process and high efficiency[1]. Pixellation of quantum dots for RGB display can not be easily accomplished because of QD's soluble process nature and conventional fine metal mask evaporation method cannot be applied. So various kind of printing methods were introduced for the pixellation[2,3]. We utilized the inkjet printing for pixellation of QDs to utilize the well estabilished inkjet equipment and technologies. Inkjet printing of QDs and fabrication of EL device, however, suffers from QD’s ligand structure. To maximize the inkjet printing processability, QD should have sufficient amount of ligand for the stabilization and solubility. But the ligand act as insulation layer for QD at EL device and it should be minimized for good EL device performance. To address these problems, we optimize the amount of ligand and post treatment for good carrier injection and efficiencies. Another issue for the inkjet printed QD EL device is pixel uniformity. To get high pixel uniformity, inkjet printed HIL, HTL and ELM layers should have very smooth surface profile and orthogonal properties each other. Bank for inkjet printing also should be orthogonal for each common layer. Inkjet printable PEDOT:PSS and high MW poly TPD, crosslinkable HTL were introduced for QD EL device structure with noble inkjet bank structure.

24 LC Beyond Displays

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:10
Session Chairs: Dr. Fang-Cheng Lin (Nat'l Chiao Tung Univ., Taiwan)
Prof. Jeong Jae Wie (Inha Univ., Korea)

H24-1 14:30~14:55

Invited Novel LC Materials for Non-Display Applications

Michael Wittek, Carsten Fritzsch, and Johannes Canisius (Merck KGaA, Germany)

Novel LC materials for non-display applications are presented and discussed. These applications range from smart windows, light guiding applications to smart antennas.

H24-2 14:55~15:20

Invited Dielectrophoretic Manipulation of Liquid Crystal Droplets and Display Applications

Jang-Kun Song and Bomi Lee (Sungkyunkwan Univ., Korea)

Electrophoresis is one of well-known approaches to achieve a non-volatile low power consumption electronic paper device, so-called e-paper. The basic mechanism of e-paper is electrophoresis with dipolar motion. That is, by changing the sign of electric signal, the actuation direction can be swiched. Meanwhile, dielectrophoresis, in which the motion is quadradically dependent on electric field (ΔE^2), had not been used in display applications, because its motion is unidirectional. In this presentation, we demonstrate that the dielectrophoretic motion in LC medium can be bidirectional depending on the LC alignment, and it can be used for liquid-type dielectrophoretic display devices. Because of the quadratic feature, the dielectrophoretic actuation is unidirectional, unlike the case of electrophoretic devices. However, the anisotropic dielectric response of liquid crystal can switch the dielectric property of medium, and the dielectrophretic actuation direction can be switchable. By introducing the novel concept, we could bidirectionally control the position of liquid droplet within nematic medium. This can be used to devise novel dielectrophoresis e-paper display with improved reliability compared to usual electrophoretic devices.

24 LC Beyond Displays

Date: Aug. 24, 2016 (Wednesday)
Time: 14:30~16:10
Session Chairs: Dr. Fang-Cheng Lin (Nat'l Chiao Tung Univ., Taiwan)
Prof. Jeong Jae Wie (Inha Univ., Korea)

H24-3 15:20~15:45

Invited Shape-Tunable Wrinkles and the Applications

Takuya Ohzono (AIST, Japan)

Methods of shaping and manipulating liquids on small scales are important for micro-patterning, microfluidics, electro-wetting-based displays and biosensing, and may provide fundamental insights into nonlinear chemical phenomena in confined small spaces. Here, we report a simple technique for shaping liquids into micrometre-scale filaments. Microgrooves on microwrinkles generated by thin film buckling on elastic substrates can function as open channel capillaries for liquids with appropriate wettabilities. Tuning the groove depth of the shape-tunable microwrinkles by applying strain, we explore the capillary action of various liquids in microgrooves, which form liquid filaments emanating from a large reservoir. This behaviour is explained in terms of sinusoidal-geometry-dependent surface energy. Based on this concept, a regular array of liquid filaments can be formed over a large area by a simple coating method, and these filaments can be further reshaped by exploiting strain-induced nonlinear changes in microwrinkle topography. With this technology, we are able to study the complicated defect structures formed within the liquid crystals bounded by this sinusoidal boundary. Especially, a self-organized zigzag line defect in a nematic liquid crystal with in the groove can be used as a sensitive chiral sensor.

H24-4 15:45~16:10

Invited LC-lens Array for 3D Bio-Medical Applications

Yi-Pai Huang, Po-Yuan Hsieh, Amir Hassanfiroozi, Chao-Yu Chu (Nat'l Chiao-Tung Univ., Taiwan), Manuel Martinez-Corral (Univ. of Valencia, Spain), and Bahram Javidi (Univ. of Connecticut, U.S.A.)

liquid crystal lens (LC-lens) array was utilized in 3D bio-medical applications including 3D endoscope and light field microscope. In 3D endoscope case, we have successfully demonstrate a multi-functional liquid-crystal lens (MFLC-lens) based on dual-layer electrode design. The diameter of the proposed MFLC-lens is only 1.42mm with tunable focal length from infinity to 80mm. In the light field microscope case, we replaced the fixed microlens array(MLA) by a Hexgonal LC-MLA. By adjusting the focal length of LC-MLA from 1.9mm to 3.5mm, and fusing those light field images together, the total depth of field (DoF) of light field microscope was extended from 1 mm to 13.5 mm.

25 OLED Optics II

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:05
Session Chairs: Prof. Chung-Chih Wu (Nat'l Taiwan Univ., Taiwan)
Prof. Jian-Xin Tang (Soochow Univ., China)

A25-1 16:30~16:55

Invited The Influence of Material Anisotropy and Panel Temperature on OLED Emission

Kristiaan Neyts, Michiel Callens, Frederique Chesterman, and Patrick De Visschere (Ghent Univ., Belgium)

Recently it has been found that many organic thin films exhibit optical anisotropy. The origin of the anisotropy is the stacking arrangement of the organic molecules that are deposited by thermal evaporation. The resulting layers have the optical axis perpendicular to the plane of the substrate. The most common type of anisotropy is negative optical anisotropy. We investigate how anisotropy can enhance the outcoupling of light by a using a well-chosen design. We have measured the power, light emission and temperature of a commercial 55" diagonal OLED panel based on the color by white approach. When the panel is driven with the maximum driving level for blue emission, the temperature in the center of the panel (estimated from infrared camera measurements) reaches 42°C. We observed that the efficacy of the light emission (measured in W/sr.A) decreases with the current density that is flowing in the OLED pixels.

A25-2 16:55~17:10

Optical Analyses and Optimization for Deep Blue Pixels of Top-Emitting OLED Displays with Horizontal Emitting Dipoles

Min Jiao, Wei-Kai Lee, Chung-Chih Wu (Nat'l Taiwan Univ., Taiwan), Hsi-An Chen, Yihwa Song, Li Wei Shih, and Jiin-Jou Lih (AU Optronics Corp., Taiwan)

We conduct optical analyses and designs of deep blue pixels for top-emitting OLED displays having horizontally oriented emitting dipoles and corroborate simulation results with experiments. Optical properties of blue emitting layer under investigation exhibits PL CIE 1976 coordinates of (u', v')=(0.12, 0.31), high PLQY>90%, and high horizontal emitting dipole ratios($Q^{//}$) ≈85%. Upon varying the layer structures (thicknesses), the optical simulation results reveal that compared to the case of $Q^{//}$ ≈67%, blue pixel OLEDs with $Q^{//}$ ≈85% give significantly higher optical out-coupling efficiency under nearly same optimized device structure. The analyses also indicate a trade-off between the out-coupling efficiency and the color (viewing) requirement of (u', v')<(0.15, 0.16) in device designs. Good agreement with experiments by simulation with $Q^{//}$ ≈85% and exciton locations at HTL/EML interface unambiguously confirms the accuracy of the simulation and also further provide insight into detailed carrier/exciton distribution and device operation.

25 OLED Optics II

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:05
Session Chairs: Prof. Chung-Chih Wu (Nat'l Taiwan Univ., Taiwan)
Prof. Jian-Xin Tang (Soochow Univ., China)

A25-3 17:10~17:25

High Performance Outcoupling Film for OLEDs Lighting

Asuka Tanaka, Hideki Etori, and Ryohei Hayakawa (Kimoto Co., Ltd., Japan)

Organic Light Emitting Diodes (OLEDs) technology started in display market and expects to grow lighting application. Lighting panel requires improvement of outcoupling enhancement and color stability to penetrate in the market. In order to meet these requirement, we have developed new outcoupling film “LENK1” by using surface transfer method. Kimoto Co., LTD. will introduce LENK1 as a high performance outcoupling film. OLED panel will not extract luminous flux well due to total reflection to substrate. It will be able to extract by micro structure on the panel. Our exist outcoupling films were constructed with diffusion layer which based on microparticles, however, it is not enough design for outcoupling enhancement because it depends on shape of microparticle. Therefore, we have replaced it to microlens layer which controlled design for improvement of outcoupling enhancement (Lens-A). As a result, we have succeeded to improve 13% outcoupling enhancement compare to diffusion layer type. White OLED panel makes color shift with different angles. Diffuser property were combined with microlens in backed adhesive to get good color stability. LENK1 has suppressed color shift excellently.

A25-4 17:25~17:50

Invited Transparent and Low-Resistance Top Electrode for Organic Light-Emitting Diodes

Jeong-Ik Lee, Hyunkoo Lee, Jong Tae Lim, Sunghee Park (ETRI, Korea), Won-Yong Jin (Chonbuk Nat'l Univ., Korea), Byoung-Hwa Kwon, Nam Sung Cho (ETRI, Korea), Jae-Wook Kang (Chonbuk Nat'l Univ., Korea), and Seunghyup Yoo (KAIST, Korea)

Indium-tin-oxide (ITO) is a typical material for bottom electrode in OLEDs owing to its high transmittance and low resistance. However, the deposition process of ITO needs high energy, resulting in damage of organic materials when the ITO is used as a top electrode in OLEDs. Thin metals are commonly utilized as a top electrode in top and transparent OLEDs but its low transmittance and high reflectance debases the performance of the device such as efficiency and color distortion depending on viewing angles. To resolve these issues, carbon-based non-metal transparent conductive materials are applied to OLEDs as a top electrode due to its high trasmittance and low reflectance. However, carbon-based non-metal transparent conductive materials have basically low conductivity, thus their resistance should be reduced for large-size device applications. In this presentation, we report transparent OLEDs employing carbon-based non-metal top electrodes. To reduce resistance of electrodes, metal auxiliary wires were inserted between non-metal electrode and supporitng film. The device with metal auxiliary wire embedded non-metal top electrode showed high optical transparency and low reflectance. In addition, the introduction of the metal auxiliary wires resulted in reduced driving voltage of the device.

25 OLED Optics II

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:05
Session Chairs: Prof. Chung-Chih Wu (Nat'l Taiwan Univ., Taiwan)
Prof. Jian-Xin Tang (Soochow Univ., China)

A25-5 17:50~18:05

Emission Behavior of Transparent White Organic Light-Emitting Diodes

Winghong Choi and Furong Zhu (Hong Kong Baptist Univ., Hong Kong)

White organic light-emitting diodes (WOLEDs) resemble light more naturally, with emission spectrum that is comfortable to the human eye. The transparent WOLEDs can emit a pleasant diffused light, allowing the surface light source to shine in both directions, an exciting new display and lighting technology that could bring new device concepts. However, angular-dependent emission in transparent WOLEDs is often observed, due to the microcavity effect. In this work, the visible-light transparency and angular-dependent emission behavior of transparent 2-color and 3-color white WOLEDs were analyzed experimentally and theoretically. High performing transparent 2-color white WOLEDs possessing weak angular-dependent EL emission and stable CIE coordinates of (0.34, 0.43) and (0.37, 0.46), measured from both anode and cathode sides, were demonstrated. It is found that avoidance of the overlap between the peak wavelengths of the emitters and the resonant wavelength of the organic microcavity moderates the angular-dependent electroluminescence emission behavior, thereby improving the color stability of the transparent white WOLEDs over a broad range of the viewing angle.

26 Oxide TFT Reliability

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~17:40
Session Chairs: Dr. Jun Hyung Lim (Samsung Display Co., Ltd., Korea)
Prof. Lei Wang (South China Univ. of Tech., China)

B26-1 16:30~16:55

Invited Theory of Defects and Doping in Wide-Band-Gap Oxides

Anderson Janotti (Univ. of Delaware, U.S.A.)

Oxide semiconductors are of great interest to high-technological device applications, including varistors, gas sensors, optically pumped lasers, high and low power transistors, and transparent electrodes for solar cells and displays. In all these applications, the presence of native defects and impurities is thought to strongly affect the performance of the oxide semiconductor material. However, experimental identification and characterization of defects and impurities in oxide semiconductors have remained quite challenging. Using first-principles calculations we have investigated the role of defects and impurities in a series of oxide semiconductors, such as ZnO, SnO_2, SnO, In_2O_3, TiO_2, and $SrTiO_3$. Here we discuss results for formation energies and thermodynamic andoptical transition levels, paying special attention to the role of defects and impurities on the of ten-observed unintentional n-type conductivity. We consider impurities that are most likely to be present in the growth or processing environments, such as hydrogen, as well as impurities that are intentionally incorporated for the purpose of doping. We focus on the behavior of oxygen vacancies and metal interstitials, providing a unified perspective on their formation and influence on electrical properties of the various oxides.

B26-2 16:55~17:10

Analysis on Light Propagation into InGaZnO Thin-Film Transistors

Saeroonter Oh (Hanyang Univ., Korea), Jong Uk Bae, Kwon-Shik Park, Soo-Young Yoon, and In Byeong Kang (LG Display Co., Ltd., Korea)

Amorphous InGaZnO (a-IGZO) thin-film transistors (TFTs) are affected by light illumination, especially under negative gate-bias temperature illumination stress (NBTIS) conditions. Suppressing NBTIS instability is crucial, since the strong backlight in LCDs and ambient light can affect the pixel TFTs if light-blocking schemes are not properly placed. Etch-stopper structures intrinsically have a bottom-gate that essentially acts as a light shield to bottom illumination. However, for high intensities of illumination the V_{th} shift under NBTIS increases, which implies that light flows into the TFT channel region despite the metal electrode serving as a light-blocking layer. In this work, accurate 3D numerical simulations are performed to compute the amount of bottom light that reaches the TFT channel region. When the gate length is shorter than the active length "length-direction light" is dominant, while "width-direction light" becomes dominant for longer gate lengths. For the latter case, light reflects off the passivation-ambient boundary and flows into the channel region. Finally, suppression of dominant light components is explored by modifying device structural parameters.

26 Oxide TFT Reliability

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~17:40
Session Chairs: Dr. Jun Hyung Lim (Samsung Display Co., Ltd., Korea)
Prof. Lei Wang (South China Univ. of Tech., China)

B26-3 17:10~17:25

Significant Sheet Resistance Reduction of a-IGZO via Low Temperature Excimer Laser Irradiation

Juan Paolo Bermundo, Yasuaki Ishikawa, Mami N. Fujii (Nara Inst. of Science and Tech., Japan), Hiroshi Ikenoue (Kyushu Univ., Japan), and Yukiharu Uraoka (Nara Inst. of Science and Tech., Japan)

We demonstrate how the sheet resistance (R_s) of a-IGZO can be significantly decreased by irradiating a-IGZO with one shot of KrF excimer laser (248 nm) at different ambient conditions. The 70 nm a-IGZO films on Si/SiO_2 substrate were irradiated in ambient air, in Ar (350 Pa), or in vacuum condition ($<10^{-3}$ Pa). The R_s was measured using standard four-point probe method. Table 1 shows that the Rs of a-IGZO was significantly reduced from a high Rs of >1000 Ω/□ to as low as 0.05 Ω/□ by increasing the fluence energy and by irradiating either in Ar or in vacuum. Changes in a-IGZO chemical composition and bonding states were measured using Secondary Ion Mass Spectrometry and X-ray photoelectron spectroscopy. 2-dimensional heat simulation (Fig 1) was performed to demonstrate how laser irradiation can be used to define low resistance a-IGZO regions at a low temperature for application in self-aligned TFTs

26 Oxide TFT Reliability

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~17:40
Session Chairs: Dr. Jun Hyung Lim (Samsung Display Co., Ltd., Korea)
Prof. Lei Wang (South China Univ. of Tech., China)

B26-4 17:25~17:40

Temperature-Dependency of the Donor Creation under Positive Gate and Drain Bias Stress in Self-Aligned Top-Gate a-InZnO TFTs

Sungju Choi, Jonghwa Kim, Jungmok Kim, Jun Tae Jang, Hara Kang, Jea-Young Kim, Daehyun Ko, Dong Myong Kim, Sung-Jin Choi (Kookmin Univ., Korea), Jae Chul Park (Samsung Advanced Inst. of Tech., Korea), and Dae Hwan Kim (Kookmin Univ., Korea)

Positive gate and drain bias stress (PGDBS)-induced instability is one of the most important issues in the oxide thin-film transistor (TFT)-driven active-matrix organic light-emitting diode (AMOLED) display backplanes. Moreover, the self-aligned top-gate oxide TFT has attracted much attention as a promising device structure for high-definition high frame rate displays due to a high current drivability and low RC delay [1-2]. However, the temperature-dependence of PGDBS-induced instability of high-mobility oxide TFTs has been rarely investigated. In this work, the temperature-dependency of PGDBS-induced threshold voltage shift (DVT) in the high-mobility amorphous indium-zinc-oxide (a-IZO) TFTs is investigated. The negative DVT is observed under PGDBS (V_{GS}=V_{DS}=13 V) [Fig. 1(a)~(f)]. By using the extracted subgap density-of-states, we show that the negative DVT results from the donor creation which originates from the oxygen vacancy ionization ($V_o \rightarrow V_o^{2+} + 2e^-$) [Fig. 1(g)]. The magnitude of DVT increases either with the increase of temperature or with wider TFT channel width [Fig. 1(a)~(d)]. In addition, the magnitude of DVTR (DVT readout condition interchanging the source and drain in comparison with those during PGDBS) is prominently larger than that of DVTF (DVT readout condition maintaining the positions of source and drain in comparison with those during PGDBS) [Fig. 1(e)~(f)].It is found that the temperature-dependenc of DVT is attributed to more activated impact ionization followed by the donor creation (Vo^{2+} creation) [3]. It suggests the electron mean free path (lc) during PGDBS becomes longer with the increase of temperature [Fig. 1(h)]. It is consistent with the thermal release of trap-limited conduction and percolation mobility model [4]. It is also shown that the TFT width-dependence and the difference between DVTR and DVTF are due to the more activated donor-creation by self-heating and the local donor-creation, respectively.

27 Wearable Sensors

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:00
Session Chair: Prof. Jiyoul Lee (Pukyong Nat'l Univ., Korea)

C27-1 16:30~16:55

Invited Wearable and Implantable Bio-Signal Monitoring Systems

Tsuyoshi Sekitani, Teppei Araki, Shusuke Yoshimoto, and Takafumi Uemura (Osaka Univ., Japan)

We will present the recent progresses and future prospects of ultra-soft, conductive gel electrodes, and wearable and implantable electronic sensors for bio-medical applications. With integrating the ultrafsoft gel electrodes, ultraflexible amplifier, Si-LSI platform consisting of wireless data-transmission module and analog-to-digital converter, Li-ion-based thin-film battery, and information engineering, here we would like to demonstrate the applications of implantable bio-compatible active sensors including 64-channel sheet-type wireless brain-signal monitoring systems. Electrocorticogram (EC_oG) and Local field Potential (LFP) have been wirelessly measured from rat's brain for more than two months. Furthermore, utilizing circuit technologies based on organic thin-film transistors (TFTs), we will present large-area, ultraflexible organic amplifier, whose total thickness is less than 10 micrometer and amplifier gain is greater than 55 dB, which is the thinnest and the largest amplifier gain among organic TFT based amplifier. We have developed ultrathin electronic potential sensors with integrating organic amplifier array and ultrasoft gel described above. This soft gel system can measure biological signals less than 1 microvolt, so that Electrocardiogram (ECG) and Electroencephalogram (EEG: Brain wave) have successfully measured.

C27-2 16:55~17:20

Invited Ultrasensitive and Elastic Artificial Skin Using Ionic Mechanotransducer

Do Hwan Kim (Soongsil Univ., Korea)

Cutaneous structure for mammalian might provide a solution for efficiently overcoming bottlenecks in artificial sensory system and an insight into eventually implementing a sensor comparable to the level of human sensation. In this talk, we propose the first ultrasensitive and elastic artificial skin sensor directly mimicking *Piezo2* ion mechanotransduction channel expressed in touch mechanoreceptors - epidermal Merkel cells that are termination of touch receptive specializations in mammalian somatosensory system. The device architecture based on the hierarchically assembled ionic and visco-poroelastic material operates in ultralow power consumption of 1mV, and shows remarkable sensitivity of 10nF/kPa at extremely small dimension. (Fig.1) Furthermore, sensing range of artificial ionic mechanotransducer unprecedentedly covers broad detecting pressure regime, including intelligent voice identification, human health monitoring, and even heavy measurement towards the realization of sophisticated human skin.

27 Wearable Sensors

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:00
Session Chair: Prof. Jiyoul Lee (Pukyong Nat'l Univ., Korea)

C27-3 17:20~17:45

Invited Stretchable Bio-Environmental Sensors with Integrated Micro-Supercapacitors

Jeong Sook Ha (Korea Univ., Korea)

In this work, we demonstrate the successful operation of stretchable bio-environmental sensors by integrated high performance energy storage devices. On a specially designed deformable polymer substrate, a strain sensor based on fragmentized graphene foam and a gas sensor based on a mixed thin film of multi-walled carbon nanotubes (MWNTs) and SnO_2 nanowires are fabricated. As energy storage devices, an array of solid-state micro-supercapacitors (MSCs) consisting of spray-coated MWNTs electrodes and patterned ion-gel electrolyte of poly(ethylene glycol) diacrylate (PEGDA)/ 1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl) imide is fabricated. Those sensors and MSCs are electrically connected via liquid metal Galinstan, eutectic alloy of Ga, In, and Sn, interconnections embedded inside the Ecoflex substrate. Using the energy stored in MSCs, the strain sensor detected the bio-signals of pulse, voice, swallowing of saliva, and body motion after attachment of the whole sensor system onto neck. In addition, the gas sensor showed a fast response to NO_2 gas exposure under stretching up-to 50% without any deterioration in sensing properties. This study clearly shows the great potential of our stretchable system for application to next-generation body-attached healthcare and environmental sensor devices.

27 Wearable Sensors

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:00
Session Chair: Prof. Jiyoul Lee (Pukyong Nat'l Univ., Korea)

C27-4 17:45~18:00

Textile-Based Touch/Pressure Sensors Using Conductive Multi-Filament Fibers

Jimi Eom, Woonghee Byun, Minho Kim, and Yong-Hoon Kim (Sungkyunkwan Univ., Korea)

Electronic textile (E-textile) including antennas, energy harvesting devices, and sensors have attracted a great interest in the areas of smart devices and internet of things which are being rapidly developed in the past few years. Particularly, textile-based sensors such as pressure, temperature, ultra-violet, gas and strain sensors using conductive fibers were widely reported. However, conventional conductive fibers such as stainless steel fibers and thick-metal-coated fibers have significant limitation when applied in textile sensors due to their poor mechanical stability. In this work, we demonstrate multi-functional textile-based sensors using silver nanowire/poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS)-coated conductive fibers. Specifically, the conductive fibers were fabricated by coating silver nanowires and glycerol-doped PEDOT:PSS on polyetser and nylon fibers. The conductive fibers had silver nanowire-embedded sturucture between PEDOT:PSS layers and the electical resistance of the conductive fiber was ~2 kΩ at a measured distance of ~10 cm. For the detection of touching and the pressure difference, two conductive fiber electrodes, displaced with a narrow distance, were sewed on a textile substrate using a sewing machine. Initially, the two electrodes are disconnected. However, with a finger in contact at the disconnected point, a current can flow through the two conductive fiber electrodes making a closed circuit and low resistance. Therefore, by monitoring the resistance change of the conductive fiber circuit, the touch motion can be detected. Moreover, the conductive fiber based sensor can also detect the pressure difference by the different levels of resistance change with varying applied pressure.

28 Printed Oxide and Organic TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chair: Dr. Hyeok Kim (KITECH, Korea)

D28-1 16:30~16:55

Invited Solution Processable Semiconductors for the Display Industry

Alexey Merkulov and Ralf Anselmann (Evonik Resource Efficiency GmbH, Germany)

Since several years, an Evonik R&D group *Electronic Solutions*, has been pursuing a vision of processing semiconducting layers from the liquid phase for the large area application in the display industry. Our technology *iXsenic*® is based on metal alkoxide precursor inks in the combination with slot-die coating deposition followed by post-treatment and annealing. This approach allows the producing of thin metal oxide functional films with tunable homogeneous composition.

D28-2 16:55~17:20

Invited All Solution Processed Low Voltage Organic Thin Film Transistor with a Thick Gate Dielectric Layer for Low Cost Display Backplane

Xiaojun Guo, Linrun Feng, Wei Tang, and J. Zhao (Shanghai Jiao Tong Univ., China)

Recently, we worked on the approach for low voltage OTFTs by reducing the sub-gap density of states (DOS) at the channel through blended solution of small molecule acene semiconductor with an insulating polymer binderThis method has been further demonstrated to be applicable to several different low-k dielectrics. Without needing large gate dielectric capacitance, it allows to use a thick (> 1 μm) low-k gate dielectric layer to realize low voltage OTFTs, and would be more compatible with low cost printing or coating processes However, due to the small gate dielectric capacitance, the charge density induced in the channel at the same gate voltage is low, resulting in smaller ON current. Through device/circuit mixed mode simulations, the performance as the switch in display backplanes for the low-voltage OTFTs with this approach and that in the same device structure and dimensions, but realized via high-k gate dielectric layer was compared. It is shown that, even with the same apparent mobility and thus less ON-state current, the low voltage OTFT with reduced sub-gap DOS at channel and a low-k gate dielectric layer can perform faster charging and discharging than the device with high-k gate dielectric layer. For further improvement, a bi-layer gate dielectric structure was also investigated for low voltage OTFTs.

28 Printed Oxide and Organic TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chair: Dr. Hyeok Kim (KITECH, Korea)

D28-3 17:20~17:45

Invited 3D Organic Transistors and Circuits Fabricated by Inkjet-Printing

Jimin Kwon (POSTECH, Korea), Yasunori Takeda, Kenjiro Fukuda (Yamagata Univ., Japan), Kilwon Cho (POSTECH, Korea), Shizuo Tokito (Yamagata Univ., Japan), and Sungjune Jung (POSTECH, Korea)

Most functional organic integrated circuits (ICs) fabricated by printing have less than a hundred transistors[1], which is similar to the integration level of the initial silicon ICs. Improvements in the integration density of printed circuits are at a standstill because the physical and mechanical limits of printing processing cannot access the submicron feature sizes used for silicon IC processing[2]. Herein, we report the first inkjet-printed vertically stacked 3D complementary organic transistors and circuits, which can double the transistor density. We fabricate a p-type organic field-effect transistor that is inkjet-printed on top of an n-type organic field-effect transistor that is also printed with a shared gate joining the two transistors. Based on the common-gate transistor-on-transistor structure, a complementary inverter array is fabricated with a high static noise margin (SNM) and reliable characteristics. Moreover, a universal logic NAND gate representing the complement of AND operation is demonstrated by using the same printing method to interconnect the vertically stacked complementary inverters. Finally, we have demonstrated a full adder with nine NAND gates based on the 3D transistor-on-transistor structure. This study demonstrates a general strategy for the 3D integration of conducting and semiconducting layers to continuously increase the transistor density of printed devices.

D28-4 17:45~18:00

Flexible Active Matrix Display based on Organic Light-Emitting Transistors

Caterina Soldano (E.T.C. s.r.l., Italy), Hsing-Hung Hsieh (Polyera Taiwan Corp., Taiwan), and Mauro Riva (SAES Getters S.p.A., Italy)

Active-matrix organic light-emitting diode (AMOLED) displays are expected to be the dominant technology for the next generation flat panel displays. In recent years, organic light-emitting transistors (OLETs) have gathered much attention due to their two-fold functionalities of combining transistor behavior with electroluminescence generation. In addition, in the tri-layer OLET architecture larger expected value of EQE is believed to be one of the main advantages. Furthermore, when comparing to a conventional OLED, the intrinsic geometrical features of OLET promote the decrease of exciton quenching and reduction of photon losses, which are two key factors to reach high light-generating performances. We fabricated flexible active matrix monochromatic displays (80x60, 50dpi) where the OLET acts as the light emitting source. The display can be operated at: 15V of bias, 100Hz of refresh rate and at over 200 cd/m^2 (for red). As such, no driving TFTs are needed when OLETs are utilized in an active-matrix displays, the requirements on backplanes are not as stringent as standard AMOLED technology, therefore reducing production costs.

28 Printed Oxide and Organic TFT

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chair: Dr. Hyeok Kim (KITECH, Korea)

D28-5 18:00~18:15

Organic–Inorganic Hybrid $CH_3NH_3PbI_3$ Perovskite Field-Effect Transistor

Xiuling Li, Hyeong Pil Kim, Anil Kanwat, and Jin Jang (Kyung Hee Univ., Korea)

Organic–inorganic hybrid perovskite materials combine the facile processing of organic materials and the remarkable carrier transport of inorganic semiconductors. Great improvement have been achieved in a short time in their photoelectronic applications such as high power conversion efficiency (PCE) solar cells (up to 20.1%), light-emitting diodes and field-effect transistor devices, owing to the strong optical absorption, tunable band gap, long carrier lifetimes and ambipolar carrier transport characteristics. However, many issues, such as the mechanism of morphology control, the electrical properties and stability still remain, which hinder the further applications of these materials. Here, we report the electrical properties of $CH_3NH_3PbI_3$ provskite evaluated from field-effect transistors (FETs). The FETs employ top gate structure having $CH_3NH_3PbI_3$ provskite semiconductor layer, poly(methyl methacrylate) (PMMA) as gate insulator and Au as electrodes. The perovskite film was deposited following one-step spin coating method, while its morphology was tuned using solvent engineering process. The electrical performance demonstrates ambipolar carrier transport, both p-type and n-type conduction at room temperature, reaching hole and electron mobilities of 1.89 and 0.92 cm^2/Vs, respectively. This can be an effective approach to the study of the charge transport in these materials, and expand their potential application towards switching electronics.

29 YLC (Young Leaders Conference)

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chairs: Prof. Hyun Jae Kim (Yonsei Univ., Korea)
Prof. Sung Kyu Park (Chung-Ang Univ., Korea)

E29-1 16:30~16:45

Effect of Light-induced Degradation on Charge Extraction Properties in PTB7:$PC_{71}BM$ Solar Cells

Jiyun Song, Priyanka Tyagi, Yongwon Kwon, Kunsik An, Myeongjin Park, Heeyoung Jung, and Changhee Lee (Seoul Nat'l Univ., Korea)

Organic solar cells (OSCs) have been considered as one of the future photovoltaic applications, achieving over 10 % of power conversion efficiencies with an advantage of low-cost and large-area manufacturability. At the same time, stability issues and understanding of degradation mechanisms of OSCs are becoming more important to make progress toward the commercialization. Among the possible failure mechanisms in OSCs, light-induced degradation is the most crucial one because the light is known to accelerate any other processes, such as oxygen, moisture or thermal-degradation. Here we investigate the light-induced degradation of PTB7:$PC_{71}BM$ bulkheterojunction (BHJ) solar cells for 24 hours under the continuous illuminated conditions. After a day of light-aging with minimized other extrinsic factors, device showed 30 % of initial performance drop, mainly through a decrease in short-circuit current and fill factor. While nanomorphology, absorbance, and chemical bonding states of PTB7:$PC_{71}BM$ layer showed negligible differences within 24 hours, charge transport and extraction characteristics of solar cells degraded quite significantly. By comparing fresh and 24 h-aged device using both morphological and electrical measurements, we conclude that the loss is primarily due to the light-induced traps inside the BHJ and two adjacent interfaces.

E29-2 16:45~17:00

Growth Temperature Dependence High Performance Indium Zinc Oxide Flexible Thin Film Transistor by Atomic Layer Deposition

Jiazhen Sheng and Jin-Seong Park (Hanyang Univ., Korea)

In this research, bottom gate top contact thin film transistors (TFTs) based on IZO channels were fabricated on polyimide (PI) substrate by atomic layer deposition (ALD) at different growth temperature. The effect and its mechanism of growth temperature of IZO channel layer was evaluated, and it was found the device, that IZO channel layer growth increased till 200˚C, exhibit best transfer performance (saturation mobility 42.3cm^2/Vs, threshold voltage 0.7V, subthreshold voltage 0.29V/decade and hysteresis 0.21V) comparing to 150˚C and 175˚C due to highest carrier concentration with increased oxygen vacancy. Besides, the positive bias thermal stress (20V, 60˚C, time = 3600s) tests were carried out, device with IZO channel grown at 200˚C also showed best stability, that threshold voltage shift 1V and almost no change of mobility and S.S. The effect of such difference was suggested by decreasing of defect in channel bulk layer and contact resistance between channel and electrode by thin film roughness decreasing when growth temperature increase. Lastly, the flexible TFT fabricated at 200˚C were bended under mechanical stress (difference radius with tensile and compression) to investigate the flexible characteristic of the ALD made TFT.

29 YLC (Young Leaders Conference)

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chairs: Prof. Hyun Jae Kim (Yonsei Univ., Korea)
Prof. Sung Kyu Park (Chung-Ang Univ., Korea)

E29-3 17:00~17:15

Effects of Oxidative Materials on MoS_2 Channel Layer during Atomic Layer Deposition

Whang Je Woo, Jeong-Gyu Song, Hanearl Jung, Bo-Eun Park, Jongseo Park, Kyunam Park, Jusang Park, and Hyungjun Kim (Yonsei Univ., Korea)

Recently, two dimensional (2D) transition metal dichalcogenides (TMDCs) such as molybdenum disulfide (MoS_2) have attracted great attention. MoS_2 is semiconducting material with a appropriate bandgap, which enables switching behavior within field-effect transistors (FETs) with large on/off current ratio (>10^8). In order to fabricate MoS_2 FET with further device scaling, gate dielectric layers with much thinner thickness is needed. For this reason, atomic layer deposition (ALD) has been adopted to MoS_2 FET fabrication process. With the demonstration of MoS_2 FET, improved performance of MoS_2 FET by introducing ALD HfO_2, Al_2O_3 were announced. Moreover, there are further studies performed to improve the coverage of high-quality ALD dielectrics on MoS_2 channels by using treatment process. However, until now, these kinds of researches have focused only on the processes of the integration of high-k dielectrics on MoS_2 layer, without investigating the effect of ALD process and precursor materials on 2D TMDCs films deeply. In this work, we explore the oxidative effects of ALD process on MoS_2 performance. We investigate the effects of oxidative precursors on MoS_2 channel layers with respect to deposition conditions. Further, we fabricated MoS_2 FET with different deposition conditions to verify the effects of oxidative species on FET performances.

E29-4 17:15~17:30

Development of Inkjet Printed N-type Organic Electronics: OFETs and Circuits

Seung Jae Moon, Wenlin Kuai (Université Rennes 1, France), Byung Seong Bae (Hoseo Univ., Korea), Tayeb Mohammed-Brahim, Maxime Harnois, and Emmanuel Jacques (Université Rennes 1, France)

In this study, N-type organic field effect transistors (OFETs) have been fabricated using epoxy based ink as insulator. Such ink, has already shown its versatility as printable material [4] and results obtained in this study demonstrate that epoxy based ink can be used as an efficient gate insulator. Indeed, electrical performances such as Ion/Ioff ratio, hysteresis and mobility is at quiet respectable level compared to the state of art of fully-printed n-type OFET. Note that, many improvements may be performed for future works such as: i) chemical modification of drain-source electrodes, ii) changing OFET structure, iii) use other more efficient OSC and so on. More interestingly, results shown in this abstract demonstrate a high electrical stability. Consequently, epoxy based ink used as insulator is a good candidate in order to fabricate complex devices that can be electrically stable in function of time even under polarization. To confirm such statement, pseudo-CMOS inverters and ring oscillators that are electrically stable have been fabricated.

29 YLC (Young Leaders Conference)

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chairs: Prof. Hyun Jae Kim (Yonsei Univ., Korea)
Prof. Sung Kyu Park (Chung-Ang Univ., Korea)

E29-5 17:30~17:45

Analysis of the Defect Sites and Electron Trapping Mechanism of the In-Zn-O and Al-Sn-Zn-In-O Thin Film Transistor

Youngin Goh, Taeho Kim (Korea Univ., Korea), Jong-Heon Yang, Ji Hun Choi, Chi-Sun Hwang, Sung Haeng Cho (ETRI, Korea), and Sanghun Jeon (Korea Univ., Korea)

Active matrix organic light-emitting diode(AMOLED) is considered as next generation display which can be used for wearable and rollable device. To drive the AMOLED, high mobility and reliable thin film transistor (TFT) is required. Oxide TFTs have recently emerged as excellent substitutes for driving AMOLED. Among them, Al-Sn-Zn-In-O (ATZIO) TFT shows excellent electrical performance as well as environmental and bias stability[1] However, the instability of threshold voltage and the degradation of mobility has been remained as a primary issue. Thus understanding on the defects are very important. To this end, we measured defect densities of In-Zn-O(IZO)and ATZIO double active layer TFT by AC device characterization methodology. With increasing the thickness of IZO interfacial layer, we meausured the defect sites by DC I-V, fast I-V, pulsed I-V and discharging current analysis method[2]. Also we measured the density of states by multi frequency C-V analysis. From these results, we found that interfacial IZO layer plays a crucial role in minimizing charge trapping of ATZIO TFT. In summary, we found that as the IZO thickness increase, the number of defect sites are decreased and the device become stable, thereby presenting high performance. This study provide the intuitive and quantitative information of charge traps in device and also give the effect of IZO in the IZO/ATZIO double active layer.

29 YLC (Young Leaders Conference)

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:15
Session Chairs: Prof. Hyun Jae Kim (Yonsei Univ., Korea)
Prof. Sung Kyu Park (Chung-Ang Univ., Korea)

E29-6 17:45~18:00

Design of Hybrid Photo Sensor Circuitry made by Solution-Processed Metal-Oxide and Organic TFTs

Jaehyun Kim (Chung-Ang Univ., Korea), Jaekyun Kim (Hanbat Nat'l Univ., Korea), Myung-Gil Kim, Sungmin Kwon, Kyung-Tae Kim, Seok Gyu Ban (Chung-Ang Univ., Korea), Yong-Hoon Kim (Sungkyunkwan Univ., Korea), and Sung Kyu Park (Chung-Ang Univ., Korea)

Metal-oxide and organic semiconductors possess distinctive characteristics such as relative high performance for oxide semiconductors and abundance of functional materials for organic semiconductors. In particular, organic-inorganic hybrid systems have received lots of attention due to its potentials to overcome the fundamental limits of organic sensor systems and also in aim to expand the application areas. In such organic-inorganic hybrid circuits, the selection of appropriate materials, integration architecture, and the process compatibility have been of great interest. However, the design of hybrid sensor circuits and identification of the roles of the inorganic functional units are also important since the performance of the sensor can be largely affected by these factors. Therefore, in this report, we demonstrated hybrid polyvalent pixel circuits and sensor arrays based on an organic sensory unit and an inorganic signal-amplifying unit, which overwhelms an organic-based sensor system.

E29-7 18:00~18:15

Control of Absorption and Scattering of the Incident Light Using Liquid Crystals Doped with Dichroic-Dye and TBAB

Jae-Won Huh, Jin-Hun Kim, Seong-Min Ji, Byeong-Hun Yu, and Tae-Hoon Yoon (Pusan Nat'l Univ., Korea)

Liquid crystal devices have been actively studied in various optical devices such as information displays, light shutters, liquid crystal lens. Especially, in light shutter application, it can be used to hide the objects or to control the transmittace for smart window and display applications. In this work, we demonstate a light shutter using liquid crystals doped with dichroic-dye and TBAB (tetra-n-butylammonium bromide). In the opaque state, the light shutter can hide objects behind it. In contrast, we can identify the objects clearly by the light shutter in the transparent state.

30 Material for Flexible Displays

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~17:35
Session Chair: Prof. Han-Ki Kim (Kyung Hee Univ., Korea)

F30-1 16:30~16:55

Invited Gels & Their Applications

Jeong-Yun Sun (Seoul Nat'l Univ., Korea)

Hydrogels are used as scaffolds for tissue engineering, vehicles for drug delivery, actuators for optics and fluidics, and model extracellular matrices for biological studies. The scope of hydrogel applications, however, is often severely limited by their mechanical behaviour. Most hydrogels do not exhibit high stretchability; for example, an alginate hydrogel ruptures when stretched to about 1.2 times its original length. Some synthetic elastic hydrogels have achieved stretches in the range 10–20, but these values are markedly reduced in samples containing notches. Most hydrogels are brittle, with fracture energies of about 10 Jm^{-2}, as compared to 1,000 Jm^{-2} for cartilage and 10,000 Jm^{-2} for natural rubbers. Intense efforts are devoted to synthesizing hydrogels with improved mechanical properties; certain synthetic gels have reached fracture energies of 100–1,000 Jm^{-2}. We have reported the synthesis of a new hydrogel from polymers that form ionically and covalently crosslinked networks. Although such gels contain 90% water, they can be stretched beyond 20 times their initial length, and have fracture energies of 9,000 Jm^{-2}. Even for samples containing notches, a stretch of 17 is demonstrated. We attribute the gels' toughness to the synergy of two mechanisms: crack bridging by the network of covalent crosslinks, and hysteresis by unzipping the network of ionic crosslinks. Furthermore, the network of covalent crosslinks preserves the memory of the initial state, so that much of the large deformation is removed on unloading. The unzipped ionic crosslinks cause internal damage, but are healed by re-zipping. These gels serve as model systems to explore mechanisms of deformation and energy dissipation, and expand the scope of hydrogel applications. Furthermore, as a new application, we have proposed a class of devices enabled by hydrogel conductors that are highly stretchable, fully transparent to light of all colors, and capable of operation at frequencies beyond 10 kHz and voltages above 10 kV. We have created a transparent actuator that can generate large strains, and a transparent loudspeaker that produces sound over the entire audible range. The electromechanical transduction is achieved without electrochemical reactions.

30 Material for Flexible Displays

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~17:35
Session Chair: Prof. Han-Ki Kim (Kyung Hee Univ., Korea)

F30-2 16:55~17:20

Invited Robust Transparent Conducting Glass-fabric Reinforced Plastic (FRP) Films for Flexible Optoelectronic Device Platform

Byeong-Soo Bae, Hyeon-Gyun Im, and Junho Jang (KAIST, Korea)

We introduce transparent conducting hybrid plastic films (TCE-GFRHybrimer) using transparent glass-fabric reinforced plastic films (GFRHybrimer) and surface-embedded metal nanostructured conducting materials. The GFRHybrimer films as basal substrates are developed by impregnating glass-fabric with refractive index-matched siloxane hybrid resin. The GFRHybrimer films exhibit high optical transparency (> 90 %), low thermal expansion coefficient (< 15 ppm/°C), high elastic modulus (> 10 GPa), and high thermal stability. To confer electrical conductivity to the films, various metal nanostructured materials such as metal nanowires (Ag or CuNW) and metal nanotrough network are used as TCEs. The metal nanostructured materials are embedded into the surface of the GFRHybrimer films during the film fabrication process, so the resulting TCE-GFRHybrimer films show excellent opto-electrical property, smooth surface topography, good mechanical flexibility, and robust thermal/chemical stability.

F30-3 17:20~17:35

Photo-Patternable and Transparent Films Using Cellulose Nanofibers for Stretchable, Origami Electronics

Sangyoon Ji, Byung Gwan Hyun, Kukjoo Kim, and Jang-Ung Park (UNIST, Korea)

Substantial progress in flexible or stretchable electronics over the past decade has extensively impacted on various technologies such as wearable devices, displays, or automotive electronics for smart cars. An important challenge here is reliability of these deformable devices against thermal stress. Different coefficients of thermal expansion (CTE) between plastic substrates and the device components which include multiple inorganic layers of metals or ceramics induce thermal stress to the devices during fabrication processes or long-term operations with repetitions of thermal cyclic loading-unloading, lead to device failure and degrade their reliability. Here we report an unconventional approach to form photo-patternable, transparent cellulose nanofiber (CNF) hybrid films as flexible and stretchable substrates toward reliable devices, using simultaneous electrospinning and spraying. The electrospun polymeric backbones and sprayed cellulose nanofiber fillers enable the resulting hybrid structure to be patternable photolithographically as a negative photoresist, and stable thermally and mechanically, with presenting outstanding optical transparency (~ 89 %) and low CTE (< 10 ppm/K). We also formed stretchable, origami substrates using the CNF hybrid, which are composed of rigid support fixtures and elastomeric joints, exploiting the photo-patternability. Demonstrations of transparent organic light-emitting diodes and touch-screen panels on the hybrid suggest a promise for next generation electronics.

31 Solution Processed Novel Device

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:10
Session Chairs: Prof. Bumjoon Kim (KAIST, Korea)
Dr. Anna Hayer (Merck KGaA, Germany)

G31-1 16:30~16:55

Invited An Alternative Way to Use the Triplet Energy of Fluorescent Dye in OLED via an External Iodide

Xing Xing, Mengying Bian, and Lixin Xiao (Peking Univ., China)

An unusual heavy atom effect has been identified in an organic light emitting device (OLED) containing polyvinylcarbazole (PVK) as the host, the red fluorescent dye DCM2 as the emitter, and non-emitting 1,8-diiodooctane (RI) as a heavy atom source instead of a rare metal. The intensity of electroluminescence (EL) of DCM2 changes with the concentration of RI, with a maximum EL intensity obtained for DCM2 at a concentration of 0.25% of RI. Photoluminescence (PL) spectra of PVK–DCM2 films show increased singlet emission from DCM2 in the presence of iodide at 12 K. The enhanced fluorescence induced by iodide is caused by energy transfer from both the singlet and triplet states of PVK to the singlet states of DCM2. These results suggest an alternative way to use the triplet energy of fluorescent materials with external heavy atoms rather than conventional phosphorescent dyes containing rare heavy metal atoms.[1] The energy levels and proposed energy transfer processes are shown in Figure 1. Fig. 1. The energy levels and proposed energy transfer processes in the OLEDs.

31 Solution Processed Novel Device

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:10
Session Chairs: Prof. Bumjoon Kim (KAIST, Korea)
Dr. Anna Hayer (Merck KGaA, Germany)

G31-2 16:55~17:20

Invited Using Novel Metal Oxides and Multiple Plasmonic Nanostructures for Emerging Organic Optoelectronic Devices

Wallace C.H. Choy (The Univ. of Hong Kong, Hong Kong)

We theoretically and experimentally investigated OSCs incorporated with multiple plasmonic metal nanostructures. For the theoretical study, we employed a multiphysics model for plasmonic organic solar cells to investigate the detailed physics of the performance enhancement. Furthermore, experimental studies were also conducted on various metallic nanostructures such as metallic nanoparticles and metallic nanogratings embedded into different regions of the solar cells, with interesting plasmonic-optical and plasmonic-electrical effects observed. For the plasmonic-optical effects, light absorption in the active layer of OSCs was enhanced by the embedded plasmonic metal nanostructures, which thus improved the photocurrent of the device. For the electrical effects by the incorporated plasmonic nanostructures, hot carrier and charge storage effects were separately studied and organic optoelectronic devices with high performance were achieved. Through a novel plasmonic-electrical concept, we recently demonstrated the surpassing of the intrinsic space-charge limit in organic semiconductors. Charge extraction and injection through developing efficient charge transport layers is equally essential for the design of high performance optoelectronic devices. In order to further reduce production costs and enable compatibility with large-area and high-throughput production, it is highly desirable to develop solution-processed approaches for the synthesis of various charge transport layers. We demonstrated effective methods to synthesize various metal oxides as hole transport layer and electron transport layer for high performance organic optoelectronic devices, with the distinctive features of solution-processed and requiring only low- or even room-temperature. Using our approaches, the metal oxide charge transport layers with moderate level of oxygen vacancies showed excellent charge transport properties. By further incorporating metal nanomaterials, charge extraction in organic photovoltaic devices was significantly improved.

31 Solution Processed Novel Device

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:10
Session Chairs: Prof. Bumjoon Kim (KAIST, Korea)
Dr. Anna Hayer (Merck KGaA, Germany)

G31-3 17:20~17:45

Invited OLED Spot-Lights with 1000 cd/A Efficacy

Stefan Höfle, Matthias Hecht, Min Zhang, Uli Lemmer, and Alexander Colsmann (Karlsruhe Inst. of Tech. Germany)

In order to employ organic light emitting diodes (OLEDs) in general lighting applications, it is of great importance to overcome their limitations in lifetime and luminous efficacy. Since the light output is proportional to the applied current, high operating currents are necessary to achieve high luminance. Unfortunately, high currents are considered to cause severe OLED degradation and, therefore, limit the device lifetime. One approach to achieve high luminance while reducing the operating current, is to combine multiple OLEDs in a monolithic stack. Some applications require unidirectional light emission. To control the direction of light emission, a micro-lens array is applied beneath substrate and a pixelated emissive area is aligned to the focal spots of the micro-lens array in order to optimize light outcoupling and to reduce absorption losses from in-between the micro-lens array. We present a new process that meets the strict alignment requirements between micro-lenses and apertures without requiring highly precise position tools. This routine can be upscaled easily, too. By combining the micro-lens array with a triple junction OLED, current efficiencies of more than 1000 cd/A are obtained in forward direction.

G31-4 17:45~18:10

Invited Highly Efficient Organic-Inorganic Hybrid Light-Emitting Diodes by Surface Engineering

Bo Ram Lee (Univ. of Cambridge, U.K.), Seungjin Lee, Jae Choul Yu, and Myoung Hoon Song (UNIST, Korea)

Highly efficient inverted organic-inorganic light-emitting diodes require well-matched energy levels according to the device configurations, a reduction of interfacial resistance and passivation of the defect sites. In this paper, we present a simple and effective method of interfacial engineering by employing a series of amine-based polar solvents (ABPSs) that contain amine groups to enable adjustment of the work function (WF), which can be used to control the desired energy level depending on the number of amine groups. In addition, treatment with an ABPS can reduce the leakage current and enhance hole-blocking behavior via the passivation of defect sites on the ZnO surface. Thus, optimized inverted organic-inorganic light-emitting diodes with ABPS treatment achieve a luminous efficiency (LE) of around 23 cd A^{-1} using super yellow and power conversion efficiency (PCE) of 9.04 %, respectively.[1]

32 LC Materials

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:00
Session Chairs: Prof. Vladimir G Chigrinov (HKUST, Hong Kong)
Prof. Jangkun Song (Sungkyunkwan Univ., Korea)

H32-1 16:30~16:55

Invited Side Chain Polyacetylene: Chiral Columnar Phase, Frustrated Chain Packing, and Thermal Reversible Actuation

Jun Wang and Er-Qiang Chen (Peking Univ., China)

We study the self-assembly of a newly synthesized cis-polyphenylacetylene (PPA) derivative, poly-(s)-4, bearing two small chiral moieties of (s)-2-methylbutyl attached to the 3,5-positions of phenyl through ester linkage. Poly-(s)-4 can form two chiral column liquid crystal phases, one simple hexagonal (Φ_h) at high temperatures and the other one with a highly ordered 3D hexagonal superlattice ($\Phi_h^{3D\text{-}SL}$) containing four chains at low temperature. The $\Phi_h^{3D\text{-}SL}$ shows a new frustrated chain packing mode. The $\Phi_h^{3D\text{-}SL}$-to-Φ_h transition associates with the conformation change of PPA from cis-cisoidal to cis-transoidal. Therefore, the uniaxially orientated poly-(s)-4 exhibits the behavior of thermoresponsive two-way shape actuator, which can elongate up to 132% upon heating and contracting upon cooling reversibly and reproducibly.

H32-2 16:55~17:20

Invited Redox-Active Liquid-Crystalline Polymer Thin Films with Nanosegregated Structures based on Perylene Bisimide Bearing Cyclotetrasiloxane Rings

Masahiro Funahashi (Kagawa Univ., Japan)

Self-organization of electro- and redox-active p-conjugated moieties in liquid-crystalline (LC) phases is effective to enhance electronic charge carrier transport. LC semiconductors have been applied to solution-processed electroluminescence devices, field-effect transistors, and solar cells.[1-3] As well as organics semiconductors, LC redox-active materials have also great potentials for electrochromic devices, conductive materials, and buttery. In these applications, the formation of insolubilized thin films with nanosegregated structures is indispensable, into which ions in electrolyte solution can penetrate without deteriorating the electronic charge carrier transport.[4] Herein, we report a new LC PTCBI derivative 2 bearing cyclotetrasiloxane rings and a triethylene oxide chain coordinating to ions (Fig, 1(a)). The spin-coated thin films of this compound can be insolubilized by the in situ ring-opening polymerization.[5] The polymerized thin films exhibited electrochromism in organic solvents (Fig. 1(b)). The conductivity was increased by a factor of 10^4 with doping in an aqueous solution of sodium dithionate in contrast to compound 1 which could not be doped in the solution of sodium dithionate.

32 LC Materials

Date: Aug. 24, 2016 (Wednesday)
Time: 16:30~18:00
Session Chairs: Prof. Vladimir G Chigrinov (HKUST, Hong Kong)
Prof. Jangkun Song (Sungkyunkwan Univ., Korea)

H32-3 17:20~17:45

Invited Photomotility of Liquid Crystalline Polymers

Jeong Jae Wie (Inha Univ., Korea), M. Ravi Shankar (Univ. of Pittsburgh, U.S.A.), and Timothy J. White (Air Force Research Laboratory, U.S.A.)

