Supplementary information

Cost-effective perovskite solar cells with a high efficiency and open-circuit voltage based on the perovskite -friendly carbon electrode

Qian-Qian Chu,† Bin Ding, † Qi Qiu,‡ Yan Liu, † Cheng-Xin Li,† Chang-Jiu Li,†

Guan-Jun Yang,† and Baizeng Fang*,§*

*† State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, 710049, P. R. China. *E-mail: ygj@ mail.xjtu.edu.cn (G.-J. Yang)*
‡College of Chemistry and Environmental Engineering, Shenzhen University, Shenzhen, Guangdong, 518060, P. R. China.
§Department of Chemical & Biological Engineering, University of British Columbia, 2360 East Mall, Vancouver, B.C. V6T 1Z3, Canada. E-mail: bfang@chbe.ubc.ca (B. Fang).

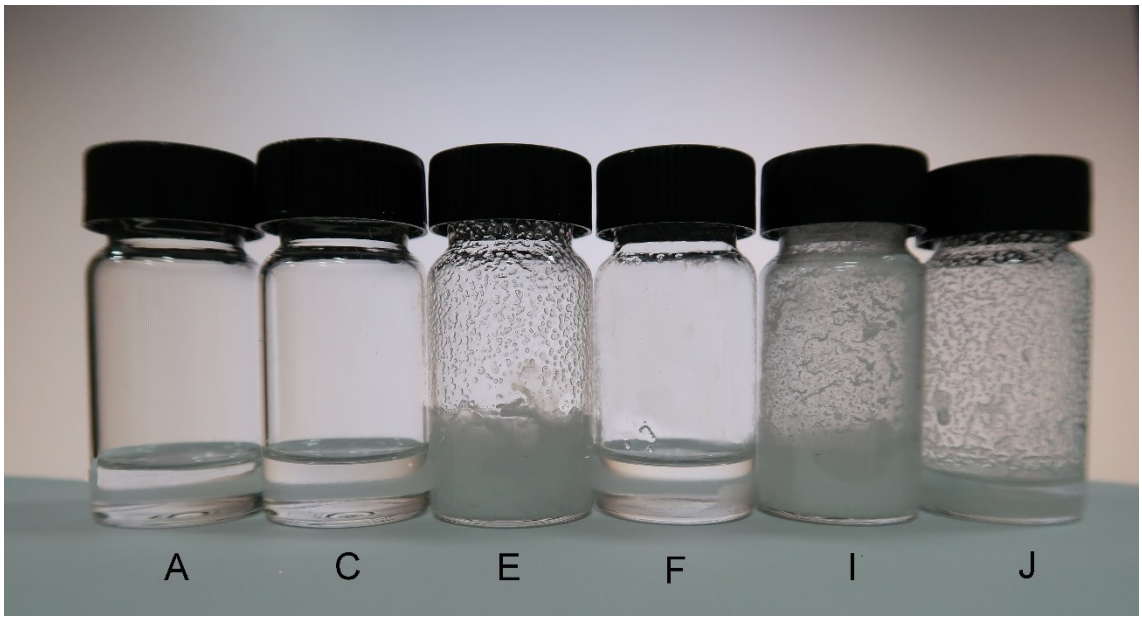

Figure S1. The dissolution of the binder (polyacrylic resin) in different solvents: A) PGMEA; C) EBAC; E) isopropanol; F) terpineol; I) cyclohexane and J: hexane.

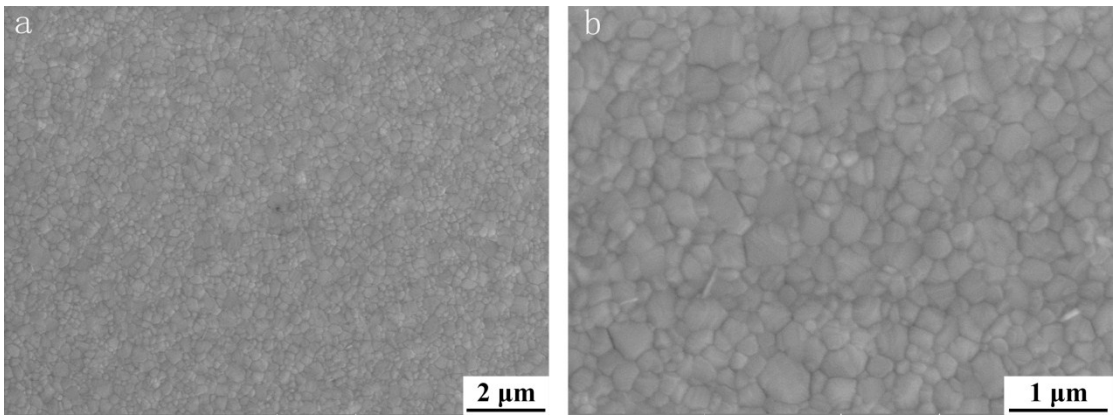

Figure S2. SEM images for a representative perovskite film on FTO/c-TiO_2/m-TiO_2 substrate.

