Supplementary Information

Anti-Solvent Engineering Enables Efficient Ambient-Processed Halide Perovskite Solar Cells

Ivy M. Asuo[a,b]*, Arezo Mahdavi Varposhti[c], Enrique D. Gomez[a,d], and Nutifafa Y. Doumon[a,b,c]*

[a] *Department of Materials Science and Engineering, The Pennsylvania State University, University Park, PA 16802*

[b] *Alliance for Education, Science, Engineering, and Design with Africa, The Pennsylvania State University, University Park, PA, 16802 USA*

[c] *Department of Engineering Science and Mechanics, The Pennsylvania State University, University Park, PA, 16802 USA*

[d] *Department of Chemical Engineering, The Pennsylvania State University, University Park, PA 16802*

*Corresponding authors: *ipa5154@psu.edu*; *nzd5349@psu.edu*

Table S1: Charge carrier lifetime calculated from bi-exponential fitting of the TRPL measured data for the perovskite thin films.

Sample Code	**τ_1 (ns)**	**τ_2 (ns)**
EtOH	3.76	34.98
CB	11.54	80.06
DCB	7.83	110.04

Table S2: Concentration in atom% determined from XPS measurement for the various samples

		Carbon Species										
Sample	**C^{total}**	**CH_x**	**C-O**	**$C-N_2$**	**COO**	**Cl**	**Cs**	**I**	**N**	**O**	**Pb^{4+}**	**Pb°**
Ethanol	11.3	7.4	1.2	2.1	0.6	4.1	1.1	50.9	2.9	3.4	23.8	2.5
Chlorobenzene	14.2	10.5	1.3	2.1	0.3	4.5	1.5	49.0	4.0	2.2	22.5	2.0
Dichloro-benzene	14.7	9.3	2.1	2.3	1.0	6.0	1.5	43.6	4.6	5.0	23.0	1.5

(ITO/SnO_2/KCl/ perovskite film (treated with EtOH, CB, and DCB).

Table S3: Absolute values of the energy levels determined from UPS measurements.

Sample	**VBM (eV)**	**WF (eV)**	**E_g (eV)**	**E_{CB} (eV)**	**E_{VB} (eV)**	**IP**
Ethanol (EtOH)	1.71	4.82	1.55	3.26	6.53	6.49
Chlorobenzene (CB)	1.91	4.56	1.55	3.46	6.47	6.46
Dichlorobenzene (DCB)	1.83	4.59	1.54	3.37	6.42	6.39

The table indicates the values for the work function (WF), ionization potential (IP) and valence band maximum (VBM) of treated perovskite films measured by UPS versus vacuum. The bandgap is determined from UV-Vis absorbance measurement. The energy at conduction band E_{CB} is calculated from the equation ($E_{CB} = E_g + VBM$). Also, the energy at the valence band is calculated from the equation $E_{VB} = -WF-VBM$. (eg for EtOH, E_{VB} = -4.82 eV -1.71 eV = -6.53 eV).

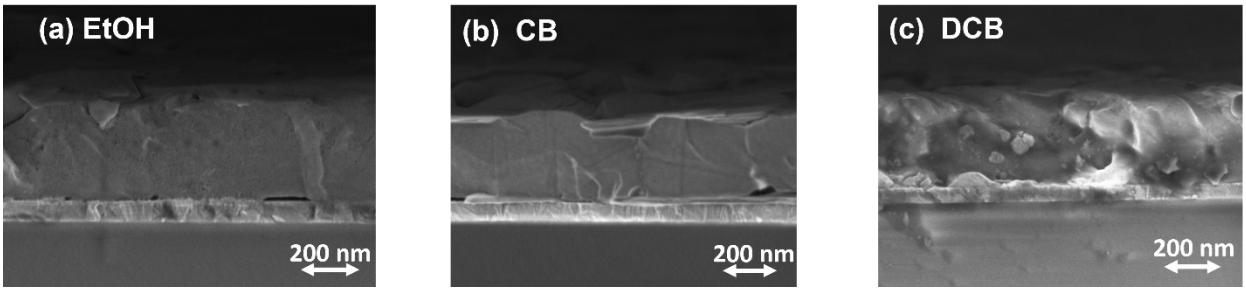

Figure S1: Cross-section SEM images of the PHJ (PSCs) devices with ITO/SnO_2/KCl/ perovskite film treated with a) EtOH, b) CB, and c) DCB.

