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Effect of Solvents of Quantum Dots on QLED Performance

Min Yang, Chun Chang, Wenjing Zhang, Zilei Liu and Qin Zhang*

Jiangxi Engineering Laboratory for Optoelectronics Testing Technology, Nanchang Hangkong University, Nanchang 330063, PR China.
Email: zhangqin0066@163.com

Abstract. The QLED that we are making now, in addition to the evaporation of the a layer, the other layers are generally obtained by solution spin-coating. In our experiments, the selection strategies for quantum dots and adjacent layers of solvents were summarized. Based on these strategies, we selected the appropriate solvent to obtain high quality films, and in order to avoid the quantum dot film layer being corroded, and the surface having streaky defects, thereby hindering the high performance of the device. This solvent selection strategy provides a common method for preparing high quality films for most solution processed multilayer optoelectronic device.

1. Introduction

QDs are microparticles of several tens of nanometers synthesized by chemical solution growth. Quantum dots have many characteristics, such as it can change its size to get different emission spectra. As shown in Figure 1 below. It has not only a very narrow emission spectrum and a wide excitation spectrum, but also has good light stability and a large Stokes shift. Apart from these, it's fluorescence lifetime is long, so it is now the ideal luminescent material for QLED. Quantum dot LEDs are comparable to the best oleds available today, because they have a wider color gamut than traditional LEDs, the emission peak is narrower and the color is more saturated.

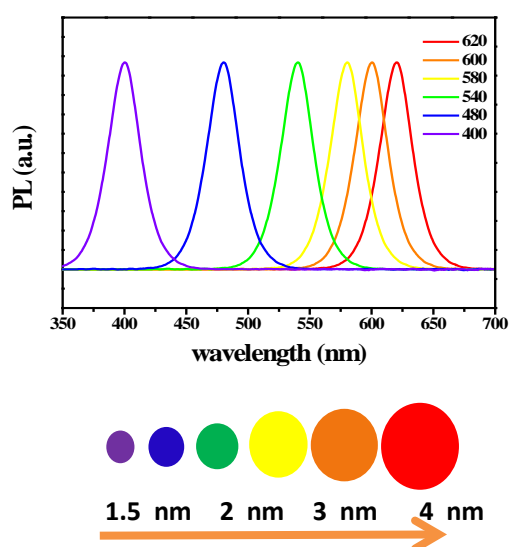


Figure 1. Different quantum dots emit light of different wavelengths



A quantum dot light-emitting diode emits light by excitons radiating a composite photon in a quantum dot. There are two main ways to form excitons: first, carriers are directly injected into the quantum dots from the transport layer to form excitons; second, excitons are formed in the hole transport layer, and then excitons in the hole transport layer pass, energy is transferred to the quantum dots to form excitons and radiate complex luminescence. The injection rate of carriers in a quantum dot directly affects the rate of formation of excitons in a quantum dot. If the film quality of each functional layer is good, it helps the injection of carriers and the formation of excitons in quantum dots, which can increase the recombination of excitons and improve the efficiency of the device.

Now the functional layer of QLED is generally formed by solution spin coating. Its structure is shown in Figure 2. It is more efficient and less expensive than inkjet printing technology. The full solution of QLED faces a huge challenge. If the solvent is not properly selected, the underlying function will be corroded by the solvent when the next layer is spin coated. Therefore, we need to obtain a smooth, pinhole-free quantum dot film to avoid serious short-circuit and non-radiative recombination of QLED. Therefore, the morphology of quantum dot films is one of the keys to determining the performance of quantum dot light-emitting diodes. We need to obtain a smooth underlying charge transport layer to improve the efficiency of QLED devices.

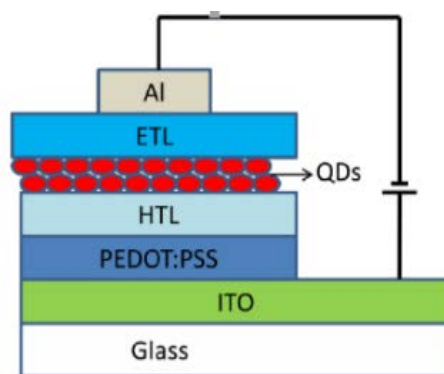


Figure 2. Structure of qled

2. Effect of Non-Orthogonal Solvent on QD Layer

In QLEDs treated with full solution, the use of orthogonal solvent dissolution between adjacent layers is the most common strategy. The quantum dot light-emitting layer has a thickness of only several tens of nanometers and is easily destroyed by the solvent of the adjacent layer. This phenomenon is avoided if the solvents are orthogonal. Quantum dots are generally dissolved in toluene, but once spin-coated on the Tpd (solvent is chlorobenzene) hole transport layer, the hole transport layer will be destroyed by the destruction of toluene. We tested the 380nm thick Tpd layer after annealing and its optical density Od decreased from 0.35 to 0.05 after cleaning with toluene.

