Supporting Information

Reduced Open-Circuit Voltage Loss for Highly Efficient Low-Bandgap Perovskite Solar Cells via Suppression of Silver Diffusion

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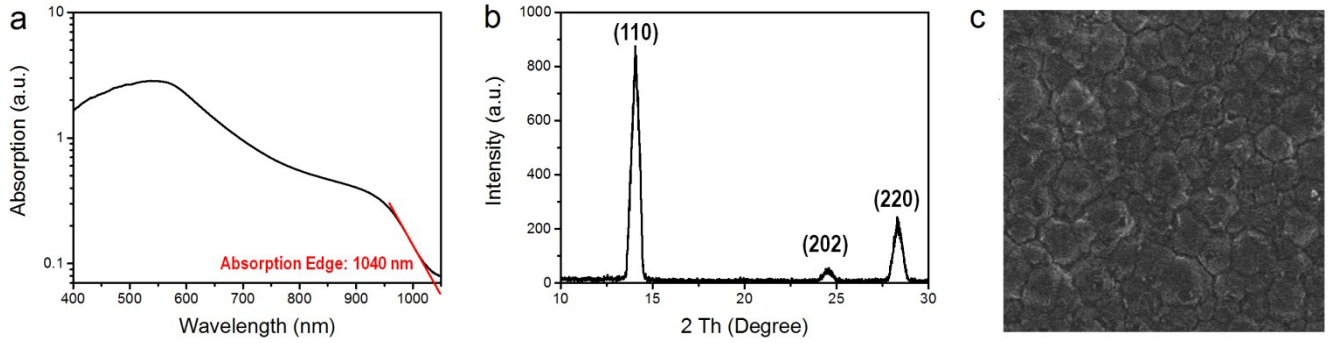

Figure S1. (a) Absorption spectrum of $FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$ film. (b) XRD pattern of $FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$ film. (c) SEM image of $FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$ film above PEDOT:PSS layer. The size of this area is 4×4 μm^2.

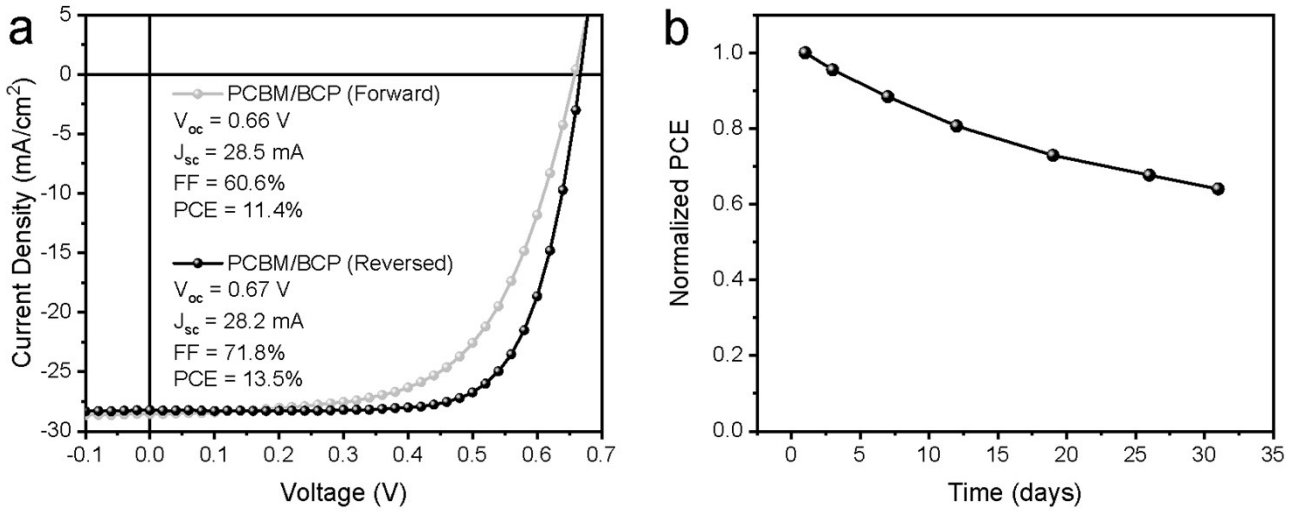

Figure S2. (a) J-V curves and (b) stability of perovskite solar cells with PCBM/BCP ETL.

