# Effective defect passivation of $CsPbBr_3$ quantum dots using gallium cations for bright perovskite LEDs

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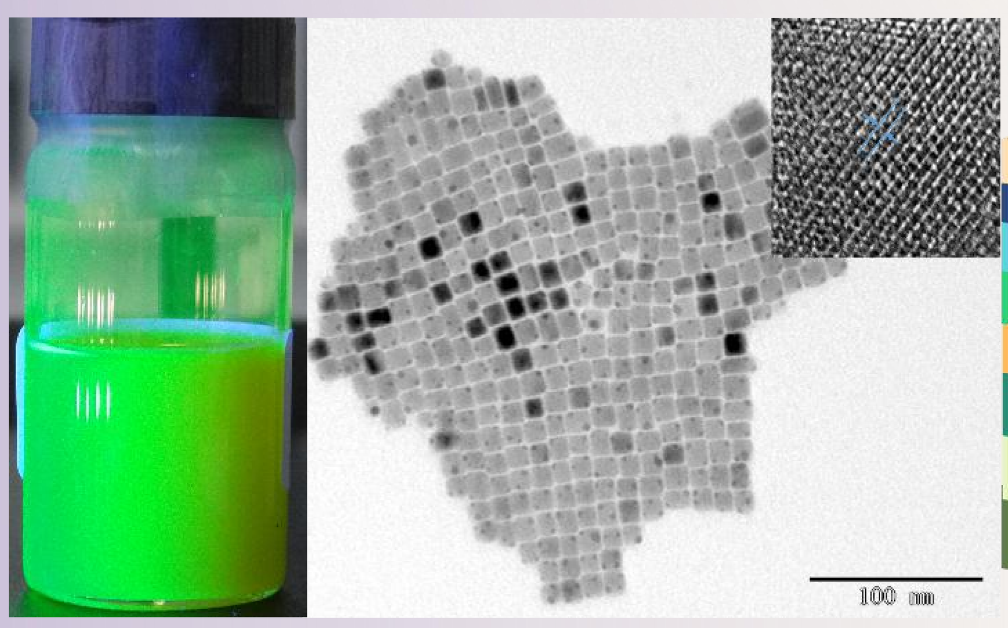
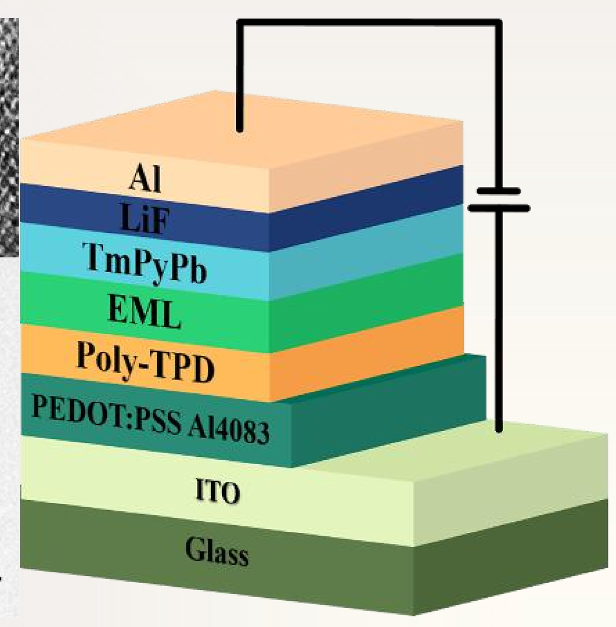
## Abstract

