Interface Properties of Poly(ethylene glycol) Dimethl Ether (PEGDE) Functionalized Al Cathode for Efficient Polymer Light-emitting Diodes

Ming-Wei Lin (林銘偉)[1], Tzung-Fang Guo (郭宗枋)[1], and Yao-Jane Hsu (許瑤真)[2]

[1]Institute of Electro-optical Science and Engineering, National Cheng Kung University, Tainan, Taiwan
[2]National Synchrotron Radiation Research Center, Hsinchu, Taiwan

Interfacial metal-molecule reaction significantly impacts the injection properties of organic electronic devices and had attracted lots of attention by many groups as well. The chemical structure of interface between PEGDE and low work function metal, aluminum (Al) studied by X-ray photoemission spectroscopy indicates the formation of a Al-carbide-like (negative carbon) bond[1][2]. The carbide-like bond formation is critical to the injection of electrons through the Al cathode. Increasing the carbide-like bond formation to improve the electron injection ability can be accomplished by inserting the Al-doped poly(ethylene glycol) dimethl ether (PEGDE) layer for the interlayer between the Al cathode and emission layer. For green polyfluorene (PF) based devices, before the insertion of Al-doped PEGDE layer, the electroluminescence efficiency was only 0.03 cd/A, the maximum light intensity was 693 cd/m^2, the light turn-on voltage was 5.9 V. On the other hand, after the insertion of Al-doped PEGDE layer by the ratio of 2:1, the electroluminescence efficiency and maximum light intensity was 14.03 cd/A and 116,350 cd/m^2, and light turn-on decreased to 2.3 V. The device results are shown in Fig. 1.

In our experiments we compared the the composition analysis and interfacial electronic structure of the PF/PEGED doped Al (2:1)/Al and PF/PEGDE/Al thin films by using the x-ray photoemission spectroscopy (XPS) and ultraviolet photoemission spectroscopy (UPS). The XPS results indicate the tendency of PEGDE to react with Al and create the C-O-Al complex which is the same as our previous report[2]. However, for PF/PEGED doped Al (2:1)/Al sample the C-O-Al complex exists both inside electron injection layer (PEGDE doped with Al layer) and also at the interface between electron injection layer and cathode Al. In order to determine which formation site is important for electron injection, we replace the cathode Al to Ag to restrict the C-O-Al formation site only inside the PEGDE doped with Al layer. The XPS measurement indicates the existing C-O-Al complex but device performance shows no significant improvement (Fig. 1). The XPS results determine that the key issue to better electron injection ability is the formation C-O-Al complex at the PEGDE doped with Al and cathode Al interface.

Further, the effect of the C-O-Al complex on electron injection ability was investigated by UPS analysis. The UPS results are shown in Fig. 2 which indicates that the PEGDE:Al(2:1)/Al sample has lowest injection barrier for electron from cathode to the emission layer. We consider that the creation of C-O-Al complex lowers the work function and results in better electron injection condition.

In summary, we have investigated the main contribution to the electron injection condition due to the formation of C-O-Al complex at the PEGDE doped Al/Al interface which lowers the injection barrier. The electroluminescence efficiency and maximum light intensity improved from 0.03 cd/A and 693 cd/m^2 to 14.03 cd/A and 116,350 cd/m^2 when inserting the PEGDE doped Al layer as the electron injection layer.

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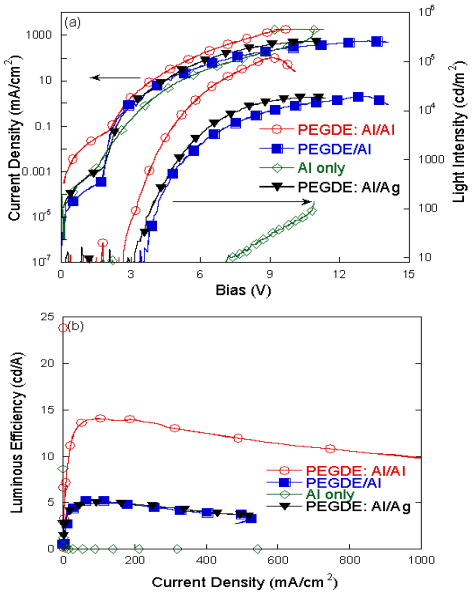

Fig. 1: (a) *I-L-V* curves and (b) The luminous efficiency versus current density of (○) PEGDE:Al/Al, (■) PEGDE/Al, (◊) Al and (▼) PEGDE:Al/Ag device.

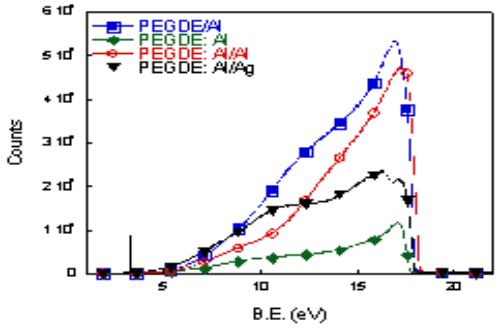

Fig. 2: UPS spectra results. The sample include (○) PEGDE:Al/Al, (■) PEGDE/Al, (◊) PEGDE:Al and (▼) PEGDE:Al/Ag device.

References

[1] Guo *et al.*, Appl. Phys. Lett. **88**, 113501 (2006).
[2] Guo *et al.*, Adv. Funct. Mater. **18**, 3036 (2008).