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

Supporting information

Enhancing the operational stability of unencapsulated perovskite solar cells through Cu-Ag bilayer electrode incorporation

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Table S1. Statistical J-V device data corresponding to data shown in Figure 1c.

	Electrode	Voc(V)	Jsc(mA/cm²)	FF	PCE(%)
$MAPbI_3$	Al	1.07 ±0.01 (1.07)	22.2 ±0.4 (22.5)	0.76 ±0.02 (0.77)	18.1 ±0.5 (18.5)
	Ag	1.08 ±0.01 (1.09)	21.9 ±0.3 (22.3)	0.77 ±0.02 (0.79)	18.2 ±0.5 (18.8)
	Cu	1.08 ±0.01 (1.08)	21.0 ±0.7 (21.6)	0.80 ±0.01 (0.81)	18.3 ±0.7 (18.9)
	Cu/Ag	1.08 ±0.01 (1.08)	20.8 ±0.7 (21.5)	0.8 1±0.01 (0.81)	18.2 ±0.6 (18.8)

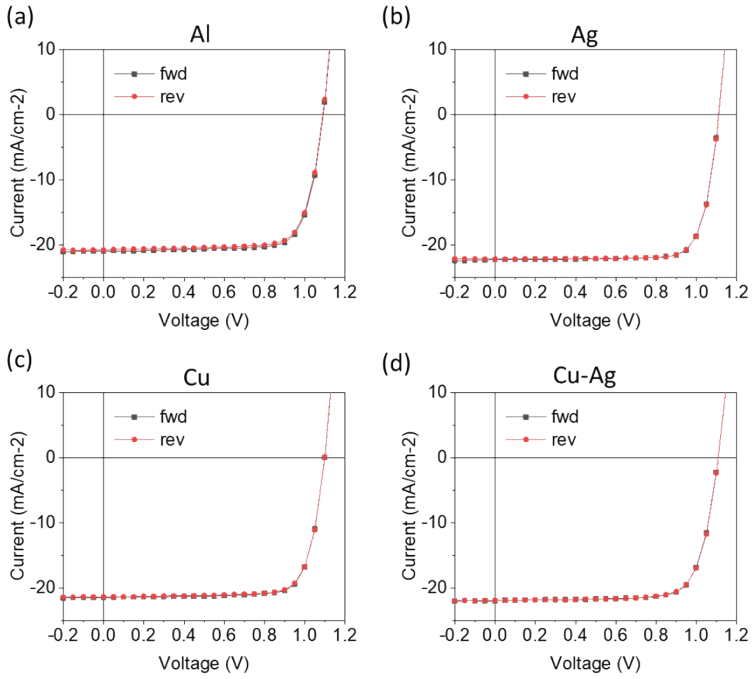

Figure S1 Forward and reverse scan of J-V characteristic of PSCs employing (a) Al, (b) Ag, (c) Cu, and (d) Cu-Ag as counter electrodes

