Electronic Supplementary Material (ESI) for Sustainable Energy & Fuels.

Ionic liquid as modulate interface for high-efficient and stable perovskite solar cells

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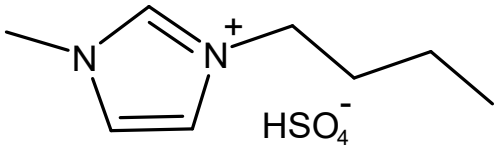

Fig.S1 Chemical structure of $BMIMHSO_4$ molecule.

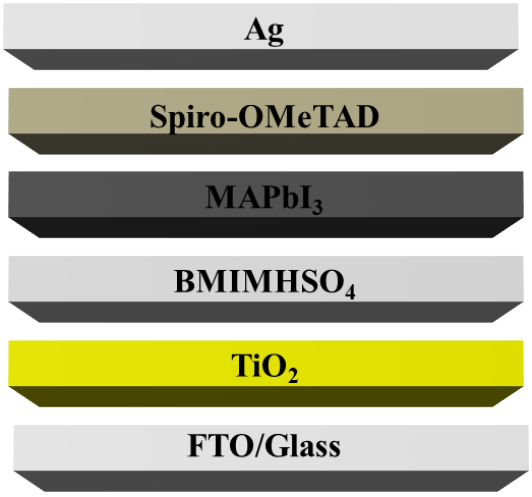

Fig.S2 Device structure of the PSCs.

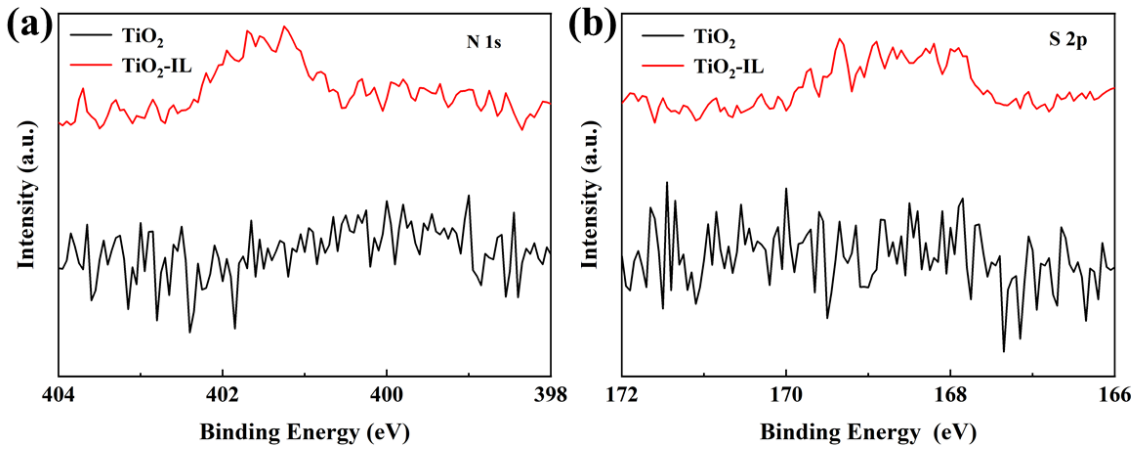

Fig.S3 The high-resolution XPS spectra of (a) N and (b) S element.