Azobenzene functionalized liquid crystalline polymer networks (azo-LCNs) are capable of direct transduction of light input into mechanical output with programmed mechanical deformation by manipulation of molecular alignment. [1] Utilization of light power source is appealing to achieve wireless and remote energy supply and motion control that can avoid weight penalty of on-board power supply systems. Towards miniaturized light weight soft robotics, we synthesized azo-LCNs in the twisted nematic conformation, where the nematic director rotates 90° across the sample thickness. To produce spiral shapes of azo-LCNs, twisted nematic offset angle is generated between the alignment of the director and the principal axes of the strips. [2] Here, we demonstrate wireless photomotility of <1 mg monolithic azo-LCN films and important parameters affecting the motility will be discussed.

H32-4 17:45~18:00

Nanostructured Films of Oriented Molecular Nanowires from Discotic Liquid Crystals

Ji Hyun Park, Kyung Ho Kim, Yung Woo Park, Jan P. F. Lagerwall, and Giusy Scalia (Seoul Nat'l Univ., Korea)

The realization of long, aligned molecular wires is a great challenge, and a variety of approaches have been proposed. Interestingly, hexapentyloxytriphenylene (HAT5) discotic liquid crystal molecules, a model system of molecules with flat and aromatic cores, can spontaneously form well aligned, micrometer long, yet only tens of nanometers thick, nanowires on solid surfaces. We have investigated the formation mechanism of these wires using different solvents with selected characteristics finding that the chemical structure of the solvent appears to have a key role. In fact it couples to the liquid crystal self-assembly by solvent molecules entering into the ordered structure if their design matches the core of HAT5 molecules, thereby guiding the assembly. In contrast dodecane or heptane, resembling the chain part produce bulkier structures and increase disorder. The electrical properties of ordered nanowires obtained with a suitable solvent show a 3 times higher electrical conductivity compared to disordered systems but also to bare HAT5 films.

33 OLED Materials I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:10
Session Chairs: Prof. Chin-Ti Chen (Academia Sinica, Taiwan)
Prof. Jian Li (Arizona State Univ., U.S.A.)

A33-1 08:30~08:55

Invited Applications of Exciplex Emission in Thermally Activated Delayed Fluorescent OLEDs

Chun-Sing Lee (City Univ. of Hong Kong, Hong Kong)

Exciplex emissions are emissions from excited state complexes formed between specific combinations of donor and acceptor molecules. Their emission spectra are typically red shifted and board comparing to those of their constituting molecules. While exciplex emissions had been considered to be harmful for device performance a couple of decades ago, their applications in high performance OLEDs have been demonstrated in the past few years. In particular, their applications in thermally activated delayed fluorescent (TADF) OLEDs have attracted much recent attention. In this talk, several aspects on exciplex emissions and their applications in TADF OLEDs will be addressed. Firstly, the criteria for selecting donor (D) and acceptor (A) molecules for giving exciplex emissions will be discussed [1]. The conditions required for an exciplex emitter to give TADF is then explained [1]. Examples on applications of TADF exciplex emitters in OLEDs of different structures will be provided. In particular, device design involving doping of conventional fluorescent dopants [2], phosphorescent dopants [3], as well as TADF dopants [4] in hosts of TADF exciplex emitters will be discussed.

A33-2 08:55~09:20

Invited Molecular Design Approach of Highly Efficient Donor-Acceptor Type Emitters

Dong Ryun Lee, Sung Yong Byun, Ji Han Kim, and Jun Yeob Lee (Sungkyunkwan Univ., Korea)

In this work, we designed the delayed fluorescent emitters based on different molecular design approaches to meet the several requirements of the thermally activated delayed fluorescent emitters. It was demonstrated that the multiple donor type design, sterically hindered design and molecularly distorted design were effective to realize high quantum efficiency and short excited state lifetime in the thermally activated delayed fluorescent devices.

33 OLED Materials I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:10
Session Chairs: Prof. Chin-Ti Chen (Academia Sinica, Taiwan)
Prof. Jian Li (Arizona State Univ., U.S.A.)

A33-3 09:20~09:45

Invited Long Lasting Blue Thermally Activated Delayed Fluorescent Organic Light-Emitting Diodes

SungHan Kim and Soo-Ghang Ihn (Samsung Electronics Co., Ltd., Korea)

Thermally activated delayed fluorescence (TADF) emitters have been developed as substitutes for the high-cost phosphorescent emitters because 100% internal quantum efficiency (IQE) can be implemented even without heavy atoms [1,2]. Even blue TADF organic light emitting diodes (OLEDs) exhibit maximum external quantum efficiency (EQE_{max}) about 20% [3]. However, it is very hard to find stable blue OLEDs using TADF. Lack of stable host materials fitted to the TADF emitters is one of the critical reasons. We here present alternative host materials educing potential abilities of given TADF emitters in both viewpoints of efficiency and device lifespan. The photochemically, electrochemically stable host material let us achieve the best performed blue TADF OLED ever exhibiting the highest EQE at a relevant brightness with the longest lifespan simultaneously.

A33-4 09:45~10:10

Invited Highly Efficient Electroluminescence based on Thermally Activated Delayed Fluorescence

Hajime Nakanotani and Chihaya Adachi (Kyushu Univ., Japan)

We demonstrate a novel pathway for highly-efficient fluorescence-based OLEDs by exploiting thermally activated delayed fluorescence (TADF) through the use of an assistant dopant, i.e., "TADF-assisted fluorescence (TAF)". In the TAF-system, triplet excitons created on a TADF molecule by electrical excitation are up-converted to the singlet state, and the singlet excitons are completely transferred to the singlet state of a fluorescent emitter molecule via a Förster energy transfer process, which results in efficient radiative decay from the singlet state of the fluorescent emitter. The OLEDs with TADF assistant dopants showed high external EL quantum efficiencies of 20%, indicating that the exciton production efficiency reached nearly 100%.

34 Oxide TFT Device Structure

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~09:45
Session Chairs: Prof. Yukiharu Uraoka (NAIST, Japan)
Prof. Saeroonter Oh (Hanyang Univ., Korea)

B34-1 08:30~08:55

Invited Achieving High Performance Metal Oxide Thin Film Transistors Through Structural and Post Treatment Engineering

Hyun Jae Kim (Yonsei Univ., Korea)

We developed various fabrication techniques to improve electrical properties through structural and post treatment engineering. For high performance oxide TFTs fabricated by solution process, the role of an interface as an electron-trapping layer in double-stacked indium gallium zinc oxide TFTs has been investigated. The device with the optimized interface location shows improved electrical characteristics, and these enhancements are attributed to the absence of an electron-trapping interface layer in the effective channel layer. In the case of sputtered oxide TFTs, we suggest two kinds of post-treatment utilizing external energy after device fabrication. High-pressure annealing (HPA) and simultaneous UV and thermal treatment (SUT) in oxide TFTs can improve the electrical properties and decrease activation temperature of metal oxide films under 150°C. The HPA increases the film density by decreasing structural defects, and improves electrical characteristics by reacting gas atmospheres. For SUT treatment, defects and trap sites in oxide films can be decreased by atomic decomposition and rearrangement. In addition, new approaches have been applied to oxide TFTs: selective etching process to achieve swtiching property, Cu incorporation for P/N type conversion, Collodion passivation layer, selective activation by voltage bias, low temperature activation with rotating magnetic field, and hydrogen radical doping on highly-hydrophilic surface.

34 Oxide TFT Device Structure

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~09:45
Session Chairs: Prof. Yukiharu Uraoka (NAIST, Japan)
Prof. Saeroonter Oh (Hanyang Univ., Korea)

B34-2 08:55~09:20

Invited High Mobility Thin-Film Transistors based on Solution Processed Low Dimensional Metal Oxides

Hendrik Faber, Yen-Hung Lin, Satyajit Das, Ivan Isakov, Nikolaos Chastas, and Thomas Anthopoulos (Imperial College London, U.K.)

Metal oxide semiconductors are seen as key components for future electronic devices in areas such as large-area displays, smart labels, and wearable technology. Suitable deposition techniques for this market require precise and reliable thickness control and cost-efficient large-area deposition with process temperatures (T_{max}) low enough to be compatible with plastic substrates. Solution processing and the involved printing techniques promise many of these benefits, however, traditionally high annealing temperatures (above 400 °C) are required to achieve well performing metal oxide devices. Here, we present recent advances of our research into low temperature fabrication of metal oxide thin-film transistors (TFTs) and the successful combination of different techniques. Based on the capability to produce ultra-thin (≈5-10 nm) films of ZnO, In_2O_3, and Ga_2O_3 by spin coating it was found that TFTs with multilayer stacks of individual films readily outperform any of the individual components. These findings were then successfully transferred to deposition techniques more suitable for upscaling, namely ultrasonic spray pyrolysis. Rather than relying on the bulk properties of a single semiconductor this approach demonstrates a promising pathway towards the development of future large-area oxide based electronics.

34 Oxide TFT Device Structure

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~09:45
Session Chairs: Prof. Yukiharu Uraoka (NAIST, Japan)
Prof. Saeroonter Oh (Hanyang Univ., Korea)

B34-3 09:20~09:45

Invited Enhancement of Metal Oxide TFT Performance by Engineering of Channel/Insulator

Shi-Jin Ding (Fudan Univ., China)

In recent years, amorphous In–Ga–Zn–O (a-IGZO) thin-film transistors (TFTs) have attracted considerable attention because of their potential applications in flexible and transparent electronic devices. This is attributed to some advantages of a-IGZO such as good electrical uniformity, high field effect mobility, visible light transparency and low processing temperature [1-2]. In this talk, we firstly compare plasma-enhanced chemical vapor deposited (PECVD) SiO_2 dielectric and plasma atomic layer deposited (ALD) SiO_2 dielectric for a-IGZO TFTs. The results indicate that the ALD SiO_2 gate dielectric can achieve much better performance of the device than the PECVD counterpart, such as much higher field effect mobility (m_{FE}), a smaller sub-threshold slope (SS) and a larger on/off current ratio. Without the need of post-annealing, the as-fabricated a-IGZO TFTs with the ALD SiO_2 gate dielectric exhibit a m_{FE} of ~64 $cm^2V^{-1}s^{-1}$, a SS of 0.14 V/dec, and a on/off current ratio of ~10^8, as shown in Fig. 1. Furthermore, the ALD SiO^{-2} device also demonstrates much better stability under negative gate bias stress, negative bias temperature stress and negative bias illumination stress, respectively, while being compared with the PECVD SiO_2 device. Such superior performance for the ALD SiO_2 device should be ascribed to a lower density of interfacial traps, weaker surface roughness scattering, and enhanced passivation of oxygen vacancies in the a-IGZO channel atop the ALD SiO_2 film with more OH groups. Moreover, both types of devices show a gradual degradation of performance as a function of post-annealing temperature in N_2, and the underlying reason will be also discussed. Such high performance ALD SiO_2 device without the need of post-annealing could be promising for the application of flexible electronics. Further, ALD SiO_2/high-k stacked dielectrics were attempted for a-IGZO TFTs, indicating that the ALD SiO_2 buffer layer played a key role in enhancing the performance of a-IGZO TFTs.

35 Stretchable / Wearable Display

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~09:50
Session Chair: Prof. Kang-Jun Baeg (Pykyong Nat'l Univ., Korea)

C35-1 08:30~08:55

Invited Printable, Transparent and Intrinsically Stretchable Electronics

Jiajie Liang (Nankai Univ., China), and Qibing Pei (Univ. of California, U.S.A.)

Stretchable electronics has been perceived as an alternative technology for the realization of the next generation of electronic applications. Stretchable displays and solid-state lighting systems would enable expandable and foldable screens for smartphones, wearable or fashionable electronic clothing, rollable or collapsible wallpaper-like lamps and biocompatible light sources for in vivo or epidermal medical devices. The emergence of devices that combine elasticity with electronic or optoelectronic properties offers exciting new opportunities for applications, but brings significant materials and fabrication/integration challenges. Here, we report a fully solution-based approach to construct intrinsically stretchable and transparent organic light-emitting devices (OLED) and display, in which all the functional components are elastic.

C35-2 08:55~09:10

Low-Temperature (150 °C) Processed Self-Aligned InGaZnO/ Organic Hybrid Thin-Film Transistor for Flexible Devices

Gengo Tatsuoka, Tatsuya Toda, Yusaku Magari, and Mamoru Furuta (Kochi Univ., Japan)

Amorphous oxide semiconductors represented by InGaZnO (IGZO) are strong candidates for an active channel of flexible TFTs fabricated on a plastic substrate. To fabricate TFTs on the plastic substrate, processing temperature must be reduced below the glass transition temperature of the substrate. Especially, high quality gate insulators (GI) should be deposited at low temperature. The coatable organic insulator is one of the candidates of a GI for flexible TFTs, because it can be formed by low-temperature (below 200 °C), simple, and vacuum-free process. Furthermore, an organic film of GI does not limit the flexibility of the plastic substrate.In this study, we fabricated self-aligned top-gate IGZO TFT at a maximum process temperature of 150 °C using a coatable organic insulator, Zeocoat®, as a channel protection layer (PL), GI and interlayer. In case of without the PL, the TFT did not turn off even at the gate voltage of -10 V. On the other hand, the TFT with PL shows a good switching properties; saturation mobility: 10.2 cm^2 / Vs, subthreshold swing: 0.19 V/dec., and hysteresis: 0.2 V. This result can be considered that the front-channel interface was effectively protected by PL from the contamination and the damage induced during the IGZO channel patterning.

35 Stretchable / Wearable Display

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~09:50
Session Chair: Prof. Kang-Jun Baeg (Pykyong Nat'l Univ., Korea)

C35-3 09:10~09:25

High Luminance Solution-Processed Organic Light Emitting Diodes on Flexible Fibers for Wearable Displays

Seonil Kwon, Hyuncheol Kim, Seungyeop Choi, Hoseung Lee, Dohong Kim, Eun Gyo Jeong (KAIST, Korea), Byoung-Cheul Park, Sin-Hyeok Kang (Kolon Glotech, Inc., Korea), and Kyung Cheol Choi (KAIST, Korea)

We demonstrate PLEDs that have been fabricated on a fiber surface using the dip coating method. The dip-coating method is a very simple method for coating fibers concentrically. The resulting light emitting devices exhibit high performances, with the highest luminance of 8,575 cd m^{-2} and the highest current efficiency of over 7 cd A^{-1}. This result is equivalent to performances obtained with control devices on glass substrates. This development holds great promise for the manufacturing of low-cost highly efficient PLEDs on fibers, using the roll-to-roll dip coating method.

C35-4 09:25~09:50

Invited Stretchable Electroluminescent Devices for Soft Display

Pooi See Lee (Nanyang Technological Univ., Singapore)

Stretchable electroluminescent (EL) devices are one essential component that enables applications such as wearable display, soft lighting devices, conformable readout systems on skins, and biomedical imaging devices. Existing challenges in developing stretchable EL devices lies in the complicated fabrication processes and lack of desired stretchabilty as they were formed with rigid light-emitting devices assembled onto elastic substrates. Alternative approach based on stretchable materials has been reported with simple and cost-effective fabrication procedures. The remained difficulties are to improve the electrical stability and stretchability of the devices. We have successfully fabricated a fully stretchable alternating-current EL devices using AgNWs as the transparent and stretchable electrodes. The stretchable device could maintain stable emission under stretching strains up to 100%. The stretchable EL device could also be integrated with a dielectric elastomer actuator to achieve a self-deformable EL device. This innovative device could be driven to dynamic shapes under external bias with well-maintained emission behavior. We have also demonstrated that the stretchability of the alternating-current EL devices can be significantly improved by using ionic conductor as the transparent and stretchable electrodes. The super-elastic EL devices can be elongated up to 700% strain with the emission intensity maintained at 70% of the initial emission intensity at 0% strain.

36 Quantum Dots for Future Displays I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:00
Session Chair: Prof. Jaeyoung Jang (Hanyang Univ., Korea)

D36-1 08:30~08:55

Invited Designing Quantum Dots for Electronic and Optoelectronic Devices through Surface and Interface Control

Soong Ju Oh (Korea Univ., Korea)

We introduce a simple, solution-based, postsynthetic colloidal, atomic layer deposition (PS-cALD) process to engineer stepwise the surface stoichiometry and therefore the electronic properties of lead chalcogenide quantum dot (QD) thin films integrated in devices. We found that unlike chalcogen-enriched QD surfaces that are structurally, optically, and electronically unstable, lead chloride treatment creates a well-passivated shell that stabilizes the QDs. Using PS-cALD of lead chalcogenide QD thin films we demonstrate high electron field-effect mobilities of 4~10 cm^2/Vs, as shown in Figure 1. In addition, we study charge injection and transport in PbSe QD thin films. By engineering the contact metallurgy and QD ligand exchange chemistry and surface passivation, we demonstrate partial Fermi-level pinning at the metal–semiconductor interface and an insulator-to-metal transition with increased coupling and doping, allowing us to design high conductivity and mobility PbSe QD thin films. We construct complementary nanocrystal circuits from n-type and p-type transistors realized from a single QD material by selecting the contact metallurgy.

36 Quantum Dots for Future Displays I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:00
Session Chair: Prof. Jaeyoung Jang (Hanyang Univ., Korea)

D36-2 08:55~09:20

Invited Identifying the Chemical Origin of Traps in PbS QDs

Gyu Weon Hwang (KIST, Korea), Donghun Kim, Jose M Cordero, and Moungi G. Bawendi (MIT, U.S.A.)

Colloidal quantum dots (QDs) are attractive materials for optoelectronic applications because of their solution processability and size-dependent tunability of band gap. QDs have been studied actively for applications as photovoltaics, light emitting diodes, and photodetectors. However, further improvements in device performance are required to make them competitive. Although suppressing the trap states in QD thin films is a key to improve the performance of QD-based optoelectronics, it has remained a major challenge primarily because fundamental understanding of trap source is lacking in these materials. Here, we investigate the chemical origin of the trap states in PbS QD thin films to find a better approach to control trap states. As shown in Fig. 1 (a) and (b), X-ray photoelectron spectroscopy (XPS) and photoluminescence (PL) spectroscopy show that ligand-exchange procedures with tetrabutylammonium iodide (TBAI) lead to the formation of under-charged Pb atoms and sub-bandgap emission features. Our experimental results are corroborated by density function theory simulation, which show that the presence of Pb atoms having a lower charge in QDs with iodine ligands and their contribution to sub-bandgap states. The results for other popular ligands for the device fabrication such as 1,2-ethanedithiol and 3-mercaptopropionic acid will be discussed in the presentation. The trap states generated after ligand exchange were significantly reduced by oxidation of under-charged Pb atoms using oxidants. The sub-bandgap emission is removed by recovering oxidation state of Pb atoms. And the density of trap states measured electrically with drive-level capacitance profiling shows that this reduces the electrical trap density by a factor of 40.

36 Quantum Dots for Future Displays I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:00
Session Chair: Prof. Jaeyoung Jang (Hanyang Univ., Korea)

D36-3

09:20~09:45

Invited Intraband Transition of Atomic Ligand Passivated Colloidal Quantum Dots

Bitna Yoon, Juyeon Jeong, Dongsun Choi, and Kwang Seob Jeong (Korea Univ., Korea)

Colloidal quantum dots have been of great interest in a number of applications including display, solar cell, bio-imaging, photodetector, sensor and transistor. For the last 32 years, the bandgap of semiconducting nanocrystal has been mainly utilized for the applications. Recently, Jeong et al. reported the steady-state intraband transition and the Guyot-Sionnnest group fabricated the first intraband IR-photodetector. The intraband transition originates from the quantum confinement and occurs through the higher quantum states in the conduction band of the nanocrystal. The doping density of nanocrystals determines the intraband transition intensity. To note, the doping does not result from impurity but from excess positive Hg ion on the surface, which is different from conventional bulk semiconductors. To efficiently use the intraband energy for further applications, the organic ligand should be efficiently replaced by other organic/inorganic ligands. However, previous reports use thiols as the ligand, which are prone to oxidation and also complicate the photophysical mechanism. Here, we report the synthesis of oleylamine ligand passivated HgS CQDs that also efficiently generate intraband transition. By using the non-thiol ligand, it was possible to synthesize atomic ligand passivation on the HgS CQDs that still exhibit intraband transition in steady state under ambient condition.

D36-4

09:45~10:00

Achieving BT.2020 with Quantum Dots Requiring No Exemption to RoHS

Ernie Lee, Chunming (Kevin) Wang, Charlie Hotz, Jason Hartlove, Jeff Yurek, ZhongSheng Luo, Hugh Daniels, and Don Zehnder (Nanosys, U.S.A.)

Cadmium-based Quantum Dots (QDs) have already been shown to achieve >90% coverage of the ITU BT.2020 color gamut in LCD displays using QDEF® Quantum Dot film technology. This paper reports on recent advances in Quantum Dot materials engineering that have enabled further improvements to a new generation of QDEF that requires no exemption to the RoHS Directive while achieving similar color and brightness performance to existing Cadmium-based solutions. This compliance is made possible by using a combination of cadmium-free and low-cadmium QDs.

37 Large Area Displays Application I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:05
Session Chair: Dr. Youngmin Kim (KETI, Korea)

E37-1 08:30~08:55

Invited Methods for Huge Amount of Holographic Data Processing

Jisoo Hong, Youngmin Kim, Sunghee Hong, Choonsung Shin, and Hoonjong Kang (KETI, Korea)

Since the first successful demonstration of analog hologram by Leith and Upatnieks, displaying holographic three-dimensional (3D) image from digital data has been studied for decades without any meaningful result. One reason is that the required amount of hologram data to show the acceptable image quality much exceeds the number of pixels of current digital imaging and display devices. Hence, various temporal and spatial multiplexing techniques which effectively increase the number of pixels are developed to provide the holographic 3D image using currently available digital devices [1]. Especially, holographic wavefront printer is studied as one extreme case of spatial multiplexing [2]. It optically reduces the size of spatial light modulator (SLM) until each pixel becomes comparable to grain size of holographic emulsion. By mosaicking those reduced SLMs, it is capable of implementing the quality of analog hologram at an expense of dynamic image feature. Moreover, recent development of digital devices started to show the viable holographic movie if some restrictions such as fixed viewpoint were imposed [3].

The other reason that the practical holographic display did not come up to the field yet is that the required computational resource to synthesize digital hologram is much more than that of conventional 2D contents. The development of digital devices should be followed by computation methods which can deal with huge amount of data to support those devices with appropriate holographic contents. In the past, usual approach of processing the data for holographic display was to derive appropriate approximation of propagation equation to reduce the computation itself [4]. As far as the approximation is not perceived by human visual system, the computation time can be effectively reduced without image quality degradation. However, the performance of graphics processing unit (GPU) is rapidly increase recently, and, if properly used, the real-time synthesis of hologram for some applications are possible even with Rayleigh-Sommerfeld diffraction formula.

In the presentation, our effort to deal with huge amount of holographic data will be presented. Our approaches include both reducing the computational complexity by approximation [5] and acceleration of computation by using GPU. Even the understanding of human perception can be a clue to reduce the computation [6]. Experimental results, demonstrated by holographic displays such as holographic wavefront printer, will be provided, and the detail of our methods will be also discussed.

37 Large Area Displays Application I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:05
Session Chair: Dr. Youngmin Kim (KETI, Korea)

E37-2 08:55~09:10

Volumetric 3D Display Using Multi-Layered Active Shutter Screens

Min-Kyu Park, Kyung-Il Joo, Heewon Park (Kyungpook Nat'l Univ., Korea), Sung-Wook Min (Kyung Hee Univ., Korea), and Hak-Rin Kim (Kyungpook Nat'l Univ., Korea)

Volumetric three-dimensional (3D) display systems have been actively studied because it can provide a 3D volume image and all the stereoscopic vision factors such as accommodation, binocular parallax, convergence and motion parallax. The volumetric 3D displays can express voxel by using physical volume. Commonly, it is required for large data to represent the depth information on voxel. Recently, simply encoding method based on the compact type of depth fused 3D display was introduced, where periodically time-varying 2D images are used to sweep out the display volume at a higher frequency than the duration of the persistence of vision. However, the depth fused 3D display require a mechanical moving device that moves the location of the 2D images at a faster rate than the eye can resolve. In this paper, we introduced a new volumetric 3D display system by using polarization distributed depth map (PDDM) image and polarization controller. Polarization controller fabricated by liquid crystal (LC) cell is able to control polarized state of the 2D image electrically, which is properly designed to convert PDDM images into sectioned images. As active screens using polymer stabilized cholesteric texture are synchronized with polarization controller, sectioned images are sequentially projected on active screens, and consequently, reconstructed 3D image can be clearly displayed.

37 Large Area Displays Application I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:05
Session Chair: Dr. Youngmin Kim (KETI, Korea)

E37-3 09:10~09:25

Large Thermal Display with Converging Far-Infrared by Square Pipe Array (SPA)

Tomoyuki Okamoto, Kenta Onuki, Sho Onose, Takaho Itoigawa, and Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

We propose a square pipe array (SPA) as a reflective imaging element with the aim of large-sized thermal display. SPA is designed to converge far-infrared radiations from a heat source to its aerial image position. Compared with the previously presented thermal display by use of crossed-mirror array, SPA features scalability to realize large-scale installation to cover human body, low cost, and high-degree of freedom in its installation. In this paper, we present the principle of converging the far-infrared rays by use of SPA and report experimental results on temperature changes due to converged far-infrared rays with our developed SPA.SPA is composed of square pipes. We used a stainless-steel pipe in 40mm-square shape. The far-infrared rays from a heater are reflected twice at SPA. Then, the far-infrared rays are converged at plane-symmetrical position of the heater regarding the SPA. We have measured the temperature changes in the converging plane over one hour. The temperature locally increased at part of thermometer. Thus, we have succeeded in converging far-infrared rays with our developed large SPA.

E37-4 09:25~09:40

The Transmission-Type Three-Dimensional Screen Using the Loop Mirror Array

Hyunsik Sung and Sung-Wook Min (Kyung Hee Univ., Korea)

We propose the loop mirror array to solve the difficult fabricating of the MHMA and analyze the characteristic of the loop mirror array through the simulation. Also, we will verify the feasibiltiy of the transmission-type 3D screen using the loop mirror array by applying to the projection-type 3D display system.

37 Large Area Displays Application I

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:05
Session Chair: Dr. Youngmin Kim (KETI, Korea)

E37-5 09:40~10:05

Invited Bringing 3D User Interfaces to Our Everyday Environments

Diego Martinez Plasencia (Univ. of Sussex, U.K.)

Current market studies foresee a bright future for VR technology, with relevant technology companies competing for a dominant position in the market. However, inherent limitations in VR technology (e.g. headsets preventing interaction with people objects around us), can seriously affect user acceptance of this technology, just like the need for 3D glasses negatively affected similar market expectations for 3DTV in 2010. In this talk, Dr Martinez reflects on these topics and presents a series of 3D display systems implemented to allow seamless access to interactive 3D content. The systems presented range from systems to extend meeting rooms or coffee tables, personal 3D mobile devices and mid-air displays covering open spaces. However, they all share the vision to allow users uninstrumented and simple access to 3D content, while retaining the ability to still interact with other people, tools and technologies around us. These factors are essential to warrant user acceptance of 3D technology in their daily life.

38 3D Application

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:15
Session Chair: Dr. Dongkyung Nam (Samsung Advanced Inst. of Tech., Korea)
Prof. Soon-Gi Park (Tokyo Univ., Japan)

F38-1 08:30~08:55

Invited Spectroscopic Investigation of Optical Materials for Display Applications by using an Inelastic Light Scattering Technique

Jae-Hyeon Ko, Byoung Wan Lee, Min-Seok Jeong, Seonhyeop Shin, Soo Han Oh, Bong Jin Cho, Jaehoon Park (Hallym Univ., Korea), Young Ho Ko, and Kwang Joo Kim (Agency for Defense Development, Korea)

Optical materials are often subject to unusual conditions such as high temperature and/or high pressure, and the evaluation of their properties under these harsh conditions is very important for device optimization and longterm reliability. Inelastic laser light scattering techniques, such as Raman and Brillouin spectroscopy, have been used in the field of materials science and solid-state physics. Raman spectroscopy is used to probe the molecular vibrations in condensed matters while Brillouin spectroscopy provides us with acoustic properties, such as sound velocity, acoustic attenuation and elastic modulus. These spectroscopic techniques can be used to investigate vibrational and acoustic properties of optical materials unver various thermodynamic conditions. The spectroscopic properties are very sensitive to the changes in temperautre, alignment condition, pressure, curing condition, etc. We demonstrate that spectroscopic investigation may contribute to the material optimization and improvement of reliability of optical devices for display and lighting applications.

F38-2 08:55~09:20

Invited Advanced 3D Peplography – Image Sensing and Visualization from Unknown Scattering Media

Myungjin Cho (Hankyong Nat'l Univ., Korea)

Dynamic imaging through unknown scattering media under natural light is a big challenge in many applications. To overcome this challenge, various methods have been proposed including non-invasive imaging, ghost imaging, and wavefront shaping. However, their results have not been satisfactory even though active light sources and scanning mechanisms were used. This is due to the fact that these techniques do not directly detect ballistic photons emanating from objects through unknown scattering media, but only estimate and remove scattering media. In this paper, we propose a novel dynamic imaging technique through unknown scattering media by directly detecting ballistic photons emanating from objects based on computational photon counting imaging and then show experimental results to support the proposed method. In addition, to reconstruct the three-dimensional (3-D) image from unknown scattering media, we use integral imaging.

38 3D Application

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:15
Session Chair: Dr. Dongkyung Nam (Samsung Advanced Inst. of Tech., Korea)
Prof. Soon-Gi Park (Tokyo Univ., Japan)

F38-3 09:20~09:45

Invited Overview for Lamina 3D Displays

Sung-Wook Min and Hogil Baek (Kyung Hee Univ., Korea)

Our lamina 3D display is a kind of projection types of multiple layered 3D displays, which can reconstruct 3D images without the visual fatigue by the vergence-accommodation conflict because the reconstructed 3D image is displayed within the laminated volume.

F38-4 09:45~10:00

Development and Evaluation of Calibration Methods for an Autoscopic 3D Display Using Light Diffusion within Micro Regions

Yoshiki Ohashi, Takuya Fujii, Ryuta Endo, Hirotake Ishii, and Hiroshi Shimoda (Kyoto Univ., Japan)

The 3D display using light diffusion within 3-dimensionally positioned micro voids processed in a crystal glass cuboid is able to present 3D objects to any number of simultaneous viewers at any viewpoint, without wearing any kind of special glass-like equipments. However, in order to successfully present 3D objects, the projection must be adjusted precisely for each individual micro void by investigating the correspondence between each projector pixel and micro voids. This process not only requires a great amount of user's effort but also consumes a lot of time. In this research, hence, calibration methods which can automatically perform such adjustment by processing images captured by a camera and recognizing projection position were developed, namely; Pixel-Scan Method, Line-Scan Method and Structured-Light Method. Specifically, Line-Scan Method and Structured-Light Method were developed in aim of shortening the processing time of the calibration. Additionally, subjective experiment was conducted in order to evaluate accuracy of the calibration methods. The results show that Structured-Light Method resulted to be faster in processing time but degraded in quality for the presented images. However, despite Line-Scan Method being faster than Pixel-Scan Method in processing time, the degradation of the presented images was minor.

38 3D Application

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:15
Session Chair: Dr. Dongkyung Nam (Samsung Advanced Inst. of Tech., Korea)
Prof. Soon-Gi Park (Tokyo Univ., Japan)

F38-5 10:00~10:15

Performance Analysis of Stereo Matching Algorithm

Seong-Pil Cheon (Sogang Univ., Korea), Sanghun Kim, Young Hwan Kim (POSTECH, Korea), and Suk-Ju Kang (Sogang Univ., Korea)

Multiview 3D displays have been used in various fields: 3D medical display systems for accurate diagnosis of patients' condition and the digital signage for advertisement. In the multiview 3D display systems, depth and stereo images are required to generate multiview images. Stereo matching has been widely used to calculate a depth image using stereo images. This paper analyzes the algorithm performance by changing parameter values (spatial threshold and census size) to select optimal values using an existing stereo matching method. The stereo matching has 4 steps: cost computation, aggregation cost, disparity computation and disparity refinement. The spatial threshold is a key parameter deciding the support region size in the cost aggregation step. The census size is related to a census block in the cost computation step. In experimental results, Tables 1 and 2 show performance indices using the bad pixel ratio when changing each parameter value. Fig. 1 shows the result images for different parameter values. In Table 1, the average bad pixel ratio maximally decreased by up to 0.88%. In Table 2, the average bad pixel ratio maximally decreased by up to 0.90%. Therefore, the optimal parameters were measured when spatial threshold is 30 or census size is 7×7.

39 Organic/Pervoskite Photovoltaics

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:10
Session Chair: Prof. Yu-Lun Chueh (Nat'l Tsing Hua Univ., Taiwan)

G39-1 08:30~08:55

Invited Design Strategy of Organic Semiconductor for Organic Photovoltaics

Yun-Hi Kim (Gyeongsang Nat'l Univ., Korea)

Organic solar cells (OSCs) have attracted much attention as renewable energy sources due to their various advantages such as low cost, light weight, large-area device fabrication, and flexibilty. The donor-acceptor bulk-heterojunction (BHJ) structure is most promising architecture, which is typically consisting of a photoactive conjugated material as donor and fullerene derivative as acceptor. The advance in PSC performance has been improved mainly by the development of new donor conjugate materials which have low optical band gap for harvesting a broad solar spectrum as well as they have the proper lowest unoccupied molecular orbital (LUMO) energy level to make exciton dissociation at the interface of donor-acceptor. In addition, they have a deep highest occupied molecular orbital (HOMO) energy level to make high open-circuit voltage (Voc). They also have high hole mobility for balanced charge collection at both electrodes. In this presentation, design strategy of new the organic semiconductor will be discussed to fulfill the several conditions.

G39-2 08:55~09:20

Invited Regioregular Donor-Acceptor Copolymers for High-Efficiency Organic Solar Cells

Youngu Lee (DGIST, Korea)

Organic solar cells (OSCs) have attracted great attention due to their advantages of flexibility, lightweight, low costs of materials, and low fabrication costs. Recently, the series of poly(thieno[3,4-b]thiophene) benzothiophene (PTB) copolymers comprised of thieno[3,4-b]thiophene (TT) and benzo[1,2-b:4,5-b']dithiophene (BDT) segments have been developed for high-efficiency OSCs. Although the PTB copolymers possess excellent physical properties, they possess intrinsically a structural drawback, negatively influencing the photovoltaic performance of solar cell devices. Since the TT segment has an asymmetric molecular structure, it is impossible to control the orientation of the TT segment in conjugated polymer backbone during the polycondensation reaction. Accordingly, the PTB copolymers basically possess random structural regioregularity. However, in spite of intensive research for the PTB copolymers, little is known about the effect of the structural regioregularity of the PTB copolymers on the physical properties and photovoltaic performance because of synthetic difficulty of the regioregular PTB copolymers. In this talk, I will present synthesis and characterization of a regioregular p-type copolymer PBDTTT-C-T comprised of TT-BDT-TT-BDT repeating units and perfectly controlled TT orientation for high-efficiency OSCs as shown in Figure 1.[1]

39 Organic/Pervoskite Photovoltaics

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:10
Session Chair: Prof. Yu-Lun Chueh (Nat'l Tsing Hua Univ., Taiwan)

G39-3 09:20~09:45

Invited Low-Temperature-Processed TiO_2 Films for Flexible Perovskite Solar Cells

Sangwook Lee (Kyungpook Nat'l Univ., Korea), Seung Lee Kwon, and Hyun Suk Jung (Sungkyunkwan Univ., Korea)

Perovskite solar cells, a kind of thin film solar cells, are one of the most attractive renewable energy conversion devices for realizing a wearable power source. The perovskite crystal-structured inorganic-organic halide-based light absorbing materials are very sutiable for low temperature solution processes, which may enable economic fabrication of the devices via continuous low temperature processes, such as roll-to-roll printing, in the near future. For this purpose, intensive researches have been focused on developing a highly flexible perovskite solar cell, while preserving the high efficiency. One of the key issues hindering fabrication of highly efficient and highly flexible perovskite solar cells is the oxide film deposition process to make compact and/or mesoporous semiconducting layers at a low temperature. Here, our recent researches on low-temperature-processed TiO_2 films-based perovskite solar cells, with high flexibility and relatively high power conversion efficiency, will be presented. First, we used an atomic layer deposition (ALD) method to form a compact titanium oixde layer at below 80°C. The flexible perovskite solar cells based on the ALD-TiO_x films exhibit high efficiecy (~12%), and high bending durability; constant device performances up to 1000 bending cycles with 10 mm of bending radius. Degradation of the device performance by the bending was the result of crack propagations origintaed from the transparent conducting oxide layer, demonstrating the excellent electrical/mechanical properties of the ALD-TiOx layer under/against the bending. Second, a reactive ion etching (RIE) process was utilized to form a mesoporous titanium dioxide layer at room temperature. By careful control of the etching conditions, a less defective TiO_2 mesoporous layer was obtained. Perovskite solar cells with the RIE-TiO_2 mesoporous layers exhibit high efficiencies of ~15% under 1 Sun condition. The excellent device performances in both ALD and RIE cases are attributed to achivement of high quality oxide films at low temperatures, without a severe amount of internal oxygen defects or hydroxyl groups.

39 Organic/Pervoskite Photovoltaics

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:10
Session Chair: Prof. Yu-Lun Chueh (Nat'l Tsing Hua Univ., Taiwan)

G39-4 09:45~10:10

Invited Solar Cells Development of Conductive Polymers for High Efficiency Organicbased Solar Cells with High Long-term Stability

Jea Woong Jo, Myung-Seok Seo, Min Jae Ko, and Hae Jung Son (KIST, Korea)

Solar energy can potentially provide a clean, sustainable alternative to fossil fuels to meet the global growing needs for energy. Solar cells based on the photovoltaic effect are an effective method to convert solar energy into electricity. It has become attractive to find solar cell technologies which exhibit lower manufacturing costs by utilizing inexpensive and abundant materials. Because of this, organic-based solar cells are actively pursued by the scientific and industrial communities. Some additional advantages conveyed by organic-based solar cells are that they are lightweight and flexible and allow for scalable material production and cost effective roll-to-roll coating and printing techniques. One of the most important components comprising the organic-based solar cells is organic-interlayer materials, which play a role of charge transport to the corresponding electrodes. The organic-interlayer materials importantly affect not only solar cell efficiency, but the device stability under the conditions such as moisture exposure. We developed a noble low temperature processable organic-interlayer material and applied it to organic solar cells and perovskite solar cells. A series of experiments were performed to achieve high solar cell performance and understand the effect of the organic-interlayer material on the photovoltaic parameters and long-term device stability.

40 Flexible LCDs

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:00
Session Chair: Prof. Dog Ki Yoon (KAIST, Korea)

H40-1 08:30~08:55

Invited A Study of 60-inch Liquid Crystal Roll Display

Mitsuhiro Shigeta, Masae Kawabata, Kazuki Kobayashi, and Masatsugu Teragawa (Sakai Display Products, Japan)

We have developed roll type liquid crystal display which has the potential creating a new market of a liquid crystal display. The empirical experiment of roll display with radius 500 mm has already begun at Osaka station in Japan. The roll display with thickness 0.3mm and radius 500mm is fabricated by glass thinning. The UV2A mode used for in roll display is free from the alignment defects due the positional displacement between the upper and lower substrates by the internal stresses. The 3D sensation of roll shape display is enhanced by the sense of perspective in the vertical direction, and texture gradient in the horizontal direction.

H40-2 08:55~09:20

Invited Structural and Optical Technologies of Polymers for Flexible LCD

Hideo Fujikake, Yosei Shibata, and Takahiro Ishinabe (Tohoku Univ., Japan)

As next-generation display, a flexible liquid crystal display (LCD) using plastic substrates instead of glass sheets, creates innovative usage methods and human interface due to excellent storability, portability and designing freedom. The flexible LCD also has great advantages of ease in fabricating large size panel / high resolution pixels, excellent fabrication / operation stability, and low cost mass production. For realizing flexible displays with high image quality, we have so far created various useful polymer technologies on flexible LCDs. The technologies include molecular-aligned polymer wall spacer for keeping plastic substrate gap constant, device fabrication process using coat-debond polyimide film substrates having excellent heat resistance, high light transmittance and low optical anisotropy, compensating techniques of optically anisotropic plastic substrates and an LC layer for high-contrast ratio and wide viewing angles, and flexible backlight technology using segment-driven reverse-mode PDLC with plastic substrates as a flexible light guide plate. Based on the coat-debond substrate techniques, we demonstrated extremely flexible / thin TN-LC devices. These advanced polymer technologies enable to establish a practical flexible LCD system with high image quality and low cost.

40 Flexible LCDs

Date: Aug. 25, 2016 (Thursday)
Time: 08:30~10:00
Session Chair: Prof. Dog Ki Yoon (KAIST, Korea)

H40-3 09:20~09:45

Invited Cholesteric Liquid Crystal Displays Suitable for Color Electronic Papers

Zhe Hong, Da-Som Yoon (Hoseo Univ., Korea), Hyun-Ji Hong, Burm-Young Lee (NDIS Corp., Korea), and Soon-Bum Kwon (Hoseo Univ., Korea)

Cholesteric liquid crystal displays have developed for longer than two decades for a variety of reflective display applications such as electronic book and signage. Most of commercialized cholesteric displays were based rigid glass substrate. Flexible substrate based cholesteric displays were also much developed but a few of them were commercialized. Cell gap stabilization needed for flexible cholesteric displays has been a key technical issue. Adhesive column spacer was applied for the cell gap stabilization and good display performance was achieved. But the fabrication process of the cholesteric displays including the column spacer formation is somewhat complicated. Our group has developed cholesteric displays with cell gap stabilization using polymer wall formation in liquid crystal layer. The polymer wall formation process is in general simple, but the residual polymer in liquid crystal rich region of the cholesteric display may cause the deterioration of electro-optical properties such as reflectance, contrast ratio and color gamut if the phase separation for the polymer wall formation is not carried out well. We were able to make good phase separation by optimizing material and process parameters and achieved good electro-optical performance.

H40-4 09:45~10:00

Physical Properties of Sphere Phase Liquid Crystals

De-Chun Hu, Zi-Ping Chen, and Jian-Gang Lu (Shanghai Jiao Tong Univ., China)

A sphere phase liquid crystal induced by chiral dopant is observed between isotropic phase and blue phase. The temperature range of the sphere phase, usually less than several Celsius (°C), can be broadened to more than 85 °C by stabilizing the disclination lines with polymer network. The electro-optical switching time of the polymer-stabilized sphere phase is demonstrated in sub-millisecond with a low switching electric field of 5 $V \cdot \mu m^{-1}$, which shows potential applications in optical switches, tunable photonics, and fast phase modulators.

41 OLED Materials II

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chair: Prof. Chun-Sing Lee (City Univ. of Hong Kong, Hong Kong)

A41-1 10:30~10:55

Invited Simple but High Performance Hybrid White OLEDs based on Platinum Complex Single Dopant with Host Dependent Electroluminescence Color

Anurach Poleok (Academia Sinica, Taiwan), Chieh Wang (Nat'l Chiao Tung Univ., Taiwan), Chiao-Wen Lin (Academia Sinica, Taiwan), Chao-Tsen Chen (Nat'l Taiwan Univ., Taiwan), and Chin-Ti Chen (Academia Sinica, Taiwan)

We have chemically synthesized and physically characterized a series of heteroleptic platinum complexes, FPtXND, of which wavelength of photoluminescence (PL) is concentration dependent in solution or host material dependent in thin film. Chemical substituent (X) of FPtXND has a significant influence on the PL wavelength and the molecular aggregation in solid state. Two kinds of simple single-emitting-layer OLEDs were fabricated. The host material is the only difference for the device and they are either CBP or 4P-NPD. With CBP as the host material, all OLEDs show greenish yellow or orange red color electroluminescence (EL) as those PL of FPtXND in diluted solution. With 4P-NPD as the blue fluorescent host material, white EL, $CIE_{x,y}$ (0.33±0.04, 0.33±0.05) can be achieved with some FPtXNDs, where X is methyl, phenoxy, piperidino, or dimethylamino group. Although color rendering index (CRI) of such hybrid white EL is high at 85 already, EL efficiency is usually low (< 7.4%, < 13.0 cd/A, < 6.7 lm/W). Nevertheless, these are few hybrid white OLEDs with simple device structure but reaching CRI over 80. To further improve EL efficiency of such hybrid white OLEDs, double-emitting–layer hybrid white OLEDs were fabricated with a single phosphorescence dopant partitioned in two layers, hosting by CBP and 4P-NPD, respectively. Hybrid white, $CIE_{x,y}$(0.33, 0.31), EL efficiency is greatly improved to 10.6%, 18.4 cd/A, or 11.6 lm/W, and CRI is enhanced further up to 91. In addition, both $CIE_{x,y}$ and CRI of the hybrid white OLEDs are relatively stable within the driving voltage of 7-11 V.

41 OLED Materials II

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chair: Prof. Chun-Sing Lee (City Univ. of Hong Kong, Hong Kong)

A41-2 10:55~11:20

Invited Isomers in Pyreneimidazole Compound: Synthesis and Configuration Effect on Optical Properties and Device Performance

Yulong Liu, Tong Shan, and Ping Lu (Jilin Univ., China)

Structural Isomer is one of the central issue in chemistry, especially for chemical applications in medicinal and material science. In optoelectronic field, they also have attracted tremendous interests. For instance, structual isomers, which contain the same bond structure but differ in the geometrical position of atoms in space, do not necessarily share similar properties even if they have the same functional groups, endowing them to be utilized as valuable and visualized model compounds to deal with the relationship between structure and property. Two structural isomers with pyreneimidazole structure, axisymmetric syn-PyDTI and centrosymmetric anti-PyDTI, are naturally formed during the synthesis process and successfully separated. Syn-PyDTI exhibits 2-folded higher quantum efficiency in crystal and 1.5-folded higher quantum efficiency in amorphous evaporated film than that of anti-PyDTI, although they possess the same apparent electronic structure. The observation reveals a dependence of molecular excited state properties derived from distinct structural symmetry. Syn-PyDTI also displays much better performance in OLEDs with a $\eta_{c.max}$ of 11.42 cd A^{-1} (8.12 cd A^{-1} for anti-PyDTI). The current work depicts the establishment of stable imidazole based isomers with very convenient accessibility and endows them with multifunctionality.

A41-3 11:20~11:35

Synthesis Dibenzothiophene Based Long Lifetime Host Materials for Blue Phosphorescent Organic Light-Emitting Diodes

Ji Han Kim and Jun Yeob Lee (Sungkyunkwan Univ., Korea)

In this study, dibenzothiophene derived host materials were synthesized as host materials of imidazole ligand based Ir emitters for blue phosphorescent device. We developed host materials via different substitution position (1-, 2-, 3-, 4- position) of the carbazole moieties on 2-, 8- position of dibenzothiophene. These three materials 2,8-bis (9-phenyl-9*H*-carbazol-1-yl)dibenzo*[b,d]*thiophene (1Cz-DBT), 2,8-bis(9-phenyl-9*H*-carbazol-3-yl)dibenzo*[b,d]*thiophene (3Cz-DBT) and 2,8-bis (9-phenyl-9*H*-carbazol-4-yl)dibenzo*[b,d]*thiophene (4Cz-DBT) had a high triplet energy (≥ 2.61 eV) and thermal stability, and were used in blue phosphorescent OLED. Maximum quantum efficiency of the 1Cz-DBT device was 25.4 % and maximum power efficiency was 59.2 lm/W. The color coordinates of the 1Cz-DBT, 3Cz-DBT and 4Cz-DBT devices were (0.19, 0.39), (0.19, 0.40) and (0.19, 0.39), respectively. The operational lifetime of 1Cz-DBT, 3Cz-DBT and 4Cz-DBT devices were shown in Figure 1.

41 OLED Materials II

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chair: Prof. Chun-Sing Lee (City Univ. of Hong Kong, Hong Kong)

A41-4 11:35~12:00

Invited Stable and Efficient Red Phosphorescent Emitter for Display Application

Guijie Li, Tyler Fleetham, and Jian Li (Arizona State Univ., U.S.A.)

The successful development of alternate low cost technology for current solid state lighting devices will have a significant impact on the U. S. economy and national security. White organic light emitting diodes (OLEDs) with potentially high power efficiency are considered as strong candidate for the next generation of illumination devices. Moreover, the use of environmentally benign organic materials in white OLEDs and their potentially low fabrication cost makes them an attractive technological prospect. In this presentation, we will discuss our continuing efforts on the design, synthesis and characterization of novel platinum complexes for displays and lighting applications. The photo-physics, electrochemistry, electroluminescent properties and operational stability of these novel platinum complexes, including deep blue narrowband emitters, blue emitters with 6-membered chelate rings and blue MADF emitters, will be discussed. The rational molecular design enables us to develop cyclometalatedPt complexes with both photon-to-photon (in thin film) and electron-to-photon (in device settings) conversion efficiency close to 100% for OLED applications. Our approaches to achieve high efficiency white OLED using a single emitter will be also included.

A41-5 12:00~12:15

Recent Progress in the Development of Deep Blue TADF Emitters as Potential Replacement for Conventionally Used Emitter Systems

Georgios Liaptsis (CYNORA GmbH, Germany)

The need for increased performance in blue pixels for AMOLED displays is addressed with organic TADF emitters as replacement for conventional fluorescent emitter systems. This allows for a decrease in power consumption while maintaining deep blue color coordinates. CYNORA´s approach is based on thermally activated delayed fluorescence (TADF) technology to provide efficient blue OLED emitters. TADF emitter systems permit an efficiency increase of up to four times compared to conventional fluorescent systems. This boost in efficiency is utilized by using both, triplet and singlet excitons for the emission of light. At the same time, they maintain deep blue emission.

42 Oxide TFT Flexible / Process

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chairs: Dr. Sung Haeng Cho (ETRI, Korea)
Dr. Hendrik Faber (Imperial College London, U.K.)

B42-1 10:30~10:55

Invited Oxide Thin Film Transistors for Flexible Devices

Y. Uraoka, J. P. Bermundo, M. Fujii, M. Uenuma, and Y. Ishikawa (NAIST, Japan)

Much attention has been gathered to flexible devices which will surely change our life style drastically. There are many kinds of flexible devices such as flexible display or medical chart. In order to realize the flexible devices, oxide thin film is one of the promising material. Because oxide film has several features which are not observed in conventional silicon materials. They are low fabrication temperature, high electrical performance or unique optical properties. To realize flexible devices with oxide thin film, several key issues should be discussed. In this talk, we will introduce several new techniques which are now being developed in our laboratory. We propose the use of IGZO thin-film transistors (TFTs) with an ionic-liquid gate dielectric in order to achieve high-density carrier-accumulated IGZO TFTs with high reliability, and we discuss a distinctive mechanism for the degradation of this organic–inorganic hybrid device under long-term electrical stress. Our results demonstrated that an ionic liquid or gel gate dielectric provides highly reliable and low-voltage operation with IGZO TFTs. Furthermore, high-density carrier accumulation helps improve the TFT characteristics and reliability, and it is highly relevant to the electronic phase control of oxide materials and the degradation mechanism for organic–inorganic hybrid devices.

B42-2 10:55~11:20

Invited High-Mobility Oxide TFT and its Application in Flexible AMOLED

Lei Wang, Miao Xu, Hua Xu, Min Li, Linfeng Lan, Jianhua Zou, Honglong Ning, Hong Tao, and Junbiao Peng (South China Univ. of Tech., China)

Recently, the achievement of high-performance AOS-TFTs based on the BCE structure using a relatively low-cost and damage-free fabrication process is drawing researchers' attentions.[1,2,3] A damage-free BCE process was achieved by introducing a nano-barrier layer. The barrier-inserted IZO-TFTs showed good electrical performance and stabilities due to the low contact resistance and less back-channel damages, respectively. TEM measurements revealed that the 3-nm-thick nano-barrier layer deposited by sputtering is enough to protect the active layer from damages caused by the H_3PO_4-based etchant. The fabricated BCE-TFTs exhibit a high field-effect mobility of 40 cm^2/Vs, a subthreshold swing of 0.15 V/dec, and an I_{on}/I_{off} ratio of 10^9. The good bias-thermal stabilities further proved that the inserted nano-barrier layer could avoid the impact on the active layer during S/D electrodes formation, and be inert for the TFT performance. These results indicated that the presented damage-free BCE process would be a low-cost alternation for the AOS-TFTs mass production. Finally, we have developed a 2-inch full color flexible AMOLED display with resolution of 200×RGB×600 (300 PPI) driven by the IZO-TFTs with BCE structure.

42 Oxide TFT Flexible / Process

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chairs: Dr. Sung Haeng Cho (ETRI, Korea)
Dr. Hendrik Faber (Imperial College London, U.K.)

B42-3 11:20~11:35

High Performance Solution-Processed Indium-Free Metal Oxide Thin-Film Transistors

Sooji Nam, Jong-Heon Yang, Sung Haeng Cho, Jihun Choi, and Chi-Sun Hwang (ETRI, Korea)

Recently, solution-processed metal oxide thin film transistors (TFTs) have attracted great attention due to their potential applications in low cost, transparent, easily-processable, flexible, and large-area electronic devices. Among the solution-processed metal oxide semiconductors, indium-based oxides have been extensively studied as channel materials for the fabrication of high-performance TFTs. Despite good electrical performances of indium-based materials, many research groups have endeavored to develop indium-free high performance oxide semiconductor alternatives since indium is becoming scarce and expensive. Zinc-tin-oxide (ZTO) is one of promising candidates but it requires the high annealing temperature above 500 °C to fully promote the metal-oxide-metal condensation. Here, we report a facile route to fabricate high performance solution-based indium-free metal oxide TFTs at low temperature of 300 °C by introducing zinc oxide (ZnO)/ tin oxide (SnO_2) bilayer as an active channel. With low temperature heat treatment after UV photo-annealing, ZnO/SnO_2 bilayer TFTs exhibit maximum mobility over 15 $cm^2 V^{-1} s^{-1}$. From transmission electron microscopy analysis, we confirm that the improvement of device performance originates from relative Sn-rich zone at the interface between channel and dielectric layer, and Zn-Sn-mixed zone between ZnO and SnO_2 layer. Thin Sn-rich channel plays a key role as a main current path and diffused Zn atoms at Zn-Sn-mixed zone stabilize the device performance. In addition, ZnO/SnO_2 bilayer TFTs show superior operational stability to external gate-bias stress compared to that of ZTO TFTs.