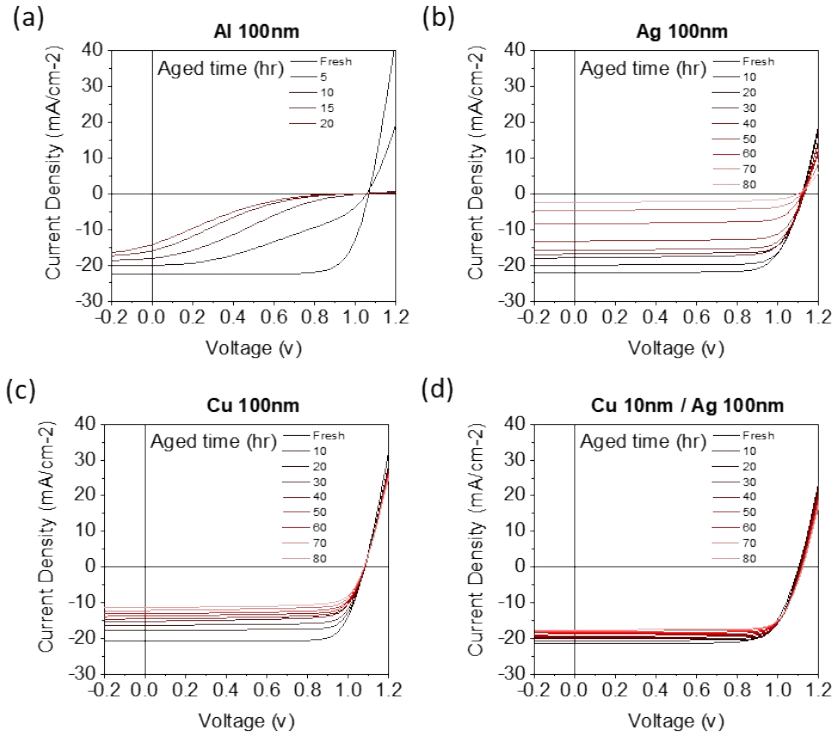

Figure S2 J-V scans of PSCs employing (a) Al, (b) Ag, (c) Cu, and (d) Cu-Ag as counter electrodes over the time periods indicated.

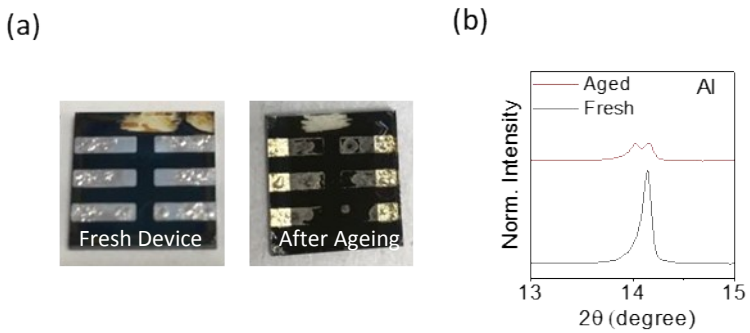

Figure S3 (a) Photographs showing as-prepared and aged (20 hours) devices employing Al electrodes. (b) XRD pattern showing the (110) diffraction peak of the MAPI device prepared with a Al electrode before and after 20 hours of lifetime testing.

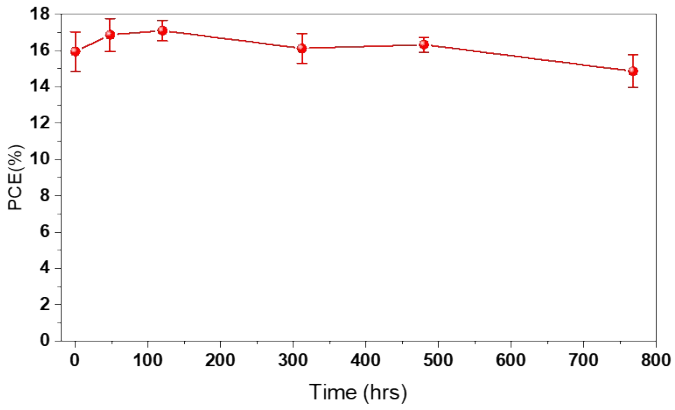

Figure S4 The shelf stability of PSC with Cu-Ag electrode. The devices were stored in dark in ambient air, with RH~40-50%.

Table S2 Secondary ion, m/z and identification of species used in ToF-SIMS depth profile analysis.

Secondary ion	Mass (m/z)	Device layer/material
Cu^-	62.9380	Copper electrode
Ag^-	106.9069	Silver electrode
C_3^-	36.0015	PCBM (HTL)
I^-	106.9153	Perovskite layer
PbI_3^-	588.7286	Perovskite layer
InO^-	130.91	ITO substrate
CuI_2^-	316.7667	Metal-halide
AgI_2^-	360.7247	Metal-halide

