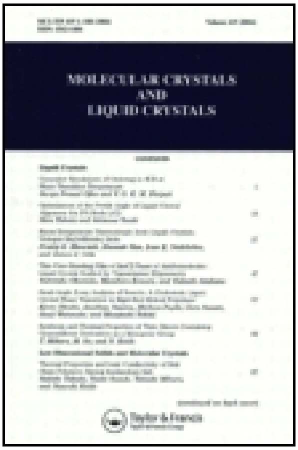

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Enhanced Quantum Efficiency in Polymer Light-Emitting Diode with Polystryrene Nanolayer

Jong Park [a], O. Park [a], Jae-Woong Yu [b], Jai Kim [b] & Young Kim [c]

[a] Center for Advanced Functional Polymers and Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology, Yuseong-gu, Daejeon, Korea

[b] Optoelectronic Materials Research Center, Korea Institute of Science Technology, Cheongryang, Seoul, Korea

[c] College of Environment and Applied Chemistry, Kyung Hee University, Kyunggi-do, Yongin, Korea

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ENHANCED QUANTUM EFFICIENCY IN POLYMER LIGHT-EMITTING DIODE WITH POLYSTRYRENE NANOLAYER

Jong Hyeok Park and O. Ok Park
Center for Advanced Functional Polymers and Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology, 373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, Korea

Jae-Woong Yu and Jai Kyeong Kim
Optoelectronic Materials Research Center, Korea Institute of Science and Technology, P. O. Box 131, Cheongryang, Seoul 130-650, Korea

Young Chul Kim
College of Environment and Applied Chemistry, Kyung Hee University, Yongin, Kyunggi-do 449-701, Korea

We report the effect of polystyrene nanolayer on electron injection in the polymer light-emitting diodes (PLEDs) in which hole is major charge carrier. Especially, when a ~10 nm-thick polystyrene layer was employed, the device gave two orders of magnitude higher external quantum efficiency than that of the one without an insulating nanolayer. This enhancement may result from the dramatic lowering of the effective barrier height for electron injection to the emitting layer.

Keywords: electron injection; insulating layer; light-emitting diodes (LEDs)

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Address correspondence to Young Chul Kim, Mat Res Center for Information Display, College of Environment and Applied Chemistry, Kyung Hee University, Yongin, Kyunggi-do 449-701, Korea. Tel.: +82-31-201-2372, Fax: +82-31-204-2530, E-mail: kimyc@khu.ac.kr

INTRODUCTION

Aluminum (Al) is inexpensive and easy to use for the cathode of PLEDs but electron injection in the devices with Al cathode has proved more difficult to occur than hole injection, resulting in unbalanced charge injection. It is necessary to use a low work function metal such as calcium (Ca) to reduce electron injection barrier for a higher efficiency [1,2]. Such metals, however, are so susceptible to moisture and oxygen that the resulting devices suffer from poor environmental stability.

In this study, for the ITO/MEH-PPV/polystyrene(PS)/Al devices with ~10 nm PS layer thickness, the quantum efficiency could be enhanced by two orders of magnitude. The mechanism of the quantum efficiency improvement demonstrated in the PLEDs with PS insulating nanolayers is also discussed.

EXPERIMENTAL

We used polystyrene (PS, Aldrich Chem., M_w: 280,000) for the insulating nanolayer, which is soluble in dimethyl formamide (DMF). ITO-coated glass substrates were subjected to a wet cleaning process and treated by oxygen-plasma before use [3]. A 100 nm-thick MEH-PPV layer was spin-cast from the chlorobenzene solution on the ITO substrate. And then, PS insulating nanolayer was also spin-cast from the solution with a ~10 nm-thickness on top of the emitting layer, followed by the thermal evaporation of al cathode in vacuum to complete the device preparation. The EL output was measured by a photodiode connected to an optical powermeter (Newport 835).

RESULTS AND DISCUSSION

Figure 1 shows the current-voltage (I-V) characteristics of the devices prepared. We observed a dramatic current density increase when a PS nanolayer was inserted between the emitting layer and the Al cathode. Generally, in the devices with Al cathode, observed current is mainly contributed by the hole current because the energy barrier to electron injection is much higher than that to hole injection in those devices [4]. So the enhanced current density indicates that the insulating nanolayers facilitate the electron injection to the device.

When the cathode is in direct contact with the emitting layer, the energy barrier to the electron injection is determined as the difference between the lowest unoccupied molecular orbital (LUMO) level of the emitting layer

