Supplementary material for paper:

Tris (ethylene diamine) nickel acetate as a promising precursor for hole transport layer in planar structured perovskite solar cells

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Fig. S1. Photo of nickel acetate (NiA) and synthesized Tris (ethylene diamine) nickel acetate (TED – NiA) precursor

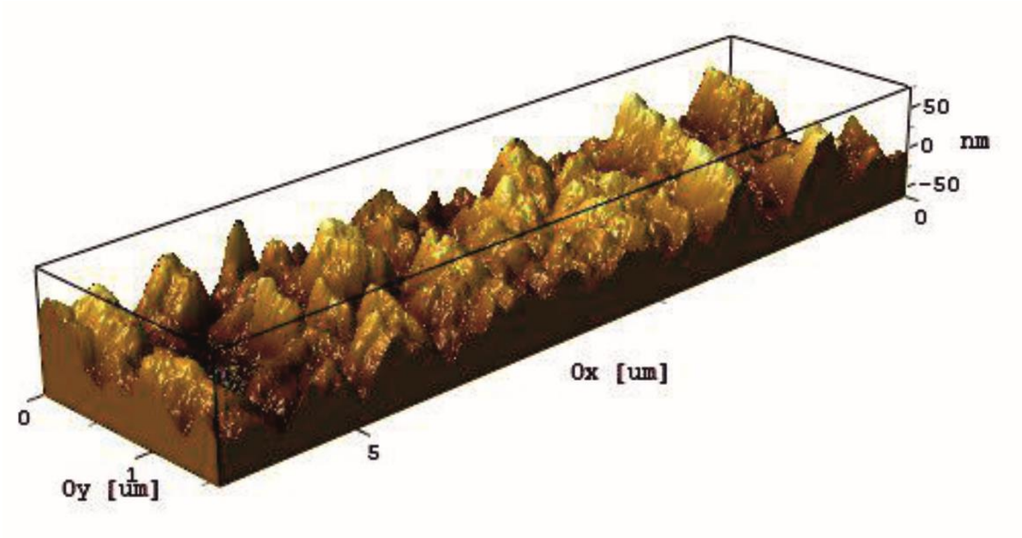


Fig. S2. AFM 3D reconstruction of 10 nm NiO film

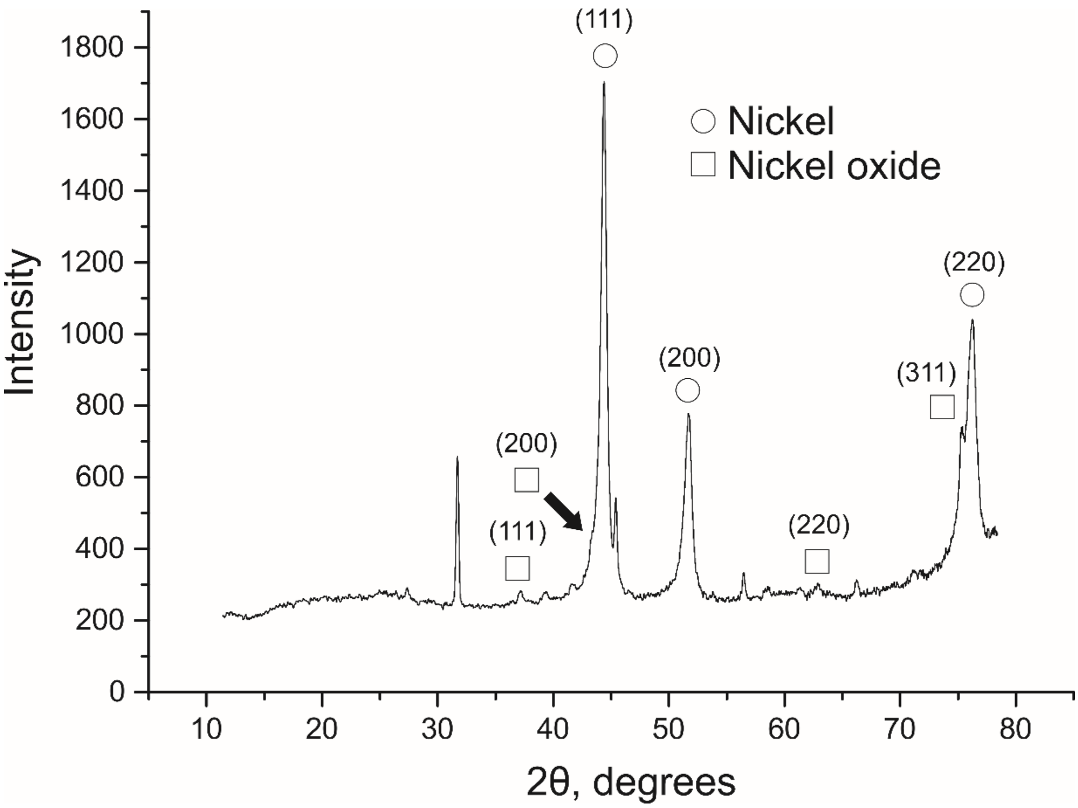


Fig. S3. XRD plot of decomposed TED-NiA film

The presence of the corresponding peaks on the XRD pattern unequivocally indicates the presence of the nickel and the roentgen-amorphous phase of nickel oxide phases[1]. In accordance with the literature, the peak at 32 degrees also refers to the phase of nickel oxide[2].

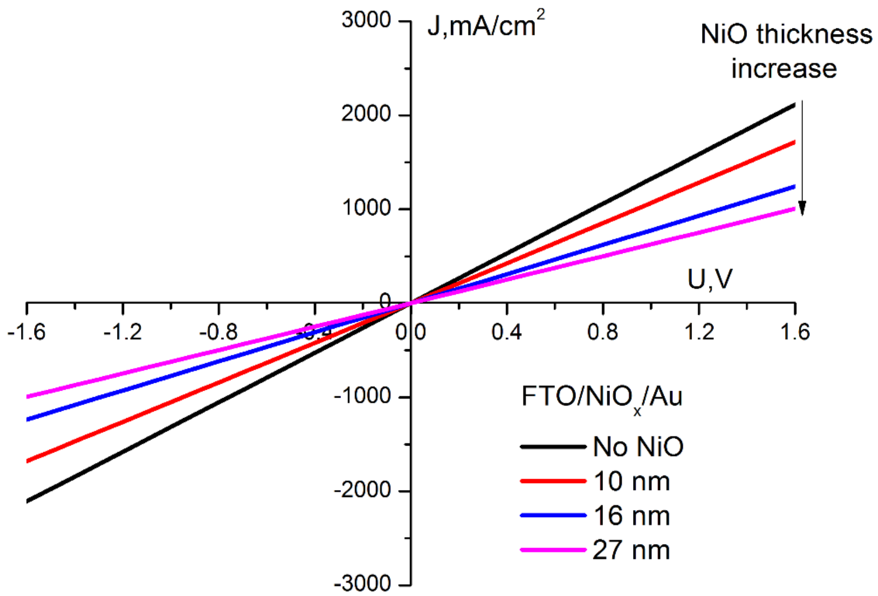


Fig. S4. JV curves of the glass/FTO/NiO/Au structures for several thicknesses of NiO

The resistivity (ρ) was calculated accordingly to equation S1:

$$\rho = \frac{R * S}{l}, \tag{S1}$$

where R-resistance (extracted from diode JV curve), ohm; S-pixel area, cm^2; l -film thickness, cm.

Tab.S1 Calculated resistivity

TED-NiA concentration, M / NiO film thickness, nm	ρ, ohm*cm
2.00 / 27 nm	$3.40*10^5$
1.50 / 16 nm	$3.31*10^5$
1.00 / 10 nm	$1.82*10^5$

Tab.S2 Output JV parameters of FTO/NiOx/CH3NH3PbI3/C60/BCP/Al devices. Each HTL thickness was tested on 12 devices.

TED-NiA concentration,M / NiO film thickness,nm	Value	Uoc, V	Jsc, mA/cm^2	FF	PCE, %	Rs, ohm*cm^2
2.00 / 27 nm	average	0.97	17.76	0.55	9.42	9.94
	best	0.99	18.42	0.64	11.00	8.23
1.50 / 16 nm	average	1.00	18.38	0.58	9.51	9.67
	best	1.02	18.95	0.64	10.92	8.19
1.00 / 10 nm	average	1.02	19.58	0.73	14.82	4.82
	best	1.02	19.68	0.77	15.31	4.61

Reverse and forward scan JV curves presented on fig. S5 (a-c) were measured for best performing HTL thickness 10 nm with 22; 135 and 345 mV/s scan rates to determine an effect of hysteresis.

