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

Supporting tables and figures

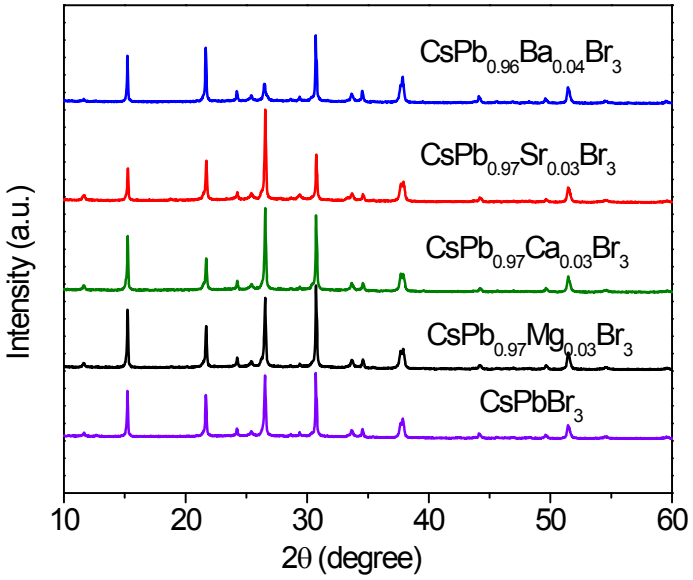


Fig. S1. XRD patterns of $CsPb_{1-x}M_xBr_3$ perovskite films.

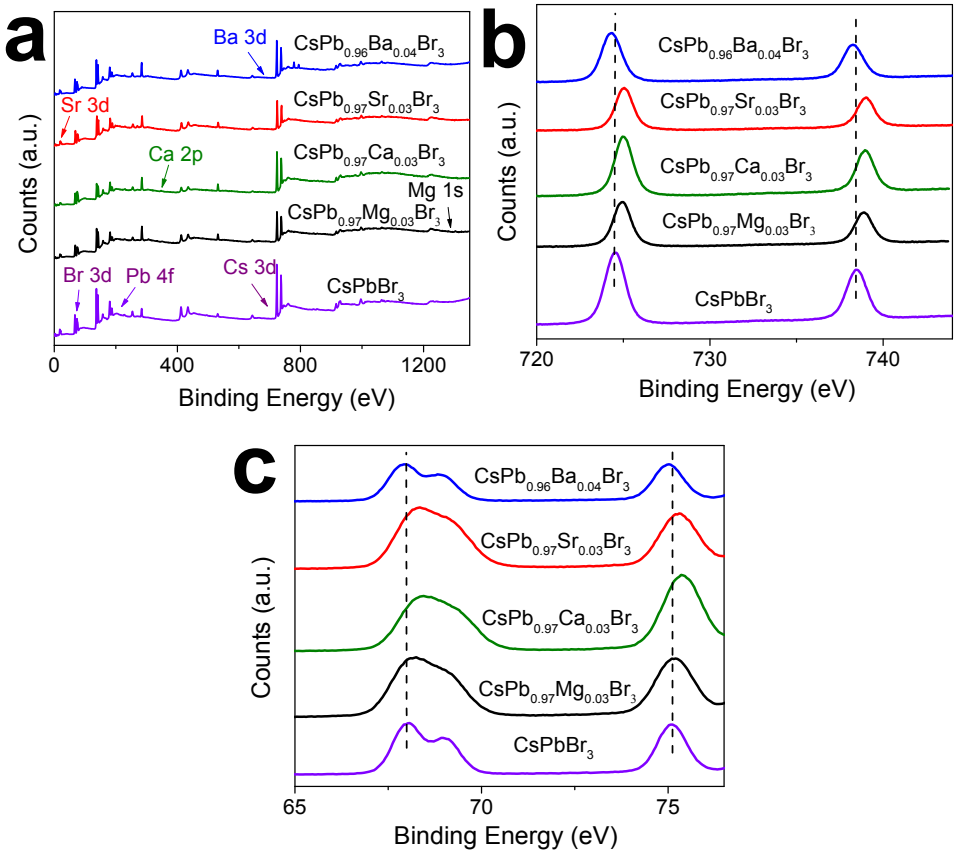


Fig. S2. (a) High-resolution XPS spectra of pure $CsPbBr_3$ (purple), $CsPb_{0.97}Mg_{0.03}Br_3$ (black), $CsPb_{0.97}Ca_{0.03}Br_3$ (green), $CsPb_{0.97}Sr_{0.03}Br_3$ (red) and $CsPb_{0.96}Ba_{0.04}Br_3$ (blue). XPS spectra of (b) Cs 3d, (c) Br 3d.

