Flexible Printed Organic TFT Device Arrays and Circuits

***Shizuo Tokito**, Kenjiro Fukuda and Daisuke Kumaki*
Research Center for Organic Electronics (ROEL)
Yamagata University, Yamagata 992-8510 Japan
Tel. +81-238-26-3725, E-mail: tokito@yz.yamagata-u.ac.jp

By providing for new applications such as flexible displays, smart labels and wearable biosensors, flexible thin-film transistor (TFT) devices fabricated on thin plastic film substrates have been attracting significant attention in research and development. In particular, TFT devices based on organic semiconductors can be fabricated at low temperatures and are more compatible with printing methods than inorganic semiconductors. However, there have been only a few reports of high performance organic TFT devices fully fabricated with printing processes on plastic film substrates. To accomplish this, solution-processable semiconductors, electrode and dielectric materials are required, as well as printing technologies for fine patterning. Recently, we have demonstrated advancements in fabrication processes for OTFT devices on plastic films using various printing techniques. Here, we will report briefly on printable materials, printed OTFT devices and their application to TFT arrays and integrated circuits.

Silver (Ag) nanoparticle inks have become important materials for the fabrication of electrode and interconnect layers in printed electronics. Accordingly, we developed an Ag nanoparticle ink that was optimized for organic TFT applications. Finely patterned Ag lines with line widths of 25 μm were fabricated by inkjet printing and sintered at temperatures lower than those reported for other Ag nanoparticle inks. A low resistivity of less than 10 μΩcm could be obtained by sintering at a relatively low temperature of 120º C.

Inkjet printing, nozzle dispensing and reverse-offset printing methods were largely employed in forming the electrode, bank and organic semiconductor layers. Printed OTFT arrays (30 x 30) were successfully fabricated by using the newly developed OSC material on plastic film substrates. By optimizing the semiconducting layer crystal growth, excellent p-type electrical performance with a high average mobility of over 1 cm^2/Vs and high on/off current ratios over 10^7 were achieved. Exceptionally uniformities of device characteristics were also observed within in the array.

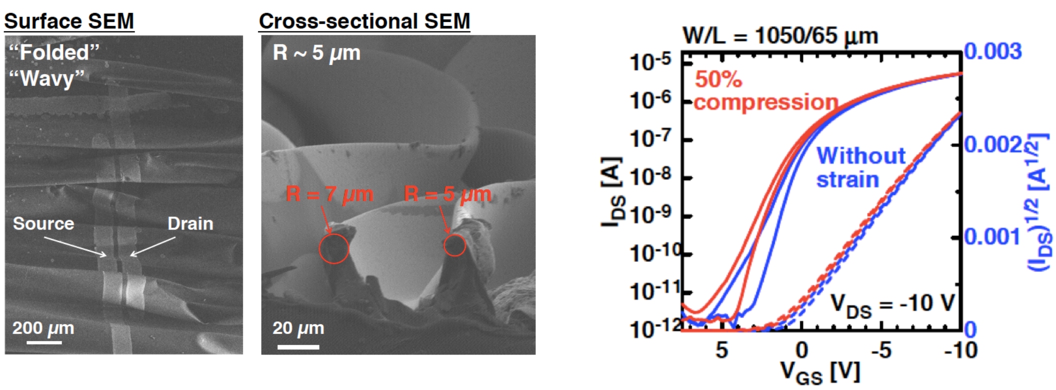

Figure 1: (a) SEM images and (b) transfer characteristics for ultra-thin OTFT devices.

Ultra-thin OTFT devices can also be fabricated using ultra-thin parylene-C films, which are prepared using chemical vapor deposition on a supporting glass carrier plate. In order to control the adhesive strength, a thin layer of fluoropolymer was formed with spin coating before preparation of parylene-C layer. The resulting ultra-thin printed OTFT devices and inverter circuits were extremely lightweight, flexible and compressible as shown in Figure 1. The mobility and on/off current ratio in the devices were about 1 cm^2/Vs and 10^7, respectively. Virtually no changes were observed in the electrical characteristics, even under 50% compression. The bending radius of the device under compression was 5 μm, which is comparable to a folded device.

We successfully fabricated pseudo-CMOS inverters using p-type OTFTs, as well as NAND and NOR logic gates that exhibited ideal characteristics. Furthermore, a more complex 1-bit flip-flop circuit using the pseudo-CMOS logic was fabricated, which exhibited an output response according to its truth table.

References

K. Fukuda, S. Tokito, et al., ACS Applied Materials & Interfaces 5, 3916 (2013).
Y. Takeda, S. Tokito, et al., Organic Electronics 14, 3362 (2013).
K. Fukuda, S. Tokito, et al., Nature Commun. 5, 243703 (2014).