유기 전기발광 소자에서 인가전압 방향에 따른 전류-전압 특성

Current-Voltage Characteristics with a direction of Voltage in Organic Light-Emitting Diodes

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Abstract

We have investigated current-voltage(I-V) characteristics of organic light-emitting diodes based on TPD/Alq_3 organics depending on the application of forward-reverse bias voltage. Luminance-voltage characteristics and luminous efficiency were measured at the same time when the I-V characteristics were measured. We have observed that the I-V characteristics shows a current mxima at low voltage, which is possibly not related to the emission from Alq_3.

Key Words : Organic light-emitting diodes, Current-voltage characteristics

1. Introduction

In 1987, Tang and VanSlyke reported a bilayer organic electroluminescent(EL) cell structure, which has a quantum efficiency of about 1% and a luminnance of 1,000 cd/m^2 for green light under the low-operating voltage below 10V[1]. Organic light-emitting diodes (OLEDs) have been received attention due to potential application to full color flat-panel display. They are attractive because of low-driving voltage and capability of multicolor emission of many synthesized organics[2-3]. The obtained power and quantum efficiency as well as lifetime are already sufficient for commercial application. Nevertheless, the detailed mechanisms on charge carrier injection, transport and recombination are not yet fully understood[4].

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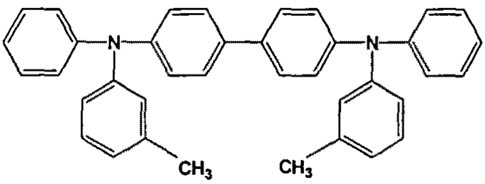
In this paper, We present anomalous behavior in the current-voltage characteristics in ITO/TPD/Alq_3/Al device with a direction of applied voltage.

2. Experimentals

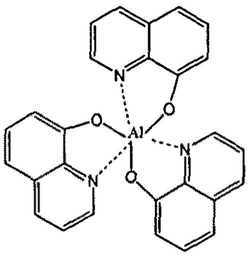
We have fabricated the OLEDs with a use of N,N′-diphenyl-N,N′-bis(3-methylphenyl)-1,1′-biphenyl-4,4′-diamine (TPD) as a hole-transport and 8-hydroxyquinoline aluminum (Alq_3) as an electron transport and emissive material. The ITO glass, having a sheet resistance of 15Ω/□ and 170nm thick, was received from Samsung Corning Co. A 5mm wide ITO strip line was formed by selective etching in solution made with hydrochloric acid (HCl) and nitric acid(HNO_3) with a volume ratio of 3:1 for 10~20 minutes at room temperature. And then the patterned ITO glass was cleaned by sonicating it in chloroform for 20 minutes at 50℃. And then the ITO glass was heated for 1 hour at

80℃ in solution made with second distilled deionized water, ammonia water and hydrogen peroxide with a volume ratio of 5:1:1. We sonicated the substrate again in chloroform solution for 20 minutes at 50℃ and in deionized water for 20 minutes at 50℃. After sonication, the substrate was dried with N_2 gas stream and stored it under vaccum. Fig. 1 shows molecular structures of TPD, Alq_3 and device structure. The organic materials were successively evaporated under 10^{-6} torr with a ratio of about 0.5~1Å/s.

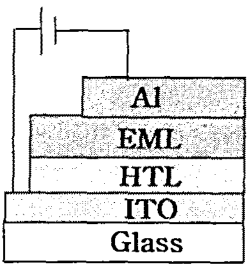
The film thickness of TPD and Alq_3 was made to be 40nm and 60nm, respectively. And Al cathode(150nm) was deposited at 1.0×10^{-5} torr. Light-emitting area was defined by using a shadow mask to be 0.3×0.5 cm^2.



(a) TPD



(b) Alq_3



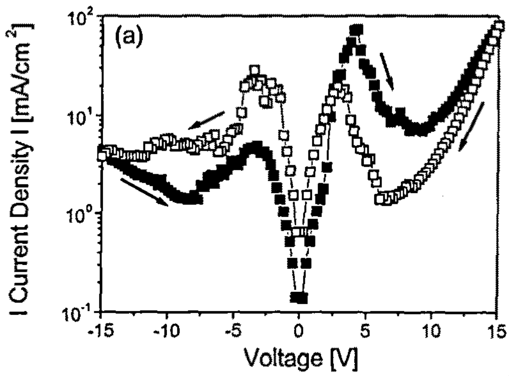
(c) Device

Fig. 1 Molecular structure of (a) TPD, (b) Alq_3 and (c) device structures.