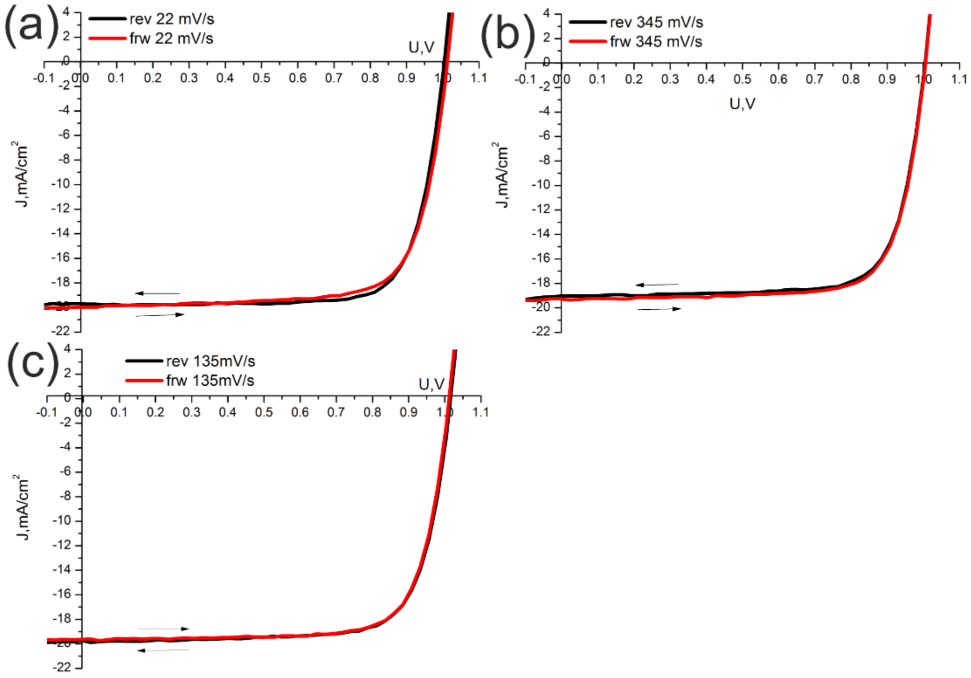


Fig. S5. Reverse and forward scan JV curves for best performing HTL thickness 10 nm with 22 (a); 135 (b) and 345 (c) mV/s

Hysteresis index was calculated accordingly equation S2:

$$H_{Index} = \left| \frac{PCE_{reverse} - PCE_{forward}}{PCE_{reverse}} \right|, \tag{S2}$$

where $PCE_{reverse}$ - efficiency calculated from reverse scan of JV curve, %;

$PCE_{forward}$ - efficiency calculated from forward scan of JV curve, %.

Tab.S3 Hysteresis index for best performing HTL thickness (10 nm)

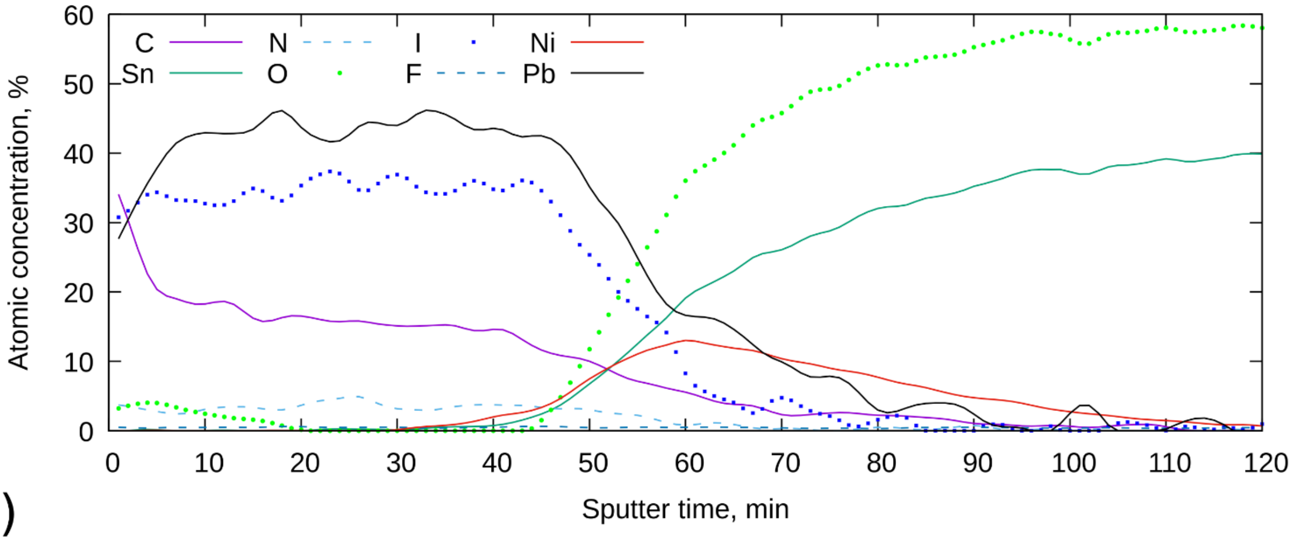
Scan rate, mV/s	H_{index}, a.u.
22	0.015
135	0.006
345	0.011

