Fully Transparent Cathode using Amorphous Oxide Semiconductors for OLEDs

Junghwan Kim[1], Satoru Watanabe[2], Nobuhiro Nakamura[1,2], Naomichi Miyakawa[2], Yoshitake Toda[1,3], Toshio Kamiya[1] and Hideo Hosono[1,3]

[1]Tokyo Institute of Technology, Nagatsuta, Midori-ku, Yokohama, 226-8503, Japan

Tel.:81-45-924-5628, E-mail: JH.KIM@lucid.msl.titech.ac.jp

[2]Research Center, Asahi Glass Co. Ltd., Hazawa, Kanagawa-ku, Yokohama 221-8755, Japan.

[3]ACCEL Program, Japan Science and Technology Agency, Kawaguchi, 332-0012, Japan.

Efficient charge injection and light extraction are critical to light-emitting devices including OLEDs. Therefore, transparent conductive oxide (TCO) has played an important role due to its high transparency. However, a low work function TCO has not yet been realized for OLEDs. This is why most TCOs are used mainly for anode electrodes, restricting the structure of OLEDs. There have been many studies, such as surface modification and dipole layers, to solve former issues. However, the surface modification and dipole layers are still not satisfactory because the effects of them are limited to certain process environment or materials.

In this work, we report a novel method to use conventional TCOs as cathode using a new transparent amorphous oxide semiconductor (TAOS) and amorphous C12A7 electride (a-C12A7:e^-) for OLEDs. The new TAOS has Ohmic contact with conventional TCOs such as ITO or FTO, as shown in figure 1. Furthermore, its high electron mobility (~1cm^2/Vs) and tunable carrier concentration can make its conductivity pretty high. Therefore, the series resistance of New TAOS is negligible in the OLEDs comprising high resistive organic layers. And finally, new TAOS and a-C12A7:e^- has very good electron injection properties, due to their intrinsically low work function; the work function was determined from in-situ UPS spectra, as shown in figure 2. The values are 3.1 eV for a-C12A7:e^-, 3.4 eV for new TAOS and 4.5 eV for ITO. In summary, a fully transparent cathode electrode was accomplished using a new TAOS and a-C12A7:e^- with ITO. This method enables conventional TCOs to be used for both cathode and anode, which would be advantageous for future displays including transparent OLEDs. More details will be presented at the conference.

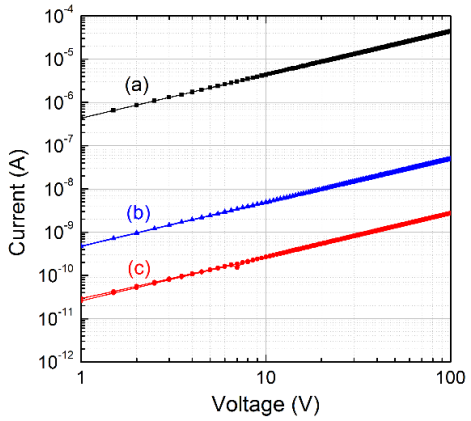

Fig.1 I-V characteristic of new TAOS films with ITO electrodes. Samples (a)~(c) have different carrier concentration.

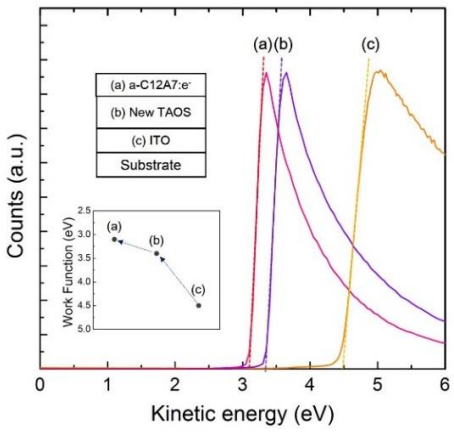

Fig. 2. UPS spectra (secondary electron cutoff) of (a) a-C12A7:e^- , (b) New TAOS and (c) ITO.

References

1. H. Hosono, M. Yasukawa, H. Kawazoe, J. Non-Cryst. Sol., 203, 334-344 (1996).
2. S.Watanabe, T.Watanabe, K.Ito, N.Miyakawa, Y.Toda, Y.Tomota, S.Ito, T. Kamiya, H.Hosono, SID'13 DIGEST, 1473-1476 (2013).
3. H. Hosono, E. Matsuzaki, Y. Toda, J. Kim, T. Kamiya, S. Watanabe, N. Nakamura, N. Miyakawa, IDW'14 Proceedings, 649-650 (2014).
4. J. Kim, S. Watanabe, E. Matsuzaki, N. Nakamura, N. Miyakawa, Y. Toda, Toshio Kamiya, Hideo Hosono, SID'15 DIGEST, 1714-1716 (2015).