Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.
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Electronic Supplementary Information

$CoBr_2$-doping-induced efficiency improvement of planar $CsPbBr_3$ perovskite solar cells

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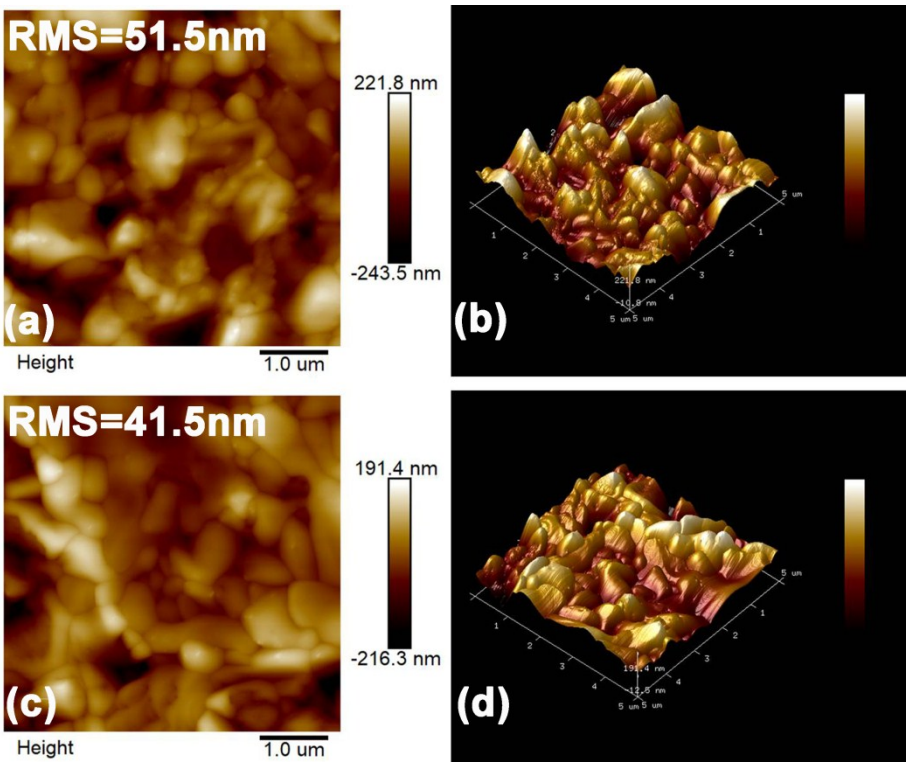

Figure S1. AFM images of $CsPbBr_3$ (a and b) and $CsPb_{0.998}Co_{0.002}Br_3$ (c and d) films.

