# Quantum Dot Light-Emitting Diodes for Next Generation Displays

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Since demonstration of electroluminescence (EL) from colloidal quantum dot (QD) light-emitting diodes (QD-LEDs) in 1994,[1] interest has continuously increased because of their impressive properties, including high efficiency, narrow emission peaks, and control of the emitted wavelength by varying the quantum dot size and composition. In 2011, we reported solution processed QD-LEDs with a multilayer structure that exhibit high brightness using crystalline ZnO nanoparticles (NPs) as the electron transport layer (ETL).[2] In this paper, we report multilayer QD-LED structures that exhibit good current and power efficiencies of 6.1 cd/A and 5.0 lm/W, 70 cd/A and 58 lm/W, and 12.3 cd/A and 17.2 lm/W for blue, green and red emitting QD-LEDs, respectively. The QD-LEDs exhibit nearly saturated colors, covering ~90% of the Rec. 2020 color space and ~170% of the NTSC 1987 color space.

The ZnCdSSe-QDs used in this study had chemical composition gradients induced during synthesis.[3] Different emission wavelengths were achieved by controlling the size and chemical composition at the center, surface and intermediate layer of the QDs. The QDs exhibited high PL quantum yields (QYs), but we are studying methodologies to further increase the QYs and achieve even more efficient EL devices.

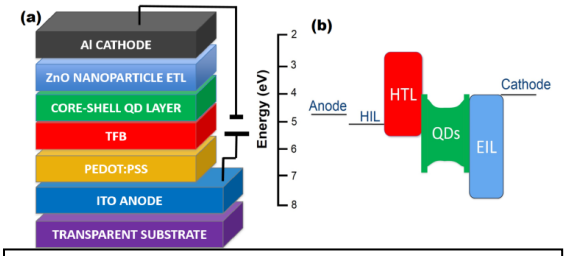


**Fig. 1.** Schematic of bottom-emitting device structure (a) and energy level diagram (b).

Our bottom-emitting device, shown in Fig. 1, consisted of a glass substrate coated with layers of indium tin oxide (ITO)/poly (ethylenedioxy-thiophene):polystyrene sulphonate (PEDOT-PSS) /poly(9,9 '-dioctylfluorene-co-bis-N,N '-(4-butylphenyl)diphenylamine) (TFB)/ ZnCdSeS controlled gradient QDs/ZnO NPs/Al. Except for the thermally evaporated Al top contact, all other layer were deposited by spin-coating from solutions using orthogonal solvents. As indicated in the energy level diagram, the band alignment between ZnO NPs, Al and QDs allows efficient electron injection from Al into the QD emitting layer (EML), while the valence band offset at the QD/ZnO NPs helps confine the holes to the TFB/QD interface The use of TFB, with a highest occupied molecular orbital (HOMO) level of 5.3 eV, also improves hole injection while the electrons are confined to the QD EML, resulting in high efficiencies. The properties of these QD-LEDs, shown in Table 1, will be discussed along with lifetime data.

**Table 1.** Comparison of the emission peak wavelength ($\lambda_{max}$), full width at half maximum (FWHM), CIE coordinates, maximum luminance ($L_{max}$), external quantum efficiency ($\eta_{EQE}$), power efficiency ($\eta_P$) and luminous efficiency ($\eta_A$) of the three QD-LEDs

| Color QD- | $\lambda_{max}$ (nm) | FWHM (nm) | CIE Coordinates 1931 (x,y) | CIE Coordinates 1976 (u',v') | $\eta_{EQE}$ (%) | | $\eta_P$ (lm/W) | | $\eta_A$ (cd/A) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | peak | $10^3$nits | peak | $10^3$ nits | peak | $10^3$ nits |
| **Blue** | 463 | 24 | (0.14,0.05) | (0.169, 0.136) | 11.2 | 9.2 | 5.0 | 2.4 | 6.1 | 5.0 |
| **Green** | 526 | 27 | (0.17,0.73) | (0.061, 0.576) | 18.3 | 18.3 | 58 | 53 | 70 | 70 |
| **Red** | 631 | 27 | (0.69,0.30) | (0.529, 0.517) | 12.0 | 12.0 | 17 | 14 | 12.3 | 12.3 |

**Acknowledgment:**
This work was supported by NSF SBIR Grants 1248863 and 1353411.

## References

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