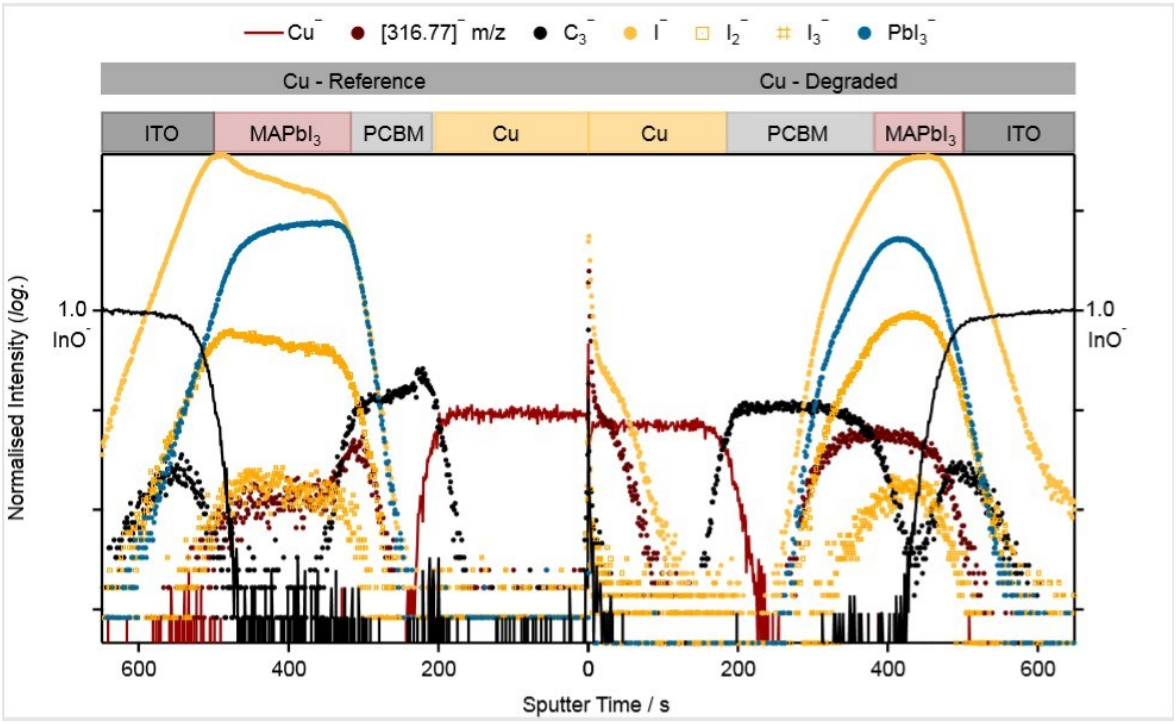

Figure S5 ToF-SIMS depth profiles of devices with Cu electrodes, fresh and aged (degraded)

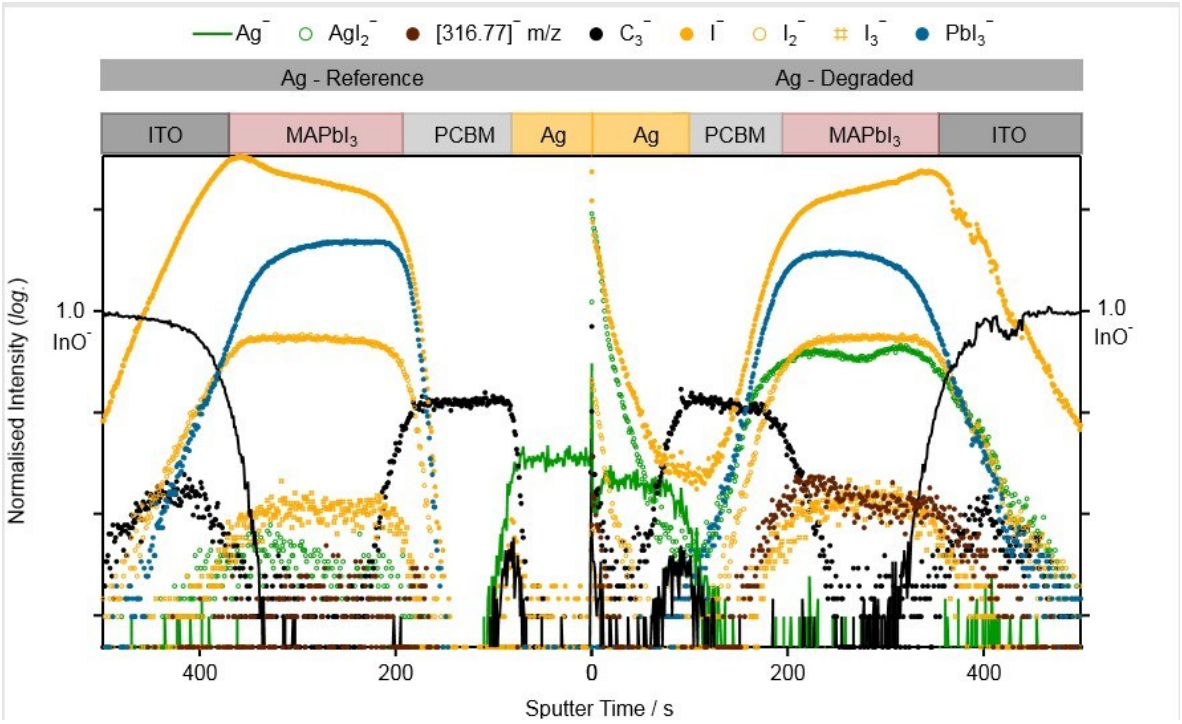

Figure S6 ToF-SIMS depth profiles of devices with Ag electrodes, fresh and aged (degraded)

