Supporting Information

Efficient and stable perovskite solar cells based on insulating polymer modified ZnO nanoparticles

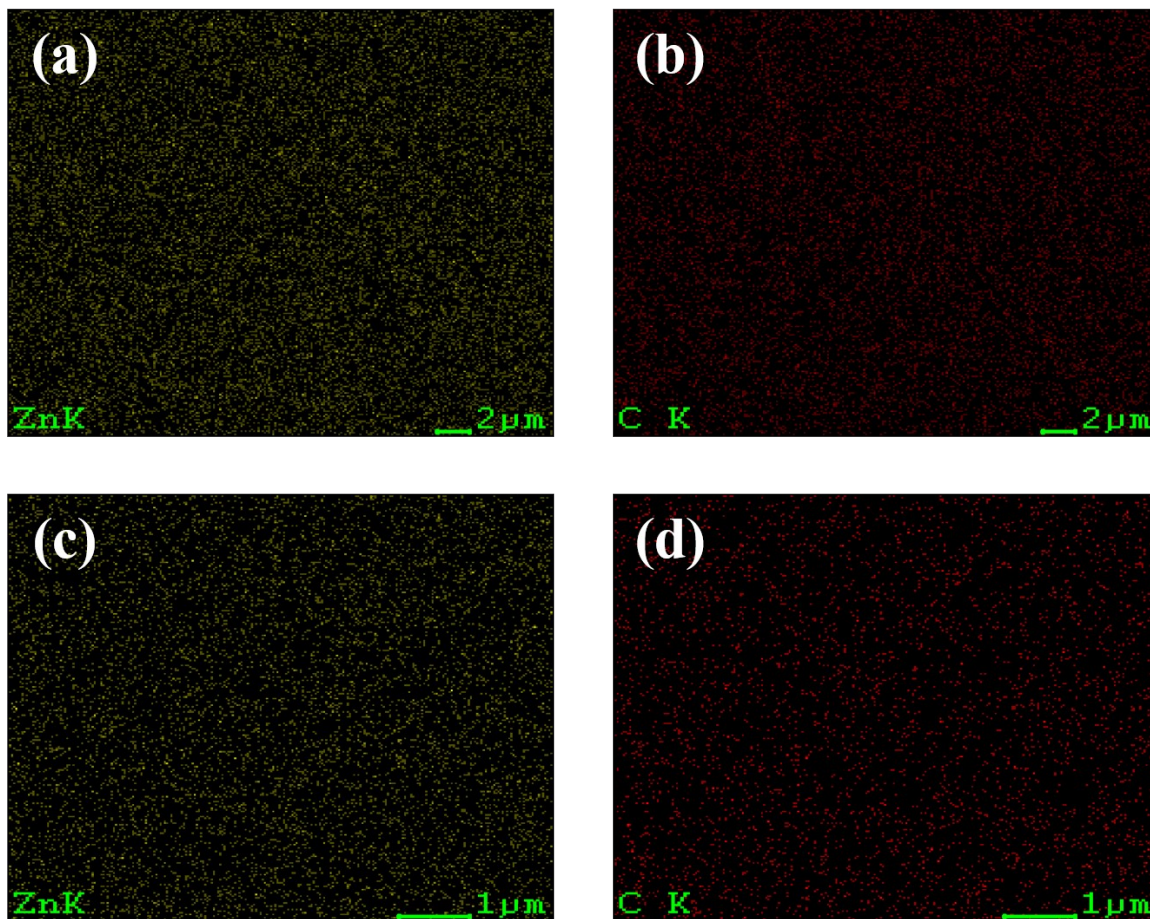Pu Fan[1], Jianghao Tian[12], Kun Wang[12], Ding Zheng[2*], Junsheng Yu[12*], Thomas P. Russell[3*]

Figure S1. EDS images about C and Zn of (a-b) pure ZnO NPs ETL, (c-d) PVA modified ZnO NPs ETL.

