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Research Highlight

QLED goes to be both bright and efficient

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Quantum dots (QDs) and QD-based light-emitting diodes (QLEDs) have been widely recognized as the key materials and devices for the next generation display due to their flexible and ultra-high definition characteristics, and for color-controllable and healthy solid state lighting [1,2].

The external quantum efficiency (EQE), brightness, and operational lifetime are usually considered the three key parameters for evaluating QLED device performance. For example, recent progress in the use of II–VI semiconductor QDs in QLEDs has boosted the brightness of red, green, and blue (RGB) to 165,000 [3], 460,000 [4], and 20,900 cd/m^2 [5], respectively, and the EQEs to 20% [6–8], receptively. However, almost all of the reported QLEDs exhibit high EQE but low luminance or vice versa [6–10]. This contradiction between QLED EQE and luminance, which has never been reported

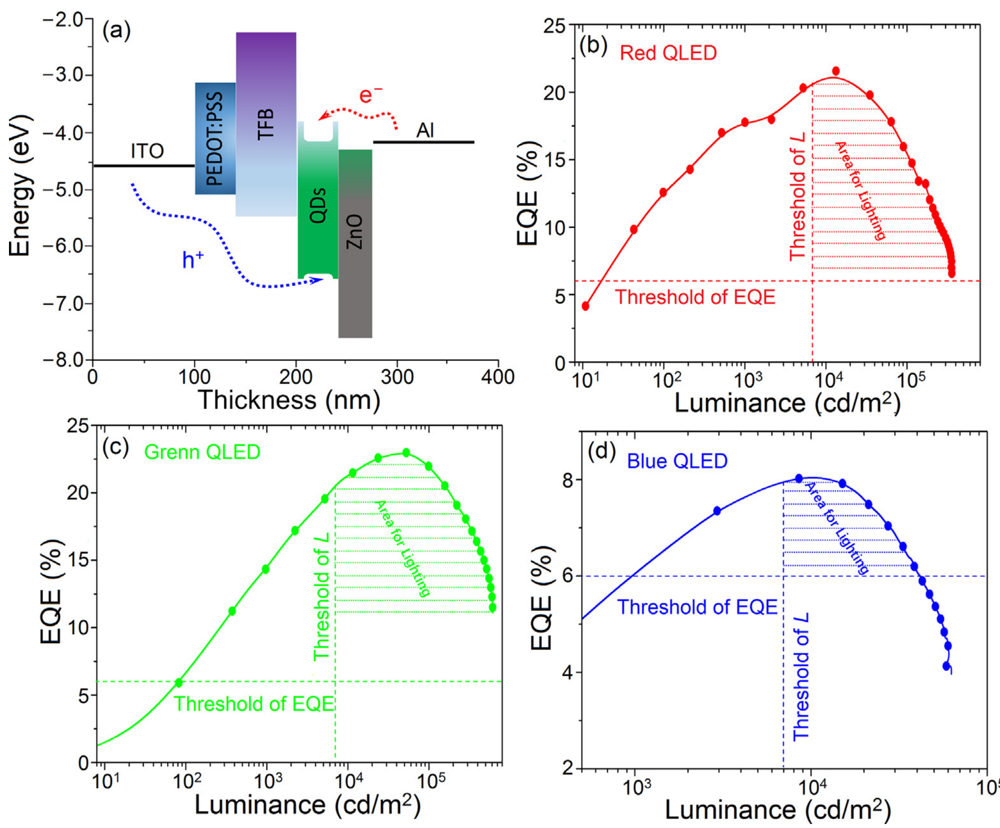

Fig. 1. (Color online) Schematic of the device architecture (a) and electroluminescence performance of the red, green and blue QLEDs (b)–(d). Adapted by permission from Ref. [11], Copyright (2019) Springer Nature.

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in GaN LEDs, highlights an important research question regarding the use of QD materials and their application in QLED configuration.

Profs. Huaibin Shen, Zuliang Du and Lin Song Li (Henan University), Prof. Zhenyu Zhang (University of Science and Technology of China) and co-workers [11] first demonstrated the simultaneous high brightness and efficiency of RGB QLEDs based on "customized" QDs. These devices exhibited maximum EQEs of 21.6%, 22.9%, and 8.05% for red, green, and blue colors, respectively, with corresponding brightness of 13,300, 52,500, and 10,100 cd/m^2, and peak luminance of 356,000, 614,000, and 62,600 cd/m^2, respectively (Fig. 1). Futhermore, the operational lifetime (T_{50}) of RGB QLEDs were up to 1,600,000, 1,760,000, and 7,000 h respectively, at the initial luminance of 100 cd/m^2. Herein, the listed luminance of these three RGB QLEDs, the EQEs for red and green QLEDs, and the operational lifetimes of green and blue QLEDs are globally recorded values. Although the operational lifetime of blue devices is shorter than those of red and green devices, it still meets the display requirements. This research made a breakthrough in developing high-EQE and high luminance QLEDs.

The key breakthrough was the implementation of an elaborate strategy, Se-dispersity controlling, to overcome the contradiction between the EQE and luminance of QLEDs. This coexistence of high-efficiency and high-luminance properties benefited from the design of these CdSe/ZnSe QD materials, with Se anions distributed throughout the core/shell regions and alloyed bridging layers at the core/shell interfaces, which improved both the photoluminescence and stability of the QDs. Further improvements to their interface properties were made based on the "low-temperature-core and high-temperature-shell growth" technique [12], with the resultant QDs possessing high absolute quantum yields (QYs) in solution (>90% for red and green, and 73% for blue). Furthermore, the implementation of these QD materials as emitting layers improved the energy-level matching between the QD-emitting layers and charge-transport layers by reducing the large hole-injection barrier resulting from the sulfied (such as CdS and ZnS) as shells [13,14], which greatly increased the carrier-injection efficiency and improved the charge-injection balance. The authors also introduced efficient luminance (EFL) concept, and constructed an equivalent circuit model via theoretical calculations and simulations, which provided a new approach for optimizating the device structure. It is possible to fabricate the RGB and white pixels by combining this approach with patterning techniques. Therefore, it is critical to speed up the commercialization of this innovative technology. This extraordinary progress holds huge potential for next-generation, cost-effective, and energy-saving solid-state lighting and flexible displays.

Conflict of interest

The author declares that he has no conflict of interest.

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