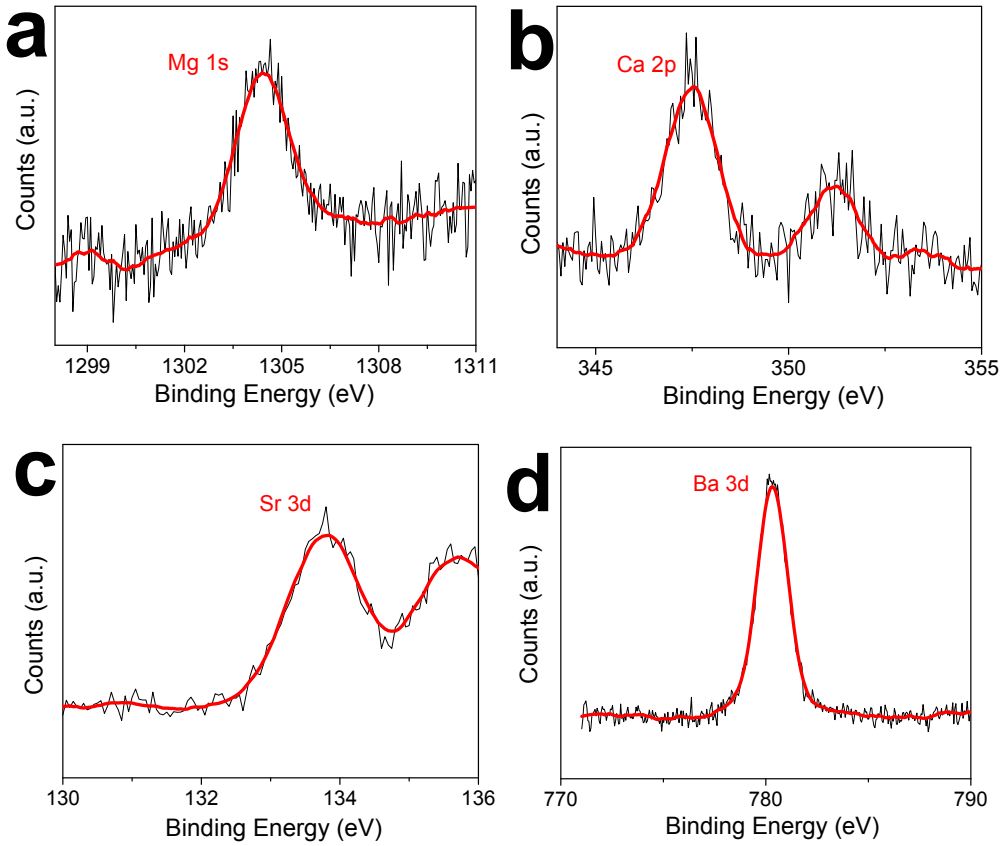


Fig. S3. High-resolution XPS spectra of the samples at (a) Mg, (b) Ca, (c) Sr and (d) Ba regions.

