ISSN : 2249 - 8877 Volume 4 Issue 2

Research & Reviews On Polymer

Full Paper

RRPL, 4(2), 2013 [52-55]

Polymer light emitting diodes: Design, fabrication and characterization

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ABSTRACT

An efficient polymer light emitting diode (PLED) was fabricated by inserting calcium (Ca) between a emissive layer and an Aluminum (Al) cathode. An efficient cathode Ca/Al used to improve the performance of PLEDs was reported. Indium tin oxide (ITO) /poly (3, 4ethylenedioxythiophene) : polystyrenesulfonate (PEDOT:PSS) / 2, 3-dibutoxy-1, 4-poly (phenylenevinylene) (DBPPV) / Ca/Al devices showed dramatically enhanced electroluminescent (EL) brightness and efficiency. The optimized DBPPV layer concentration device with the 60 nm layer of Ca with cathode structure of Ca/Al showed the improved current efficiency than the control device of the Cesium fluoride (CsF) /Aluminum cathode. The drive voltage of the device with the Ca/Al cathode was decreased compared with CsF/Al device. The enhanced properties of the device with such a cathode are considered to the improved balance of electron/hole injection in the emitting layer.

KEYWORDS

Polymer light emitting devices;
Electron injection layer;
Electroluminescence.

INTRODUCTION

Polymeric light emitting diodes are gradually evolving from a research topic into a commercial opportunity. The main obstacle to their application in displays or monitors is still their lack of stability and efficiency. To achieve an efficient electroluminescence (EL) of a PLED, a balance in the injection and transport of charge carriers is required[1-6]. ITO/PEDOT:PSS is used as the anode to attain a hole injection ability. For the cathode, a common approach is the application of a metal with a low work function to realize a lower injected barrier for electrons. However, these metals are susceptible to degradation caused by oxygen and moisture. From a practical viewpoint, it is desirable to use a stable metal as the cathode, such as Al or Ag, having a higher barrier for electron injection[7-18].

In this work, we aimed to optimize the best device parameter, so we fabricated different weight ratios of the concentration of polymer solution and two different cathode materials. The two weight ratios were 0.5%, and 0.6% and the two cathode materials were CsF/Al and Ca/Al. Furthermore, we compared the electrical properties, than found out the best performing device.

EXPERIMENTAL

The ITO coated glass with a sheet resistance of 25 ohm/cm was used for the anode for PLED fabrication. For the preparation of PLEDs, the ITO glass was cleaned sequentially in ultrasonic bath of isopropanol, acetone, and de-ionized water. Finally, the ITO glass was sonicated in deionization water and then blown dry with N2 gas. The poly (styrenesulfonate)(PSS)-doped poly (3,4-ethylenedioxythiophene)(PEDOT) was used as the hole transport layer (HTL). A 40 nm thick PEDOT:PSS was spin coated onto precleaned and UV-O3 treated ITO substrates. The PEDOT:PSS layer was first baked at 150°C for 30 min to remove residual water and then moved into a glovebox under N_2 filled environment. The electroluminescent (EL) polymer films (DBPPV) was spin coated from solution to form on top of the PEDOT:PSS layer. The sample was baked at 60°C for 30 min to remove the residual solvent. Finally a different thickness of CsF/Al or Ca/Al metal cathode film was thermally deposited through a shadow mask to form top electrode in a vacuum of $1X10^{-6}$. EL spectra of the devices were measured by PR650 spectra scan spectrometer and the current-voltage-brightness characteristics were simultaneously measured by a Keithley 2400 programmable voltage-current source. All the measurements were carried out at room temperature under ambient conditions. The active emissive area of the device is 6 mm^2.

RESULTS AND DISCUSSION

Figure 1 shows that schematic diagram of ITO/PEDOT:PSS/DBPPV/CsF or Ca/Al Polymer LED and Chemical structure of the DBPPV polymer. CsF is common material which was used as a buffer layer in PLED, so we tried to utilize this material in our devices.

Figure 2(a) shows the current-voltage curves of the PLED fabricated from two different concentrations of DBPPV. We observed that the turn on voltage decreased and current density increased as the weight ratio of DBPPV decrease. We supposed that when concentration of polymer increased, the polymer solution became dense and the thickness of the polymer layer increased. Then thickness of device increased affected the turn on voltage increased and current density decreased[3,11,12].