Element	Wt%	At%
NK	04.56	10.15
OK	18.02	35.15
MgK	01.53	01.96
SiK	34.11	37.89
AuM	04.07	00.64
InL	28.13	07.65
CaK	06.57	05.12
ZnK	03.02	01.44
Matrix	Correction	ZAF

(b)

Element	Wt%	At%
CK	29.34	45.71
OK	25.01	29.26
NaK	00.00	00.00
MgK	00.39	00.30
AlK	00.54	00.37
SiK	29.56	19.70
AuM	03.18	00.30
KK	02.62	01.25
CaK	02.37	01.11
ZnK	07.00	02.00
Matrix	Correction	ZAF

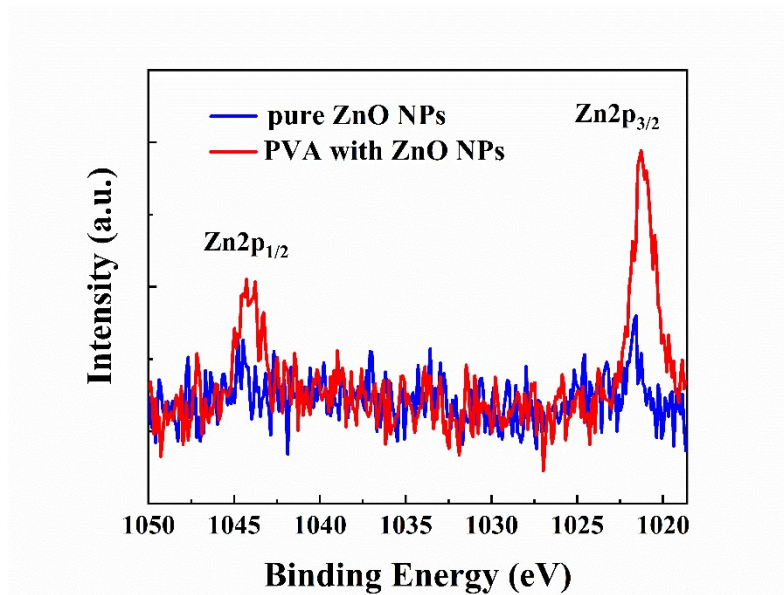Figure S2. EDS element statistics of (a) pure ZnO NPs and (b) PVA modified ZnO NPs.
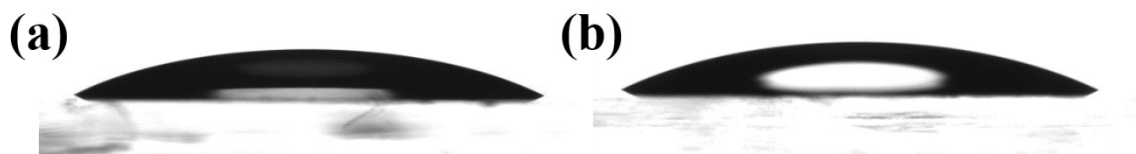
Figure S3. Zn2p peak of different ETLs.