Tab.S4 Reverse and forward JV output performance for best performing HTL thickness 10 nm with 22; 135 and 345 mV/s scan rate

Scan rate, mV/s	Scan direction	Uoc, V	Jsc, mA/cm^2	FF	PCE, %
22	reverse	1.01	-19.68	077	15.31
	forward	1.02	-19.98	0.74	15.08
135	reverse	1.02	-19.76	0,75	15.12
	forward	1.02	-19.64	0,75	15.02
345	reverse	1.01	-19.04	0.76	14.62
	forward	1.01	-19.26	0.76	14.78

The MAPI/NiO/FTO Auger depth profiles presented on fig. S6 (a,b) for the glass/FTO/NiO/MAPI stack.

(a)



(b)

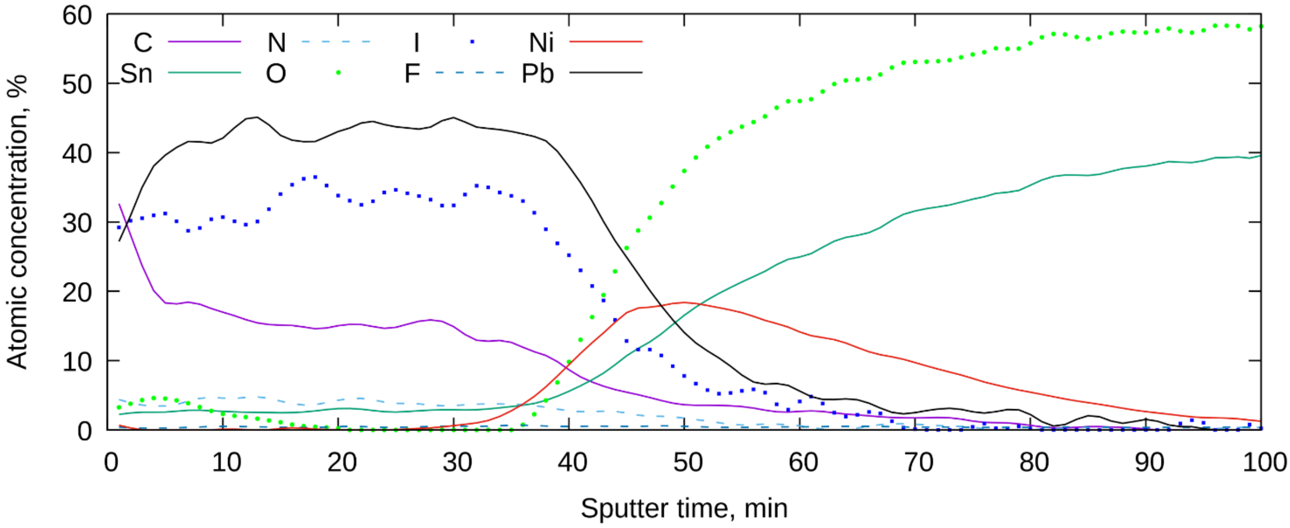


Fig.S6. MAPI/NiO/FTO Auger profiling for 10 nm (a) and 16 nm (b) thick NiO HTL

Shelf life measurement (presented on fig. S7 (a-d)) were provided for 10 nm thick NiO HTL device at standard 1.5 AM G conditions.