42 Oxide TFT Flexible / Process

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chairs: Dr. Sung Haeng Cho (ETRI, Korea)
Dr. Hendrik Faber (Imperial College London, U.K.)

B42-4 11:35~11:50

Self-Aligned Coplanar a-IGZO TFT Fabricated by UV Irradiation

Myeong-Ho Kim, Sung-Ho Jeon, So-Yang Choi (Hanyang Univ., Korea), Jun-Hyung Lim (Samsung Display Co., Ltd., Korea), and Duck-Kyun Choi (Hanyang Univ., Korea)

In recently, It is well known that a high overlap capacitance between the gate and source/drain electrodes causes RC signal delay. It leads to the voltage drop known as the kickback/feedthrough voltage, which induces poor luminescence uniformity, flickering, and image sticking [1,2]. Therefore, a self-aligned coplanar structure that can minimize the overlap capacitance is essential for oxide TFT backplanes in large-area, high-resolution active matrix displays. In this research, we propose a deep ultra violet (DUV) irradiation method to fabricate the self-aligned coplanar top gate TFT. We systematically study the effect of DUV irradiation energy on the electrical properties of a-IGZO film and the self-aligned TFT. The resistivity of a-IGZO films decreased with various DUV irradiation energies [3]. As a result, the electrical characteristics including a field effect mobility, threshold voltage, subthreshold swing, and on/off current ratio of the self-aligned coplanar TFT with source/drain regions formed by DUV irradiation remarkably improved compare to that of the pristine TFT. The self-aligned coplanar TFT with DUV irradiation energy of 20 J/cm^2 has a field-effect mobility of 22.0 cm^2/V·s, a threshold voltage of 2.2 V, a subthreshold swing value of 0.24 V/decade, and an on/off current ratio of 1.34X106, respectively.

B42-5 11:50~12:05

Analysis on PBTS Stability Improvement in Self-Aligned Coplanar InGaZnO Thin Film Transistors

Dohyung Lee, Ju Heyuck Baeck, Taeuk Park, Saeroonter Oh, Jong-Uk Bae, Kwon-Shik Park, and Soo Young Yoon (LG Display Co., Ltd., Korea)

In this study, top-gate self-aligned coplanar a-IGZO TFTs were fabricated on a glass substrate. We will denote four different device types as: type I ~ type IV, which have different GI conditions. To quantify the quality of the interface, we extracted the interface trap density (D_{it}) from photonic capacitance-voltage measurements. PBTS stability characteristics are clearly influenced by the GI conditions. Transfer curves shift in the positive direction during PBTS due to electron trapping occurring at the a-IGZO/GI interface or inside the GI bulk. We optimized the GI conditions towards better PBTS stability. As GI conditions improved, the D_{it} peak level reduced, and the trend of D_{it} matches well with PBTS stability. We have quantitatively correlated the D_{it} of self-aligned coplanar a-IGZO TFTs with PBTS. XRR results show that a well inter-diffused a-IGZO/GI interface can reduce electron traps. PBTS stability of self-aligned coplanar TFTs can significantly be improved by lowering D_{it} by means of optimization of deposition conditions of SiO_2 layers adjacent to the active layer.

43 Stretchable / Wearable Electronics

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chair: Prof. Kang-Jun Baeg (Pukyong Nat'l Univ., Korea)

C43-1 10:30~10:55

Invited The Solvent Selection for High Performance Solution Processed Quantum Dot Light Emitting Diodes

Tao Song, Yatao Zou, and Baoquan Sun (Soochow Univ., China)

Quantum light emitting diodes (QLEDs) exhibit high color purity and stability, which is suitable for next generation information display. We demonstrated that the solvent selection is very important for solution processed QLEDs. By using completely orthogonal solvent, chlorobenzene for TFB, alkanes for quantum dots and ethanol for ZnO nanoparticles, high performance solution processed QLEDs were fabricated. Several common alkanes were chosen to dissolve quantum dots in order to analyze the effects of solvents to the quantum dots film morphology and the device performance.

C43-2 10:55~11:10

Bio-Inspired Electronic Skins based on the Interlocked and Hierarchical ZnO Nanowire Arrays for Static and Dynamic Pressure-Sensing

Minjeong Ha, Seongdong Lim, Jonghwa Park, Doo-Seung Um, Youngoh Lee, and Hyunhyub Ko (UNIST, Korea)

Electronic skin (e-skin) has been attracted in the fields of robotics, wearable electronics, and medical applications. To achieve the highly-sensitive and ultra-fast e-skin, we propose a novel bio-inspired design of hierarchical polydimethylsiloxane micropillar arrays decorated with ZnO nanowire (NW) arrays in an interlocked geometry. The hierarchical ZnO NW arrays based e-skin can perceive both static and dynamic tactile stimuli through piezoresistive and piezoelectric transduction modes, respectively. Furthermore, the interlocked and hierarchical bio-inspired design enables a stress-sensitive variation in the contact area between the interlocked ZnO NWs and also the efficient bending of ZnO NWs, which allow the sensitive detection of both static and dynamic tactile stimuli. Our piezoresistive mode of e-skin shows a high pressure sensitivity (-6.8 kPa^{-1}) and an ultra-fast response time (<5 ms), which enables the detection of extremely small stimuli such as minute static pressure (0.6 Pa), vibration level (0.1 m/s^2), and sound pressure (~57 dB). Whereas, the piezoelectric mode of e-skin can perceive fast dynamic stimuli such as high frequency vibrations (~250 Hz). Our bio-inspired e-skin, which allows the simultaneous perceptions of static and dynamic tactile stimuli, may satisfy the applications requiring both static and dynamic tactile perceptions such as robotic hands and healthcare monitoring devices.

43 Stretchable / Wearable Electronics

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chair: Prof. Kang-Jun Baeg (Pukyong Nat'l Univ., Korea)

C43-3 11:10~11:25

Flexible High-Sensitive Bimodal Sensor for Electronic Skin

Minhyun Jung, Kyungkwan Kim, Taeho Kim (Korea Univ., Korea), Heedo Chae, Oh-sun Kwon, Kwanwoo Shin (Sogang Univ., Korea), and Sanghun Jeon (Korea Univ., Korea)

The development of flexible and multifunctional sensors is an emerging technological goal in field of electronic skin (e-skin) for robot, health care-monitoring system and wearable devices. In order to fully mimic e-skin, high sensitivity as well as multimodal sensing capability are required. This work present the realization of a flexible bimodal sensor using ink-jet printing method which provides low-cost fabrication process and is suited for large area device. We employed a vertically stacked bimodal device architecture, where temperature sensor was stacked on top of the pressure sensor. For the temperature sensor placed in top layer, we used thermoelectric effect (TE). According to Seebeck effect, thermocouple, a closed loop formed by two different metals have capability to convert heat into electric energy. we used a conductive polymer—poly (3, 4-ethylenedioxythiophene–poly (styrenesulfonate) (PEDOT: PSS) and silver nano particles (AgNP). These materials were printed on flexible substrate to form thermoelectric circuit. This circuit functions as a temperature sensor. Regarding the pressure sensor positioned in the bottom layer, we used micro-dimension pyramid structured polydimethylsiloxane (PDMS) and PEDOT:PSS as a bottom electrode was coated on this structure. Counter electrode for pressure sensor was fomred on the back side of thermoelectric temperature sensor.

43 Stretchable / Wearable Electronics

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chair: Prof. Kang-Jun Baeg (Pukyong Nat'l Univ., Korea)

C43-4 11:25~11:40

Hierarchically Designed ZnO Nanowire Arrays on Honeycomb-Structured Si Membranes for Omnidirectional and Flexible Photodetectors

Seongdong Lim, Doo-Seung Um, Minjeong Ha, Youngsu Lee, and Hyunhyub Ko (UNIST, Korea)

Flexible photodetectors are of great importance in future optoelectronic applications such as flexible image sensors, artificial retina, biomedical imaging, and smart wearable systems. One significant property of flexible photodetectors is the omnidirectional light-detection capability, which would allow a wide field of view and thus precise monitoring of a moving object. Here, we suggest omnidirectional and flexible photodetectors based on hierarchically designed ZnO nanowires (NWs) on honeycomb-structured Si (H-Si) membranes. The hierarchical ZnO NW/H-Si structures exhibited excellent omnidirectional light-absorption ability with greatly diminished reflectance over the entire range of light from UV to NIR with variable angles. In addition, the photocurrent of hierarchical ZnO NWs/H-Si structures was highly maintained over I_A / I_0=0.7 when the angle of incident light changed from 0 to 70°, which can be favorably compared to ZnO films on flat Si (F-Si) structures. Furthermore, the unique honeycomb structures in the flexible photodetectors provided high mechanical flexibility (a 10% decrease in photocurrent at a bending radius of 3 mm) and durability (minimal change in photocurrent over 10,000 bending cycles). The proposed hierarchically designed nanowire arrays on honeycomb-structured semiconductor membranes can be used in a valuable platform for various optoelectronic devices requiring enhanced light-absorption properties and mechanical flexibility.

43 Stretchable / Wearable Electronics

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:05
Session Chair: Prof. Kang-Jun Baeg (Pukyong Nat'l Univ., Korea)

C43-5 11:40~12:05

Invited High-Performance GaAs Nanowire Solar Cells for Flexible and Transparent Photovoltaics

Johnny C. Ho (City Univ. of Hong Kong, Hong Kong)

Among many available photovoltaic technologies at present, gallium arsenide (GaAs) is one of the recognized leaders for the performance and reliability; however, it is still a great challenge to achieve cost-effective GaAs solar cells for smart systems such as transparent and flexible photovoltaics. In this study, highly crystalline long GaAs nanowires (NWs) with minimal crystal defects are synthesized economically by chemical vapor deposition and configured into novel Schottky photovoltaic structures by simply using asymmetric Au-Al contacts. Without any doping profile such as p-n junction and complicated co-axial junction structures, the single NW Schottky device shows a record high apparent energy conversion efficiency of 16% under air mass 1.5 global illumination by normalizing to the projection area of the NW. The corresponding photovoltaic output can be further enhanced by connecting individual cells in series and in parallel as well as by fabricating NW array solar cells via contact-printing showing an overall efficiency of 1.6%. Importantly, these Schottky cells can be easily integrated on the glass and plastic substrates for transparent and flexible photovoltaics, which explicitly demonstrate the outstanding versatility and promising perspective of these GaAs NW Schottky photovoltaics for next-generation smart solar energy harvesting devices.

44 Quantum Dots for Future Displays II

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chairs: Prof. Doh Chang Lee (KAIST, Korea)
Dr. Wan Ki Bae (KIST, Korea)

D44-1 10:30~10:55

Invited Interface Chemistry of Colloidal Quantum Dots for Display Applications

Weon-kyu Koh (Samsung Advanced Inst. of Tech., Korea)

Colloidal quantum dots (QDs) have great potential in conventional display applications of light emitting diodes (LEDs) and lasers, as well as new area of photonic applications such as single photon emitters in quantum cryptography and communication. While there have been extensive research and development of colloidal QDs in display applications from understanding carrier dynamics to realizing electroluminescence devices and QD-based ultra high density TV, intrinsic challenge of QD application is still remained in engineering interface chemistry of QDs. As an individual, single dot spectroscopy is useful in understanding the role of interface in multi-shell QD structures. Cadmium selenide and indium phosphide-based QDs will be discussed to compare their probability density plots and Auger ionization efficiencies determined by analyzing their photoluminescence blinking dynamics. As a multi-component solid state device, we will discuss the critical role of interfaces in QD LEDs using spectroscopy and electrochemistry studies. These results suggest that the interface of QDs is closely associated with their charge transfer and radiative process, providing insight into the development of highly efficient QD-based display applications.

D44-2 10:55~11:20

Invited Surface Functionalization of Colloidal Quantum-Dot Nanocrystals with Inorganic ligands for Electronic Device Application

Jaeyoung Jang (Hanyang Univ., Korea)

Colloidal nanocrystals can combine the advantages of crystalline inorganic semiconductors with the size-tunable electronic structure and inexpensive solution-based device fabrication. They are of great interest due to these unique advantages for use in electronic and optoelectronic devices such as field-effect transistors (FETs), photovoltaic cells, and light-emitting diodes. Efficient charge transport is crucial for high performance of nanocrystal-based electronic and optoelectronic devices. Many practical implementations of nanocrystals are hindered by the poor electronic coupling in close-packed nanocrystal films, caused by the presence of bulky organic surface ligands. To address this fundamental problem, various types of inorganic surface ligands are introduced. These new approaches to surface termination of colloidal nanocrystals provide a set of advantages such as all-inorganic design and diverse compositional tunability for both nanocrystal and ligand constituents. By using optimized inorganic surface ligands, nanocrystal solids are prepared exhibiting band-like charge transport, high photoconductivity and tunable doping level. Finally, a solution-based “soldering” process is introduced to fabricate ultra-high electron mobility (>300 cm^2/Vs) nanocrystal solids using colloidal nanocrystals with molecular “solders”.

44 Quantum Dots for Future Displays II

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chairs: Prof. Doh Chang Lee (KAIST, Korea)
Dr. Wan Ki Bae (KIST, Korea)

D44-3 11:20~11:45

Invited Quantum Dot Clay Composites for Display Applications

Sanghwa Jeong (POSTECH, Korea), Seungho Cho (Univ. of Cambridge, U.K.), and Sungjee Kim (POSTECH, Korea)

Quantum dots (QDs) have demonstrated the potential for the key materials in next-generation electronic and optoelectronic devices because of their unique physical properties such as the tunable band gap. It is of paramount importance to guarantee the photoluminescecne (PL) stability of QDs in solid state as incorporated in devices against light, moisture, oxygen, and/or heat. Two dimensional and positively-charged metal hydroxide layers, layered double hydroxides (LDHs), are balanced by intercalation of interlayer anions of choice. We report a designed strategy for fabricating highly fluorescent and photostable QD composites via a facile incorporation of negatively-charged QDs into positively-charged metal hydroxide interlayer galleries of LDH. The incorporation strategy of LDH-QD composites can be applicable to various kinds of QDs including CdSe/CdS/ZnS Core/Shell/Shell QD, InP/ZnS Core/Shell QD, and PbS/CdS Core/Shell QD. The LDH-QD composites exhibited strongly enhanced PL quantum yields and thermal stability, and improved resistance to photobleaching compared to those of the non-incorporated QDs. We have demonstrated the pseudo white down-conversion type LEDs using LDH-QD composites, and QD-LDH composite-based IR-emitting codes that can be potentially used for military or security purposes such as identification codes or anti-counterfeit printing.

D44-4 11:45~12:00

Inkjet-Printed Quantum Dot Light-Emitting Diodes for Full Color Displays

Donghyun Ko, Jongseok Han, Jeongkyun Roh, Yeseul Park, and Changhee Lee (Seoul Nat'l Univ., Korea)

We demonstrated the feasibility of using inkjet printing for large area full color QLED displays. According to a target resolution of 60-inch UHD TV, we designed subpixel size and pixel-pitch which correspond to the resolution of 73 pixel per inch (ppi). Red, green, and blue (R/G/B) QDs based on a CdSe core and ZnS shell were inkjet-printed onto the pre-patterned bank. Formation of QD inks and surface engineering of the bank will be discussed in terms of optimizing morphology of inkjet-printed QD films and device performance of inkjet-printed QLEDs.

44 Quantum Dots for Future Displays II

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chairs: Prof. Doh Chang Lee (KAIST, Korea)
Dr. Wan Ki Bae (KIST, Korea)

D44-5 12:00~12:15

Transparent Quantum Dot Light Emitting Diodes with Various Inorganic Electron Transport Layer and Oxide Top Electrode

Min Suk Oh, Hee Yeon Kim, Yu Jin Park (KETI, Korea), Yohan Kim (Fraunhofer Inst. for Applied Polymer Research, Germany), Jiwan Kim (Kyonggi Univ., Korea), Chul Jong Han (KETI, Korea), Armin Wedel (Kyonggi Univ., Korea), and Heesun Yang (Hongik Univ., Korea)

Because of the outstanding optoelectronic properties of colloidal quantum dot (QD) semiconductors, many researchers have developed various kinds of devices for next-generation display applications. Cd-based devices have shown excellent properties and the eco-friendly QD materials also have attracted many attentions due to the environmental regulation. And, because there are many problems about the stability of conventional QD-LEDs with organic charge transport layers, a stable charge transport layers have to be used. Here, we propose the organic/inorganic hybrid QD-LEDs with various QDs (CdSe, InP and so on) as light emitting layer and inorganic layers as charge transport layer such as ZrO_2 and TiO_2. The QD-LED with bottom emission structure which was fabricated at low temperature showed the luminescence of > 30,000 cd / m^2 and the current efficiency of > 19 cd/A. Also, to realize the transparent QD-LED display, the two-step sputtering process of indium zinc oxide (IZO) top electrode was used and we could fabricate transparent QD-LED device with the transmittance of more than 74 % for whole device. And, since the HIB between anode and HIL decreased, the hole injection from anode could be enhanced and we could reduce the charging of QDs by excess electrons. Therefore we could eliminate the roll-off phenomenon caused by Auger recombination.

45 Large Area Display System

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chairs: Prof. Jun Ho Lee (Kongju Nat'l Univ., Korea)
Prof. Diego Martinez (Univ. of Sussex, U.K.)

E45-1 10:30~10:55

Invited High Dynamic Range Rear Projection System

Nobuki Nakajima, Tadashi Furukawa, and Ryosuke Nakagoshi (JVCKENWOOD Corp., Japan)

Image of a projector with the sequential contrast ratio close to the human eye, is able to express a realistic object. We have developed a High Dynamic Range Rear Projection System for business use with high brightness, high sequential contrast ratio, and wide colour gamut. This paper describes the realization of Metameric Match with High Dynamic Range monitor.

E45-2 10:55~11:10

3 by 3 Glasses-Free 3D Signage Display

Kewseung Lee, Dongman Jeong, Dowoo Kwon, Daehwan Shin, and Wootae Kim (LG Electronics Co., Ltd., Korea)

In this work, we propose a large area display in type of multivision. With this display, users can enjoy 2D/3D contents in higher resolution without special tools like polarized glasses or active shutter glasses. Nine commercial 55 inch UHD TVs are used for 3 by 3 multivision, which is of 165 inches. Each TV set has a specially designed 3D filter on its screen to show 3D contents. A main computer for this display has five graphic cards and nine HDMI cables from those graphic cards are connected to TVs. Every 3D image consists of 40 view information for a more realistic experience. This system can play 3D videos in 20 fps and each frame contains images from 40 view points. Any objects of 3D contents can be displayed in +/- 40 cm depth space whose center is positioned on the multivision screen. The optimal viewing distance of the system is 4m away from the screen. This system numerically has 9 times more pixels than a normal UHD TV has but the 3D filter degrades a resolution of this system. Thus its resolution is theoretically just 1.35 times as high as an UHD display.

45 Large Area Display System

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chairs: Prof. Jun Ho Lee (Kongju Nat'l Univ., Korea)
Prof. Diego Martinez (Univ. of Sussex, U.K.)

E45-3 11:10~11:25

Developments of Large Aerial LED Display with Aerial Imaging by Retro-Reflection(AIRR)

Sho Onose, Tomoyuki Okamoto, Kenta Onuki, Masashi Takahashi, and Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

In recent years, many types of LED panels have been used for digital signage. we propose a new way of digital signage by use of a large full-color LED panel with aerial imaging by retro-reflection (AIRR). AIRR is a method to form aerial display by use of retro-reflective material.1,2 The purpose of this paper is to realize large aerial LED display which covers human body size or life scale.

E45-4 11:25~11:50

Invited Smooth Motion Parallax Projection Displays for Highly Realistic Applications

Munekazu Date (Nippon Telegraph and Telephone Corp., Japan)

Image quality of displays has made advance greatly so that almost everyone are satisfied for displayed 2D images or videos. Though 2D display cannot reproduce directional information due to Monna Lisa Effect, it is an advantage for entertainment use. However, when users communicate through electronic display, the lack of directional information is a severe problem, because users cannot understand to whom a remote user is accosting. Using a smooth and exact motion parallax display, users can feel not only a face direction but also feel direction of interest, a slight change of mind, a sense of material and a feel of existence. In this presentation, a conceptual demonstration system of Space Composite Telecommunication, which can connect remote and local places, is shown. It uses life-size glasses-type 3D projection display with smooth motion parallax by head tracking of remote and local users. Our recent trial for glasses-free displays is also demonstrated.

45 Large Area Display System

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~12:15
Session Chairs: Prof. Jun Ho Lee (Kongju Nat'l Univ., Korea)
Prof. Diego Martinez (Univ. of Sussex, U.K.)

E45-5 11:50~12:15

Invited Analysis of ADS Technology Advantages for Large Size 8K Resolution TV Panel

Yanping Liao, Xibin Shao, Fang Yu, Zhenyu Zhang, Dongchuan Chen, and Ming Chen (Beijing BOE Display Tech. Co., Ltd., China)

Nowadays, BOE ADS (Advanced Super Dimension Switch) liquid crystal display technology has been continuously evolving to exhibit better image quality and widely various application fields, such as mobile, tablet PC, monitor, TV and super large size high resolution panel. However, for the pixel structure difference among ADS, IPS and VA mode, pixel storage capacitance formed by the overlap area between common ITO electrode and pixel ITO electrode in ADS, not like that in IPS and VA as is formed by part common metal electrode overlap with pixel electrode shown in Fig.1, will be more bigger, resulting in pixel charging difficulty or lower panel transmittance. Although such a situation, 110inch 4K, 98inch 8K, 110inch 8K and 82inch 10K LCD panels have been developed successfully by some novel panel design and driven technologies in BOE [1-3]. Figure 2 shows the calculated pixel storage capacitance as a function of panel size for the three kinds of LC mode. It can be seen that the capacitance of 55inch ADS FHD panel is about fifteen times bigger than that valued about 0.2pF in IPS or VA panel, but the capacitance decreases as the resolution increases. For an 8K resolution and panel size of 55inch, 65inch and 75inch, the capacitance values in the three LC mode are almost equal. That means the transmittance in ADS will be bigger than that in IPS and VA based on the same pixel charging ratio. Because the structure to form Cst in ADS will not affect light transmission, but which in IPS or VA is affected by un-transparent metal electrode. For VA mode, to avoid the transmittance decrease, a tradeoff is to change eight domains to four domains.

46 Automobile Displays

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:25
Session Chairs: Prof. Byung Doo Chin (Dankook Univ., Korea)
Prof. Chang-Jae Yu (Hanyang Univ., Korea)

F46-1 10:30~10:55

Invited Technical Trend of Automotive Displays

Jeong-Hwan Yoon, Kyoung-Ho Park, Soo Young Choi, Young-Seop Lee, Dae-Lim Park, Yong-Keun Kim, Sang-Kyu Kim, Hong-Man Moon, and Byeong-Koo Kim (LG Display Co., Ltd., Korea)

Automotive display technology was developed with vehicle's development simultaneously. At the first, the simple needle gages were adapted to inform vehicle's status. Now, the flat panel display is adapted to car information display such as center information display(CID), and cluster display. Its usage is varied from not only information of cars but also navigation map and entertainment contents. Those automotive display is under developing with four representative trends. First trends is the integragation of infortainment on display. Because inforamtion and entertainment content should be delivered precisely on a screen, the display requires of visibility enhancement such as big size, high resoution and high brightness. Second is the convenient interaction between system and user. Jog dial and resistive touch sensor panel(TSP) were adapted before, operating was incovenient and not intuitive. So, capacitive TSP which is familiar to user for the smart phone and tablet is requred of car displays. Third is eco-friendly technoloy which maximize energy effeciency. To enhace the visitility, the high luminace back light and high resolution panel are needed. Those lead lower efficiency than conventional display. So, high efficient display technology which features high transmittance is required. Forth is the desgin flexiblilty which means change of squared flat panel display. The only component which is not harmonius to interior is squared flat display. To give design flexibility to the car interior, free form and non-flat displays are needed. To head four trends, display technologies are being developed more and more. First, AH-IPS[1,2] technology is most adavanced candidate for the automotive displays. AH-IPS which car makers want to adapt is suitable to enlarge size and resolution display which is poroven from the TV and the mobile applications. Oxide TFT of LTPS TFT are considered as backplanes for autmotive AH-IPS LCDs to overcome the extreme environment of automotive applications. Second, one of capacitive TPS solutions is the Advanced In-cell Touch(AIT)[3] which features cover-less, high transmittance and low reflectance. Touch sensor layer is placed in TFT, addtional glass for touch sensors is not needed. No ITO layer is placed on the color filter glass, the color filter efficiency of transmittance and reflectance can be maximized. To replace the ITO, a new conductive component which is discharged and shielding property for touch sensor is used. Third, high energy efficiency can be achieved by the new pixel arrangement such as M+ technology. M+ features high transmittance with an additional white sub-pixel and a new pixel arrangement. The transmittance of white pixel is 3 times higher than colored pixel, the transmittance can be increased over 30%. The white pixel may cause image distortion, the pixel rendering technology can reduce the distortion. Forth, hiding gate line technology to have narrow bezel, new cutting process for round, hole shaped display are needed. To minimize the width of bezel, gate IC integration should be applied. The reliability issue blocks integration in TFT, other possible method is proposed and being tested. As non-flat display, plastic based display can be considered, because glass based display has limitation of shape. Plastic is easy to be curved, twisted, bended, is suitable to non-flat display. In the paper, four trends of automotive displays are proposed, and four display technologies are introduced to follow the trends. Detailed trends and technologies will be reported.

46 Automobile Displays

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:25
Session Chairs: Prof. Byung Doo Chin (Dankook Univ., Korea)
Prof. Chang-Jae Yu (Hanyang Univ., Korea)

F46-2 10:55~11:10

Designs of the Head Up Display Test Systems: Reflective and Transparent

Yongjin Park (Chung-Ang Univ., Korea), Chinh Ngo (SP-Tech., Korea), and Jongwon Seok (Chung-Ang Univ., Korea)

Head up display (HUD) is a transparent display that can present visual data without requiring drivers to shift their gaze from which they are naturally looking. A couple of past studies on the HUD systems applied to the automobile industry1,2 inspired us to propose two designs of the HUD test systems: reflective and transparent. The present systems can be used not only to test the optical components of the HUD systems but also to find their design requirements because the system is designed with very high flexibility. The system is can also be an effective tool to analyze the relationship of the essential parameters of the HUD systems.

F46-3 11:10~11:25

Light Shutter Using Dye-Doped Cholesteric Liquid Crystals with Polymer Network Structure

Byeong-Hun Yu, Seong-Min Ji, Jin-Hun Kim, Jae-Won Huh, and Tae-Hoon Yoon (Pusan Nat`l Univ., Korea)

Recently, active studies on a transparent organic light-emitting diode (OLED) are in progress as a next generation display. However, transparent displays suffer from poor visibility because background objects are always seen along with the displayed images because of the transparent window area. This visibility problem can be overcome by placing a light shutter at the backside of a transparent display. By switching the light shutter, we can hide or see through the background objects of a transparent display. Therefore, we can operate a transparent display in the transparent or high-visibility display modes by using a light shutter.In this study, we propose a light shutter using dye-doped ChLCs with the polymer network structure. The proposed light shutter shows the initially focal-conic state by forming the polymer network structure at the focal-conic state. By applying the polymer network structure, we can easily switch a ChLC light shutter between the focal-conic and homeotropic states.

47 Photovoltaic Materials

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:40
Session Chair: Dr. Yong-Duck Chung (ETRI, Korea)

G47-1 10:30~10:55

Invited Control of Preferred Orientation and Secondary Phases of SnS Thin Film and its Application to Solar Cell

Jeong-Yoon Kang, Sreedevi Gedi, and Chan-Wook Jeon (Yeungnam Univ., Korea)

In this study, we explored a new technique to control the preferred orientation of SnS thin film achieved by sulfurization of Sn metallic precursor deposited on Mo-coated soda lime glass substrate. Prior to the Sn deposition, a thin SnS layer with a thickness of 100 nm was inserted on Mo back contact using electron beam evaporation at room temperature. The thin SnS layer was confirmed to act as a seed layer for the SnS formation. The Sn precursor deposited by DC-magnetron sputtering on the seed layer was sulfurized at an elevated temperature ranging from 300 to 500°C. The impact of seed layer on the structural and morphological properties of SnS absorber layer were investigated using appropriate characterization tools such as, X-ray diffraction (XRD) and scanning electron microscopy (SEM) respectively. XRD studies revealed that, the preferred orientation of SnS film was changed from (040) to (111) with presence of the seed layer. In addition, SnS absorber without seed showed some of secondary phases whereas a pure SnS phase was obtained with presence of the seed layer, which indicated that the seed layer prevented the formation of impurity phases in the absorber. SnS solar cell with seed layer exhibited improved PV performance of 1.61 % efficiecy compared to that withoud seed (0.30% efficiency).

47 Photovoltaic Materials

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:40
Session Chair: Dr. Yong-Duck Chung (ETRI, Korea)

G47-2 10:55~11:10

Low Dimensional Micro- and Nano-Structures Cu(In,Ga)Se_2 Thin Film Solar Cell

Yu-Lun Chueh (Nat'l Tsing-Hua Univ., Taiwan)

In this talk, I will introduce the development of low dimensional nanomaterials in my group and its applications on Cu(In, Ga)Se_2 solar cell. The direct formation of large area Cu(In,Ga)Se_2 nanotip arrays (CIGS NTRs) by using one step Ar^+ milling process without template. By controlling milling time and incident angles, the length of CIGS NTRs with adjustable tilting orientations can be precisely controlled. Formation criteria of these CIGS NTRs have been discussed in terms of surface curvature, multiple components, and crystal quality, resulting in a highly anisotropic milling effect. In addition to physical approach to form nanostructures on the CIGS film, a reactive mold-assisted chemical etching (MACE) process through an easy-to-make agarose stamp soaked in bromine methanol etchant to rapidly imprint larger area micro- and nano- arrays on CIGS substrates was demonstrated in my group. Interestingly, by using the agarose stamp during the MACE process with and without additive containing oil and triton, CIGS microdome and microhole arrays can be formed on the CIGS substrate. Final part of my talk, i will introduce Au NPs to achieve efficiency enhancement of CIGS flexible photovoltaic devices. The incorporation of Au NPs can eliminate the obstacles in the way of developing ink-printing CIGS flexible TFPV, such as the poor absorption at wavelengths in high intensity region of solar spectrum, and that occurs at large incident angle of solar irradiation. The enhancement of external quantum efficiency and photocurrent have been systematically analyzed via the calculated distributions of electric field. Finally, the major benefits the LSPR in shorter wavelength have been investigated by ultrabroadband pump-probe spectroscopy, which gives a solid evidence on the strong absorption and reduction of surface recombination that increases electron-hole generation and improves the carrier transportation in the vicinity of pn-juction. These results suggest a promising way for rapidly improving the performance of CIGS flexible photovoltaic devices with low-cost.

47 Photovoltaic Materials

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:40
Session Chair: Dr. Yong-Duck Chung (ETRI, Korea)

G47-3 11:10~11:25

Controllable Perovskites Crystallization for High-Performance Solar Cells

Zhao-Kui Wang (Soochow Univ., China)

The rise of organometal halide perovskite solar cells (PSCs) brings a very competitive and fascinating prospect on photovoltaic commercialization via their unimaginable power conversion efficiency (PCE) racing. Recently, planar structure based PSCs have been proposed because of their simple device architecture, easy fabrication procedure and low temperature processing. In a typical planar heterojunction PSC, the perovskite light-absorbing layer is sandwiched between the two suitable electrodes. Actually, film morphology including uniformity and coverage, and crystal quality in terms of grain size and crystal orientation of the perovskite active layer, are regarded as the main factors in achieving high performance PSCs. Therefore, crystallization control is very important for obtaining high-quality crystal perovskites toward high-performance PSCs. In this talk, I will introduce several efficient means, such as interface-assisted, additive-induced, and doping-enhanced crystallizations, to tune and control the the growth of crystalline perovskite films in our group. Accordingly, a best performance with 17.55% PCE and a fill factor of 78% has been achieved from the planar PSCs by using a doping technique presently.

G47-4 11:25~11:40

Green Si Thin Film Photovoltaic Technology for Electricity and Energy Harvesting

Chang-Hong Shen, Wen-Hsien Huang, Chih-Chao Yang, and Jia-Min Shieh (Nat'l Nano Device Laboratories, Taiwan)

Energy security has been the major concern of human being. Photovoltaic (PV) technology is attractive for its potential to be the major carbon-free renewable energy source. Hydrogenated amorphous silicon (a-Si:H) is well suited for PV applications with the advantages of low cost, low fabrication temperature and high production capability. We investigate the performance of a single-junction amorphous Si (a-Si) solar cell fabricated with Plasma deposition technique. The technology resulting single-junction a-Si solar cells yield a conversion efficiency of 9.6% with improved light-soaking stability [1]. A sandwiched light-trapping structure which consists of capping aluminum-doped ZnO (AZO) layer, dispersed plasmonic Au-nanoparticles (Au-NPs), and a micro-structured transparent conductive electrode, is employed to stabilize and boost the hydrogenated amorphous silicon solar cells conversion-efficiency to 10.1% [2]. Besides, Si thin film solar cell with good UV-visible responses and charge transport exhibits excellent indoor light energy harvesting capability for the application of internets of things. For high performance Si crystalline hetero-junction solar cell, hydrogenated amorphous silicon also provide excellent surface passivation, resulting in conversion efficiency of Si crystalline hetero-junction solar cell of 19%.

48 Reflective LCDs

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:55
Session Chair: Prof. Soon-Bum Kwon (Hoseo Univ., Korea)

H48-1 10:30~10:55

Invited Reflective Liquid Crystal Displays for Future Display Applications

Takahiro Ishinabe, Yosei Shibata, and Hideo Fujikake (Tohoku Univ., Japan)

The development of color-type reflective displays with low power consumption, high reflectivity, and broad color gamut, together with motion image capability have been anticipated for future display applications. In this presentation, we discuss the development of an achromatic polarizer which has no wavelength dependency in both parallel and crossed states, high transmittance and high dichroic ratio by using new dichromatic pigments and manufacturing process. We also developed a novel light diffusion film for reflective type displays based on the optimization of the internal refractive-index distribution of the polymer film by controlling the degree of parallelization and angle of incidence of the UV light, resulting in a high reflectivity across a wide angle range.
We have successfully developed monochrome-type reflective LCD and achieved high reflectance of L*=71, high contrast ratio (over 100:1), paper white characteristics superior to the electrophoretic displays. In addition, we have developed a low-power color-type reflective LCD with wide color gamut (50% of NTSC) as well as motion image capability. We also discuss a development of flexible reflective LCD using stainless steel substrate with heat resistance. We believe that this technology will create new display applications, including e-book readers, electronic shelf-edge labels and large digital signages.

48 Reflective LCDs

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:55
Session Chair: Prof. Soon-Bum Kwon (Hoseo Univ., Korea)

H48-2 10:55~11:10

55-Inch Plastic Substrate Based Color Reflective Displays Using Cholesteric Liquid Crystal with High Definition

Byunghwa Seo, Hongsuk Kim, Hyunmin Song, Tatsuhiro Otsuka, Juncheol Bae, Moonil Jung (Samsung Electronics Co., Ltd., Korea), Zhe Hong, Burm-Young Lee, Soon-Bum Kwon (NDIS Corp., Korea), and Ginam Kim (Samsung Electronics Co., Ltd., Korea)

Emerging markets in outdoor digital signage is increasing at a rapid rate; however, because of the strong output of the sun, current displays are limited to energy-intensive and low-resolution LED (light emitting diode) displays or limited use LCDs (liquid crystal displays). Reflective displays based on cholesteric liquid crystals (CLC) could offer a viable alternative to these technologies.[1-2] Their advantages are sunlight readablility and low power consumption. There are several challenges to realize this technology for commercial use: (1) Cost, which is related to the driver ICs and maximum resolution; (2) Uniformity, especially for displays larger than 55''; (3) High color gamut; (4) Color drive scheme; and (5) Color temperature stability. Based on plastic substrates, we realized a 24'' full color prototype having 64 colors, 10% NTSC color gamut, 30% reflectivity, HD resolution (1280x720) and driven by passive matrix. We also demonstrated 55'' size full-color panels. This technology can also be applied to a wide number of other uses. For example: by adding a switchable black layer, a novel transparent, flexible display based on reflective technology can be realized and can be applied to: "always on" smart watches, translucent full-color e-reader devices, smart phone flip covers, "infotainment" windows for general home use, future appliances and automobile heads up display (HUD) or media control center.

48 Reflective LCDs

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:55
Session Chair: Prof. Soon-Bum Kwon (Hoseo Univ., Korea)

H48-3 11:10~11:25

Reduction of Residual DC Voltage by RC Matching in LCD

Nakcho Choi, Jonggun Chong, Jaehong Choi, Yeogeon Yoon, and Jangsoo Kim (Samsung Display Co., Ltd., Korea)

The capacitance coupling (CC) liquid crystal mode has been developed as one of methods for reduction of color washout in vertical alignment liquid crystal mode.[1] However, residual dc voltage in a floating electrode of CC mode induced image sticking after long time driving. Mr. Huang proposed additional refresh technology (ART) as a method of reduction of residual DC voltage by adding a small TFT. [2] But it was difficult to control the size of small TFT as well as the design made the aperture ratio of pixel smaller. In this paper, we suggested the origin of residual dc voltage in CC mode and the solution of image sticking. As modeling liquid crystal and SiNx as serial RC circuits, we simplified the CC mode. Then Pspice simulation helped us to understand the voltage shift phenomenon happened when two RCs mismatched each other. After all, two rc values(time constant,τ) matching of LC and SiNx was the key to reduction of residual DC voltage. We controlled the resistance of SiNx by changing the gas ratio of N_2, NH_3 and SiH_4. We confirmed that the same time constant of liquid crystal and SiNx reduced residual DC voltage in CC mode a clue of eliminating image sticking by making LCD proto sample.

H48-4 11:25~11:40

Spontaneous Slippery Interfaces -Reduction of Driving Voltage of Blue Phases-

Masumi Yamashita, Shogo Kato, Yoichi Takanishi (Kyoto Univ., Japan), Isa Nishiyama (DIC, Japan), Hirotsugu Kikuchi (Kyushu Univ., Japan), and Jun Yamamoto (Kyoto Univ., Japan)

We have invented the concept of "Slippery interfaces", which has zero anchoring force for attached LC molecules on the interfaces, and demonstrated the drastic reduction of driving voltage in DH-FLC mode (>1 order) keeping the fast switching response (<100msec) .On the contrary to the SmC*, in order to reduce the driving voltage of PSChBP, the new mechanism is necessary to cover the polymer rods in PSChBP by slippery interfaces spontaneously, because the nano-scale interfaces are deeply embedded in the ChBP. In this paper, we propose new principle for designing the spontaneous slippery interfaces based on the disorder effect near the interfaces. Finally, we stabilized the ChBP by Azo-dye acrylate monomer with the di-acrylate binder. Azo-dye acrylate is concentrated in the core of ChBP during the polymerization as similar to the conventional PSChBP. We surely reduce the driving voltage of PSChBP about 20% by slippery interfaces which are produced by the trans-cis isomerization of localized azo-dye by shining the UV light.

48 Reflective LCDs

Date: Aug. 25, 2016 (Thursday)
Time: 10:30~11:55
Session Chair: Prof. Soon-Bum Kwon (Hoseo Univ., Korea)

H48-5 11:40~11:55

Electro-Optic Switching with Liquid Crystal Graphene

Ji Hyun Park, Min Jae Kim, Youn Sang Kim (Seoul Nat'l Univ., Korea), Jun Yamamoto, and Giusy Scalia (Univ. of Luxembourg, Luxembourg)

The process of producing graphene by chemical methods goes through the formation of an oxidative form of graphene, called graphene oxide (GO), that turns into graphene by reduction. One of the greatest advantages of GO is its dispersability in water due to the presence of hydrophilic functional groups and, interestingly, GO aqueous suspensions can form liquid crystal phases (LC) above certain threshold concentration. Also, isotropic GO suspensions can show birefringence by application of small electric fields due to high Kerr coefficient, very attractive in electro-optical applications. Reduced graphene oxide (r-GO) is expected to have superior electronic properties due to the higher polarizability thus greater response to electric fields compared to GO. However, stable dispersions are difficult to realize due to the aggregation of the hydrophobic graphene flakes in water after that the functional groups are removed. We have shown that using surfactants during reduction a stable suspension of r-GO can be achieved that also forms liquid crystal phases by shearing and electric field application. R-GO reveals to be an attractive electro-optic material with very small fields able to modulate its optical response with superior electro-optical performance but also longer-term stability compared to GO LC. Finally we have estimated the optical contribution from the absorption of the flakes finding also an anisotropic behaviour confirming our proposed reorientational mechanism i. e. that the flakes align with their long axis along the external field direction.

49 OLED Novel LEDs

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:35
Session Chairs: Prof. Hideyuki Murata (JAIST, Japan)
Dr. Pavel Kudlacek (Holst Center TNO, Netherlands)

A49-1 08:30~08:55

Invited Next Light Emitters: Organometal Halide Perovskite Light-Emitting Diodes

Tae-Woo Lee (POSTECH, Korea)

Organometal halide perovskites are emerging low-cost emitters with very high color purity (full width at half maximum ~ 20 nm). However, the low electroluminescence efficiency at room temperature originating from exciton dissociation and quenching is a challenge that should be overcome. Here, we introduce problems of organometal halide perovskites decreasing electroluminescence efficiency and present solutions of these problems for achieving high-efficiency perovskite light-emitting diodes (PeLEDs). First, hole injection barrier between ITO anode and perovskite emission layer (EML) should be reduced. Also, exciton quenching at the interface between hole injection layer (HIL) and EML decreases electroluminescence efficiency. We introduced a self-organized buffer hole injection layer (Buf-HIL) to reduce the hole injection barrier and block the exciton quenching at the interface. Photoluminescence and transient photoluminescence experiments showed that the blocking capability of exciton quenching of Buf-HILs increases with perfluorinated ionomer quantity. Furthermore, we found that the formation of metallic lead atoms cause strong exciton quenching by X-ray photoelectron spectroscopy, and it was prevented by finely increasing the molar proportion of methylammonium bromide (MABr) by 2 to 7 % in $MAPbBr_3$ solution. Use of excess MABr also reduced the hole injection barrier from self-organized conducting polymer anodes to $MAPbBr_3$ layers with decreased ionization energy. Also, we suggest that the efficiency in PeLEDs can be increased by decreasing $CH_3NH_3PbBr_3$ grain sizes and consequently improving uniformity and coverage of $CH_3NH_3PbBr_3$ nanograin layers. Use of an optimized nanocrystal pinning process contributed to the change in the morphology of $CH_3NH_3PbBr_3$ layers from scattered micrometer-sized cuboids to well-packed nanograins with uniform coverage, which greatly reduced leakage current and increased efficiency. Furthermore, A $CH_3NH_3PbBr_3$ film with decreased grain size exhibited a very small exciton diffusion length. Using these strategies, a highly efficient perovskite light-emitting diode (PeLED) was achieved (current efficiency = 42.9 cd/A, external quantum efficiency = 8.53%). The achievement of high efficiency implies that the technical gap between PeLEDs and OLEDs or quantum dot LEDs is substantially reduced and that solution-processed PeLEDs can be promising next-generation light emitting units in display and lighting industries.

49 OLED Novel LEDs

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:35
Session Chairs: Prof. Hideyuki Murata (JAIST, Japan)
Dr. Pavel Kudlacek (Holst Center TNO, Netherlands)

A49-2 08:55~09:10

High-Efficiency $CsPbBr_3$ Perovskite Light-Emitting Diodes and Investigation on Recombination Mechanism

Himchan Cho, Christoph Wolf (POSTECH, Korea), Hyung Joong Yun, Jong Seong Bae (KBSI, Korea), and Tae-Woo Lee (POSTECH, Korea)

Cesium lead bromide ($CsPbBr_3$) perovskite is a new class of emitting materials with high color purity and stability. Here, we report on the realization of high-efficiency $CsPbBr_3$ perovskite light-emitting diodes (PeLEDs) and in-depth investigation on their recombination mechanism. With uniform and highly emissive $CsPbBr_3$ nanograin layers achieved by optimizing the concentration of $CsPbBr_3$ solution and annealing temperature, the PeLEDs exhibited very high current efficiency and luminance. Furthermore, we have shown that recombination mechanism of the PeLEDs changes from monomolecular to bimolecular as increasing temperature. The PeLEDs showed gradually increasing current hysteresis above 200 K, which can be ascribed to Br^- anion migration generating charge carrier traps (point defects) that causes the enhancement of electroluminescence at the blue-shifted position. Our work provides a facile way to improve performance of $CsPbBr_3$ PeLEDs and shows their electroluminescence mechanism for the first time.

A49-3 09:10~09:35

Invited Quantum Dot Electroluminescence Paves the Way to REC 2020 Displays

Poopathy Kathirgamanathan, Muttulingam Kumaraverl, Seenivasagam Ravichandran, Nicola Bramananthan, Lisa M. Bushby, and Sivagnanasundram Surendrakumar (Brunel Univ., U.K.)

Research on the electroluminescence of colloidal quantum dots is gathering momentum as the requirement for Rec 2020 (ITU-R-BT2020) cannot be achieved by means of state of art OLED materials (1-18). Quantum dots offer saturated colours, narrow emission and control over the emitted wavelength by varying the quantum dot size and composition. OLEDs have high efficiency and long lifetime and thus they have been accepted into the mainstream products such as mobile phones and curved TV. However, while efficiency of green QLEDs have exceeded that of PHOLEDs, the red and the blue QLEDs are yet to achieve sufficiently high efficiencies. The life-times of QLEDs are not yet long enough for commercial acceptance. The question is whether quantum dots would be good enough to yield colour co-ordinates satisfying the REC 2020 specification. This paper reports our successful effort to achieve the REC 2020 colour co-ordinates for red with world record efficiency and long life time to be a serious contender for the Red Pholeds. To the best of our knowledge, this is the first report of achieving the REC colour co-ordinate of (0.708, 0.292) and indeed exceeding to (0.712, 0.288) indicating that it is also possible to achieve REC 2020 green and blue colour co-ordinates if suitable QDs are developed and appropriate device architecture built.

50 Oxide TFT I

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:50
Session Chairs: Prof. Do Kyung Hwang (KIST, Korea)
Prof. Shengdong Zhang (Peking Univ., China)

B50-1 08:30~08:55

Invited Simplicity Meets High Performance: Solution Processed Metal Oxide TFTs

E. Fortunato, R. Branquinho, E. Carlos, P. Barquinhal, D. Salgueiro (Universidade NOVA de Lisboa and CEMOP/UNINOVA, Porutugal), A. Liu, F.K. Shan (Qingdao Univ., China), and R. Martins (Universidade NOVA de Lisboa and CEMOP/UNINOVA, Porutugal)

The recent and fast evolution from rigid silicon-based electronics to flexible electronics requires the use of new materials with novel functionalities that allow non-conventional, low-cost and environmental friendly processing technologies. Among the alternatives, metal oxide semiconductors have brought to attention as backplane materials for the next generation of flat panel displays [1]. After the huge success and revolution of transparent electronics and with the worldwide interest in displays where metal oxide thin films (MOTF) have proved to be truly semiconductors, display backplanes have already gone commercial in a very short period of time, due to the huge investment of several high profile companies: SHARP, SAMSUNG, LG, BOE [2]. These materials have demonstrated exceptional electronic performance as active semiconductor components and can be tuned for applications where high transparency/electrical conductivity is demanded. The global market for transparent electronics is expected to grow to nearly $7.1 billion by 2018. Fig. 1 shows the forecast for transparent displays as well as the main areas of applications up to 2025.

50 Oxide TFT I

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:50
Session Chairs: Prof. Do Kyung Hwang (KIST, Korea)
Prof. Shengdong Zhang (Peking Univ., China)

B50-2 08:55~09:20

Invited Printed and Electrolyte-Gated Oxide Electronics

Subho Dasgupta (Indian Inst. of Science, India)

Printed oxide field-effect transistors and logics are emerging as possible alternative to their organic counterparts. The markedly superior transport properties (e.g. carrier mobility) and environmental stability make them worthwhile to investigate. In addition, the abundance of very high performing n-type oxide semiconductors may also well complement the dominant organic *p*-type variants and open possibilities for hybrid electronics. On the other hand, there are also substantial obstacles toward successful printing of oxide electronics, namely poor spatial homogeneity, large surface/interface roughness, need for high process temperatures etc. In this regard, it will be demonstrated that the use of a solid electrolytes as the gate insulator is a unique approach in printed oxide electronics which can overcome most of the above mentioned shortcomings. For example, Fig. 1 depicts an exemplary completely room temperature processed and ink-jet printed all-oxide CMOS inverter. Next, it will also be shown that the high polarizability, extremely high gating efficiency and especially the 3-D gating ability of the *electrolyte as an electronic* insulator approach can provide a novel solution to the limited printing resolution issue of the commercial printers; in fact, arguably the insufficient printing resolution is the primary drawback for printed transistors that restricts the possibility of printed circuits to be operated at higher frequencies.

B50-3 09:20~09:35

Fiber-Based Metal-Oxide Thin-Film Transistors (TFTs) Using Low-Temperature Photoactivation for Electronic Textiles

Jae Sang Heo, Jun Ho Lee, Su Min Jung (Chung-Ang Univ., Korea), Han Lim Kang (Korea Univ., Korea), and Sung Kyu Park (Chung-Ang Univ., Korea)

In this study, we demonstrate high-performance metal-oxide fiber-based TFTs via low-temperature photochemical activation and solution process for the first time. Particularly, solution-processing combined with low-temperature photochemical activation were used to obtain dense and reliable metal-oxide dielectric and semiconducting layers on a cylindrical shape fiber substrate. Using these processes, high mobility indium gallium zinc oxide (IGZO) fiber-based TFTs were successfully realized, having electrical performances comparable to those fabricated on a planar substrate such as an extremely low leakage current density of ~10^{-7} A/cm^2 and a high breakdown field of 4.1 MV/cm. Furthermore, the IGZO fiber-based TFTs, which are photochemically activated at a low temperature (<150 ˚C), showed an average field-effect mobility and on/off ratio of 1.52 cm^2/V.s and >10^5, respectively as shown in Figure 1, which we believe are among the highest performance fiber-type TFTs reported to date.

50 Oxide TFT I

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:50
Session Chairs: Prof. Do Kyung Hwang (KIST, Korea)
Prof. Shengdong Zhang (Peking Univ., China)

B50-4 09:35~09:50

Copper Top Gate Oxide TFT with Double-Layered SiNx/Al_2O_3 Gate Insulator for the Application to the Large Area, High Resolution AMOLED

Yujin Kim, Geumbi Moon, Kyoungwoo Park, and Sang-Hee Ko Park (KAIST, Korea)

As recent display market has rapidly evolved into ultra-high resolution, technology of minimizing RC delay and establishing high mobility, high integrated, and reliable TFT has become very important. Accordingly, developing top gate oxide TFT becomes necessary to produce highly stable and reliable backplane to realize high-resolution and large-area AMOLED for next generation. For that reason, low resistance electrode and self-aligned structured TFT should be applied in order to minimize RC delay which impedes transmission of electrical signal. We examined gate insulator materials in top gate structure, mimicking self-aligned structure with copper top gate electrode. To overcome the problem with hydrogen diffusion which can influence on the number of carrier in oxide semiconductor and increase the driving capability, we adopted high dielectric constant double-layered gate insulator. The double-layered gate insulator is composed of Al_2O_3 deposited by atomic layer deposition (ALD) and SiN_x by plasma-enhanced chemical vapor deposition (PECVD). The first gate insulator layer, Al_2O_3, barely allows hydrogen to diffuse into channel area, and the second layer, SiN_x, performs a role of good copper barrier as well. Consequently, both SiN_x and Al_2O_3 which are deposited directly next to a-IGZO active layer hardly let hydrogen, metal material, or any other environmental elements affect TFT characteristics. We analyzed film characteristics, and properties of the each transistor, and moreover, study on stability, various available barriers of copper, and also high mobility oxide material with this structure will be proceeded.

51 Stretchable / Wearable TFT

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:05
Session Chair: Prof. Jiyoul Lee (Pukyong Nat'l Univ., Korea)

C51-1 08:30~08:55

Invited A-Few-Monolayer Organic Semiconductor Crystals and High-Performance Transistor Circuits on Plastic Substrates

C. Mitsui, J. Takeya, A. Yamamira (The Univ. of Tokyo, Japan), and M. Uno (TRI-Osaka, Japan)

A-few-molecular layers of molecular assembly are the minimally thick soft boundary to function as a separating film for efficient communication between outer and inner volumes. Here, we created bi-layers of self-organized pi-conjugated molecules achieving both outstanding carrier transport in the film and the most efficient carrier injection from an outer electrode through the ultrathin film. With the carrier mobility of 15 cm^2 /Vs, their transistor devices shows the most rapid response ever realized with molecular semiconductors. This presentation also focuses on recent development for integrated circuitry on plastic films using the flexible and high-performance organic transistors. We demonstrate a temperature sensing circuits on filmas, incorporating a printed polymer temperature sensor, an AD converter to digitize the data, multi-bit counters to manipulate the digital data and RFID communication circuits to send the data wirelessly. The circuitry contains more than 300 printed transistors of organic semiconductors.

C51-2 08:55~09:20

Invited Pulsed Laser Deposition of 2D and Bulk II-VI Materials

Manuel A. Quevedo-Lopez (Univ. of Texas at Dallas, U.S.A)

In this paper pulsed laser deposition (PLD) methods are used to study p-n II-VI homo and heterojunctions fabricated *in-situ. In-situ* film deposition allows higher quality p-n interfaces by minimizing spurious contamination from the atmosphere. Morphologic and structural analyses were carried for CdTe films deposited on various substrates and different deposition conditions and the electrical characteristics and performance of the resulting junctions are studied. In addition, a scalable and catalyst-free method to deposit stoichiometric two dimensional molybdenum disulfide (2D MoS_2) films over large areas is reported with the maximum area limited by the size of the substrate holder. The method allows deposition of MoS_2 layers on a wide range of substrates without any additional surface preparation including single crystals (sapphire and quartz), polycrystalline (HfO_2), and amorphous (SiO_2).