3. Effect of Different Alkane Solvents on QD Layer

Since the vapor pressure and surface tension of the alkane are related to the length of the carbon chain in the alkane, and the vapor pressure and surface tension of the solvent are important parameters determining the quality of the film, the quality of the quantum dot-forming film in which different types of alkane are dissolved is also different. To this end, we tested the contact angle of QDs deposited with different solvents, as shown in Figure 3 below. We calculate the surface tension by using the Young's equation, which is the force that characterizes the shrinkage of the liquid surface. At a temperature of 20 °C, the surface tension of n-hexane is 18.43 mN/m, the surface tension of n-octane is 21.76 mN/m, and the surface tension of decane is 23.92 mN/m.[1]. The smaller the surface tension, the higher the volatility, so the rate of volatilization of n-hexane is the fastest. During the volatilization process, the contact surface of the liquid and air has the highest degree of roughness due to the capillary effect. Therefore, from the viewpoint of surface tension, n-hexane is not suitable as a solvent for quantum dots.

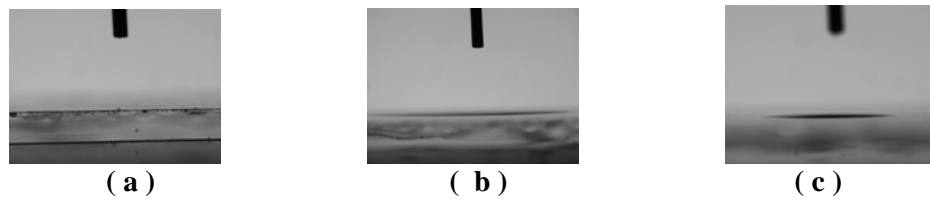


Figure 3. (a) Quantum dots dissolved in n-hexane on tpd
(b) Quantum dots dissolved in n-octane on tpd
(c) Quantum dots dissolved in decane on tpd

From the viewpoint of vapor pressure, at 20 °C, the vapor pressure of n-octane is 1.33 kPa, the vapor pressure of decane is 0.147 kPa, and the vapor pressure of n-hexane is 16.13 kPa. The lower the vapor pressure, the longer film drying time during spin coating, and the quantum dot film deposition is more perfect. Therefore, from the viewpoint of vapor pressure, we can also exclude n-hexane as a solvent for quantum dots. From the solubility point of view, we dissolved the quantum dots in n-octane, n-hexane, decane, toluene, and then measure the roughness of their films with AFM. The results showed that the value of n-octane was the lowest, its surface is the smoothest. Since decane is not easy to dissolve quantum dots, there will be many quantum dot aggregates during spin coating. The rough film morphology will reduce the charge injection efficiency, which will reduce the performance of the device and increase the device's ignition voltage. The solubility of n-octane to quantum dots is very high, so n-octane as solvent can avoid this phenomenon. Therefore, from the viewpoint of solubility, decane is not suitable as a solvent for quantum dots.

Through the above analysis, we selected n-octane as a solvent for quantum dots from the angles of contact angle, surface tension, vapor pressure, and solubility.

4. Conclusion

As shown in the figure 4 below. With n-octane, the external quantum efficiency of qled increased from 5% to 14.6%, and the current efficiency increased from 2 cd/A to 3.8 cd/A, and the performance of the device was significantly improved. It can be seen from the above experiments that the solvent of the luminescent layer should be orthogonal to the solvent of the upper layer, so as to avoid corrosion between the upper and lower layers and resulting in a surface that is not smooth and thus degrades the performance of the device.

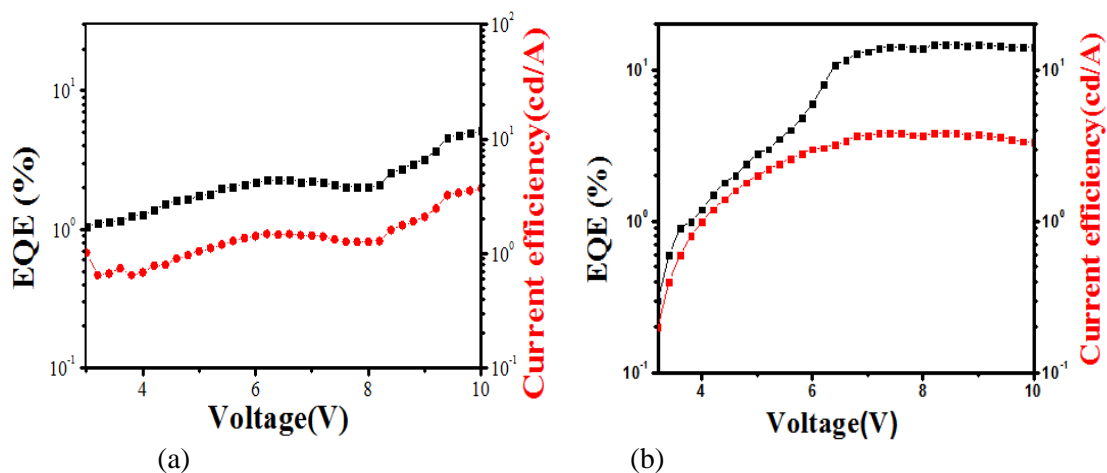


Figure 4. (a) Figure a is a qled performance diagram of dissolved quantum dots in toluene.
(b) Figure b is n-octane is a qled performance diagram of dissolved quantum dots.

5. References

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