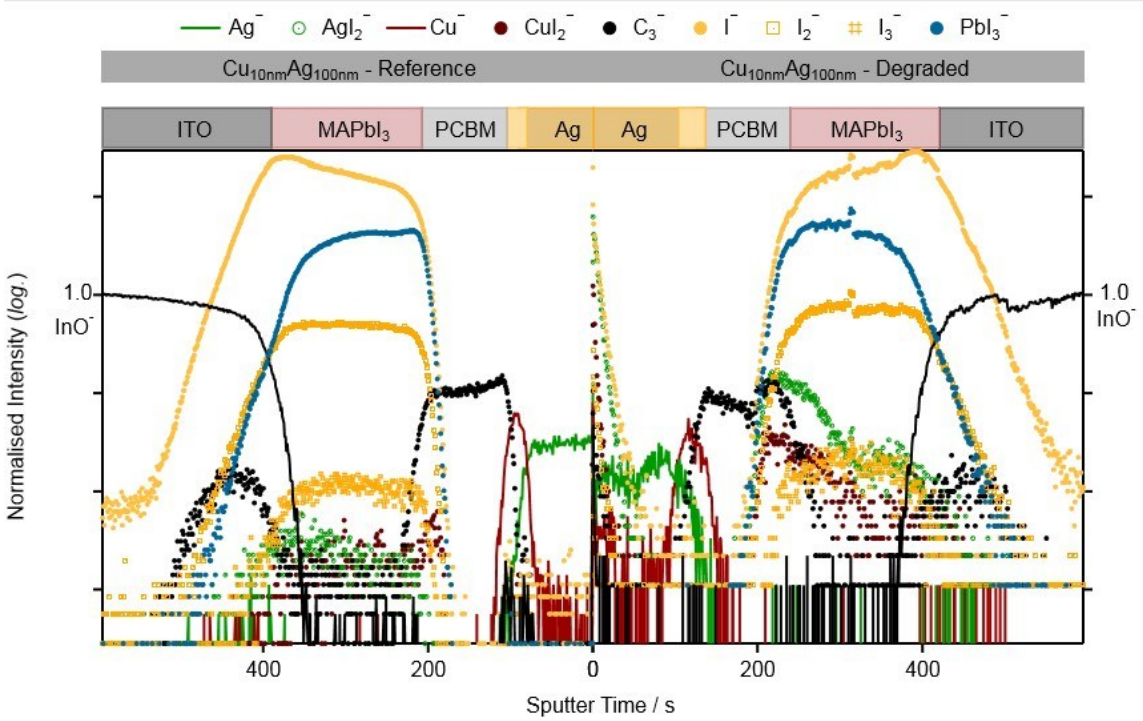

Figure S7 ToF-SIMS depth profiles of devices with Cu-Ag electrodes, fresh and aged (degraded)

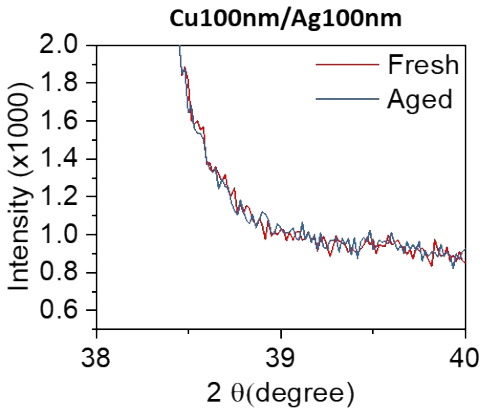

Figure S8 Magnified XRD pattern of PSC employing Cu10nm/Ag100nm electrode. The anticipated diffraction peak of CuO at 39.2° 2θ is not observed.

