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Supporting Information

for

Hydrothermally-processed $CuCrO_2$ nanoparticles as inorganic hole transporting material for low-cost perovskite solar cells with superior stability

by

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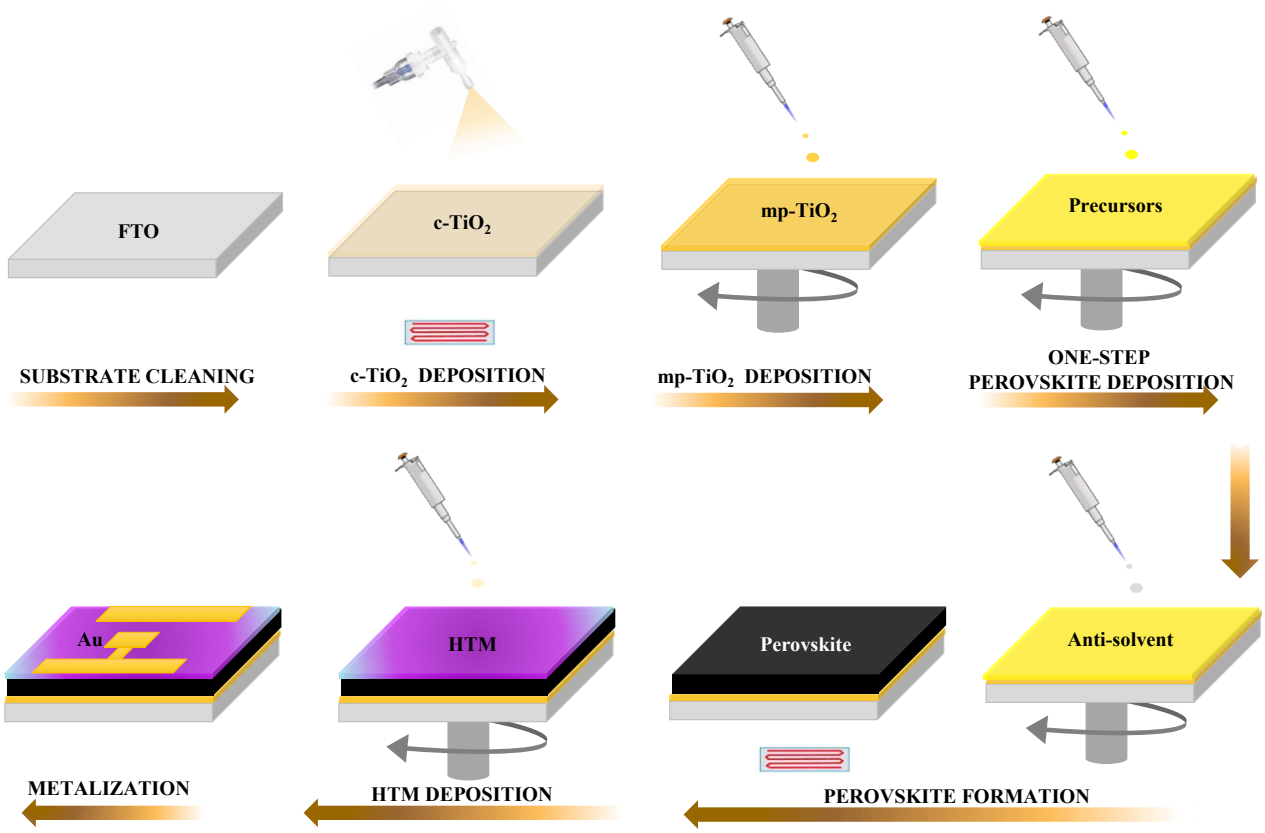

Figure S1. Schematic illustration of PSC formation.

