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Invited paper

Localized surface plasmon-enhanced green OLEDs by Au nanoparticles embedded ZnO

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ABSTRACT

Organic light-emitting devices (OLEDs) were fabricated with Au-doped ZnO and or ZnO nanoparticles (NPs) as hole injection layer (HIL) and CBP: Ir $(TSDPI)_2$ (pic) as emissive layer to enhance device performances. The photoluminescence intensity of 4,4′-N,N'-dicarbazole-biphenyl(CBP): Ir $(TSDPI)_2$ (pic)/Au −ZnO film at 514 nm is increased by 2.01 times than device with CBP: Ir $(TSDPI)_2$ (pic)/ZnO film. The current efficiency(η_c) and luminance efficiency (L)of green OLEDs with CBP: Ir $(TSDPI)_2$(pic)/10% wt Au −doped ZnO film was 58.6% and 57.0%, respectively higher than CBP: Ir $(TSDPI)_2$ (pic)/ZnO film and 71.6% and 66.0%, respectively higher than device without HIL. This enhanced efficiencies with Au-doped ZnO was correlated with the out-coupling efficiency due to localized surface plasmon resonance (LSPR) generated by Au NPs incorporated in Au-doped ZnO.

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1. Introduction

Organic light-emitting devices (OLEDs) have been attractive owing to their utilization in flexible displays [1–3] and 100% internal quantum efficiency (η_{int}) have been harvested from high-performance OLEDs with phosphorescent materials as emitter [4–6]. However, the external quantum efficiency (EQE) is still low due to poor (30%) light extraction efficiency [7,8], therefore, it is necessary to increase the light extraction efficiency of OLEDs. The metal NPs, Ag or Au modified indium tin oxide (ITO) anode, enhance the hole injection (HI) from anode to organic hole transport layer (HTL) and luminance by metal NPs in OLEDs [9].The enhanced device performances with metal NPs as HIL was found to generate from the coupling of localized surface plasmon (LSPR) of the metal NPs with emission from emitting profile [10]. The 25% of electroluminescence intensity has been reported with Au NPs as HIL and poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) [11] or tris-(8-hydroxyquinoline)aluminum [12] as emitter in OLEDs due to out – coupling efficiency.

The two competitive processes in exciton-surface plasmon system are; emission enhancement due to localized surface plasmon (LSPs) and non-radiative losses due to metal. The efficiency of the coupling was exponentially decreases with increasing distance from the emitter to the metal surface [10]. The non-radiative quenching of exciton at metal surface was reported when the distance is smaller (Fig. 1a) therefore the distance between them should be optimized for intensity enhancement. When the emitter is in proximity with the metal NPs two kinds of enhancement was observed as the function of interlayer thickness: with 5–10 nm spacer thickness (near-field effect) and with 80–120 nm interlayer thicknesses (far-field enhancement) (Fig. 1a). This enhancement could be attributed to increasing radiative rate (k_r) by metal NPs when the distance ($>\lambda/10$) between metal NPs and emissive layer is larger [13].

For maximum coupling interaction of exciton with SPs, the emission wavelength (λ_{emi}) of exciton needs to match with the absorption wavelength (λ_{abs}) of LSPs [14,15]. Though the enhanced device efficiencies with Au NPs have been reported, investigations with doped metal oxide NPs was found to be rare. Herein we report the enhanced efficiencies of fabricated OLEDs with Au- doped ZnO as hole injection layer (HIL) and a 4,4′-N,N'-dicarbazole-biphenyl (CBP):Iridium(III)bis-2-(4-(trifluoromethyl)styryl)-1-(3,5-dimethoxyphenyl)-1H- phenanthro[9,10-d]-imidazolato-N,C^2)(picolinate)[Ir(TSPDI)$_2$ (pic)] as emitter and the efficiency of electroluminescent device with Au- doped ZnO as HIL was discussed in detail with the electroluminescent parameters harvested from CBP: Ir $(TSDPI)_2$ (pic)/ZnO film and also device without HIL (CBP: Ir $(TSDPI)_2$ (pic)). The current efficiency (η_c) and luminance(L) efficiency of the green OLEDs with CBP:Ir$(TSDPI)_2$ (pic)/10 wt% Au −ZnO film was 58.6% and 57.0%, respectively, is

