Improvement of PLED Efficiency by Post-annealing Process

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Abstract

In this study, we manufactured polymer-LED using light emitting copolymer as the active layer. After cathode layer deposition, we did post-annealing at 150 ℃ during 10 min in N_2 glove box. Then, we confirmed that the efficiency of the device was significantly enhanced by post annealing process. Its value was increased from 0.18(cd/A) to 1.32(cd/A), approximately 7 times. This phenomenon is a result of improved stability between polymer and metal cathode for injection of electrons as the contact density increases.

1. Introduction

OLED(Organic Light Emitting Diode) is suitable to display moving-picture caused of fast response time and simple construct of panels can be made to light, rugged, conformable and thin, moreover inexpensive to easy fabrication steps[1,2]. Also, it has excellent operating characteristics of low operating voltage, power efficient and wide temperature range. On the contrary, it also has critical disadvantages such as life time, full color realization and application of large screen.

Until now, the research on improving efficiency has advanced steadily on each field. One of the efforts is the method that tunes energy level between adjacent materials by inserting layer. For example, there is device containing two- dimensional (2D) SiO2 /SiN*x* photonic crystal (PC) layers. Inserting 2D SiO2 /SiN*x* PC between glass and ITO, they showed the result that the light extraction efficiency increased by over 50% compared to the typical OLED because of the release of the photons trapped in the high-index guiding layers [3]. And there is report that use charge-carrier blocking materials. It demonstrates experiment that involves a cyclometallated iridium compound (bis(2-(4,6- difluoro- phenyl) pyridyl-N, C20) iridium(III) picolinate, FIrpic) as a hole- blocking material. Devices which conjugated FIrpic as a incorporated hole blocking and electron transporting layer gave external quantum efficiencies upper than 14% [4]. Also, other experimenters of J.A.Hagen et al. performed work using electron blocking material. They enhanced electro-luminescent efficiency using a deoxyribonucleic acid (DNA) complex as an electron blocking material by manufacturing so-called bioLEDs. The value of maximum luminous efficiency was 8.2 cd/A [5].

The other effort uses excimer layer about PLEDs. They fabricated on irradiated indium-tin-oxide surfaces by KrF excimer laser. And then they found the improvement of charge-injection balance and prevention of cathode metal quenching, resulting in a remarkable increase in external quantum efficiency [6].

Unlike the above, we did experiment using thermal treatment so that efficiency of device improves. In general, most layers are formed by spin-coating method but Al metal cathode layer is formed by vacuum deposition necessarily. Case on vacuum deposition, bad contact between interfaces leads to decreasing mobility of carrier injected from Al metal cathode. In the result, the device has inferior characteristics such as efficiency and brightness. This phenomenon can be improved by thermal treatment after cathode layer deposition [7].

Post-annealing process enhances the efficiency characteristic especially. It attributes the improvement to an altered polymer/metal interface. Through thermal treatment, composition of polymer/Al interface is closer than previous state. So, electrons injected from Al metal cathode layer are transported well and device functions stable.

2. Experimental

In this study, we fabricated polymer-LED using light emitting copolymer as the active layer. This device consisted of anode, hole injection layer (HIL), hole transport layer (HTL), copolymer as the emission layer and cathode to evaluate LED device[8].