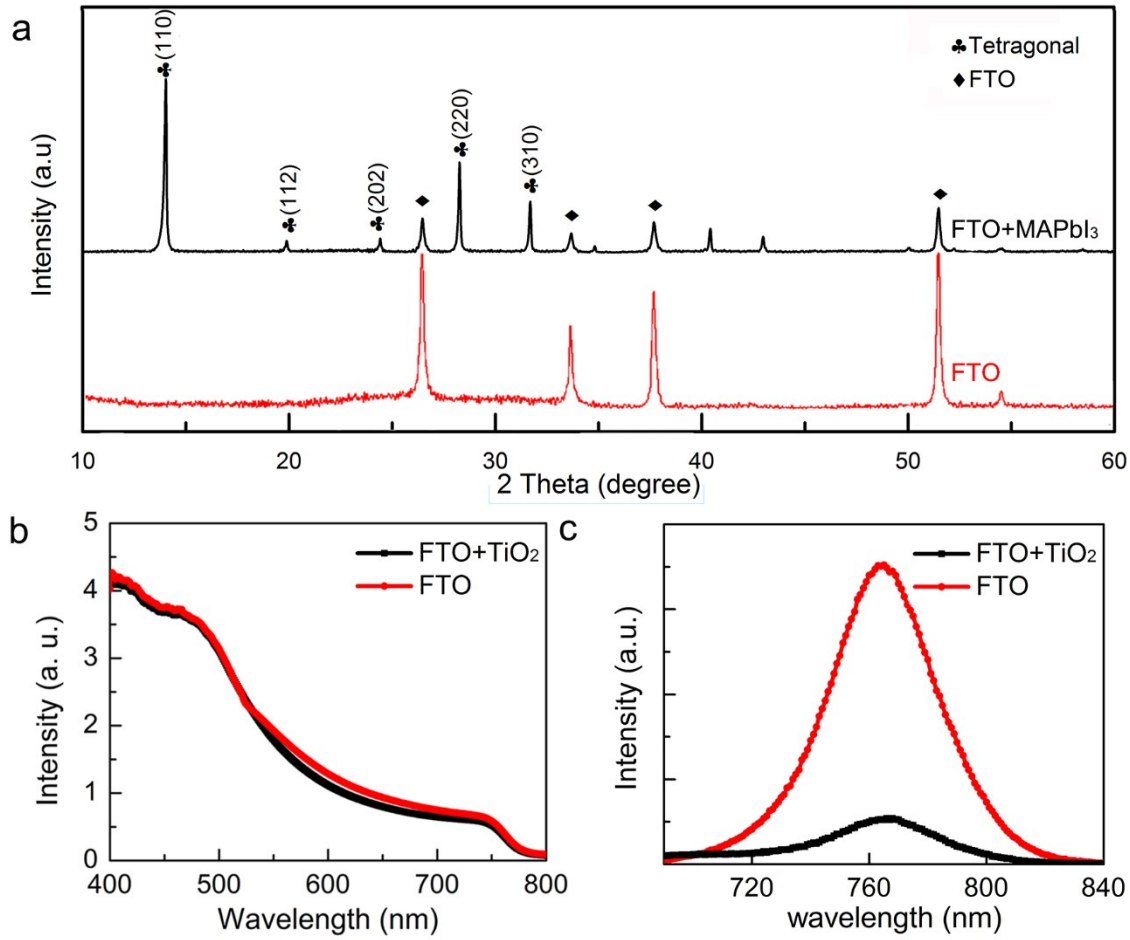

Figure S3. a) Representative XRD patterns of the perovskite film. b) UV-vis absorption spectra and c) the PL emission spectra of the perovskite film on the FTO and FTO/TiO_2 substrates.

