

Polymer Light-Emitting Diode with Controlled Nano-Structure

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Introduction

Over the past decade, intensive academic and industrial research, and impressive scientific and technological progress has been achieved in the conjugated polymers with semi-conducting properties due to their applicability in the field of optic and opto-electronic devices such as light-emitting diodes, photovoltaic devices, transistors and lasers. In particular, the LEDs based on conjugated polymers have attracted much attention because of their good processability, low voltage, fast response times, and facile color tunability over the full visible range which well suitable for flat-panel displays. However, the efficiency and stability of polymer light emitting diodes(PLEDs) still need to be improved in order to fully realize the advantage of organic materials.

Here, we report our effort to enhance the PLED's performance in two approaches :

- 1) Utilizing nano-structured materials such as nano particles, nanoclay, nano porous silica in active layer
- 2) Modifying the device structure in nano scale

to improve not only the device efficiency but also its stability.

Nano-structured materials in active layer

Nanoclay The introduction of silicate layers into polymers to create composite materials with improved mechanical properties has been widely investigated. Nanocomposites exhibit markedly better mechanical, thermal, and physicochemical properties than neat polymer of conventional (micro scale) composites. However, studies on the effects of layered silicate on the properties of functional materials such as photoresponsive polymer nanocomposites are in their infancy. We used several layered silicate such as Nanomontmorillonite, laponite RD, C20A which act as barrier, and these devices shows high emission color quality, better long-term stability, and enhanced luminescence properties. The enhanced emission-color purity of the nanocomposite films is attributed to the reduced interchain interactions achieved by isolating the conjugated polymer chains within the confined geometry of the nanolayer. The nanolayers in the nanocomposite films not only inhibit the photochemical oxidation of polymer by blocking the oxygen penetration, but also prevent exciton migration by steric hindrance, these two effects are combined to improve the photostability of films.

Nano porous silica The dielectric walls(MCM-41), just like nanoclay, are also introduced in active layer. This organic/inorganic nanocomposite materials with a three-dimensional geometry gives good barrier properties which can prevent photo-oxidation by blocking the penetration of oxygen, stability at high temperature and enhanced light output by reduction in interchain interaction.

Nanoparticle Oxidation in many luminescent polymers begins with the formations of singlet oxygens via energy transfer from long-lived triplet excitons, resulting in chain scission and carbonyl defect formation on polymer chain ends. To block the action of oxygen, we incorporate metal nanoparticle into polymer. The triplet excitons of luminescent polymers are quenched as a result of the overlap of their energy levels with the optical absorptions of the added nanoparticle, so device shows enhanced stability.

Device structure modifying

Bi-layer structure One of the most important current challenges in the field of polymer EL devices is to obtain the balanced carrier injection in order to enhance the light output and efficiency. For this goal we prepared bilayer LEDs consist of hole transport layer/active layer with different film thickness ratios. Narrower emission bands were observed in the PL and EL spectra compared with the single

layer system, meaning that the emission zone is located in the interface between hole transport layer and active layer. The increased hole injection and the controlled electron confinement which resulted from the variation of layer thickness improves the device light output dramatically.

Insulating nanolayer Aluminum(Al) is inexpensive and easy to use for the cathode of PLEDs but electron injection in the devices with Al cathode has proved more difficult to occur than hole injection, resulting in unbalanced charge injection. It is necessary to use a low work function metal such as calcium(Ca) to reduce electron injection barrier for a higher efficiency. Such metal, however, are so susceptible to moisture and oxygen that the resulting devices suffer from poor environmental stability. To balance injection of holes and electrons without using low work function metals, we introduced kind of polymer-insulating nanolayer that are capable of electron tunneling and are of different dielectric constants. From this, we could reduce the electron injection barrier height at the cathode/emitting layer interface, especially the employment of the PS nanolayer not only brings about a highly improved quantum efficiency but also lowers the turn-on voltage compared with the single layer device.

nano-porous morphology Aggregation is indeed a crucial obstacle in conjugated polymer since most films are spin coated from solutions with high enough concentration. When the polymer chains are in contact with others in the film, the number of primary photoexcitations that result in interchain species would be prevalent, so that the formation of weakly emissive interchain species significantly reduce the efficiency of electroluminescence. To decrease interchain interaction, nano-structured materials (nanoclay, nano porous silica) was introduced into emissive layer as we said in previous section. Here, instead of using foreign materials, we made active layer have nano-porous morphology itself. This nano porous morphology suppressed the interchain interaction of polymer, and their luminance and efficiency were greatly improved.

Conclusion

Both environmental stability and high efficiency of PLEDs can be achieved by utilizing nano structured materials into the active layer or by modifying the device structure in nano scale. Oxidation of polymer is restrained through introducing penetration barrier (nanoclay, nano porous silica) or quenching triplet energy by nanoparticle. For the high efficiency, balanced charge injection and reduction of interchain interaction are accomplished by multi-layered structure and morphology control of active layer, respectively.

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