Emission Characteristics of Green OLED with Hole Transport Material

Xinwei Gao[*1], Jong Yek Park[1], Yong Gu Baek[1], Sung Hoo Ju[2], Jae Woong Yang[2], Bong Sub Lee[2], Jung Taek Kim[3], Kyeong Kap Paek[3]*

[1] ELM Co., Ltd., 2nd Floor, Boram B/D, Geumjeong-dong, Gunpo-si, Gyeonggi 435-824, Korea

[2] Dept. of Advanced Materials Science and Engineering, Daejin University, Seondan-dong, Pocheon, Gyeonggi 487-711, Korea

[3] Dept. of Electronic Engineering, Daejin University, Seondan-dong, Pocheon, Gyeonggi 487-711, Korea

Phone: 82-31-539-1902, E-mail: kkpaek@daejin.ac.kr

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Abstract

OLED devices with a multilayer structure were fabricated using newly synthesized hole transport materials. We confirmed that ELM229 and ELM339, hole transport materials did not affect the electroluminescence color, and that by adopting this novel hole transport materials, OLEDs with a lower driving voltage but a higher efficiency were developed.

1. Introduction

Since the first thin-film organic light-emitting diode (OLED) device was fabricated by Tang and Van Slyke in 1987,[1] many research works have been done to obtain the OLED performance which satisfies the practical display or illumination application requests. Research works have shown that the charge transport in OLED can be balanced by adopting the multilayer structure with the hole injection layer (HIL), hole transport layer (HTL), emission layer (EML), electron transport layer (ETL), electron injection layer (EIL) and that consequently, electrical property, efficiency, and lifetime of the device can be greatly improved, compared with a single layer device.[2]

As an essential part of an efficient and durable OLED device, the HTL material has critical influences on the device performance. It is known that one of the poor durability mechanisms in the small-molecule based OLED is due to crystallization or melting of the organic material caused by Joule heating at high current level,[3] and it is believed that the HTL materials with high glass transition temperatures (T_g) can improve the durability of the OLED,[4] and that HTL materials with proper energy level and charge mobility for the charge transport between different functional layers can remarkably improve the electrical characteristics and efficiency of the device.[5] Thus it is meaningful and necessary to develop excellent hole transport materials to achieve high performance OLEDs.

In this work, a series of new hole transport materials ELM 325, ELM 326, ELM 327, ELM 337, ELM 338, ELM 339, and ELM 229 were synthesized and their hole transport characteristics were tested by being adopted into multilayer OLED devices deposited in high vacuum level.

2. Experimental

The structure of OLED device consisted of an indium tin oxide (ITO), a hole injection layer (HIL), a hole transport layer (HTL), an emission layer (EML), an electron transport layer (ETL), and a cathode, as shown in Fig. 1.

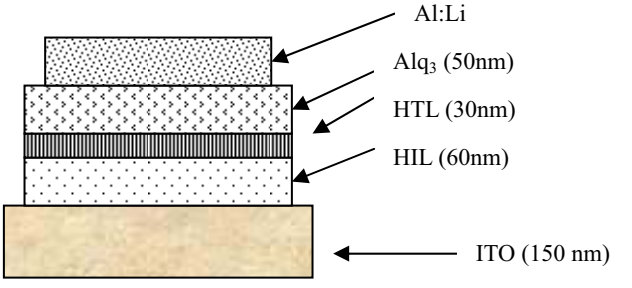

Fig. 1. Side view of OLEDs in this work.

OLED devices were fabricated using newly synthesized HTL materials. To improve the purity of the synthesized material, the purification process was performed using re-crystallization and multi-zone

sublimation system. Fig. 2 shows the HPLC analysis result of material after ELM229 as one of hole transport materials was purified using re-crystallization and multi-zone sublimation method. The main peak in the chromatogram was observed to be 14.6667 min (99.9664% area) and another peak was observed to be 17.5833 min (0.0336% area). As a result, we found that the material purity of the synthesized ELM229 was over 99.95%.

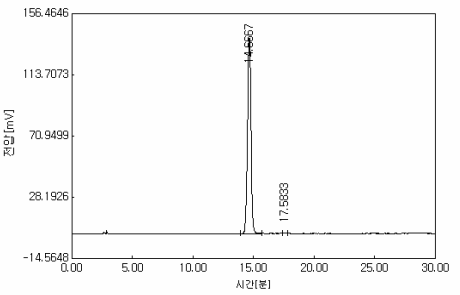

Fig. 2. HPLC analysis result of HTL material (ELM 229).