Indium tin oxide (ITO) for using anode was deposited on glass to a thickness of 1,500 Å and patterned through photolithography process. We performed cleaning procedure of IPA, acetone, methanol and DI(Deionized Water) using ultra-sonic for 5 min. Then, we formed a HIL with PEDOT:PSS (poly (ethylenedioxythiophene): polystyrene sulphonate, Baytron VPAI 4083, H. C. Starck) on ITO to a thickness about 25 nm. After, we worked thermal annealing under 10 min on 150℃ plate. It was used as the buffer layer on the anode mainly to increase the anode work function from 4.7 eV (ITO) to 5.0 eV and reduce the surface roughness of the anode to obtain stable and pin-hole-free electrical conduction across the device. Next, we formed HTL with poly-TPD (poly(N,N'-bis(4-butylphenyl)-N,N'-bis(phenyl)benzidine), ADS 254BE) dissolved in the dichlorobenzene with 2 wt% to thickness of 50 nm. After spin-coating on PEDOT:PSS, we did thermal process in vacuum oven for 30 min. Its highest occupied molecular orbital (HOMO) level is 5.2 eV, which is very close to the work function of the ITO/PEDOT:PSS anode. Moreover, poly-TPD has proven to be a good resistor to non-polar organic solvents such as toluene and xylene. We used light emitting copolymer (ADS 233YE) dissolved in the toluene with 1 wt% and formed EML on poly-TPD. After EML formation, we worked thermal treatment for 10min on 150℃ plate. ADS 233YE is Poly[9,9-dioctylfluorenyl-2,7-diyl] –co-(1,4-benzo- {2,1',3}-thiadiazole)] end-capped with DMP. And it has emitting characteristic with maximum photoluminescent of 528nm (fig 1) that means green light emitting device when it used active layer. Also its property is weakened if it is exposed to oxygen atmosphere so be keeped under argon atmosphere. The Al metal layer for cathode was deposited on EML intersected with anode through thermal evaporation with shadow mask.

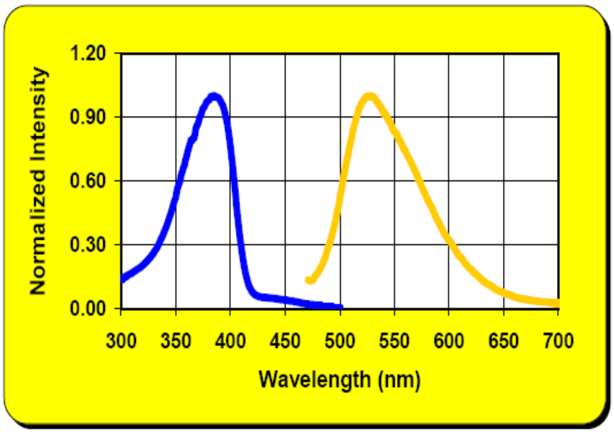

Fig. 1. Absorption and emission spectra of ADS233YE film on ITO glass

At this time, the area of emission layer perpendicular to each electrode is 9 mm^2. After that, we performed post-annealing at 150℃ during 10 min in N_2 glove box for stability of interface characteristic in device.

3. Results and discussion

Polymer-LED with 233YE emitting layer was fabricated as presented method (fig 2) and its energy band diagram is exhibited in figure 3. Adjacent materials are selected by considering their energy level for smooth carrier mobility.

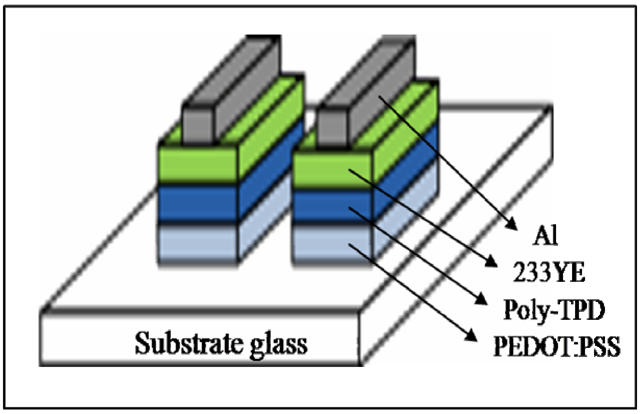

Fig. 2. Schematic diagram of fabricated device structure.