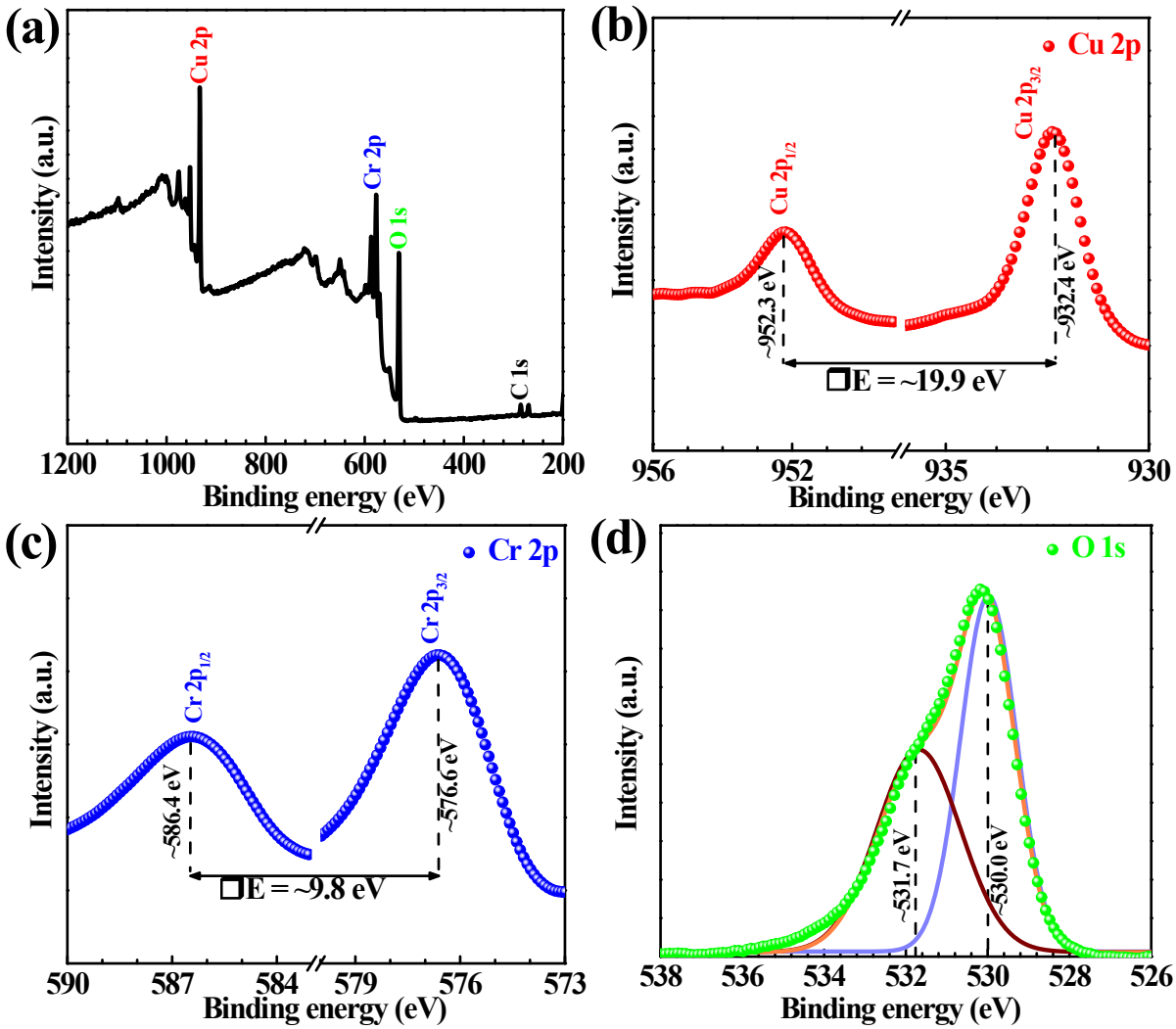

Figure S2. (a) XPS survey spectra of the CCO sample. (b)-(d) High resolution XPS spectra of Cu 2p, Cr 2p and O 1s, respectively.

