

Supporting Information

Improvement of Thermal Stability and Photoelectric Performance of $\text{Cs}_2\text{PbI}_2\text{Cl}_2/\text{CsPbI}_{2.5}\text{Br}_{0.5}$ Perovskite Solar Cells by Triple-Layer Inorganic Hole Transport Materials

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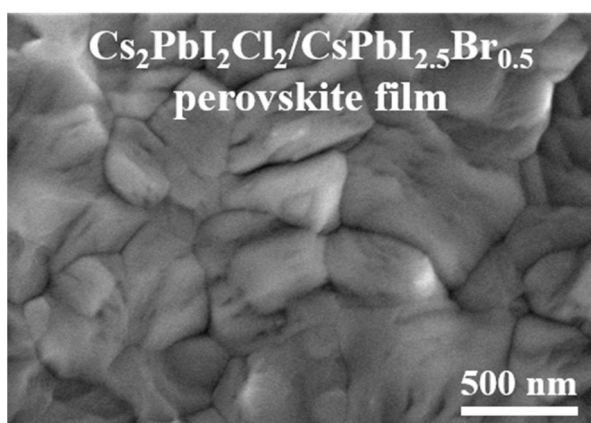


Figure S1. Top-view SEM image of the $\text{Cs}_2\text{PbI}_2\text{Cl}_2/\text{CsPbI}_{2.5}\text{Br}_{0.5}$ perovskite film.

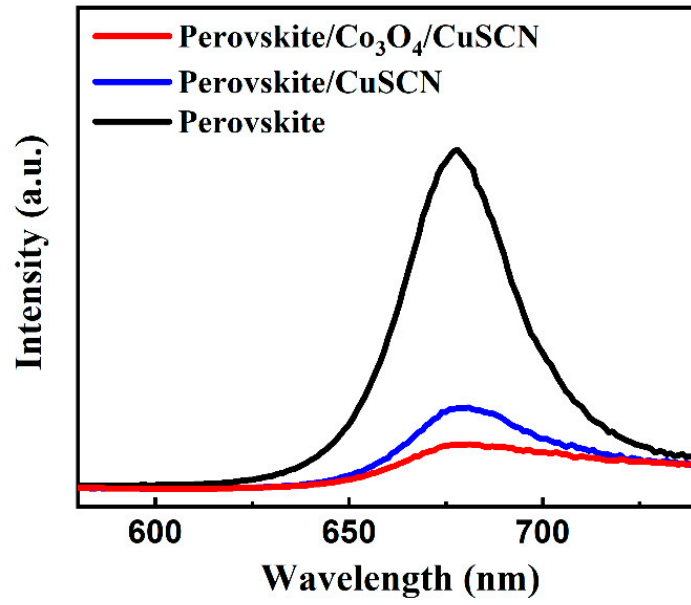


Figure S2. PL spectra of perovskite film, perovskite/CuSCN film and perovskite/Co₃O₄/CuSCN film

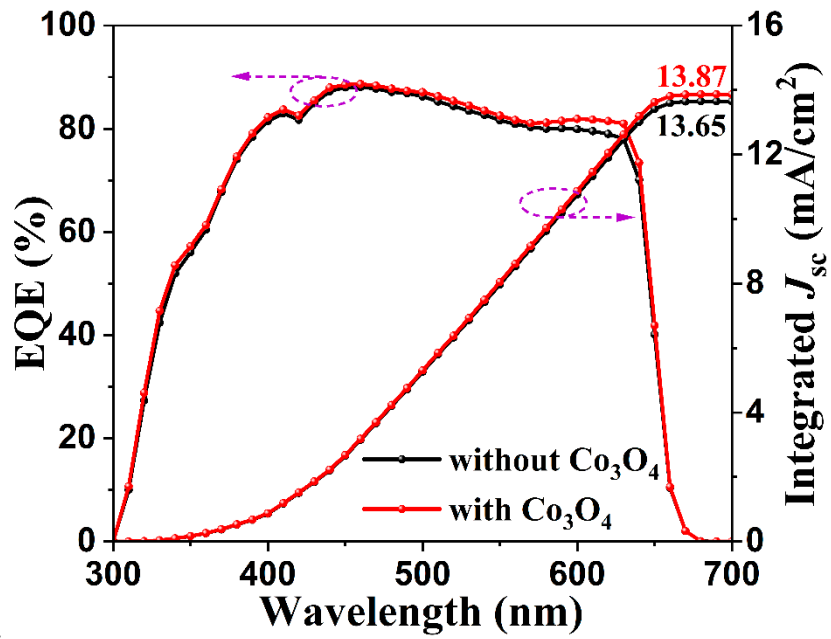


Figure S3. The EQE and integrated J_{sc} curves of Cs₂PbI₂Cl₂/CsPbI_{2.5}Br_{0.5} perovskite solar cells without Co₃O₄ buffer layer and with 1 mg/mL Co₃O₄ buffer layer.

