Supporting Information

Use of long-term stable $CsPbBr_3$ perovskite quantum dots in phospho-silicate glass for highly efficient white LEDs

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Experimental Section

Materials and chemicals

Lead bromide ($PbBr_2$, 99%), caesium carbonate (Cs_2CO_3, 99%), sodium bromide (NaBr, 99%), phosphorus pentoxide (P_2O_5, 98%), silicon dioxide (SiO_2, 99%) and zinc oxide (ZnO, 99%) were purchased from Aladdin. $CaAlSiN_3:Eu^{2+}$ red phosphor was purchased from HangZhou YingHe Photoelectron Materials Co. Ltd. All chemicals were used without further purification.

Preparation of $CsPbBr_3$ QDs glass

Highly efficient green emitting $CsPbBr_3$ QDs glasses were producted with the following method. Glass specimens with the nominal compositions (mol%) of $50P_2O_2$-$25SiO_2$-3ZnO-$4PbBr_2$-9NaBr - $9Cs_2CO_3$ were prepared by conventional melt-quenching. The raw chemicals were melted in an alumina crucible at 1100 ℃ for 10 min; the obtained melt was poured into a preheated copper mold and annealed in a furnace slightly below the glass transition temperature (T_g) for 3 h. Finally, the prepared glasses were cut into small species with a size of 10×10×1 mm for the heat treatment. $CsPbBr_3$ QDss were formed in the specimens upon the thermal treatment at a temperature determined from the thermal analysis results.

Construction of WLEDs

To fabricate the WLEDs, a simple spin-coating method was used to deposit a commercial red-emitting $CaAlSiN_3:Eu^{2+}$ phosphor embedded epoxy resin film on the upper surface of the as-prepared $CsPbBr_3$ QDs glass (heat-treated at 450 ℃ for 10 h). A drying treatment was performed in vacuum to solidify the film and eliminate the air in the film. Ultimately, the obtained color converter was coupled with a commercial blue GaN chip to construct a remote type WLED.

Characterizations

The structure and phase purity of the $CsPbBr_3$ QDs glass were confirmed by using X-ray diffraction (XRD, D8 Advance, Bruker, Germany) with Cu Kα radiation at 40 kV and 40 mA. The microstructure of the sample was investigated using an FEI Tecnai F20 transmission electron microscope (TEM) and a high-resolution TEM (HRTEM). The photoluminescence (PL), PL quantum efficiency (QY) and temperature-dependent emission spectra of the samples were collected using a spectrofluorometer (Edinburgh, FS5), which was equipped with both continuous (150 W) and pulsed xenon lamps. Finally, the optical properties of the WLEDs, such as the luminous efficacy (LE), chromaticity coordinates, color rendering index (CRI), and correlated color temperature (CCT), were measured using an integrating sphere (PMS-50, Everfine, China) with a forward current of 20 mA.

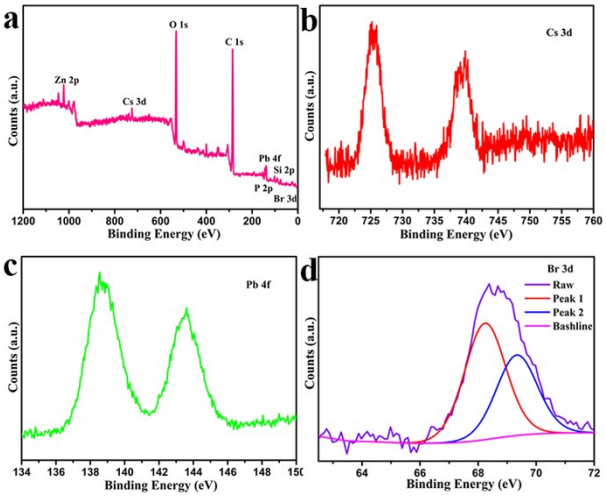

Fig. S1 (a) XPS spectra of $CsPbBr_3$ QDs glass and high resolution spectra of (b) Cs 3d, (c) Pb 4f, (d) Br 3d.