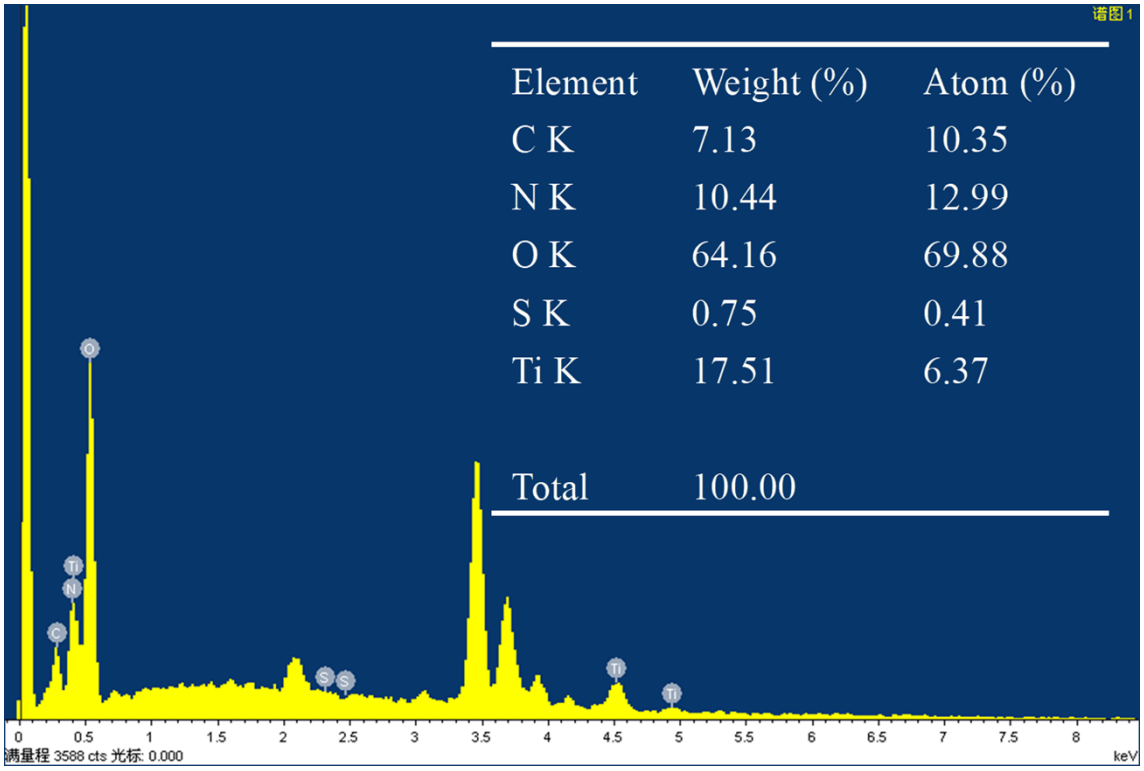

Fig.S4 The EDS measurement of TiO_2-IL sample with the top-right showing the detail element analysis.

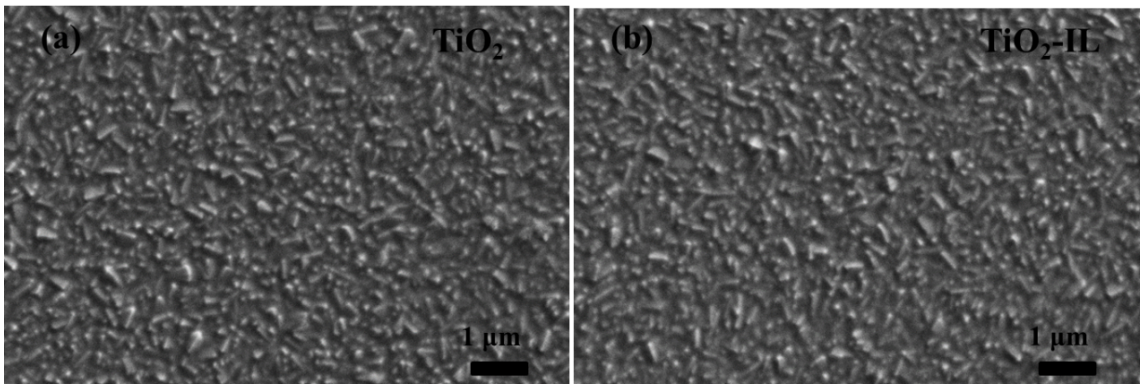

Fig.S5 The SEM images of (a) TiO_2 and (b) TiO_2-IL film.