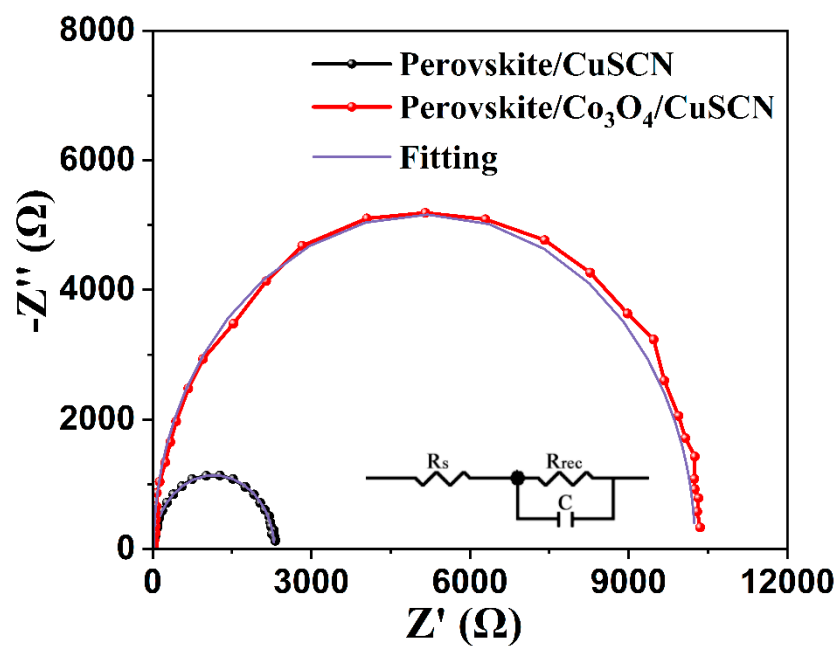


Figure S4. Nyquist diagrams for $\text{Cs}_2\text{PbI}_2\text{Cl}_2/\text{CsPbI}_{2.5}\text{Br}_{0.5}$ perovskite solar cells without Co_3O_4 buffer layer and with 1 mg/mL Co_3O_4 buffer layer; the inset depicts the equivalent circuit model of the devices in the EIS.

Table S1. Photoelectric performance parameters of Cs₂PbI₂Cl₂/CsPbI_{2.5}Br_{0.5} perovskite solar cells with different concentrations of Co₃O₄ between perovskite/CuSCN layers.

Device	J_{sc} (mA cm ⁻²)	V_{oc} (V)	FF (%)	PCE (%)
Perovskite/CuSCN	13.93	1.07	66.28	9.87
Perovskite/0.50-Co ₃ O ₄ /CuSCN	14.06	1.09	66.14	10.12
Perovskite/0.75-Co ₃ O ₄ /CuSCN	14.00	1.10	68.41	10.55
Perovskite/1.00-Co ₃ O ₄ /CuSCN	14.05	1.11	71.26	11.13
Perovskite/1.50-Co ₃ O ₄ /CuSCN	13.64	1.07	64.07	9.34
Perovskite/2.00-Co ₃ O ₄ /CuSCN	13.67	1.02	62.12	8.64

Table S2. Carrier lifetimes of perovskite, perovskite/CuSCN, and perovskite/Co₃O₄/CuSCN films obtained from curve-fitting TRPL spectra using a double exponential function.

Sample	A ₁	τ_1 (ns)	A ₂	τ_2 (ns)	τ_{ave} (ns)
Perovskite	0.46	1.64	0.53	15.70	9.08
Perovskite/CuSCN	0.99	1.87	0.18	13.45	4.27
Perovskite/Co ₃ O ₄ /CuSCN	0.57	1.15	0.41	5.71	3.00

Table S3. Performance parameters of the fitted EIS maps for Cs₂PbI₂Cl₂/CsPbI_{2.5}Br_{0.5} perovskite solar cells without Co₃O₄ buffer layer and with 1 mg/mL Co₃O₄ buffer layer.

Device	R_s (Ω)	R_{rec} (Ω)	C (F)
Perovskite/CuSCN	18.05	2315	4.86×10 ⁻⁹
Perovskite/Co ₃ O ₄ /CuSCN	17.72	10184	4.21×10 ⁻⁹