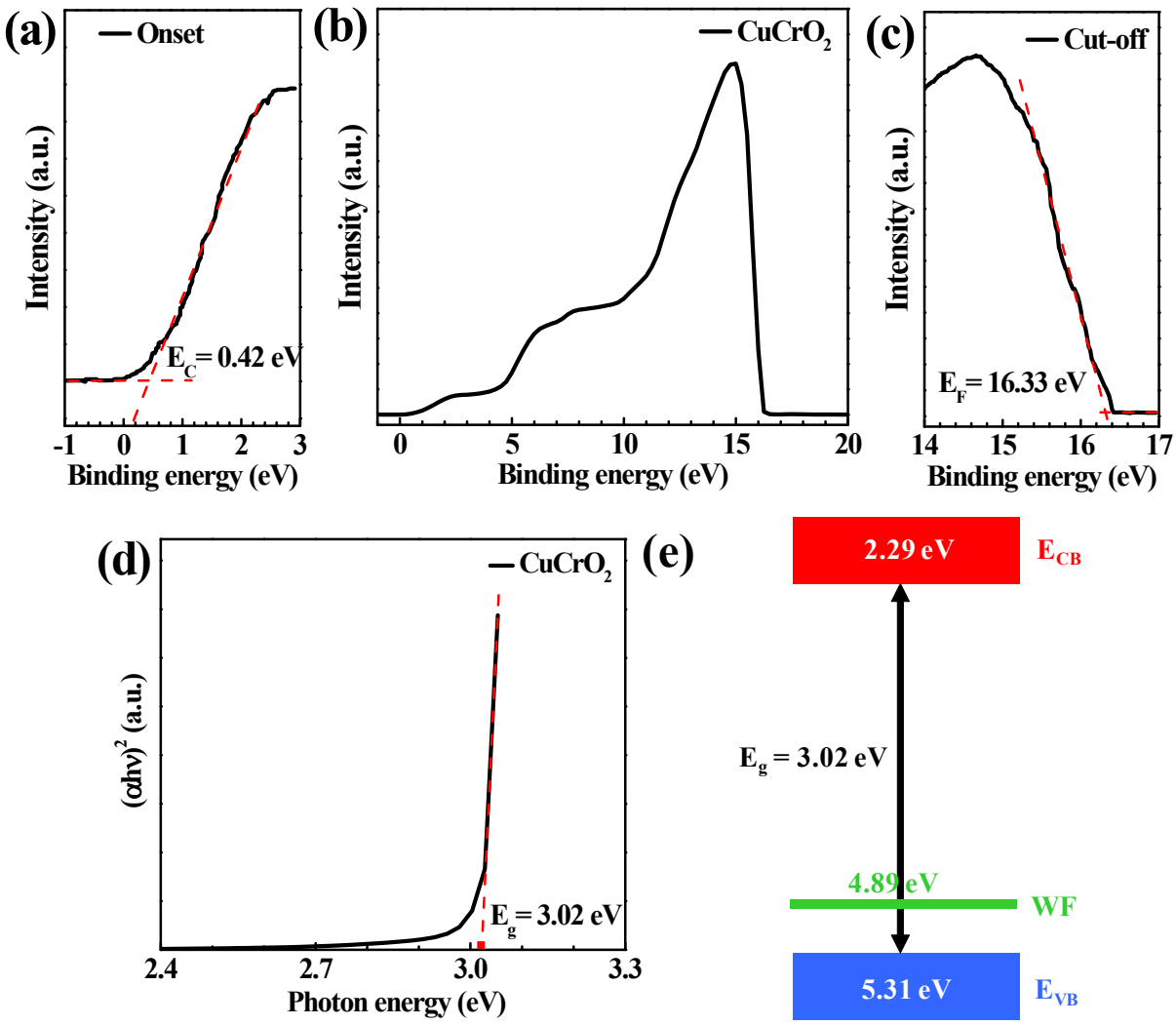

Figure S3. (a) VBM (b) UPS spectrum (c) Secondary electron cut-off of CCO NPs deposited on a substrate by spin-coating. (d) The Tauc plot of CCO NPs. (e) The energy diagram of CCO. The valence band energy (E_{VB}) of the CCO was determined according to the following equation: $E_{VB} = -21.22 + (E_{cut\text{-}off} - E_{onset})$, where E_{onset} is the onset of photoemission in the low binding energy region, $E_{cut\text{-}off}$ is the inelastic cut-off binding energy and 21.22 eV is the energy of the light source (He 1α).

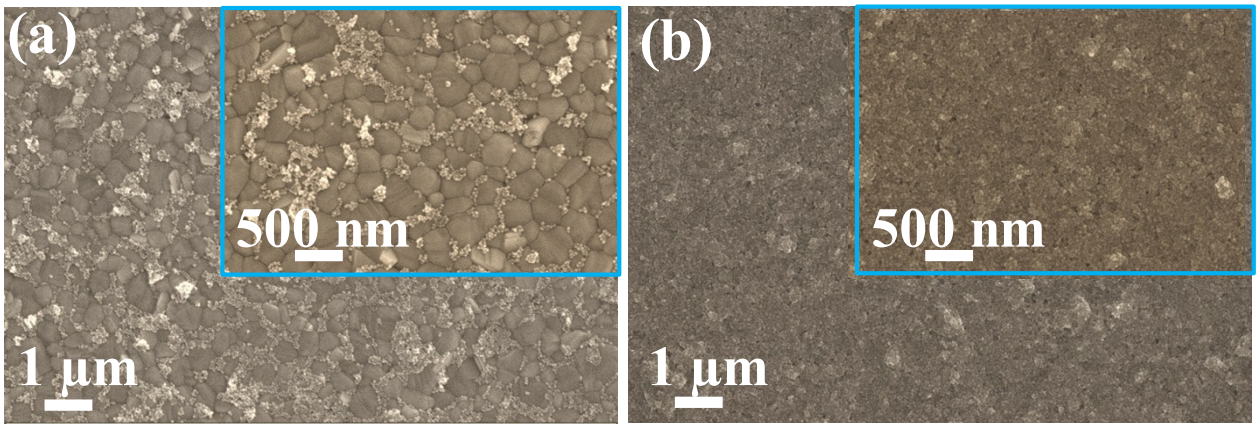

Figure S4. Top-view FE-SEM images of the CCO HTM deposited perovskite films as a function of solution concentration (a) 1 mg/ml and (b) 20 mg/ml.