Figure S4. Water contact angle of different ETLs, (a) pure ZnO NPs; (b) PVA with ZnO NPs.
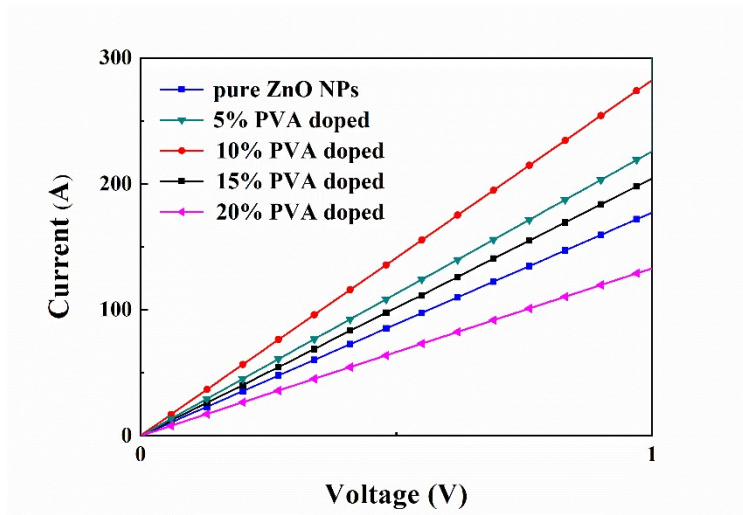
Figure S5. ETL conductivity corresponding to different PVA doping concentrations.
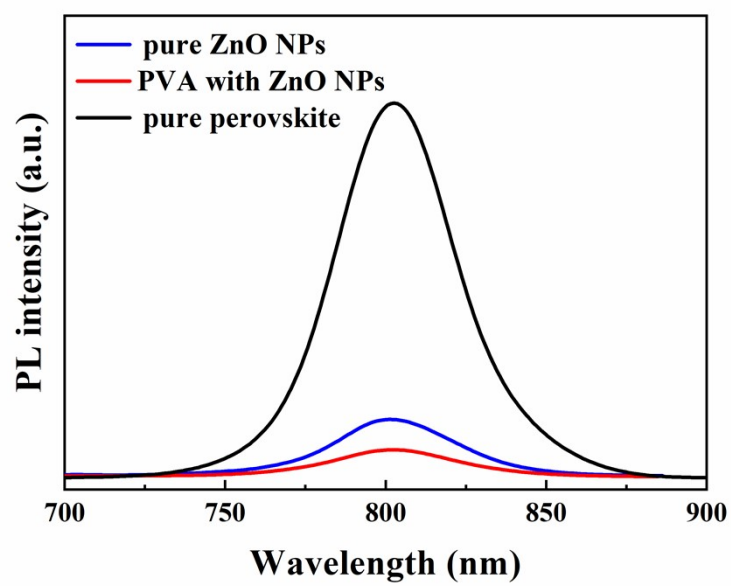
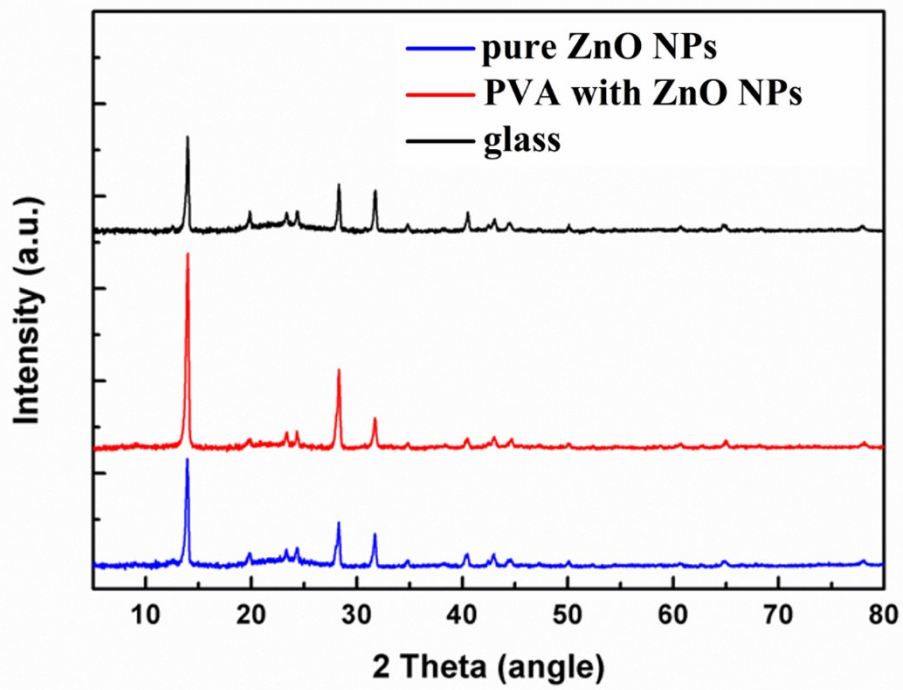Figure S6. PL spectra of perovskite film upon different layer.