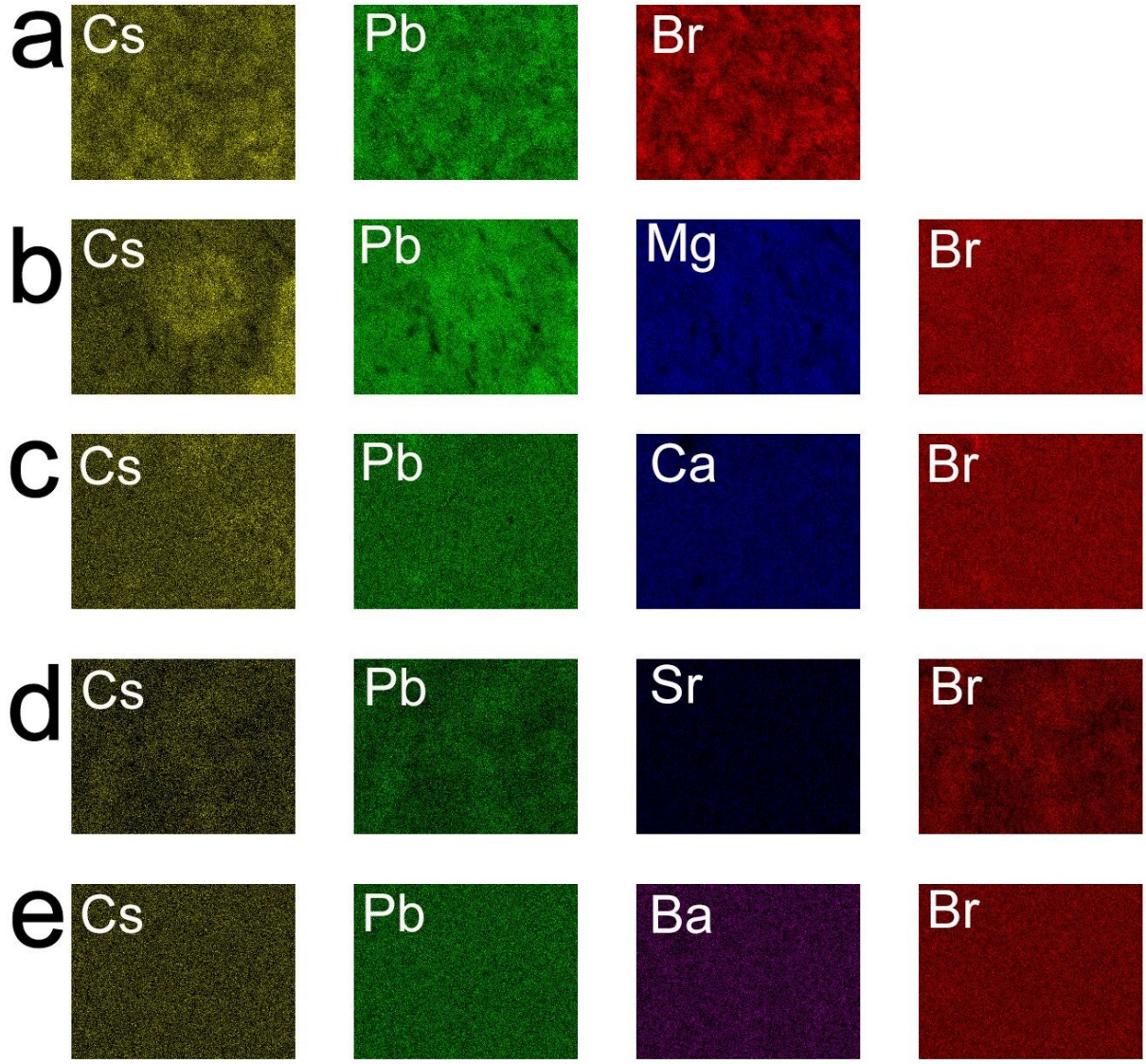


Fig. S4. Element mapping images of (a) $CsPbBr_3$ (b) $CsPb_{0.97}Mg_{0.03}Br_3$, (c) $CsPb_{0.97}Ca_{0.03}Br_3$, (d) $CsPb_{0.97}Sr_{0.03}Br_3$ and (e) $CsPb_{0.96}Ba_{0.04}Br_3$ perovskite films.

