Design and optimization of organic light-emitting diodes with scattering layers

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Organic light-emitting diodes (OLEDs) are regarded as a promising light source for next-generation solid-state lighting. To compete with the existing light sources, however, it is necessary to find a cost-effective way that can lead to further enhancement in improving external quantum efficiency (EQE). Among the various techniques proposed to improve EQE, those based on scattering layers are considered as relatively simple yet highly effective. Whether internal or external, structures relatively immune to defects and leakage currents are known to be feasible.[1] Due to the random, incoherent nature of scattering media, it is essential to model OLEDs in a trans-scale fashion and perform the global optimization to maximize the efficiency of OLEDs involving scattering layer. Instead of full Monte-Carlo simulation that tends to take too long, we here explore the feasibility of 'radiative transfer theory' for trans-scale simulation and fast optimization of OLEDs with scattering media.

Scattering layers were prepared first by mechanically stirring 20wt% of TiO_2 dispersion with the mixture of elastomer polydimethylsiloxane (PDMS) and curing agent (10:1) and then by spin-coating it onto a substrate at 2000 rpm for 60s. Under Henyey-Greenstein phase function approach, asymmetric parameter (g) and the ratio of a scattering layer thickness to mean free path (= relative thickness) were estimated to be 0.82 and 3.5, respectively, by comparing measured total and diffuse transmittance of scattering layer on glass substrate with the optical simulation. Next, the scattering layer was optically coupled to the back side of an OLED as shown in Fig. 1(a). The EQE of a device without the scattering layer was 22.1%, which is consistent with the simulation result based on rigorous dipole simulation (See Fig. 1(b).). Devices with the scattering layer showed 34.5% of EQE, which is 56.1% enhancement compared to that of the reference device. It shows an excellent agreement with the calculated value (35.0%) obtained with the trans-scale simulation based on the rigorous dipole model and radiative transfer theory (Fig. 1(c)), illustrating the validity of the proposed method. We believe the present approach will provide a facile means to optimize the structure of OLEDs involving a scattering medium.

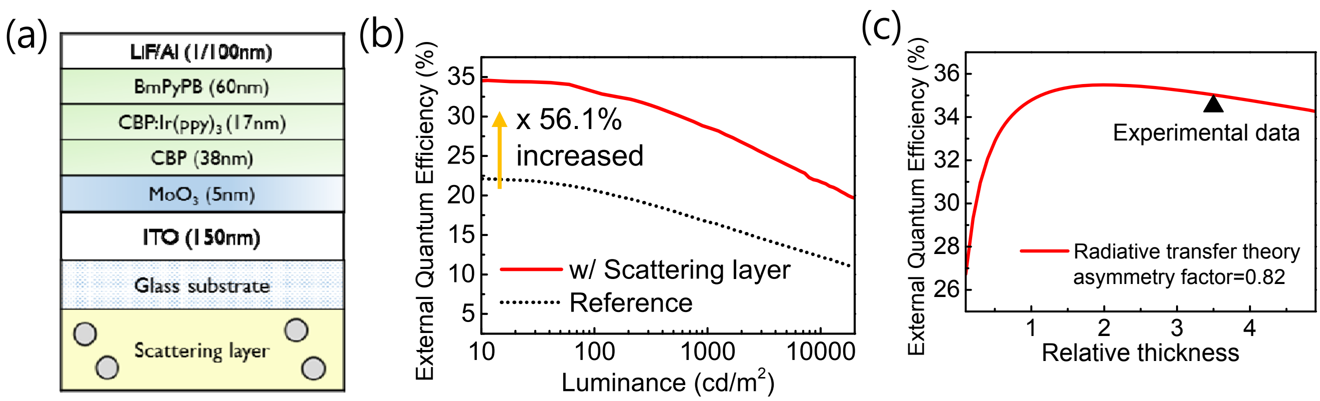

Fig. 1. (a) Device structure including scattering layer (b) External quantum efficiency vs. Luminance graph. (c) Simulated External quantum efficiency with asymmetry factor=0.82 according to Relative thickness (ratio of scattering layer thickness and mean free path for scattering)

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References

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