51 Stretchable / Wearable TFT

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:05
Session Chair: Prof. Jiyoul Lee (Pukyong Nat'l Univ., Korea)

C51-3 09:20~09:35

AMOLED Panel with 64 x 64 Pixels on Large Area PET Fabric Substrate

Jae Seon Kim and Chung Kun Song (Dong-A Univ., Korea)

Displays are essential components in wearable electronics which employ electronic devices on fabric substrates. However, it is challenge to fabricate a display panel on fabric substrates because of their drapery property, non-uniform surface energy, and rough surface. In this paper, we fabricated an AMOLED panel driven by OTFTs on polyethylene terephthalate (PET) fabric substrate. The AMOLED panel consists of 64 x 64 pixel array with the aspect ratio of 22 % on the area of 10 x 9 cm, and a pixel consists of 2 OTFTs and 1 capacitor and 1 OLED. TIPS-pentacene was used as the semiconductor of OTFTs and phosphorescene OLEDs were adopted to produce the brighter light. The key processes are like the followings; the smoothening process of rough surface, a process to secure uniform thickness of gate dielectric layer over the large area and thus to prevent the electrical short, the self-patterning process of photo-acryle (PA) for gate dielectric, a patterning process to confine the solution of TIPS-pentacene within the channel area of OTFTs, and top emission structure of OLED producing high brightness. The rough surface of the PET fabric substrate was smoothened by coating poly urethane layer, and thus the surface roughness reduced to 0.59 um from 10 um. To obtain the uniform thickness of PA gate dielectric, the additional PA layer was coated to modify the surface energy of PU layer before evaporation of Al gate electrode. Then, the PA gate dielectric was coated over the Al gate electrodes, and thus the uniform PA gate dielectric could be obtained with the thickness of 200 nm and 10 % deviation over 10 x 9 cm area. By using a special bank structure, TIPS-pentacene solution was successfully patterned in the channel as shown in Fig.1a). The OTFTs exhibited the mobility of 0.3 $cm^2/V{\cdot}sec$ and the on/off current ratio of ~10^7. OLEDs used top emission structure by using Al for the bottom electrode to reflect light to the top and a thin transparent Al top electrode. The OLEDs exhibited the intensity of 15,000 cd/m^2 at 6.5 V. The final AMOLED panel successfully worked to display check pattern as shown in Fig.1b).

51 Stretchable / Wearable TFT

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:05
Session Chair: Prof. Jiyoul Lee (Pukyong Nat'l Univ., Korea)

C51-4 09:35~09:50

Flexible Highly Sensitive Pressure Sensor with Double Electrode Layer for Application in Electronic Skin

Kyungkwan Kim, Minhyun Jung, Taeho Kim, and Sanghun Jeon (Korea Univ., Korea)

Recently, flexible high-sensitivity pressure sensors are emerging important parts of an electronic skin (e-skin) and wearable health monitoring system. Here, we used flexible double electrode layer and polydimethylsiloxane (PDMS) in order to fabricate an efficient high-sensitivity flexible pressure sensor. By stacking silver nano particle (AgNP) ink and the composite of conductive polymer poly (3, 4-ethylenedioxythiophene–poly (styrenesulfonate) PEDOT: PSS and elastomer—polyurethane dispersion (PUD) onto the micro pyramid structured PDMS substrate, we have fabricated the pressure sensor. The pressure sensor is operated on the basis of resistive change and exhibits a low operating voltage (< 0.1V), a low detectable pressure limit (3Pa) and a fast response time (20ms) as well as outstanding working stability (>20000 loading/unloading cycles). We expect that our technology could be widely used into wearable electronics such as e-skin, flexible touch displays, health-care monitoring and biomedical prosthesis of the future.

C51-5 09:50~10:05

Performance Improvement of OTFTs with Carbon Nanotube/Metal Hybrid Electrodes

Yuseon Jeong, Jinwook Jeong, and Chung Kun Song (Dong-A Univ., Korea)

Electrode contact resistance is an important factor that seriously affects the performance of organic thin film transistors (OTFTs). In this paper, new low contact resistance carbon nanotube (CNT) based hybrid electrodes are introduced for the source and drain electrodes of OTFTs. The hybrid electrodes consist of solution-processed CNTs and a metal (Al; CNT/Al or Au; CNT/Au) layer evaporated on the CNTs. The contact resistance of the CNT/Al and CNT/Au hybrid electrodes was found to vary depending on the thickness of the Al and Au layer. The contact resistance of the CNT/Al hybrid electrodes exhibited a minimum of 2.9 KW·cm (V_{GS} = -30 V) at an Al thickness of 5 nm, which was lower than the 13 KW·cm of the bare CNT electrodes, and tremendously less than the 4 MW·cm of the pure Au electrode. It is notable that the minimum contact resistance of the CNT/Au was 0.9 KW·cm at an Au thickness of 5 nm, and is the lowest value ever reported. The mobility of the OTFTs, which used pentacene as the semiconductor and polyvinylphenol as the gate dielectric, also followed the same dependence on metal thickness as the contact resistance. The maximum mobility of the OTFTs using CNT/Al and CNT/Au electrodes was 0.61 $cm^2/V \cdot sec$ and 1.0 $cm^2/V \cdot sec$, respectively, at the same metal thickness of 5 nm, which was larger than 0.3 $cm^2/V \cdot sec$ of the bare CNT electrodes. The major origin of these enhancements was found to be the small energy difference between the work function of the CNT/metal hybrid electrodes and pentacene HOMO (5.1 eV), which was obtained at the metal thickness of 5 nm.

52 Materials for Flexible TFT

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:05
Session Chair: Prof. Tatsuyu Okada (Univ. of the Ryukyus, Japan)

D52-1 08:30~08:55

Invited The Nonbonding Conformational Locks for Constructing Highly Planar π-Conjugated Systems

Tao Dong, Pan Ye, Lei Lv, Lei Yang, Xinlong Wang, and Hui Huang (Univ. of Chinese Academy of Sciences, China)

Novel building blocks with S···O and Se···O nonbonding conformational locks were designed, synthesized and characterized. The TTVTT(OE) is a novel and highly planar conjugated molecule with S···O nonbonding conformation locks, confirmed by single crystal X-ray diffraction. Interestingly, it is a unique AIE-active molecule that can be used as a biological dye for lipid droplets. Furthermore, the molecule and TTVTT(OE)-based conjugated polymers were employed to construct OTFTs with high charge transport mobilities, which is several orders higher than those of classical AIE molecules. Another novel conjugated molecule SeVSe(OE) has also highly planar conjugated molecule with Se···O nonbonding conformation locks, which was employed to construct p-type and n-type conjugated polymers for high performance OTFTs and OPV.

D52-2 08:55~09:20

Invited OLED Driving Circuits based on Printed SWCNT Thin Film Transistors

Jianwen Zhao, Weiwei Xu, Wenya Xu, Chunshan Zhou, Xiang Zhang, and Zheng Cui (Chinese Academy of Sciences, China)

In this work, we developed a valid method to sort large-diameter semiconducting single-walled carbon nanotubes (sc-SWCNTs) by using different new conjugated organic materials and produce a few printable sc-SWCNT inks. Sorted sc-SWCNT inks were used to directly fabricate printed SWCNT TFT arrays and 15×15 pixel OLEDs on glass substrates. Printed SWCNT TFTs exhibited low operating voltage, small hysteresis, high mobility (up to $20cm^2V^{-1}s^{-1}$) and on/off ratios ($\sim10^6$). Furthermore, it has been demonstrated that the driving circuits based on printed SWCNT TFTs exhibit the ability to control the brightness of OLED pixel arrays. This work shows that printed sc-SWCNT TFTs can be viable for backplanes of OLED display.

52 Materials for Flexible TFT

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:05
Session Chair: Prof. Tatsuyu Okada (Univ. of the Ryukyus, Japan)

D52-3 09:20~09:35

Photoelectric Characteristics of Lateral Thin Film Si Photodiode by Metal Electrodes for SoP

Tatsuyuki Higashizako, Charith Jayanada Koswaththage, Kota Nakao, Tatsuya Okada, and Takashi Noguchi (Univ. of the Ryukyus, Japan)

Integrating thin film photosensors with TFTs (Thin Film Transistors) using SoP (System on Panel) technology which can fabricate multifunctional devices on panel shorten the manufacturing process and leads to cost reduction. In photosensors, improving the photocurrent and decreasing dark current are important issues in order to obtain high photosensitivity. To improve the light sensitivity of lateral thin photodiode, simulations were carried out for thin Si films, and electrical characteristics were evaluated for the fabricated poly-Si film using BLDA (Blue Laser Diode Annealing).

D52-4 09:35~09:50

Advanced Low Temperature Crystallization of PE CVD Si Films without De-Hydrogenation Using BLDA (Blue Laser Diode Annealing)

Futa Gakiya, Takuya Ashitomi, Taisei Harada, Tatsuya Okada, Takashi Noguchi (Univ. of the Ryukyus, Japan), Osumu Nishikata, Atsushi Ota, and Kazuya Saito (ULVAC Inc., Japan)

Poly-Si TFTs (Thin Film Transistors) are used for displays of TV panels or smartphones. Reducing the production cost for the display panel is important as well as the device performance. Generally, the source/drain regions of conventional LTPS TFTs are formed by adopting ion implantation method. The machine cost and its running cost are expensive for the implantation process. Therefore, low-cost fabrication of Si TFT with metal source/drain without using ion implantation has been proposed and the TFT characteristics have been demonstrated [1]. On the other hand, TFT fabrication on flexible substrates such as PI (Polyimide) or PC (Polycarbonate) etc. is required. To perform the stable laser crystallization, initial deposited silicon film is required to dehydrogenate at rather high temperature before the laser annealing. However, the high processing temperature is not advantageous for plastic substrate. Additionally, for the TFT manufacturing, the reduction in the fabrication cost is needed. In this study, BLDA (Blue Laser Diode Annealing) was performed directly to PE-CVD (Plasma Enhanced Chemical Vapor Deposition) a-Si films without dehydrogenation.

52 Materials for Flexible TFT

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:05
Session Chair: Prof. Tatsuyu Okada (Univ. of the Ryukyus, Japan)

D52-5 09:50~10:05

Subthreshold Current Increase due to Grain Boundary Barrier Lowering of LTPS TFT

GeumJu Moon, YoungHa Sohn, KwangHyun Choi (Konkuk Univ., Korea), Young-Sang Kim (Sungkyunkwan Univ., Korea), and KeeChan Park (Konkuk Univ., Korea)

As the resolution of mobile OLED display increases, thin-film transistor (TFT) with smaller feature size is required. Low-temperature poly-crystalline silicon (LTPS) TFTs used in the mobile OLED display suffer from severe short-channel effects such as drain-induced barrier lowering (DIBL)[1-3]. DIBL of LTPS TFT is observed even for 2μm channel length, which is not common with single-crystalline silicon MOSFET. The drain current of LTPS TFT is dominantly determined by the grain structure of poly-Si active film. The severe DIBL phenomena of LTPS TFT may also originate from grain boundaries in the poly-Si layer. We investigated the relationship between the potential barrier height of grain boundary and the subthreshold current of LTPS TFT using TCAD simulation. Fig. 1 shows the profile of valence band edge (E_V) of p-channel LTPS TFT near source junction when V_{DS}= -10V and V_{GS}= -1V (subthreshold region) for various channel lengths (L). As the channel length gets shorter below 2μm, the barrier height at the grain boundary is lowered significantly. Fig. 2 shows how the subthreshold current is affected by the potential barrier height. The barrier height decreases considerably as the channel length gets shorter below 2μm. It should be noted that the degree of DIBL is not only determined by the channel length but also by the grain size. However, the drain current in log scale is almost linearly propotional to the barrier height decrease regardless of grain size. This indicates that the DIBL of short-channel LTPS TFT appears mainly due to the barrier height lowering at the grain boundaries.

53 Large Area Displays Application II

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:25
Session Chairs: Prof. Hirotsugu Yamamoto (Utsunomiya Univ., Japan)
Dr. Munekazu Date (NTT Corp., Japan)

E53-1 08:30~08:45

Continuous Depth Perception by Only Two Small-Light Sources in Non-Overlapped DFD (Depth-Fused 3D) Display

Rue Takano, Haruki Mizushina, and Shiro Suyama (Tokushima Univ., Japan)

In this paper, we propose a Non-overlapped DFD display not using LED sources but using small-light sources. Moreover, even when only two small-light sources are used as front and rear images, these two light sources can be fused to one depth, which is continuously changed by changing luminance ratio. Because we have not yet clarified the main factors for fusing two images to one depth image, such as light source, structure, lighting distribution, or etc. In conclusion, Non-overlapped DFD display provides almost linear depth perception by using small-light sources. Moreover, only two light sources can be successfully fused to one perceived depth which has almost linear dependence of perceived depth.

E53-2 08:45~09:00

High-Resolution Light Field Stereoscope

Chulwoong Lee, Junho Seok, Mugeon Kim, and Joonku Hahn (Kyungpook Nat'l Univ., Korea)

Recently, the market of virtual reality has emerged so fast that the technology related with it has become familiar to the public. Various near-eye display systems have been reported. In particular, a head mounted device where a smart phone is inserted becomes popular since many users already have their own phones. In this paper, we are inspired by the previous works presented by F.-C. Huang. The light field display with multiple layers of panels has great advantage to integrate lots of pixels within a given area by stacking the pixels vertically. In this system, two panels are used where each is detached from the smart phone, G3 manufactured by LG electronics. By using commercial panels, our system has lots of benefits in dimension and the size of our system is compatible to the commercial head mounted devices. To combine two panels, a half-wave retarder film is placed between them. Physically, one panel is positioned at the focal plane of the eyepieces and the other is positioned nearer to the eyepieces. Therefore, the former displays the objects placed far from the eyes and the later displays the objects placed near to the eyes.

53 Large Area Displays Application II

Date: Aug. 26, 2016 (Friday)
Time: 08:30~09:25
Session Chairs: Prof. Hirotsugu Yamamoto (Utsunomiya Univ., Japan)
Dr. Munekazu Date (NTT Corp., Japan)

E53-3 09:00~09:25

Invited VR vs. LF, 3D Immersion without Headgear

Tibor Balogh (Holografika Kft, Hungary)

The evolution of 3D technologies shows cyclical learning curve with series of hypes and dead-ends, with mistakes and consequences. 3D images contain significantly more information than corresponding 2D. 3D display systems should be built on more pixels, or higher speed components[1]. For true 3D this factor is in the order of 100x, a real technology challenge. If not fulfilled, 3D systems' capabilities will be compromised: headgears will be needed, or viewers should be positioned / tracked, single user devices, lack of parallax, missing cues, etc.The temptation is always there: why to provide all the information, just what the person absorbs that moment (subjective or objective visualization). This leaded to the short-cut to 3D: 2x stereo, the 3DTV hype (rather 2 x ½). The 3D the industry promised and what people expected was not what they got. Was it a mistake? Yes, since 3DTV failed, but we learnt a lot about the artifacts, camera rigs, view synthesis (depth/disparity, inter /extrapolation), stereo content editing, audience reactions, etc. VR glasses were around for more than two decades. With the latest technical improvements and the market start signal by the 2B$ acquisition of Oculus, VR became the next hype. 3D immersion was added, as a new phenomenon, however VR represents an isolated experience, requires headgears and a controlled environment (AR in this sense if different). Will VR/AR hype with the headgears be a mistake? Might be. On the other hand it will be B$ business and we will learn that 3D requires more information (and more than 2 cameras). Although the geometry of next-generation 3D systems may be different, as shown in Figure 1., we will learn a lot about camera arrays, high-performance 3D computation, immersive 3D content, complementing technologies, like 3D tracking, motion platforms, haptic feedback, etc., and range of novel VR/AR applications, areas, professions will be born.

54 Light Field & 3D Imaging System I

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:00
Session Chair: Dr. Jisoo Hong (KETI, Korea)

F54-1 08:30~08:55

Invited Eye Tracking Based Light Field Display

Dongkyung Nam, Jingu Heo, Juyong Park, and Kyuhwan Choi (Samsung Advanced Inst. of Tech., Korea)

The fundamental problems of the glasses-free 3D display may be summed up as 'insufficiency of pixel resources'. The typical 2D display panel has about 2~8 million pixels, which may be enough for the 2D information, but far too less to express the 3D spatial information. By this reason, the current glasses-free 3D display has several limitations such as narrow viewing angle, low resolution and image quality degradation from the crosstalk. To overcome this problem, we suggest a 3D display system based on the light field reconstruction and the eye tracking technology.

F54-2 08:55~09:20

Invited Efficient Light Field Rendering

Young Ju Jeong, Jin-ho Lee, and Dongkyung Nam (Samsung Advanced Inst. of Tech., Korea)

To generate realistic 3D displays, light field 3D displays provide a huge number of light rays though multi-projection 3D displays and flat panel 3D displays. However the conventional image rendering processing for light field displays, such as image based rendering algorithm, needs a large amount of cameras or input images. This creates difficulties in designing both the acquiring system and memory storage. We propose efficient light-field rendering algorithms for light field displays. For multi-projection 3D displays.

F54-3 09:20~09:45

Invited Software Technologies for 4D Light Field Display

Takafumi Koike (Hosei Univ., Japan)

Advancement of Light field display needs not only optics and hardware devices but also software technologies. We implemented some light field display and have proposed future 4D and 5D light field display. We present three software technologies of light field display studied in our laboratory. The first one is a simulation method to design light field display and second one is generating panorama light field for contents of 4D light field display and third one is controlling method of drone for large size light field display.

54 Light Field & 3D Imaging System I

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:00
Session Chair: Dr. Jisoo Hong (KETI, Korea)

F54-4 09:45~10:00

A Simple Method for Preparing a Polymeric Microlens Array

Zuowei Zhou and Hongwen Ren (Chonbuk Nat'l Univ., Korea)

The photomask is prepared by depositing a chromium dot array on a glass plate. UV-curable monomer NOA164 (Norland *Optical* Adhesive) is chosen as the lens material. The monomer is spin-coated on a glass substrate to form a thin layer. The monomer is exposed by a UV light through the photomask. In the exposed area, the thickness of the monomer layer shrinks because of photo-polymerization in the bulk. The monomers on the surface are hard to be cured because of oxygen inhibition. The uncured monomers on the surface attract each other to form a curved surface due to surface tension. After second time solidification by UV light, a plano-convex polymeric MLA is obtained.

55 Chalcogenide Photovoltaics

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:10
Session Chairs: Dr. Jae Ho Yun (KIER, Korea)
Dr. Won Seok Han (ETRI, Korea)

G55-1 08:30~08:55

Invited Development of Vacuum Processes for Solar Cells with Earth-Abundant Materials

Dae-Hwan Kim, Kee-Jeong Yang, Shi-Joon Sung, Dae-Kue Hwang, Dae-Ho Son, Si-Nae Park, Sang-Ju Lee, Yong Chan Choi, Jun-Hyoung Sim, Young-Ill Kim, Dong-Hwan Jeon, JungSik Kim, and Jin-Kyu Kang (DGIST, Korea)

The kesterite compounds, including Cu_2ZnSnS_4 (CZTS), $Cu_2ZnSnSe_4$ (CZTSe) and $Cu_2ZnSn(S,Se)_4$ (CZTSSe) have been of great interest for many years as promising solar cell absorbers because they mainly consist of earth-abundant and readily available elements, show good absorption properties and have adequate bandgap energies. Many process approaches, such as hydrazine based solution method, thermal co-evaporation, sputtering, pulsed laser deposition, electrochemical deposition, have been attempted for preparing these materials and, up to now, an efficiency of 12.6 % is the highest one in kesterite solar cells. However, the process of the best CZTSSe solar cell uses a highly toxic hydrazine solvent and lacks scalability due to strict process conditions. It is expected, hopefully, that vacuum processes will give us a better chance to increase the CZTSSe solar cell efficiency because they generally provide reliable and reproducible results. To achieve efficiencies over 12 % with CZTSSe via vacuum based process, we have been developing a 2-step process which includes a precursor preparation step by a sputtering and a chalcogenization step by a furnace equipped with chalcogen elements. Among various variables, especially, the structure of precursor stack and S/Se element ratio during chalcogenization have big influences on device properties. Characteristics of our high efficiency cells over 12% will presented. In addition, the basic preparation of $CuSbS_2$ absorbers, another earth-abundant Cu containing materials, and the resultant device characteristics will be discussed.

55 Chalcogenide Photovoltaics

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:10
Session Chairs: Dr. Jae Ho Yun (KIER, Korea)
Dr. Won Seok Han (ETRI, Korea)

G55-2 08:55~09:20

Invited Efficient Chalcogenide Thin Film Solar Cells Consisting of Earth-Abundant, Cheap, and Non-Toxic Elements

Se Won Seo and Jin Young Kim (Seoul Nat'l Univ., Korea)

Kesterite $Cu_2ZnSn(S,Se)_4$ (CZTSSe) thin films are attracting a lot of interest as an alternative system to $Cu(In,Ga)Se_2$ (CIGS) and/or CdTe thin films, owing to their majority carrier type (p-type), proper band gap energy (1.0-1.5 eV), and high optical absorption coefficient (> 10^4 cm^{-1}). More promisingly, the CZTSSe is composed of earth-abundant (cf. In in CIGS), environmentally-friendly (*cf.* Cd in CdTe), and relatively cheap elements. We have recently reported that a highly efficient CZTSSe thin film solar cell can be fabricated via an electrochemical method involving the electrochemical deposition of metallic Cu-Zn-Sn (CZT) precursor thin films and the subsequent sulfurization/selenization process. In this presentation, we propose general strategies for improving the photovoltaic properties of the CZTSSe thin film solar cells, involving the manipulation of the film composition and its gradient. For achieving the compositionally graded CZTSSe thin films, we systematically investigated the effect of the electrochemical deposition parameters and the post annealing conditions on the structural and chemical properties of the final CZTSSe thin films. In addition, we demonstrate the successful application of new transparent electrode material for highly efficient CZTSSe thin film solar cells. After a series of the optimizing processes, a high efficiency close to 10% was obtained, which is the highest efficiencies reported on the electrochemically deposited CZTSSe thin film solar cells.

G55-3 09:20~09:45

Invited Alternative n-Type Buffer Layers for $Cu_2ZnSn(S,Se)_4$ Thin Film Solar Cells

Hee Kyeung Hong, Dongha Lim, Jae Yu Cho, Gwang Yeom Song, and Jaeyeong Heo (Chonnam Nat'l Univ., Korea)

Research has been rapidly grown on fabricating earth-abundant solar cells which can possibly replace CIGS-based cell. One of the candidate materials is $Cu_2ZnSn(S,Se)_4$ (CZTSSe). The detailed and comparative study on the application of atomic layer deposition (ALD)-based buffer layers on CZTSSe thin film solar cells is crucial to improve the cell efficiency. In this talk, I will first introduce the reaction mechanism of ALD and growth reaction of ALD-Zn(O,S) buffer layers. Structural, electrical, and optical properties will be reviewed and application of the new buffer layers to CZTSSe will be demonstrated. O/(O+S) ratio was found to influence the overall cell performance and XPS, J-V, and TEM analyses were used to correlate their relationship in-detail.

55 Chalcogenide Photovoltaics

Date: Aug. 26, 2016 (Friday)
Time: 08:30~10:10
Session Chairs: Dr. Jae Ho Yun (KIER, Korea)
Dr. Won Seok Han (ETRI, Korea)

G55-4 09:45~10:10

Invited Interpretation of Interfacial Properties of $Cu(In,Ga)Se_2$ Solar Cell with Zn-Based Buffer Layers

Yong-Duck Chung, Dae-Hyung Cho, Jae-Hyung Wi, Woo-Jung Lee, Hye-Jung Yu, and Won Seok Han (ETRI, Korea)

$Cu(In,Ga)Se_2$ (CIGS) has continuously received attention for the photovoltaic market because of its outstanding photovoltaics performances. Traditionally, high-efficiency devices contain a CdS buffer layer processed by chemical bath deposition (CBD) between CIGS absorber and transparent front electrode. The use of Cd, however, is undesirable because Cd is highly toxic and CdS buffer layer reduces transmittance of short-wavelength light that reaches CIGS absorber. Because Zn-based buffer layer can overcome these disadvantage of CBD-CdS, there are many approaches to replace CBD-CdS layer, for example, ZnS layer by S-cracker, Zn(O,S) layer by reactive sputtering, and CBD-ZnS. The importance of these contacting layers in polycrystalline thin film solar cells has steadily increased, since the interface properties play crucial role to determine the conversion efficiency of the solar cells. In this presentation, the interpretation of CIGS/Zn-based buffer interfaces will be discussed with respect to electronic, chemical, and structural properties. The device characteristics of CIGS solar cells with Zn-based buffer will be also investigated.

57 OLED Degradation & Encapsulation

Date: Aug. 26, 2016 (Friday)
Time: 10:30~12:00
Session Chair: Prof. Poopathy Kathirgamanathan (Brunel Univ., U.K.)

A57-1 10:30~10:55

Invited Recent Progress of Degradation Analysis of Flexible Organic Light Emitting Diodes

Hideyuki Murata (JAIST, Japan)

Degradation in organic light emitting diodes (OLEDs) can be caused by the formation of dark spots, the occurrence of electrical shorts leading to a sudden decrease in luminance or intrinsic degradation. In this study, a recent progress of degradation analysis of OLEDs in terms of both dark spot formation and intrinsic degradation will be presented. Dark spot formation and edge leakage were reported at accelerated environmental conditions. A reliable evaluation method to quantify water penetration in an adhesive used for flexible OLEDs was developed. The water penetration time in an adhesive was predicted by apparent water diffusion coefficient, which agrees with the start time of the dark spots formation and non-emissive area. Regarding the intrinsic degradation, we have developed the degradation analysis based on a time resolved photoluminescence (TRPL) technique. We can detect the origin of PL loss of emitting materials in OLEDs during the device operation. Detail analysis of TRPL in the degraded OLEDs based on either Alq_3 or $Ir(ppy)_3$ show that at leaset two kind of degradation reactions are taking place during a decrease in electroluminescence under constant current operation. In both OLEDs, a creation of quencher plays crucial role for the intrinsic degradation.

A57-2 10:55~11:20

Invited Enabling Flexible and Foldable Air Stable OLED Devices with Thin Film Barriers

Jie Shen, Peter van de Weijer, Piet C. P. Bouten, Pradeep Panditha, Pavel Kudlacek, Jan Laurens van der Steen, Gerard Haas, Pim Groen, Gerwin H. Gelinck, Paul Poodt, and Hylke B. Akkerman (Holst Centre, Netherlands)

Organic electronic devices, in particular OLEDs, are extremely sensitive to the ambient and need to be protected to achieve long operational and shelf life times. Holst Centre has developed a double-layer thin-film encapsulation for OLEDs on glass, which was successfully transferred to production. Here, we will present our work on thin-film barriers in relation to flexible devices. High quality thin-film barriers, TFT backplanes and most OLED stacks, all contain at least a single brittle layer. The flexibility of the device is dependent on the total thickness of the stack, the position of the neutral line and the intrinsic mechanical properties of the individual layers. By mechanically optimizing the total stack, great flexibility can be achieved. Here we will show flexible OLEDs that do not show any barrier or OLED degradation after 100.000x rolling over 10 mm radius. Furthermore, we will demonstrate that bending radii of 500 µm and below are possible without barrier or OLED failure, despite the fact that the stacks contain fragile brittle layers.

57 OLED Degradation & Encapsulation

Date: Aug. 26, 2016 (Friday)
Time: 10:30~12:00
Session Chair: Prof. Poopathy Kathirgamanathan (Brunel Univ., U.K.)

A57-3 11:20~11:35

Plasma Enhanced Atomic Layer Deposition SiO_2 Deposited at a Low Temperature for Thin Film Encapsulation

Young-Soo Lee, Dong-won Choi (Hanyang Univ., Korea), Jae-Young Lee, Ji-Min Kim (LG Display Co., Ltd., Korea), and Jin-Seong Park (Hanyang Univ., Korea)

Organic electronic devices have recently required a passivation layer that protects the active layers from oxygen and moisture. Thin-film encapsulation (TFE) is most effective in preventing oxygen permeation and water vapor into the flexible devices. Plasma-enhanced atomic layer deposition (PEALD) technique, which provides growth characteristics that are similar to those of thermal ALD, enables a low temperature deposition by using O_2 plasma and N_2O plasma instead of water (H_2O) vapor. Although the ALD Al_2O_3 film has excellent barrier properties, disadvantages of Al_2O_3 thin film are difficulty of particle removal, barrier etching and problem of in-situ. SiO_2 has excellent properties, such as the large energy band gap (8.9 eV), low leakage current, impurity of low levels and low interface state density in the film. The required properties of SiO_2 thin films are lower deposition temperature, particle damage free process, excellent step coverage, and high throughput. PEALD provides a technique to regulate these problems. The PEALD method is a well-known deposition based on self-limiting and sequential surface reactions, exhibiting saturation growth behavior and thickness control. In this study, we investigated the properties of SiO_2 films on flexible PEN substrates deposited by PEALD encapsulation of OLEDs. As a result, the effects of deposition parameters on oxide film properties in terms of growth rate, refractive index, RMS roughness and water vapor transmittance rate (WVTR) will be discussed.

57 OLED Degradation & Encapsulation

Date: Aug. 26, 2016 (Friday)
Time: 10:30~12:00
Session Chair: Prof. Poopathy Kathirgamanathan (Brunel Univ., U.K.)

A57-4 11:35~12:00

Invited Transparent and Conductive Thin-Film Permeation Barriers - Towards Self-Encapsulating Organic Opto-Electronics

Andreas Behrendt, Tim Becker, Sara Trost, Tobias Gahlmann, and Thomas Riedl (Univ. of Wuppertal, Germany)

Gas diffusion barriers (GDB) are inevitable to protect sensitive organic devices against ambient gases. Typically, thin-film GDBs are insulators. Work on transparent conductive GDB (TCGDBs) is very limited. TCGDBs based on ZnO prepared by ALD have been reported. Due to the chemical instability of ZnO, it turns out that their electrical conductivity deteriorates by orders of magnitude upon exposure to damp heat conditions after very short time. We will show that these issues can be overcome by the use of tin oxide (SnO_2). Conductivities of up to $3x10^2$ S/cm and extremely low water vapor transmission rates (WVTR) on the order of 10^{-6} g/(m^2 day) can been achieved in SnO_x layers prepared by ALD at low temperatures (<150°C). A sandwich of SnO_x/Ag/SnO_x is shown to provide an average transmittance of 82% and a low sheet resistance of 9 Ω/sq. At the same time the resulting electrodes are extremely robust. E.g., while unprotected Cu and Ag electrodes degrade within a few minutes at 85°C/85%rH (e.g. Cu lost 7 orders of magnitude in electrical conductivity), sandwich structures of SnO_X / (Cu or Ag)/SnO_X remain virtually unchanged even after 100 h. We demonstrate the application of these TCGDBs as electrodes for organic solar cells and OLEDs.

58 Oxide TFT II

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:35
Session Chair: Dr. Hui Huang (Univ. of Chinese Academy of Sciences, China)

B58-1 10:30~10:55

Invited Implantable Organic Electronics for Pathologies of the Central Nervous System

Michele Di Lauro, Marcellp Berto, Carlo Augusto Bortolotti (Univ. of Modena and Reggio Emilia, Italy), Mauro Murgia (CNR-ISMN, Italy), Michele Zoli (Univ. of Modena and Reggio Emilia, Italy), and Fabio Biscarini (Univ. of Modena and Reggio Emilia, Italy)

Several pathologies of the central nervous system quest for implantable devices capable of performing electrical stimulation and bidirectional communication as basis for novel therapies. It would be desirable also to integrate these devices with local pharmacological treatments or advanced therapies based on stem cell transplants. The implants must therefore fulfill different requirements at the same time: multi-–-functionality on one hand and minimal invasiveness or total biocompatibility, in order to avoid inflammatory reactions and undesired foreign body reactions. In this presentation, the development of a new platform of implantable devices, integrating all-–-organic electrolyte-–-gated organic field effect transistors (EGOFETs) onto flexible polymer films. The fabrication technology is based on direct patterning of the PEDOT:PSS electrodes and deposition on the patterned channel of C8-–-BTBT. Our approach is suitable for prototyping, which is very important owing to the diversity of the anatomic requirements. The EGOFETs are patterned on a biocompatible polymer foil (PDMS, PEN, PET) or biodegradable (PLGA, PHB), and a microfluidics is monolithically integrated onto it. The different immunogenic properties of the devices will be discussed. We validate the devices in physiological fluids and demonstrate their operations in vitro with neuronal cell cultures and in vivo in a murine animal model of the Parkinson’s disease. We gratefully acknowledge the MIUR Italy/Sweden Bilateral Project “Poincaré”.

58 Oxide TFT II

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:35
Session Chair: Dr. Hui Huang (Univ. of Chinese Academy of Sciences, China)

B58-2 10:55~11:20

Invited Oxide Thin-Film Transistors with In Situ Anodized Passivation Layers

Shengdong Zhang, Yang Shao, Xiang Xiao, Yong Le, Letao Zhang, and Xiaoliang Zhou (Peking Univ., China)

In this work, a low cost, low temperature and high throughput technique is proposed and investigated to fabricate high-performance Metal Oxide TFTs. It includes the growth of thin high-k gate dielectric, property modulation of oxide channel layer and in-situ formation of passivation layer by an anodization technique. HfO_2 films with an equivalent oxide thickness (EOT) of 3.8 nm are grown by anodization. Room-temperature fabricated a-IGZO TFTs are gated by the anodized HfO_2 gate dielectrics. An anodization treatment is proposed and investigated to modulate electrical properties of oxide channel layers. Homo-junction ITO TFT is fabricated at room temperature successfully. Lastly, a technique of forming in-situ back-channel passivation by anodization is proposed and investigated, in which a-IGZO TFTs with in situ anodized Al_2O_3 passivation layer and ITO TFTs with in-situ anodized Ta_2O_5 passivation layer are both demonstrated.

B58-3 11:20~11:35

High Performance Siloxane Hybrid Polymer Gate Insulator for Amorphous InGaZnO Thin-Film Transistors.

Chaiyanan Kulchaisit, Yasuaki Ishikawa, Mami N. Fujii, Haruka Yamazaki, Juan Paolo Bermundo, and Yukiharu Uraoka (NAIST, Japan)

Amorphous InGaZnO (*a*-IGZO) is a well-known material for next generation displays which are flexible and transparent. But due to ambient effects, the performance of this material still needs to improve. Siloxane materials were developed to improve the performance of *a*-IGZO TFT. These organic-inorganic hybrids based on Si-O backbone combines many desirable properties of conventional organic and inorganic components. Siloxane become a candidate for making film layer for TFTs structure because this material has good transparency and high thermal resistance. We try to prove that this material can improve the TFT characteristics and reliability as both passivation layer and gate insulator roles which can be used in printable, flexible, and transparent devices in the future. In this study, we focus on *a*-IGZO TFT top gate structure by using siloxane as a gate insulator together with bottom gate structure act as a passivation layer. We suggest that hydrogen from siloxane layer diffused into *a*-IGZO layer and siloxane protected the surface of *a*-IGZO from ambient effects which improved characteristics. According to the results, siloxane is the promising material for both passivation and gate insulator of flexible and transparent AOS TFTs.

59 Tunable Metamaterial Devices

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:35
Session Chairs: Prof. Hwi Kim (Korea Univ., Korea)
Dr. Junghyun Park (Samsung Electronics Co., Ltd., Korea)

C59-1 10:30~10:55

Invited Electrically Tunable Metafilm Absorber and its Application in Visual Display

Junghyun Park (Samsung Electronics Co., Ltd., Korea), Ju-Hyung Kang, and Mark Brongersma (Stanford Univ., U.S.A.)

We present an electrically tunable metafilm absorber based on an ultrathin transparent conducting oxide (TCO) sandwiched by a planar metal substrate and nano-patterned metal structures. The gap plasmon resonance occurs when the Fabry-Perot resonance condition is satisfied, giving rise to substantial electric field enhancement inside the strip-cavities. Electrical gating induces the formation of accumulation or depletion layer in TCO, which in turn leads to the change of the mode index of gap plasmons. The reflection spectrum is perturbed by the change of propagation phase forming the Fabry-Perot resonance. For higher modulation, it is required to operate the devised configuration both with the accumulation and depletion since those two operations contribute to opposite direction of the spectral shift. In infrared regime, the modulation efficiency was achieved as up to 18%P, with the unit cell size of 600 nm . This talk will also deal with the potential approaches to enhance the modulation efficiency. With further improvement in performance, it is believed that this working principle may pave a way to development of next-generation imaging and display devices.

C59-2 10:55~11:20

Invited Electronically Tunable Conducting Oxide Metasurfaces for Beam Steering and Color Filtering

Ho Wai Howard Lee (Baylor Univ., U.S.A.)

I will present recent results on gate-tunable metasurface that enables dynamic electrical control of the phase and amplitude of the plane wave reflected from the metasurface. A phase shift of π and ~ 30% change in the reflectance are achieved by applying 2.5 V gate bias, a basic requirement for electrically tunable beam-steering phased array metasurfaces that potentially would integrate into the CMOS imaging sensor. I will also present the use of metasurface structure to develop a tunable plasmonic color-filters based on the conducting oxide materials. In addition to the fundamental interest of tunable metasurfaces, these structures have many potential applications for future ultrathin optical components for display and imaging system, such as dynamic holograms, tunable ultrathin lens, reconfigurable beam steering devices, nano-projectors, and nanoscale spatial light modulators.

59 Tunable Metamaterial Devices

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:35
Session Chairs: Prof. Hwi Kim (Korea Univ., Korea)
Dr. Junghyun Park (Samsung Electronics Co., Ltd., Korea)

C59-3 11:20~11:35

Plasmonic Cavity for Engineering Complex-Valued Reflectance of Visible Light

Hyeonsoo Park, Joonsoo Kim (Seoul Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), and Byoungho Lee (Seoul Nat'l Univ., Korea)

In this paper, we propose a novel plasmonic cavity structure for achieving complex-valued reflectance at visible frequency. The plasmonic cavity comprises of two parallel slit apertures with different depths, and it is directly attached to a square aperture waveguide. We optimize the structural parameters to achieve perfect absorbing condition, then arbitrary complex-valued reflectance is obtained by gradually tuning depths of the apertures. We expect that this novel type of structure can be applied to pixel design of reflection-type spatial light modulators with extremely large viewing angle.

60 Driving Circuit and Panel Design

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:55
Session Chairs: Prof. Byong-Deok Choi (Hanyang Univ., Korea)
Prof. Seung-Woo Lee (Kyung Hee Univ., Korea)

D60-1 10:30~10:55

Invited A 13-Bit Universal Column Driver for Various Displays of OLED and LCD

Seong-Young Ryu, Dong-Hoon Baek, Hyun-Wook Lim, Sang-Kyo Han, Kyung-Ho Ryu, Kwang-Hyun Park, Jin-Yong Park, Jung-Min Lee, Tae-Jin Kim, Jae-Youl Lee, and Gyeong-Nam Kim (Samsung Electronics Co., Ltd., Korea)

A universal column driver is implemented in a 0.13-μm high-voltage CMOS process for not only TFT-LCD but also OLED applications. The proposed column driver employs 13-bit linear DAC to cover all gamma curves of display applications and address-based configuration for intra- panel interface protocol to support both TV and IT applications. Measured results demonstrate the average voltage of output channels (AVO) is under 1mv, which satisfies 1-LSB resolution at 18.5V of AVDD.

D60-2 10:55~11:10

Pixel Architecture for Low-Power LCDs by Only Oxide TFTs

Byung-Chang Yu, Seung-Hyuck Lee, and Seung-Woo Lee (Kyung Hee Univ., Korea)

These days, owing to environmental and energy concerns, a low-power feature has become indispensable in liquid crystal displays (LCDs). Here, we propose a new pixel architecture that comprises only Oxide TFTs (Ox-TFTs). The proposed circuit is composed of four Ox-TFTs and two capacitors. In our proposed pixel structure, we can achive low-power features through low refresh rate. We have proposed a new pixel architecture for low-power LCDs without any memory device.

D60-3 11:10~11:25

A Multi-Dot Inversion Data Addressing Method for Low Power and High Image Quality LCDs

Bo-Gun Seo, Woo-Kyu Sang (LG Display Co., Ltd., Korea), and Oh-Kyong Kwon (Hanyang Univ., Korea)

In recent years, as the size and resoution of liquid crystal displays (LCDs) increase, the load of data line increases and the row line time decreases. Thus, a data driver IC consumes more power to charge the large load in a short time. To overcome this problem, several low power data addressing methods have been researched. Column inversion methods achieved high power-efficiency, but degraded image quality due to vertical crosstalk. Dot inversion methods achieved high image quality, but performed low power-efficiency. In this paper, we propose the new multi-dot inversion method to realize low power and high image quality LCDs.

60 Driving Circuit and Panel Design

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:55
Session Chairs: Prof. Byong-Deok Choi (Hanyang Univ., Korea)
Prof. Seung-Woo Lee (Kyung Hee Univ., Korea)

D60-4 11:25~11:40

A Decoder-Type Integrated Gate Driver with Enhanced Stability for Felxible Display Using Oxide TFTs

Chang-Sub Moon, Jong-Seok Kim, Yong-Duck Kim, and Byong-Deok Choi (Hanyang Univ., Korea)

The conventional integrated gate driver propagates the output signal from one stage to the next stage. Consequently, operation of each stage is affected by the previous stages. This strucure is unfavorable for the flexible displays since the errors caused by the mechanical stress are accumulated throughout the stages, and this possibly makes a severely degraded performance or a malfunction. To resolve this problem, the individual-channel gate driver has been proposed. In this work, to enhance the stability of the decoder-type gate driver, we suggest a new design method for driving TFT. By using the overlap driving method shown in Fig. 2, we can relax the rising time requirement, which leads to the reduced width of the driving TFT. As a result, the gate driver can achieve a higher stability.

D60-5 11:40~11:55

Low-Dropout Regulator based on a-InGaZnO Thin-Film Transistors for Display Driving Systems

Yongchan Kim and Hojin Lee (Soongsil Univ., Korea)

In this paper, we designed an a-InGaZnO TFT based LDO regulator fully integrated on the glass substrate for supplying the designated power to display systems. Through the extensive simulation, the proposed LDO regulator was confirmed to suppress the output voltage ripple below 48mV when VIN was changed from 14V to 15V with 100mV fluctuation. We expected the proposed LDO regulator could be used for the power control and driving systems for various display applications.

61 Touch and UX Technologies

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:25
Session Chair: Dr. Keum Hwan Park (KETI, Korea)

E61-1 10:30~10:55

Invited Robust and Patternable Electrodes for Paper Electronics

Jung-Yong Lee (KAIST, Korea)

We propose a fabrication process for extremely robust and easily patternable silver nanowire (AgNW) electrodes on paper. Using an auxiliary donor layer and a simple laminating process, AgNWs can be easily transferred to copy paper as well as various other substrates using a dry process. Intercalating a polymeric binder between the AgNWs and the substrate through a simple printing technique enhances adhesion, not only guaranteeing high foldability of the electrodes, but also facilitating selective patterning of the AgNWs. Using the proposed process, extremely crease-tolerant electronics based on copy paper can be fabricated, such as a printed circuit board for a 7-segment display, portable heater, and capacitive touch sensor, demonstrating the applicability of the AgNWs-based electrodes to paper electronics. (Fig. 1)

E61-2 10:55~11:10

Novel Positive-Intrinsic-Oxide Semiconductor (P-I-OS) Photo Sensor for Flat Panel Displays

Won-Kyu Lee, Jae Hwan Oh, Deokhoi Kim, and Chung Yi (Samsung Display Co., Ltd., Korea)

A new P-I-OS photo sensor has been developed using IGZO semiconductor as the cathode region instead of n+ doped Si. As a result, only one ion implantation step is required for mass production, instead of the two ion implantation steps that are required for conventional P-I-N photo sensors. Ion implantation at large sizes is expensive and difficult, so it is very desirable to avoid the second ion implantation step. Therefore, the new PMOS-only photo sensor can be used with single-stage ion implantation, such that used for large AM-OLED displays, without the associated ion implantation complexity of a conventional P-I-N structure. This paper is the world's first report of such a structure. Dynamic range of the proposed P-I-OS photo sensor is 53.3 dB under -5V of anode bias and 10,000 lx of illumination. That performance is comparable to typical lateral P-I-N photo sensors. It is expected that the P-I-OS photo sensors will be preferable for PMOS-only large area interactive applications such as digital TV and digital information displays.

61 Touch and UX Technologies

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:25
Session Chair: Dr. Keum Hwan Park (KETI, Korea)

E61-3 11:10~11:25

A New Estimation Method for Scan Frequency of a Touch Screen Panel Using Touch System and Touch IC Models

Kicheol Kim and Yeontae Kim (Samsung Display Co., Ltd., Korea)

The prediction of scan frequency is required to know whether the TSP meets the the target performance or not. With the increase of a TSP load such as an in-cell TSP, the estimation of scan frequency is hard to predict. To consider drive strength of a touch IC, the Tx buffer model which is modeling in Verilog-A language. And the full channel of the TSP critical path from a touch IC's Tx to a touch IC' Rx is modeled. The proposed method using touch system and touch IC models for an accurate estimation is more efficient than the previous method.

62 Light Field & 3D Imaging System II

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:45
Session Chairs: Dr. Youngmin Kim (KETI, Korea)
Prof. Sumio Yano (Shimane Univ., Japan)

F62-1 10:30~10:55

Invited Long-Range 3D Imagery by Depth-Fused Displays

Soon-gi Park and Yasuhiro Takaki (Tokyo Univ. of Agriculture and Tech., Japan)

Realization of a long-range 3D display is a challenging task for a glasses-free 3D display. For realizing windows-type long-range 3D system, we propose a depth-fused display method using optically translated screens. As depth-fusing effect is based on the accommodation of multi-layer displays, imaging layers can be relocated to far distance by using optical components. The accommodation changes according to the dioptric distance which is inversely proportional to the metric distance. For this reason, the large depth in metric distance can be converted to a small dioptric depth especially when objects are located far from the observer. The feasibility of the proposed method is demonstrated by experiment. A spherical screen is adopted for the imaging plane located at infinity in order to compensate the aberration of the optics. For the near imaging plane, transparent or emissive display can be used. Reconstruction of 3D image can be achieved by several algorithms including linear depth blending, focus oriented blending, and multiplicative light field factorization according to the specification of the system parameters.

F62-2 10:55~11:20

Invited Viewing Angle Enhancement of Holographic Display Systems

Byungchoon Yang, Yunseon Do, Hyesog Lee, Jaeho Yu (Samsung Display Co., Ltd., Korea), Subin Choi, and Hwi Kim (Korea Univ., Korea)

Unlike other three dimensional(3D) display technologies, the holographic display technology satisfys four major depth cues : binocular parallax, accommodation, convergence, and motion parallax. Usually pixelated digital devices are used to play a moving 3D picture, working as a spatial light modulator (SLM). The pixel pitch of the SLM has an important role to determine the viewing angle and the quality of holographic images. In this work, we propose a digital holographic system which consists of a high resolution LCD panel as SLM.

62 Light Field & 3D Imaging System II

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:45
Session Chairs: Dr. Youngmin Kim (KETI, Korea)
Prof. Sumio Yano (Shimane Univ., Japan)

F62-3 11:20~11:45

Invited Super Multi-View Display based on Pupil Expasion Technique

Joonku Hahn (Kyungpook Nat'l Univ., Korea)

To provide more natual views, the conflict between vergence and accommodation needs to be removed and holographic method and super multi-view method are assumed as possible solutions. When we compare two methods, the border between them become ambiguious. The well-known practical limitation in the digital holgoram is the small space-bandwidth product(SBP) of the display device. In several approaches, time-multiplexing have been applied for increasing the SBP of the system. In previous works, it is used to enlarge the viewing zone in order to provide motional parallax. Up to my knowledge, there is no trial to apply the time-multiplexing in order to insert multiple views within the puil of the eye. I think that it is an example of the combination of the holographic method and the super multi-view method.

63 OLED Manufacturing and Equipment

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:40
Session Chair: Prof. Seungjun Yi (Korea Univ., Korea)

G63-1 10:30~10:55

Invited Ultra-High Gas Barrier Coating Technology for Flexible AMOLEDs

MunPyo Hong, YunSung Jang, and Seungjun Yi (Korea Univ., Korea)

Recently, flexible display technolgies for next generation displays have attracted much attention. Plastic substrates are used for flexible displays. Because typical plastic fims, however, have poor chemical & heat resistance, high gas permeativity, they require functional thin film coatings including gas barriers. More than this, OLEDs are easily degraded by moisture and oxygen penetration, plastic substrates for OLEDs should satiesfy the ultralow water vapor transmission rate (WVTR) as low as 1×10^{-6}g/m^2·day [1]. To achieve the ultralow WVTR, dense and defect-free gas barrier films must be formed [2]. Defects generated by particles can be prevented by controlling the process carefully, but defects generated in grain boundaries can not be avoided because low temperature processing is required for plastic substrates and OLEDs. In this study, we presents a single gas barrier layer of nano-structured Al_2O_3 formed by neutral beam assisted sputtering (NBAS) technology. Fig. 1 shows a schematic illustration of the NBAS system; the NBAS system is based on a conventional RF magnetron sputtering system, and it has an electron cyclotron resonance (ECR) plasma source and conductor reflector to generate a neutral particle beam. Ar^+ ions in the ECR plasma are accelerated by the plasma sheath between the plasma and the conductor reflector, which are then neutralized by Auger neutralization [3]. The NBAS process formates very unique style thin films as a nano crystalline-imbeded polymerphous structure within a single inorganic thin film. This NBAS effect can lead to the formation of nano-structured gas barrier layer, which effectively passivates and heals gas diffusion paths between grain boundaries. The nano-structure of NBAS processed Al_2O_3 gas barrier layer was confirmed through the dielectric constant measurement, Ellipsometry, AFM, and TEM analysis. Finally, the WVTR of a single gas barrier layer of nano-structured Al_2O_3 was measured to be under 1×10^{-6}g/m^2·day, as shown in Fig. 2. The single gas barrier layer of nano- structured Al2O3 is very suitable for flexible OLED applications.

63 OLED Manufacturing and Equipment

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:40
Session Chair: Prof. Seungjun Yi (Korea Univ., Korea)

G63-2 10:55~11:10

Plane Source Evaporation for New Patterning Techniques of High Resolution AMOLEDs

Chanhun Hwang, Young Im, JJ Kim, HS Park, JS Choi, and YM Oh (Sunic System Co., Ltd., Korea)

The plane source evaporation works as that the organic film is previously deposit to the metal plate and re-evaporated by heating the back side the metal film. It gives the highly and vertically collimated organic beam to deposit to the substrate with shadow suppression via fine metal mask openings. Sunic reports that the shadow distance has been measured recently using the prototype of plane source setup and the high ppi (over 1000ppi) pattern deposition processes can be done in the near future for the high resolution flexible AMOLED. Note that the plane source FMM technology can be applied toward mobile display process and the plane source SMS technology to RGB OLED TV production.

G63-3 11:10~11:25

Improvement in 8th Generation Linear Source for AMOLED TV Mass Production

Sungmoon Kim, Daejoon Ji, Hyun Seo, Eunsang Jung, Younghyuck Na, and Jungkyu Lee (R&D Center of YAS Co., Ltd., Korea)

YAS developed 8th generation linear source which is 2400mm in length. There were several technical problems; Uniformity problem caused by loading effect, and long time stability problem caused by differential remains. We will introduce 8G linear soure and several ideas to overcome such problems.

63 OLED Manufacturing and Equipment

Date: Aug. 26, 2016 (Friday)
Time: 10:30~11:40
Session Chair: Prof. Seungjun Yi (Korea Univ., Korea)

G63-4 11:25~11:40

Full Roll-to-Roll OLED Fabrication Using Silver Nanowire-Coated PET Films

Eun Jung, Bongsung Kim, Haksoo Lee, Chanho Kim, Minha Kim, Yeongeun Sul, Jintaek Han, Hokyoon Chung, and Sungmin Cho (Sungkyunkwan Univ., Korea)

For the fabrication of organic light-emitting diodes (OLEDs) on a plastic substrate, we utilized full roll-to-roll processes including the moisture-barrier deposition, transparent-electrode coating, and OLED deposition. The substrate for the devices was polyethylene terephthalate (PET) film of 100 μm thickness. At first, a Al_2O_3 moisture-barrier layer was prepared on the PET film substrate by a roll-to-roll ALD equipment. Silver-nanowire (AgNW) network transparent electrode was prepared on the barrier surface by a series of roll-to-roll coating equipment. In order to make the AgNW electrode surface flat, AgNW-coated surface on a polyimide roll substrate was coated evenly with a UV resin and the AgNW-embedding resin was subsequently transferred to the PET roll substrate after UV curing of the resin. The transferred AgNW-embedding resin surface was flat enough to be utilized as a continuous anode for OLEDs. After a screen printing of patterned insulator on the AgNW electrode surface, an OLED was deposited on the electrode by a roll-to-roll vacuum evaporation equipment. Finally, an OLED device fabrication was completed by laminating a moisture-barrier film on top of the OLED surface. In this presentation, we will report the performance of moisture-barriers, AgNW transparent electrode, and OLEDs in detail.

64 Micro LEDs and Displays

Date: Aug. 26, 2016 (Friday)
Time: 10:30~12:00
Session Chair: Prof. Seung Ju Park (GIST, Korea)

H64-1 10:30~10:55

Invited Gallium Nitride Micro-Displays for Structured Illumination and Visible Light Communications

Martin D. Dawson (Univ. of Strathclyde, U.K.)