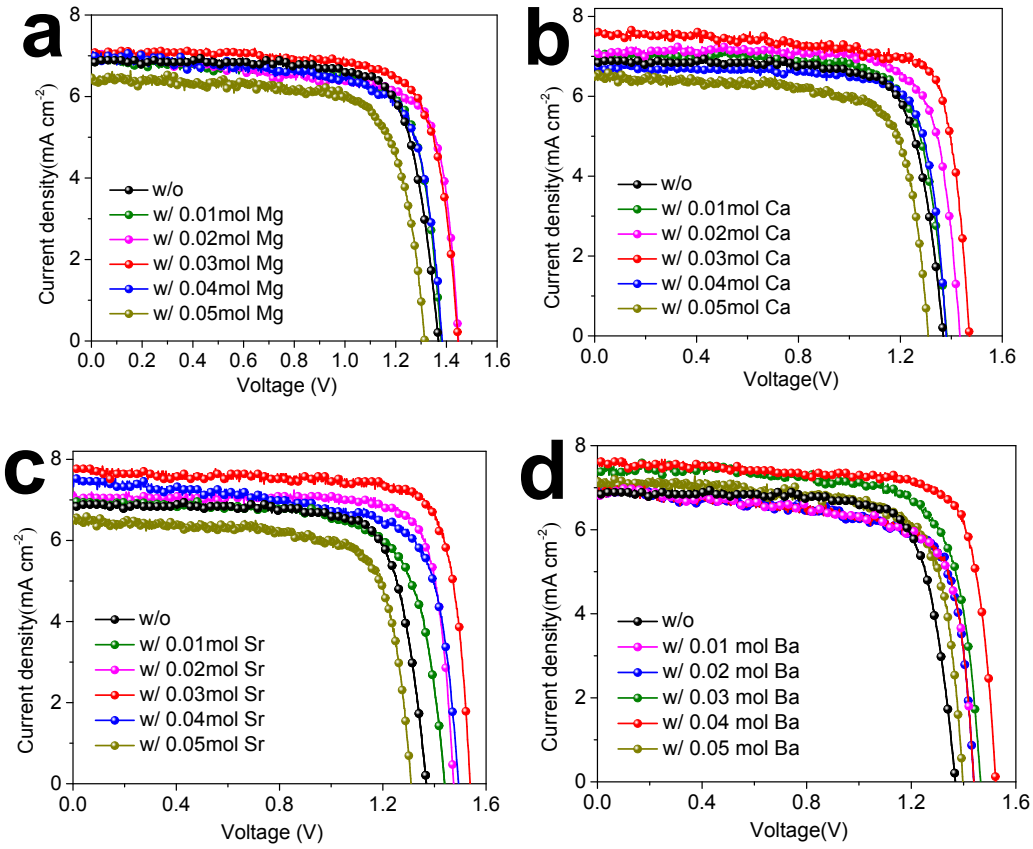


Fig. S5. *J-V* curves of (a) $CsPb_{1-x}Mg_xBr_3$, (b) $CsPb_{1-x}Ca_xBr_3$, (c) $CsPb_{1-x}Sr_xBr_3$ and (d) $CsPb_{1-x}Ba_xBr_3$ based PSCs under air mass 1.5 global (AM1.5G, 100 mW cm^{-2}) illumination.

