White organic light emitting diodes with enhanced light extraction and self-cleaning property served by ZnO nanopillars

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WOLEDs are considered to be a promising candidate for future lighting applications. However, the external quantum efficiency in conventional WOLEDs is still limited due to total internal reflection at the glass substrate/air and ITO/substrate interfaces. A further enhancement of the light extraction is pivotal importance to enable commercialization of this revolutionary illumination technology.

One simple method to increase the light extraction from WOLEDs by using ZnO nanopillars as Bragg-scattering gratings is demonstrated. The wavelength-scaled ZnO NPs are directly prepared on the opposite side of ITO coated glass substrate via chemical bath-deposition process. The ZnO NPs can dramatically suppress the totle reflection at the glass/air interface and increase the efficiency of WOLEDs (Fig. 1). The ZnO NPs are quasi-periodic, thus the output light through ZnO NPs is enhanced evidently during the whole wavelength of WOLED without directionality, approximately to be a Lambertian emission pattern. The current efficiency is enhanced by 70%, and intensity increase is observed during the whole wavelength span of coventional WOLED (Fig. 2).

The distributing ranges of ZnO NPs can be controlled by the concentration of solution and the bath duration to extract the light of targeting wavelength, which is an effective and economic way to adjust the chromaticity coordinate, having potential of approaching solar light. The peak wavelength of ZnO NPs can be calculated from the AFM measuring result by FFT. The power lost to total reflection at substrate/air interface can be extracted by the Bragg diffraction gratings with wavelength-scale periodic structure. The relation between the wavelength of the in-plane component that could be recovered and the periodic of the grating at normal direction can be calculated by the Bragg equation. Fig. 3 shows the electroluminescent (EL) spectra of the WOLEDs with different ZnO NPs at the voltage of 6 V in the normal direction.

An Octafluorobutane(C_4F_8) coating is done on the ZnO NPs to generate a superhydrophobic and self-cleaning surface. Decorated by C_4F_8, which has a low surface energy, the substrate with ZnO NPs behaves self-cleaning property (Fig. 4).

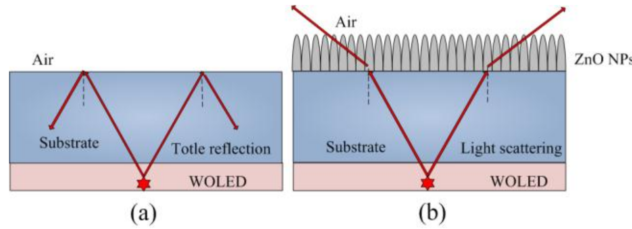

Figure 1: Illustration of light propagation in (a) planar glass substrate and (b) glass substrate with ZnO NPs;

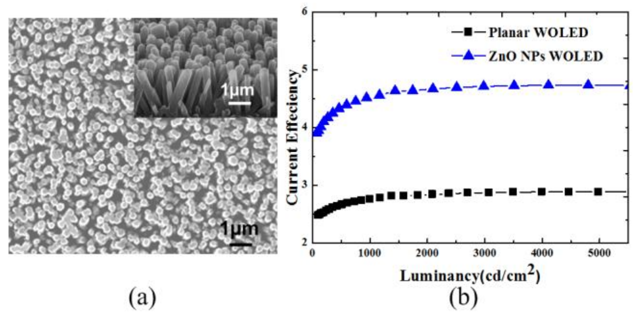

Figure 2: (a) SEM images of ZnO NPs;(peak wavelength at 600nm) (b) current efficiency with and without ZnO NPs;((peak wavelength at 600nm)

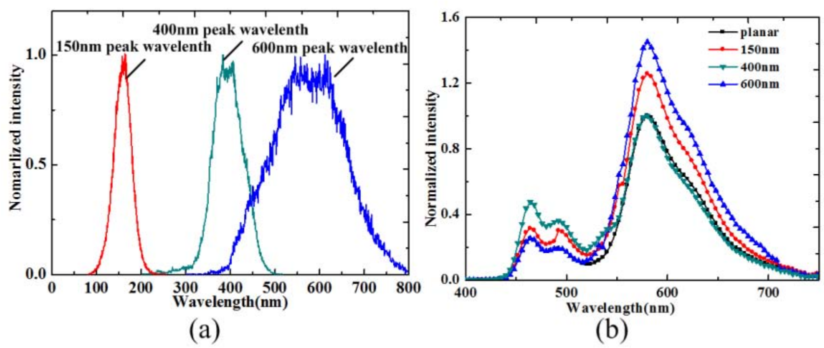

Figure 3: (a) Three different periodical distributions of ZnO NPs with peak wavelength at 150nm,400nm, 600nm, respectively;(b) The normalized spectrum intensity of WOLED with different periodical distributions of ZnO

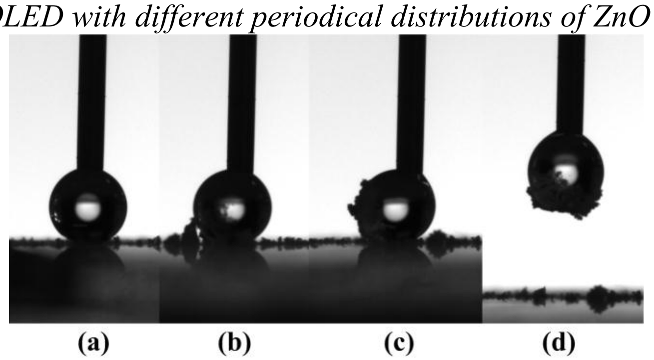

Figure 4: Self-cleaning property testing on dust covering substrate. (a) to (d) illustrate the process of water droplet moving along the substrate with ZnO NPs.