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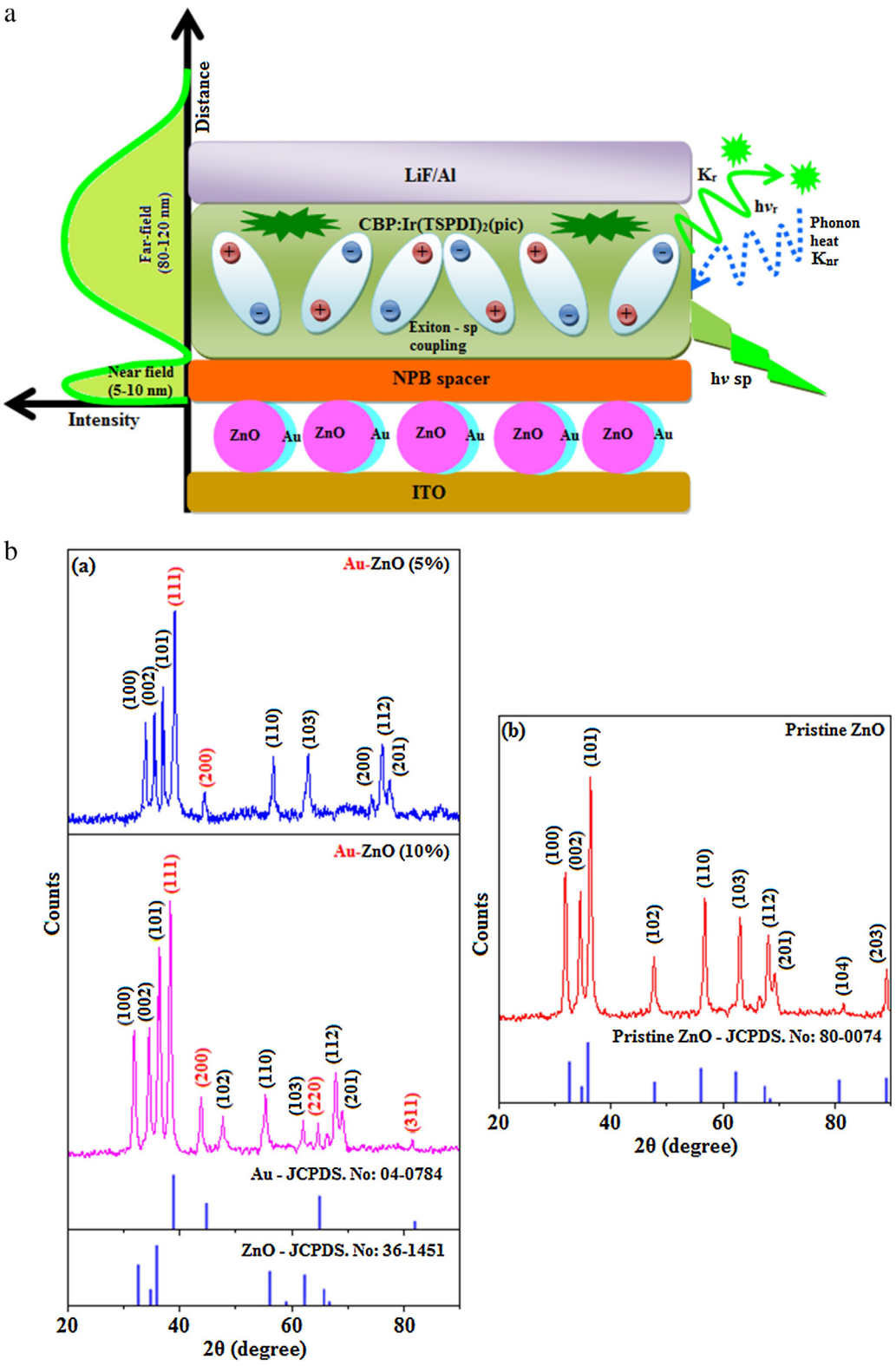

Fig. 1. (a.) Sachematic diagram of the electron–hole recombination and exciton-surface plasmon (SP) coupling mechanism. (b.) (a) X-ray diffraction pattern of 5 and 10% of Au-doped-ZnO; (b) X-ray diffraction pattern of Pristine ZnO.

larger than the device II (10 wt% ZnO as HIL) and 71.6 and 66.0%, respectively, higher than device without HIL. This enhanced efficiencies by Au-ZnO NCs was attributed to the out-coupling efficiency due to localized surface plasmonic resonance (LSPR) by Au NPs incorporated in Au- doped ZnO NCs.

2. Experiment and characterization

Sigma-Aldrich supplied chemicals for synthesizing TSDPI, Ir $(TSDPI)_2$ (pic) (Scheme 1) and pristine ZnO and Au-doped ZnO nanomaterials. NMR and mass spectral data of TSDPI and Ir

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