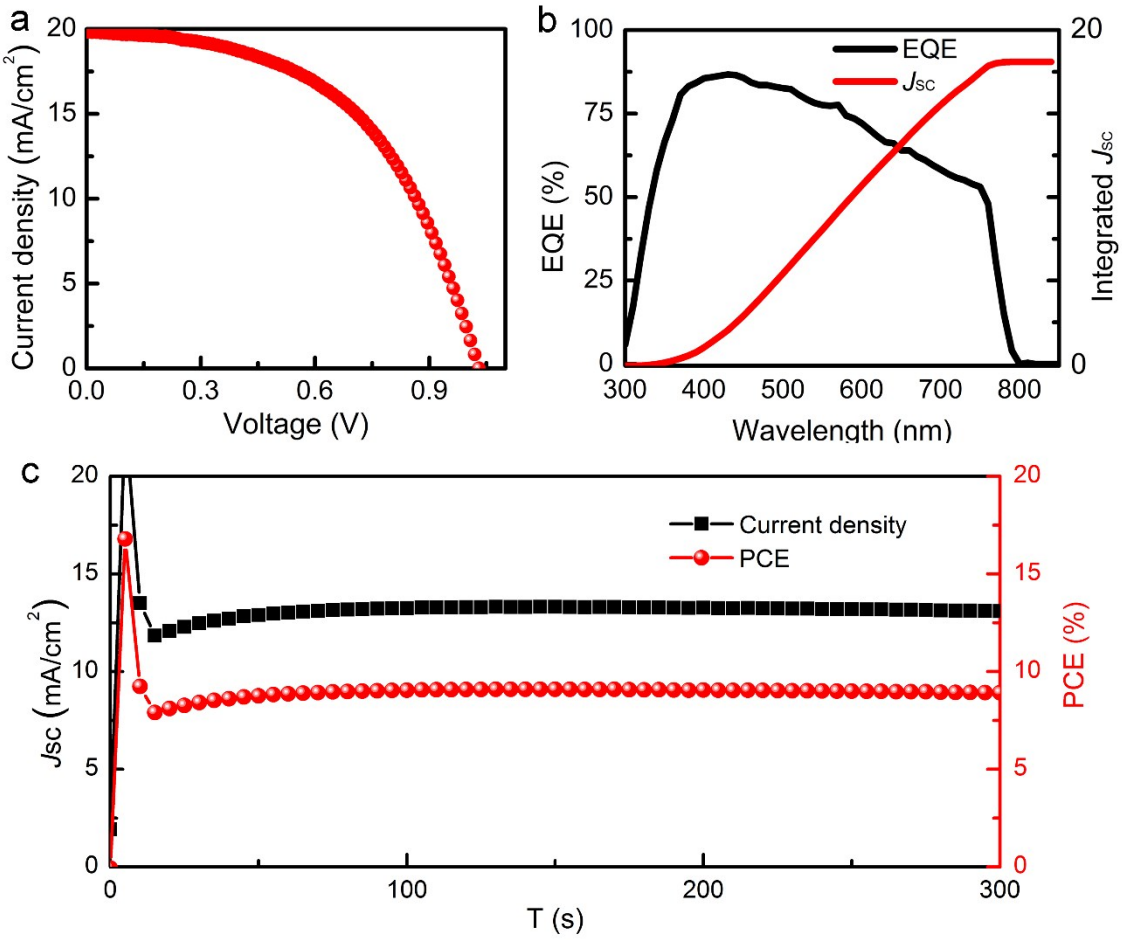

Figure S4. a) *J-V* curve, b) the corresponding EQE and c) the corresponding steady-state output conversion efficiency data at the maximum power point of the carbon based PSC with PGMEA as the solvents of carbon paste.