OLED devices of the structure ITO/HIL/New_HTL/Alq_3/Al:Li were fabricated as follows. First, photoresist (PR) was spin-coated on a glass substrate of 100 mm × 100 mm in size deposited with a 150 nm thick ITO beforehand, and the ITO glass was patterned by PR UV exposure using patterning photo mask. After that, PR was spin-coated on patterned ITO glass and exposed to UV light again, and emission pixels of 3 mm × 3 mm in size was formed by using an insulator photo. To improve work function of ITO with pixels of 3 mm × 3 mm in size, the substrate was surface-treated and prepared during 2 min using UV. On top of the ITO substrate, ELM200 as a hole injection layer was deposited 60 nm thick, at a deposition rate of 1.0–2.0Å/s. In addition, ELM229, ELM325, ELM325, ELM327, ELM 337, ELM338, and ELM339 as newly synthesized HTL materials, were respectively deposited 20 nm thick, using the same method as that in the reference NPB HTL material.

To minimize external cause, Alq_3 which did not use dopant was used as an emission layer and also as an electron transport layer. Alq_3 was deposited 50 nm thick at a deposition rate of 1.0–2.0Å/s. After deposition of organic layers, the device was transferred into a metal chamber via glove box without exposure to air, and Al:Li (Li, 0.5 wt%) as a cathode electrode was deposited 100 nm thick at a deposition rate of 5–10 Å/s. Both the organic and metal layers were deposited under a vacuum level of below 10^{-7} torr and a quartz crystal was used as thickness monitor. Voltage and current were applied to OLED devices fabricated as such, using Keithley (model 2400) source measurement unit. Emission brightness and spectrum in response to applied voltage and current were measured using PR-650 SpectraScan SpectraColorimeter.

3. Results and discussion

Fig. 3 shows a graph of current density vs. applied voltage in OLED devices fabricated with structure ITO/HIL/New_HTL/Alq_3/Al:Li. As voltage applied to devices was increased, current in the devices was abruptly increased. Compared with NPB as a reference material, currents in newly developed materials, ELM325, ELM337, ELM338, and ELM339, increased faster, and ELM229 had a similar trend in a current increase. ELM326 and ELM327 had a slower current increase. This result means that ELM229, ELM325, ELM337, ELM338, and ELM339 can have the same or lower driving voltage, and ELM326 and ELM327 can have a higher driving voltage, compared with NPB as a reference material.

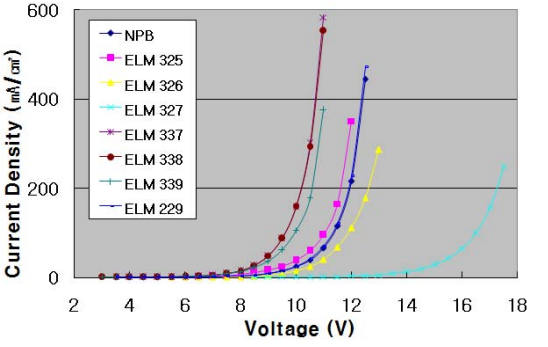

Fig. 3. Current density vs. applied voltage in OLED devices using various kinds of HTL materials.

Fig. 4 shows the change of luminance vs. applied voltage. As voltage applied to devices was increased, luminance was increased with a similar trend to current increase in Fig. 3. Compared with NPB as a reference material, in case of ELM229, ELM337, ELM338, and ELM339, a higher luminance was shown when the same voltage was applied. In case of ELM325, ELM326, and ELM327, a lower luminance was shown with the same voltage applied. When comparing Figs. 3 and 4, in case of ELM325, a higher current in the device and a lower luminance was shown at the same voltage. Therefore, we think that ELM325 was unsuitable for a HTL material.

Fig. 5 shows the luminance efficiency vs. applied voltage when computed from Figs. 3 and 4. Compared with NPB as a reference material, in case of ELM229 and ELM339, a higher luminance efficiency was shown. In case of ELM325, ELM326, ELM327, ELM337, and ELM338, a lower luminance efficiency was shown. From these results, compared with NPB, a commercial material, we found that ELM229 and ELM339 had an excellent hole transport capability.