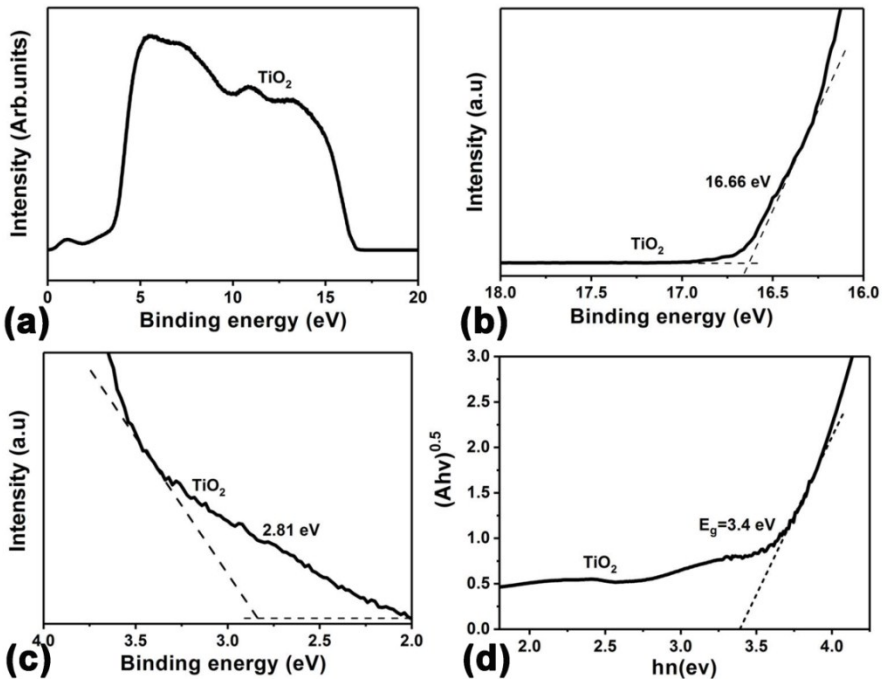

Figure S2. UPS spectrum (a), the cut-off energy ($E_{cut\text{-}off}$) region (b), the Fermi edge ($E_{F,\ edge}$) region (c), and Tauc plots (d) of TiO_2 ETL.

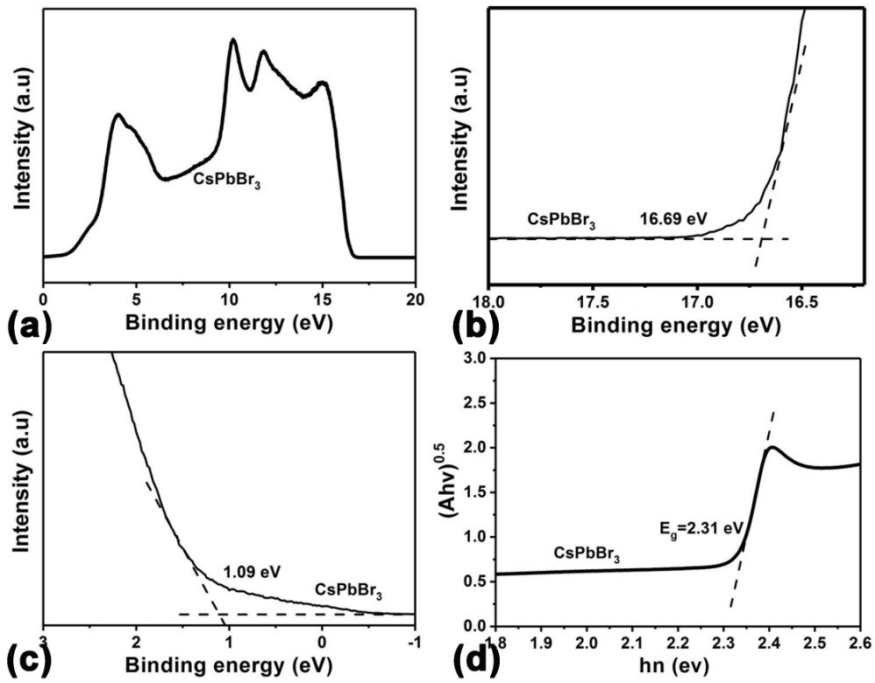

Figure S3. UPS spectrum (a), the cut-off energy ($E_{cut\text{-}off}$) region (b), the Fermi edge ($E_{F,\ edge}$) region (c), and Tauc plots (d) of $CsPbBr_3$ film.