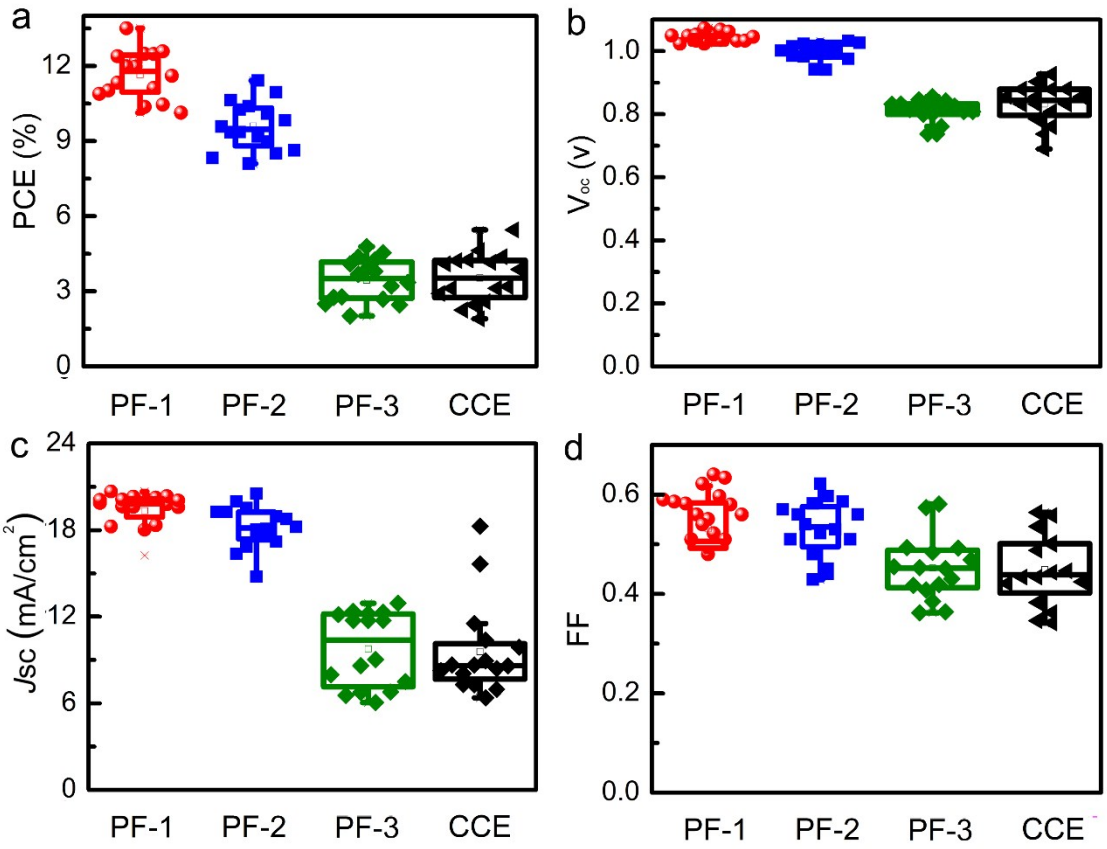

Figure S5. a) The PCE, b) the open circuit voltage (V_{oc}), c) the short circuit current density (J_{sc}) and d) fill factor (FF) of the as-constructed 16 carbon based perovskite solar cells with the four kinds of carbon electrodes.

