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Electroluminescent characteristics of DBPPV-ZnO nanocomposite Polymer light emitting devices

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1. Introduction

Polymer light emitting diodes(PLEDs) have attracted much attention in recent year, due to their potential applicability to flat , large area displays[1-2]. Major important technological issues related to commercial applications are the quantum efficiency, device stability, and easy fabrication. However, the potential use of electroluminescence devices is limited by their low quantum efficiency as well as poor stability. In spite of these critical drawbacks, the polymer light emitting device is still receiving considerable attention due to its several merits they are easy fabrication with low cost, low operating voltage, flexibility, etc. Therefore, a lot of researches have focused on solving the problem of low efficiency and the poor stability[3-5]. One of the major reasons for the low quantum efficiency of single layer PLEDs is that the electron injection is more difficult than hole injection in most polymer light emitting devices due to high energy barrier to electron injection and low electron mobility in most conjugated polymers. Therefore, one of the most important challenges in the field of polymer LEDs is to achieve balanced charge carrier injection that is essential for high efficiency[1-2]. One way to overcome the electron injection and transport limitations is to combine polymers with inorganic semiconductor which have low energy barrier to electron injection and high electron mobility(6-9). Semiconducting nanoparticles into polymer matrices is an area of current interest in organic nanoelectronics. Recently, polymer- nanoparticles composite has been increasingly studied[10-15].

In this work, nanoparticle composite materials consisting of conjugated polymers and metal oxides are the focus of interest due to their physical, electronic and optical properties. An n-type semiconductor material ZnO, possessing a direct wide band gap(3.37 eV), a large exciton binding energy (60 meV) with strong piezoelectric and pyroelectric properties. It is one of the most promising candidates for the fabrication of short wavelength optoelectronic devices[16-18]. To our best knowledge, this could be the first report of PLEDs that consists of DB-PPV and the inorganic semiconductor metal oxide (ZnO).

2. Experimental

2,3-dibutoxy-1,4-poly(phenylenevinylene) (DBPPV) was purchased from Eternal Chemical and used without further purification. LEDs with an ITO/PEDOT:PSS/DB-PPV-ZnO/Ca/Al structure were fabricated using the following procedures. Patterned ITO-Coated glass subrates were cleaned with detergent, distilled water, acetone, and 2-propanol and subsequently in ultrasonic bath. The substrates were dried in an oven at 100 ^{o}C , before treatment with UV-Ozone. After treatment UV-Ozone for 25 minutes, a 40nm layer of PEDOT:PSS was spin-coated onto the substrates, followed by drying on a hotplate at 150^{o}C for 30 min. The weight ratios of DBPPV versus ZnO were changed from 4:1 to 2:1for DBPPV-ZnO (4:1 by wt.)[DB4-ZnO), DBPPV-ZnO(3:1 by wt.)[DB3-ZnO] and DBPPV-ZnO(2:1 by wt.)[DB2-ZnO). The polymer light emitting devices of the DB-PPV-ZnO composite single layer were fabricated as follows:

The DBPPV and ZnO were pre-dissolved in toluene and well mixed to give different volume ratios. Composite single layers of DBPPV- ZnO were spin-coated from toulene solutions with a speed of 3000 rpm for 1 min on top of the PEDOT:PSS by spin coating from toluene solution. Followed by baking on a hotplate at 60oC for 30 min inside the glow box. Then, the Ca(60nm) and Al(120nm) electrodes were thermally evaporation in a vacuum of about 2×10^{-6} Torr. For the measurements of device characterstics. Current density-voltage-luminance(J-I-V) changes were measured using a power supply (keithley 2400) and a flouorescence spectrophotometer(Ocean optics usb 2000), and the luminance was further corrected by spectaScan PR650 spectrophotometer. The active are of the EL devices by overlapped of the ITO and the cathode electrodes was 6 mm2. The Schematic diagram of a LED is shown in Fig.1.

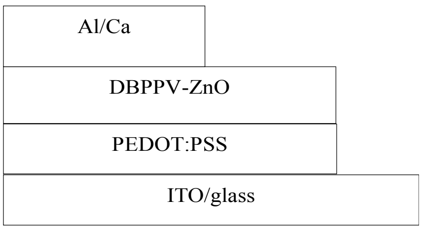

Fig.1. Schematic diagram of our PLED structures.

