Electronic Supplementary Information

Plasmon Enhanced Up-conversion Nanoparticles in Perovskite Solar Cells for Effective Utilization of Near Infrared Light

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Fig. S1. Fabrication process of UCNPs-incorporated perovskite solar cells (PSCs). The PSCs were fabricated by using a conventional one-step process with anti-solvent method, and the UCNPs were transferred by dry transfer method. The PSC has a structure consisting of fluorine-doped tin oxide (FTO)/compact TiO$_2$ (c-TiO$_2$)/mesoporous TiO$_2$(mp-TiO$_2$)/perovskite;(MAPbI$_3$)$_{0.85}$(FAPbI$_3$)$_{0.15}$/spiro-OMeTAD/UCNPs/Au.
Fig. S2. Mechanism of the NaYF₄:Yb³⁺,Er³⁺ for up-conversion luminescence.
Fig. S3. Photographs showing the decomposed spiro-OMeTAD (HTL)/perovskite film when the UCNPs solution was dropped on the HTL: (a) color change immediately after dropping the UCNPs solution; (b) the perovskite film was rapidly decomposed along the moving trajectory of UCNPs solution.
**Fig. S4.** Schematic illustration to show the transferred UCNPs at different locations within a perovskite solar cell.
**Fig. S5.** Statistical distribution of PV parameters *vs.* concentration of UCNPs in solution. PV parameters of reference PSC (without UCNPs) are also included for comparison.
Fig. S6. (a) Comparison of Nyquist plots of two PSCs without UCNPs (reference) vs. with UCNPs on ETL. (b) The magnified Nyquist plots in the high-frequency region. The inset represents the equivalent circuit utilized to fit the Nyquist plot.
Table S1. Recombination resistance ($R_{\text{rec}}$) and charge transport resistance ($R_{\text{ct}}$) of PSCs obtained by fitting the Nyquist plots to the equivalent circuit.

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<th>Reference</th>
<th>On the ETL</th>
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<tr>
<td>Recombination resistance, $R_{\text{rec}}$ (Ω)</td>
<td>408</td>
<td>242</td>
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<tr>
<td>Charge transport resistance, $R_{\text{ct}}$ (Ω)</td>
<td>19.9</td>
<td>34.4</td>
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