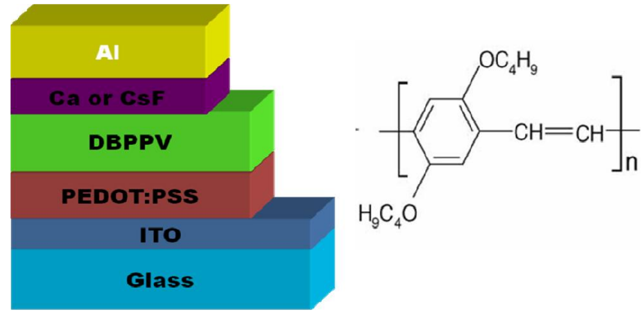

Figure 1 : Schematic diagram of PLED and chemical structure of the polymer

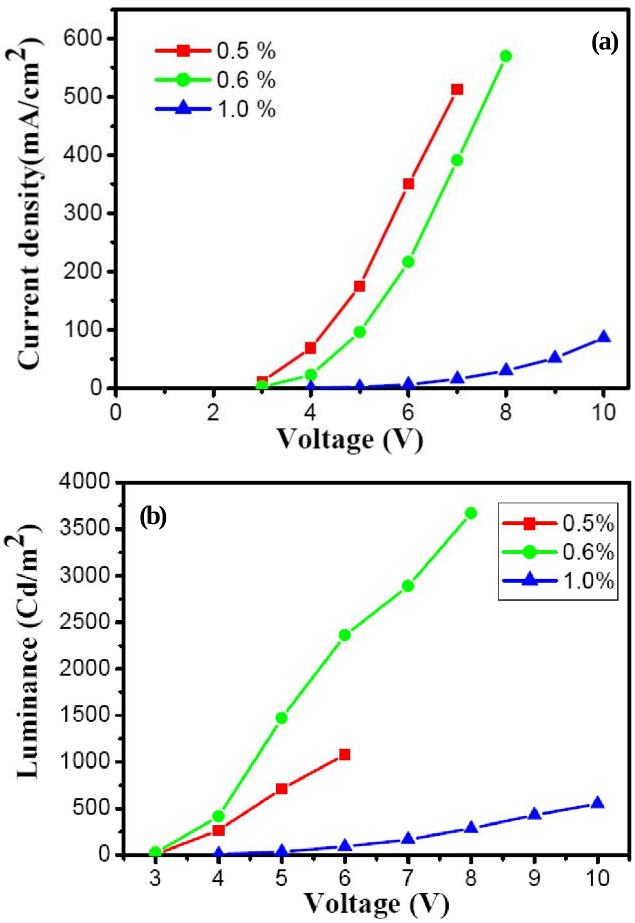

Figure 2 : (a) Current-Voltage (b) Luminance-Voltage Characteristics of the PLED (ITO/PEDOT:PSS/DBPPV/CsF/Al)

Figure 2(b) shows the luminance versus voltage curves of PLED fabricated from two different concentrations of DBPPV. Although the device fabricated from 0.5% weight have higher current density, the luminance-voltage curve shows that the luminance of 0.6% weight device higher that 0.5% weight device. In Figure 3, we can see that the luminous efficiency of 0.6% weight device is higher than 0.5% weight device.

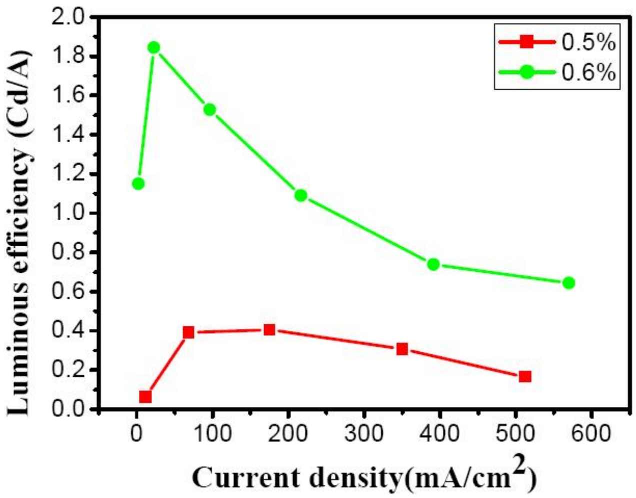

Figure 3 : Luminance efficiency-current density characteristics of the PLED (ITO/PEDOT : PSS/DBPPV/ CsF/Al)