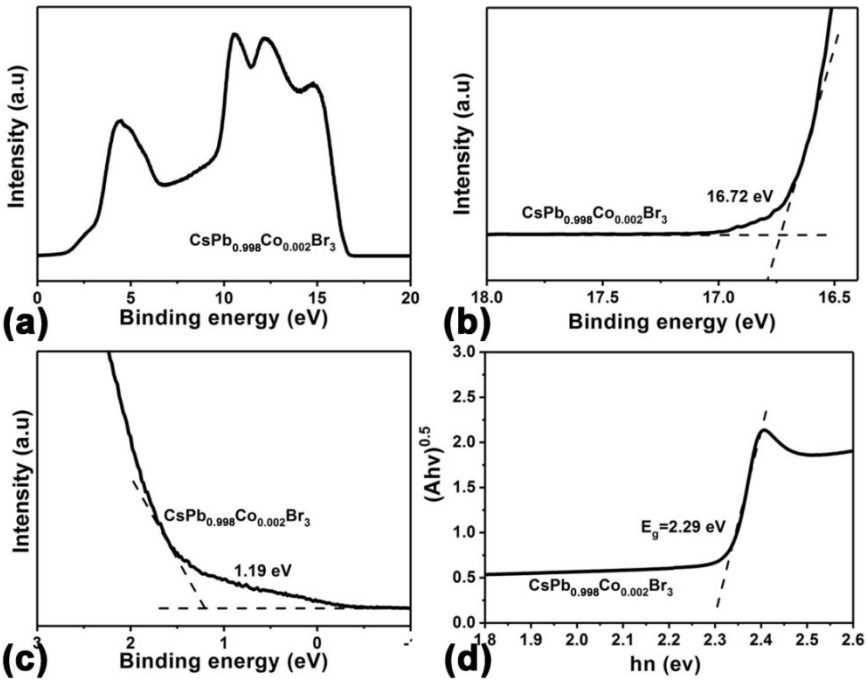

Figure S4. UPS spectrum (a), the cut-off energy ($E_{cut\text{-}off}$) region (b), the Fermi edge ($E_{F,\ edge}$) region (c), and Tauc plots (d) of $CsPb_{0.998}Co_{0.002}Br_3$ film.

Table S1. Energy levels of the TiO_2 ETL, $CsPbBr_3$ and $CsPb_{0.998}Co_{0.002}Br_3$ layers calculated from the UPS and Tauc plots data*.

Functional layer	$E_{cut\text{-}off}$ (eV)	$E_{F,\ edge}$ (eV)	E_g (eV)	E_F (eV)	E_{VB} (eV)	E_{CB} (eV)
TiO_2	16.66	2.81	3.40	4.56	-7.35	-3.95
$CsPbBr_3$	16.69	1.09	2.31	4.53	-5.62	-3.31
$CsPb_{0.998}Co_{0.002}Br_3$	16.72	1.19	2.29	4.50	-5.69	-3.40

*The Fermi levels (E_F) is calculated from the equation of E_F=$E_{cut\text{-}off}$ (cut-off binding energy)-21.2 eV (emission energy from He irradiation); the valence band maximum (E_{VB}) is calculated from the equation of E_{VB}= E_F-$E_{F,\ edge}$; the energy bandgap (E_g) is obtained from the Tauc plots; the E_{CB} is determined from E_g and E_{VB} [S1].

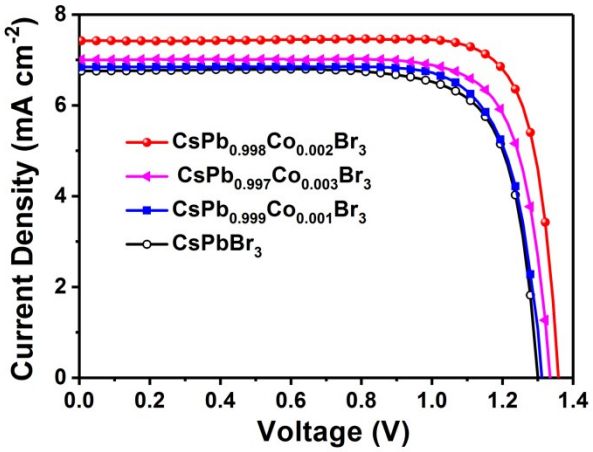

Figure S5. J-V curves of the $CsPbBr_3$ and $CoBr_2$ doped $CsPbBr_3$ planar PSCs.

Table S2. Photovoltaic parameters of the $CsPbBr_3$ and $CoBr_2$ doped $CsPbBr_3$ planar PSCs.

