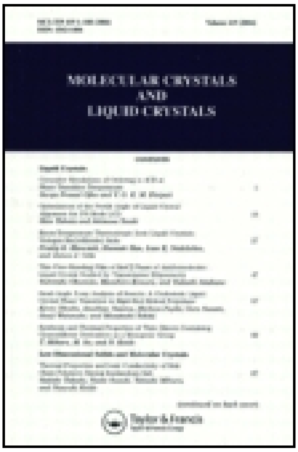

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Influence of Hole Accumulation and Leakage at Organic/Organic Interface on Device Characteristics of Organic Light-Emitting Diodes

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Influence of Hole Accumulation and Leakage at Organic/Organic Interface on Device Characteristics of Organic Light-Emitting Diodes

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ABSTRACT

We measured static characteristics and dynamic behavior of OLED devices, and we confirmed experimentally that device characteristics of OLED devices were dependent on ionization potential of a hole transport layer through a space charge layer formation in the device.

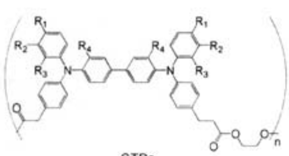
Keywords organic EL; organic light-emitting diode; space charge layer; hole transport material; charge injection

INTRODUCTION

In organic light-emitting diodes (OLEDs), hole injections into organics are rather easy compared with electron injections.[1] Therefore, excess injected holes form positive space charge layers (SCLs) in the device, and the SCLs influence the electron injections. Therefore, we investigated device characteristics in detail when hole-injection property was controlled by changing ionization potential (Ip) of a hole transport layer (HTL).

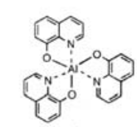
EXPERIMENTAL

TPD like hole transport polymers, CTPs, whose Ip was varied from 5.0 eV to 5.4 eV by chemical modifications, were used as a HTL. Sample devices were fabricated as follows. A 50 nm-thick CTP layer as a hole transport layer (HTL) was spin-coated on an indium tin oxide (ITO) coated glass substrate. Alq was deposited on the CTP in vacuum, and then Mg:Ag (10:1) or Al was deposited on the Alq layer in vacuum. Thicknesses of the Alq layer and the cathode were set to be, respectively, 50 nm and 200 nm. A voltage response of the OLED device was measured by a fast voltage pulsar and a digital oscilloscope. Chemical structure and Ip are shown in Fig. 1 with structure of the other chemicals.



CTPs

CTPs	R_1	R_2	R_3	R_4	Ip (eV)
CTP-5	CH_3	CH_3	H	CH_3	5.2
CTP-6	H	H	H	CH_3	5.35
CTP-8	CH_3	CH_3	H	H	5.08
CTP-9	OCH_3	H	H	H	4.96
CTP-10	OCH_3	H	CH_3	H	5.05



Alq

FIGURE 1 Structure of chemicals used in this study.

RESULTS AND DISCUSSION

Figure 2 shows the light emission onset voltage (V_{LEO}), which is defined here as a voltage at a luminance of 1 cd/m^2, when an energy barrier height for hole at a CTP/Alq interface was changed. This barrier was defined here as the hole block barrier (Φ_{BB}). As shown in Fig. 2, the V_{LEO} increased with increasing the Φ_{BB}. Furthermore, a hole leakage current (I_{HL}, also shown in Fig. 2), which was defined here as a current density at a bias voltage of 3 V, increased with decreasing the Φ_{BB}. Thus, the V_{LEO} positively depends on the I_{HL}. At this low voltage region where the electron injection hardly occurred, the electron injection will be assisted by a positive SCL that is formed by holes in Alq caused by hole injections into Alq through the CTP/Alq interface.

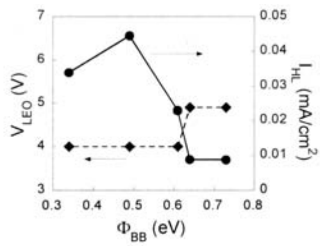


FIGURE 2 Φ_{BB} dependence of V_{LEO} and I_{HL}.

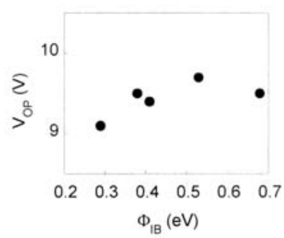


FIGURE 3 Φ_{IB} dependence of V_{OP}.

On the other hand, as shown in Fig. 3, the operation voltage (V_{OP}), which was defined as a voltage at a current density of 100 mA/cm^2, decreased when an energy barrier height at an ITO/CTP interface decreased. This barrier is defined here as the hole injection barrier (Φ_{IB}). At this high current density operation region, the positive SCL described above will disappear by plenty electron injections. However, another positive SCL is formed at the CTP/Alq interface because the injection unbalance between hole and electron is yet remained. The SCL at the CTP/Alq interface also enhances the electron injection, and the strength of the SCL depends on the energy barrier height at the ITO/CTP interface. Therefore, V_{OP} positively depends on Φ_{IB}.

We have carried out the voltage response measurement of the OLED devices for confirming the formation of the SCL. Figure 4 shows transient voltage behavior of different two devices, which were respectively composed of CTP-6 (Φ_{IB}=0.65 eV) or CTP-10 (Φ_{IB}=0.35 eV) as a HTL. In the case of CTP-6, the decay is single exponential, but in the case of CTP-10, a slow decay component was also observed. A lifetime (190ns) of the fast decay was consistent with a time constant of the RC circuit, where R is composed of a internal resistor (50 Ω) of the pulsar and other wiring resistors (14 Ω) , and C is equal to a capacitance when the OLED device is assumed to a parallel electrodes capacitor. Since the slow component was caused by the accumulated holes, it was confirmed that the accumulated holes existed and amount of that is dependent on Φ_{IB}.

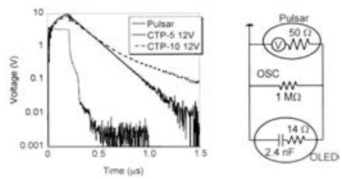


FIGURE 4 Voltage response of OLED devices and equivalent circuit of voltage response measurement system.

CONCLUSION

We measured static characteristics and dynamic behavior of OLED devices, and we confirmed experimentally that device characteristics of OLED devices were dependent on Ip of HTLs through the SCLs formation.

Acknowledgments
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References

[1] L. S. Hung, C. W. Tang, M. G. Mason, Appl. Phys. Lett. **70**, 152 (1997).