Figure S7. XRD spectra of perovskite upon different substrates.
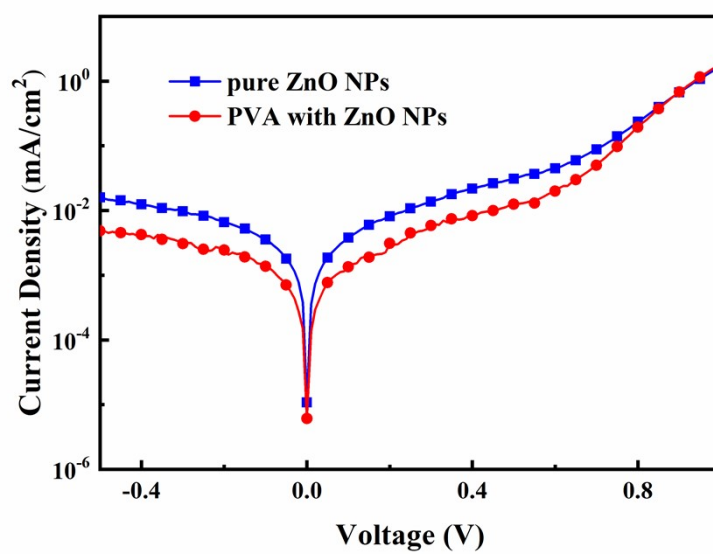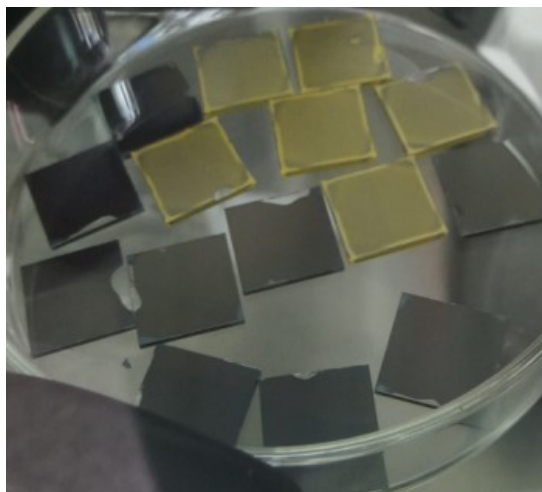
Figure S8. Dark state J-V curves of PSCs.

Figure S9. Images of perovskite films upon different ETLs, the yellow ones are fabricated on the original ETLs, and the black ones are fabricated on the PVA modified ETLs.

Table S1. Key photovoltaic parameters of PSCs with different ETLs

ETL	Scanning direction	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF (%)	PCE (%)
pure ZnO NPs	RS	1.13	21.64	71.93	17.59
	FS	1.11	20.98	69.44	16.17
PVA with ZnO NPs	RS	1.14	22.79	76.56	19.89
	FS	1.13	22.50	73.68	18.72

Table S2. Key photovoltaic parameters of PSCs with different ETLs[a]

PVA ratio (wt %)	V_{OC} (V)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
0 (control)	1.13±0.01	20.38±0.73	70.43±1.26	16.96±0.60
5	1.14±0.01	20.96±0.62	72.94±1.64	18.09±0.52
10	1.14±0.01	21.63±0.54	75.23±1.53	19.26±0.41
15	1.14±0.01	20.75±0.57	73.84±1.87	18.17±0.63
20	1.12±0.01	19.82±0.55	70.67±1.59	16.39±0.54

[a]**All parameters are average value collected from 16 devices.**

Table S3. Key photovoltaic parameters of MAPbI$_3$ PSCs with different ETLs[a]

ETL	V_{OC} (V)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
pure ZnO NPs	1.01	21.64	68.76	15.03
PVA with ZnO NPs	1.02	22.87	70.98	16.56