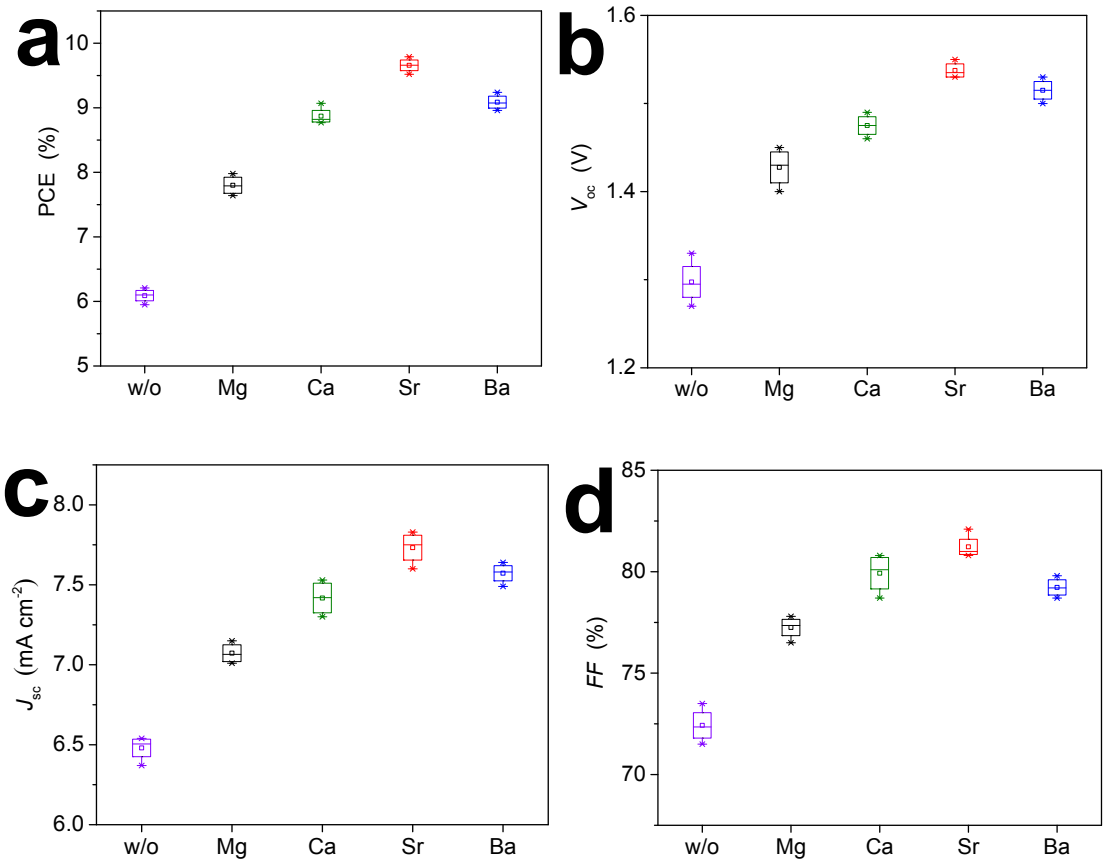


Fig. S6. The statistical distribution of photovoltaic parameters for five types PSCs: (a)PCE, (b)V_{oc}, (c) J_{sc} and (d) *FF*.