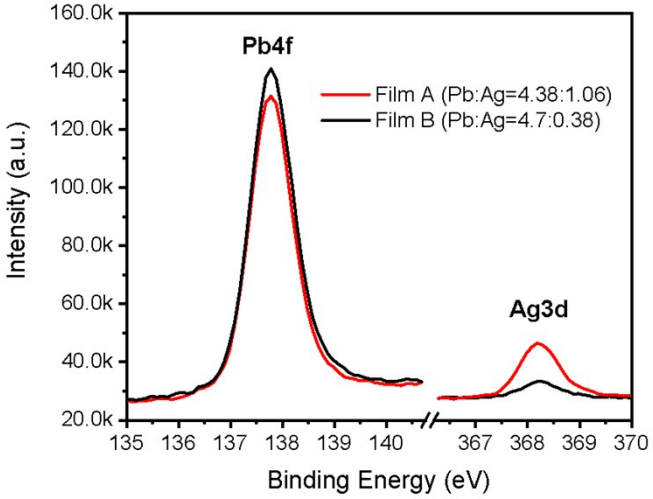

Figure S3. XPS data of Pb4f and Ag3d signal in Film A and Film B. The atomic ratio of Pb4f in Film A and Film B is 4.38% and 4.7%, respectively; the atomic ratio of Ag3d signal in Film A and Film B is 1.06% and 0.38%, respectively, suggesting a much smaller Pb to Ag ratio in Film A.