3. Results and Discussion

The current versus voltage(I-V) and light output versus voltage(L-V) characteristics of ITO/PEDOT:PSS/DBPPV-ZnO/Ca/Al Polymer light emitting diodes are shown in Fig.2(i) and (ii) respectively . It is obviously that device current increased with increasing nanoparticle. Electroluminescence (EL) efficiency versus current density of devices are plotted in Fig.3(i). Optimized luminance efficiency could reach 1.78 Cd/A with DB3-ZnO at a current density of 36.16 mA/cm-2 and a brightness of 643 cd/m2. A maximum brightness of 4317 cd/m2 at 7V eas measured. The current turn-on voltage(VI-on) of ca.3.76(pure DBPPV) and 3.10(DB3-ZnO), at the current of 0.5 mA, which is the majority carrier injection voltage. The DB3-ZnO device also had a low turn on voltage(3.255V) at a brightness of 100 cd/m2, which is 0.76V lower than that of the pure DBPPV. The majority carriers in DB3-ZnO and pure devices are not holes, after doping ZnO nanoparticles carrier injection is change. when comparing the device performances, some important characteristics are observed. First of all, the luminance efficiency is improved significantly, for ZnO doping devices in comparison of pure DBPPV. The interface state between the metal oxide –polymer layers in the prepared device is critical determining factor for the optical performance and physical of polymer light emitting diodes. However, doping is still regarded as an effective technique to adjust the interfacial energy level distribution in processing electronic and optical devices[10-15].

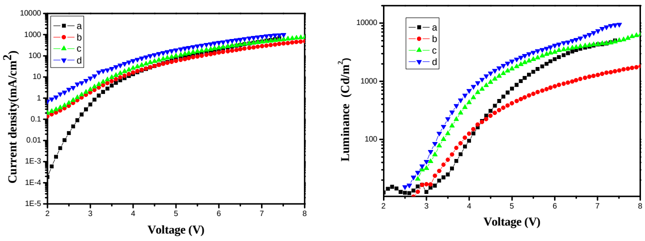

Fig.2. (i) current density-voltage(I-V) and (ii) Luminescence-voltage characterisitics of (a) DBPPV, (b) DB2-ZnO, (c) DB3-ZnO and (d) DB-4ZnO devices

Fig.3(ii) show the normalized electroluminescence as a function of the emission wavelength(EL) of PLEDs with Pure DBPPV, DB2-ZnO, DB3-ZnO, and DB4-ZnO were shown in Fig. We obvious found that ZnO doped DBPPV the emission peak from the inter-chain vibration of DBPPV was reduced, that suppose the possible reason the nanoparticle assist the polymer arrangement and reduce the conformational disorder of polymer in the emission layer, and then cause the probability for inter-chain emission of device to reduce[19].

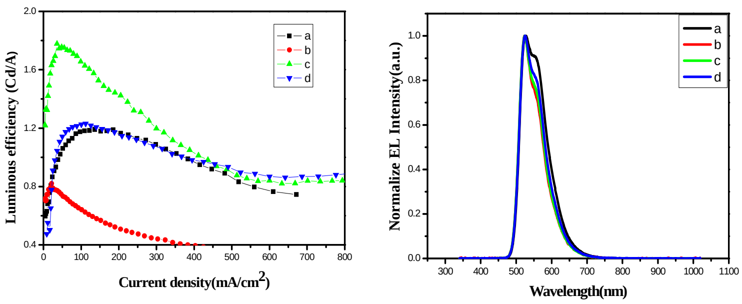

Fig. 3 (i) The luminescence efficiency versus current density (ii) normalized EL spectrum characteristics of (a) DBPPV, (b) DB2-ZnO, (c) DB3-ZnO and (d) DB-4ZnO devices

4. Conclusions

In summary, we have fabricated PLEDs based on DBPPV:ZnO nanocomposites. It I-V and L-V curves demonstrated that the ZnO nanoparticle have the ability to improve the current density, brightness and luminance efficiency, which may be caused by the enhancement of charge injection and charge transport. From the EL spectrum, shoulder peak intensity of nanocomposite devices reduced, suppose that nanoparticle reduced the conformational disorder of the polymer. The brightness and luminance efficiency of the PLEDs could be improved by annealing, for the DB3-ZnO device investigated.

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