The use of gallium nitride light-emitting diode (GaN LED) technology as the basis of solid-state lighting is now well established, offering advantages including energy-efficiency, long operating lifetime and fine colour control. This technology interfaces very effectively to electronics and it is now beginning to be recognised that the associated 'digitisation of lighting' offers further benefits including a new means to implement high-performance optical wireless communications. We have ben investigating micro-pixel array formats of GaN LEDs (GaN micro-displays) interfaced to CMOS as a means of achieving very high (Gb/s) data rates for such visible light communications applications, including routes to implement spatial and spectral multi-plexing. Moreover, the structured illumination capability of these arrayed sources offers projection of rapidly sequenced binary patterns that can be used to locate, track and target objects. This talk will review our recent progress in implementing these smart display systems.

H64-2 10:55~11:20

Invited Integration of GaN-Based LEDs for Micro Flat-Panel Displays

Tohru Honda, Tomohiro Yamaguchi, and Takeyoshi Onuma (Kogakuin Univ., Japan)

GaN-based light-emitting diodes (LEDs) have attracting much attention for the application to μ-displays because of their high emission intensity. Although the integration of flip-chip LEDs for the pixels in the micro display has been reported, the planar-type integration will be required for their cost-effective fabrication in the sense of the fabrication with integration circuits (ICs). The red, green and blue (RGB) light-emitters are required to form the color pixels in the displays. For their cast-effective fabrication, monolithically integration of UV LEDs with RGB phosphors is a candidate. Here, the improvement of quantum efficiencies in the LEDs is a crucial issue for the mobile equipment. The internal quantum efficiency in the operation conditions including sub mW injections is a key for the application to μ-displays. On the other hand, in case of the integration, we have to mention about "cross talk." The cross talk is occurred by the light propagation in the emission layer, whose structure act as a waveguide. Furthermore, the light is propagated in the waveguide reduce the light extraction efficiency. These mean that the new device design should be considered for the monolithic integration. These technical issues will be discussed in the presentation.

64 Micro LEDs and Displays

Date: Aug. 26, 2016 (Friday)
Time: 10:30~12:00
Session Chair: Prof. Seung Ju Park (GIST, Korea)

H64-3 11:20~11:45

Invited Three-Terminal Voltage-Controlled LED Monolithically Integrated with High-Electron-Mobility Transistor

Kei May Lau, Chao Liu, and Yuefei Cai (Hong Kong Univ. of Science and Tech., Hong Kong)

An InGaN/GaN light emitting diode (LED) and an AlGaN/GaN high electron mobility transistor (HEMT) are integrated monolithically by selective area epitaxial growth. Direct contact of the HEMT channel and the n-GaN electrode of the LED allows for conversion of a current-controlled LED to a voltage-controlled device by the gate and drain biases. The three-terminal integrated HEMT-LED emits mW of optical power from the LED part with a modulated injection current up to 80 mA through the HEMT. A schematic of the finished HEMT-LED device is shown in Fig. 1 (a). Fig. 1(b) illustrates the fully modulated light output power (LOP) of the integrated HEMT-LED by V_{GS} and V_{DD} through the injection current from the driving transistor. No light emission was observed while the HEMT is pinched off with a V_{GS} below -4 V. With increasing V_{GS}, a nearly linear modulation of the LOP can be observed before saturation. Note that the saturation of the LOP appears at a more negative V_{GS} when the HEMT-LED is biased at a smaller V_{DD}. Besides the gate modulation, the brightness of the HEMT-LED can also be tuned by V_{DD}.

H64-4 11:45~12:00

Micro Pixelated LED Arrays Having a Multi-Junction Structure

Duk-Jo Kong, Chang-Mo Kang, Jun-Yeob Lee, and Dong-Seon Lee (GIST, Korea)

The InGaN/GaN-based light-emitting diodes (LEDs) have already found a wide utilization for general illumination and are also finding uses in other applications such as displays and wearable devices due to their high brightness and high efficiency characteristics. Moreover, wearable devices such as a virtual reality device or a smart glass demand an efficient micro display for which pixelated LEDs are well suited because of improved color emission and efficiencies of the LEDs. Thus, to address this need, many studies on an LED device for emitting full color are ongoing, and to that end, the role of a monolithic LED structure of InGaN/GaN having multiple emission colors is expected to be developed. Some research groups have reported visible-color LEDs fabricated using, for example, InGaN/GaN nanostructures. However, while these studies have demonstrated multiple color emissions, no independent color control has been achieved. This is due to the fact that the control of the current for each of the active regions producing a color is not independent. In our previous study, we already demonstrate a blue-green color tunable monolithic LED having a multi-junction structure [1]. This is achieved by growing a blue LED on a conventional green LED by metal-organic chemical vapor deposition (MOCVD). In this study, we discuss a 3 X 3 micro pixelated LED arrays with blue-green color-tunable monolithic InGaN/GaN LEDs having a multi-junction structure. The device has an n-p-n structure consisting of a green and a blue active region, i.e., an n-GaN / blue-MQW / p-GaN / green-MQW / n-GaN / Al_2O_3 structure with a passive matrix. Detailed mechanism of the device is also discussed.

65 OLED Device Physics & Eng. I

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chair: Prof. Shi-Jian Su (South China Univ. Tech., China)

A65-1 13:00~13:25

Invited Application of Doping Techniques in Organic/Inorganic Electronics

Zhao-Kui Wang (Soochow Univ., China)

Organic semiconductor, as an alternative for inorganic one, has been broadly used in the field of modern photo electronic devices owing to their many advantages such as easy synthesizing, cheap cost, light weight etc. However, the electric properties such as carrier mobility in organic semiconductors is relative weak owing to the charge hopping transport means between molecules via Van der Waals and dipole-dipole interactions. By controlled and suitable doping in organic semiconductors, it is possible for realization of improved electric properties, reduced contact barrier at organic/metal interface, and even controlled energy level alignments between different materials, which is desirable for improving the performance of organic electronic devices. Recently, we tried to use doping technique to improve the device performance in organic electronics and investigated the physical properties of these doped organic semiconductors systems. The understanding of the nature of the physical properties and mechanisms in doped-organic electronics devices would be useful to improve the material design and control of doped-organic semiconductors, and the performance of doped-organic electronic devices.

A65-2 13:25~13:40

Determination of Emission Zone Shifts in OLEDs at High Currents and Correlation with the Charge Balance Factor

Markus Regnat, Simon Züfle (Zurich Univ. of Applied Sciences, Switzerland), Adrian Gentsch (FLUXIM AG, Switzerland), Kurt Pernstich, and Beat Ruhstaller (Zurich Univ. of Applied Sciences, Switzerland)

We demonstrate the determination of the emission zone in a phosphorescent, three-layer OLED and how it evolves with increasing applied current. To elucidate the shape and position of the emission zone we have measured the angular electroluminescence (EL) spectra and employed an optical fit algorithm to determine the number and the position of the emissive dipoles inside a 35 nm thick emissive layer (EML) [1]. As a result of the fit to the angular emission spectra we find an emission zone that is split into two narrow regions at either side of the EML (CBP:Ir(ppy)$_2$(acac)). At high currents more emissive dipoles are formed at the TCTA/EML layer interface as can be expressed by the ratio of the two emission zone peak intensities while at low currents they are more balanced. We present a comprehensive electro-optical model that calculates the exciton density from charge drift-diffusion and exciton continuity equations [1]. The model nicely reproduces the observations of the emission zone splitting as well as the dependence on current density and allows to relate the efficiency roll-off with a reduction of the charge balance factor.[1] Simulation software SETFOS version 4.3 by Fluxim AG, www.fluxim.com, Switzerland

65 OLED Device Physics & Eng. I

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chair: Prof. Shi-Jian Su (South China Univ. Tech., China)

A65-3 13:40~13:55

Highly Efficient Deep Blue Fluorescent Organic Light-Emitting Diodes with Thermally Activated Delayed Fluorescence Process

Dae Hyun Ahn, Mi Jin Park, Seong Keun Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Blue OLEDs are still using the fluorescent emitters due to their good operational stability in spite of their low internal quantum efficiency of 25%. Recently to overcome low efficiency of fluorescent emitters many researchers are trying to utilize triplet excitons by thermally activated delayed fluorescence (TADF) process and the TADF assistant dopant technology was reported. However, there was no good report on the deep blue fluorescent OLEDs with utilization of triplet excitons by the TADF assistant dopants. In this work, we report highly efficient fluorescent deep blue OLEDs with TADF assistant dopant process. Our device showed 2.6 times higher current efficiency compared with normal fluorescent device, and showed CIE color coordinates of (0.146, 0.117).

A65-4 13:55~14:20

Invited On the Role of Polar Molecules and Charge Injection in OLEDs

Stéphane Altazin (Fluxim AG, Switzerland), Evelyne Knapp(Zurich Univ. of Applied Sciences, Switzerland), Simon Züfle, Martin Neukom (Fluxim AG, Switzerland), Lars Jäger, Tobias Schmidt, Wolfgang Brütting (Univ. of Augsburg, Germany), and Beat Ruhstaller (Fluxim AG, Switzerland)

In this contribution we discuss charge transport processes in multi-layer OLEDs by means of combined simulations and experiments. We combine, for the first time, drift-diffusion device simulations [2] and comprehensive electrical measurement data [3] of OLEDs with polar electron transport layers (ETLs), in order to understand the impact of such materials on the device operation and efficiency. Depending on the sign of the spontaneous orientation polarization, simulations predict either a beneficial or a detrimental effect of the polar layer on the device performance in agreement with published experimental data [1]. Both capacitance data vs. frequency and vs. voltage are analysed. Moreover, from temperature-dependent impedance spectroscopy data we are able to extract the barrier for hole injection and discuss the role of the hole-injection layer HAT-CN. In order to quantitatively describe and understand these effects, we present a physical model and efficient device simulation algorithm. These recent developments illustrate our efforts to establish reliable and comprehensive physical models for optical [4], electrical and thermal [5] processes in OLED devices and panels [6].

66 Oxide TFT III

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chairs: Prof. Sang-Hee Ko Park (KAIST, Korea)
Dr. Katsouras Ilias (Holst Centre / TNO, Nethelands)

B66-1 13:00~13:25

Invited The Evolution and Breakthrough of Thin-Film-Transistors for Displays

Yen-Yu Huang (Chunghwa Picture Tubes, Taiwan)

Metal oxide-based semiconductor materials were developed using its unique features. The ultra low leakage current and relative higher mobility than 10 are well-utilized to fullfill the requirements for portable and/or wearable devices with low refreshing rate (<1Hz) for energy-saving purpose and with demultiplexer (DeMUX) function for panel definition higher than 500. In this case, a 5.5-in. 5120x2880 resolution with 0.8mm bezel is successfully developed. On the other hand, a worldwide first soluble metal oxide material using slot-die coating avenue is also successfully conducted to a 5.8-in. TFT-LCD panel with current facility compatibility. All the stereotype-breaking behaviors of metal oxide material reveal the sufficient competition potential to conventional amorphous and polycrystalline silicon-based material.The low temperature (<120°C) proceeded organic TFT is also investigated. The well-controlled crystal orientation lead to the less boundary discontiunity and straightforwardly improved the mobility (~5 cm^2/Vs). This excellent performance is successfully adopted to perform a flexible 4-in. QVGA AMOLED panel with PEN substrate.

B66-2 13:25~13:50

Invited Metal Oxide Thin Film Transistor Based Platform Technology for New Electronic and Optoelectronic Applications

Young Tack Lee, Tae-Hee Yoo, Won Kook Choi, and Do Kyung Hwang (KIST, Korea)

Amorphous InGaZnO (IGZO) metal oxide semiconductor-based thin film transistors (TFTs) have attracted considerable attention as an emerging technology to replace amorphous and polycrystalline Si TFTs. Until now, the main application of IGZO TFTs has been in the active matrix backplane as a pixel driver for flat panel displays. However, IGZO TFTs can offer a versatile platform for various electronic or optoelectronic applications.In the first part, we introduce a new approach to fabricate PbS QD sensitized IGZO hybrid phototransistors for cost-effective NIR detection. The new hybrid phototransistor exhibits excellent photoresponsivity of over 10^6 A/W and a specific detectivity in the order of 10^{13} Jones for NIR (1000 nm) light. Furthermore, we demonstrate an NIR imager using photo-gating inverter pixels based on PbS/IGZO phototransistors at an imaging frequency of 1 Hz. In the second part, we report on Ag nanowire (NW) mesh as the top gate electrode in IGZO TFT-based sensors that were able to detect the pH a solution in aqueous medium. The porous Ag nanowire mesh top gate electrode enabled charged species such as $[H^+]$ or $[OH^-]$ ions to diffuse in and out of the gate dielectric, thereby changing the effective gate potential. As a result, the device with a Ag NW mesh electrode showed significant turn-on voltage shifts corresponding to the pH.

66 Oxide TFT III

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chairs: Prof. Sang-Hee Ko Park (KAIST, Korea)
Dr. Katsouras Ilias (Holst Centre / TNO, Nethelands)

B66-3 13:50~14:05

Photo-Carrier Dynamics and Recovery Behaviors in Thermally Annealed and Photochemically Activated Solution-Processed Metal-Oxide TFTs

Minkyung Lee, Seungbeom Choi, Seungho Song, and Yong-Hoon Kim (Sungkyunkwan Univ., Korea)

Solution-processed metal-oxide semiconductors have received considerable interest as an active layer for thin-film transistors, which is an important building block in an active-matrix display. Although metal-oxide semiconductors have high electrical performance, good flexibility and transparency even in amorphous state, light-induced instability issues such as negative-bias illumination stress (NBIS) and persistent photoconductivity (PPC) are still problematic, which may induce a large negative V_{th} shift and a slow recovery of the conductivity [1]. To solve these light-induced instability related issues, J.-Y. Kwon et al. investigated the influence of the gate dielectric material on the NBIS stability of oxide TFTs and found that the V_{th} stability was improved by utilizing SiO_x and AlO_x rather than SiN_x and HfO_x because of reduced trapping of photo-induced holes [2]. J. S. Park et al. implemented SiN_x and SiO_x passivation to improve the light stability by protecting the device surface from an ambiguous environment [3]. Also, S.-H. K. Park proposed top gate structured TFTs to block the light illumination [4]. Here, we proposed another possible solution to reduce the influence from an light illumination by implementing deep-ultraviolet-induced photochemical activation process so that the active layer having a rapid recovery of free electrons in the conduction band is formed. We applied conventional thermal annealing (at 350°C) and photochemical activation process to fabricate indium-gallium-zinc-oxide (IGZO) active layers. Figure 1 shows the time-variant recovery characteristics of drain current for thermally annealed and photochemically activated IGZO TFTs. As indicated, the photochemically activated IGZO active layers show more rapid recovery after the light illumination compared to thermally annealed one, which can be attributed to a variation in concentration of oxygen vacancies. In addition, the In:Zn ratio-dependent relaxation time in indium-zinc-oxide (IZO) TFTs and their density of states were also investigated to find out the influence of metallic component ratio on the recovery characteristics of IZO semiconductors.

66 Oxide TFT III

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chairs: Prof. Sang-Hee Ko Park (KAIST, Korea)
Dr. Katsouras Ilias (Holst Centre / TNO, Nethelands)

B66-4 14:05~14:20

Performance Enhancement of Solution-Processed InGaZnO Thin Film Transistors by Lithium Doping

Jongsu Jang, Daesik Kim, and Yongtaek Hong (Seoul Nat'l Univ., Korea)

In this paper, we report the effects of lithium doping on the electrical characteristics of solution-processed IGZO TFTs. Different amount of lithium (Li) has been introduced in the IGZO precursor solution and then, the Li-doped IGZO films were deposited on p++Si/SiO_2 substrate by spin coating method. The deposited films were annealed at 400 °C for 1 hour. The 5% Li-doped IGZO TFTs showed a good saturation mobility of 1.84 cm^2/Vs and a subthreshold swing of 0.18 V/decade, compared with the un-doped IGZO TFTs value 0.77 cm^2/Vs and 0.25 V/decade respectively. In case of 15% Li-doped IGZO TFTs, its saturation mobility was increased to 3.11 cm^2/Vs. Although there is slight increase in the off-current compared with 5% Li-doped IGZO TFTs, off-current can be further reduced by patterning the oxide layer. This enhancement of performance on lithium doped oxide TFTs is due to increased electron concentrations, improved oxygen vacancy defect states in active layer [2,3]. Therefore, we believe that Li-doping is an effective method to achieve better electrical characteristics on solution-processed oxide TFTs.

67 Physics of Metamaterials

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:35
Session Chairs: Prof. Hwi Kim (Korea Univ., Korea)
Dr. Sungyeol Lee (ETRI, Korea)

C67-1 13:00~13:25

Invited Low-Loss Epsilon-Near-Zero Materials in the Visible and Near-Infrared Frequency Range

Young Chul Jun (UNIST, Korea)

Epsilon-near-zero (ENZ) materials have attracted much attention for their highly unusual and intriguing optical properties. Initially, metamaterial structures were considered to obtain ENZ behavior, but later it was extended to natural plasmonic materials, where dielectric constants are tunable by doping densities. In these materials, the real part of the dielectric constant (Re[ε]) becomes zero at a certain wavelength (i.e. ENZ wavelength), depending on the doping level. In this talk, we will discuss our recent work on natural ENZ materials. We have investigated various ENZ responses, using ultra-thin, doped semiconductors and conducting oxides. This could be interesting for many optical devices based on thin films.

C67-2 13:25~13:50

Invited Metamaterials for Dynamic Photon Emission

Xinyu Liu and Willie J. Padilla (Duke Univ., U.S.A.)

The ability to control photons emitted from the surface of a material underpins many energy harvesting and ligh-emitting applications ranging from thermophotovoltaics and low-E glass to single photon sources and displays. Here we demonstrate a photon emission device based on metamaterial micro-electro-mechanical systems (MEMS) which realize real-time tunable emission over a band in the thermal infrared. Our device may be controlled by temperature or with an applied electric bias.

C67-3 13:50~14:05

Self-Complementary Meta-Atom Based Transmissive Terahertz Metasurface with High Transparency in Visible Range

Hyunseung Jung and Hojin Lee (Soongsil Univ., Korea)

In this paper, we developed self-complementary meta-atoms (SCMs) that not only exhibit transmissive resonance but also can be transparent in other frequency ranges. The proposed SCMs consist of cut-wire pair and pseudo complementary cut-wire hole and designed to exhibit transmissive resonance at 1.5 THz with high transparency in visible frequencies. For the hole width variation of conventional structures and SCMs, we found that the resonance properties of SCMs were well defined in comparison with conventional structures and thus the SCMs can be a good alternative for transmissive meta-surfaces.

67 Physics of Metamaterials

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:35
Session Chairs: Prof. Hwi Kim (Korea Univ., Korea)
Dr. Sungyeol Lee (ETRI, Korea)

C67-4 14:05~14:20

Phase Modulation in MIM Plasmonic Waveguide Using Dielectric Surface Gratings

Sang-Eun Mun, Eui-Young Song (Seoul Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), and Byoungho Lee (Seoul Nat'l Univ., Korea)

Recently, the control and manipulation of optical waves have been widely investigated. Various examples for optical complex modulation on ultrathin plasmonic structures were reported, which used plasmonic waveguides, directional coupler of surface plasmon polaritons and metallic nanoantennas on metasurfaces. Especially, modulating the phase distribution is very important because this is essential capability for the hologram or imaging technology. It can be represented by encoding the phase information of objective images into extremely small pixel structures. However, previous reports on a transmission type of phase modulation have not been sufficiently studied due to efficiency limitations. Here, we numerically analyze optical phase modulation pixel structure based on single metal-insulator-metal (MIM) waveguide having dielectric surface gratings to realize a transmission type of modulation. We design the parameter of period for dielectric gratings in case of normal incident light. Full phase modulation is possible by adjusting the off-set distances of surface gratings when the thickness of gratings is a predetermined value. Furthermore, the proposed pixel structure shows the modulation profile of high sensitivity by controlling the off-set distances in each side, respectively.

C67-5 14:20~14:35

Two Metal-Air-Dielectric Waveguides for Complex Modulation of Light

Jongwoo Hong, Eui-Young Song, Joonsoo Kim (Seoul Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), and Byoungho Lee (Seoul Nat'l Univ., Korea)

In holography, spatial light modulators (SLMs) have been used to reconstruct three-dimensional (3D) object images. However, commercial SLMs can only modulate the amplitude or the phase although 3D objects have complex information, which limits the capability of SLM in holography. Recently, the complex SLM was achieved by regarding two pixels as a macro-pixel. In addition, reduction of pixel size to 8 μm for wide viewing angle was studied where the limitation of scale-down occured because of trade-off between scale-down and modulation efficiency. In this paper, we propose a new method for complex modulation of light. The structure consists of two plasmonic waveguides. This structure shows that the macro-pixel size is down to 2 μm. Amplitude and phase are modulated by changing the thickness of air-layer which affects the surface plasmon mode in the waveguides. Specifically, amplitude profile is symmetric and the range of phase profile is from $-\pi$ to π by variation of thickness of air-layer from 20 nm to 60 nm at fixed length of waveguides. These two waveguide with varying air-thickness can generate a dark state or other complex profile.

68 Flexible Silicon and Oxide TFT

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:30
Session Chairs: Prof. Qun Zhang (Fudan Univ., China)
Prof. Elvira Fortunato (New Univ. of Lisbon, Porutugal)

D68-1 13:00~13:25

Invited Innovative Field Printed Wirable Universal Device for Integrated Circuit Design in Active Matrix Display Technology

Yong-Sang Kim and Dong-Hoon Lee (Sungkyunkwan Univ., Korea)

Enhancement of resolution and narrowing the bezel is an important part of display technology research, to improve the visual experience of user [1]. The use of thin film transistor (TFT) for the gate driver circuit in active matrix panel addresses both of these issues. The drive circuit design is an important factor to determine the bezel size of the panel [2], [3]. However, the development of drive circuit is restrictive because of the expensive process and mask cost. For this reason, most of the companies use space area of panel to develop the circuit. Recently, many research groups are focused on CMOS TFT circuit to improve and simplify circuit performance and design. In the CMOS TFT based circuit, the space area cannot be used. Therefore, in this work, we propose an innovative field printed wirable universal device (FPWD) for integrated circuit in active matrix display. As shown in Figure 1, the designed FPWD consists of 3 parts to control the width of the TFT, internal and external circuit design. Finally, we demonstrate the performance circuit as inverter and ring-oscillator. The FPWD based circuit and individual developed circuit showed no difference in performance. The FPWD is an innovative collaboration technology of solution and vacuum based process. It includes the advantages of each technology; high performance of vacuum based process and cost competitive and simple process of the solution process. Additionally, it is of universal type, which can be easily designed and modified as per the user requirement. This mask-less technique provides benefits as simple, fast and low cost circuit development.

D68-2 13:25~13:50

Invited Surface-Potential Compact Model for Amorphous-IGZO Thin-Film Transistors

Zhiwei Zong, Nianduan Lu, Ling Li, and Ming Liu (IMECAS, China)

We present a surface potential based compact model for amorphous-InGaZnO TFTs, based on multiple trapping and detrapping theory. The calculation of surface potential is analytical which can be used for rapid calculation of transistor characteristics during circuit simulation. The proposed model is verified by both the numerical simulation and experimental result, and a good agreement is achieved over a wide range of operation regions. Meanwhile, the model provides physics-based consistent description of DC and AC device characteristics and enables accurate circuit design of a-IGZO TFTs.

68 Flexible Silicon and Oxide TFT

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:30
Session Chairs: Prof. Qun Zhang (Fudan Univ., China)
Prof. Elvira Fortunato (New Univ. of Lisbon, Porutugal)

D68-3 13:50~14:15

Invited Introducing an All-New Spot-Beam-Based Laser-Crystallization Method for Manufacturing Advanced AMOLED Displays

James S. Im (Columbia Univ., U.S.A.)

Over the past ten years, the laser-annealing-based low-temperature polycrystalline Si (LTPS) technology has established itself as the preferred and dominant method for manufacturing high-resolution LCDs and OLED displays. As it happens, the LTPS field is expected to undergo additional and substantial growth as the demand for advanced AMOLED displays with various value-added features is increasing rapidly. In order for the LTPS technology to efficiently address these present and future application-driven opportunities, and thereby further evolve and transform itself into a more compelling business-competitive and technology-enabling proposition in the process, it can be argued that the underlying laser crystallization method should be improved specifically by (1) reducing the operating costs associated with the laser-processing step, and (2) enhancing the microstructural quality of the crystallized polycrystalline Si films on which laser-mura-free AMOLED displays can be easily and readily fabricated. In this paper, we present a new "platform-level" laser-crystallization method that possesses some intrinsic features and technical elements that are well suited for, among other things, satisfying the above-mentioned requirements. By utilizing a small spot beam generated using a solid-state laser to crystallize Si films, the method, which we are referring to as spot-beam crystallization (SBC) and which was conceived at Columbia University, stands to largely avoid or significantly reduce the line-beam-associated microstructural non-uniformity and laser-operation-cost issues that are encountered with the current excimer-laser annealing (ELA) manufacturing method. Here, we focus on describinga particularly compelling example of the SBC method, which can be optimally implemented using ultra-high-frequency (~100s of MHz) pulsed UV lasers (with correspondingly reduced pulse durations, and commensurately low pulse energies). For such lasers, it is possible to leverage a well-known and well-developed beam-irradiation scheme involving raster-scanning of a small Gaussian spot beam (as utilized, for instance, in printing and micro-machining/marking applications). By overlap scanning of an appropriately sized spot beam, it is possible to use the temporally isolated and spatially shifted pulses to induce multiple-pulse-based accumulative heating of the "small" irradiated region over tens (to hundreds) of nanoseconds (the very range of which is established as being optimal for crystallizing Si films on glass or plastic substrates), and subsequently either partially or completely melt and solidify the region (depending on the value of deposited energy density integrated over the spot-beam dwell time) in a "continuous melt" fashion; doing so in a raster-scanning manner with an appropriate stepping distance between the scans (in the perpendicular direction) will lead to, respectively, either "ELA-like" partial-melting-based crystallization or sequential lateral solidification (SLS) of the films that can be largely and effectively devoid of the "shot-mura" and "scan-mura" issues that are inevitably present in any line-beam-based laser-crystallization techniques, all without high operating costs resulting from frequent and periodicchange of the laser tube.

68 Flexible Silicon and Oxide TFT

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:30
Session Chairs: Prof. Qun Zhang (Fudan Univ., China)
Prof. Elvira Fortunato (New Univ. of Lisbon, Porutugal)

D68-4 14:15~14:30

Calculation of Temperature Distribution in Si Films on Polyimide during Blue Multi-Laser Diode Annealing

Tatsuya Okada, Yusuke Shizu, and Takashi Noguchi (Univ. of the Ryukyus, Japan)

In order to perform laser crystallization stably using BLDA, in this work, we calculated temperature distributions of a-Si films on polyimide substrate during BLDA to obtain suitable conditions for crystallization of the Si films without thermal damage against polyimide for application to flexible flat panel display. For the calculation, we assumed crystallization of 50-nm-thick a-Si film on the polyimide sheet, and the laser power was adjusted to reach ~1300 K in temperature of the Si film at the constant scanning speed of 500 mm/s. To reduce the thermal damage against polyimide, ZnS-SiO_2 layer of low thermal-conductive material with the thickness ranging from 1 to 2 μm was inserted between Si and polyimide. By increasing ZnS-SiO_2 thickness from 1 to 2 μm, temperature around polyimide surface was decreased effectively. With the ZnS-SiO_2 thickness of 2 μm, the temperature at polyimide surface was kept less than 660 K. BLDA to a-Si/ZnS-SiO_2/polyimide structure will be effective to realize poly-Si TFT on polyimide.

69 Latest Issues of Image Quality Evaluation & Enhancement

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chairs: Mr. Vincent Leroux (ELDIM, France)
Dr. Jongseo Lee (Samsung Display Co., Ltd., Korea)

E69-1 13:00~13:25

Invited Metrology Considerations for HDR Displays

Joe Miseli (JVM Research and Tech., U.S.A.)

In 2015, HDR (High Dynamic Range) TVs were quietly introduced. They were called 4K ultra HD displays and similar terms, but the "HDR" terminology was generally not mentioned. Before that, HDR displays were very specialized for professional monitor applications such as for production studios, with quite high prices. With 2016, comes the 2nd generation of HDR televisions, making them widely available to the consumer market at modest prices. Now it is time to develop display metrology to provide standardized measurement methods to test and verify the HDR performance of displays. This effort is taking place in the ICDM (International Committee for Display Metrology), the display metrology committee within SID (Society for Information Display), and should within the next year.

E69-2 13:25~13:50

Invited Simulation and Evaluation of Color Performance for LCDs Using Photo-Generated Quantum Dots

Liu Weidong, Qiao Mingsheng, Li Fulin, Yang Jia, and Zhang Yuxin (Hisense Electric Co., Ltd., China)

Using of photo-generated quantum dots in LED backlight could dramatically enhance the color performance of LCDs. This article discusses how to match the color spectrum with quantum dots and color filter of LCDs in order to get the wider color gamut, and gives the method of evaluating color performance of LCDs using quantum dots. Also gives the comparison result between ULED(LCD TV using quantum dots) and OLED.

E69-3 13:50~14:05

Improving Sunlight Readability of FFS LCD

Xinhui Zhong, Jia Liu, Hongqing Cui, De-Jiun Li, and Po-Hua Lung (Wuhan China Star Optoelectronics Tech. Co., Ltd., China)

Visual performance including contrast and color gamut of FFS LCD under different ambient lighting conditions was evaluated. The influences of several factors such as cover lens, AR coating, QWP retarder film and backlight brightness were studied, which implies methods to improve sunlight readability of LCD.

69 Latest Issues of Image Quality Evaluation & Enhancement

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:20
Session Chairs: Mr. Vincent Leroux (ELDIM, France)
Dr. Jongseo Lee (Samsung Display Co., Ltd., Korea)

E69-4 14:05~14:20

A New View on Qualified Viewing Spaces of Two-View Autostereoscopic Displays

René de la Barré (Heinrich-Hertz-Inst., Germany)

The common description of the viewing spaces (VS) in the lobes of glasses-free 3D displays bases on a geometric approach of the display setup. This idealized approach does not consider as well as influences like crosstalk (CT) and annoying pixel structures. Therefore, the concept of qualified spaces has been developed to deliver a comparable value for the quality of different autostereoscopic displays under the ergonomic point of view. The most familiar qualified space is the qualified stereoscopic viewing space (QSVS). For a use of QSVS a number of challenges are to overcome. Qualified spaces are crosstalk oriented parameter. The determination of qualified spaces based on the crosstalk analysis of luminance profiles. This detailed look for qualified spaces shows their relevance and limitation.

70 3D Human Factors & Metrology

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:30
Session Chairs: Dr. Kwang-Hoon Lee (KOPTI, Korea)
Prof. Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

F70-1 13:00~13:25

Invited Depth Perception based on Binocular Eye Movement in the Integral Photography

Sumio Yano, Makoto Suzuki (Shimane Univ., Japan), and Min-Chul Park (KIST, Korea)

In this article, the depth perception for the integral photography (here by IP) image is described based on experimental results using measurements of eye movement and subjective tests. The difference of depth perception for the real object is also discussed. At first, the depth perception for integral photography was presumed from the measurement of eye movement, and evaluated with subjective tests. As results, the tendency of the depth perceptions in both results is coincidental even though there is the difference of the perceived modality in the experiments. Next, the depth perception for the real object was presumed from the measurement of the eye movement. The depth perception for the real object and IP image show the same tendency in the range near the viewer. The depth perception for these visual stimuli was not the same for the range far from the viewer. As a result, the depth was perceived as being farther in the case of IP images compared with real objects when an IP image was displayed far from the viewing position. However, it is unknown at present whether this result is due to IP image blur or incompleteness of the developed IP display.

F70-2 13:25~13:50

Invited Effect of Different Disparities on Visual Comfort: Comparison between Reference 2D and SMV Random-Dot Multigrams

Sunghcul Mun (KIST, Korea)

Many studies on developing super multi-view (SMV) displays have been conducted to provide natural 3D images free from the accommodation-vergence conflict. In spite of the growing number of the studies, however, attempts to determine effects that different disparities in SMV displays have on perceived visual comfort have rarely been done. Thus, this study investigated the effects of different disparities on visual comfort by comparing perceived naturalness from a reference 2D image and SMV images with sixteen different crossed and uncrossed disparities. A prototype SMV display based on parallax barrier, which generates 108 viewing zones was used in the experiment. Seventeen random-dot multigrams (RDMs) including the reference 2D image were randomly presented to each of ten participants. The intuitive feelings of visual comfort were continuously recorded during 1 min per each condition. The single stimulus continuous quality evaluation (SSCQE) method with 1 to 100 continuous scales (sampling rate: 0.5 s) was used in the evaluation.

70 3D Human Factors & Metrology

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:30
Session Chairs: Dr. Kwang-Hoon Lee (KOPTI, Korea)
Prof. Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

F70-3 13:50~14:15

Invited Accommodation in Viewing 3D Display

Hyungki Hong (Seoul Nat'l Univ. of Science and Tech., Korea)

In viewing 3D display or virtual reality (VR), the accommodation plays the important role. Accommodation is the change of optic power of the eye to sharply see the object at the different distances. Accommodative response in viewing 3D display had been measured to be somewhat different from viewing 2D display and the real object. Accommodation-convergence conflict had been considered as one of the main cause of the fatigue for 3D using special glasses. Yet, if Depth of Field (DOF) is considered, accommodation-convergence conflict may cause the fatigue only when 3D object is located too near to the viewer.

F70-4 14:15~14:30

Evaluation the Visual Fatigue Caused by 3D with and without Crosstalk

Ying Wang, Lili Wang, and Yan Tu (Southeast Univ., China)

With the rapid development of 3D display, the concerns for the 3D visual fatigue have been increased. One cause of visual fatigue is crosstalk. In this paper, the influence of crosstalk on visual fatigue was investigated with specially designed questionnaire, EEG, and eye-associated parameters (pupil diameter, blink, saccade and fixation). The results showed that, crosstalk (19.3%) only had significant influence on the power of α component of EEG and the pupil diameter. The decrement of pupil diameter and the increment of the power of α component were larger after watching 3D movie without crosstalk compared to the condition with crosstalk at significant level. It revealed that the degree of visual fatigue induced by watching 3D movie without crosstalk for a long time (about 30-min) was significant higher than that under 3D movie with crosstalk. This result should due to the decreased depth perception induced by large crosstalk, which showing a more important influence of depth on visual fatigue compared to crosstalk.

71 Display Manufacturing and Equipment

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:25
Session Chair: Dr. Xuena Zhang (AMAT, U.S.A.)

G71-1 13:00~13:25

Invited Novel Non-Destructive Rapid in-Line SEM for High Resolution Defect Review, Analysis and Ultra Precise Metrology

Xuena Zhang (Applied Materials, U.S.A.), Bernhard Mueller, Ludwig Ledl, Volker Daiker (Applied Materials GmbH, Germany), Ryan Lin (Applied Materials, Taiwan), Thomas Schwedes, Edgar Kehrberg, Axel Wenzel, Georg Jost (Applied Materials GmbH, Germany), George Tzeng (Applied Materials, U.S.A.), Robert Trauner, Bernhard Schueler, Alfred Koelbl, Peter Staffansson (Applied Materials GmbH, Germany), Santosh Mhalsekar, Jonathan Cerezo, and Peter Nunan (Applied Materials, U.S.A.)

Recent surging demand of high resolution mobile displays is driving display metrology technologies to the next level. Continuous increase of high PPI densities demands fast, reliable, non-destructive, whole substrate in-line defect review technology in submicron region, exceeding capabilities of existing optical techniques and lab Scanning Electron Microscopes (SEMs). Applied Materials E-Beam Review (EBR) system is the industry's first in-line SEM metrology tool for G6 and beyond, Fig. 1(a). Based on Applied Materials' decade long production-proven platform of E-Beam Array Tester (EBT) in display fabs and 20+ years' expertise of SEMVision® in semiconductor applications, the new EBR system offers state-of-the-art low energy high-resolution imaging down to 10 nm scale. The stage automatically locates defects reported by other inspection tools or defined area-of-interest for process monitor, the SEM therefore covers entire glass or even multi-glass with stage movement. Multiple SEM column modules are used to reduce equipment footprint. The integrated EDX makes in-line failure analysis possible, Fig. 1(b). The acquisition rate of EBR system is <5sec per SEM image, <10sec per EDX point measurement, or 100 points/hour for automatic defect review (DR) and advanced process inspection (API) application. Utilizing the unique low electron beam energy (15 KeV down to 200 eV), a damage-free defect inspection can be performed on the most critical device layers/structures, organic or inorganic, such as polycrystalline silicon TFTs, photon resist, planar layers, etc. for both LCD and OLEDs, Fig. 1(c). Secondary electron (SE) and back scattered electron (BSE) technology enable exceptional measuring of complex and fine features of devices. The innovative low energy beam coupled with newly developed tilted electron beam (Etilt®) further enables in-line 3D metrology (ECD®) for fast, accurate on-device CD SEM metrology. All these distinct capabilities make EBR the industry's superior fast, reliable, non-destructive, full glass in-line SEM for locating, identifying and analyzing defects at high precision. EBR system enables display makers accelerating process development, productions yield ramping, excursion control and device performance improvement in high-volume production.

71 Display Manufacturing and Equipment

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:25
Session Chair: Dr. Xuena Zhang (AMAT, U.S.A.)

G71-2 13:25~13:40

Registration Metrology of Masks for State-of-the-Art LCD and OLED Display Backplanes

Tor Sandstrom (Mycronic AB, Sweden)

The recent development of high-PPI displays and the complex pixel circuits in OLED displays have necessitated a new generation of exposure equipment with higher resolution, and a new generation of maskwriters with improved pattern fidelity. Qualification to tighter specifications makes developments of the metrology and workflow necessary. With a new generation of x-y metrology systems, flatter mask blanks, and better clamping correction it is possible to catch overlay errors even between masks written by different maskwriters in different mask shops. A cross-industry standardization of coordinate systems becomes a realistic goal, e.g. by reference to incoming inspection equipment at dominating mask users. A possible industry-wide standardization brings up the question of traceability. The calibration procedure, Fig. 1, creates an ideal x-y grid, but the absolute scale needs to be referenced to a physical object. Currently, each mask user has his own preferred absolute scale, but it is technically feasible to make the scale traceable to an independently verified length standard. Especially OLED displays are sensitive to small-scale overlay errors between mask layers, affecting stray capacitances between conductors in different layers. This creates "invisible mura", so called because it is difficult to detect in a single mask. Methods to detect and quantify registration errors which can generate invisible mura are in development.

G71-3 13:40~13:55

Writing Next Generation Display Photomasks

Youngjin Park (Mycronic Co., Ltd., Korea) and Mikael Wahlsten (Mycronic AB, Sweden)

In recent years there has been a fast technological development within the display industry. The pixels get smaller. At the same time there is a trend towards more complex displays such as AMOLED, which require more complicated pixel designs. In this paper Mycronic shares what is needed to meet current and future requirements in terms of next generation mask writer performance and platform stability. It is demonstrated how to achieves high resolution with better than 40nm CD uniformity without jeopardizing productivity on areas larger than 1.5 square meter.

71 Display Manufacturing and Equipment

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:25
Session Chair: Dr. Xuena Zhang (AMAT, U.S.A.)

G71-4 13:55~14:10

Micro-Patterned Interconnections for the Applications of the Flexible/Wearable Devices

Yongjin Kim, Jun Yeob Song, Jae Hak Lee, and Seung Man Kim (KIMM, Korea)

For many years, even though organic based materials and devices for flexible electronics show significant disadvantages such as low charge transport, process temperature limitation, and etc., they are still recognized as a promising field and application due its benefits (low cost, flexibility, mass production, etc.). Those limitations, based on material itself, make the flexible electronic device very difficult to compete with Si-based rigid electronics that have excellent device performance and much advanced design rule. However, the rigid Si based devices are also vulnerable to any types of mechanical stress when they are in use for the flexible applications. Thus, we strongly feel the need to combine benefits from the organic based flexile devices and from the Si based rigid devices by attaching the rigid thin chips on the flexible substrates such as PI (Polyimide), PET (Polyethylene phthalate) and PDMS (Polydimethylsiloxane) which is accepted as a new or future trend for the next generation of the flexible/wearable electronic devices. In order to achieve this new concept, thin device (≤ 50μm) showing high device performance needs to be attached on the surface of deformable substrates to construct flexible electronic device circuits and it is required to interconnect the thin Si based chip with the flexible polymer substrate. For this specific interconnection, we utilized an ElectroHydroDynamic (EHD) micro-patterning system which is not damaging the flexible substrate unlike the conventional wire bonding method that mechanically damages during the bonding process. To form narrow Ag based metal interconnections, we optimized various experimental parameters (flow rate [μl/min], applying voltage [kV], working distance [μm], jetting velocity and acceleration [mm/s, mm/s^2]) and the metal lines were sintered at 150°C for 30 mins to remove any solvent contained in the solution based Ag ink. As a result, we expect that this work will contribute to the fabrication of 3D devices on the flexible substrate that will be possibility used for the flexible/wearable applications

G71-5 14:10~14:25

Inspection of Touch Screen Panel Electrodes Using Polymer-Dispersed Liquid Crystal

Sunggu Yeo, Yonghwan Oh, and Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

We used the PDLC panel for the inspection of the touch screen panel (TSP) electrodes inspection instruments. When the electrodes of the TSP are disconnected somewhere, the electric field is not applied at the defect area and the light is scattered. If the electrode is well connected, the PDLC layer becomes transparent. We also varied the fabrication process and the overcoat materials for the protection of the PDLC panel during the inspection process.

72 Advanced Fabrication with Nano Structures

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:15
Session Chairs: Prof. Kei May Lau (Hong Kong Univ. of Science and Tech., Hong Kong)
Prof. Xiaobing Luo (Huazhong Univ. of Science and Tech., China)

H72-1 13:00~13:25

Invited Extraction of More Photons from LED by Photonic Crystal, Hierarchical Structure, and Nanotubes

Young-Chul Leem and Seung-Ju Park (GIST, Korea)

Although GaN-based light-emitting diodes(LEDs) have a remarkably high internal quantum efficiency (~80%), the light extraction efficiency (LEE) of LEDs is primarily limited by the total internal reflection (TIR) effect of light, which is caused by the abrupt change in refractive indices at the interface between GaN (n=2.5) and air (n=1). In this study, we propose a few novel approaches to increase the LEE of LEDs First, we investigate blue LEDs containing photonic crystals (PhCs) that are fabricated in InGaN/GaN multiple quantum wells (MQWs) by plasma etching. Sulfide passivation of the etched surfaces in the LEDs using thioacetamide/ammonium solution effectively reduces the content of surface defects that induce defect-related recombination and the reverse leakage current through the sidewall surface of PhCs. Sulfide passivation enhances the optical output power of the PhC LEDs by 71% at 20 mA compared with that of planar LEDs. The large enhancement of optical power is attributed to out-coupling of confined light by the PhCs and the effective recovery of internal quantum efficiency by sulfide passivation We also demonstrate that well-ordered nanostructures can be fabricated to form hierarchical structures on vertical LEDs(VLEDs) with curved microdome surfaces. The VLEDs with hierarchically structured surfaces show a 3.12-fold increase in the power of the emitted light compared to the planar VLEDs at an injection current of 350 mA, as shown in Fig. 1. In addition, the hierarchical surface on VLEDs demonstrates superhydrophobicity and high oleophobicity, due to the high fraction of air pockets at the interface between the liquid droplet and hierarchical surface structures. Lastly, we demonstrate that the surface nanostructure of TiO_2 NTs on the n-GaN layer greatly enhances the optical output of VLEDs. The TiO_2 NTs grown on the VLEDs efficiently enhance the light output power by 23% and 189%, compared to the ZnO NR VLEDs and planar VLEDs, respectively, at an injection current of 350 mA. The large enhancement in the optical output power is attributed to the superior suppression of the TIR between the GaN layer and air by employing refractive index matched and geometric configuration controlled TiO_2 NTs. These results provide architectural design guidelines for novel structured surfaces to improve the photon extraction and optical performance of various optoelectronic devices such as semiconductor LEDs, organic LEDs, and solar cells.

72 Advanced Fabrication with Nano Structures

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:15
Session Chairs: Prof. Kei May Lau (Hong Kong Univ. of Science and Tech., Hong Kong)
Prof. Xiaobing Luo (Huazhong Univ. of Science and Tech., China)

H72-2 13:25~13:50

Invited Group III Nitride Materials for Large Area Flexible Devices

Hiroshi Fujioka, Kohei Ueno, Atsushi Kobayashi, and Jistuo Ohta (The Univ. of Tokyo, Japan)

It is generally believed that III-V compound semiconductor devices are not suitable for large area applications such as displays or solar cells because they are extremely expensive. The high cost stems mainly from single crystal substrates and low throughput epitaxial growth process by MOCVD or MBE. It is quite natural to believe that group III nitride devices prevail quickly in the large applications once low cost fabrication epitaxial process is established. For this purpose, we have recently developed a new PVD-based growth technique called PSD (pulsed sputtering deposition).[1] PSD has already attracted much attention of industry engineers because its productivity is much higher than that of MOCVD and sputtering is commonly used in fabrication lines for LSIs or LCDs. Various nitride devices such as LEDs, solar cells, MISFET, and HEMTs were already fabricated by the use of PSD and operated successfully. [2-5] In this technique, surface migration of the film precursors is enhanced and, therefore, the temperature for epitaxial growth is dramatically reduced. The other advantage of the PSD lies in the fact that raw materials in the PSD process does not include carbon or hydrogen atoms. Hence, we can expect formation of nitride films with low impurity levels even at high growth ragte. We have found that PSD low temperature process is quite compatible with growth of high In concentration InGaN which is necessary for fabrication long wavelength light emitting devices and solar cells. In fact, we have successfully fabricated RGB full color LEDs. This reduction in growth temperature also allows us to utilize various low cost flexible substrates such as metal foils, graphite sheets, or mica sheets that have not been used for growth of semiconductors so far due to their chemical and thermal vulnerability. In this presentation, we will discuss feasibility of large area flexible nitride devices such as LED displays or solar cells fabricated with PSD on various low cost substrates. Although growth of crystalline group III nitrides on amorphous substrates such as glass has been believed to be extremely difficult, we have found that the use of graphene buffer layer alleviates this difficulty and helps to enhance the crystallinity. We will also show the successful operation of RGB LEDs on glass substrates by the use of graphene buffer layers in this presentation. We will also discuss the feasibility of room temperature direct growth of nitride materials on polymer films and its device applications in this presentation, which will possibly used for future inoganic flexible devices.

72 Advanced Fabrication with Nano Structures

Date: Aug. 26, 2016 (Friday)
Time: 13:00~14:15
Session Chairs: Prof. Kei May Lau (Hong Kong Univ. of Science and Tech., Hong Kong)
Prof. Xiaobing Luo (Huazhong Univ. of Science and Tech., China)

H72-3 13:50~14:15

Invited Controlled Growth of GaN Nanorod Arrays with an Orientation-Induced Buffer Layer

Si-Young Bae, Kaddour Lekhal, Ho-Jun Lee (Nagoya Univ., Japan), Jung-Wook Min, Dong-Seon Lee (GIST, Korea), Manato Deki, Yoshio Honda, and Hiroshi Amano (Nagoya Univ., Japan)

Low-temperaure buffer layers have been a key role to develop high-quality GaN epilayers on common c-plane sapphire substrates for seveal decades. With regard to the growth of three dimensional (3D) structures such as micro- or nanorods, a preferentioal orientation of the buffer layer is also important since it determines the direction of upper building blocks. To date, c-plane GaN has been predominantly grown on c-plane sapphire or Si(111) substrates due to highly coherent lattice property. However, recent progress of ex-situ buffer layer deposition techniques has provided a new means to control the preferential orientation of GaN on Si(001) and/or amorphous substrates. In the epitaxial view, these substrates are quite difficult to induce a single crystal domain due to the wide degree of freedom during the growth process. Motivated by these issues, here, we report a directionally controlled GaN nanorods arrays grown on the challenging substrates by an orientation-induced buffer layer.

73 OLED Device Physics & Eng. II

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:05
Session Chairs: Prof. Zhao-Kui Wang (Soochow Univ., China)
Dr. Beat Ruhstaller (Fluxim Inc., Switzerland)

A73-1 15:00~15:25

Invited Application of Organic Heterojunctions in OLEDs

Dongge Ma (South China Univ. of Tech., China)

We presented the concept of the organic semiconductor heterojunctions composed of a p-type organic semiconductor and an n-type organic semiconductor, respectively, as charge injectors and CGLs in OLEDs. It is found that as charge injectors instead of metal electrode, the fabricated OLEDs show high efficiency. More attractively, the charge carrier injection is only dependent on the electric field on the heterojunction, and the metal electrodes here just play the function of providing an electric field. Therefore, the organic heterojunction injector-based OLEDs still achieve excellent EL performance even though using air- and chemistry-stable high work function metals such as Au, Ag, and Cu as contact electrodes, which is generally very difficult in conventional OLEDs. As CGLs in tandem OLEDs, we found that not only the brightness and current efficiency are doubled, but also the power efficiency is also greatly improved, which is difficult in tandem OLEDs based on general CGLs.

A73-2 15:25~15:40

A Highly Efficient OLED based on a Scattering Layer having High Asymmetry Parameter

Jinouk Song, Seungwoo Shin, Eunhye Kim, Jaeho Lee, YongKeun Park, and Seunghyup Yoo (KAIST, Korea)

Scattering-based approaches have been popular for light extraction methods in organic light-emitting diodes (OLEDs) not only because they have proven highly effective but also due to their various practical merits such as color stability, simple process, and low cost. However, despite the importance of the forwardness of scattering in enhancing efficiency, studies fully utilizing the forwardness of scattering events have been rarely done for OLEDs. Hence, we herein investigate how one can realize a forward-intensive scattering layer in a controllable manner and demonstrate a highly efficient OLED using the proposed scattering layers.

73 OLED Device Physics & Eng. II

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:05
Session Chairs: Prof. Zhao-Kui Wang (Soochow Univ., China)
Dr. Beat Ruhstaller (Fluxim Inc., Switzerland)

A73-3 15:40~16:05

Invited Highly Efficient OLEDs with Ultralow Driving Voltage and Simplified Structure

Shi-Jian Su (South China Univ. of Tech., China)

A novel strategy towards simultaneously low-driving voltage and high efficiency fluorescent OLEDs was proposed using an active planar pn heterojunction as the exciton generation region and conventional fluorescent dye or thermally activated delayed fluorescence (TADF) material as the emitter. Low driving voltage and high efficiency fluorescent OLEDs w or w/o a conventional green fluorescent dye DMQA were demonstrated based on an active planar pn heterojunction as an exciton generation and a self-emission region. With a green TADF emitter $ACRDSO_2$ doped at different positions of a planar pn heterojunction, low-driving voltage and high efficiency could be achieved along with switchable emission between green and yellow. Both the high efficiencies and low operation voltages of these devices containing $ACRDSO_2$ emitter represent for the best level among the reported TADF devices. The current findings highlight the significance of the role of the organic active planar pn heterojunction in fabrication of high-performance and structure-simplified OLEDs with conventional fluorescent and TADF emitters, and also enlighten that organic active pn heterojunction should play a much more important role in electric-to-light conversion devices as it has done in the light-to-electric photovoltaic devices.

74 Oxide TFT IV

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chairs: Dr. Ling Li (Chinese Academy of Sciences, China)
Dr. Yen-Yu Huang (CPT, Taiwan)

B74-1 15:00~15:25

Invited Investigation of Indium Oxide Based Thin Film Transistors with Tungsten as Dopant

Qun Zhang, Zhao Yang, Ting Meng, Honglei Li (Fudan Univ., China), and Han-Ping D. Shieh (Nat'l Chiao Tung Univ., Taiwan)

The oxide TFTs with tungsten doped indium oxide (IWO) as channel layers have been prepared by rf sputtering. The influence of oxygen flow rates on the a-IWO-TFTs, as well as the electrical stability under different wavelength illumination was investigated. The transfer curves reveal that with the increasing of oxygen flow rate, the number of oxygen vacancy decreased and the devices show typical and good transfer characteristics. The threshold voltage positively shifts with increasing oxygen flow rate. When the ratio of O_2/Ar flow rate is 2:28, the TFT device with saturation mobility of 27.6 $cm^2V^{-1}s^{-1}$, threshold voltage of - 0.5 V and drain current on-off ratio of 10^8 is obtained. It is found that when the a-IWO-TFTs exposed to different wavelength illumination, V_{th} and SS value change notably in the wavelength shorter than 650 nm and at the illumination time longer than 100 s. And we think that the increasing of total trap density Nt under different wavelength illumination is ascribed to the oxygen vacancies formation. Shorter wavelength light provides enough energy to ionize oxygen vacancies, which results in the increasing of N_t and the instability of the illuminated devices.

B74-2 15:25~15:50

Invited High-Mobility Transistors by Spatial-Atomic Layer Deposition of InZnO

Ilias Katsouras, Andrea Illiberi, Brian Cobb, Paul Poodt, and Gerwin Gelinck (Holst Centre/TNO, Netherlands)

We have developed a process based on plasma-enhanced spatial atmospheric atomic layer deposition (sALD) to deposit thin-films of InZnO. TFTs show a high mobility of 30cm^2/Vs, low-off current, a switch-on voltage of ~0V and excellent bias stress stability, demonstrating the potential of plasma-enhanced sALD in growing high quality, high performance amorphous oxide semiconductors for low-cost, large-area electronics.

