Supplementary information

Eu$^{2+}$ ions as an antioxidant additive for Sn-based perovskite light-emitting diodes

Xi Wang,$^{a,b,#}$ Lihua Liu,$^{c,#}$ Zhao Qian,$^{d,#}$ Congcong Gao,$^{a}$ Hongyan Liang$^{a,b,*}$

$^{a}$ School of Materials Science and Engineering, Tianjin University, Tianjin 300350, P. R. China

$^{b}$ Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, Ministry of Education, Tianjin University, Tianjin 300350, P. R. China

$^{c}$ College of Innovation and Entrepreneurship, Shanghai Jianqiao University, Shanghai 201306, P. R. China

$^{d}$ Key Laboratory of Liquid-Solid Structural Evolution and Processing of Materials (Ministry of Education), Shandong University, Jinan 250061, P. R. China

Corresponding Author

* E-mail: hongyan.liang@tju.edu.cn
**Figure S1.** High-resolution XPS I 3d spectra of perovskite films (a) without and (b) with Eu$^{2+}$ ions.

**Figure S2.** High-resolution XPS Eu 3d spectra of perovskite films (a) without and (b) with Eu$^{2+}$ ions.
Figure S3. Photoluminescent images of perovskite film (a) without and (b) with Eu$^{2+}$ ions under confocal microscope.

Figure S4. XRD patterns of perovskite films (a) without and (b) with Eu$^{2+}$ ions at different air-exposure times.
Figure S5. TRPL spectra of perovskite films without (orange) and with (green) Eu$^{2+}$ ions.

Figure S6. Cross-sectional SEM image of the tin-based LEDs.
Figure S7. Steady-state PL spectra of perovskite film with different concentration of Eu$^{2+}$ ions.

Figure S8. I-V and L-V curves (a) and EQE characteristics (b) of LEDs with different concentration of Eu$^{2+}$ ions.
Table S1. TA decay parameters of perovskite films without and with Eu\(^{2+}\) ions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>(\tau_1) (ps)</th>
<th>(A_1)%</th>
<th>(\tau_2) (ps)</th>
<th>(A_2)%</th>
<th>(\tau_{ave}) (ps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>61.4245</td>
<td>50.06</td>
<td>420.6911</td>
<td>30.573</td>
<td>351.37</td>
</tr>
<tr>
<td>With Eu(^{2+})</td>
<td>68.2022</td>
<td>44.106</td>
<td>575.3293</td>
<td>32.88</td>
<td>505.75</td>
</tr>
</tbody>
</table>

Table S2. TRPL decay parameters of perovskite films without and with Eu\(^{2+}\) ions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>(\tau_1) (ns)</th>
<th>(A_1)%</th>
<th>(\tau_2) (ns)</th>
<th>(A_2)%</th>
<th>(\tau_3) (ns)</th>
<th>(A_3)%</th>
<th>(\tau_{ave}) (ns)</th>
<th>(\chi^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>1.50368</td>
<td>37.88</td>
<td>0.12864</td>
<td>41.24</td>
<td>4.00589</td>
<td>20.88</td>
<td>2.89</td>
<td>1.00595</td>
</tr>
<tr>
<td>With Eu(^{2+})</td>
<td>1.67516</td>
<td>47.41</td>
<td>5.29</td>
<td>16.55</td>
<td>0.1565</td>
<td>36.04</td>
<td>3.48</td>
<td>1.04461</td>
</tr>
</tbody>
</table>