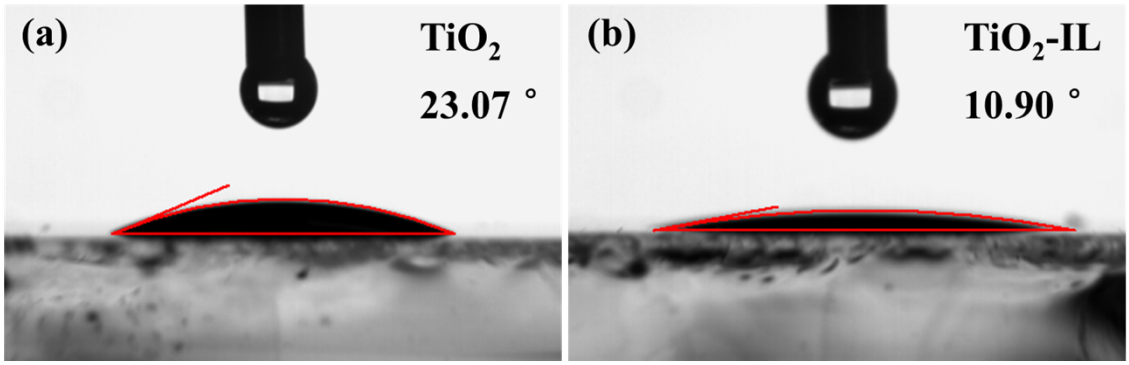

Fig.S6 Contact angle performance using DMSO solvent of (a) TiO_2 and (b) TiO_2 film.

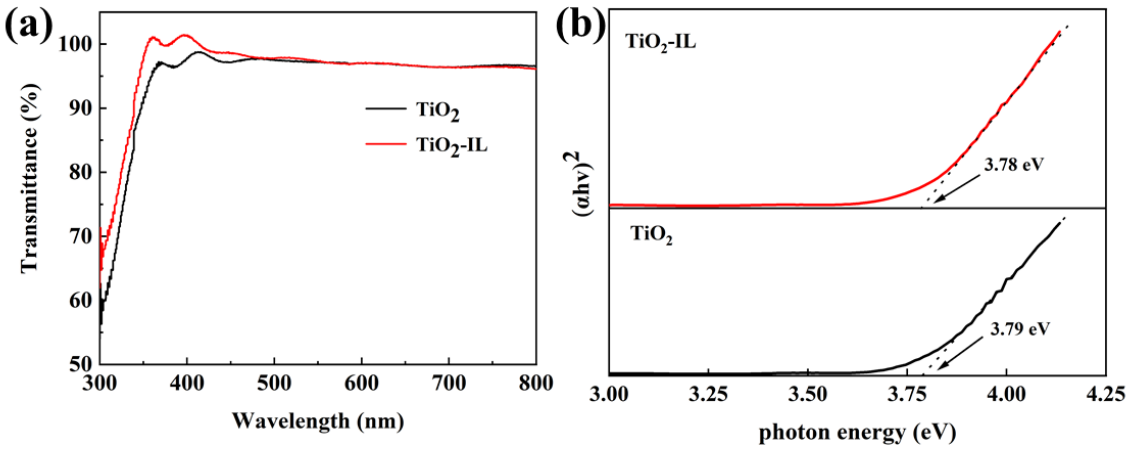

Fig.S7 (a)Transmission spectra and (b) Tauc plot of absorption spectra of TiO_2 and TiO_2-IL film.

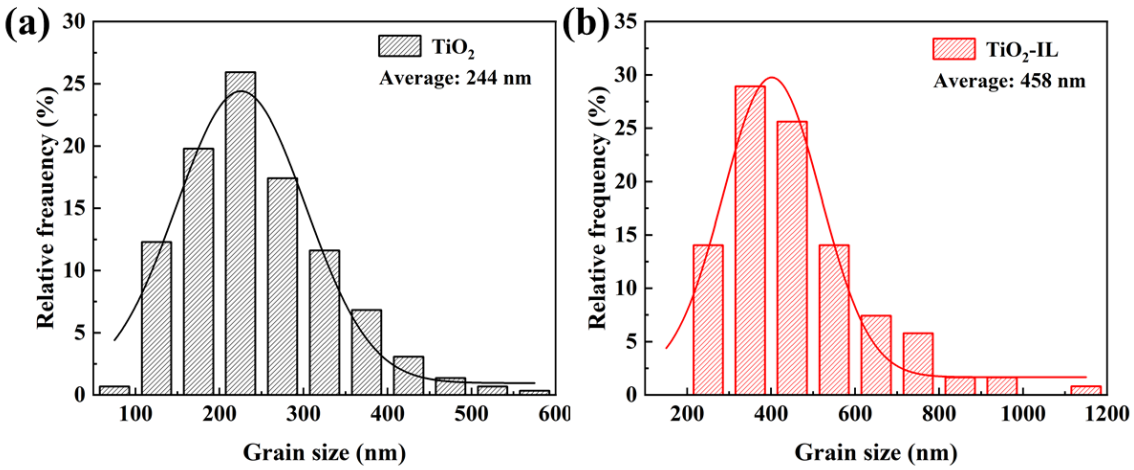

Fig.S8 The grain size distribution histograms of (a) TiO_2-based and (b) TiO_2-IL-based perovskite film.