74 Oxide TFT IV

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chairs: Dr. Ling Li (Chinese Academy of Sciences, China)
Dr. Yen-Yu Huang (CPT, Taiwan)

B74-3 15:50~16:05

Improvement in Bias Stability of Amorphous IGZO Thin Film Transistor Using Hafnium Oxide Passivation Layer Deposited by Solution Process at Low Temperature

Seonghwan Hong, Sung Pyo Park, Yeong-Gyu Kim, Byung Ha Kang, and Hyun Jae Kim (Yonsei Univ., Korea)

We suggested a solution processed hafnium oxide (HfO_x) passivation layer with a low processing temperature of 150°C. We fabricated an inverted staggered amorphous indium gallium zinc oxide (a-IGZO) TFT using vacuum process. For the HfO_x passivation layer, HfO_x solution was prepared by dissolving 0.1 M of hafnium chloride ($HfCl_4$) in deionized water. The HfO_x passivation layer was deposited by spin coating and annealed in air at 150°C for 1 hour. We also prepared an unpassivated IGZO TFT fabricated with the same annealing process. To confirm the effects of the solution processed HfO_x passivation layer, the positive bias stress (PBS) test (VGS = 20 V and VDS = 10.1 V, applied 10,000 s) was performed. After PBS test for these TFTs, the threshold voltage shift (ΔV_{th}) of the HfO_x passivated TFT was 1.68 V, whereas that of the unpassivated TFT was 4.83 V. Therefore, the solution processed HfO_x layer which was fabricated at 150°C could successfully play a role as a passivation layer. Furthermore, it has a great potential for being adopted in the flexible electronics due to its low temperature processability.

B74-4 16:05~16:20

A Novel Pixel Compensation Circuit for AMOLED Displays

Tingting Zhang, Hui Zhu, Siming Hu, Xiaoyu Gao, and Xiuqi Huang (Kunshan New Flat Panel Display Tech. Center Co., Ltd., China)

The compensation effectiveness of the proposed circuit is verified by Smart SPICE. The simulation model parameters were based on the measurements of fabricated OLED panels and LTPS TFT. The deviation percentage from the original OLED current of the driving TFT is ±0.5 V. The current error rates of all data ranges in proposed circuit are below 9.79%.The related normalized current of the OLED in the proposed pixel circuit versus the OLED threshold voltage shift. Compared with the conventional 2T1C pixel circuit, the proposed circuit successfully increases OLED current to ameliorate the degradation of OLED luminance. Due to the initialization of the OLED anode, the anode voltage is maintained at a lower potential and the OLED can not emit, avoiding the image sticking caused by the OLED capacitor discharge.

75 Plasmonic Structures for Display

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chair: Prof. Young Chul Jun (UNIST, Korea)

C75-1 15:00~15:25

Invited Digital Holography Using a Thermally Driven Phase-Change Material

Seung-Yeol Lee, Yong-Hae Kim, Gi Heon Kim, Tae-Youb Kim, Seong-Mok Cho, Hojun Ryu, Jae-Eun Pi, Jong-Heon Yang, Ji-Hun Choi, and Chi-Sun Hwang (ETRI, Korea)

In this presentation, we proposed that a digital hologram pattern can be written by excimer laser lithography on thin GST film. Since the diffraction obtained by thick GST film cannot provide clear hologram image due to its low diffraction efficiency, we applied thin GST film encapsulated by upper and lower dielectric material. Numerical simulations based on Fourier modal method (FMM) has been performed to find the appropriate position of thin GST film within the dielectric layer. We also find that FP resonances of dielectric layer have significant role for determining the optimized GST film location, and by using such characteristics, it is also possible to make the light illuminating to digital holography pattern can be diffracted wavelength-selectively.

C75-2 15:25~15:50

Invited Spectral Band Engineering with Resonant Thin-Film Subwavelength Gratings

Jae Woong Yoon (Hanyang Univ., Korea), Robert Magnusson, Manoj Niraula, Kyu Jin Lee (Univ. of Texas – Arlington, U.S.A.), Jun Hyung Lee, and Seok Ho Song (Hanyang Univ., Korea)

We show versatile spectral and spatial light-controlling functionalities of subwavelength-periodic thin film structures based on metals, dielectrics, and semiconductors. We discuss principles, our recent progress, and future prospect of such optical elements for developing practical devices and instruments.

75 Plasmonic Structures for Display

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chair: Prof. Young Chul Jun (UNIST, Korea)

C75-3 15:50~16:05

Transmission Improvement of Plasmonic Color Filters

Hansik Yun, Hyeonsoo Park, and Byoungho Lee (Seoul Nat'l Univ., Korea)

Many display industries have tried to improve the resolution of display images and to miniaturize the device size. In these days, some research groups have studied on the application of surface plasmons to color filters in order to improve their performance in terms of resolution, efficiency, and size. However, plasmonic color filters have a problem of low transmission efficiency due to small dimensions of nanostructures. There are some methods to improve the transmission. For the cavity-aperture in our previous research, the substitution of a nanoslit type for a nanoaperture can widen the transmission area, and the novel design of aperture shape can enhance the transmission efficiency, and the optimization of the width and thickness of a nanoaperture can change the transmittance. After modifying the nanoaperture of the cavity-aperture, the transmission efficiency increases by more than three times, and it is expected to be applied to practical optical devices including plasmonic color filters.

C75-4 16:05~16:20

Microscope for Measuring Spectrum of Color Digital Hologram based on Structural Coloration

Mugeon Kim (Kyungpook Nat'l Univ., Korea), Dajeong Im (Korea Univ., Korea), Sungjin Lim, Jiseob Yoon (Kyungpook Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), Jun-Ho Jeong (KIMM, Korea), and Joonku Hahn (Kyungpook Nat'l Univ., Korea)

Recently, development of nanofabrication makes the structural coloration possible in color digital hologram. Usually, in diffractive optical element (DOE) such as rainbow hologram, the color of diffracted wave changes according to the diffraction angle. But, color digital hologram has a definite advantage to represent natural color independent of diffraction angle.The measurement of the spectrum of the DOE is a very elaborate work since the spectrum is very sensitive to the direction of the incident wave and the position of interest that the wave illuminates. Therefore, we need to invent a microscope specially proper to measurement of the spectrum of color digital hologram based on structured coloration. Figure 1 shows our proposed system. A light source and a sensor of a spectrometer are respectively coupled with optical fibers. In order to define the incident angle, the end of the fiber from the light source is mounted on a goniometer stage. The end of the fiber from the spectrometer is mounted on a translation stage in order to define the region of interest. At the same time, the point of the measurement is monitored by the CCD image sensor.

76 Oxide TFT Circuit / Application

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:40
Session Chairs: Prof. Hyun-Suk Kim (Chungnam Nat`l Univ., Korea)
Prof. Mamoru Furuta (Kochi Univ. of Tech., Japan)

D76-1 15:00~15:25

Invited High-Performance p-Type Oxide Thin-Film Transistors Processed at Low Temperatures with Hole Mobility Exceeding 25 $cm^2/V\ s$

Fukai Shan, Ao Liu, and Guoxia Liu (Qingdao Univ., China)

Despite there are a few research on solution-processed p-channel oxide thin-film transistors (TFTs), the strict fabrication conditions and the poor electrical properties have limited their application in low-power complementary metal oxide semiconductor (CMOS) electronics. Here, solution-processed p-type NiO channel layers and their implementation in TFT devices are reported. Solution-based fabrication techniques have been highly emphasized in literatures and industrial production fields because of their roll-to-roll capability, easy control of composition ratio, atmospheric processing, and low cost. The optimized NiO TFTs were achieved at low annealing temperatures (~300°C) and exhibited decent electrical properties. Encouraged by the inspiring results obtained on SiO_2/Si substrates, the TFT performance was further optimized by device engineering, employing high-k AlO_x as the gate dielectric. The fully solution-processed NiO/AlO_x TFT could be operated at a low voltage of 3 V and exhibit a high hole mobility of 25 $cm^2/V{\cdot}s$. By replacing SiO_2 with Al_2O_3 gate dielectric, the operating voltage of the TFT was decreased from 30 V to 3 V, which is important for low-power, battery-driven electronics. Our work demonstrates the ability to grow high-quality p-type oxide films and devices via polyol reduction method over large area substrates while at the same time it provides guidelines for further p-type oxide material and device improvements.

D76-2 15:25~15:50

Invited Unique Applications Using Oxide TFTs

Mutsumi Kimura and Tokiyoshi Matsuda (Ryukoku Univ., Japan)

Oxide semiconductors are promising for low-temperature fabricated, transparent, high performance, high uniformity, and low cost devices. Recently, a-IGZO thin film are actively researched all over the world. Particularly, we are investigating novel applications using oxide TFTs. In this presentation, we will show a 3-D stacked complementary TFT device using n-type a-IGZO and p-type F8T2 TFTs, light irradiation history sensor using a-IGZO TFT exposed to ozone annealing, and maximum applied voltage detector using a-IGZO TFT.

76 Oxide TFT Circuit / Application

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:40
Session Chairs: Prof. Hyun-Suk Kim (Chungnam Nat`l Univ., Korea)
Prof. Mamoru Furuta (Kochi Univ. of Tech., Japan)

D76-3 15:50~16:15

Invited Solution Processed CMOS Metal Oxide Thin Film Transistor Technology

George Adamopoulos (Lancaster Univ., U.K.) and Arokia Nathan (Cambridge Univ., U.K.)

This work reports on the development of novel intrinsically p-type and new n-type metal oxide semiconductors processed at moderate temperatures on flexible substrates employing inkjet printing and spray coating. More precisely, we show solution processed p-type metal oxide-based TFTs employing NiOx-based semiconducting channels with hole mobilities in the range between 5 and 10 cm^2 V^{-1} s^{-1} and reasonable on/off current modulation ratio of about 10^4. We demonstrate similar solution processed TFTs employing In_2O_3:W semiconducting channels on a-$LaAlO_3$ gate dielectrics with electron mobilities of about 10 cm^2 V^{-1} s^{-1} and with excellent stability under negative bias stress. These results indicate the potential for the rapid development of metal oxide digital and analog circuits based on both p- and n-channel TFTs at low manufacturing cost employing solution processing paradigms.

77 Perceptual Image Quality Evaluation & Enhancement

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:10
Session Chairs: Dr. Joe Miseli (JVM Research, Austria)
Prof. Yung Kyung Park (Ewha Womans Univ., Korea)

E77-1 15:00~15:25

Invited New Developments in Viewing Angle Metrology for Quality Control of Displays

Pierre Boher, Thierry Leroux, Vincent Leroux, Thibault Bignon, and Véronique Collomb-Patton (ELDIM, France)

Viewing angle properties are certainly the most common characteristics measured on displays. Historically, the goniometer was the first equipment used to perform such angular measurements. In 1992 ELDIM introduced an optical Fourier transform (OFT) system with a specific optic in order to convert angular field map into a planar one to allow rapid and precise measurements. The theoretical and practical advantages of this technology with regards to goniometers or hemisphere based imagers has long been recognized. Since then, this type of system has been used by all major companies. Along the years the system has seen main developments and improvements for different specific applications: large angular aperture systems with spot size up to 6mm, multispectral systems, high angular resolution systems for 3D displays and polarization analysis have been successively proposed. In the present paper, we will introduce the new generation of OFT systems, VCProbe dedicated to quality control of any type of displays. This new probe allows high angular resolution measurements with high angular aperture in a very compact setup. The use of a robotic arm gives a versatile and cost effective solution for quality control of any display size and geometry.

E77-2 15:25~15:40

A New Assessment with Perceptual Luminance on OLED Display

Jong-Ho Chong, Su Young Kim, Eunjung Lee, ByeongHwa Choi, Seungbae Lee, JongHyuk Lee, and Sungchul Kim (Samsung Display Co., Ltd., Korea)

White luminance is the best property of the display characteristics. But there is a limitation to elucidate the display quality, according to the physical characteristics, like white luminance. In these experiments, it is attempted to match a perceptual luminance as a full white luminance that reflects black luminance, color gamut and a loading ratio of OLED display under ambient conditions. As a result of experiments, it is hard to get the perceptual luminance with only white luminance, and it is known that the perceptual luminance should be organized with some human visual concepts, such as simultaneous contrast and Helmholtz-Kohlrausch (H-K) effect, mainly. With these experiments, the results are obtained, which OLED display could have a performance to present higher brightness at the relatively low white luminance than LCD.

77 Perceptual Image Quality Evaluation & Enhancement

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:10
Session Chairs: Dr. Joe Miseli (JVM Research, Austria)
Prof. Yung Kyung Park (Ewha Womans Univ., Korea)

E77-3

15:40~15:55

Optimum Luminance of Display Depending on Ambient Illuminance

Jeong-Sik Kim, Seung-Ryeol Kim, Seung-Hyuck Lee, Dong-Hwan Jeon, and Seung-Woo Lee (Kyung Hee Univ., Korea)

In this paper, we analyzed the influence of ambient illuminance on display luminance for the users. We performed a psychophysical experiment where ten subjects participated.

E77-4

15:55~16:10

Simulation of Perceived Images in Transparent OLED Displays

Chang-Mo Yang (Inha Univ, Korea), Hyeok-Jun Kwon, Min-Cheol Kim (LG Display Co., Ltd., Korea), Dong-Hyeok Lee, Choon-Woo Kim (Inha Univ., Korea), Ji-Young Ahn, and Pu-Reum Kim (LG Display Co., Ltd., Korea)

In this paper, a new simulation method for perceived image in transparent OLED displays attached with transparent plastics is presented. In transparent OLED displays, information on the displays is overlapped with the objects behind displays. The following factors are incorporated in the proposed simulation: the spectral transmittance of the transparent OLED displays and transparent plastics, distance from displays to the objects and haze value of the transparent plastics. The effectiveness of the proposed method is verified based on human visual experiments.

78 Holography & Emerging 3D Display Techniques

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:35
Session Chair: Prof. Joonku Hahn (Kyungpook Nat'l Univ., Korea)

F78-1 15:00~15:25

Invited Development of High Efficiency Coherent Backlight System for Generation of Digital Hologram Display

Hyesog Lee, Yunseon Do, Jaeho Yu, and Byungchoon Yang (Samsung Display Co., Ltd., Korea)

As the concept of analogue holography has been around for more than half a century, there are widening efforts in recent days to advance the holographic display technology. One of the core principles of generating hologram images, namely the requirement of coherent light sources, is one of major hurdles to overcome on the road to bringing this technology into commercial markets.In order to tackle the challenge of building a compact coherent backlight unit, rather limited number of previous reports have suggested using LGPs with modulated surfaces for light extraction [1], and using a couple of HOEs (Holographic Optical Elements) to convert a point source to a planar BLU [2]. Both of these cases suffer greatly from low power efficiency. We are developing mobile digital holographic displays at Samsung Display, and we are working on building a coherent BLU system with only one HOE to achieve both a compact form factor and a high power efficiency.In order to test the concept, we have built a prototype that consists of conventional optical elements such as lenses and mirrors with a HOE, which will be used as a testbed for realizing a milimeter-scale slim BLU unit for mobile systems.

F78-2 15:25~15:50

Invited Real Image Forms SF Display

Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

Many science-ficition movies depict transparent and floating information displays. Our goal is to realize such Super-Future displays without special eyewear. This paper introduces our developments on aerial display, which forms a real image floating in mid-air. In order to form aerial LED signage, we have fabricated crossed-mirror array (CMA). In order to form a real image with extremely wide viewing angle, aerial imaging by retro-reflection (AIRR) has been utilized for several types of aerial displays. Our fabricated CMA is composed of comb-shaped mirrors. Because hollow apertures in our CMA can reflect and converge far-infrared radiations from a thermol source, we have succeeded in a floating thermal 3D display. Furthermore, enlarging the aperture size in CMA, possibility of floating acoustic display has been demonstrated. AIRR features scalability, cost, and wide viewing angle. Because lights from almost all over the table top converge to the image position, the formed real image can be viewable without scattering material like screen. We have demonstrated Screen-Free interation system by combining aerial high-speed LED display and fast stereoscopic cameras. By introducing transparent retro-reflector, the viewing zone of the real image has been extended to include even a source display surface. Thus, AIRR enables Screen-Free display.

78 Holography & Emerging 3D Display Techniques

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:35
Session Chair: Prof. Joonku Hahn (Kyungpook Nat'l Univ., Korea)

F78-3 15:50~16:05

Perceived Depth Dependence of Transparent Layered Images in the Depth-Fused 3D Display

Koki Sakamaki, Haruki Mizushina, and Shiro Suyama (Tokushima Univ., Japan)

In recent years, various 3D display methods have been developed. As one of promising 3D displays, we have studied DFD (Depth-fused 3D) display, which has merits of less visual fatigue, simple device configuration and robustness to anisometropia. DFD display is composed of front and rear images overlapped from midpoint of observer's eyes. Perceived depth can be changed by changing the luminance ratio of the front and rear images. As application scenes for 3D display have several transparent images, such as a show window, overlapped transparent plastic folders and structure in the house, Ms.Yoshimune (2014) has developed two layered transparent images by using three image planes. However this method has a problem that two layered images cannot be positioned in the same depth area. In this paper, in order to expand depth range of overlapped transparent layered images, we have proposed a new transparent DFD display by changing the combination of the image planes to be fused and evaluated the perceived depth dependences.

F78-4 16:05~16:20

Viewing Zone Expansion by Blurring Edge Parts in Edge-Based DFD (Depth-Fused 3D) Display

Tomohiro Yamamoto, Haruki Mizushina, and Shiro Suyama (Tokushima Univ., Japan)

In various 3D display technologies, we have studied Edge-based DFD (Depth-fused 3D) display which has merits of a simple structure, a little fatigue and robustness for 2D vision. Edge-based DFD display was composed of two layered images with a gap; usual 2D image and its edge parts whose luminances are determined by its designed depths. Two overlapped images with the gap can be perceived as a single depth image. Whose perceived depth image continuously changes as the edge-part luminance ratio is changed. However edge-based DFD display has demerits of narrow viewing angle for 3D image and needs for using the same gap as desired 3D image depth and so on. This is because 3D depth can be perceived in DFD display only when two layered images are overlapped from midpoint of observer's eyes. In this paper, we have developed a new method for enlarging viewing zone by blurring edge parts in edge-based DFD display.

78 Holography & Emerging 3D Display Techniques

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:35
Session Chair: Prof. Joonku Hahn (Kyungpook Nat'l Univ., Korea)

F78-5 16:20~16:35

Perceived Depth and Smooth Image Shift of Motion Parallax by Using Layered Multi-View DFD (Depth-Fused 3D) Display

Tatsuhiko Eguchi, Haruki Mizushina, and Shiro Suyama (Tokushima Univ., Japan)

We propose a new method of 3D display using layered multi-view displays, to obtain smooth image shift and appropriate perceived depth of motion parallax with a small amount of informations. DFD (Depth-fused 3D) display technology is also used for the layered images to reduce the amount of informations. The proposed display is composed of layered multi-view displays with a gap. Our method has three mechanisms to obtain smooth image shift and appropriate perceived depth of motion parallax. Firstly, this method can simply increase the number of viewpoints by using several multi-view displays. Secondly, direction differences of parallax by the gap between layered multi-view displays results in increasing effective number of inconsistent parallax. Thirdly, our display has small motion parallax because DFD display has small motion parallax. In the experiments perceived depths in the layered multi-view DFD display are much improved from degraded depths in the multi-view display. Thus, our layered multi-view DFD display has smooth image shift as compared to those of conventional method. These results lead to the conclusion that our proposed method by using layered multi-view DFD display is promising for providing smooth image shift and monocular appropriate depth perception of motion parallax.

80 LEDs for Various Applications

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chair: Dr. Si-young Bae (Nagoya Univ., Japan)

H80-1 15:00~15:25

Invited **Versatile Phosphor-in-Glass for Solid-State Lighting Applications**

Won Bin Im (Chonnam Nat'l Univ., Korea)

Phosphor-converted white LEDs used for solid-state lighting have major drawbacks like non-uniform degradation of one of the component phosphors, and thereby reduces the expected life time of the device. Even after decades of researches a white LED phosphor which meet all the required criteria were hardly found. In addition few host compounds which meet the necessary emission requirements under standard conditions were not used owing to its chemical and thermal instability under operating conditions. Also the reduction in efficiency of the system under high temperature operation takes a toll on the overall efficiency of the system. To overcome these problems, different techniques have been applied by the researchers, but most of them were proved to be less effective. In this talk, firstly we propose a new, simple, and facile technique to encapsulate moisture sensitive phosphors like halides and sulfides. Then we have selected a moisture sensitive halide phosphor and studied its emission properties after moisture test under standard conditions. The results indicates that the technique proposed in this work has efficiently protected the phosphor form degradation and thus the output of this work paves way to commercial use of high efficient and cheap, but seldom used halide and sulfide phosphors in solid-state lighting. In addition, a graphene-wrapped phosphor-in-glass plate, in which single-layer graphene was employed to modulate the effect of thermal shock on the phosphor was demonstrated, with a two-dimensional cellular automata simulation technique.

80 LEDs for Various Applications

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chair: Dr. Si-young Bae (Nagoya Univ., Japan)

H80-2 15:25~15:40

Light-Emission Properties and Electronic Structure of Amorphous Oxide Thin film Phosphor, a-GaO_x:Eu

Naoto Watanabe, Junghwan Kim, Keisuke Ide, Hidenori Hiramatsu, Hideo Hosono, and Toshio Kamiya (Tokyo Inst. of Tech., Japan)

Recently, we succeeded in fabricating light-emitting amorphous oxide (LEAO) thin film phosphor at room temperature, which emit intense visible light. The LEAO thin films would attract much attention for future light-emitting devices overcoming the chemical instability of conventional organic light-emitting layers. In this work, we chose amorphous GaO_x (a-GaO_x) thin films as a host because it has deeper VBM than a-IGZO. The a-GaO_x:Eu thin films were fabricated using pulsed laser deposition in an O_2 atmosphere. The a-GaO_x:Eu thin film deposited at room temperature exhibited intense red emission peaked at 612 nm. The optimum Eu concentration in a-$(Ga_{1-y}Eu_y)O_x$ was y = 9 mol%. On the other hand, we found that the PL intensity depend strongly on the partial oxygen pressure (PO_2) during film deposition. No PL was observed at lower PO_2 (< 4Pa) region, which is attributed to two factors; one is the auger-recombination owing to free carriers and the other one is trap-assisted recombination through oxygen-deficiency-related defects. PL intensity decreased with the increasing PO_2 at 12 Pa; it would be plausible that the trap-assisted recombination is enhanced by weakly-bonded oxygen (O_{wb}) defects. Consequently, the most intense PL was observed at 11 Pa.

80 LEDs for Various Applications

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chair: Dr. Si-young Bae (Nagoya Univ., Japan)

H80-3 15:40~15:55

Flexible Inorganic LEDs for Bio-Implantable Applications

Seung Hyun Lee, Han Eol Lee, Jung Ho Shin, and Keon Jae Lee (KAIST, Korea)

Recently, the fabrication of lighting sources on flexible substrates has attracted a great interest for future display system and biomedical applications. Organic light emitting diodes (OLEDs) have been studied actively in the past decades with its feasibility of direct fabrication process on flexible substrates. However, OLEDs have limitations in biomedical applications due to short life time, low efficiency, and low brightness compared to inorganic LEDs (ILEDs). In addition, OLEDs are vulnerable to humidity which is abundant in living organisms. ILEDs have superior advantages in long-term stability, high efficiency, strong brightness and stability. With these advantages, ILEDs have expanded its applications to consumer electronics such as energy efficient light lamp, back-light unit of displays. However, ILEDs cannot be made directly on flexible substrate because efficient ILEDs need rigid, robust, and flat substrate for epitaxial growth.This problem can be handled by standard micro-fabrication and soft lithography techniques in which the thin film on bulk substrate followed by high temperature annealing and then transferred onto flexible substrates. Since the first invention of flexible III-V materials in 2005, Rogers' group has presented flexible inorganic LEDs by using micro-structured GaAs/GaN. Recently in 2011, Lee et al. established the flexible waterproof InGaN ILED on a liquid crystal polymer substrate for biomedical application by using micro-structure transferring process. Although this work proposed the feasibility for flexible LED and its application to biosensor, the realization of more efficient ILEDs is crucial for various biomedical applications which require both higher optical power and lower temperature during operation.Herein, we demonstrated the noble strategies for fabrication of flexible vertical structure LEDs (f-VLEDs). Thin layer of LEDs were detached from sapphire or GaAs mother substrate using wet etching or universal soft lithographic transferring protocol. Anisotropic conductive film facilitates vertical interconnection between LED chips and metal lines. Due to the advantage of high quality LED properties originally grown on mother substrate, much higher brightness flexible ILEDs have made. f-VLEDs will provide the opportunities for the promising future flexible displays and biomedical devices.

80 LEDs for Various Applications

Date: Aug. 26, 2016 (Friday)
Time: 15:00~16:20
Session Chair: Dr. Si-young Bae (Nagoya Univ., Japan)

H80-4 15:55~16:20

Invited Key Problems in High Performance Light-Emitting Diodes Packaging

Xiaobing Luo (Huazhong Univ. of Science and Tech., China)

Light-emitting diodes (LEDs), due to their extraordinary characteristics, are widely used in our daily lives. Usually, LED chips must be packaged into modules and further assembled into products for application. LED packaging is a complicated science and engineering technique. It mainly concerns optics, thermology, materials, mechanics, electronics, packaging process and fluid flow, it plays a key function in mechanical protection, external signal and electrical connection, heat dissipation and optical parameter control. Advanced processes, precise fabrication and careful operation are essential for achieving high performance LEDs.

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-1

All Solution Processed Organic Light Emitting Diode with Buffer Layer Preventing Silver Penetration

Joo-Bin Kim, Jun-Ho Song, and Jae-Woong Yu (Kyung Hee Univ., Korea)

P1-2

Intense Pulsed Light Annealed Scattering Layer for Enhanced Light Extraction from Organic Light-Emitting Devices

Sangmin Park, Joobin Kim, and Jae-Woong Yu (Kyung Hee Univ., Korea)

P1-3

Recycling of Organic Materials Using Purification by Recrystallization for Solution-Processed Organic Light-Emitting Diodes

Ki-Young Hong, Jin-Young Lee, Dong-Kyun Shin, Su-ho Yoo, and Jongwoon Park (Korea Univ. of Tech. and Education, Korea)

P1-4

Phase Transformation with Heat-Treatment of Alq3 Materials via Imidazolium Based Ionic Liquids

Yong-Taeg Oh and Dong-Chan Shin (Chosun Univ., Korea)

P1-5

Balancing Charge Carrier Injection on Polymer Electrochemical Light Emitting Cells

Seunghan Kim, Seok Hwan Kong, Jaemok Koo, and Moon Sung Kang (Soongsil Univ., Korea)

P1-6

Diphenylaminocarbazoles as Host Materials for High Efficiency Solution-Processed Green Phosphorescent Organic Light-Emitting Diodes

Shahid Ameen, Yongguk Lee, Jaemin Lee, and Changjin Lee (KRICT, Korea)

P1-7

The Influence of the Thickness of Hole Transport Layer and Bipolar Exciton Blocking Layer on the Lifetime of Solution-Processed Organic Light Emitting Diodes

Dong Heon Shin and Min Chul Suh (Kyung Hee Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-8

Analysis of Mixed Interface in Organic Light-Emitting Diodes by Impedance and Ultraviolet Photoelectron Spectroscopy

Dong A Ahn, Seung Jun Lee (Kyung Hee Univ., Korea), Jae Gwan Chung (Samsung Advanced Inst. of Tech., Korea), Young Sup Park, and Min Chul Suh (Kyung Hee Univ., Korea)

P1-9

The Influence of MoNb Buffer Layer for Copper Metal on the Performance of IGZO Thin Film Transisitor

Jincheng Gao, Zhengliang Li, Shuang Sun, Zhanfeng Cao, Seung jin Choi, and Guan-bao Hui (BOE Tech. Group Co., Ltd., China)

P1-10

Indium-Zinc-Oxide TFTs Prepared with Electrohydrodynamic-Jet Printing

Young-Jin Kwack, Hunho Kim, Yunsoon Ka, Namhun Baek, Kyung-Hyung Lee, and Woon-Seop Choi (Hoseo Univ, Korea)

P1-11

Oxide BCE GOA Technology Development

Yinglong Huang, Chunfang Zhang, Ce Ning, Haoliang Zheng, Jiali Lv, and Junjung Mok (BOE Tech. Group Co., Ltd., China)

P1-12

Metal Catalytic Crystallization of Amorphous Zinc Tin Oxide Semiconductors for High Mobility Thin-Film Transistors

SangTae Kim, KiJune Lee, YeonWoo Shin, TaeJung Gim, and Jae Kyeong Jeong (Hanyang Univ., Korea)

P1-13

High-Mobility Zinc Oxynitride Thin-Film Transistors for Next-Generation Display Applications

Yang-Soo Kim, Jong-Heon Kim, and Hyun-Suk Kim (Chungnam Nat'l Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-14

Solution-Processed SiO_2 Gate Insulator Fabricated at Low Temperature for Flexible Oxide Transistors

Hyeonjoo Seul, Nuri On (Hanyang Univ., Korea), Azida Binti Azmi (Inha Univ., Korea), Jiwon Lee, Minhwae Cho, and Jaekyeong Jeong (Hanyang Univ., Korea)

P1-15

High Electrical Performance of Zinc-Tin-Oxide Thin Films via Adding Lithium Material Using Mist Chemical Vapor Deposition

Keun-Tae Oh, Hyun-Jun Jeon, Donghyun Kim, and Jin-Seong Park (Hanyang Univ., Korea)

P1-16

Effect of Li Doping on Low Temperature Crystallization of InZnO Thin Film

Soo-Yeun Han, Manh-Cuong Nguyen, Jae-Won Choi, An Hoang-Thuy Nguyen, Jung-Youn Kim, and Rino Choi (Inha Univ., Korea)

P1-17

Effect of Bilayer Gate Insulator with Silicon Nitride and Poly (4-Vinylphenol) for In-Zn-O Thin Film Transistors

Do Kyeong Lee, Sang Cheol Park, Hyunji Shin, Dongwook Kim, and Jong Sun Choi (Hongik Univ., Korea)

P1-18

Rapid Fabrication of High-Performance, Solution-Processed Indium Oxide Thin-Film Transistors Using Flash Lamp Annealing

Chan-mo Kang, Hoon Kim, Yeon-Wha Oh, Kyu-Ha Baek, and Lee-Mi Do (ETRI, Korea)

P1-19

Fabrication of IGZO Transistor using Vapor Deposited Polymer Gate Insulator

Hongkeun Park, Hyejeong Seong (KAIST, Korea), Chan Woo Park, Jae Bon Koo (ETRI, Korea), and Sung Gap Im (KAIST, Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-20

On the Characterization of InO_x / ZnO_x Multi-layered Thin Film Transistors with Plasma-Enhanced Atomic Layer Deposition

Jeong-Mu Lee (Korea Univ. of Sci. and Tech., Korea), Hwan-Jae Lee, Seung-Youl Kang, and Seong-Deok Ahn (ETRI, Korea)

P1-21

Study of Solution-Processed In–Ga–Zn–O Thin-Film Transistors Using Flash Lamp Annealing by Controlling the Radiation Conditions

Hoon Kim, Chan-mo Kang, Yeon Wha Oh, Kyu-Ha Baek, and Lee-Mi Do (ETRI, Korea)

P1-22

Development of CdTe Channel Device via Solution Process for Thin Film Transistor

Azida Azmi (Inha Univ., Korea), Hyeonjoo Seul, Nuri On, and Jaekyeong Jeong (Hanyang Univ., Korea)

P1-23

Short Time Activation of Solution-Processed Aluminum Oxide Gate Dielectric Using Flash Lamp Annealing

Yeon-Wha Oh, Hoon Kim, Lee-Mi Do, Kyu-Ha Baek (ETRI, Korea), Ga-Won Lee (Chungnam Univ., Korea), and Chan-mo Kang (ETRI, Korea)

P1-24

Comparison of a-IGZO and a-ITZO Thin Film Transistors Stability under UV-Ozone Exposure

So Young Lee, Jongsu Oh, Eung-Kyu Park, Dong-Hoon Lee (Sungkyunkwan Univ., Korea), Kee-Chan Park (Konkuk Univ., Korea), and Yong-Sang Kim (Sungkyunkwan Univ., Korea)

P1-25

Solution-Processed High-k Magnesium Oxide Dielectric for n-Type In_2O_3 and p-Type NiO Thin Film Transistors

Fukai Shan, Guixia Jiang, and Guoxia Liu (Qingdao Univ., China)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-26

Understanding on the Defects and Charge Trapping Mechanism in Oxide-Thin Film Transistors by Pulse I-V Method

Taeho Kim and Sanghun Jeon (Korea Univ., Korea)

P1-27

High-Fidelity Patterning of Conducting Polymers on Stretchable Substrate Using Selective Wetting Technique

Sujie Kang, Bo-Yeon Lee, and Sin-Doo Lee (Seoul Nat'l Univ., Korea)

P1-28

Silver Nanowire-Based Stretchable Electrodes by Spray Coating

Jin-Young Lee, Ki-Young Hong, Dongkyun Shin, Su-ho Yoo, and Jongwoon Park (Korea Univ. of Tech. and Education, Korea)

P1-29

Stretchable Ferroelectric Memory Transistors on Elastomeric Substrate

Yu Gyeong Moon (Korea Univ. of Science and Tech., Korea), Jae Bon Koo (ETRI, Korea), Chan Woo Park (Korea Univ. of Science and Tech., Korea), Bock Soon Na, Nae-Man Park, Ji-Young Oh, Sang Seok Lee, Seung-Youl Kang, Seongdeok Ahn, and Soon-Won Jung (ETRI, Korea)

P1-30

Flexible Substrate Fabrication and Wavy Characteristic for Next Generation Display

Sang Chul Lim, Myung Chan An, Dong Ic Lee, Se Hyuk Yeom, Gyeong Tae Park, Chang Taek Seo, Jung Sik Koo, Heon Gon Kim (GERI, Korea), and Jong Won Lee (Hanbat Nat'l Univ., Korea)

P1-31

High Optical Contrast Reflective Electrochromic Device

Ik Jang Ko, Yong Cheol Kim, Jin Hwan Park, Gyeong Woo Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-32

Reflective-Type Organic Photoplethysmography (PPG) Sensors for Wearable Healthcare Applications

Hyeonwoo Lee, Yongsu Lee, Hoyeon Kim, Jaeho Lee, Mincheol Kim, Hoi-Jun Yoo, and Seunghyup Yoo (KAIST, Korea)

P1-33

Simple Spray Coating of ATO Nanoparticles on Self-Assembled Ag Network Electrode for Transparent and Flexible Heaters

Jae-Gyeong Kim, Hae-In Shin, Sung-Hyun Park, Doo-Hee Kim, Eun-Hye Ko, Kyung-Soo Cho, Jeong-Il Park, Sang-Mok Lee, and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-34

Low Voltage Pressure Sensitive Transistor Using Elastomeric Nanowire Composite

Jaeyoung Yoon, Yunsik Joo, Jewook Ha, Taehoon Kim, and Yongtaek Hong (Seoul Nat'l Univ., Korea)

P1-35

Electrical Reliability of Metal Electrode for Flexible Devices during Cyclic Mechanical Deformations

Byoung-Joon Kim (KIMS, Korea)

P1-36

Molecular Weight Effect of Polymer Insulator on the Operating Voltage of the Polymer-Based Resistive Memory

Sin-Hyung Lee, In-Ho Lee, Hea-Lim Park (Seoul Nat'l Univ., Korea), Min-Hoi Kim (Hanbat Nat'l Univ., Korea), and Sin-Doo Lee (Seoul Nat'l Univ., Korea)

P1-37

Investigation of Multilayer Molybdenum Disulfide Transistors with Dielectric Passivaiton

Seong Yeoul Kim and Woong Choi (Kookmin Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-38

Effect of Al_2O_3 Passivation Layers on Back-gated Multilayer $MoSe_2$ Field-Effect

Hyun Ah Lee, Seonyoung Park, and Woong Choi (Kookmin Univ., Korea)

P1-39

Interface Properties of Atomic-Layer-Deposited Al_2O_3 Dielectric on Ultraviolet/Ozone-Treated Multilayer MoS_2

Seonyoung Park, Yura Choi (Kookmin Univ., Korea), Myungjun Kim, Hyunjung Shin (Sungkyunkwan Univ., Korea), Jiyoung Kim (Univ. of Texas at Dallas, U.S.A.), and Woong Choi (Kookmin Univ., Korea)

P1-40

Dependence of Characteristics of RF-Sputtered MoS_2 Films on the After-Deposition Annealing Conditions

Young-Jin Kim and Ho-Nyeon Lee (Soonchunhyang Univ., Korea)

P1-41

Fabrication of a Free-Standing MoS_2 Two-Dimensional Film Using a Reactive Thermal Evaporation Method and its Device Application

Tae-Kwang Park and Ho-Nyeon Lee (Soonchunhyang Univ., Korea)

P1-42

Thermal- and Photo-Induced Phase-Transition Behaviors of a Ribbon-Shaped Dendritic Liquid Crystal

Minwook Park, Dae-Yoon Kim, and Kwang-Un Jeong (Chonbuk Nat'l Univ., Korea)

P1-43

Hierarchical Structures Constructed by the Photopolymerization of Discotic Reactive Liquid Crystal

Minwook Park and Kwang-Un Jeong (Chonbuk Nat'l Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-44

Gate Tunable Black Phosphorus and p-InGaAs Hetero-Junction Diode for Multi-Functional Devices

Youngsu Lee, Doo-Seung Um, Seongdong Lim, and Hyunhyub Ko (UNIST, Korea)

P1-45

Organic Light-Emitting Diodes with Graphene Anode

Hee Yeon Noh and Seok-Hwan Chung (DGIST, Korea)

P1-46

Enhanced Antibacterial Properties of Graphene Oxide-MoS_2 Nanocomposite Film

Tae In Kim, Buki Kwon, Ick-Joon Park, and Sung-Yool Choi (KAIST, Korea)

P1-47

The Performance of Flexible Organic Thin-Film Transistors with/without Encapsulation Layer

Jongsu Oh, Jin-Ho Kim, Min Su Kim, So Young Lee (Sungkyunkwan Univ., Korea), Kee-Chan Park (Konkuk Univ., Korea), and Yong-Sang Kim (Sungkyunkwan Univ., Korea)

P1-48

Photolithography Patterning of Graphene Film

Yunping Di, Fangzhen Zhang, Zhijun Lv, Shuang Sun, Jikai Yao, and Jaiil Ryu (BOE Tech. Group Co., Ltd., China)

P1-49

Investigation of Cs_2CO_3 Doped Transparent Graphene Electrode as a Cathode of Inverted Organic Light Emitting Diodes

Ick-Joon Park, Dohong Kim, Tae In Kim, Young-Wook Ha, Kyung Cheol Choi, and Sung-Yool Choi (KAIST, Korea)

P1-50

Negative Dispersion of Birefringence in 2-D Self-Organized Smectic Composite: Dependence of Dispersion on the Guest Molecules Structure

Jiyong Hwang, Seungbin Yang, Yu-Jin Choi, Kwang-Un Jeong, and Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-51

Electrical Characteristics of Multilayer MoS_2 Transistors on Solution-Processed High-k Oxide Gate Dielectric

Sol Lea Choi, Byungwook Yoo, Min Suk Oh, Chuljong Han, Jeongno Lee, and Geonwook Yoo (KETI, Korea)

P1-52

Rapid Synthesis of Continuous Layer of CVD Graphene on Plasma Modified Cu Surface

Wimalananda M. D. S. L., Jae-Kwan Kim, and Ji-Myon Lee (Sunchon Nat'l Univ., Korea)

P1-53

Electrical Properties of Transferred Graphene Films on Pre-Treated Polyimide Substrate by Inductively Coupled Plasma

Kyung Ho Kang, Jae-Kwan Kim, and Ji-Myon Lee (Sunchon Nat'l Univ., Korea)

P1-54

Analysis on the Performance of Photodetector based on the Band Structure of Transition Metal Dichalcogenide Active Layer

Young-Woong Song, Ah-Jin Cho, and Jang-Yeon Kwon (Yonsei Univ., Korea)

P1-55

Facile Synthesis of Hexagonal Boron Nitride Nanosheet with a Lewis Base

Jeong-Hee An and Yong-Seog Kim (Hongik Univ., Korea)

P1-56

Analysis of Humidity Effects on Electrical Performance of MoS_2 TFT Device by Chemical Vapor Deposition

Yun-Jin Park, Hyung-Jun Kim, and Jang-Yeon Kwon (Yonsei Univ., Korea)

P1-57

A New Stable GOA Circuit Construction and Optimization

Zheng Wang, Ning Cui, Yingfang Deng, Xiaopeng Cui, Weitao Chen, LiangZhang, and Xibin Shao (BOE Display Tech. Co., Ltd., China)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-58

Surface Engineering of Gate Dielectric for High Performing Organic Field-effect Transistors

Yanlian Lei and Furong Zhu (Hong Kong Baptist Univ., Hong Kong)

P1-59

Effect of Injection Barrier Height on Current On/Off Ratio of Vertical Organic-Field-Effect Transistor

Gyujeong Lee, In-Ho Lee, Hea-Lim Park, Sin-Hyung Lee, Eui-Sang Yu, Bo-Yeon Lee, and Sin-Doo Lee (Seoul Nat'l Univ., Korea)

P1-60

Low Temperature Photo-Annealed Indium Gallium Zinc Oxide Thin Film Transistors with Sodium-Doped Alumina Dielectrics

Kwang-Ho Kim (KETI, Korea), Sung-Kyu Park (Chung-Ang Univ., Korea), and Byungwook Yoo (KETI, Korea)

P1-61

Electrowetting Driven Spreading of Sandwiched Droplet on Connecting Substrates

Amir Shahzad and Jangkun Song (Sungkyunkwan Univ., Korea)

P1-62

Organic-Oxide Hybrid Transistors with High Mobility and High Photosensitivity

Amos Amoako Boampong, Jae-Hyun Lee, Yoonseok Choi, and Min-Hoi Kim (Hanbat Nat'l Univ., Korea)

P1-63

Analysis a Side Mura Formed in Passivation Deposition Process

Ji Li, Zhaozhe Xu, Xiaobin Yin, Sheng Wang, Ku Hyun Park, Yun Bok Lee, Man Wang, Chuncheng Che, and Seung Kyu Lee (Hefei BOE Optoelectronics Tech. Co., Ltd., China)

P1-64

Solution-Processable Al_2O_3 Multi-Stacking Gate Insulator for Organic Thin-Film-Transistors

Eung-Kyu Park, Sihan Wang, So Young Lee, Hyeong Jun Cho, Dong-Hoon Lee, and Yong-Sang Kim (Sungkyunkwan Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-65

Two-Step Treatment with L-Cysteine and PEDOT:PSS for Bottom Contact Structured Organic Thin Film Transistors

Sihan Wang, Eung-Kyu Park, Jin-Ho Kim, Hyeong Jun Cho, Dong-Hoon Lee, Jongsu Oh, and Yong-Sang Kim (Sungkyunkwan Univ., Korea)

P1-66

High Performance SiOxNy Insulator for 441-PPI AMOLED

Tao Zhu, Jinqiang Liu, Yucheng Liu, Xiaoyu Gao, and Xiuqi Huang (Kunshan New Flat Panel Display Tech. Center Co., Ltd., China)

P1-67

One Etch Stop Layer Process for High Resolution AMOLED

Wangfeng Xi, Tao Zhu, Yucheng Liu, Xiaoyu Gao, and Xiuqi Huang (Kunshan New Flat Panel Display Tech. Center Co., Ltd., China)

P1-68

High Performance Flexible 3D Organic Circuits Fabricated by Solution Process

Sujeong Kyung, Jimin Kwon (POSETCH, Korea), Yun-Hi Kim (Gyeongsang Nat'l Univ., Korea), and Sungjune Jung (POSTECH, Korea)

P1-69

Solution Processed Hafnium Silicate films as a Gate Insulator

Na Young Lee and Byoung Deog Choi (Sungkyunkwan Univ., Korea)

P1-70

High Performance Pentacene-Based Inverter Using Organic/Inorganic Hybrid Gate Insulated Thin-Film Transistors

Min Su Kim, Dong-Hoon Lee, Hyeong-Jun Cho, So Young Lee (Sungkyunkwan Univ., Korea), Kee-Chan Park (Konkuk Univ., Korea), and Yong-Sang Kim (Sungkyunkwan Univ., Korea)

P1-71

Effect of Selective Etching Process on Solution-Processed In-Zn-O Thin-Film Transistors

Jae Won Na, Hee Jun Kim, Jin Hyeok Lee (Yonsei Univ., Korea), Andrew Suh (St. Paul's School, U.S.A.), and Hyun Jae Kim (Yonsei Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-72

Research on Manufacturing Technology for Large Area Hologram Using Mechanically Micro Machining

Je-Ryung Lee (KIMM, Korea), Hwi Kim (Korea Univ., Korea), Dae-Hee Choi, Tae-Jin Je, and Eun-Chae Jeon (KIMM, Korea)

P1-73

Broadband Green Source by Nickel Diffused Tandem Pole Lithium Tantalate Waveguide for Despeckling Application

Seong-Jin Son, Do-Kyeong Ko (GIST, Korea), Lung-Han Peng (Nat'l Taiwan Univ., Taiwan), and Nan Ei Yu (GIST, Korea)

P1-74

Forming an Aerial Image Perpendicular to the Table Top

Tomofumi Kobori, Kenta Onuki, Shogo Morita, and Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

P1-75

Aerial LED Signage by Use of Transparent Acrylic Cubes

Shogo Morita, Sho Onose, and Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

P1-76

Optimal Design for Full Color Waveguide-Type Head Mounted Display Using Holographic Optical Elements

Han-Ju Yeom and Jae-Hyeung Park (Inha Univ., Korea)

P1-77

Shape-Controllable Lens Array by Dispensing Techniques for Bezel-Less Display Application

Seunghwan Lee, Hyungsoo Yoon, Chang-Kun Lee, Jongjang Park, Junghwan Byun, Byeongmoon Lee, Seungjae Lee, Geonhee Kim, Byoungho Lee, and Yongtaek Hong (Seoul Nat'l Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-78

Research of Pattern Delay of TN Mode TFT-LCD

Mingchao Wang, Xiaopeng Cui, Jiarong Liu, Xingliang Li, Xiaona Liu, Weitao Chen, Liang Zhang, and Xibin Shao (Beijing BOE Display Tech. Co., Ltd., China)

P1-79

Improvement of H-line Mura in ADS Mode Adopted 2-Pixel-2-Domain

Yuanhui Guo, Yan Wang, Bingbing Wu, Ronghua Jin, Yisan Zhang, Hui Wang, Chun Wang, Junsheng Chen, Xiaohe Li, Chuncheng Che, and Seung Kyu Lee (Hefei BOE Optoelectronics Tech. Co., Ltd., China)

P1-80

Polymer-Stabilized Blue Phase Liquid Crystal Fresnel Cylindrical Lens Fabricated by Patterned Light via Spatial Light Modulation

Shuaijia Huang, Yan Li, Na Rong, and Yikai Su (Shanghai Jiao Tong Univ., China)

P1-81

Dielectric Dispersion in a Newly Synthesized Bent Core Liquid Crystal

Anoop Kumar Srivastava, Jongyoon Kim, Jinyoung Jeong, Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea), and E-Joon Choi (Kumoh Nat'l Inst. of Tech., Korea)

P1-82

Synthesis of New Reactive Mesogen and its Photosensitivity

Ah-Young Jo, Min Jae Lee, Shin Woong Kang, and Myong-Hoon Lee (Chonbuk Nat'l Univ., Korea)

P1-83

Synthesis of New Photo-Alignment Layer for VA Mode LCD

Yun-Jong Ko, Sukwoon Chang, He-Rui, Shin Woong Kang, Seung Hee Lee, and Myong-Hoon Lee (Chonbuk Nat'l Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-84

Unusual Doping Effect of Achiral Bent-Core Molecules Possessing Helical Nanofilament Phase

Seong-Yong Jo, Seong-Wok Jeon, and Suk-Won Choi (Kyung Hee Univ., Korea)

P1-85

Observation of the Micro-Particle in Deformed Director Field of Nematic Liquid Crystal

Beom-Kyu Lee, Sung-Jo Kim, and Jong-Hyun Kim (Chungnam Nat'l Univ., Korea)

P1-86

Asymmetry Organic-Inorganic Hybrid Giant Monosubstituted Molecular Nanoparticles for Formation of Vertical Alignment of Liquid Crystals

Won-Jin Yoon, Dae-Yoon Kim, Yu-Jin Choi, and Kwang-Un Jeong (Chonbuk Nat'l Univ., Korea)

P1-87

Photopolymerization of Reactive Amphiphiles and Polyhedral Oligoemric Silsequioxane for Automatic Vertical Alignment of Liquid Crystals with Strong Surface Anchoring Energy

Won-Jin Yoon and Kwang-Un Jeong (Chonbuk Nat'l Univ., Korea)

P1-88

Synthesis of Polymerizable Chiral Dopant for Cholesteric LC Display Application

Da Som Han, Hong Min Kim, Shin Woong Kang, and Myong-Hoon Lee (Chonbuk Nat'l Univ., Korea)

P1-89

Effect of the Doped Dye on Electro-Optical Properties of Thermal Induced LC Composite Display

Sujung Kim, Won-Jae Lee, Yong-Hae Kim, Chi-Sun Hwang, and Gi Heon Kim (ETRI, Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-90

Polymer Stabilized Reduced Graphene Oxide Enriched Blue Phase Liquid Crystals

R.K. Mishra, Ramesh Manda, G. Murali, Tae-Hyung Kim, Jee Hun Kim, Byoung-Suhk Kim, and Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

P1-91

Liquid-Crystalline Phthalocyanine Derivatives Bearing Oligosiloxane Moieties –Stabilization of Columnar Phases by Nanosegregation

Ryutaro Yamaoka and Funahashi Masahiro (Kagawa Univ., Japan)

P1-92

Scattering Free and Electrically Tunable Optically Isotropic Liquid Crystals Diffractor for Spatial Light Modulation

Ramesh Manda, Eun Jeong Shin, Srinivas Pagidi, R.K. Mishra, and Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

P1-93

High Transmittance of the Optically Isotropic Liquid Crystal (OILC) Device using Cholesteric LC

Eunjeong Shin, Chul Ho Park, Ramesh Manda, Murali G., Young Jin Lim, and Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

P1-94

Active Fine Laser Tuning in Broad Spectral Range with Dye Doped Cholesteric Liquid Crystal Wedge Cells by Temperature Control

Mi-Yun Jeong (Gyeongsang Nat'l Univ., Korea)

P1-95

Investigate the Relation of VHR to Flicker in Mobile Displays

Ji Li, Zhaozhe Xu, Lisen Wang, Hao Chu, Sheng Wang, Ku Hyun Park, Yun Bok Lee, Ran Tong, Chuncheng Che, and Seung Kyu Lee (Hefei BOE Optoelectronics Tech. Co., Ltd., China)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-96

Development of Hand-Held Type 3D Optical Profilometry Module

Heewon Park, Mugeon Kim, Kyung-Il Joo, Min-Kyu Park, Joonku Hahn, and Hak-Rin Kim (Kyungpook Nat'l Univ., Korea)

P1-97

Dependence and Minimize Condition of Image Flicker on Flexoelectric Coefficients and Interdigitated Electrode Structure in Fringe Filed Switching Liquid Crystal with Negative Dielectric Anisotropy

Jongyoon Kim, Hyungmin Kim, and Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

P1-98

Effect of Anchoring Energy on Alignment of Uniformly Lying Helix Configuration under Intermediated Pretilt Angle

Meixuan Piao, You-Jin Lee, Jae-Hoon Kim, and Chang-Jae Yu (Hanyang Univ., Korea)

P1-99

Asymmetric Space-Divided Pixel Design for Reflective Cholesteric Liquid Crystals Displays

Heekeun Lee, Nakcho Choi, Haeju Yun, Yeogeon Yoon, Kichul Shin, and Jangsu Kim (Samsung Display Co., Ltd., Korea)

P1-100

The Influence of Anchoing Energy on Cholesteric Liquid Crystal Process

Haeju Yun, Nakcho Choi, Heekeun Lee, Donchan Cho, Junho Song, and Hyunhwan Kim (Samsung Display Co., Ltd., Korea)

P1-101

Novel Plane-to-Line Switching LCD with Zigzag-Shaped Horizontal Electrode

Kwangsoo Bae, Jungsuk Bang, Haeju Yun, Pilsook Kwon, Minjeong Oh, Donchan Cho, and Hyeon Hwan Kim (Samsung Display Co., Ltd., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-102

Chiral Domains Formed by Achiral Photoresponsive Liquid Crystal Molecule

Sung-Wook Jeon, Seong-Yong Jo, and Suk-Won Choi (Kyung Hee Univ., Korea)

P1-103

Formation of Low Pretilt Angle in a LC Cell by Applying Electric-Field during LC Injection Process

Byung Wok Park, Tae-Hoon Choi, and Tae-Hoon Yoon (Pusan Nat'l Univ., Korea)

P1-104

On-Cell Retarder By Parylene for Vertical Alignment Liquid Crystals Displays

Sangji Park, Nakcho Choi, Heekeun Lee, Junho Song, and Hyunhwan Kim (Samsung Display Co., Ltd., Korea)

P1-105

Polarized Photoluminescence of Polymer Film Obtained by Photo-Polymerization of Fluorescence Monomer in Nematic Liquid Crystal Medium

Vijay Kumar Baliyan, Vineet Kumar, Aboozar Nasrollahi (Chonbuk Nat'l Univ., Korea), Jinsoo Kim (KRICT, Korea), and Shin-Woong Kang (Chonbuk Nat'l Univ., Korea)

P1-106

Crystallization and Localization of 6,13-bis(triisopropylsilylethynyl) Pentacene by a Liquid Crystalline Solvent

Seo-Yeon Lee, Hyun Bae Park, Jae-Hoon Kim, and Chang-Jae Yu (Hanyang Univ., Korea)

P1-107

Homogeneous Alignment Control of Nematic Liquid Crystals Using Linearly Polarized Visible Light

Vineet Kumar, Vijay Kumar Baliyan (Chonbuk Nat'l Univ., Korea), Heung-Shik Park, Jae Jin Lyu (Samsung Display Co., Ltd., Korea), Myong-Hoon Lee (Chonbuk Nat'l Univ., Korea), and Shin-Woong Kang (Hanyang Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-108

Cholesteric Liquid Crystal Infrared Light Window Shutter

Gyu Jin Choi, Hye Min Jung (Yeungnam Univ., Korea), Seung Hee Lee (Chonbuk Nat'l Univ., Korea), and Jin Seog Gwag (Yeungnam Univ., Korea)