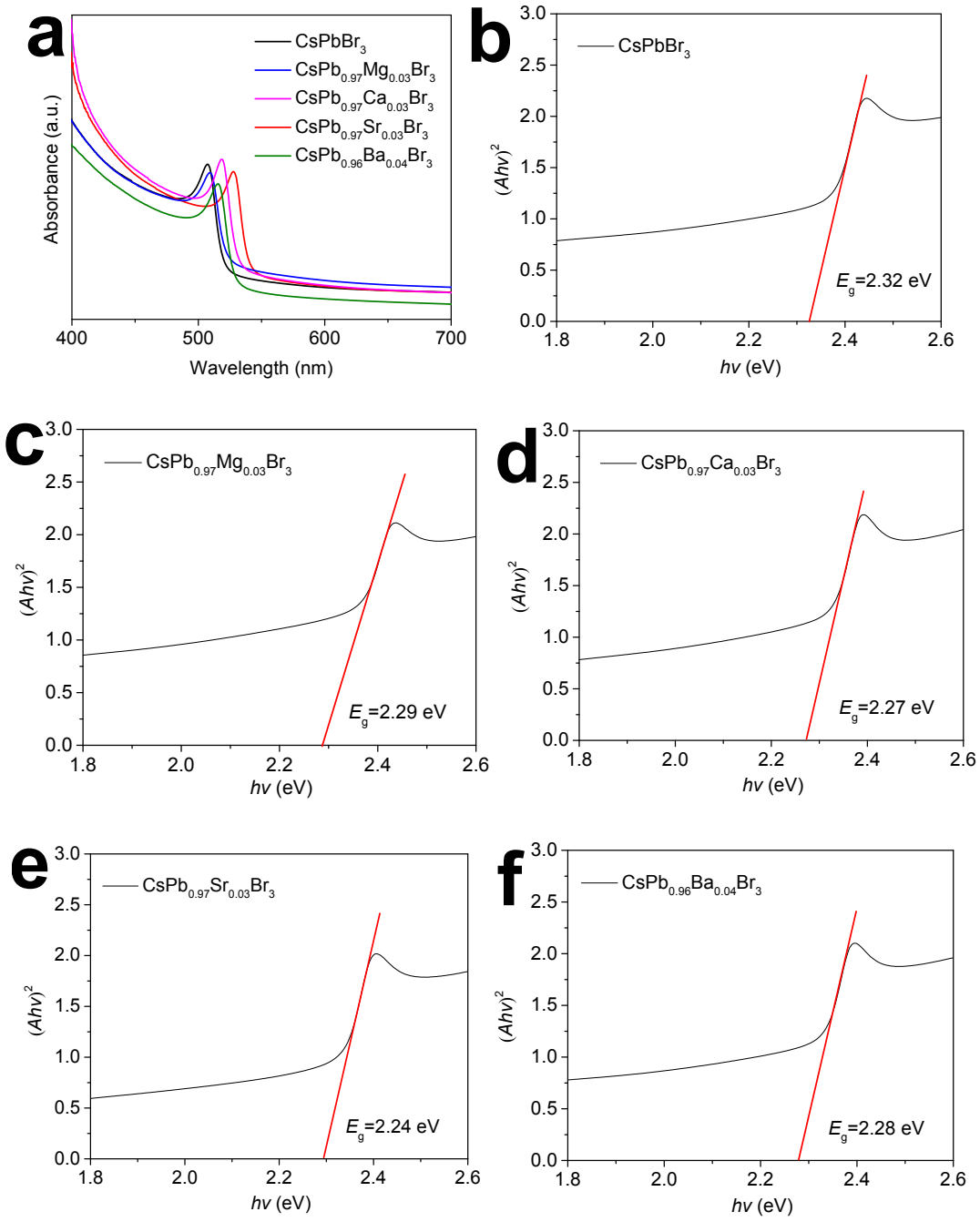


Fig. S7. (a) Absorption spectra and corresponding $(Ahv)^2$ vs energy (hv) curves converted from the UV-vis absorption spectra for (b) $CsPbBr_3$, (c) $CsPb_{0.97}Mg_{0.03}Br_3$, (d) $CsPb_{0.97}Ca_{0.03}Br_3$, (e) $CsPb_{0.97}Sr_{0.03}Br_3$ and (f) $CsPb_{0.96}Ba_{0.04}Br_3$ perovskite films. The band gaps of these five films were measured to be ~2.32, 2.29, 2.27, 2.24 and 2.28 eV, respectively.