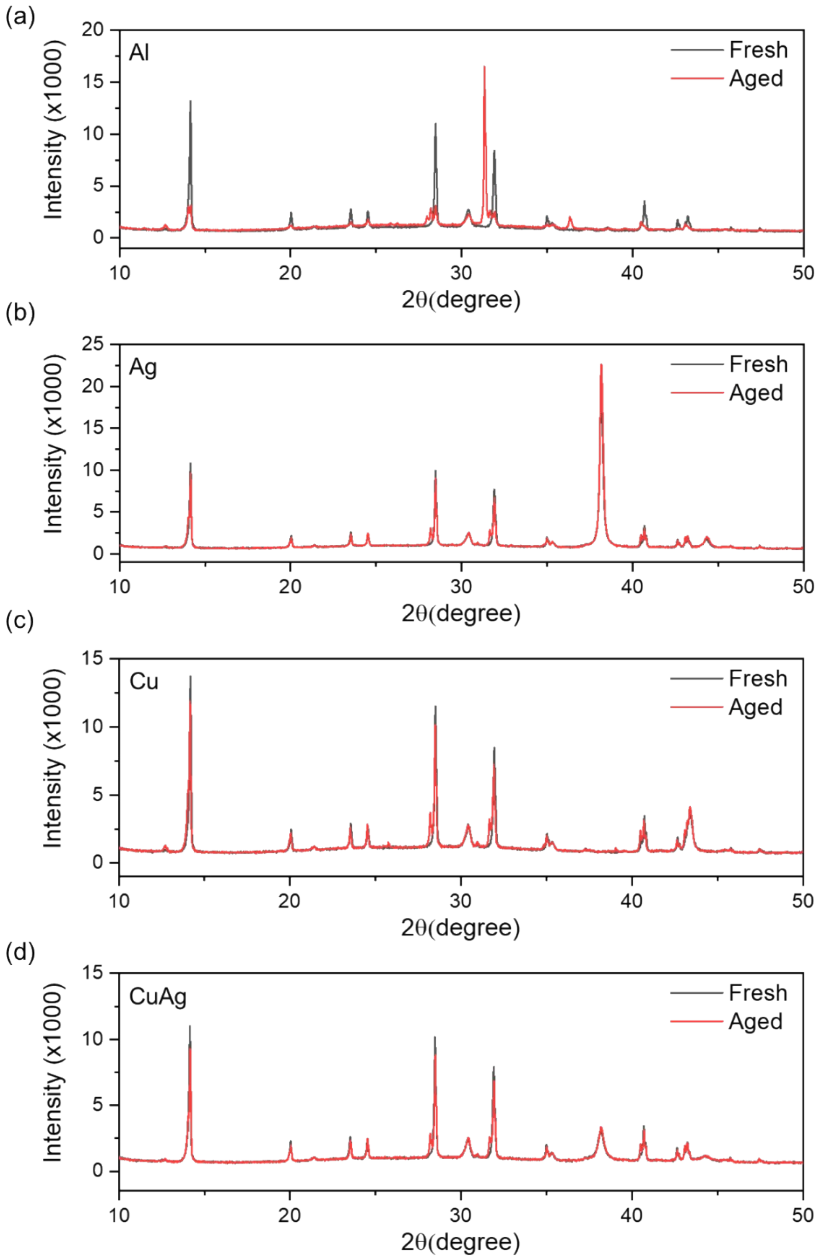

Figure S9 . Full XRD patterns of fresh and aged $MAPbI_3$ devices with (a)Al (b)Ag (c)Cu (d) Cu-Ag electrodes.

Table S3. Parameters of XRD fitting for data shown in Figures 4d-g.

Peak	Peak type	Integrated area	FWHM	Max height	Centre Gravity	Integrated area %
Fresh device (110/002)						
002	Gauss	0.0286	0.160	0.168	14.03	23.65
110	Gauss	0.0923	0.102	0.844	14.15	76.34
Aged device (110/002)						
002	Gauss	0.0533	0.166	0.659	14.03	44.83
110	Gauss	0.0656	0.093	0.301	14.15	55.17
Fresh device (220/004)						
004	Gauss	0.0067	0.183	0.034	28.19	5.47
220	Gauss	0.1210	0.150	0.760	28.47	94.53
Aged device (220/004)						
004	Gauss	0.0233	0.150	0.146	28.19	20.6
220	Gauss	0.0894	0.124	0.679	28.47	79.3