Perovskite composition	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
$CsPbBr_3$	1.301	6.79	77.08	6.81
$CsPb_{0.999}Co_{0.001}Br_3$	1.311	6.85	79.99	7.18
$CsPb_{0.998}Co_{0.002}Br_3$	1.357	7.45	84.84	8.57
$CsPb_{0.997}Co_{0.003}Br_3$	1.332	6.92	79.92	7.36

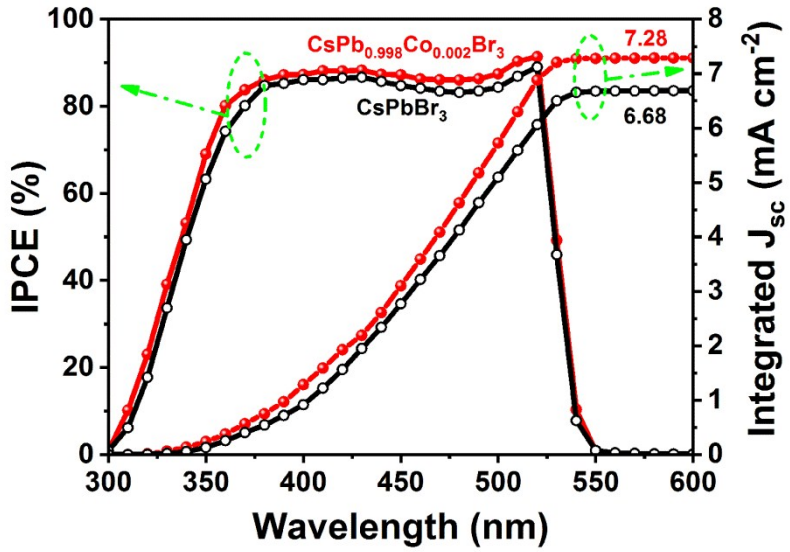

Figure S6. IPCE curves and integrated J_{sc} of the $CsPbBr_3$ and $CsPb_{0.998}Co_{0.002}Br_3$ planar PSCs.

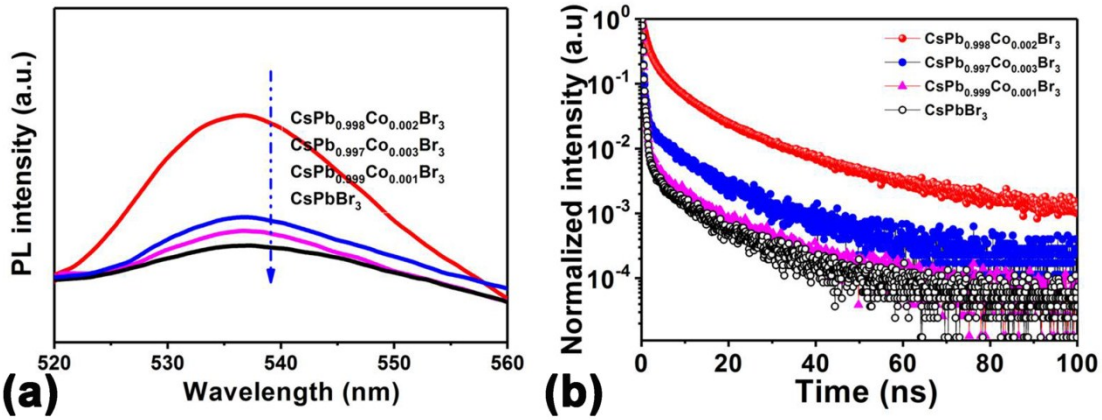

Figure S7. PL (a) and TRPL (b) spectra of the $CsPbBr_3$ and $CoBr_2$ doped $CsPbBr_3$ films.

Table S3. TRPL key parameters of the $CsPbBr_3$ and $CoBr_2$ doped $CsPbBr_3$ films.

Samples	τ_{ave} /ns	τ_1 /ns	τ_2 /ns	A_1/%	A_2/%
$CsPbBr_3$	2.55	8.60	0.24	72.36	27.64
$CsPb_{0.999}Co_{0.001}Br_3$	3.34	9.20	0.25	64.71	35.29
$CsPb_{0.998}Co_{0.002}Br_3$	10.71	15.74	2.96	60.58	39.42
$CsPb_{0.997}Co_{0.003}Br_3$	6.34	9.74	0.26	64.09	35.91

[S1] J. Song, W. N. Zhang, D. Wang, K. M. Deng, J. H. Wu, Z. Lan, Colloidal synthesis of Y-doped SnO_2 nanocrystals for efficient and slight hysteresis planar perovskite solar cells, Solar Energy 2019, 185, 508–515.