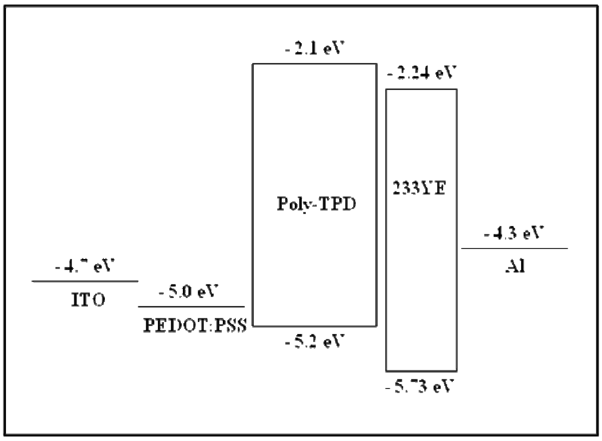

Fig. 3. Energy band diagram of fabricated device.

Figure 4 shows typical current density and luminance curves as a function of applied voltage for OLED. The luminance characteristics were measured with a LS-100 (Minolta, Japan). This device demonstrated turn-on voltages of 4.5 V. The maximum luminance is about 7,000 cd/m^2 and current density is 7,000 A/m^2, respectively. Inset image in figure 4 shows a maximum luminance of fabricated device at 13.4 V.

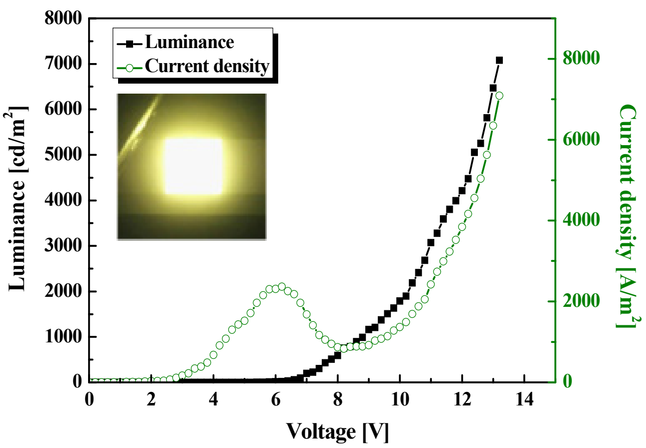

Fig. 4. J-V-L curves of fabricated LED device and emitting image (inset).

Figure 5 shows the luminance efficiency according to the injection current with post-annealing case and non-post-annealing case, respectively. By post-annealing, we confirmed that the efficiency was improved from 0.18 cd/A to 1.32 cd/A, approximately 7 times. This effect results from increasing contact density between active layer and metal cathode. The increase of contact density contributes to electronic injection from Al metal cathode to active layer. Therefore the creation of electron-hole pair(EHP) in active layer is easy, considering hole mobility is better than electron mobility on organic material.

Post-annealing treatment in nitrogen atmosphere seems to be an attractive way of achieving efficiency enhancements, as it is a simple low-cost process.

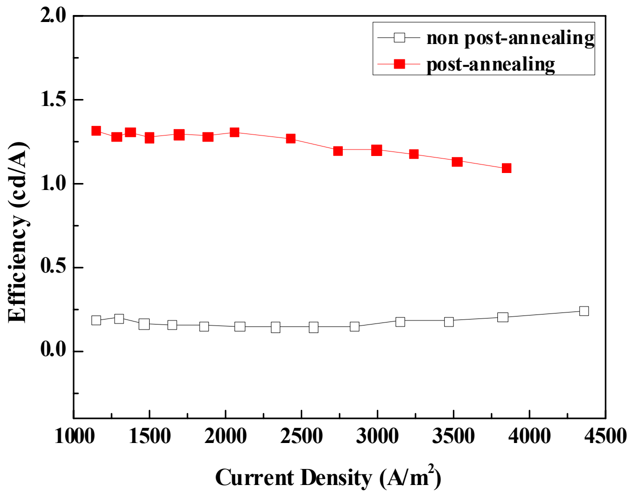

Fig. 5. Efficiency characteristic according to injection current.

4. Summary

After manufacturing organic electro-luminescent device using polymer, we confirmed that the efficiency under same current density was improved from 0.18 cd/A to 1.32 cd/A as a result of post-annealing treatment in nitrogen atmosphere. The fabricated device had characteristics that turn-on voltage was 4.5 V and maximum luminance was 7,000 cd/m^2.

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