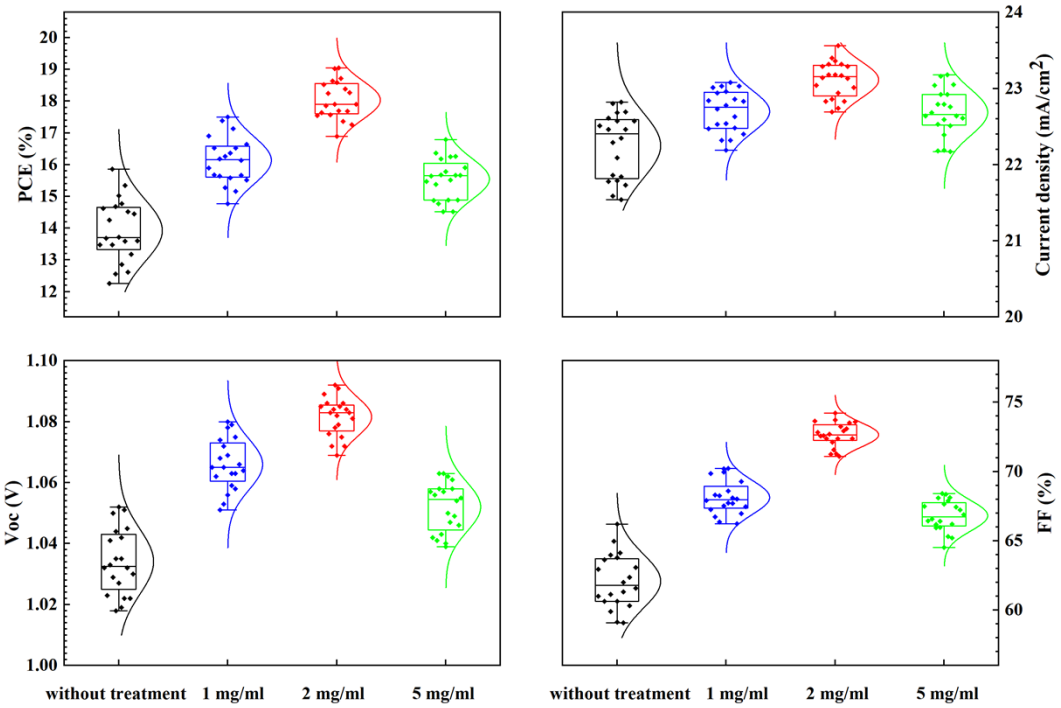

Fig.S9 Statistics on photovoltaic parameters for studied PSCs at various IL concentrations. J-V curves collected at 1 sun irradiation are utilized to derive parameters. A box is used to illustrate the standard error. Twenty devices with a cell active area of 0.06 cm^2 were fabricated for each PSC structure.

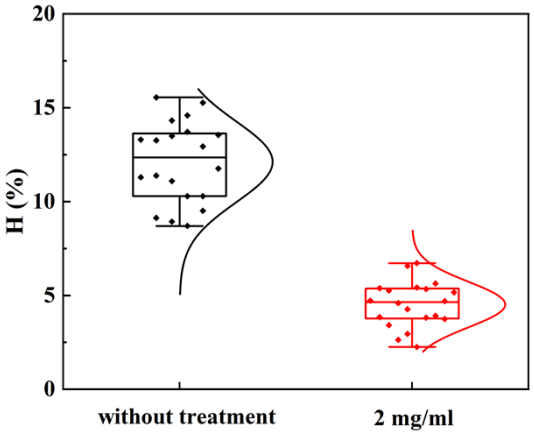

Fig.S10 Hysteresis index of twenty devices.