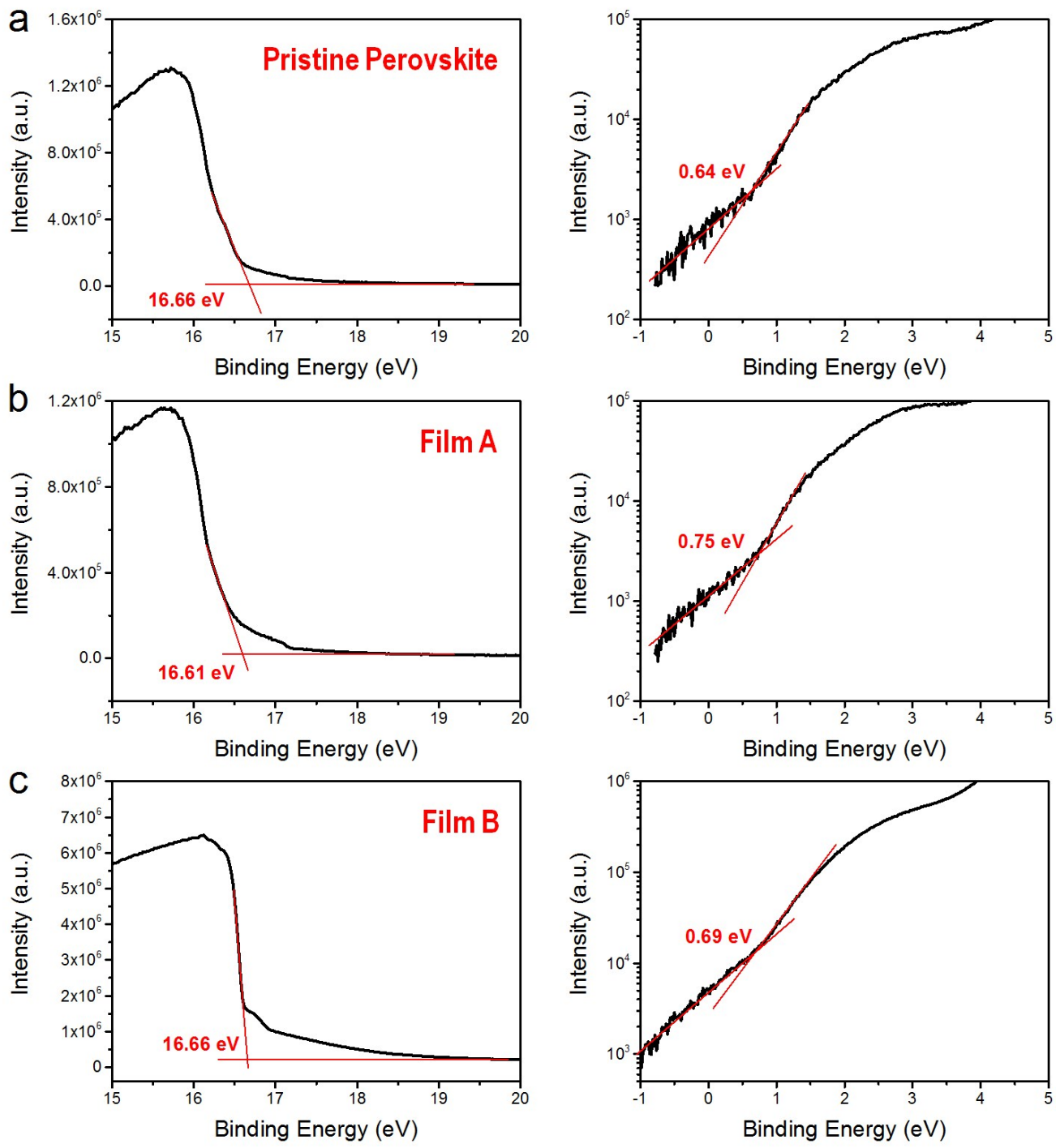

Figure S4. UPS spectra of $FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$ perovskite films. In the UPS measurements, a He I source with photon energy of 21.22 eV was used to excite the sample. Therefore, the calculated valence bands for (a) pristine perovskite, (b) Film A and (c) Film B are 5.20 eV, 5.36 eV and 5.25 eV, respectively.

Table S1. Photovoltaic parameters of perovskite solar cells with various PCBM thicknesses.

PCBM thickness (nm)	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)	PCE (%)
0	0.22	20.5	56.7	2.5
15	0.33	29.1	63.1	6.0
35	0.43	29.5	52.8	7.3
50	0.55	27.4	66.7	9.7
70	0.59	28.8	64.6	11.0
100	0.63	29.7	63.7	12.0
130	0.64	29.2	65.8	12.4
160	0.66	27.8	68.3	12.5
190	0.69	25.5	70.5	12.4

Table S2. A summary of PCE and V_{oc} loss of low-bandgap PVSCs based on published reports.

Perovskite	Bandgap (eV)	V_{oc} (V)	V_{oc} loss (V)	PCE (%)	Ref.
$MASn_{0.5}Pb_{0.5}I_3$	1.17	0.584	0.586	7.27	S1
$FASn_{0.5}Pb_{0.5}I_3$	1.28	0.695	0.585	10.76	S2
$MASn_{0.25}Pb_{0.75}I_3$	1.3	0.73	0.57	15.2	S3
$FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$	1.3	0.78	0.52	14.2	S4
$FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$+AA	1.3	0.78	0.52	14.01	S5
$FAPb_{0.7}Sn_{0.3}I_3$+MASCN	1.28	0.78	0.5	16.26	S6
$MASn_{0.5}Pb_{0.5}I_xCl_{3-x}$	1.19	0.70	0.49	12.3	S7
$MASn_{0.5}Pb_{0.5}I_xCl_{3-x}$ + NAP	1.19	0.71	0.48	13.4	S8
$MASn_{0.5}Pb_{0.5}I_3$	1.2	0.75	0.45	13.6	S9
$FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$	1.2	0.75	0.45	17.6	S10
$(FASnI_3)_{0.6}(MAPbI_3)_{0.4}$+GuaSCN	1.25	0.834	0.416	20.5	S11
$(FASnI_3)_{0.6}(MAPbI_3)_{0.4}$	1.2	0.795	0.405	15.08	S12
$(FASnI_3)_{0.6}(MAPbI_3)_{0.4}$	1.25	0.85	0.4	17.6	S13
$FA_{0.5}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$ + SnF_2 + $Pb(SCN)_2$	**1.19**	**0.79**	**0.4**	**18.1**	**Our Work**
$(FASnI_3)_{0.6}(MAPbI_3)_{0.4}$+PBDB-T:ITIC	1.25	0.86	0.39	18.03	S14
$(FASnI_3)_{0.6}(MAPbI_3)_{0.4}$+Br	1.272	0.888	0.384	19.03	S15

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