Supplementary Information

Room-temperature synthesis of blue-emissive zero-dimensional cesium indium halide quantum dots for temperature-stable down-conversion white light-emitting diodes with a half-lifetime of 186 h

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Table S1 Comparison of synthesis methods, morphology, size and PLQY of Cs$_3$InBr$_6$ QDs and other In-based halide materials.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Method</th>
<th>Morphology</th>
<th>Size</th>
<th>PLQY</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs$_3$InBr$_6$</td>
<td>M-LARP</td>
<td>QDs</td>
<td>4.5 nm</td>
<td>46%</td>
<td>This work</td>
</tr>
<tr>
<td>Cs$_3$InBr$_6$</td>
<td>Hot-injection method</td>
<td>Hollow NCs</td>
<td>20.5 nm</td>
<td>22.3%</td>
<td>[1]</td>
</tr>
<tr>
<td>(C$_6$H$_5$CH$_2$NH$_3$)$_3$InBr$_6$</td>
<td>Hydrothermal method</td>
<td>Single crystal</td>
<td>~1 cm</td>
<td>35%</td>
<td>[2]</td>
</tr>
<tr>
<td>Cs$_2$InBr$_5$·H$_2$O</td>
<td>Hydrothermal method</td>
<td>Single crystal</td>
<td>~2 mm</td>
<td>33%</td>
<td>[3]</td>
</tr>
<tr>
<td>Cs$_2$InCl$_5$·H$_2$O</td>
<td>Low temperature crystallization</td>
<td>Single crystal</td>
<td>~6 mm</td>
<td>18%</td>
<td>[4]</td>
</tr>
<tr>
<td>Cs$<em>2$InCl$</em>{2.5}$Br$_{2.5}$·H$_2$O</td>
<td>Hydrothermal method</td>
<td>Single crystal</td>
<td>-</td>
<td>24.4%</td>
<td>[5]</td>
</tr>
<tr>
<td>Cs$_2$InBr$_4$·H$_2$O</td>
<td>Hydrothermal method</td>
<td>Single crystal</td>
<td>-</td>
<td>1%</td>
<td>[5]</td>
</tr>
<tr>
<td>Rb$_2$InCl$_5$·(H$_2$O)</td>
<td>Hydrothermal method</td>
<td>Single crystal</td>
<td>-</td>
<td>~1%</td>
<td>[6]</td>
</tr>
<tr>
<td>Rb$_3$InCl$_6$</td>
<td>Sonication method</td>
<td>Powder</td>
<td>-</td>
<td>-</td>
<td>[7]</td>
</tr>
<tr>
<td>(C$<em>4$H$</em>{14}$N$_2$)$_2$In$<em>2$Br$</em>{10}$</td>
<td>Solution-phase method</td>
<td>Single crystal</td>
<td>-</td>
<td>~3%</td>
<td>[8]</td>
</tr>
</tbody>
</table>
Fig. S1 (a) PL spectra and (b) PLQYs of Cs$_3$InBr$_6$ QDs synthesized under different CsBr/InBr$_3$ ratios, respectively.
**Fig. S2** PLQY data of the Cs$_3$InBr$_6$ QDs solution measured by integrating sphere.
**Fig. S3** TEM images of the Cs$_3$InBr$_6$ QDs continuously exposed to electron beam.
**Fig. S4** Total XPS spectrum of the Cs$_3$InBr$_6$ QDs.
Fig. S5 Integrated PL intensity of Cs$_3$InBr$_6$ QDs as a function of excitation power density.

We further analyzed the slope of the fitted curve of the excitation-power-dependent PL emission intensity to determine the recombination kinetics. The dependence of the PL intensity $I$ on the excitation power $L$ can be estimated by the equation $I \approx L^k$, where $k$ is an exponent between 0 and 2.40.$^9,^{10}$ Generally, $k = 2$ indicates recombination between a free electron and a hole, $1 < k < 2$ corresponds to free or bound exciton decay, while $k < 1$ correlates with impurity-related emission. As shown in Fig. S5, the plot of log($I$) vs log($L$) is linear with a slope of $1.92 \pm 0.04$, indicating the exciton transition. The excitation intensity dependence of emission is consistent with the bound and free exciton emission. Considering the broadband emission feature of Cs$_3$InBr$_6$ QDs, the PL emission in Cs$_3$InBr$_6$ is essentially excitonic and results from the recombination of bound excitons and multiphonon emission.
**Fig. S6** (a) Normalized PL spectra of Cs$_3$InBr$_6$ QDs monitored at different excitation wavelengths. (b) Normalized PL excitation spectra of Cs$_3$InBr$_6$ QDs monitored at different emission wavelengths.
**Fig. S7** The bandgap of Cs$_3$InBr$_6$ QDs determined from a Tauc plot of absorption spectrum.
Fig. S8 The predicted density of states (PDOS) of Cs$_3$InBr$_6$ using PBE functional.
Fig. S9 XRD patterns of (a) Cs$_3$InCl$_6$, and (b) Cs$_3$InI$_6$ QDs, respectively.
Fig. S10 Size distribution histograms of (a) Cs$_3$InCl$_6$, and (b) Cs$_3$InI$_6$ QDs, respectively.
**Fig. S11** PL spectra evolution of the Cs$_3$InBr$_6$ QDs under different UV light irradiation time.
Fig. S12 Stability test of the Cs$_3$InBr$_6$ QDs film under continuous 365 nm UV lamp irradiation and high humidity (20–30 °C, 70–80% humidity) environment. The insets show the luminescence photos of the Cs$_3$InBr$_6$ QDs film before and after treatment.
Fig. S13 XRD results of the Cs$_3$InBr$_6$ QDs film after storage in air ambient (20–35 °C, 50–60% humidity) for 60 days.
**Fig. S14** Plots of the normalized PL intensity of Cs$_3$InBr$_6$ QDs at two typical temperature points (20 °C and 100 °C) over 15 heating/cooling cycles.
**Fig. S15** The corresponding color temperature (CCT) of the WLED under different driving currents.
**Fig. S16** Emission intensity evolution of the WLED measured at the driving current of (a) 100 mA, and (b) 200 mA, respectively.
References