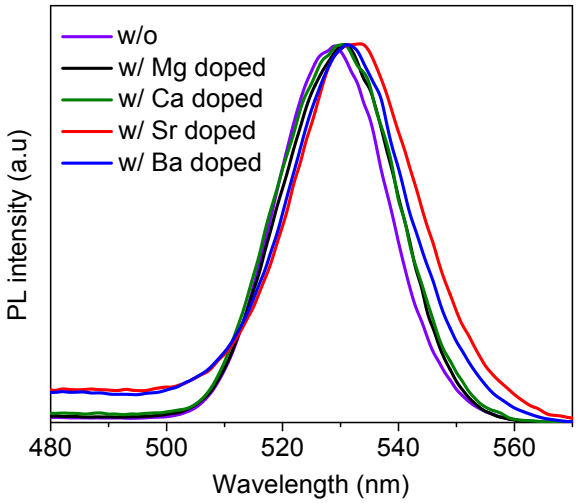
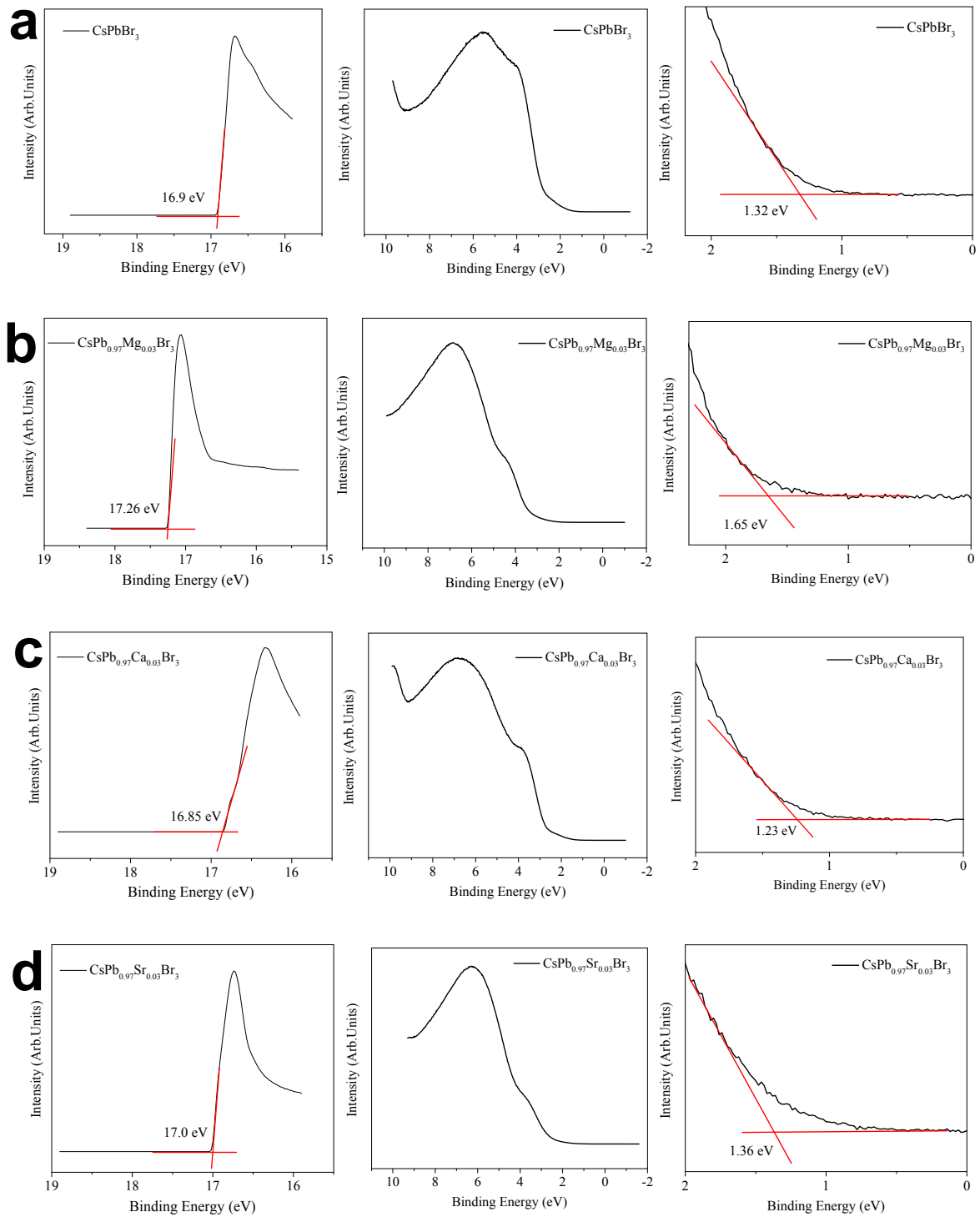


Fig. S8. Representative PL spectra of five inorganic perovskite films.


a
CsPbBr3
Intensity (Arb.Units)
16.9 eV
Binding Energy (eV)
CsPbBr3
Intensity (Arb.Units)
Binding Energy (eV)
CsPbBr3
Intensity (Arb.Units)
1.32 eV
Binding Energy (eV)
b
CsPb0.97Mg0.03Br3
Intensity (Arb.Units)
17.26 eV
Binding Energy (eV)
CsPb0.97Mg0.03Br3
Intensity (Arb.Units)
Binding Energy (eV)
CsPb0.97Mg0.03Br3
Intensity (Arb.Units)
1.65 eV
Binding Energy (eV)
c
CsPb0.97Ca0.03Br3
Intensity (Arb.Units)
16.85 eV
Binding Energy (eV)
CsPb0.97Ca0.03Br3
Intensity (Arb.Units)
Binding Energy (eV)
CsPb0.97Ca0.03Br3
Intensity (Arb.Units)
1.23 eV
Binding Energy (eV)
d
CsPb0.97Sr0.03Br3
Intensity (Arb.Units)
17.0 eV
Binding Energy (eV)
CsPb0.97Sr0.03Br3
Intensity (Arb.Units)
Binding Energy (eV)
CsPb0.97Sr0.03Br3
Intensity (Arb.Units)
1.36 eV
Binding Energy (eV)