Inorganic metal halide perovskite quantum dots (QDs) have emerged as a new class of solution-processable semiconductor materials for the next-generation display. However, the instability of perovskite QDs due to the surface defects, results in low quantum yields and inefficient charge carriers transport in perovskite LED. Herein, we propose a facile strategy to effectively reduce the surface defects of $CsPbBr_3$ quantum dots by using gallium (III) cations passivation. Significantly, both the optical and electronic properties of $CsPbBr_3$ QDs were greatly improved through modification with gallium (III) cations. The photoluminescence quantum yield of 40% Ga-modified $CsPbBr_3$ QDs is increased from 60.2% to 86.7%. Interfacial carriers transport characteristic of gallium (III) modified QDs is also improved significantly. The luminance and current efficiency of the PeLEDs made from the Ga-modified QDs are more than two times higher than that of the pristine QDs-derived device. The corresponding operational stability is also greatly enhanced, which is seven times longer than the pristine QDs-derived devices. The proposed gallium (III) cation passivation strategy can open up a wide prospect of perovskite QDs for perovskite LEDs displays and light conversion based Micro-LED displays.

## Experiment Section



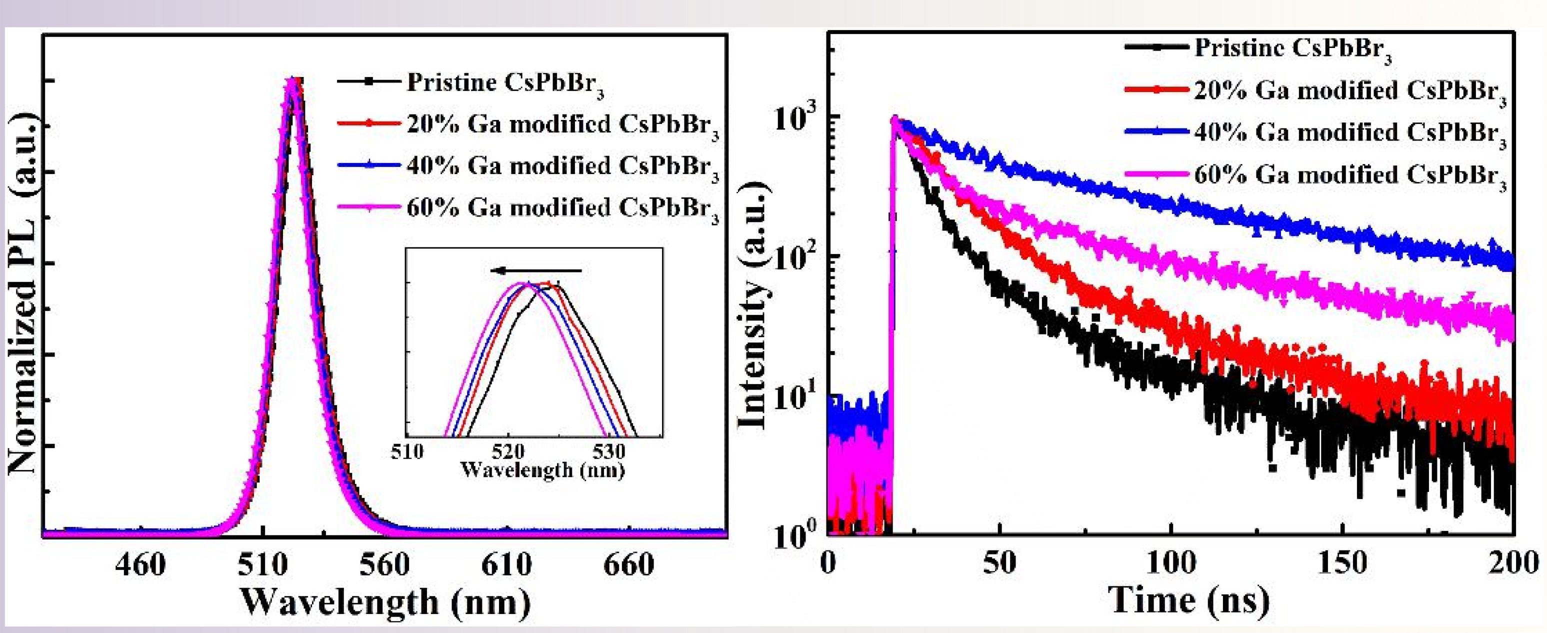

**Synthesis of CsPbBr3 Nanocrystals:**

$PbBr_2$ (0.188 mmol), ODE (5 mL) and different molar ratios of $Ga(NO_3)_3$•$9H_2O$ and $PbBr_2$ (20%, 40%, 60%) were loaded into a 50 mL three-neck flask and were dried under vacuum. OA (2 mL) and OAm (2 mL) mixtures were injected at 100 ℃ for 30 min when there was not any bubbles. Then the temperature was increased to 160 ℃ under $N_2$ atmosphere. Afterward, 0.6 mL CsOA was injected into the prepared solution quickly. After 5 s, the three-neck flask was placed in an ice-water bath and was cooled down to room temperature.

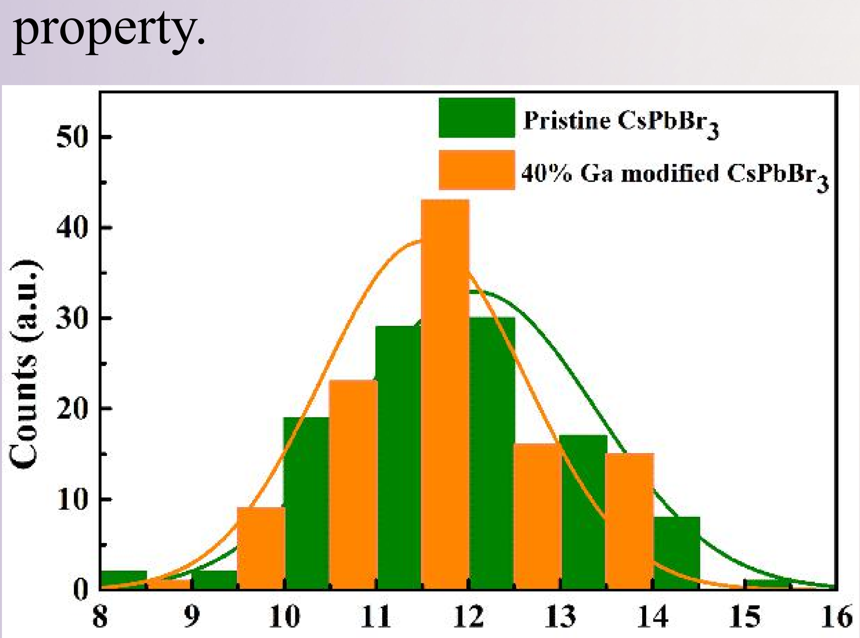
**Device Fabrication:**

ITO substrates were cleaned and treated with UV-Ozone. PEDOT:PSS (Baytron Al 4083) was spin-coated on the ITO, the substrates were transferred into a high purity $N_2$ filled glove box. The hole transporting layer was prepared by spin-coating Poly-TPD. Perovskite QDs layer (30 nm) was deposited by a similar spin-coating method. TmPyPb and LiF/Al were deposited by thermal evaporation in a vacuum chamber. Light emitting areas were 14 $mm^2$.

