How to choose excitation wavelength for quantum-dot-converted light-emitting diodes?

Light-emitting diodes (LEDs) are fundamental devices for backlights and displays. Nowadays, three different-color epitaxial chips are mainly applied in an RGB pixel: Blue, green, and red LED chips. However, it is difficult to further improve the color quality in the current common RGB pixel because of the epitaxial material property limitation. Using a short-wavelength light to excite fluorescent materials to attain high-quality color is an attractive potential solution. Fluorescent materials are key to improving display performance such as the color gamut. As a new type of luminescent material, quantum dots (QDs) are quite promising owing to their narrow half-peak width down to 30 nm, wide excitation wavelength, high color purity, and tunable emission. LED combined with QDs is an important candidate for next-generation high-quality semiconductor devices. By taking the advantages of the QD, a green or red LED could restore the natural color to the greatest extent. In order to obtain green and red LEDs, QDs are typically excited by short wavelengths such as blue or ultraviolet (UV) light. However, how to choose excitation wavelength for quantum-dot-converted light-emitting diodes(QDLEDs) is still unclear.

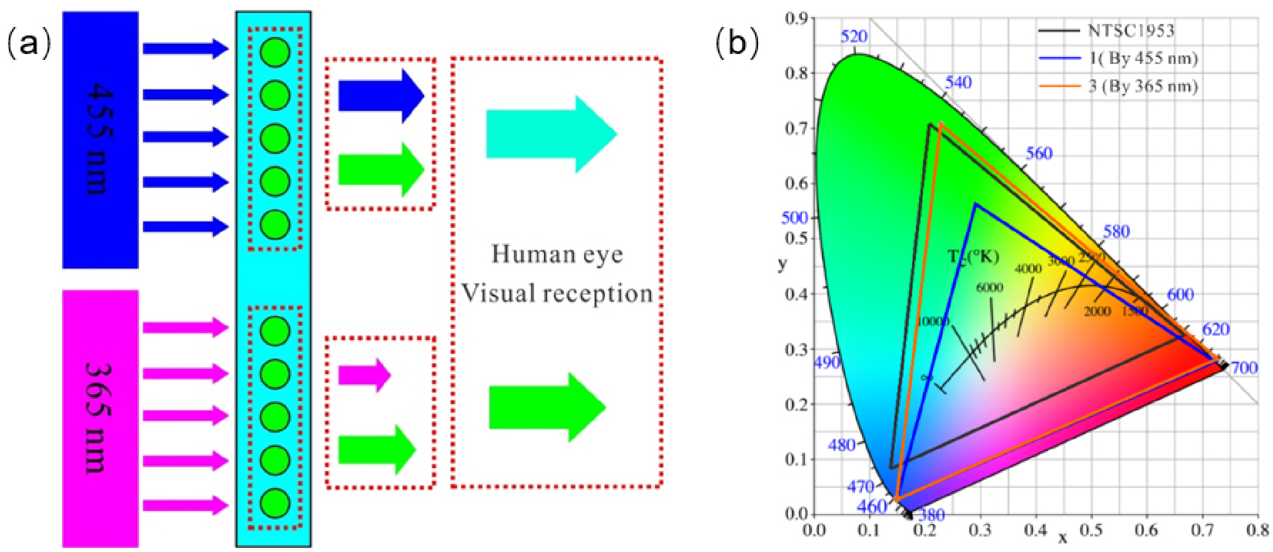

Fig. 1. (a) Light conversion optical models of QD LED; (b) comparison of color gamut between blue (455-nm) excitation and ultraviolet (365-nm) excitation solutions.

Herein, we focus on the excitation wavelength of the LED chip for QDLED. Using CdSe QDs, the performance of QD-converted green and red LEDs at different excitation wavelengths, from a typical 365 nm UVA wavelength to a blue 455 nm wavelength(including 365, 385, 405 and 455 nm), are compared. It turns out the excitation wavelength of the LED chip has an important impact on the overall device performance. Light conversion optical model of QD LED is established and

LED light transformation can be summarized into three stages: (1) absorption, (2) conversion, (3) output, as shown in Figure 1 (a). From the perspective of radiometry, QD LEDs excited at 365 nm have unique advantages in eliminating original peak from the LED chip owing to the stronger absorption ability, compared with 455 nm-excited QDLED. Moreover, under different excitation wavelength, the typical 455 nm blue-excited QDLED is 6.4% and 14.1% higher than the 365 nm UV excitation in QD conversion efficiency and energy conversion efficiency with 20 mW incident radiant flux. Therefore, the blue light is recommended to exciting QDs from the terms of energy utilization. From the view of colorimetry, besides the stronger elimination of short-wavelength peak by 365 nm excitation, the naked eye is not sensitive to residual 365 nm ultraviolet light. As a result, the green or red light excited by 365 nm ultraviolet light has an advantage in colorimetry. Even the 455 nm LED with the highest QD concentration at 7.0 wt%, its green color quality could not compete with the 365 nm LED with the lowest QD concentration. After detailed optimization, thanks to the excellent color characteristic of QD itself, the color gamut of 365 nm-excited RGB system could be high as 117.5%, 32.6% higher than of the blue light 455 nm-excited solution (84.9%), as shown in Figure 1 (b). Thus, in terms of color purity, the excitation of QDs by ultraviolet light such as 365 nm can maximize the advantages of the quantum-dot color quality. This UV excitation solution is recommended for display applications.

Consequently, we provide an understanding of the properties of QD-converted LEDs under different wavelength excitations. It is believed that these basic discoveries have important practical guiding significance for the selection in pumping source for QDs, which helps expand the future large-scale application of QD LED.

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