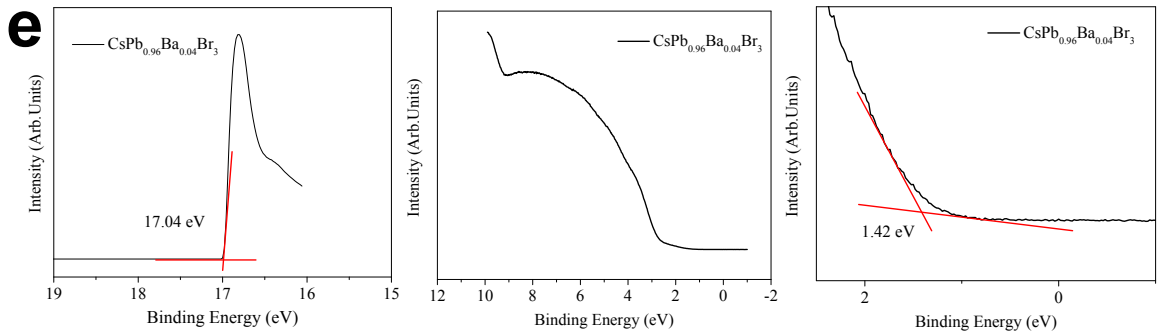


Fig. S9. Valence band UPS spectra of (a) $CsPbBr_3$, (b) $CsPb_{0.97}Mg_{0.03}Br_3$, (c) $CsPb_{0.97}Ca_{0.03}Br_3$, (d) $CsPb_{0.97}Sr_{0.03}Br_3$ and (e) $CsPb_{0.96}Ba_{0.04}Br_3$ perovskite films.

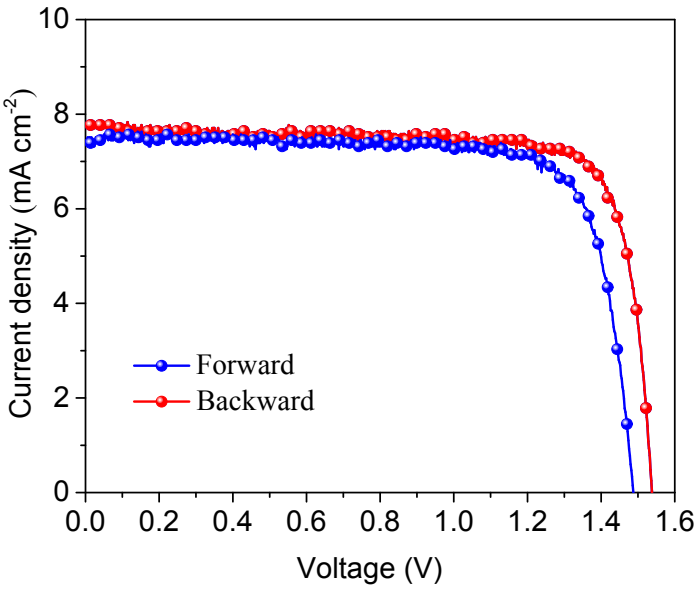


Fig. S10. *J-V* curves of the Sr doped PSC under different scan conditions under air mass 1.5 global (AM1.5G, 100 mW cm^{-2}) illumination.

Table S1. XRD analysis of (100) and (110) peaks for $CsPb_{1-x}M_xBr_3$ films fitted with the Gaussian function. Lattice constants were calculated according to Bragg's law. Cu-Kα radiation (1.5418 Å) was used for the measurements.

Sample	(100) peak		(110) peak	
	2θ [deg]	A [Å]	2θ [deg]	A [Å]
$CsPbBr_3$	15.213	5.819	21.654	4.101
$CsPb_{0.97}Mg_{0.03}Br_3$	15.227	5.814	21.682	4.096
$CsPb_{0.97}Ca_{0.03}Br_3$	15.232	5.812	21.717	4.089
$CsPb_{0.97}Sr_{0.03}Br_3$	15.244	5.808	21.728	4.087
$CsPb_{0.96}Ba_{0.04}Br_3$	15.264	5.799	21.736	4.085