

High-performance $\text{CsPb}_{1-x}\text{Sn}_x\text{Br}_3$ perovskite quantum dots for highly efficient light-emitting diodes

All inorganic CsPbBr_3 perovskite quantum dots (QDs) have attracted considerable interest because of their high photoluminescence, tunable and narrow emission wavelength, and facile synthesis. Given these advantages, all inorganic CsPbBr_3 perovskite QDs can be used in solar cells, lasing, light-emitting diodes (LEDs) and bioimaging. However, the toxicity of Pb^{2+} has a negative impact on the environment. Hence, the total or partial replacement of Pb^{2+} is necessary. At present, the most suitable substitute elements are the less toxic Sn(II) , Sn(IV) , Bi(III) and Mn(II) ions. Thus, partially Sn-substituted perovskite QDs were prepared in a colloidal solution. After a long reaction time, the Sn(IV) ions reached the maximum substitution ratio, and the valence state

of the Sn ions was confirmed by X-ray absorption near-edge spectroscopy (XANES). The Sn K-edge XANES spectra of the $\text{CsPb}_{1-x}\text{Sn}_x\text{Br}_3$ QDs indicated that the absorption edge energies of all the analyzed samples were the same and fit the Sn(IV) ion standard curve. These results are attributed to the easy oxidation of Sn(II) ions during the synthesis of QDs at high temperature. According to the inert pair effect, the stable valence state of Sn is Sn(IV) . The absolute photoluminescence quantum yield (PLQY) of $\text{CsPb}_{1-x}\text{Sn}_x\text{Br}_3$ QDs substituted with Sn(IV) increased from 45% to 83%, where the best substitution ratio was $x = 0.33$. Based on femtosecond transient-absorption (TA), time-resolved photoluminescence (TRPL), and single-dot spectroscopies, we concluded that the observed

PLQY enhancement was due to the reduction of trion formation in the perovskite QDs. These highly luminescent $\text{CsPb}_{0.67}\text{Sn}_{0.33}\text{Br}_3$ QDs that exhibit an emission wavelength of 517 nm have potential for application as emitters for electroluminescent displays. Thus, $\text{CsPb}_{1-x}\text{Sn}_x\text{Br}_3$ -based quantum dot LEDs (QLEDs) with the structure ITO/PEDOT:PSS/TFB/PQDs/TPBi/LiF/Al were fabricated.

The optimized device exhibited a luminescence of 12,500 cd/m^2 , a current efficiency (CE) of 11.63 cd/A , an external quantum efficiency (EQE) of 4.13%, a power efficiency (PE) of 6.76 lm/w , and a low turn-on voltage of 3.6 V.

