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Enhanced luminescence efficiency by Ag nanoparticles dispersed on indium tin oxide for polymer light-emitting diode

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1. Introduction

Polymer light-emitting diodes (PLEDs) that are based on conjugated polymers have attracted a lot of attention in recent years because of their extreme thinness, high peak brightness, high dark room contrast, lower power consumption, superviewing ability, and fast response time for use in low-cost optoelectronic devices. The typical structure of a PLED is metal (cathode) / polymer film / hole transport layer (HTL) / transparent conducting oxide (TCO) film (anode) / glass substrate; its quantum efficiency depends on efficient dual carrier injection and transportation to balance electrons and holes. TCO films are typically manufactured from indium tin oxide (ITO). ITO has been extensively used as an anode in PLEDs because it has a high visible transmittance, a low electrical resistivity and a relatively high work function (WF). To improve further the luminescence efficiency of PLEDs, several studies [1-5] have sought to increase the conductivity and the WF of the ITO anode by coating an additional hole transport layer. However, Ag nanoparticles, which are introduced between the HTL layer and the ITO layer, have not been investigated in detail for their effects on the performance of PLEDs.

In this work, we report on the characteristics of an Ag nanoparticles-dispersed ITO anode for enhancing hole injection in phosphorescent PLEDs. The Ag nanoparticles were fabricated using low-power sputtering method at room temperatures. Atomic force microscopy (AFM), conducting atomic force microscopy (CAFM), and scanning surface potential microscopy (SSPM) were then employed to elucidate the impact of Ag nanoparticles on the surface microstructure and electrical properties of the ITO film. Finally, a polymer material was spin-coated onto the Ag nanoparticles-dispersed ITO substrate, and then deposited onto the metal electrodes to form the proposed PLED structure . A spectral measurement system was used to observe any enhancement of the optical gain during electroluminescence. The experimental results proved that the novel PLED device is highly practical, and the simple and low-cost fabrication makes it commercially feasible.

2. Results and Discussion

To investigate variations in the composition of Ag/ITO substrate prepared at different Ag deposition process times, we perform elemental analyses of Ag/ITO surfaces using XPS. The Ag concentration (shown in Table 1) is determined by calculating the peak areas of the binding energy at 364 eV. The calculated concentrations (in atomic percentages) for the Ag/ITO samples deposited at Ag deposition process times of 10, 20, 30, 40, and 50 s are 15.1%, 31.4%, 47.8%, 54.3%, and 61.9%, respectively.

Tab. 1. Ag concentration, RMS roughness values, coverage percentages of conducting regions, and mean WFs of bare ITO and Ag/ITO surfaces using various Ag deposition process times.

		Deposition process times of Ag (s)				
	ITO	10	20	30	40	50
Ag concentration (%)	0	15.1	31.4	47.8	54.3	61.9
RMS roughness value (nm)	5.68	6.52	6.91	6.32	6.24	6.23
Coverage percentages of conducting regions (%)	78.3	84.2	86.4	89.8	93.2	96.8
Mean work functions (eV)	4.82	4.92	4.83	4.66	4.35	4.30

3. Conclusions

This paper proposes a PLED structure, ITO/Ag nanoparticles/PEDOT:PSS/F8BT/LiF/Al. CAFM measurement showed that the Ag deposited on ITO at approximately 10 s can increase the oxygen vacancies, causing the coverage of the conducting regions to increase by 4.9 %. Furthermore, due to the product of Ag_2O nanoparticles on the Ag/ITO surface, the mean WF measured using SSPM increases from 4.82 eV to 4.92 eV, which can effectively improve hole injection efficiency for PLEDs. When the optimal Ag-deposited ITO substrate is used as the anode material of a green PLED, the EL intensity increases by 330% compared to a standard green PLED with bare ITO substrate. The prepared device offers a new design scheme for optimizing the carrier injection and recombination, which is potentially advantageous for various organic-semiconductor-based devices.

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