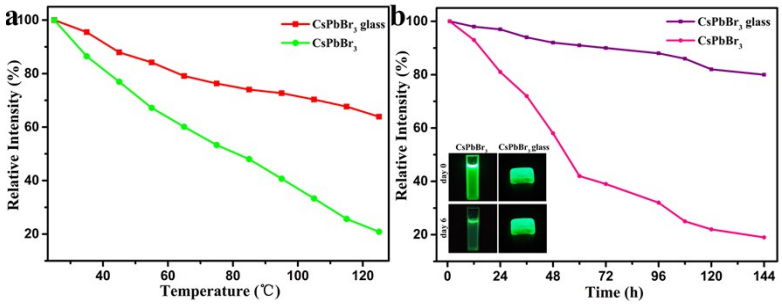

Fig. S2 (a) Thermal stability test of the $CsPbBr_3$ QDs glass and pure $CsPbBr_3$ QDs. (b) Photostability test of the $CsPbBr_3$ QDs glass and pure $CsPbBr_3$ QDs; inset shows digital photos of the pure $CsPbBr_3$ QDs and $CsPbBr_3$ QDs glass under UV (365 nm) illumination after exposured to ambient air.

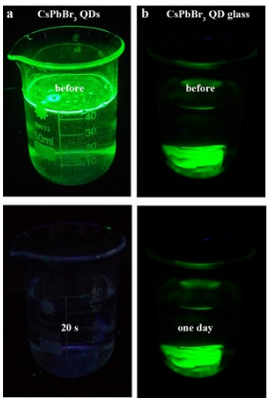

Fig. S3 $CsPbBr_3$ QDs and $CsPbBr_3$ QDs glass before and after immersion in an aqueous solution.

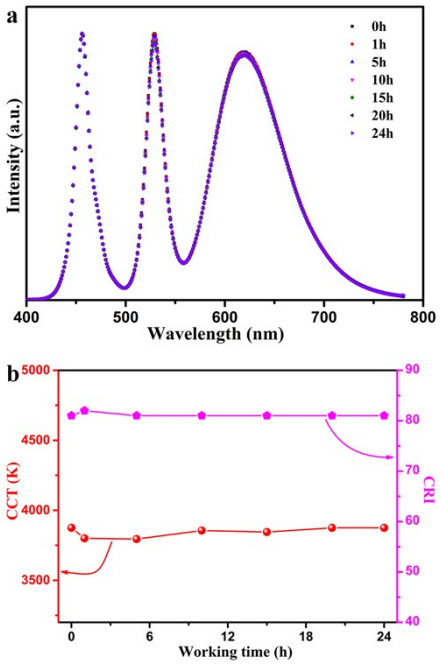

Fig. S4 (a) EL spectra of the WLED in different working time intervals. (b) Related CCT and CRI as a function of the working time.

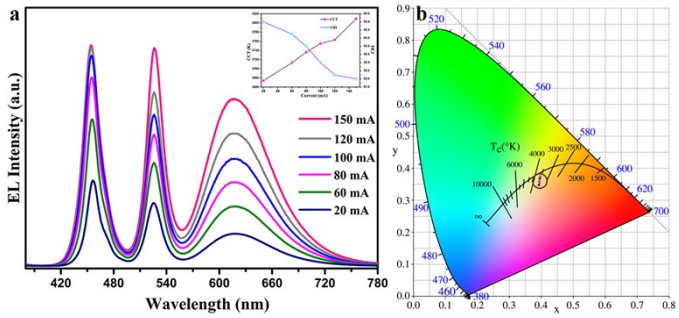

Fig. S5 (a) EL spectra of the fabricated WLED at various operational currents (20-150 mA); the inset shows the CCT and CRI at different currents. (b) The corresponding colour coordinates of the WLED in a CIE diagram.

Table. S1 Parameter comparisons of the as-prepared QDss glass and the reported QDss by the other approaches.

	Preparation methods	QY (%)	Particle size (nm)	Dispersion	Photo-stability	Thermal stability	Ref.
QDs glasses	Heat-treatment	42	3.2	Glass	> 2 months	High	This work
QDs	Hot injection	>80	4-15	Hexane	< 6 days	Low	[21]
	Room temperature	>80	7.8	Hexane	-	Low	[36]

Table. S2 Optical parameters of the as-constructed WLED at an operating current of 20 mA.

	Φv (mlm)	**CRI**	**CCT (K)**	**LE (lm/W)**
QDs glass+CASNE	2733	83.4	3815	50.5