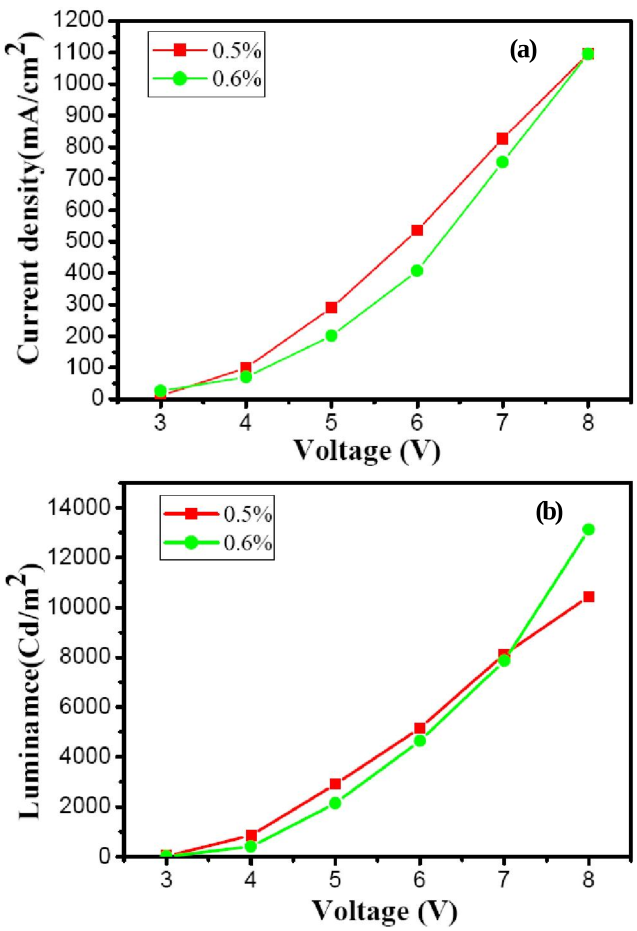

Figure 4 : (a) Current-Voltage (b) Luminance-Voltage Characteristics of the PLEDITO / PEDOT : PSS/DBPPV/ Ca/Al

Figure 4(a) shows the current versus voltage cure, we observed that similar results to Figure 2(a). The 0.5% weight device has better current characteristic, but the differences of two devices were not obvious like the device used CsF/Al as cathode. In Figure 4(b), we found the luminance of these two devices is very close, and we have observed the same results in Figure 2(b), the 0.6% weight device has higher luminance. Therefore, in Figure 5 we can get that the luminous efficiency of 0.6% weight device would have better results that 0.5% weight device.

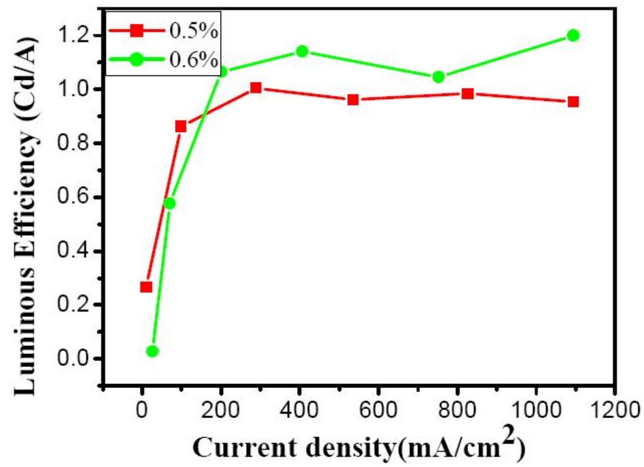

Figure 5 : Luminance efficiency-current density characteristics of the PLED ITO / PEDOT : PSS/DBPPV/ Ca/Al

CONCLUSION

We have design, fabricated, and characterized DBPPV polymer based light emitting diodes. Improved the performance of DBPPV based PLEDs by introducing a Ca layer between the DBPPV layer and Al cathode. Turn-on voltages are reduced and luminous efficiencies are enhanced as compared to CsF/Al cathode device.

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