Fabrication of a Flexible/Detachable Film with Light Extraction Structure to Improve Efficiency of QD-OLEDs

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Abstract

We report a flexible/detachable film with high-refractive-index particles and green-QDs to improve the light extraction efficiency of OLEDs. The fabricated film was attached to the outside of the blue-OLEDs, and the external light extraction efficiency was improved by approximately 22.3% while simultaneously color-conversion.

Author Keywords

Quantum Dot, Organic light-emitting didoes, QD-OLED, light extraction, High refractive index particles

1. Introduction

Quantum dots (QDs) have been proven as a next-generation display technology such as wide color gamut, high color purity, and improved quantum efficiency. QDs have various advantages such as controlling the emission color by controlling the size of the particles and implementing narrow full width at half maximum. According to previous studies, research is being conducted to expand the color gamut of the screen and show high color purity by using blue-organic light-emitting diodes (OLEDs) as a backlight and applying QDs as a color-filter. However, there are still limitations to overcome. Some of the light emitted from QDs may not be extracted and may be trapped inside the OLEDs due to internal reflection. [1-2] In addition, the simultaneous application of QDs and OLEDs requires a complex manufacturing process and high-cost due to low-production efficiency and yield. [3]

In this study, we developed a detachable/flexible QD film fabricated using a simple process for OLEDs. The fabricated films can be applied as a color conversion layer from blue-OLEDs and effectively extract light by applying high-refractive nano-scattering particles.

2. Experimental

A green-QD solution containing quantum dots or TiO_2 particles has been prepared. The QDs are dispersed in a suitable solvent to ensure uniform distribution. The prepared QD-TiO_2 mixture is stirred to prevent aggregation and disperse the particles within the curing agent solution using an ultra-sonicator. The QD-TiO_2 solution is spin-coated into a Si wafer. The composite film was uniformly coated through the spin-coat process. After baking on a hotplate, the flexible QD-TiO_2 film is carefully detached from a Si wafer, maintaining its structural integrity and flexibility. Finally, the flexible QD film is applied to the OLEDs as a color conversion and light extraction layer. The TiO_2 particles embedded within the film efficiently extract light by reducing internal reflections.

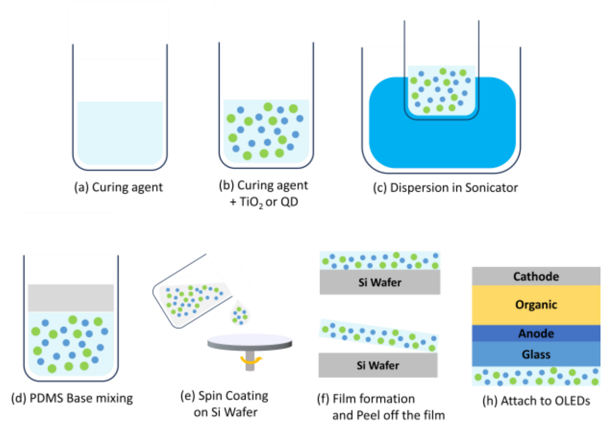

Figure 1. The illustration shows the step-by-step fabrication and application of a detachable/flexible QDs film integrated with high-refractive-index nano-scattering particles (TiO_2) for light extraction of OLEDs.

3. Result

In Figure 2, the effects of various flexible films with TiO_2 nanoparticles, QDs, or a combination of both were evaluated as applied to blue-OLEDs. The TiO_2 nanoparticles function to reduce total internal reflection and enhance light extraction. The QDs show a color conversion layer, but the absence of scattering particles limits its light extraction performance. Film A is a transparent PDMS film without particles, and its efficiency is the same as that of bare OLEDs. Film B, with a 24.6% enhancement, is attributed to the high-refractive-index TiO_2 particles, which significantly increase light scattering at the air/substrate interface. Film D, achieving a 22.3% enhancement, demonstrates the synergistic effect of combining TiO_2 particles and QDs, balancing color conversion and scattering effects. The slight reduction in efficiency compared to Film B suggests the potential possibility for further optimization in particle distribution and film thickness. The fabricated films were applied to blue-OLEDs

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as the light source, the incorporation of QDs led to a shift in emission color from blue to green due to the intrinsic photoluminescent properties of the QDs. The QD particles absorbed blue light emitted from the OLEDs and re-emitted it in the green light, as evidenced by the CIE 1931 color coordinates shifting towards the green spectrum. This result not only demonstrates the effectiveness of QDs in color conversion but also highlights the potential of such films for tuning emission wavelengths to meet specific application requirements.

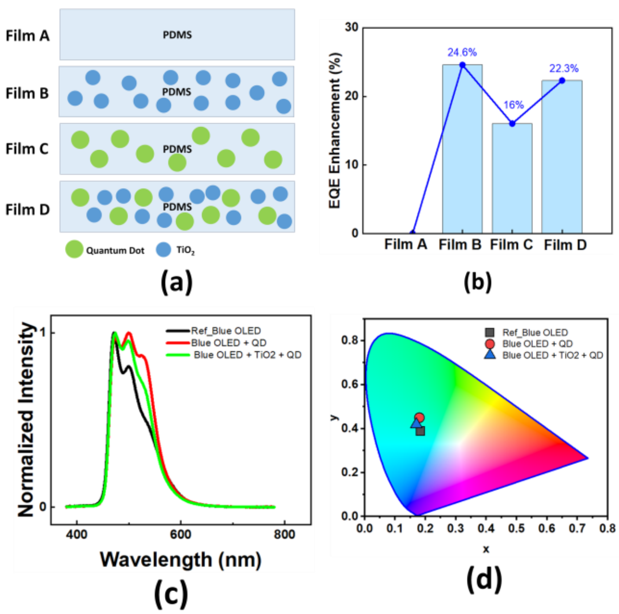

Figure 2. Characteristics of the film attached to the outside of the blue OLEDs

In summary, we fabricated a flexible and detachable light extraction film with QDs and TiO_2 particles to increase the external light extraction efficiency of OLEDs. QDs have color conversion and light extraction functions, and TiO_2 enhances the outcoupling effect of the device through the light scattering effect. In addition, the film fabricated through a simple process improved the external light extraction efficiency of OLEDs by up to 22.3%.

4. Impact

The flexibility and durability of the fabricated film with light extraction particles has been successfully demonstrated. The fabricated films are suited for next-generation flexible OLEDs, including wearable electronics and bio-display technologies.

5. Acknowledgements

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6. Reference

1. Kim, Y. W., Kim, S., Lee, C., Jeong, J. H., Jeong, Y. H., Bak, Y., ... & Jeon, Y. (2024). White Light-Emitting Flexible Displays with Quantum-Dot Film and Greenish-Blue Organic Light-Emitting Diodes. Micromachines, 15(12), 1518.
2. Jeong, B. S. (2021). Device Modeling of Quantum Dot–Organic Light Emitting Diodes for High Green Color Purity. Applied Sciences, 11(6), 2828.
3. Jang, E., & Jang, H. (2023). Quantum dot light-emitting diodes. *Chemical Reviews*, *123*(8), 4663-4692.