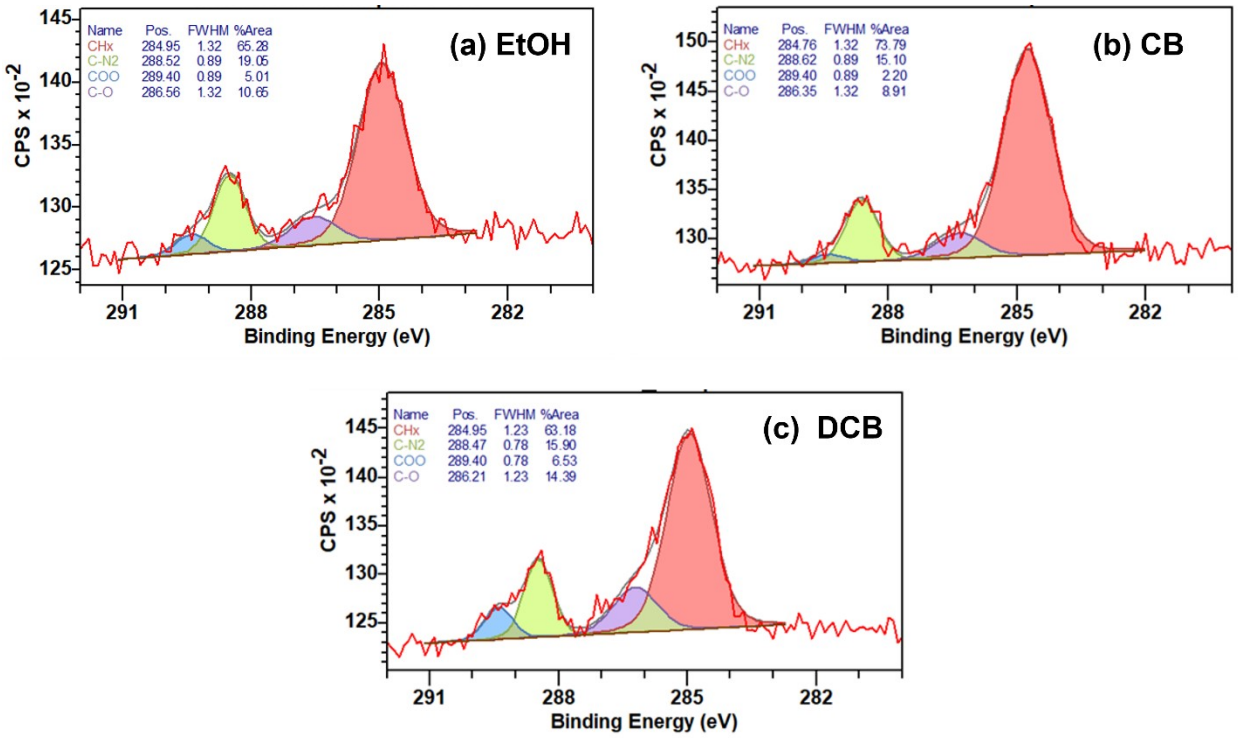

Figure S2: The XPS spectra of the samples attributed to the C 1s6 core level of perovskite film treated with a) EtOH, b) CB, and c) DCB.

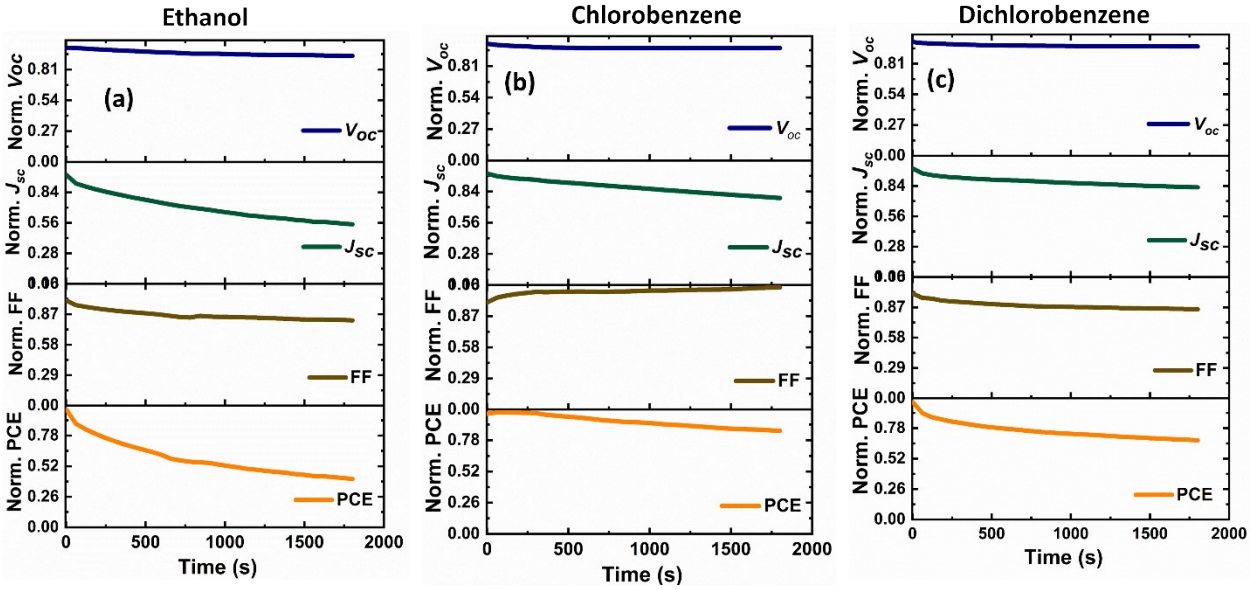

Figure S3: Short-term stability of the PHJ (PSCs) for a) EtOH, b) CB, and c) DCB, under continuous 1 sun white LED illumination in ambient conditions (RH≈20%, Temperature: 21° C) for 30 minutes.