Table S1 The electron mobility and conductivity parameters based on two ETL.

Samples	Mobility ($cm^2 V^{-1} S^{-1}$)	Conductivity ($mS cm^{-1}$)
TiO_2	1.43×10^{-7}	1.27×10^{-3}
TiO_2-IL	4.88×10^{-7}	1.93×10^{-3}

Table S2 Photovoltaic parameters of PSCs based on TiO_2-IL with different concentrations.

Samples	Jsc ($mA cm^{-2}$)	Voc (V)	FF (%)	PCE (%)
Without treatment	22.82	1.05	66.20	15.92
1 mg/ml	23.08	1.08	70.23	17.56
2 mg/ml	23.56	1.09	74.21	19.13
5 mg/ml	23.18	1.06	68.36	16.83

Table S3 Photovoltaic parameters measured at different scan directions of the champion PSCs based on the 0 mg/ml and 2 mg/ml IL concentration devices.

Samples	Scan direction	Jsc ($mA cm^{-2}$)	Voc (V)	FF (%)	PCE (%)	H (%)
Without treatment	Reverse	22.82	1.05	66.20	15.92	8.70
	Forward	22.55	1.04	61.76	14.53	
2 mg/ml	Reverse	23.56	1.09	74.21	19.13	2.40
	Forward	23.45	1.09	72.86	18.67	

Table S4. The fitting parameters of TRPL of perovskite film for growing on TiO_2 and TiO_2-ILsubstrates.

Samples	A_1	τ_1 (ns)	A_2	τ_2 (ns)	τ_{avg} (ns)
TiO_2	1.12	6.53	0.25	212.79	187.86
TiO_2-IL	1.89	2.64	0.57	23.55	17.88

Table S5 the electron trap density was calculated by SCLC measures of the deposited on TiO_2 film and TiO_2-IL film devices.

Samples	V_{TFL}(V)	N_{trap} (cm^{-3})
TiO_2	0.683	1.20×10^{14}
TiO_2-IL	0.475	0.83×10^{14}

Table S6 EIS parameters of PSCs based on TiO_2 and TiO_2-IL devices.

Samples	Rs (Ω)	Rrct (Ω)
TiO_2	30.48	12388.32
TiO_2-IL	22.31	17704.03

Table S7 summarized the stability research about $BMIMHSO_4$ IL with other ILs.

Ionic liquid	Perovskite	PCE (%)	Decrease in stability (%) after hours	Ref

MAAc	$CsPbIBr_2$	8.85	Air(room temperature), remains 82% of initial PCE after 30 days.	[1]
$BMIMPF_6$	$CsPbI_2Br$	13.19	Air(20 ℃, ~20% RH), remains 91% of initial PCE after 60 days.	[2]
$FBABF_4$	$(FAPbI_3)_{1-x}(MAPbBr_3)_x$	23.07	Air(35±5% RH), remains 85% of initial PCE after 3000h.	[3]
$N(CH_3)_4OH$ (TMAH)	$FA_{0.75}MA_{0.25}PbI_{2.5}Br_{0.5}$	20.28	Desiccator(~15% RH), remains 97% of initial PCE after 360h.	[4]
$BMIMBF_4$	$MAPbI_3$	19.62	Air(AM 1.5G illumination), remains 85% of initial PCE after 240 min.	[5]
$BMIMBF_4$	$FA_{0.83}MA_{0.17}Pb(I_{0.83}Br_{0.17})_3$	20.80	Air(85 ℃, dark, under 45% RH), remains less than 50% of initial PCE after 800h.	[6]
EMIMI	$MAPbI_3$	14.59	Dry air(RH<5%), remains 93% of initial PCE after 360h; air (30-40% RH), remains 51% of initial PCE after 360h.	[7]
$[EMIM]PF_6$	$MAPbI_3$	13.50	Air, remains 93.5% of initial PCE after 45 days.	[8]
MAAc	$MAPbI_3$	21.08	Light, N_2-filled glovebox, remains 86% of initial PCE after 400h.	[9]
$BMIMHSO_4$	$MAPbI_3$	19.13	Air(~40% RH,25±5℃, dark), remains 90% of initial PCE after 600h.	This work

Reference

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