In summary, we demonstrate the hot-injection synthesis of

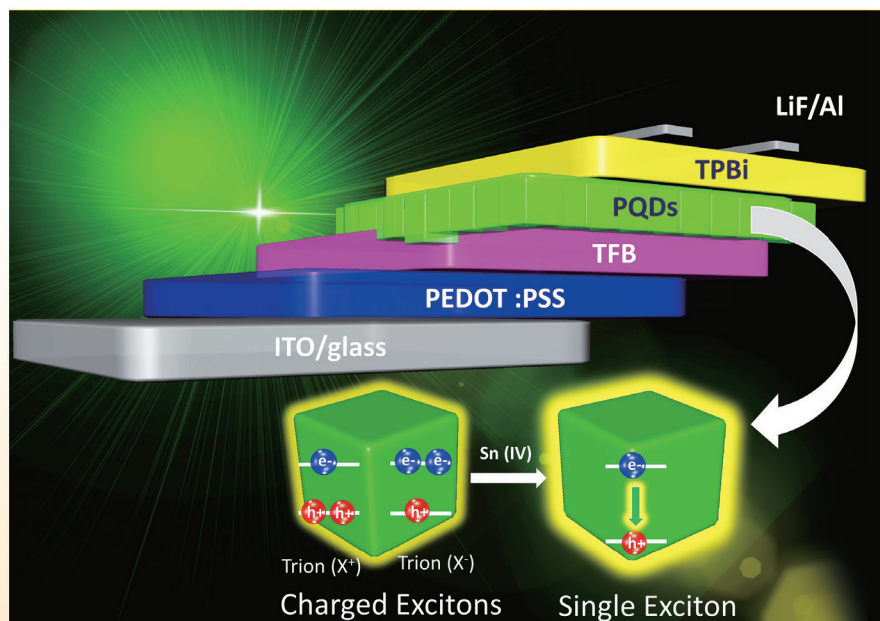


Figure 1. Schematic of trion formation suppression in $\text{CsPb}_{1-x}\text{Sn}_x\text{Br}_3$ perovskite QLEDs used for a backlight display.

CsPb_{1-x}Sn_xBr₃ perovskite QDs with Sn(IV) substitution. Sn(IV) doping effectively suppresses the formation of trions, as revealed by single-dot, TRPL, and TA spectroscopies. The best perovskite QLED device displays a luminescence of 12,500 cd/m², a CE of 11.63 cd/A, an EQE of 4.13%, a PE 6.76 lm/w, and a low turn-on voltage of 3.6 V, which are the highest values reported among all Sn-based perovskite QLEDs.

Reference

Hung-Chia Wang, Weigao Wang, An-Cih Tang, Hsin-Yu Tsai, Zhen Bao, Toshiyuki Ihara, Naoki

Yarita, Hirokazu Tahara, Yoshihiko Kanemitsu, Shuming Chen, and Ru-Shi Liu (2017). High-Performance Novel CsPb_{1-x}Sn_xBr₃ Perovskite Quantum Dots for Highly-Efficient Light-Emitting Diodes. *Angewandte Chemie International Edition*, 129(44), 13650–13654. DOI:10.1002/ange.201706860.

Glossaries

Exciton: the combination of an electron and a positive hole, which is free to move through a nonmetallic crystal as a unit.

Trion: a localized excitation which consists of three charged quasiparticles. A negative trion consists of two electrons and one hole and a positive trion consist of two holes and one electron.

PEDOT:PSS (poly(3,4-ethylenedioxythiophene) polystyrene sulfonate): a polymer mixture of two ionomers that functions as a hole injection layer in QLEDs.

TFB (poly[(9,9-dioctylfluorenyl-2,7-diyl)-co-(4,4'-(N-(4-sec-butylphenyl)diphenylamine))]): a polymer that functions as a hole transport layer in QLEDs.

TPBi (2,2',2''-(1,3,5-benzinetriyl)-tris(1-phenyl-1-H-benzimidazole): a kind of electron transport layer in QLEDs.

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Deciphering brown root rot disease of trees

The comparative and population genomics landscape of *Phellinus noxius*

Under most circumstances, fungi coexist with trees or act as saprotrophs responsible for carbon and nitrogen cycling in forest systems. The order Hymenochaetales is dominated by wood decay fungi and belongs to Agaricomycetes in Basidiomycota. Most species in this order are saprotrophic or weakly pathogenic, but a few of these species exhibit strong pathogenicity. In various parts of the world, there has been an emergence of tree disease outbreaks, including brown root rot

caused by *Phellinus noxius* and laminated root rot caused by *Phellinus sulphurascens*. Despite the ecological importance of these fungi and the impact of the diseases that they cause, little is known about their evolution and transmission patterns.

During the last 20 years, brown root rot disease has become a serious threat to a variety of agricultural, ornamental, landscape, and forest trees in Taiwan; the Ryukyu Islands and the Ogasawara Islands of Ja-

pan; Hong Kong; and Macao. The pathogen *P. noxius* has an extremely wide host range that spans more than 200 broad-leaved and coniferous tree species (in at least 59 families), such as longan, litchi, camphor, banyan, and pine trees. The corresponding disease is widespread in tropical and subtropical areas in Southeast Asia, East Asia, Oceania, Africa, Central America and the Caribbean. This geographical distribution appears to be related to the growth temperature range of *P. noxius*, which is