P1-109

Smart Wireless Contact Lens for Ocular Theragnosis

Sanghyun Sung, Beomho Mun (KAIST, Korea), Do Hee Keum (POSTECH, Korea), Heeseung Wang (KAIST, Korea), Jae-Yoon Sim, Sei Kwang Hahn (POSTECH, Korea), and Keon Jae Lee (KAIST, Korea)

P1-110

Lyotropic Liquid Crystal Polymer as a Novel Alignment Layer

Bo Sung Kim (Korea Univ., Korea), Jae-Won Huh, Tae-Hoon Choi (Pusan Nat'l Univ., Korea), You Sang Son, Byoung-Ho Cheong, Jae Byung Park (Korea Univ., Korea), Tae-Hoon Yoon (Pusan Nat'l Univ., Korea), and Sung Tae Shin (Korea Univ., Korea)

P1-111

Analysis of Color Break Up Suppression by Complementary Color Backlights for Field-Sequential-Color Displays

Jae Byung Park (Korea Univ., Korea), Hyun Min Cho, Jong Hyuk Kang, Sung-Jin Hong (Samsung Display Co., Ltd., Korea), Bo Sung Kim, Byoung-Ho Cheong, and Sung Tae Shin (Korea Univ., Korea)

P1-112

Static and Dynamic Image Flicker in an FFS LCD

Seung-Won Oh, Jong-Min Baek, Jung-Wook Kim, and Tae-Hoon Yoon (Pusan Nat'l Univ., Korea)

P1-113

Distribution of Liquid Crystal Molecules in Relation with the Surface Anisotropy of Rubbed Polyimide Alignment Layer Characterized by Using Ellipsometry

Sung Yong Cho (Ajou Univ., Korea), Sang Uk Park (Ellipso Tech. Co., Ltd., Korea), Sung Mo Yang, and Sang Youl Kim (Ajou Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-114

Common Electrode Parameters Optimization to Improve Transmittance for Fringe-Field Switching Mode LCD

Weiyun Huang, Xiaojing Qi, Shan Gao, Yang Wang, and Tingliang Liu (Chengdu BOE Optoelectronics Tech. Co., Ltd., China)

P1-115

Electro-Optical Properties of Novel Pyrene-Fused Chromophorese

Jaehyun Lee, Hayoon Lee, Hyocheol Jung, Seokwoo Kang, and Jongwook Park (Catholic Univ. of Korea, Korea)

P1-116

Characteristic of Phosphorescent Organic Light-Emitting Diodes by Doping Profile with Double Emissive Layer Structure

Dongho Kim , Kanghoon Kim, Ukrae Lee, Daeho Song, and Sang Soo Kim (Sungkyunkwan Univ., Korea)

P1-117

Effect of the Slope Angle of the Pixel Definition Layer on the Light Emission Characteristics in Top-Emitting Organic Light-Emitting Diodes

Kyungnam Kang, Jungho Kim (Kyung Hee Univ., Korea), Hyesog Lee, and Byungchoon Yang (Samsung Display Co., Ltd., Korea)

P1-118

Construction of High-Fidelity Patterns of Solution-Processed Organic Light-Emitting Diodes Using Surface Modified Banks by Wettability

Hwi Kim, Hea-Lim Park, Se-Um Kim, Jeng-Hun Suh, Bo-Yeon Lee, and Sin-Doo Lee (Seoul Nat'l Univ., Korea)

P1-119

Hybrid Digital and Analog Drive Strategy for High Gray Level Flat Panel Display

Yuan Ji, Liping Man, Chengqi Wang, Feng Ran, and Meihua Xu (Shanghai Univ., China)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-120

Advanced Flexible Redundant Pixel Schemes for Large-Sized OLEDs

Ki-Wook Kim, Dong-Gyu Kim, and Jun-Hoo Choi (Samsung Display Co., Ltd., Korea)

P1-121

Direct Transfer of Flexible Moisture Barrier to Organic Light-Emitting Diodes for Facile Thin Film Encapsulation

Haksoo Lee, Youngki Chae, Jintaek Han, and Sung Min Cho (Sungkyunkwan Univ., Korea)

P1-122

Application of Semitransparent Nano-Tri-Metal-Layer Electrode for Flexible R, G, B, and W Organic Light-Emitting Diodes

Ho Won Lee, Song Eun Lee, Hyun Jung Baek, Tae Joon Yoon (Hongik Univ., Korea), Se Hyun Kim, Seung Soo Yoon (Sungkyunkwan Univ., Korea), and Young Kwan Kim (Hongik Univ., Korea)

P1-123

Improvement of Light Efficiency of Organic Light-Emitting Diode with Nano-Sized Morphology

Hyemin Jung and Jin Seog Gwag (Yeungnam Univ., Korea)

P1-124

Improvement of Lifetime on OLEDs by Using New Electron Transport Material

Da Young Park, Mi Young Ha (Soonchunhyang Univ., Korea), Dae Hyuk Choi, Jin Seok Choi (Heesung Material Ltd., Korea), and Dae Gyu Moon (Soonchunhyang Univ., Korea)

P1-125

Water Vapor Transmission Rate Measuring of Epoxy-Polyimide Encapsulated OLED Package

Chuyi Ye, Jun-Yeong Park, Yea-Na Suh, Oyunsaikhan Battur, and Cheol-Hee Moon (Hoseo Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-126

Viewing-Angle Dependency of the Slope Angle of the Micro-Meshed Indium Tin Oxide in Bottom-Emitting Organic Light-Emitting Diodes

Hyeonseok Sim, Kyungnam Kang, and Jungho Kim (Kyung Hee Univ., Korea)

P1-127

Efficiency Enhancement of Organic Light-Emitting Diodes (OLEDs) Using Periodic Nanohole Array

Minji Hwang, Chanho Kim, Hyekyung Choi, and Sung Min Cho (Sungkyunkwan Univ., Korea)

P1-128

Improvement of the Stability of Blue Phosphorescent Iridium(III) Complex Driven by Intramolecular Hydrogen Bond in Ancillary Ligand

Won-Sik Han (Seoul Women's Univ., Korea), Seungjun Yi, Yang-Jin Cho (Korea Univ., Korea), Jiwon Lee (Seoul Women's Univ., Korea), Ho-Jin Son, and Sang Ook Kang (Korea Univ., Korea)

P1-129

A Method on Choosing the Preferred Camera Resolution for Mura Compensation

Euiyeol Oh, Dae Keun Kim, Jong Sang Baek (LG Display Co., Ltd., Korea), and Yoonsik Choe (Yonsei Univ., Korea)

P1-130

Spontaneous Buckling in Flexible Organic Light-Emitting Devices for Enhanced Light Extraction

Yun-Hee Cho, Jae-Yeop Rho, Jong-Min Lim, Hyo-Joo Kong (Daewoo Technopark, Korea), and Hong-Goo Jeon (Kwangwoon Univ., Korea)

P1-131

Efficient Proper Polarity Host for Blue Thermally Activated Delayed Fluorescence Organic Light Emitting Diodes

Raju Lampande (Kyung Hee Univ., Korea), Ju Sik Kang (Korea Univ., Korea), Gyeong Heon Kim, Gyeong Woo Kim (Kyung Hee Univ., Korea), Dong Hoon Choi (Korea Univ., Korea), and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-132

Roll-to-Roll Fabrication of Silver-Nanowire/Silver-Grid Embedded Hybrid Flexible Transparent Electrode for OLEDs

Chanho Kim, Min Ha Kim, Yeong Eun Sul, and Sung Min Cho (Sungkyunkwan Univ., Korea)

P1-133

Analysis of Thermal Stress Effect on Blue Fluorescent Organic Light-Emitting Diodes for Device Stability

Song Eun Lee, Ho Won Lee, Hyun Jung Baek, Tae Joon Yoon, Ho Keun Jo, Tae Wan Kim, and Young Kwan Kim (Hongik Univ., Korea)

P1-134

Study of Organic Light-Emitting Diodes Efficiency with Fluorescence Dye Photoresist

Sooin Kim, Seungbeom Lee, Younghoon Kim, Musun Kwak, Mike Jun, and Inbyeong Kang (LG Display Co., Ltd., Korea)

P1-135

Analytical Method for Calculating the Potential Distribution of the Metal-Organic Interface

Gookbin Cho, Jungho Kim, Seungjun Lee, and Yongsup Park (Kyung Hee Univ., Korea)

P1-136

Emission Characteristics of Thermal Active Delayed Fluorescent Dopant 4CzIPN in Organic Light Emitting Diodes by Time Resolved Measurement

Sang-Min Lee, Cheol-Won Yoon (KETI, Korea), Byeong-Kwon Ju (Korea Univ., Korea), and Chan-Jae Lee (KETI, Korea)

P1-137

Novel Structure of Down-Conversion Phosphor Layer-Converted White Organic Light Emitting Diodes for High Color Rendering Index and Light-Extraction Efficiency

Seunghwan Lee, Bongsung Kim, Jonghoon Choi, and Sung Min Cho (Sungkyunkwan Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-138

High-Efficiency OLEDs with Thermally Activated Delayed Fluorescent Dopants

Sunyoung Sohn, Jimin Kwon (POSTECH, Korea), Bong Hyun Koh, Jae Yeul Baek, Hyun Chan Byun, Jae Hyun Lee, Dong-Seon Shin (Kyeong-Nam Science High School, Korea), Hyungju Ahn, Han-Koo Lee (Pohang Accelerator Lab., Korea), Jaeyoung Hwang, Yun-Hi Kim (Gyeonsang Nat'l Univ., Korea), and Sungjune Jung (POSTECH, Korea)

P1-139

Increase of Charge-Carrier Recombination Rate and Improved Luminance Efficiency Using F-nSAM in Organic Light-Emitting Diodes

Hye Rim Kim, Jung Eun Oh, Ho Keun Jo (Hongik Univ., Korea), Jin Woong Hong (Kwangwoon Univ., Korea), Sang-Geon Park (Silla Univ., Korea), and Tae Wan Kim (Hongik Univ., Korea)

P1-140

Synthesis of Host Materials for Blue Phosphorescent Organic Light-Emitting Diodes

Sung Yong Byeon and Jun Yeob Lee (Sungkyunkwan Univ., Korea)

P1-141

Enhanced Light Harvesting in Polymer Solar Cells Featuring Biomimetic Light Trapping Scheme

Yan-Qing Li and Jian-Xin Tang (Soochow Univ., China)

P1-142

Large-Scale Bar-Coating Alignment of Silver Nanowires for High Performance Transparent Electrodes

Seungse Cho, Saewon Kang, and Hyunhyub Ko (UNIST, Korea)

P1-143

Optimization of Resistance with Various Oxygen Particle Pressure in ITO Films

Solbaro-Kim, Byung-Jin Hwang, and Seung-ho Yang (HeeSung Metal Ltd., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-144

Embedded Silver Nanowire-Based Transparent Conducting Electrodes for Flexible OLED Devices

Min Ha Kim, Eun Jung, Yeong Eun Sul, and Sung Min Choi (Sungkyunkwan Univ., Korea)

P1-145

Effective Synthesis and Recovery of Silver Nanowires by Using Continuous Flow Tapered Reactor

Hyung Duk Yun, Duck Min Seo (UNIST, Korea), Min Yoeb Lee (Kyungpook Nat'l Univ., Korea), Soon Yong Kwon, and Lee Soon Park (UNIST, Korea)

P1-146

The Mechanical Stress Test Methods for Foldable Displays

Jung Bum Kwon, Chang Hoon Choi, and Ho Gil Kang (LG Display Co., Ltd., Korea)

P1-147

Enhanced Moisture Barrier Property and Flexibility of an Encapsulation Layer for Foldable OLED Displays

YoungKi Chae, Haksoo Lee, JinTaek Han, and Sung Min Cho (Sungkyunkwan Univ., Korea)

P1-148

Chitin Nanofiber Transparent Paper for Flexible Green Electronics

Jungho Jin (Univ. of Ulsan, Korea), Daewon Lee, Hyeon-Gyun Im, Yun Cheol Han, Eun Gyo Jeong (KAIST, Korea), Marco Rolandi (Univ. of California-Santa Cruz, U.S.A.), Kyung Cheol Choi, and Byeong-Soo Bae (KAIST, Korea)

P1-149

Preparation of Organic-Inorganic Hybrid Coating Layers on Plastic Substrate for Barrier Property Enhancement

Haesook Kim, Hana Ra, Jae Yong Jang, Jihae Eun, Hyun Gi Kim, and Sung Soo Kim (Kyung Hee Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-150

Fabrication of Transparent and Conducting Cu Nanowire Networks Electrode by Electrospun Nanofiber Mask Template

Tae Hyung Kim, Jee Hun Kim, R. K. Mishra, Young Cheol Chae, Han Sol Choi, Hyeong Gyun Ham, Jae-Wook Kang, and Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

P1-151

Self-Alignment of Micro-Spheres on Fast-Moving Ball Actuator

Ho Won Yoon, Kyung Hwan Yang, and MunPyo Hong (Korea Univ., Korea)

P1-152

Capacitive Force on Conductive Micro Sphere Actuation for Novel E-Paper

Kyung Hwan Yang, Ho Won Yoon, and MunPyo Hong (Korea Univ., Korea)

P1-153

Octopus-Inspired Smart Adhesive Pads for Transfer Printing of Semiconducting Nanomembranes

Hochan Lee, Doo-Seung Um, Youngsu Lee, Seongdong Lim, and Hyunhyub Ko (UNIST, Korea)

P1-154

Development of a Roll-to-Roll, Organic/Inorganic Hybrid Evaporation System for Flexible OLED Devices

Moonyong Lee, Minsoek Kim (GJM Co., Ltd., Korea), Kyoohee Woo (KIMM, Korea), Eungki Lee (Kongju Nat'l Univ., Kore), and Sin Kwon (KIMM, Korea)

P1-155

Research of Reliability of Metal Line in Flexible Display

Sheng Gao, Yucheng Liu, Bo Yuan, Xiaoyu Gao, and Xiuqi Huang (Kunshan New Flat Panel Display Tech. Center Co., Ltd., China)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-156

Ag-Grid Transparent Electrode with Low Reflectivity via Black Polymer Layer

Young-Chul Shin, Ji-Sub Park, Jun-Chan Choi, and Hak-Rin Kim (Kyungpook Nat'l Univ., Korea)

P1-157

High Optical Contrast Passive Matrix Electrochromic Display for Back-Light Compensation of Digital Camera

Jin Hwan Park, Ik Jang Ko, Yong Cheol Kim, Gyeong Woo Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P1-158

Compensation of Bending-Induced Retardation of Substrate Film by Coating Polymer with Opposite Birefringence

Jinyoung Jeong, Seungbin Yang, and Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

P1-159

Controlled Aqueous Synthesis of Ultra-Long Copper Nanowires for Stretchable Transparent Conducting Electrode

Byung Doo Choi, Cha Hwan Hwang, Joohyung Park, Jongkook Won, Seungwoo Yu, and Myung-Gil Kim (Chung-Ang Univ., Korea)

P1-160

Stretchable and Semi-Transparent Ag Electrodes Fabricated on Wavy-Patterned PDMS Substrate for Stretchable Electronics

Eun-Hye Ko, Sung-Hyun Park, Doo-Hee Kim, Hae-In Shin, Kyung-Su Cho, Jeong-Il Park, Sang-Mok Lee (Kyung Hee Univ., Korea), Tae-Woong Kim, Ki-Hyun Kim (Samsung Display Co., Ltd., Korea), and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-161

High Performance ITO/Cu/ITO Multilayer based on Transparent Flexible Heater

Sang Mok Lee, Sung Hyun Park, Doo Hee Kim, Hae In Shin, Eun Hye Ko, Kyung Su Cho, Jeong Il Park, Jae Gyeong Kim (Kyung Hee Univ., Korea), Sang Jin Lee, Jae Heung Lee (KRICT, Korea), and Han Ki Kim (Kyung Hee Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-162

Electrical, Optical, and Mechanical Properties of the Thermal Evaporated SnO_2/APC/SnO_2 Multilayer Cathode for Transparent Flexible AMOLED TV

Doo-Hee Kim, Eun-Hye Ko, Sung-Hyun Park, Hae-In Shin, Kyung-Su Cho, Jeong-Il Park, Jae-Gyeong Kim, Sang-Mok Lee, Man-Su Kim, Young-Chul Kim, and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-163

Transparent and Flexible Ag Nanowire Network Covered by Thin ITO Layer for Flexible Organic Light Emitting Diodes

Doo-Hee Kim, Eun-Hye Ko (Kyung Hee Univ., Korea), Ki-Hyun Kim, Tae-Wong Kim (Samsung Display Co., Ltd., Korea), and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-164

P-Type Li-Doped Cu_2O Films for p-n Heterojunction Thin Film Piezoelectric Nanogenerators

Kyung-Su Cho, Doo-Hee Kim, Sung-Hyun Park, Hae-In Shin, Eun-Hye Ko, Jeong-Il Park, Sang-Mok Lee, Jae-Gyeong Kim, and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-165

Comparison of Transparent ITO Films Sputtered on PET and Colorless PI Substrate Using Roll-to-Roll Sputtering System

Jeong-Il Park, Sung-Hyun Park, Sang-Mok Lee (Kyung Hee Univ., Korea), Ki-Il Hon (KOLON Central Research Park, Korea), and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-166

Highly Flexible, Transparent and Freestanding All Organic Transistors Modulated by Ionic Elastomer Dielectric

Kyeong Ah Nam, Do Hyung Park, Sangsik Park, and Do Hwan Kim (Soonsil Univ., Korea)

P1-167

Electrical and Optical Properties of Near UV Transparent Conductive ITO/Ga_2O_3 Multilayer Films Deposited by Long-Throw RF Magnetron Co-Sputtering

Jae-Kwan Kim and Ji-Myon Lee (Sunchon Nat'l Univ., Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-168

Roll-to-Roll Slot-Die Coating of 400 mm Width, Flexible, Transparent Ag Nanowire Films for Flexible Touch Screen Panels

Dong-Ju Kim, Hae-In Shin, Eun-Hye Ko (Kyung Hee Univ., Korea), Ki-Hyun Kim, Tae-Woon Kim (Samsung Display Co., Ltd., Korea), and Han-Ki Kim (Kyung Hee Univ., Korea)

P1-169

Synthesis of 15-nm-diameter Ag Nanowires with Aspect Ratio of 1000 Using High-Pressure Hydrothermal and its Application for Transparent Electrode

Hae-Won Jang, Yong-Hye Kim, Bu-Yeon Hwang, Ki-Wook Lee, and Jin-Yeol Kim (Kookmin Univ., Korea)

P1-170

Barrier Characteristics of Montmorillonite/Poly-Dthylenimine Bi-Layer Film via Layer-by-Layer Process

Kwangjoon Kim, Doyoon Lee, and Yongseog Kim (Hongik Univ., Korea)

P1-171

Thin Film Encapsulation Using Non-Covalently Functionalized Graphene for OLED Displays

Seung-Yeol Yang, Sun-Kyo Kim, and Yong-Seog Kim (Hongik Univ., Korea)

P1-172

Inkjet Printing Based Solution Processable Thin-Film Transistors for Flexible Display

Soo-Jung Kim (Korea Univ., Korea), In-Kyu You (ETRI, Korea), Heon Lee (Korea Univ., Korea), and Sung-Hoon Hong (ETRI, Korea)

P1-173

Flexible Transparent Oxide Thin-Film Transistor Using Laser Lift-Off

Han Eol Lee, Seung Hyun Lee, Tae-Hong Im, and Keon Jae Lee (KAIST, Korea)

P1-174

Low Power Phase Change Memory Array Assisted by Block Copolymer Self-Assembly

Beom Ho Mun, Byoung Kuk You, Do Hyun Kim, Tae Jin Kim, Yeon Sik Jung, and Keon Jae Lee (KAIST, Korea)

Poster Session I

Date: Aug. 24, 2016 (Wednesday)
Time: 13:00~14:30

P1-175

Flash-Induced Self-Limited Plasmonic Welding of Silver Nanowire Network for Transparent Flexible Energy Harvester

Jung Hwan Park, Dae Yong Park, and Keon Jae Lee (KAIST, Korea)

P1-176

Fabrication of Embedded Ag Grid in Flexible Polymer Matrix and its Application to Organic Solar Cell

Gyeong Seok Hwang, Seung Suk Baek, Seok Ho Hwang, and Byung-Doo Chin (Dankook Univ., Korea)

P1-177

Ultrathin Magnesium Oxide and Alumina Nanolaminated Structure for Flexible Moisture Multi Barrier

Ki Suk Kang, Jeong Hyun Kwon, Eun Gyo Jeong, and Kyung Cheol Choi (KAIST, Korea)

P1-178

Transparent, Flexible and Conductive Gas Permeation Barriers based on Mg-Doped AZO

Jeong Hyun Kwon, Seungyeop Choi, Yong Min Jeon, and Kyung Cheol Choi (KAIST, Korea)

P1-179

Electrical and Optical Properties of Aluminum doped Zinc Oxide Film Fabricated by Solution Process for Transparent Electrode

Jun Min Yoon, Tae Soo Jang, Chul Gyu Jhun, and Dong Chul Oh (Hoseo Univ., Korea)

P1-180

Rubbing Mura Analysis and Removal for the Vertical Aligned Nematic LC's

Liangyu Shi, Wanlong Zhang, Abhishek Kumar Srivastava, Vladimir G. Chigrinov, and Hoi Sing Kwok (The Hong Kong Univ. of Science and Tech., Hong Kong)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-1

The Effect of in-situ Oxygen Plasma Treatment of InOx Thin Film Transistors by PEALD

HwanJae Lee, Jeong-mu Lee, Seugn-Youl Kang, and Seong-Deok Ahn (ETRI, Korea)

P2-2

AC Device Characterization of High Mobility Bilayer Oxide Thin Film Transistor

Hyunsuk Woo, Taeho Kim, and Sanghun Jeon (Korea Univ., Korea)

P2-3

High Performance and High Stability Amorphous In-Sn-Zn-O Thin Film Transistors for Next-Generation Display Applications

Dae-Gyu Yang and Hyun-Suk Kim (Chungnam Nat'l Univ., Korea)

P2-4

A Semiconductor/Dielectric Bilayer Channel Structure for High Performance Solution-Processed Metal-Oxide Thin Film Transistors

Woobin Lee, Jaeyoung Kim, Jinsol Seo, and Yong-Hoon Kim (Sungkyunkwan Univ., Korea)

P2-5

Experimental and First-Principles Studies on High-Mobility Zinc Oxynitride Semiconductors

Jong-Heon Kim, Yang-Soo Kim, and Hyun-Suk Kim (Chungnam Nat'l Univ., Korea)

P2-6

Effects of Fluorine Incorporation during Dry Etching from CF_4 Gas on Electrical Properties of Top-Gate Bottom-Contact TFTs

Joonyong Choe, Hye-In Yeom, Seunghee Lee, Sang-Hee Ko Park (KAIST, Korea), and Chi-Sun Hwang (ETRI, Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-7

Solution-Processed Indium Zinc Oxide Thin-Film Transistors with Mo Electrode via Back-Channel Wet Etching Process

Sung Woon Cho, Myeong Gu Yun, Da Eun Kim, and Hyung Koun Cho (Sungkyunkwan Univ., Korea)

P2-8

High Performance of Dynamic Digital X-Ray Detector based on a-IGZO Thin Film Transistor

Ji-hwan Jung, Myeong-ho Kim, Jun-won Park and Duck-kyun Choi (Hanyang Univ., Korea)

P2-9

Improvement of Instability under NBIS Condition of Dual Active Layer In Amorphous InGaZnO TFTs

Jun-won Park, Myeong-Ho Kim, and Duck-Kyun Choi (Hanyang Univ., Korea)

P2-10

The Electrical Characteristics of Self-Aligned Coplanar a-IGZO TFT with DUV Irradiation based on Flexible Substrate.

Sung-ho Jeon, So-yang Choi (Hanyang Univ., Korea), Jun-hyung Lim (Samsung Display Co., Ltd., Korea), and Duck-kyun Choi (Hanyang Univ., Korea)

P2-11

A High Mobility of p-type SnO Thin Films Grown by Atomic Layer Deposition for Thin Film Transistors

Soo Hyun Kim, Jin-Sang Kim, and Seong Keun Kim (KIST, Korea)

P2-12

Oxygen Ratio Dependent of Positive Bias Stability and Recovery in Amorphous IGZO Thin-Film Transistors

Nuri On, Sangtae Kim, Kijun Lee, Hyeonju Seol, and Jae Kyeong Jeong (Hanyang Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-13

Reliable Performance of Short Channel Al-InSnZnO Thin Film Transistor Passivated with Al_2O_3 Deposited by Plasma-Enhanced Atomic Layer Deposition at low Temperature

Guk-Jin Jeon, Kwang-Heum Lee, Geum Bi Mun, Yunyong Nam, and Sang-Hee Ko Park (KAIST, Korea)

P2-14

Effective Electrical Transport Properties Control of In_2O_3 Thin Film Transistors via Mg Doping

Fengyun Wang, Hongchao Zhang, and Fukai Shan (Qingdao Univ., China)

P2-15

Effect of Stability of Amorphous IGZO Based Flexilbe TFT after NH_3 Plasma Treatment

Longlong Chen, Xifeng Li, Jifeng Shi, Xiang Sun, Shuai Zhang, and Jianha Zhang (Shanghai Univ., China)

P2-16

P/N Type Semiconductor Conversion of Heterojunction Oxide Semiconductor

Junhyeon Bae, Jaewon Na, Young Jun Tak, Hee Jun Kim, and Hyun Jae Kim (Yonsei Univ., Korea)

P2-17

Metal-Doped Protein Pyrolysis Effects on InGaZnO Field Effect Transistors

Sung-Joon Koh, Seok Daniel Namgung (Yonsei Univ., Korea), Junghyun An, Jaehun Lee, Ik Rang Choe, Ki Tae Nam (Seoul Nat'l Univ., Korea), and Jang-Yeon Kwon (Yonsei Univ., Korea)

P2-18

Correlation of Ba/Ti Ratio Variation in Electrical Properties of Solution-Processed $BaTiO_3$

Joyce Siening Lau and Byoungdeog Choi (Sungkyunkwan Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-19

Flexible FETs with DPP-Based Thin Film for Highly Sensitive Gas Sensor

Gi-Seong Ryu (Dongguk Univ., Korea), Dongyoon Khim (Imperial College, U.K.), and Yong-Young Noh (Dongguk Univ., Korea)

P2-20

Ultrahigh Mobility and Fast Ion Gated Transistors: Direct Evaporation on Ion Gel Based Blended Polymer Matrix

Benjamin Nketia-Yawson and Yong-Young Noh (Dongguk Univ., Korea)

P2-21

The Improvement of Instability for Oxide Thin-Film Transistors Using Hydrogen Peroxide

Sung Pyo Park (Yonsei Univ., Korea), Naomi. S. Kim (The Bishop's School, U.S.A.), and Hyun Jae Kim (Yonsei Univ., Korea)

P2-22

Hybrid Complementary Thin-Film Transistor Using Inorganic/Organic Active Layers

Hyeong Jun Cho, Dong-Hoon Lee, Min Su Kim, Eung-Kyu Park, So Young Lee (Sungkyunkwan Univ., Korea), Kee-Chan Park (Konkuk Univ., Korea), and Yong-Sang Kim (Sungkyunkwan Univ., Korea)

P2-23

Novel P-type Organic Thin-Film Transistors based on Phenyl and Phenylthienyl Derivatives

Hyungsug Kim and Choongik Kim (Sogang Univ., Korea)

P2-24

Novel Organic Semiconductor based on Arylacetylene Derivative as Solution Processable Organic Semiconductors for Organic Thin-Film Transistors

Hyekyoung Kim and Choongik Kim (Sogang Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-25

Threshold Voltage Control in Organic Thin Film Transistors by Modifying the Composition of Copolymer Dielectrics

Kwanyong Pak, Hyejeong Seong, Junhwan Choi (KAIST, Korea), Wan-Sik Hwang (Korea Aerospace Univ., Korea), and Sung Gap Im (KAIST, Korea)

P2-26

Synthesis of Fluorinated Copolymer Gate Insulator via Initiated Chemical Vapor Deposition (iCVD) for Organic Thin Film Transistor (OTFT)

Junhwan Choi, Hyejeong Seong, Kwanyong Pak, and Sung Gap Im (KAIST, Korea)

P2-27

Photolithography-Adaptive Polymer Semiconductors for High-Resolution Flexible Tandem Electronics

Han Wool Park, Keun-Yeong Choi (Soongsil Univ., Korea), Boseok Kang (POSTECH, Korea), Hee Jun Yoon (Gyeongsang Nat'l Univ., Korea), Hae Jung Hwang (Soongsil Univ., Korea), Kilwon Cho (POSTECH, Korea), Yun-Hi Kim (Gyeongsang Nat'l Univ., Korea), Hojin Lee, and Do Hwan Kim (Soongsil Univ., Korea)

P2-28

Electrical Properties Induced by Light Absorption of OTFTs based on TIPS-Pentacene/TiO_2 Nanocomposite Active Layer

Hyunji Shin, Dongwook Kim, Dokyeong Lee (Hongik Univ., Korea), Xue Zhang, Jaehoon Park (Hallym Univ., Korea), and Jong Sun Choi (Hongik Univ., Korea)

P2-29

Periodic Surface Formations of Poly-Si by DPSS Laser Annealing

Byoung-Ho Cheong (Korea Univ., Korea), Oleg N. Prudnikov (Novosibirsk State Univ., Russia), Jaeyong Kim, Young-Bok Kang (EO Technics Co., Ltd., Korea), Jae Byung Park, and Sung Tae Shin (Korea Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-30

Simultaneous Improvement of Electrical Characteristics and Stability for Amorphous Indium Gallium Zinc Oxide Thin-Film Transistor via Collodion Passivation Layer

Kwan Yup Shin, Young Jun Tak, Won-Gi Kim, Seonghwan Hong, Sung Pyo Park, and Hyun Jae Kim (Yonsei Univ., Korea)

P2-31

Low-Temperature Fabrication of Solution-Processed HfO_x Gate Insulator by Thermally Purified Solution Process

Jusung Chung, Young Jun Tak, Tae Soo Jung, Won-Gi Kim, Heesoo Lee, and Hyun Jae Kim (Yonsei Univ., Korea)

P2-32

Controlled-Growth and Alignment of Ultra-Flexible Organic Single Crystals on a Photochemically Patterned Polymer Layer

Jingu Kang, Jeong-Wan Jo, Insik Hwang (Chung-Ang Univ., Korea), Jaekyun Kim (Hanbat Nat'l Univ., Korea), and Sungkyu Park (Chung-Ang Univ., Korea)

P2-33

Driver Method for Improve Stability of Integrated a-Si H TFT Gate Driver Circuits on TFT-LCDs

Zhang Bin, Chen weitao, Zhang Liang, Wang Guangxing, and Dong Dianzheng (BOE Display Tech. Co., Ltd., China)

P2-34

Corrosion Mechanisms in Multi-Layer Metal Electrodes for Display Panels

Taekyung Yim, Yeogeon Yoon, and Jangsoo Kim (Samsung Display Co., Ltd., Korea)

P2-35

Multi-Level Memory Cell Comprising Oxide Thin Film Transistors.

Jae-Hee Jo, Seung-Hyuck Lee (Kyung Hee Univ., Korea), Hoon-Ju Chung (Kumoh Nat'l Inst. of Tech., Korea), and Seung-Woo Lee (Kyung Hee Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-36

Audible Noise Improvement through applied via Radial around the Pad.

Min-Cheul Kim, Joo-Hee Kwon, Hak-Su Kim, Seung-Hak Yang, Cheol-Woo Park, and Byeong-Koo Kim (LG Display Co., Ltd., Korea)

P2-37

VLID: Visible Light Identification System Using Smartphone for Door Lock Application

Seok-Jeong Song, Dowon Kim, Jeongrim Seo, Ki-Hyuk Seol, and Hyoungsik Nam (Kyung Hee Univ., Korea)

P2-38

Analysis of Linearity for Overdrive Technology in Voltage Domain

Dong-Hwan Jeon and Seung-Woo Lee (Kyung Hee Univ., Korea)

P2-39

In-Panel TFTs Photo Sensor in LCD Display

Joonggun Chong, Nakcho Choi, Jehong Choi, Yeo-Geon Yoon, and Jangsoo Kim (Samsung Display Co., Ltd., Korea)

P2-40

Cortical Analysis of Optogenetically Induced Absence Seizure by Flexible Electrode Array

Seung Hyun Lee, Jung Ho Shin, Han Eol Lee, and Keon Jae Lee (KAIST, Korea)

P2-41

Low-Complexity Visually Lossless Compression and its Design Implications

Dale Stolitzka, Gregory W. Cook, David M. Hoffman, and Wei Xiong (Samsung Display Co., Ltd., U.S.A.)

P2-42

ADS Mode LCD Panel Research of the DC Image Sticking and Built-in Electric Field

Weihao Hu, Rui Guo, Song Liu, Hengyu Yan, Liang Zhang, Xibin Shao,Ming Chen, Zhiming Meng, Baoxiao Lan, Yinlong Zhang, Jinhui Cheng, Chunbing Zhang, Weibiao Geng, Wei Hao, Zhankun Meng (Beijing BOE Display Tech. Co., Ltd., China)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-43

Development of In-line Sputtering System for Thinned LCD Application

Allen Chang and Yao-Chin Wang (Bay Zu Precision Co., Taiwan)

P2-44

Real-Time Monitoring of the Curing Process of Polymeric Resins by Using Inelastic Light Scattering Techniques

Soo Han Oh, Bong Jin Cho, Byoung Wan Lee, Min-Seok Jeong, and Jae-Hyeon Ko (Hallym Univ., Korea)

P2-45

A Polyimide-PDMS Hybrid Flexible/Stretchable Substrate Targeted for the Next Generation Wearable Devices

Sang Il Rhee, Yonjin Kim, and Jun Yeob Song (KIMM, Korea)

P2-46

Study on Multi Slot-Die Coating Process Based Multi Thin Film Coating by Roll-to-Roll System for Printed Electronics

M. K. Kim, C. G. Park, J. T. Kim, and D. H. Sung (Deviceeng, Korea)

P2-47

A New Sputtering System for High Performance Thin Film Transistor

Jae-chul Do, Wan-woo Park, Yong-suk Roh (Advanced Vacuum & Clean Equipment Optimizer Co., Ltd., Korea), Jae-han Ahn, Kwang-heum Lee, Sang-hee Ko Park (KAIST, Korea), Sung-haeng Cho (ETRI, Korea), and Byeong-cheol An (Advanced Vacuum & Clean Equipment Optimizer Co., Ltd., Korea)

P2-48

High Performance Carbon Nanotube Electron Beams with CNT Emitters for High Resolution Devices

Jung Su Kang, Ha Rim Lee, and Kyu Chang Park (Kyung Hee Univ., Korea)

P2-49

Research of Long Distance Two Barcode Type Image Analysis and Development in the Manufacturing System

Yongkwi Lee (Chungnam Nat'l Univ., Korea), Jihyun Son, Hyunjong Kim, Youngae Jeon (ETRI, Korea), (ETRI, Korea), HyunSoo Lim, and Hyunjung Gong (Chungnam Nat'l Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-50

Selective Sintering Process for Interconnection on Flexible Substrates

Seungman Kim, Yoonsang Shin, Yongjin Kim, Jae Hak Lee, and Jun Yeob Song (KIMM, Korea)

P2-51

Comparative Study on Mo, MoTi, and Ti as Copper Barrier Layers for Back Channel Etching InGaZnO TFT

Jeong-Hyun Kim, Byoung O Kim (Korea Aerospace Univ., Korea), Soon-Young Jeong, Soo-Hyun Kim (Yeungnam Univ., Korea), and Jong Hyun Seo (Korea Aerospace Univ., Korea)

P2-52

Two-Dimensional FDTD Simulation Study of SiO_2-Based Nano-Structures for Antireflection Applications

Bong Jin Cho, Ji Soo Park, Jung Min Hwang, and Jae-Hyeon Ko (Hallym Univ., Korea)

P2-53

Roll-to-Roll Sputtering System for Low-Stressed Flexible ITO Film

Sunyoung Sohn (POSTECH, Korea), Sang Kooun Jung, and Do Hoon Kim (ECC Co., Korea)

P2-54

The Study of H_2O Absorption on Organic Material

Jonghwan Park (Sungkyunkwan Univ., Korea), Byoungyong Kim (Samsung Display Co., Ltd., Korea), and Sangsoo Kim (Sungkyunkwan Univ., Korea)

P2-55

Solution-Free Large Area Printing by Linear-Mode Organic Vapor-Jet Printing

Jungmin Choi, Sungyeon Kim, and Seunghyup Yoo (KAIST, Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-56

Plane Source SMS Evaporation for RGB OLED TV

Changhun Hwang, Young Im, JJ Kim, HS Park, JS Choi, and YM Oh (Sunic System Co., Ltd., Korea)

P2-57

A Flexible Guided Weighted Median Filter for Stereo Matching

Wang Lizhen and Xia Jun (Southeast Univ., China)

P2-58

Image-Size Scalable Color Digital Holographic Table-Top Display

Keehoon Hong, Youngjun Lim (ETRI, Korea), Joonku Hahn (Kyungpook Nat'l Univ., Korea), Hyon-Gon Choo, and Jinwoong Kim (ETRI, Korea)

P2-59

Accommodation Behavior and its Effect on Visual Discomfort in Stereoscopic 3-Dimension and Super Multi-View Displays

Yeo-Hun Kim, Min-Koo Kang, Ki-Hyuk Yoon, and Sung-Kyu Kim (KIST, Korea)

P2-60

Comparisons of Retro-Reflectors for Polarization Modulation in the Aerial Imaging by Retro-Reflection

Kenta Onuki, Tomoyuki Okamoto, Syo Onose, Masao Nakajima, Norikazu Kawagishi, and Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

P2-61

Analysis on Viewing Window in Color Digital Holographic Display System

Yongjun Lim, Keehoon Hong, Hyon-Gon Choo, and Jinwoong Kim (ETRI, Korea)

P2-62

Controlling Hologram Size in Fresnel Propagation by Adaptive Deformation of Digital Holograms

Joongki Park, Min Sung Yoon, Hyon-Gon Choo, Jinwoong Kim, and Jonghyun Jang (ETRI, Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-63

Table-Top Multi-View Fog Display based on Viewing Window Technology

Jiman Yu, Junho Seok, Junghoo Yun, Changhwan Park, Hosung Jeon, and Joonku Hahn (Kyungpook Nat'l Univ., Korea)

P2-64

Volumetric Table Display with Linear Reciprocating Motion

Jinseung Sin, Geunseop Choi, Kyungdo Ham, and Joonku Hahn (Kyungpook Nat'l Univ., Korea)

P2-65

Cylindrical Directional Display with Multiple Spinning Slits

Geunseop Choi, Hosung Jeon (Kyungpook Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), and Joonku Hahn (Kyungpook Nat'l Univ., Korea)

P2-66

Occlusion Removal Considering the Erasing Part Using Variance Map

Kotaro Inoue, Min-Chul Lee, Naoki Konishi (Kyushu Inst. of Tech., Japan), and Myungjin Cho (Hankyong Nat'l Univ., Korea)

P2-67

Computation of Elemental Images in Convexly Curved Lenticular Display

Minwoo Jung, Chulwoong Lee, Sungjin Lim, and Joonku Hahn (Kyoungpook Nat'l Univ., Korea)

P2-68

Adaptive Microlens Array Using PVC/DBP Gels

Miao Xu and Hongwen Ren (Chonbuk Nat'l Univ., Korea)

P2-69

Multi-Layered Aerial LED Display by Utilizing Aerial Imaging by Retro-Reflection (AIRR) Twice

Nao Kurokawa, Kenta Onuki, Tomoyuki Okamoto, and Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-70

Advanced Depth Camera-Based Computer-Generated Integral Imaging System for Real Objects Using Polygon Model

Munkh-Uchral Erdenebat, Ji-Seong Jeong, Ki-Chul Kwon, Nam Kim, and Kwan-Hee Yoo (Chungbuk Nat'l Univ., Korea)

P2-71

Computer Generated Hologram for Real Scene Using Depth Camera

Yan-ling Piao, Ki-chul Kwon, Young-tae Lim, and Nam Kim (Chungbuk Nat'l Univ., Korea)

P2-72

Development of Holographic Transmission Grating for Head-Mounted Display Using Holographic Optical Elements

Hui-Ying Wu, Chang-Won Shin, and Nam Kim (Chungbuk Nat'l Univ., Korea)

P2-73

Lightweight Texture Mapping Method for Computer Generated Hologram by using Similarity of the Triangular Mesh

Yeong-Min Ji, Han-Ju Yeom, and Jae-Hyeung Park (Inha Univ., Korea)

P2-74

HMD Type Integral Imaging System by using Waveguide Configuration

Seong-Bok Kim and Jae-Hyeung Park (Inha Univ., Korea)

P2-75

Analysis of Influences of Optical Bonding on 3D Image Qualities in a Light Field Three-Dimensional Display

Jaejoong Kwon, Joowoan Cho, Yi Joon Ahn, Yeonmun Jeon, Hyungdon Na, Beomshik Kim, Sujung Huh, Insun Hwang, and Hye Yong Chu (Samsung Display, Co., Ltd., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-76

Stereoscopic Table Display

Jiseob Yoon, Sungjin Lim, and Joonku Hahn (Kyungpook Nat'l Univ., Korea)

P2-77

Computer-Generated Integral Imaging System Using Expanded Depth Images in Real Space

Min-Ho Song, Byung-Muk Lim, Ji-Seong Jeong, Munkh-Uchral Erdenebat, Ki-Chul Kwon, Nam Kim, and Kwan-Hee Yoo (Chungbuk Nat'l Univ., Korea)

P2-78

2D/3D Switchable Voltage Controlled LC Lens for the Full Parallax Light Field 3D Display

Sujung Huh, Yeonmun Jeon, Yijoon Ahn, Jaejoong Kwon, Hyungdon Na, Beomshik Kim, Joowoan Cho, Insun Hwang, Keunkyu Song, and Hye Yong Chu (Samsung Displays, Co., Ltd., Korea)

P2-79

Deep Edge-Based DFD Display with Long Viewing Distance and Large Screen

Yusuke Nagao, Haruki Mizushina, and Shiro Suyama (Tokushima Univ., Japan)

P2-80

The Effects of Crosstalk on ADS Mode High Frequency Drive Display

Honglin Zhang, Yingying Qu, Hebin Zhao, Dan Wang, and Xibin Shao (BOE Display Tech. Co., Ltd., China)

P2-81

The Study of Image Sticking for ADS Mode with Negative LC

Feifei Wang, Xibin Shao, Deqiang Liu (BOE Display Tech. Co., Ltd., China), Ping Song (BOE Tech. Group Co., Ltd., China), S. M. Lee, Honglin Zhang, and Hebin Zhao (BOE Display Tech. Co., Ltd., China)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-82

A High-Speed 2-in-1 Imaging Colorimeter for Display Testing in Production Lines

Martin Wolf and Jürgen Neumeier (Inst. Systems GmbH, Germany)

P2-83

21:9 Curved TV Design and Compensation for Preventing Side Effects

ChulGyu Jung, KiMan Kim, YuXin Bi, ZeZhou Yang, and RuoYu Ma (BOE Tech. Group Co., Ltd., China)

P2-84

Research of Light Source Shadow for Large Size TV

Qing Liu, Ruoyu Ma, Zezhou Yang, and ChulGyu Jung (BOE Tech. Group Co., Ltd., China)

P2-85

Analysis and Improvement of Line Zara in TFT-LCD

Shichao Wang, Hongpeng Lee, Jingpeng Lee, Haiyun Lin, Wei Wang, and Xuezhi Zhang (Beijing BOE Optoelectronics Tech. Co., Ltd., China)

P2-86

A New Method of Local Pixel Uniformity Measurement for LCDs and OLEDs

Me-You Kim, SeungWon Jung, and JinYong Kim (LG Display Co., Ltd., Korea)

P2-87

Analysis of Horizontal Stripes Caused by Inadequate Charge for Fringe Field Switching Liquid Crystal Display

Haiyun Lin, Bin Li, Dongzhao Li, Qi Xu, Shichao Wang, Yifeng Qin, Jingpeng Li, Wei Wang, and Xuezhi Zhang (Beijing BOE Optoelectronics Tech. Co., Ltd., China)

P2-88

Research on the Effect of Prism Angle on the Quality of Module Display

Jinhui Yang, Jeff Lai, Ying Zhu, Tianwen Wang, and Xuehui Wang (InfoVision Optoelectronics Corp., China)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-89

Improvement of AMOLED Display Quality by Suppressing the TFT Leakage Current

Bo Yuan, Yucheng Liu, Sheng Gao, Xiaoyu Gao, and Xiuqi Huang (KunShan New Flat Panel Display Tech. Co., Ltd., China)

P2-90

Effect of APF Polarizer on TFT Device Characteristics

Yue Shi, Shufeng Wang, Xiaobin Li, Hao Chu, Qiuyun Guo, Lisen Wang, Ku Hyun Park, Yun Bok Lee, Chuncheng Che, and Seung Kyu Lee (Hefei BOE Optoelectronics Tech. Co., Ltd., China)

P2-91

Improvement for Color Difference in Large Format Display Application

Yu Zhang, Hao Zhou, Wei Zhang, Junjie Zhao, Yanping Liao, Weihao Hu, and Xibin Shao (Beijing BOE Display Tech. Co., Ltd., China)

P2-92

Characteriztion of Flexible InGaN LEDs with Various Curvatures

Won-Sik Choi, Jun-Beom Park, Sin Jae Kim (KOPTI, Korea), June Key Lee (Chonnam Nat'l Univ., Korea), and Tak Jeong (KOPTI, Korea)

P2-93

Study of BLU Optical System for High Color Gamut LCD

Yun-ha Nam, Moon-Hwan Chang, Hyun-Hyang Kim (Samsung Display Co., Ltd., Korea), and Jang-kun Song (Sungkyunkwan Univ.,Korea)

P2-94

$Lu_3Al_5O_{12}:Ce^{3+}$-$Lu_2CaMg_2Si_3O_{12}:Ce^{3+}$ Solid-solution Phosphor for Enhanced Luminescent Properties and Cost Reduction

Yoon Hwa Kim, Sanjith Unithrattil, Seob Won, Van Hien Hoang, and Won Bin Im (Chonnam Nat'l Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-95

Upconversion YF_3:Yb^{3+}/Er^{3+} Nanocrystals with Both High Luminescence Intensity and Controlled Morphology

Jae Myeong Lee, G. Murali, Young Cheol Chae, Sandeep Kaur (Chonbuk Nat'l Univ., Korea), Dong-Kwon Lim (Korea Univ., Korea), and Seung Hee Lee (Chonbuk Nat'l Univ., Korea)

P2-96

Color-tunable Garnet $CaGd_2ZrSc(AlO_4)_3$:Ce^{3+}, Tb^{3+}, Pr^{3+} Phosphor and its Energy Transfer Mechanism for High Quality LED Lighting

Ha Jun Kim, Arunkumar Paulraj, Ngoc Hung Vu, and Won Bin Im (Chonnam Nat'l Univ., Korea)

P2-97

Design Factors for P-bonding Electrodes in GaN-based Light-emitting Diodes

Jun-Hyuk Choi, Seimin Kim, and Ja-Soon Jang (Yeungnam Univ., Korea)

P2-98

Non-resonant Vibrational Energy Harvester Using for UV-LED Devices

Min-Sang Kim, Seon-Jun Jang, Tae-Hee Ban, Gantulga Munkh-Enerel, and Cheol-Hee Moon (Hoseo Univ., Korea)

P2-99

Front Light Units for Reflective LCDs

Ming Zhu, Shou Ye, Kang Guo, Bing Ji, Guangkui Qin, Zezhou Yang, Yanyan Yin, Jing Lv, and Jikai Yao (BOE Tech. Group Co., Ltd., China)

P2-100

Reaction Mechanism of Eu^{2+}-doped Strontium Silica Nitride for Phosphor Synthesis

Tae Gil Lim, Yong Ha Choi, Myoung Su Jang, and Jae Soo Yoo (Chung-Ang Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-101

Optical Analysis of Hot-spot Phenomena in Light Guide Plate by Brightness Distribution Function

Jun Min Yoon (Hoseo Univ., Korea), Yeon Hak Jeong, Young Gil Kim, Seong Uk Hyeon (Starion Co., LLtd., Korea), and Chul Gyu Jhun (Hoseo Univ., Korea)

P2-102

Synthesis of $BaMgAl_{10}O_{17}:Mn^{2+}$, Eu^{2+} Phosphor for the Wide Color-gamut Display Application

Myoung Su Jang, Tae Gil Lim, Yong Ha Choi, and Jae Soo Yoo (Chung-Ang Univ., Korea)

P2-103

Fabrication of Transparent Ceramic Phosphor Plate for Laser Diode Application

Yong Ha Choi, Myoung Su Jang, Tae Gil Lim, and Jae Soo Yoo (Chung-Ang Univ., Korea)

P2-104

Self-Powered Flexible Light-Emitting Systems Using Flexible Piezoelectric Energy Harvester

Jae Hyun Han, Chang Kyu Jeong, Seung Hyun Lee, and Keon Jae Lee (KAIST, Korea)

P2-105

Nanoscale Tunable Triboelectric Generator via Block Copolymer Self-Assembly

Hee Seung Wang, Chang Kyu Jeong, and Keon Jae Lee (KAIST, Korea)

P2-106

A Reconfigurable Rectified Inorganic Flexible Nanogenerator via Solid-state Single Cystal Grown PMN-PZT

Dong Hyun Kim, Geon-tae Hwang, and Keon Jae Lee (KAIST, Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-107

Exciton Blocking Layer between Emission Layer and Electron Transport Layer for Improved Efficiency and Lifetime in Blue Phosphorescent Organic Light-emitting Diodes

Jeong Min Choi and Jun Yeob Lee (Sungkyunkwan Univ., Korea)

P2-108

Performance Improvement of Fluorescent Blue Device by Reducing the Hole Injection Barrier

Chao Min, Weiwei Li, Siran Zhou, Wei Ao, Song Liu, Yucheng Liu, Xiaoyu Gao, and Xiuqi Huang (Kunshan New Flat Panel Display Tech. Center Co., Ltd., China)

P2-109

Extremely Flexible and Flat Substrate Having Embedded Metal Electrode and Light Extraction Layer for OLED Lightings

Sunghoon Jung and Dogeun Kim (KIMS, Korea)

P2-110

Transparent Cathode for Highly Efficient Micro-Cavity Top-Emitting Organic Light Emitting Diodes

Mi Jin Park, Dae Hyun Ahn, Seong Keun Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P2-111

Chemical and Physical Changes of Tris(8-hydroxyquinolinato) Aluminium under Extreme Storage Conditions

Seob Shim, Jin-Tae Kim, Nak-Kwan Chung, Min-Woo Nam, Bo-Geum Lee, and Ju-Young Yun (KRISS, Korea)

P2-112

New Dibiphenylsilane Based Host Materials for Blue Phosphorescence OLEDs

Gyeong Woo Kim (Kyung Hee Univ., Korea), Doo Ri Yang (Wonkwang Univ., Korea), Yong Cheol Kim, Hye In Yang (Kyung Hee Univ., Korea), Jin Guo Fan, Quynh Pham Bao Nguyen, Kyu Yun Chai (Wonkwang Univ., Korea), and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-113

Synthesis and Properties of Organic Light Emitting Liquid Crystals

Sa-Wook Kim (Kumoh Nat'l Inst. of Tech., Korea), You-Jin Lee, Jae-Hoon Kim (Hangyang Univ., Korea), and E-Joon Choi (Kumoh Nat'l Inst. of Tech., Korea)

P2-114

Synthesis and Characterization of Organic Light Emitting Mesogenic Molecules

Myung-Ha Kim (Kumoh Nat'l Inst. of Tech., Korea), You-Jin Lee, Jae-Hoon Kim (Hangyang Univ., Korea), and E-Joon Choi (Kumoh Nat'l Inst. of Tech., Korea)

P2-115

Device Performance Comparison between 2nd and 3rd Order Micro-Cavity Top-Emitting Organic Light Emitting Diodes

Seong Keun Kim, Mi Jin Park, Dae Hyun Ahn, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P2-116

High Efficiency Hybrid White OLED with Blue Thermally Activated Delayed Fluorescent Material

Hye In Yang, Hyeong Woo Bae, Gyeong Woo Kim, Joon Beom Im, Gyeong Heon Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P2-117

Highly Efficient Deep-Blue Organic Light Emitting Devices Using Thermally Activated Delayed Fluorescent Emitter

Hyeong Woo Bae, Hye In Yang, Gyeong Woo Kim, Joon Beom Im, Gyeong Heon Kim, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P2-118

Thermally Activated Delayed Fluorescent Material with Multiple Acceptors for Highly Efficient Organic Light Emitting Diode

Kwang Jong Kim, Gyeong Heon Kim, Joon Beom Im, Ju Young Lee, Jae Yeol Lee, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-119

New Thermally Activated Delayed Fluorescence Materials with Ene-nitrile Acceptor Moiety

Joon Beom Im, Gyeong Heon Kim, Ji Su Moon, Ju Young Lee, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P2-120

Color Stable, Efficient White OLEDs - Optical Effect of Transparent Electrodes

Jaeho Lee, Eunhye Kim, Jinouk Song, Eungjun Kim, Jin Chung, and Seunghyup Yoo (KAIST, Korea)

P2-121

Characteristics of Organic Light-Emitting Diodes Using Fluorinated Photoresist Process on the Hole Transport Layer

O Jun Kwon (Univ. of Seoul, Korea), Jongchan Son, Seung Gun Chae, Dong Jun Lee, Jun Han Bae (Inha Univ., Korea), Jin-Kyun Lee (Univ. of Seoul, Korea), and Byung Jun Jung (Inha Univ., Korea)

P2-122

Efficient Triplet Harvesting in White Organic Light-Emitting Diodes with Non-Doped Blue Emitter

Yongwon Kwon, Jiho Sohn, and Changhee Lee (Seoul Nat'l Univ., Korea)

P2-123

Enhanced Light Out-coupling Efficiency of Flexible Organic Light Emitting Diodes

Akpeko Gasonoo, Chur-Hyun Shin, Min-Hoi Kim, Jae-Hyun Lee, and Yoonseuk Choi (Hanbat Nat'l Univ., Korea)

P2-124

Effect of Electron Injection Layer on the Lifetime of Organic Light-Emitting Diodes

Jiho Sohn, Yongwon Kwon, Jongseok Han, and Changhee Lee (Seoul Nat'l Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-125

Emission Characteristics of Carrier Blocking Structured PHOLEDs with Different Doping Location

Ukrae Lee, Kanghoon Kim, Dongho Kim, Wonhyeok Park, Hyunjun Lim, Deho Yune, Younghoon Kang, and Sang Soo Kim (Sungkyunkwan Univ., Korea)

P2-126

High Efficiency Blue Phosphorescent Organic Light- emitting Diodes Using n-type Common Layer

Geum Jae Yun, Yeon Kyu Jeong (Hoseo Univ., Korea), Tae Joon Yoon, Hyun Jung Baek, Song Eun Lee, Young Kwan Kim (Hongik Univ., Korea), and Woo Young Kim (McMaster Univ., Canada)

P2-127

Low-cost and Simple Fabrication of Thermally Aggregated Silver Nanoparticles for Light Extraction in Organic Light-Emitting Diodes

Jongseok Han (Seoul Nat'l Univ., Korea), Hyung-jun Song (Los Alamos Nat'l Lab., U.S.A.), Yongwon Kwon, Jiho Sohn, and Changhee Lee (Seoul Nat'l Univ., Korea)

P2-128

Continuous-jet Multi Nozzle Coater for Organic Thin Film Deposition

Kwon-Yong Shin, Mingyu Kang, Kyungtae Kang, Heuiseok Kang, Kwan-Hyun Cho, and Sang-Ho Lee (KITECH, Korea)

P2-129

Enhanced Compensation Timing for High Resolution OLED Display

Yu-na Noh (Kyungpook Nat'l Univ., Korea), Hak-su Kim (LG Display Co., Ltd., Korea), Jin-tae Kim, and Pyung Choi (Kyungpook Nat'l Univ., Korea)

P2-130

Highly Efficient Blue Thermally Activated Delayed Fluorescent Materials with a New Electron-donor Moiety

Gyeong Heon Kim, Joon Beom Im, Ju Young Lee, and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-131

Study of Light Extraction Efficiency of OLEDs with Nano-sized Diffractive Gratings

Tae-Bin Lim, Kwan Hyun Cho, Kyung-Tae Kang, Shin Ae Song, Ki Young Kim (KITECH, Korea), Yong-Hoon Kim (Sungkyunkwan Univ., Korea), and Yong-Cheol Jeong (KITECH, Korea)

P2-132

Foldable Circuits on the Surface Modified Paper Substrates and its Application for Top Emitting OLED

Sung Min Jo, Se Ho Choi, and Byung Doo Chin (Dankook Univ., Korea)

P2-133

The Effect of Blue Light in Display on Retinal Epithelial Cells

Jiyoung Moon, Jong-In Baek, Byeonghee Won, Young-Jun Seo, Seock-Hwan Kang, Hongshik Shim, Won-Sang Park, and Hye Yong Chu (Samsung Display, Co., Ltd., Korea)

P2-134

Influence of Lateral Current Caused by Hole Injection Layer in the AMOLED

Sun-kap Kwon, Kwan-soo Kim, Hyun-chul Choi (LG Display Co., Ltd., Korea), and Jang Hyuk Kwon (Kyung Hee Univ., Korea)

P2-135

The Novel Design of TADF Blue Dopant Materials based on OLEDs

M.H. Hwang, C.W. Lee, and B.D. Chin (Dankook Univ., Korea)

P2-136

Electronic Alteration of End-on Phenyl Groups of Bis-Triazolyl-Silanes: Electrontransport Materials for Blue Phosphorescent OLEDs

Mi-Rang Son, Jin-Hyoung Kim, Woo-Ri Bae, Ho-Jin Son, Sang Ook Kang, and Seungjun Yi (Korea Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-137

Comprehensive Spectroscopic Studies of Cis and Trans Isomers of Redphosphorescent Heteroleptic Iridium(III) Complexes

Jin-Hyoung Kim, Yang-Jin Cho, So-Yeon Kim, Ho-Jin Son, Dae Won Cho, Sang Ook Kang, and Seungjun Yi (Korea Univ., Korea)

P2-138

Investigating the Role of D-EML Architecture on Emission Efficiency in PHOLEDs

Younghoon Kang, Kanghoon Kim, Dongho Kim, Wonhyeok Park, Ukrae Lee, Hyunjun Lim, Deho Yune, and Sang Soo Kim (Sungkyunkwan Univ., Korea)

P2-139

High Power Conversion Efficiency of Organic Solar Cells with Energy Conversion Layer Using Inorganic Fluorescence Material.