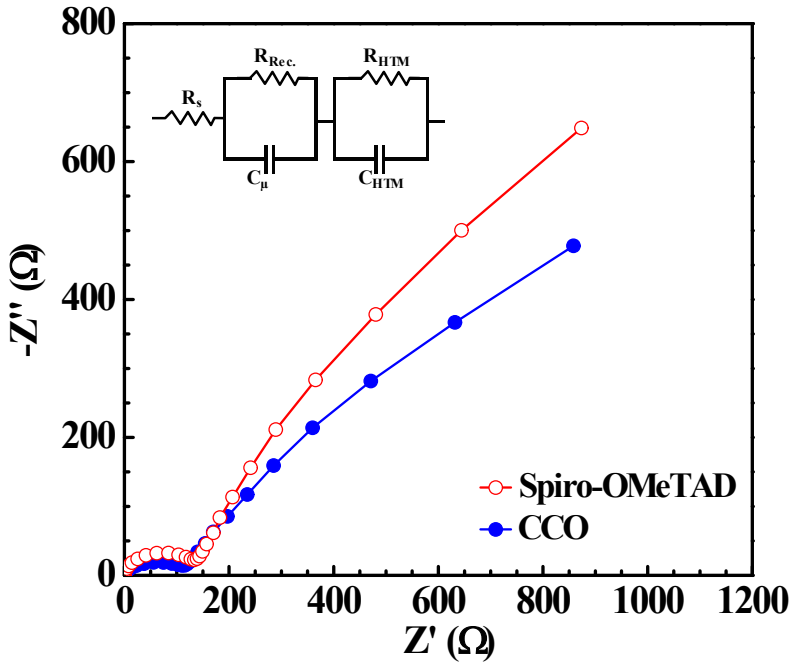

Figure S5. Nyquist plots (V_{app} = 0 mV) of the devices with CCO and Spiro-OMeTAD HTMs. The inset shows the equivalent circuit model employed for analysis.

Table S1. Carrier lifetimes for perovskite and perovskite/HTM samples.

Samples	τ_1 (ns)	τ_2 (ns)	A_1	A_2	τ_{ave} (ns)
Perovskite	3.97	79.07	0.20	0.75	78.08
Perovskite/Spiro-OMeTAD	0.91	31.64	0.74	0.20	28.68
Perovskite/CCO	0.93	20.36	0.78	0.14	16.42

Table S2. The photovoltaic parameters of CCO HTM based PSCs as a function of CCO concentration.

Concentrations (mg/ml)	J_{sc} (mA.cm^{-2})	V_{oc} (V)	FF	PCE (%)
1	19.83	0.883	0.46	8.08
	17.63	0.899	0.41	6.42
	18.99	0.905	0.45	7.75
5	22.22	1.002	0.54	12.04
	21.19	0.995	0.54	11.38
	21.88	1.001	0.58	12.77
10	22.79	1.038	0.69	16.34
	23.02	1.009	0.69	16.05
	23.19	1.028	0.67	15.97
20	20.46	0.999	0.62	12.53
	21.09	1.007	0.67	14.22
	21.10	0.995	0.66	13.91

Table S3. Survey of estimated cost for Spiro-OMeTAD and CCO HTMs. This cost estimation only compares the HTMs without considering other outgoings such as profit, labor cost, energy consumption, etc.

HTMs	Materials	Required Amount[a]	Material Cost (€)[b]	Obtained Amount[c]	Number of Devices[d]	Cost per Device (€)
Spiro-OMeTAD	Spiro-OMeTAD	90 mg	34.15	1 ml	25	1.39
	CB	1 ml	0.24			
	Li-TFSI in ACN	20.6 µl	0.09			
	4-tBp	35.6 µl	0.12			
	TOTAL		34.60 €			
CCO	$Cu(NO_3)_2$	4.75 g	2.41	1.8 g	4500	0.004
	$Cr(NO_3)_3$	8.08 g	8.65			
	NaOH	8 g	0.33			
	DIW	100 ml	0.20			
	HCl	50 ml	1.92			
	Ethanol	50 ml	3.83			
	TOTAL		17.34 €			

a: The used amount for each synthesis.
b: The estimated material cost taken from https://www.sigmaaldrich.com.
c: The obtained amount of product for each synthesis: 1 ml of Spiro-OMeTAD solution and ~1.8 g of CCO powder. Therefore, ~180 ml of CCO solution can be obtained for the best concentration of CCO (10 mg/ml).
d: The amount of solution required to deposit one HTM layer is 40 µl. Therefore, 1 ml / 40 µl = 25 Spiro-OMeTAD and 180 ml / 40 µl = 4500 CCO hole transport layers can be deposited.