Fig. 6 shows the power efficiency vs. luminance curves as computed from data of Figs. 3 and 4. At the same luminance intensity, ELM 339 and ELM 229 show higher power efficiency than the NPB reference, and ELM 337 and ELM 338 show similar power efficiency with the NPB reference, while ELM 325, ELM 326 and ELM 327 show lower power efficiency than the NPB reference. This result means that if these HTL materials are applied in an OLED display, display with ELM 339 or ELM 229 HTL material works with less power consumption than that with a NPB HTL material. This once again proves that ELM 339 or ELM 229 can be better as a hole transport material than the NPB commercial hole transport material.

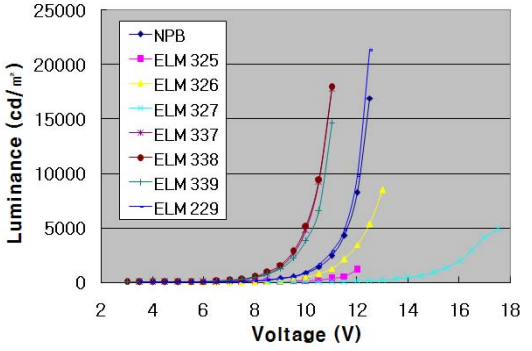

Fig. 4. Luminance vs. applied voltage in OLED devices using various kinds of HTL materials.

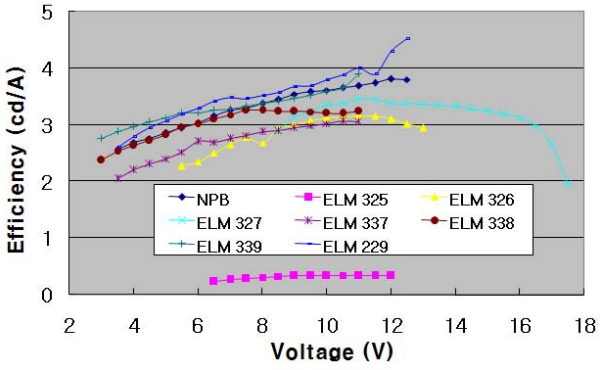

Fig. 5. Luminance efficiency vs. applied voltage in OLED devices using various kinds of HTL materials.

Fig. 7 shows the electroluminescent spectrum of OLED devices fabricated by adopting various hole transport materials. In this figure, as hole transport material changed, a minute change in the electroluminescent spectrum was observed. However, in the viewpoint of color coordinate, almost a similar value was shown. Therefore, we think that hole transport materials did not affect the luminance color in the emission layer. We confirmed that when devices were fabricated using newly synthesized hole transport materials, ELM229 and ELM339 did not affect the luminance color, and that the materials with a lower driving voltage and a higher luminance efficiency were developed.

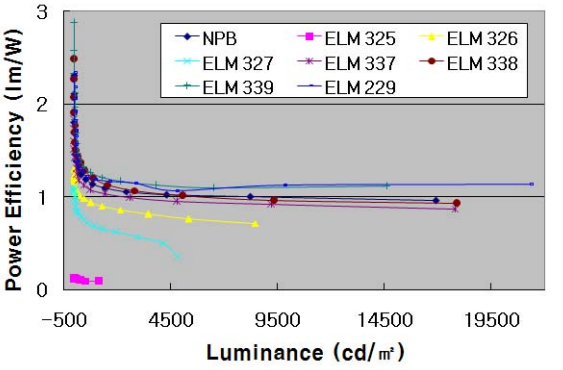

Fig. 6. Power Efficiency vs. luminance in OLED devices using various kinds of HTL materials.

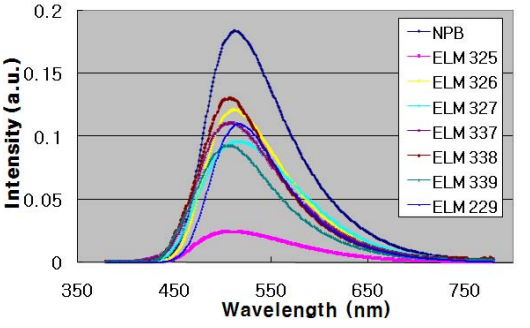

Fig. 7. Electroluminescent spectrum of OLED devices using various kinds of HTL materials.

4. Summary

We confirmed that when OLED devices were fabricated by using above newly synthesized hole transport materials, ELM229 and ELM339 did not affect the electroluminescence color, and by adopting these two hole transport materials, the OLED devices showed a lower driving voltage and a higher luminance efficiency. Further research work will be done to invest the thermodynamic and energy level characteristics of these novel hole transport materials.

5. Acknowledgments

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6. References

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