Current-voltage characteristics and luminance-voltage characteristics of OLEDs were measured using Keithley 236 SMU source-measure unit, 617 electrometer and Si-photodiode. Luminance-voltage characteristics and luminous efficiency were also measured at the same time when the current-voltage characteristics were measured. Luminous efficiency was calculated based on the luminance, EL spectra and current densities.

3. Results and Discussion

Fig. 2 shows the semi-logarithmic plot of current-voltage and luminance-voltage characteristics of ITO/TPD/Alq_3/Al device.



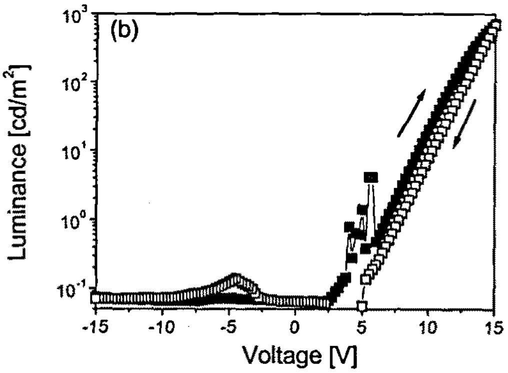


Fig. 2 (a) Current-voltage characteristics and (b) luminance-voltage characteristics in ITO/TPD/Alq_3/Al device.

The current and luminance were measured as the voltage is increasing from -15V to +15V continuously and then decreasing backwards from +15V to -15V with 100ms delay time at each measurement.

Fig. 2(a) clearly shows that current follows different paths depending on the direction of applied voltage. There are quasi-reversible current maxima at around ±3.5V and minima at approximately ±8V. Quite surprisingly, there exists negative differential resistance(NDR) region in between 3.5V to 8V. Even though the maximum current at about 3.5V is about the same as that at 15V, the luminance at 3.5V is much lower than that at 15V(see Fig. 2(b)).

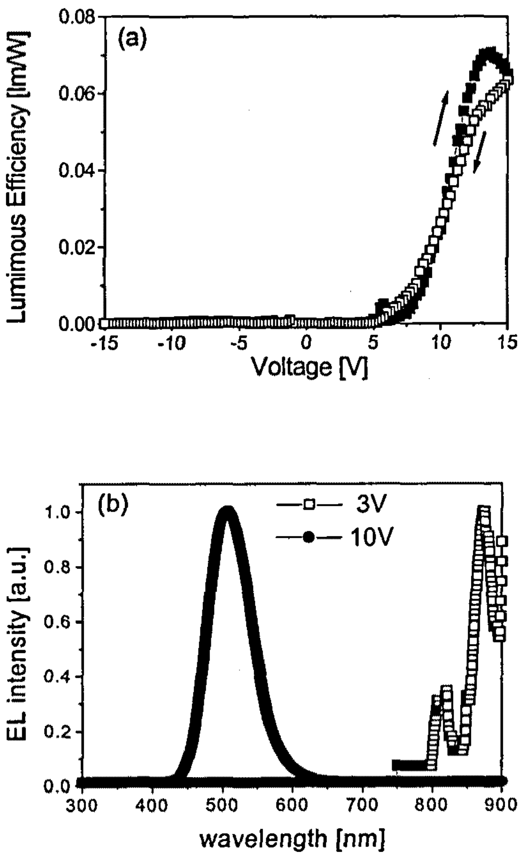


Fig. 3 (a) Luminous efficiency-voltage characteristics and (b) normalized EL spectrum of ITO/TPD/Alq_3/Al devices.

The luminance in NDR region appears only when the voltage goes either from 0V to -15V or from 0V to +15V.

Fig. 3 shows the luminous efficiency and EL spectrum of ITO/TPD/Alq_3/Al device. When the voltage increases above 5V, the variation of efficiency is a little bit steeper than the other way around. Fig. 3(b) shows the normalized EL spectrum of device at two different voltages; 3V and 10V. The emission at 3V is very weak and this emission is possibly not from Alq_3. In the experiment, we can see that there are some localized spots in device at low voltage. We dont fully understand it yet where it is originated from.

4. Conclusions

We have observed the anomalous behavior in current-voltage characteristics of ITO/TPD/Alq_3/Al device with the direction of applied voltage. There is a high current at low voltage and there is a NDR region in between 3.5V and 8V. It seems that the conduction mechanism at low voltage is totally different from the one at high voltage.

[Acknowledgement]

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