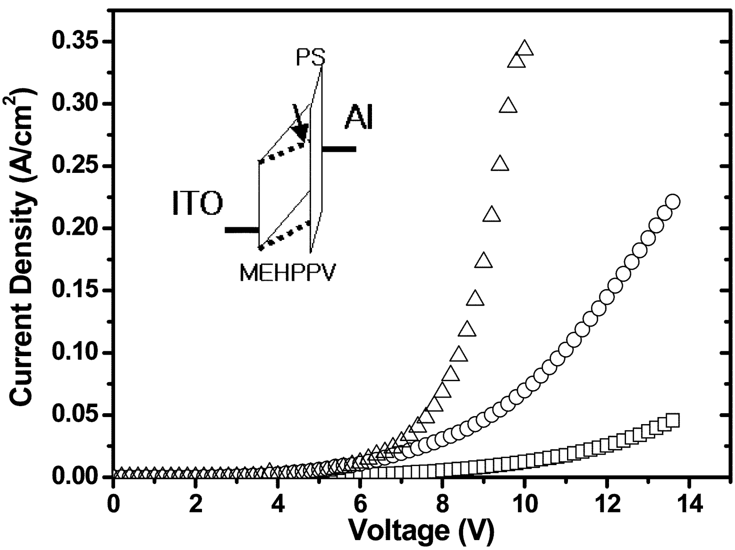

FIGURE 1 Current density vs. voltage characteristics for the EL devices of the ITO/MEH-PPV/Al (□), ITO/MEH-PPV(120 nm)/PS(10 nm)/Al (○), and ITO/MEH-PPV(80 nm)/PS(10 nm)/Al (△) structures. The inset shows a schematic representation of the charge injection barrier lowering for positively biased sandwich devices of the ITO/MEH-PPV/PS/Al structure.

and the work function of the cathode. However, when an insulating layer is inserted between the cathode and the emitting layer, the barrier height can be decreased due to the lowering of band bending slope as shown in the inset of Figure 1. [5]. In this study, when PS was used for the insulating nanolayer, dramatically increased electron injection was observed.

The optical outputs of the devices with insulating layers were shown in Figure 2. As is typical to PLEDs, the emission intensity increases with increasing electron current for all the devices. The PS nanolayer also affected the turn-on threshold voltage. The operation of the Al-cathode device requires an additional bias potential to that under the "flatband" condition in order for the electrons to overcome the high barrier height [turn-on threshold voltage, $V_{on} = 2.4\,V$]. For the devices with PS insulating nanolayers, V_{on} decreased to 1.75 V, indicating that lower electric fields are required for electron injection.

It is expected from the work of Kim's group [5] that the emitting layer thickness also affects the potential barrier for the emitting layer/Al cathode interface. Figure 2 shows the luminance-voltage (L-V) characteristics of the ITO/MEH-PPV(120 nm)/PS(10 nm)/Al and ITO/MEH-PPV

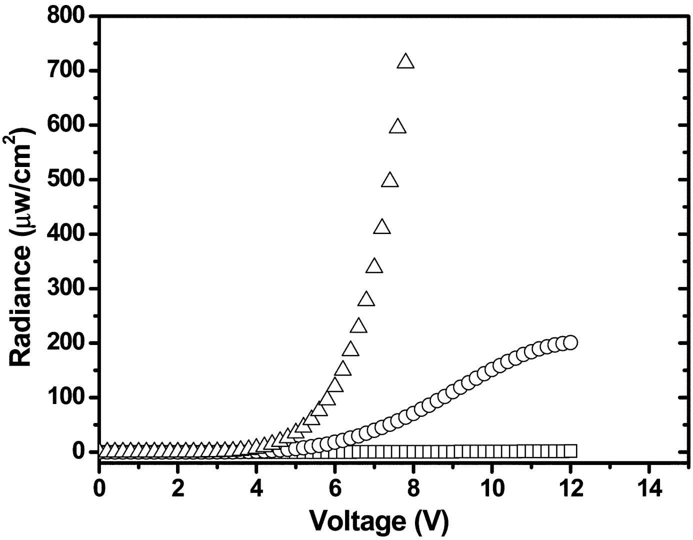

FIGURE 2 Radiance vs. voltage characteristics for the EL devices of the ITO/MEH-PPV/Al (□), ITO/MEH-PPV(120 nm)/PS(10 nm)/Al (○), and ITO/MEH-PPV(80 nm)/PS(10 nm)/Al (△) structures.

(80 nm)/PS(10 nm)/Al devices. The electron injection and optical output of the device with a 80 nm-thick MEH-PPV layer was hugely improved compared with the device with a 120 nm-thick MEH-PPV layer, which implies that the emitting layer thickness plays a crucial role in controlling the band bending and the electron injection from the cathode.

CONCLUSIONS

The employment of the PS nanolayer not only brings about a highly improved Q.E. but also lowers the turn-on threshold voltage compared with the single layer device. Presence of the PS nanolayer at the Al cathode/MEHPPV interface causes a considerable lowering of the electron injection barrier height, which is attributed to the improved balancing of charge injection.

REFERENCES

[1] Braun, D. & Heeger, A. J. (1991). *Appl. Phys. Lett.*, *58*, 1982.
[2] Aratani, S., Zhang, C., Pakbaz, K., Hoger, S., Wudle, F., & Heeger, A. J. (1994). *J. Electron Mater.*, *22*, 745.

[3] Kim, J. S., Granstrom, M., Friend, R. H., Johansson, N., Salaneck, W. R., Daik, R., Feast, W. J., & Cacialli, F. (1998). *J. Appl. Phys.*, *84*, 6859.
[4] Parker, I. D. (1994). *J. Appl. Phys.*, *75*, 1656.
[5] Kim, Y. E., Park, H., & Kim, J. J. (1996). *Appl. Phys. Lett.*, *69*, 599.