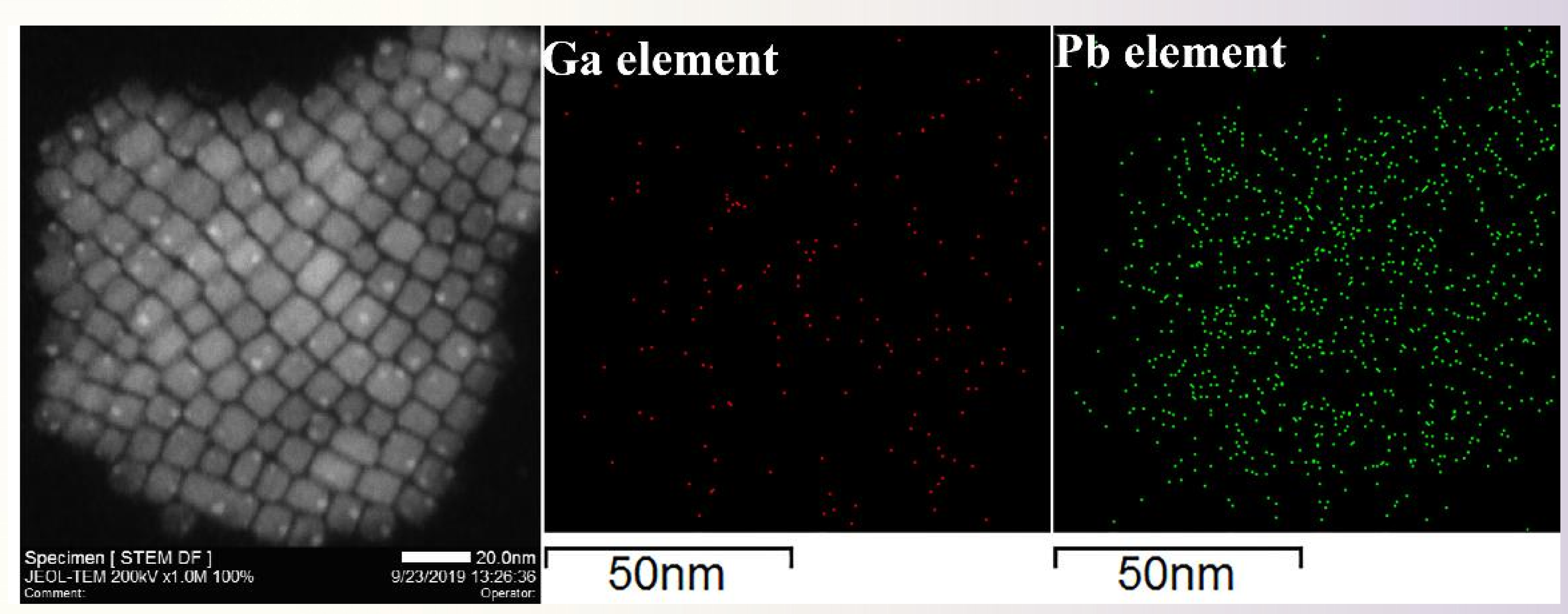
## Discussion



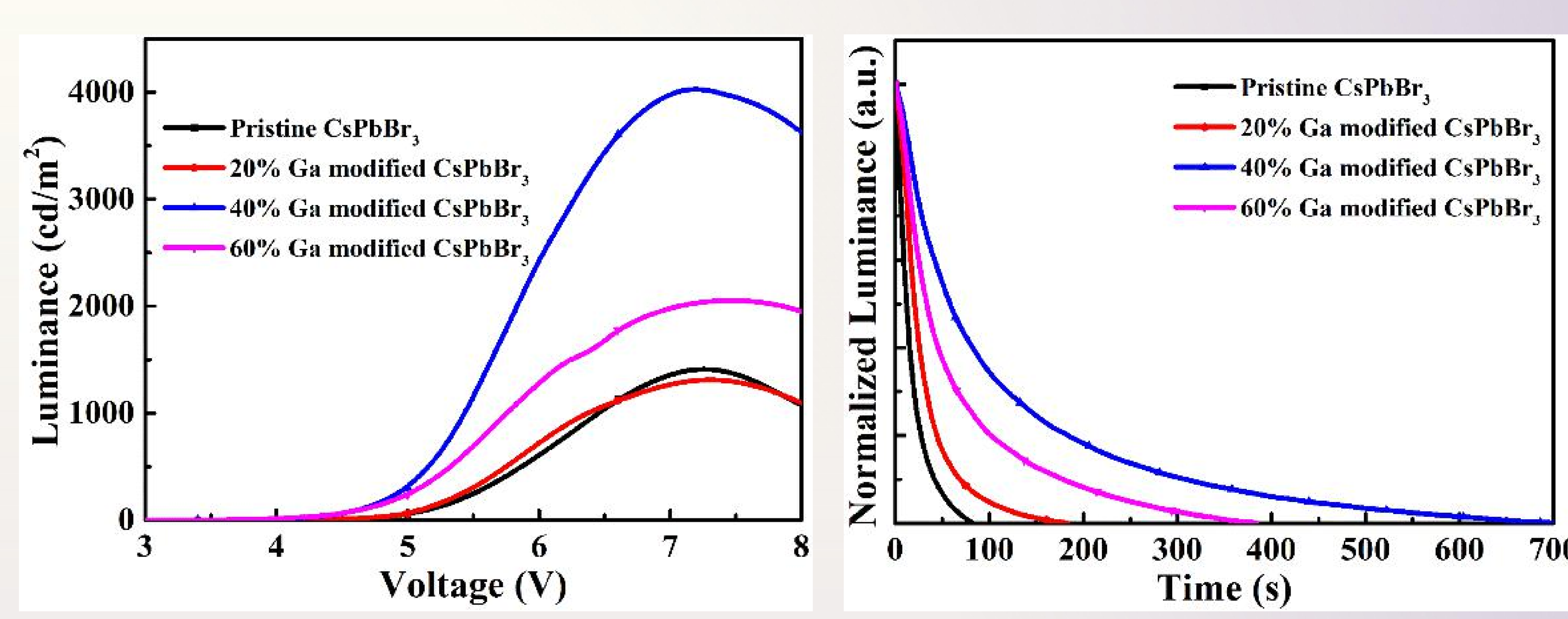

- The PL spectra and inset indicates that the emission peak progressively blue-shifts from 525 nm to 521 nm with increasing the Ga concentration.
- Both the radiative recombination lifetime and the trap-assisted recombination lifetime of Ga-modified QDs increase progressively. $Ga^{3+}$ cations bound to the QDs surface have remarkably passivated the trap states on the surface of QDs.
- 40% Ga modified $CsPbBr_3$ QD samples exhibit the best optical property.




- Statistical analysis reveals the average diameter of the pristine $CsPbBr_3$ QDs and 40% Ga ions modified QDs is 12.08 ± 1.3 nm, and 11.54 ± 1.1 nm. Ga ions modified QDs have a slightly smaller size when compared with the pristine ones.




- The Cs, Pb and Br elements show the denser elemental profiles and are homogeneously dispersed around the 40% Ga-modified CsPbBr3 QDs, while the Ga elemental profile appears to be sparser when compared with the above three elements




- The luminance value of the 40% Ga-modified QDs-derived device is more than two times higher than that of the pristine QDs-derived device, due to the better carrier transport path by optimizing ratio of Ga ions and organic ligand.
- The Ga ions modified QDs based devices exhibit significantly enhanced operational stability in comparison with the pristine QDs-derived devices, and especially for the 40% Ga ions modified device.

## Conclusion

In summary, we have reported a simple method of preparing high-valent metal Ga-modified $CsPbBr_3$ QDs using hot injection method. The Ga ions attached to the surface of QDs are able to passivate the surface defects of QDs, giving rise to a higher PLQY, longer PL lifetime, and better carrier transport performance have been achieved for the Ga-modified $CsPbBr_3$ QDs compared with the pristine ones. The highest luminance value have been achieved for the PeLEDs made from the 40% Ga ions modified QDs, with a great performance improvement over the pristine $CsPbBr_3$ PeLEDs. The operational stability of 40% Ga ions modified PeLEDs is also significantly improved by 7 times, compared with pristine $CsPbBr_3$ PeLEDs. This study paves the way towards the preparation of highly efficient all inorganic PeLEDs using hot injection method through the Ga(III) cations passivation strategy.

## Acknowledgements

The author thanks to the China Postdoctoral Science Foundation (No. 2020M672550), GDAS' Project of Science and Technology Development (2019GDASYL-0103070), the Science and Technology Planning Project of Guangdong Province (2017B010114002, 2019B010925001), the Science and Technology Project of Guangzhou (201807010093), and the Technology Innovation Program of Foshan (2018IT100222).