Jae Yoon Lee, Dong Bin Yeo, Sang Hoon Chae, Chang-Bum Moon, Woo Young Kim, Jwa Yeon Kim, and Chul Gyu Jhun (Hoseo Univ., Korea)

P2-140

One Step Fabrication of Complex Orthogonal Pattern by Light Interference Lithography

Kang-Han Kim and Yong-Cheol Jeong (KITECH, Korea)

P2-141

Enhancement of Electroluminescence for the Green Organic Light-Emitting Diodes with Plasmonic Silver Nanoplates

Minwoo Nam, Seob Shim (Chung-Ang Univ., Korea), Sung Gyu Pyo (KRISS, Korea), Ju Young Yun, Bogeum Lee, and Nak-Kwan Chung (Chung-Ang Univ., Korea)

P2-142

Complex Spatial Light Modulation Structures on a Microscale

Hwi Kim (Korea Univ., Korea), Gun-Yeal Lee, Hyeonsoo Park, Joonsoo Kim, Eui-young Song, and Byoungho Lee (Seoul Nat'l Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-143

The Influence of TCO Sputtering Conditions on Cu(In,Ga) $(S,Se)_2$-Based Thin Film Solar Cells

Jae Yu Cho and Jaeyeong Heo (Chonnam Nat'l Univ., Korea)

P2-144

Highly Efficient Electron Transport Obtained by Doping Cross-linked PCBSD with Graphdiyne in Planar-Heterojunction Perovskite Solar Cells

Meng Li, Zhao-Kui Wang, and Liang-Sheng Liao (Soochow Univ., China)

P2-145

Enhancement Mechanisms of the Power Conversion Efficiency of Organic Photovoltaic Devices due to the Surface Plasmonic Resonance Effect of Au-WO_3 Nanocomposites

Yong Hun Lee, Dae Hun Kim, and Tae Whan Kim (Hanyang Univ., Korea)

P2-146

Color Analysis of DSC Using FDTD Simulation

Hyeong-Seok Kim, Jeonghoo Jo, Ganghu Lee (Korea Aerospace Univ., Korea), Joo-Cheol Lee (Dong-Jin Semichem Inc., Korea), and Myunghun Shin (Korea Aerospace Univ., Korea)

P2-147

Al Doped Zinc Oxide Thin Film Growth by CVD for TCO Application

Keon Woo Yang, Jung Sam Kim (Kunsan Nat'l Univ., Korea), Yong Ho Jung (Nat'l Fusion Research Inst., Korea), and Sung Ku Kwon (Kunsan Nat'l Univ., Korea)

P2-148

Influence of The Growth Temperature on The Properties of Tin Sulfide Thin Films Deposited by Thermal Evaporation

Dongha Lim, Gwang Yeom Song, Jae Yu Cho, and Jaeyeong Heo (Chonnam Nat'l Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-149

Improve Doping Efficiency in Al-doped ZnO Thin Films based on The Control of ALD Pulse Sequence

Gwang Yeom Song, Dongha Lim, Jae Yu Cho, and Jaeyeong Heo (Chonnam Nat'l Univ., Korea)

P2-150

Enhanced Efficiency of Planar Perovskite Solar Cells with Flat Cathode Interface Modified by a Doped Interfacial Layer

Yanhui Lou (Soochow Univ., China)

P2-151

Effect of the Incoherent Thick Substrate in Thin-Film Solar Cells Calculated by the Equidistant Thickness Method

Kyungnam Kang, Jungho Kim (Kyung Hee Univ., Korea), Sungchul Kim (Myongji Univ., Korea), Younho Han, and Seungin Baek (Samsung Display, Co., Ltd., Korea)

P2-152

Charge Generation Analysis of Thin Film Solar Cells with Direct Probing Method

Kunsik An, Jiyun Song, Seunghyun Rhee, Hyunho Lee, Jaehoon Kim, Jaeyeol Kim, Taesoo Lee, and Changhee Lee (Seoul Nat'l Univ., Korea)

P2-153

Comparison of Spin-Coated and Sputtered ZnO Buffer Layers for Inverted Organic Solar Cells

Sung-Hyun Park, Eun-Hye Ko, Doo-Hee Kim, Hae-In Shin, Kyung-Su Cho, Jeong-Il Park, Sang-Mok Lee, Jae-Gyeong Kim (Kyung Hee Univ., Korea), Yoon-Young Choi (KOLON Central Research Park, Korea), and Han-Ki Kim (Kyung Hee Univ., Korea)

P2-154

Functionalization of Conductive Oxides by Self-Assembled Monolayers for OHPV

P. Lang, J-Y Piquemal, R. Wang A. Lombana, N. Battaglini (CNRS Universite Paris Diderot, France), and Furong Zhu (Hong Kong Baptist Univ., Hong Kong)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-155

The Effect of Thermal Degradation in the Inverted Organic Solar Cells Depend on the Different Crystalline Polymers

Hyunho Lee, Jiho Sohn, Jiyun Song, Kunsik An, Jaehoon Kim, Seunghyun Rhee, Jaeyoul Kim, Priyanka Tyagi, and Changhee Lee (Seoul Nat'l Univ., Korea)

P2-156

Slot-Die Coated Ag Nanowire Passivated by InSnTiO Layer for Flexible Organic Solar Cells

Hae-In Shin, Doo-Hee Kim, Eun-Hye Ko, Sung-Hyun Park, Jae-Gyeong Kim, Sang-Mok Lee, Kyung Su Cho, Jeong Il Park (Kyung Hee Univ., Korea), Yong-Jin Noh, Seok-In Na (Chonbuk Nat'l Univ., Korea), and Han-Ki Kim (Kyung Hee Univ., Korea)

P2-157

Characteristics of Ga-Codoped AZO Film Prepared by Magnetron Sputtering for $Cu_2ZnSn(S, Se)_4$ Thin Film Solar Cells

Se Won Seo (Seoul Nat'l Univ., Korea), Jung Woo Seo (Korea Univ., Korea), Ik-Jae Park, Min-Ah Park, Jae-Hyun Park, Hee Chan Joo, Dong Seok Lee, Seong Eun Hur, and Jin Young Kim (Seoul Nat'l Univ., Korea)

P2-158

Fabrication of Ultra-Thin OLED with Conventional On-Cell TSP

In-Young Han, Hwan-Hee Jeong, and Yeon-tae Kim (Samsung Display Co., Ltd., Korea)

P2-159

Study on Pattern Design for Large Scale Touch Screen Panel

Youngsoo No, In young Han, Hwanhee Jeong, Kicheol Kim, Taejon Kim, and Yeontae Kim (Samsung Display, Co., Ltd., Korea)

P2-160

Study on Force Touch Sensor Pattern

Kyungsu Lee, Youngsoo No, In young Han, Hwanhee Jeong, Kicheol Kim, Taejoon Kim, and Yeontae Kim (Samsung Display, Co., Ltd., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-161

Capacitive Touch Screen Sensing Method Using Differential Reception Technique in Frequncy Domain

Seunghee Han and Yuseok Kang (Gyeonggibuk Science High School, Korea)

P2-162

Multi-Layered IR Sensors for Accurate Spatial (3D) Touch

Young Seok Kim, Chan-Jae Lee (KETI, Korea), Hwan Seog Yong, and Yong-Chul Kim (RNDPLUS Co., Ltd., Korea)

P2-163

IR Based Air Touch with Visual Hapic Recognition

Young Seok Kim, Chan-Jae Lee (KETI, Korea), Hwan Seog Yong, and Yong-Chul Kim (RNDPLUS Co., Ltd., Korea)

P2-164

Capacitive Sensor Pixel Circuit with Single Transistor

In Hye Kang, Min Taek Hong, Jong Mo Lee, and Byung Seong Bae (Hoseo Univ., Korea)

P2-165

All Solution-Processed Quantum Dot Light Emitting Diode with Printed Silver Electrode

Yunsoon Ka, Namhun Baek, Byambaa Erdenedagva, Young-Jin Kwack, Hunho Kim, and Woon-Seop Choi (Hoseo Univ., Korea)

P2-166

Fabrication Process and Characteristics of Quantum-Dot Light-Emitting Diodes with RF-Sputtered Metal-Oxide Electron-Transporting Layers

Dong-Jin Kim and Ho-Nyeon Lee (Soonchunhayng Univ., Korea)

P2-167

Effects of Multi-Colored Quantum Dot Configurations on Bias-Dependent Spectral Variations of Full-Color Electroluminescent Devices

Chang-Yeol Han, Ki-Heon Lee, Jung-Ho Jo, Eun-Pyo Jang, Min-Seok Kim, and Heesun Yang (Hongik Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-168

Fabrication of Electrically-Driven White Lighting Device based on Cu-Ga-S Quantum Dots

Eun-Pyo Jang, Jong-Hoon Kim, Chang-Yeol Han, Ki-Heon Lee, Bu-Yong Kim, and Heesun Yang (Hongik Univ., Korea)

P2-169

Tunable White Fluorescent Manganese-Doped Copper Gallium Sulfide Quantum Dots for White Light-Emitting Diode Fabrication

Jong-Hoon Kim, Jung-Ho Jo, Jong-Woo Shin, and Heesun Yang (Hongik Univ., Korea)

P2-170

Bright and Efficient White Hybrid Quantum Dot Light-Emitting Devices by Adjusting Polymer Distribution in Quantum Dots

Jae-Sung Lee, Sang-Hyup Kim, Jun-Woo Lee, Byoung-Ho Kang, Sang-Won Lee, Sai-Anand Gopalan, Sae-Wan Kim, Ju-Seong Kim, Jin-Beom Kwon, and Shin-Won Kang (Kyungpook Nat'l Univ., Korea)

P2-171

Fabrication of Brihgtly Deep Blue Light-Emitting Diode from Carbon Dot as Luminous Materials

Hong Hee Kim, Yeonju Lee (KIST, Korea), Cheolmin Park (Yonsei Univ., Korea), Do Kyung Hwang, and Won Kook Choi (KIST, Korea)

P2-172

QD/Polymer Hybrid Light Emitting Electrochemical Cells

Jeehye Yang, Jong Ik Lee, Seunghan Kim, Seok Hwan Kong, Jihye Shin, and Moon Sung Kang (Soongsil Univ., Korea)

P2-173

Efficient Emission from Nanocrystals of Formamidinium Lead Bromide

Yonghun Shin, Yeonkyung Lee, and Changhee Lee (Seoul Nat'l Univ., Korea)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-174

Enhanced Optical Properties of Color Filters with Quantum Dots for Reflective Displays

Sae Yeon Yoo (Hoseo Univ., Korea), Dong Kun Lee, Jang-Kun Song (Sungkyunkwan Univ., Korea), and Chul Gyu Jun (Hoseo Univ., Korea)

P2-175

Enhanced Efficiency in Quantum Dot Light-Emitting Diodes by Mixing Cesium Carbonate in Electron Transport Layer

Jaeyun Kim (The Univ. of Seoul, Korea), Jin Young Yun (Korea Univ., Korea), and Jeonghun Kwak (The Univ. of Seoul, Korea)

P2-176

Shell Thickness Dependent Performance of Electroluminescent Devices based on CdSe/$Zn_{1-X}Cd_XS$ Core/Shell Heterostructured Quantum Dots

Byeong Guk Jeong, Jun Hyuk Chang, Yo Han Kim, and Wan Ki Bae (KIST, Korea)

P2-177

Recent Trend of Quantum Dot Solar Cell and Combination of Perovskite

Gihwan Kim, Jin Young Kim (UNIST, Korea), and Edward. H Sargent (Univ. of Toronto, Canada)

P2-178

Permanently Heat/Moisture Stable Siloxane Encapsulated Quantum Dot Nanocomposite

Hwea Yoon Kim, Junho Jang, Gwang-Mun Choi, and Byeong-Soo Bae (KAIST, Korea)

P2-179

Hyper Spectral Colorimetric Technology

Y.Izaki, T.Okasaki, K.Komatsu, K.Nishimura, M.Higashimura, Y.Kamei, and S.Fujii (Topcon Technohouse Corp., Japan)

Poster Session II

Date: Aug. 25, 2016 (Thursday)
Time: 13:00~14:30

P2-180

Two Metal-Air-Dielectric Waveguides for Complex Modulation of Light

Jongwoo Hong, Eui-Young Song, Joonsoo Kim (Seoul Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), and Byoungho Lee (Seoul Nat'l Univ., Korea)

P2-181

Phase Modulation in MIM Plasmonic Waveguide Using Dielectric Surface Gratings

Sang-Eun Mun, Eui-Young Song (Seoul Nat'l Univ., Korea), Hwi Kim (Korea Univ., Korea), and Byoungho Lee (Seoul Nat'l Univ., Korea)

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17. Transparent and Flexible Displays	
Chair	Dr. Yeon Gon Mo (Samsung Display Co., Ltd., Korea)
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IMID 2016 Invited Papers

A1-1 Advanced Near-to-Eye Displays and Sensors by OLED Microdisplays
Uwe Vogel, Bernd Richter, Olaf Hild, Philipp Wartenberg, Karsten Fehse, Matthias Schober, Stephan Brenner, Judith Baumgarten, Peter König, Beatrice Beyer, Gerd Bunk, Steffen Ulbricht, Christian Schmidt, Matthias Jahnel, Elisabeth Bodenstein, Stefan Saager, Christoph Metzner, and Volker Kirchhoff (Fraunhofer Inst. for Organic Electronics, Electron Beam and Plasma Tech. FEP, Germany)

A1-4 New Architectures for OLED Displays: How to Increase Lifetime and Resolution
Michael S. Weaver, Woo-young So, Michael G. Hack, and Julie J. Brown (Universal Display Corp., U.S.A.)

A1-5 Integration Strategy For Flexible and Stretchable Solid State Display
Muhammad Mustafa Hussain, Amir Hanna, Kelvin Chow, and Marlon Diaz (King Abdullah Univ. of Science and Tech., Saudi Arabia)

B2-1 Superior Electron Transport Properties of ZnON Semiconductors: An Extensive Study on the Materials Characteristics and the Associated Field Effect Devices
Yang Soo Kim and Hyun-Suk Kim (Chungnam Nat'l Univ., Korea)

B2-2 High Mobility Oxide Materials and Their Applications
Yuki Tsuruma, Emi Kawashima, Kazuyoshi Inoue, and Koki Yano (Idemitsu Kosan Co., Ltd., Japan)

B2-3 What have been clarified for Defects in a-In-Ga-Zn-O and What we can obtain?
Toshio Kamiya, Keisuke Ide, Hideya Kumom, and Hideo Hosono (Tokyo Inst. of Tech., Japan)

C3-1 Immersive and Interactive Augmented and Virtual Reality Devices with Intel® RealSenseTM Technology
Achintya K. Bhowmik (Intel Corp., U.S.A.)

C3-2 Holographic Application in AR/VR and SLM(Spatial Light Modulator) Development
Wilbur Wei-Chen Chiang (Selcos Co., Ltd., Korea), Po-Sheng Chiu (Nat'l TsingHua Univ., Taiwan), and Cheng-Huan Chen (Nat'l Tung Univ., Taiwan)

D4-1 Additive Printing of Flexible Electronics for Sensing
Ping Mei (Palo Alto Research Center, U.S.A.) and Tse Nga Ng (Univ. of California San Diego, U.S.A.)

D4-2 Megahertz Flexible Low-Voltage Organic Thin-Film Transistors
Hagen Klauk (Max Planck Inst. for Solid State Research, Germany)

D4-3 Patterned Top-Contact Fabrication for Short-Channel Organic Transistors
Takafumi Uemura (Osaka Univ., Japan)

D4-4 Small Molecule Organic Field-Effect Transistors for Light Detection and Thin Film Circuits: Effects of Device Structure and Interface Modification
Yingquan Peng (China Jiliang Univ., China), Wenli Lv, Xiao Luo, Yao Li, Lei Sun (Lanzhou Univ., China), Ying Wang, Sunan Xu, Ying Tang, and Yi Wei (China Jiliang Univ., China)

E5-1 Graphene for Bionic Contact Lens Sensors and Displays
Sangkyu Lee (Seoul Nat'l Univ., Korea) and Byung Hee Hong (LG Electronics Co., Ltd., Korea)

E5-2 Toward Graphene OLED Display
Jaehyun Moon, Jin-Wook Shin, Jun-Han Han, Hyunsu Cho, Byoung-Hwa Kwon, Nam Sung Cho (ETRI, Korea), Kisoo Kim, Seungmin Cho (Hanwha Techwin R&D Center, Korea), and Jeong-Ik Lee (ETRI, Korea)

E5-3 Infrared Plasmonics in Graphene
Min Seok Jang (KAIST, Korea)

F6-5 Characterization of the On-Screen Performance of Curved AMOLEDs
Jyrki Kimmel (Nokia Technologies, Finland)

G7-2 Solution-Processed Tandem Organic Light-Emitting Devices
Yong-Jin Pu, Takayuki Chiba, Satoru Ohisa, and Junji Kido (Yamagata Univ., Japan)

G7-3 Universal Charge Generation Layers for Solution Processed Tandem OLEDs
Stefan Höfle, Min Zhang, and Alexander Colsmann (Karlsruhe Inst. of Tech., Germany)

H8-1 A High Image Quality Eco-Display Using Stencil-FSC Methods
Fang-Cheng Lin and Yi-Pai Huang (Nat'l Chiao Tung Univ., Taiwan)

H8-2 Ideal Retarder with Negative Dispersion of Birefringence and Wide Field-of-View
Ji-Hoon Lee (Chonbuk Nat'l Univ., Korea)

H8-3 Polarized Backlights based on Aligned Nanorods: a New Approach for LCDs with High Power Efficiency
Kristiaan Neyts, Michiel Callens, Mohammad Mohammadimasoudi, and Jeroen Beeckman (Ghent Univ., Belgium)

H8-4 Advanced Liquid Crystal Materials for FFS Mode
Chen ChaoYuan, Wenming Han, Haibin Xu, and Wenyang Ma (Jiangsu Hecheng Display Tech. Co., Ltd., China)

A9-1 OLED Microarrays as Versatile Light Sources for Biophotonics
Anja Steude, Andrew Morton, Caroline Murawski, and Malte C. Gather (Univ. of St Andrews, U.K.)

A9-3 Laser Micronanostructuring for High-Performance Organic Optoelectronic Devices
Hong-Bo Sun, Yue-Feng Liu, Yan-Gang Bi, and Jing Feng (Jilin Univ., China)

A9-4 Unlocking the Efficiency Potential of Metal Halide Perovskite Light Emitting Devices
Ross A. Kerner, Zhengguo Xiao, and Barry P. Rand (Princeton Univ., U.S.A.)

B10-1 Chemical Reaction-Mediated High Mobility Metal Oxide Semiconductor for TFT Application
Yeonwoo Shin, Sang Tae Kim, and Jae Kyeong Jeong (Hanyang Univ., Korea)

B10-2 Studies on High Mobility Oxide TFTs
Meili Wang, Yun Qiu, Peilin Zhang, Dan Wang (Beijing BOE Display Tech. Co., Ltd., China), and Liangchen Yan (BOE Tech. Froup Co., Ltd., China)

C11-1 New Insights into Foveated Rendering
Joohwan Kim, Anjul Patney, Marco Salvi, Anton Kaplanyan, Chris Wyman, Nir Benty, Aaron Lefohn, and David Luebke (Nvidia, U.S.A.)

C11-2 Redesigning Vision: Achieving Super Human Eyesight by Head Mounted Displays
Kiyoshi Kiyokawa (Osaka Univ., Japan)

C11-3 Recent Advances in High Brightness Full Color OLED Microdisplay for AR/VR
Tariq A. Ali, Ilyas I. Khayrullin, Evan P. Donoghue, Ihor Wacyk, Kerry Tice, Fridrich Vazan, Laurie Sziklas, and Amal P. Ghosh (eMagin, U.S.A.)

D12-1 Molecular Structure Dependent Bias Stress Stability in Organic Thin-Film Transistors
Boseok Kang, Byungho Moon, Hyun Ho Choi, and Kilwon Cho (POSTECH, Korea)

D12-2 Physical and Compact Modeling of Organic Diodes and Transistors
Gilles Horowitz (Ecole Polytechnique, France)

D12-3 Electrical Transport Mechanisms for Organic Field Effect Transistor based on Monolayer Small Molecule
Chao Jiang and Jiawei Wang (Nat'l Center for Nanoscience and Tech., China)

D12-4 Boosting the Electron Mobility of Solution-Grown Organic Single Crystals via Reducing the Amount of Polar Solvent Residues
Hanying Li (Zhejiang Univ., China)

E13-1 Emerging Optical Properties of 2D Semiconductors: a Hint for Valleytronics
Hualing Zeng (Univ. of Science and Tech. of China, China), and Xiaodong Cu (The Univ. of Hong Kong, Hong Kong)

F14-1 Development of the All-Print Manufacturing Technology of the High Resolution Flexible TFT for Flexible Display
Toshihide Kamata (Nat'l Inst. of Advanced Industrial Science and Tech., Japan), Shinichi Nishi, and Yasuyoshi Mishima (Japan Advanced Printed Electronics Tech. Research Association, Japan)

F14-2 Foldable AMOLED with High Flexibility by Simplified Structure
Yung-Hui Yeh, Jia-Chong Ho, Glory Chen, Chen-Chu Tsai, Chih-Chung Liu, Ming-Hua Yeh, Cheng-Chung Lee, and Janglin Chen (Display Tech. Center/Industrial Tech. Research Inst., Taiwan)

G15-1 Latest Development of Polymer Light-Emitting Material for Printed OLED
Takeshi Yamada (Sumitomo Chemical Co., Ltd., Japan)

G15-2 Inkjet Technology for OLED Mass Production: TFE to RGB
Christopher T. Brown (Kateeva Inc., U.S.A.)

H16-1 Stabilized Azo Dye Photo-Alignment Layer for Liquid Crystal Displays
Hoi-Sing Kwok, Man-Chun Tseng, Abhishek Kumar Srivastava, and Vladimir Chigrinov (The Hong Kong Univ. of Science and Tech., Hong Kong)

H16-2 Fast High Contrast Low Power Photoaligned Ferroelectric LCD: New Challenge
Vladimir Chigrinov (Hong Kong Univ. of Science and Tech., Hong Kong)

A17-1 OLED Light Out-Coupling: Transparent Electrode and Dipole Orientation Effects
Chung-Chih Wu, Chun-Yang Lu, Min Jiao, and Wei-Kai Lee (Nat'l Taiwan Univ., Taiwan)

A17-4 Outcoupling Enhanced Flexible OLEDs on Nanostructured Plastic Substrates
Jian-Xin Tang and Yan-Qing Li (Soochow Univ., China)

B18-1 High Mobility Oxide TFT for the Application to the High Resolution Active Matrix Display
Sang-Hee Ko Park, Yujin Kim, Kwang-Heum Lee, Geumbi Mun, Guk-Jin Jeon, Jae-Han Ahn (KAIST, Korea), Jae Chul Do, and Wan Woo Park (Advanced Vacuum and Clean Equipment Optimizer, Korea)

B18-2 High Resolution Display Using High Electrical and Reliable Performance Oxide Thin Film Transistors
Jun Hyung Lim, Keunkyu Song, Masataka Kano, Yeonkeon Moon, Hyunsup Lee, HyungIl Jeon, Junghun Noh, Sang Hee Jang, Byung-Seok Choi, Hye Yong Chu, and Junho Song (Samsung Display Co., Ltd., Korea)

B18-3 High Mobility Oxide Thin-Film Transistors with In-W-Zn-O Channel
Mamoru Furuta, Daichi Koretomo, Yuta Hashimoto (Kochi Univ. of Tech., Japan), Kenichi Watatani, Miki Miyanaga, and Hideaki Awata (Sumitomo Electric Industries, Ltd., Japan)

C19-1 Printable Cu Electrodes for Flexible Thin-Film Electronics
Zijian Zheng (The Hong Kong Polytechnic Univ., Hong Kong)

E21-1 Optoelectronics with Two-Dimensional Atomic Crystals
Thomas Mueller (Vienna Univ. of Tech., Austria)

E21-2 Optical and Electro-Optical Properties of 2D Semiconductors
Goki Eda (Nat'l Univ. of Singapore, Singapore)

E21-3 Luminescence Properties in Atomically Thin Two-Dimensional Material and its Heterostructure
Kazunari Matsuda (Kyoto Univ., Japan)

F22-1 Development of Flexible Polymer Complementary Integrated Circuits
Yong-Young Noh (Dongguk Univ., Korea)

F22-4 Controlling the Crystallization of Small Molecule Organic Semiconductors Using Solution Shearing and Their Application to Field-Effect Transistors and Circuits
Steve Park (KAIST, Korea), Gaurav Giri (Univ. of Virgia, U.S.A.), Ioannis (John) Kymissis (Columbia Univ., U.S.A.), Yongtaek Hong (Seoul Nat'l Univ., Korea), and Zhenan Bao (Stanford Univ., U.S.A.)

G23-1 Novel Solution-Processable Materials for Efficient Long-Lived Phosphorescent OLEDs
Anna Hayer, Philipp Stoessel, Christian Ehrenreich, Nils Koenen, Florian Maier-Flaig, Holger Heil, Peter Levermore, Beate Burkhart, Katja Stegmaier, Edgar Böhm, and Herwig Buchholz (Merck KGaA, Germany)

G23-2 Solution-Processed Multi-layer OLEDs Utilizing Photo-Crosslinkable Azide-Containing Hole-Transporting Polymers
Joon Woo Park, Hyeong Jun Kim, and Bumjoon J. Kim (KAIST, Korea)

G23-3 Highly Efficient Injection Layer for Solution Processed OLED
Jun Liu, Yang Wang, Zhiyuan Min, Xinkai Wu, and Gufeng He (Shanghai Jiao Tong Univ., China)

G23-4 Development of Quantum Dots as Electroluminescent Material for Solution Processable Display Applications
Sung Hoon Jo (KETI, Korea), Sungoh Lim (Dankook Univ., Korea), Min suk Oh, Jiwan Kim, and Chul Jong Han (KETI, Korea)

H24-1 Novel LC Materials for Non-Display Applications
Michael Wittek, Carsten Fritzsch, and Johannes Canisius (Merck KGaA, Germany)

H24-2 Dielectrophoretic Manipulation of Liquid Crystal Droplets and Display Applications
Jang-Kun Song and Bomi Lee (Sungkyunkwan Univ., Korea)

H24-3 Shape-Tunable Wrinkles and the Applications
Takuya Ohzono (AIST, Japan)

H24-4 LC-lens Array for 3D Bio-Medical Applications
Yi-Pai Huang, Po-Yuan Hsieh, Amir Hassanfiroozi, Chao-Yu Chu (Nat'l Chiao-Tung Univ., Taiwan), Manuel Martinez-Corral (Univ. of Valencia, Spain), and Bahram Javidi (Univ. of Connecticut, U.S.A.)

A25-1 The Influence of Material Anisotropy and Panel Temperature on OLED Emission
Kristiaan Neyts, Michiel Callens, Frederique Chesterman, and Patrick De Visschere (Ghent Univ., Belgium)

A25-4 Transparent and Low-Resistance Top Electrode for Organic Light-Emitting Diodes
Jeong-Ik Lee, Hyunkoo Lee, Jong Tae Lim, Sunghee Park (ETRI, Korea), Won-Yong Jin (Chonbuk Nat'l Univ., Korea), Byoung-Hwa Kwon, Nam Sung Cho (ETRI, Korea), Jae-Wook Kang (Chonbuk Nat'l Univ., Korea), and Seunghyup Yoo (KAIST, Korea)

G31-4 Highly Efficient Organic-Inorganic Hybrid Light-Emitting Diodes by Surface Engineering
Bo Ram Lee (Univ. of Cambridge, U.K.), Seungjin Lee, Jae Choul Yu, and Myoung Hoon Song (UNIST, Korea)

H32-1 Side Chain Polyacetylene: Chiral Columnar Phase, Frustrated Chain Packing, and Thermal Reversible Actuation
Jun Wang and Er-Qiang Chen (Peking Univ., China)

H32-2 Redox-Active Liquid-Crystalline Polymer Thin Films with Nanosegregated Structures Based on Perylene Bisimide Bearing Cyclotetrasiloxane Rings
Masahiro Funahashi (Kagawa Univ., Japan)

H32-3 Photomotility of Liquid Crystalline Polymers
Jeong Jae Wie (Inha Univ., Korea), M. Ravi Shankar (Univ. of Pittsburgh, U.S.A.), and Timothy J. White (Air Force Research Laboratory, U.S.A.)

A33-1 Applications of Exciplex Emission in Thermally Activated Delayed Fluorescent OLEDs
Chun-Sing Lee (City Univ. of Hong Kong, Hong Kong)

A33-2 Molecular Design Approach of Highly Efficient Donor-Acceptor Type Emitters
Dong Ryun Lee, Sung Yong Byun, Ji Han Kim, and Jun Yeob Lee (Sungkyunkwan Univ., Korea)

A33-3 Long Lasting Blue Thermally Activated Delayed Fluorescent Organic Light-Emitting Diodes
SungHan Kim and Soo-Ghang Ihn (Samsung Electronics Co., Ltd., Korea)

A33-4 Highly Efficient Electroluminescence Based on Thermally Activated Delayed Fluorescence
Hajime Nakanotani and Chihaya Adachi (Kyushu Univ., Japan)

B34-1 Achieving High Performance Metal Oxide Thin Film Transistors Through Structural and Post Treatment Engineering
Hyun Jae Kim (Yonsei Univ., Korea)

B34-2 High Mobility Thin-Film Transistors Based on Solution Processed Low Dimensional Metal Oxides
Hendrik Faber, Yen-Hung Lin, Satyajit Das, Ivan Isakov, Nikolaos Chastas, and Thomas Anthopoulos (Imperial College London, U.K.)

B34-3 Enhancement of Metal Oxide TFT Performance by Engineering of Channel/Insulator
Shi-Jin Ding (Fudan Univ., China)

C35-1 Printable, Transparent and Intrinsically stretchable Electronics
Jiajie Liang (Nankai Univ., China) and Qibing Pei (Univ. of California, U.S.A.)

C35-4 Stretchable Electroluminescent Devices for Soft Display
Pooi See Lee (Nanyang Technological Univ., Singapore)

D36-1 Designing Quantum Dots for Electronic and Optoelectronic Devices through Surface and Interface Control
Soong Ju Oh (Korea Univ., Korea)

D36-2 Identifying the Chemical Origin of Traps in PbS QDs
Gyu Weon Hwang (KIST, Korea), Donghun Kim, Jose M Cordero, and Moungi G. Bawendi (MIT, U.S.A.)

D36-3 Intraband Transition of Atomic Ligand Passivated Colloidal Quantum Dots
Bitna Yoon, Juyeon Jeong, Dongsun Choi, and Kwang Seob Jeong (Korea Univ., Korea)

E37-1 Methods for Huge Amount of Holographic Data Processing
Jisoo Hong, Youngmin Kim, Sunghee Hong, Choonsung Shin, and Hoonjong Kang (KETI, Korea)

E37-5 Bringing 3D User Interfaces to Our Everyday Environments
Diego Martinez Plasencia (Univ. of Sussex, U.K.)

F38-1 Spectroscopic Investigation of Optical Materials for Display Applications by using an Inelastic Light Scattering Technique
Jae-Hyeon Ko, Byoung Wan Lee, Min-Seok Jeong, Seonhyeop Shin, Soo Han Oh, Bong Jin Cho, Jaehoon Park (Hallym Univ., Korea), Young Ho Ko, and Kwang Joo Kim (Agency for Defense Development, Korea)

F38-2 Advanced 3D Peplography – Image Sensing and Visualization from Unknown Scattering Media
Myungjin Cho (Hankyong Nat'l Univ., Korea)

F38-3 Overview for Lamina 3D displays
Sung-Wook Min and Hogil Baek (Kyung Hee Univ., Korea)

G39-1 Design Strategy of Organic Semiconductor for Organic Photovoltaics
Yun-Hi Kim (Gyeongsang Nat'l Univ., Korea)

G39-2 Regioregular Donor-Acceptor Copolymers for High-Efficiency Organic Solar Cells
Youngu Lee (DGIST, Korea)

G39-3 Low-Temperature-Processed TiO_2 Films for Flexible Perovskite Solar Cells
Sangwook Lee (Kyungpook Nat'l Univ., Korea), Seung Lee Kwon, and Hyun Suk Jung (Sungkyunkwan Univ., Korea)

G39-4 Solar Cells Development of Conductive Polymers for High Efficiency Organicbased Solar Cells with High Long-term Stability
Jea Woong Jo, Myung-Seok Seo, Min Jae Ko, and Hae Jung Son (KIST, Korea)

H40-1 A Study of 60-inch Liquid Crystal Roll Display
Mitsuhiro Shigeta, Masae Kawabata, Kazuki Kobayashi, and Masatsugu Teragawa (Sakai Display Products, Japan)

H40-2 Structural and Optical Technologies of Polymers for Flexible LCD
Hideo Fujikake, Yosei Shibata, and Takahiro Ishinabe (Tohoku Univ., Japan)

H40-3 Cholesteric Liquid Crystal Displays Suitable for Color Electronic Papers
Zhe Hong, Da-Som Yoon (Hoseo Univ., Korea), Hyun-Ji Hong, Burm-Young Lee (NDIS Corp., Korea), and Soon-Bum Kwon (Hoseo Univ., Korea)

A41-1 Simple but High Performance Hybrid White OLEDs based on Platinum Complex Single Dopant with Host Dependent Electroluminescence Color
Anurach Poleok (Academia Sinica, Taiwan), Chieh Wang (Nat'l Chiao Tung Univ., Taiwan),Chiao-Wen Lin(Academia Sinica, Taiwan), Chao-Tsen Chen (Nat'l Taiwan Univ., Taiwan), and Chin-Ti Chen (Academia Sinica, Taiwan)

A41-2 Isomers in Pyreneimidazole Compound: Synthesis and Configuration Effect on Optical Properties and Device Performance
Yulong Liu, Tong Shan, and Ping Lu (Jilin Univ., China)

A41-4 Stable and Efficient Red Phosphorescent Emitter for Display Application
Guijie Li, Tyler Fleetham, and Jian Li (Arizona State Univ., U.S.A.)

B42-1 Oxide Thin Film Transistors for Flexible Devices
Y. Uraoka, J. P. Bermundo, M. Fujii, M. Uenuma, and Y. Ishikawa (NAIST, Japan)

B42-2 High-Mobility Oxide TFT and its Application in Flexible AMOLED
Lei Wang, Miao Xu, Hua Xu, Min Li, Linfeng Lan, Jianhua Zou, Honglong Ning, Hong Tao, and Junbiao Peng (South China Univ. of Tech., China)

C43-1 The Solvent Selection for High Performance Solution Processed Quantum Dot Light Emitting Diodes
Tao Song, Yatao Zou, and Baoquan Sun (Inst. of Functional Nano & Soft Materials, Soochow Univ., China)

C43-5 High-Performance GaAs Nanowire Solar Cells for Flexible and Transparent Photovoltaics
Johnny C. Ho (City Univ. of Hong Kong, Hong Kong)

D44-1 Interface Chemistry of Colloidal Quantum Dots for Display Applications
Weon-kyu Koh (Samsung Advanced Inst. of Tech., Korea)

D44-2 Surface Functionalization of Colloidal Quantum-Dot Nanocrystals with Inorganic ligands for Electronic Device Application
Jaeyoung Jang (Hanyang Univ., Korea)

D44-3 Quantum Dot Clay Composites for Display Applications
Sanghwa Jeong (POSTECH, Korea), Seungho Cho (Univ. of Cambridge, U.K.), and Sungjee Kim (POSTECH, Korea)

E45-1 High Dynamic Range Rear Projection System
Nobuki Nakajima, Tadashi Furukawa, and Ryosuke Nakagoshi (JVCKENWOOD Corp., Japan)

E45-4 Smooth Motion Parallax Projection Displays for Highly Realistic Applications
Munekazu Date (Nippon Telegraph and Telephone Corp., Japan)

E45-5 Analysis of ADS Technology Advantages for Large Size 8K Resolution TV Panel
Yanping Liao, Xibin Shao, Fang Yu, Zhenyu Zhang, Dongchuan Chen, and Ming Chen (Beijing BOE Display Tech. Co., Ltd., China)

F46-1 Technical Trend of Automotive Displays
Jeong-Hwan Yoon, Kyoung-Ho Park, Soo Young Choi, Young-Seop Lee, Dae-Lim Park, Yong-Keun Kim, Sang-Kyu Kim, Hong-Man Moon, and Byeong-Koo Kim (LG Display Co., Ltd., Korea)

G47-1 Control of Preferred Orientation and Secondary Phases of SnS Thin Film and its Application to Solar Cell
Jeong-Yoon Kang, Sreedevi Gedi, and Chan-Wook Jeon (Yeungnam Univ., Korea)

H48-1 Reflective Liquid Crystal Displays for Future Display Applications
Takahiro Ishinabe, Yosei Shibata, and Hideo Fujikake (Tohoku Univ., Japan)

A49-1 Next Light Emitters: Organometal Halide Perovskite Light-Emitting Diodes
Tae-Woo Lee (POSTECH, Korea)

A49-3 Quantum Dot Electroluminescence Paves the Way to REC 2020 Displays
Poopathy Kathirgamanathan, Muttulingam Kumaraverl, Seenivasagam Ravichandran, Nicola Bramananthan, Lisa M. Bushby, and Sivagnanasundram Surendrakumar (Brunel Univ., U.K.)

B50-1 Simplicity Meets High Performance: Solution Processed Metal Oxide TFTs
E. Fortunato, R. Branquinho, E. Carlos, P. Barquinhal, D. Salgueiro (Universidade NOVA de Lisboa and CEMOP/UNINOVA, Porutugal), A. Liu, F.K. Shan (Qingdao Univ., China), and R. Martins (Universidade NOVA de Lisboa and CEMOP/UNINOVA, Porutugal)

B50-2 Printed and Electrolyte-Gated Oxide Electronics
Subho Dasgupta (Indian Inst. of Science, India)

C51-1 A-Few-Monolayer Organic Semiconductor Crystals and High-Performance Transistor Circuits on Plastic Substrates
C. Mitsui, J. Takeya, A. Yamamura (Univ. of Tokyo, Japan), and M. Uno (TRI Osaka , Japan)

C51-2 Pulsed Laser Deposition of 2D and Bulk II-VI Materials
Manuel A. Quevedo-Lopez (Univ. of Texas at Dallas, U.S.A.)

D52-1 The Nonbonding Conformational Locks for Constructing Highly Planar π-Conjugated Systems
Tao Dong, Pan Ye, Lei Lv, Lei Yang, Xinlong Wang, and Hui Huang (Univ. of Chinese Academy of Sciences, China)

D52-2 OLED Driving Circuits Based on Printed SWCNT Thin Film Transistors
Jianwen Zhao, Weiwei Xu, Wenya Xu, Chunshan Zhou, Xiang Zhang, and Zheng Cui (Chinese Academy of Sciences, China)

E53-3 VR vs. LF, 3D Immersion without Headgear
Tibor Balogh (Holografika Kft, Hungary)

F54-1 Eye Tracking Based Light Field Display
Dongkyung Nam, Jingu Heo, Juyong Park, and Kyuhwan Choi (Samsung Electronics Co., Ltd., Korea)

F54-2 Efficient Light Field Rendering
Young Ju Jeong, Jin-ho Lee, and Dongkyung Nam (Samsung Advanced Inst. of Tech., Korea)

F54-3 Software Technologies for 4D Light Field Display
Takafumi Koike (Hosei Univ., Japan)

G55-1 Development of Vacuum Processes for Solar Cells with Earth-Abundant Materials
Dae-Hwan Kim, Kee-Jeong Yang, Shi-Joon Sung, Dae-Kue Hwang, Dae-Ho Son, Si-Nae Park, Sang-Ju Lee, Yong Chan Choi, Jun-Hyoung Sim, Young-Ill Kim, Dong-Hwan Jeon, JungSik Kim, and Jin-Kyu Kang (DGIST, Korea)

G55-2 Efficient Chalcogenide Thin Film Solar Cells Consisting of Earth-Abundant, Cheap, and Non-Toxic Elements
Se Won Seo and Jin Young Kim (Seoul Nat'l Univ., Korea)

G55-3 Alternative n-Type Buffer Layers for Cu2ZnSn(S,Se)$_4$ Thin Film Solar Cells
Hee Kyeung Hong, Dongha Lim, Jae Yu Cho, Gwang Yeom Song, and Jaeyeong Heo (Chonnam Nat'l Univ., Korea)

G55-4 Interpretation of Interfacial Properties of Cu(In,Ga)Se$_2$ Solar Cell with Zn-Based Buffer Layers
Yong-Duck Chung, Dae-Hyung Cho, Jae-Hyung Wi, Woo-Jung Lee, Hye-Jung Yu, and Won Seok Han (ETRI, Korea)

A57-1 Recent Progress of Degradation Analysis of Flexible Organic Light Emitting Diodes
Hideyuki Murata (JAIST, Japan)

A57-2 Enabling Flexible and Foldable Air Stable OLED Devices with Thin Film Barriers
Jie Shen, Peter van de Weijer, Piet C. P. Bouten, Pradeep Panditha, Pavel Kudlacek, Jan Laurens van der Steen, Gerard Haas, Pim Groen, Gerwin H. Gelinck, Paul Poodt, and Hylke B. Akkerman (Holst Centre, The Netherlands)

A57-4 Transparent and Conductive Thin-Film Permeation Barriers - Towards Self-Encapsulating Organic Opto-Electronics
Andreas Behrendt, Tim Becker, Sara Trost, Tobias Gahlmann, and Thomas Riedl (Univ. of Wuppertal, Germany)

B58-1 Implantable Organic Electronics for Pathologies of the Central Nervous System
Michele Di Lauro, Marcellp Berto, Carlo Augusto Bortolotti (Univ. of Modena and Reggio Emilia, Italy), Mauro Murgia (CNR-ISMN, Italy), Michele Zoli (Univ. of Modena and Reggio Emilia, Italy), and Fabio Biscarini (Univ. of Modena and Reggio Emilia, Italy)

B58-2 Oxide Thin-Film Transistors with In Situ Anodized Passivation Layers
Shengdong Zhang, Yang Shao, Xiang Xiao, Yong Le, Letao Zhang, and Xiaoliang Zhou (Peking Univ., China)

A65-4 On the Role of Polar Molecules and Charge Injection in OLEDs
Stéphane Altazin (Fluxim AG, Switzerland), Evelyne Knapp (Zurich Univ. of Applied Sciences, Switzerland), Simon Züfle, Martin Neukom (Fluxim AG, Switzerland), Lars Jäger, Tobias Schmidt, Wolfgang Brütting (Univ. of Augsburg, Germany), and Beat Ruhstaller (Fluxim AG, Switzerland)

B66-1 The Evolution and Breakthrough of Thin-Film-Transistors for Displays
Yen-Yu Huang (Chunghwa Picture Tubes, Taiwan)

B66-2 Metal Oxide Thin Film Transistor Based Platform Technology for New Electronic and Optoelectronic Applications
Young Tack Lee, Tae-Hee Yoo, Won Kook Choi, and Do Kyung Hwang (KIST, Korea)

C67-1 Low-Loss Epsilon-Near-Zero Materials in the Visible and Near-Infrared Frequency Range
Young Chul Jun (UNIST, Korea)

C67-2 Metamaterials for Dynamic Photon Emission
Xinyu Liu and Willie J. Padilla (Duke Univ., U.S.A.)

D68-1 Innovative Field Printed Wirable Universal Device for Integrated Circuit Design in Active Matrix Display Technology
Yong-Sang Kim and Dong-Hoon Lee (Sungkyunkwan Univ., Korea)

D68-2 Surface-Potential Compact Model for Amorphous-IGZO Thin-Film Transistors
Zhiwei Zong, Nianduan Lu, Ling Li, and Ming Liu (IMECAS, China)

D68-3 Introducing an All-New Spot-Beam-Based Laser-Crystallization Method for Manufacturing Advanced AMOLED Displaysz
James S. Im (Columbia Univ., U.S.A.)

E69-1 Metrology Considerations for HDR Displays
Joe Miseli (JVM Research, U.S.A.)

E69-2 Simulation and Evaluation of Color Performance for LCDs Using Photo-Generated Quantum Dots
Liu Weidong, Qiao Mingsheng, Li Fulin, Yang Jia, and Zhang Yuxin (Hisense Electric Co., Ltd., China)

F70-1 Depth Perception Based on Binocular Eye Movement in the Integral Photography
Sumio Yano, Makoto Suzuki (Shimane Univ., Japan), and Min-Chul Park (KIST, Korea)

F70-2 Effect of Different Disparities on Visual Comfort: Comparison between Reference 2D and SMV Random-Dot Multigrams
Sunghcul Mun (KIST, Korea)

F70-3 Accommodation in Viewing 3D Display
Hyungki Hong (Seoul Nat'l Univ. of Science and Tech., Korea)

G71-1 Novel Non-Destructive Rapid in-Line SEM for High Resolution Defect Review, Analysis and Ultra Precise Metrology
Xuena Zhang (Applied Materials, U.S.A.), Bernhard Mueller, Ludwig Ledl, Volker Daiker (Applied Materials GmbH, Germany), Ryan Lin (Applied Materials, Taiwan), Thomas Schwedes, Edgar Kehrberg, Axel Wenzel, Georg Jost (Applied Materials GmbH, Germany), George Tzeng (Applied Materials, U.S.A.), Robert Trauner, Bernhard Schueler, Alfred Koelbl, Peter Staffansson (Applied Materials GmbH, Germany), Santosh Mhalsekar, Jonathan Cerezo, and Peter Nunan (Applied Materials, U.S.A.)

H72-1 Extraction of More Photons from LED by Photonic Crystal, Hierarchical Structure, and Nanotubes
Young-Chul Leem and Seung-Ju Park (GIST, Korea)

H72-2 Group III Nitride Materials for Large Area Flexible Devices
Hiroshi Fujioka, Kohei Ueno, Atsushi Kobayashi, and Jistuo Ohta (The Univ. of Tokyo, Japan)

H72-3 Controlled Growth of GaN Nanorod Arrays with an Orientation-Induced Buffer Layer
Si-Young Bae, Kaddour Lekhal, Ho-Jun Lee (Nagoya Univ., Japan), Jung-Wook Min, Dong-Seon Lee (GIST, Korea), Manato Deki, Yoshio Honda, and Hiroshi Amano (Nagoya Univ., Japan)

A73-1 Application of Organic Heterojunctions in OLEDs
Dongge Ma (South China Univ. of Tech., China)

A73-3 Highly Efficient OLEDs with Ultralow Driving Voltage and Simplified Structure
Shi-Jian Su (South China Univ. of Tech., China)

B74-1 Investigation of Indium Oxide Based Thin Film Transistors with Tungsten as Dopant
Qun Zhang, Zhao Yang, Ting Meng, Honglei Li (Fudan Univ., China), and Han-Ping D. Shieh (Nat'l Chiao Tung Univ., Taiwan)

B74-2 High-Mobility Transistors by Spatial-Atomic Layer Deposition of InZnO
Ilias Katsouras, Andrea Illiberi, Brian Cobb, Paul Poodt, and Gerwin Gelinck (Holst Centre/TNO, Netherlands)

C75-1 Digital Holography Using a Thermally Driven Phase-Change Material
Seung-Yeol Lee, Yong-Hae Kim, Gi Heon Kim, Tae-Youb Kim, Seong-Mok Cho, Hojun Ryu, Jae-Eun Pi, Jong-Heon Yang, Ji-Hun Choi, and Chi-Sun Hwang (ETRI, Korea)

C75-2 Spectral Band Engineering with Resonant Thin-Film Subwavelength Gratings
Jae Woong Yoon (Hanyang Univ., Korea), Robert Magnusson, Manoj Niraula, Kyu Jin Lee (Univ. of Texas – Arlington, U.S.A.), Jun Hyung Lee, and Seok Ho Song (Hanyang Univ., Korea)

D76-1 High-Performance p-Type Oxide Thin-Film Transistors Processed at Low Temperatures with Hole Mobility Exceeding 25 cm^2 / Vs
Fukai Shan, Ao Liu, and Guoxia Liu (Qingdao Univ., China)

D76-2 Unique Applications Using Oxide TFTs
Mutsumi Kimura and Tokiyoshi Matsuda (Ryukoku Univ., Japan)

D76-3 Solution Processed CMOS Metal Oxide Thin Film Transistor Technology
George Adamopoulos (Lancaster Univ., U.K.) and Arokia Nathan (Cambridge Univ., U.K.)

E77-1 New Developments in Viewing Angle Metrology for Quality Control of Displays
Pierre Boher, Thierry Leroux, Vincent Leroux, Thibault Bignon, and Véronique Collomb-Patton (ELDIM, France)

F78-1 Development of High Efficiency Coherent Backlight System for Generation of Digital Hologram Display
Hyesog Lee, Yunseon Do, Jaeho Yu, and Byungchoon Yang (Samsung Display Co., Ltd., Korea)

F78-2 Real Image Forms SF Display
Hirotsugu Yamamoto (Utsunomiya Univ., Japan)

H80-1 Versatile Phosphor-in-Glass for Solid-State Lighting Applications
Won Bin Im (Chonnam Nat'l Univ., Korea)

H80-4 Key Problems in High Performance Light-Emitting Diodes Packaging
Xiaobing Luo (Huazhong Univ. of Science and Tech., China)

Author Index

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

Q

R

S

T

U

V

W

X

Y

Z

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  2. Trend of Killer Applications with Next-Generation Display
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