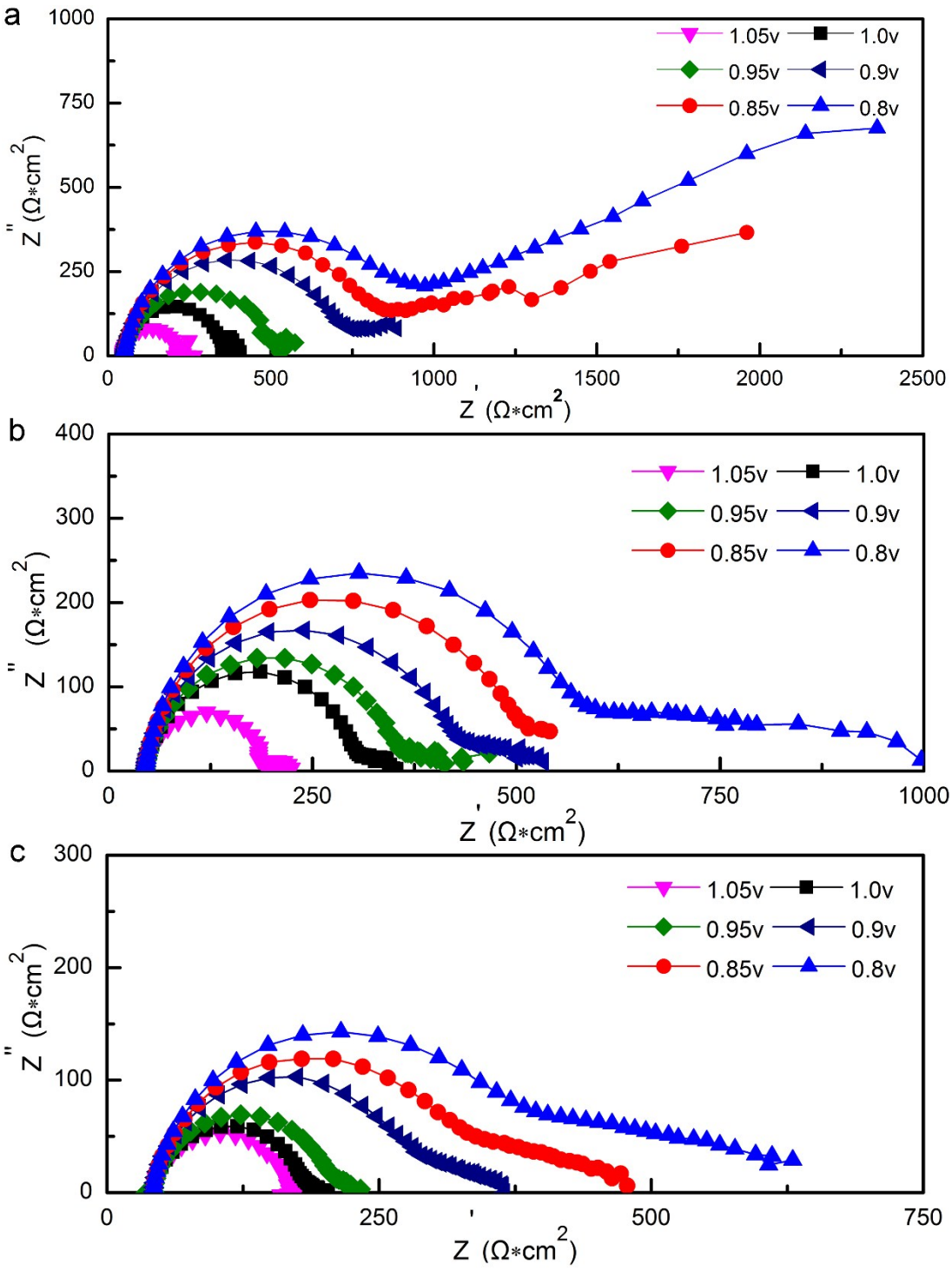

Figure S6 Nyquist plots at various bias voltages for the device based a) PF-2, b) PF-3, c) CCE

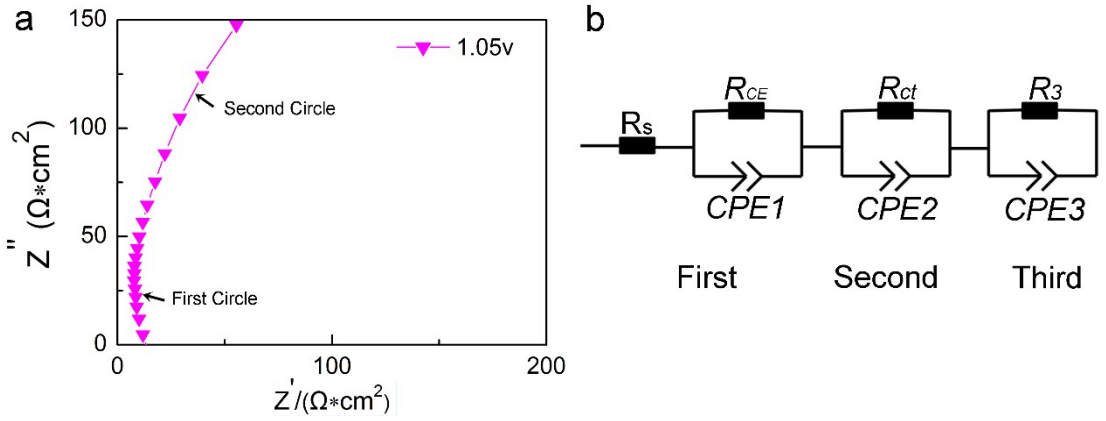

Figure S7 a) Nyquist plots of PF-1 in high frequency, b) the corresponding equivalent circuits of the Nyquist plots of the PSCs.

Table S1. Solar cell parameters of the four as-fabricated carbon-based perovskite solar cells.

Cell	Scan	PCE (%)	V_{oc} (v)	J_{sc} (mA/cm^2)	*FF*
PF-1	Reverse scan	13.5	1.05	20.25	0.63
	Forward scan	12.5	1.01	20.01	0.62
PF-2	Reverse scan	11.2	1.02	19.90	0.55
	Forward scan	10.0	1.03	18.69	0.52
PF-3	Reverse scan	4.77	0.73	18.20	0.36
	Forward scan	2.37	0.59	13.03	0.31
CCE	Reverse scan	5.26	0.93	11.73	0.48
	Forward scan	3.04	0.86	10.46	0.34