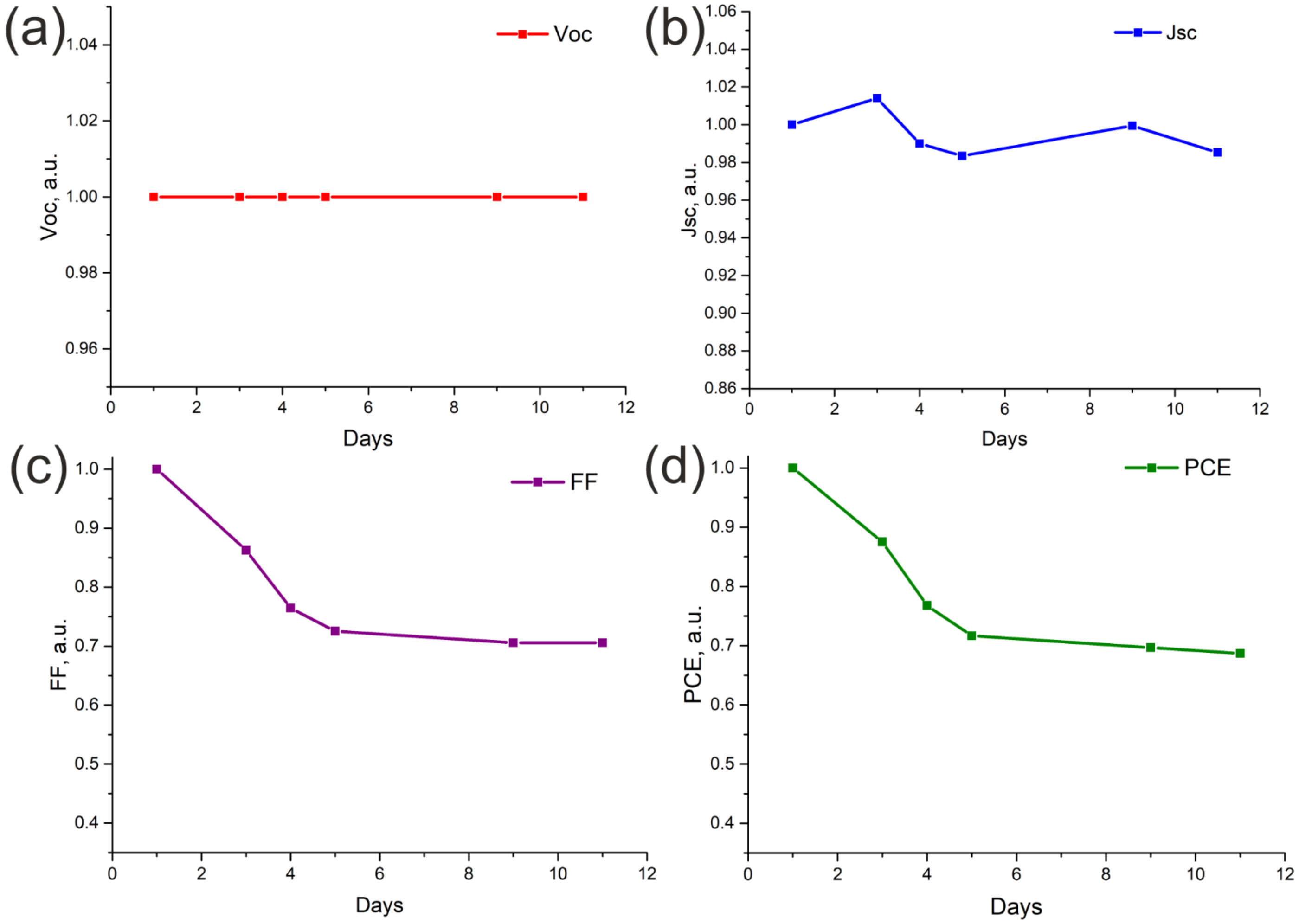


Fig.S7. Shelf life of PSC with 10 nm NiO HTL

References:

[1] J. T. Richardson, R. Scates, M. V Twigg, *Appl. Catal. A Gen.* **2003**, *246*, 137–150.

[2] B. B. Nayak, S. Vitta, A. K. Nigam, D. Bahadur, **n.d.**, DOI 10.1016/j.tsf.2005.10.018.