

Direct Observation of Cation-Exchange in Liquid-to-Solid Phase Transformation in $\text{FA}_{1-x}\text{MA}_x\text{PbI}_3$ Based Perovskite Solar Cells

Yue-Min Xie,^{a, b} Binbin Yu,^{a, b} Chunqing Ma,^c Xiuwen Xu,^{a, b} Yuanhang Cheng,^{a, b} Shuai Yuan,^d
Zhao-Kui Wang,^d Hrisheekesh Thachoth Chandran,^{a, b} Chun-Sing Lee,^c Liang-Sheng Liao,^d and
Sai-Wing Tsang^{*a, b}

^a Department of Materials Science and Engineering, City University of Hong Kong, Hong Kong SAR, P. R. China

^b City University of Hong Kong Shenzhen Research Institute, Shenzhen, P. R. China

E-mail: saitsang@cityu.edu.hk

^c Center of Super-Diamond and Advanced Films (COSDAF), City University of Hong Kong, Hong Kong SAR, P. R. China

^d Jiangsu Key Laboratory for Carbon-based Functional Materials & Devices, Institute of Functional Nano & Soft Materials (FUNSOM), Soochow University, Suzhou, Jiangsu, China.

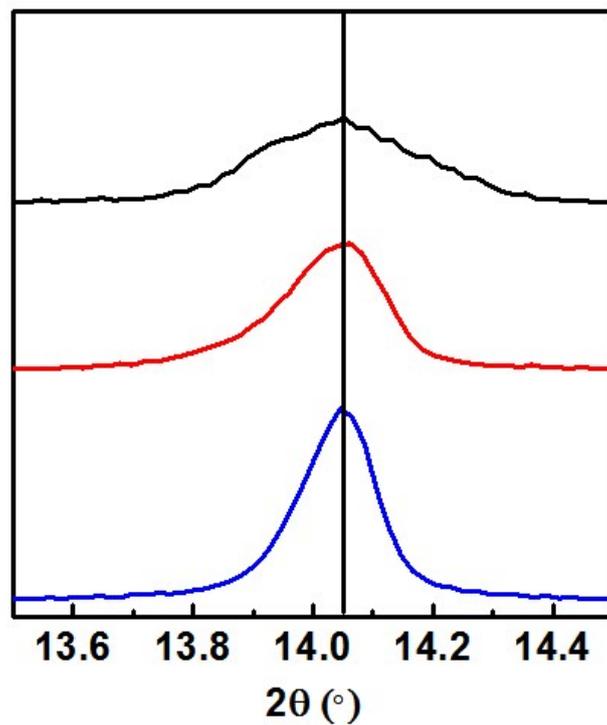


Figure S1. Detailed view of main XRD peak of MOCPs prepared with NSPS FA_{0.85}MA_{0.3}PbI₃ without thermal annealing (stand still for 5 min after spin-coating) and annealed at 130 °C for 2 or 10 min respectively.

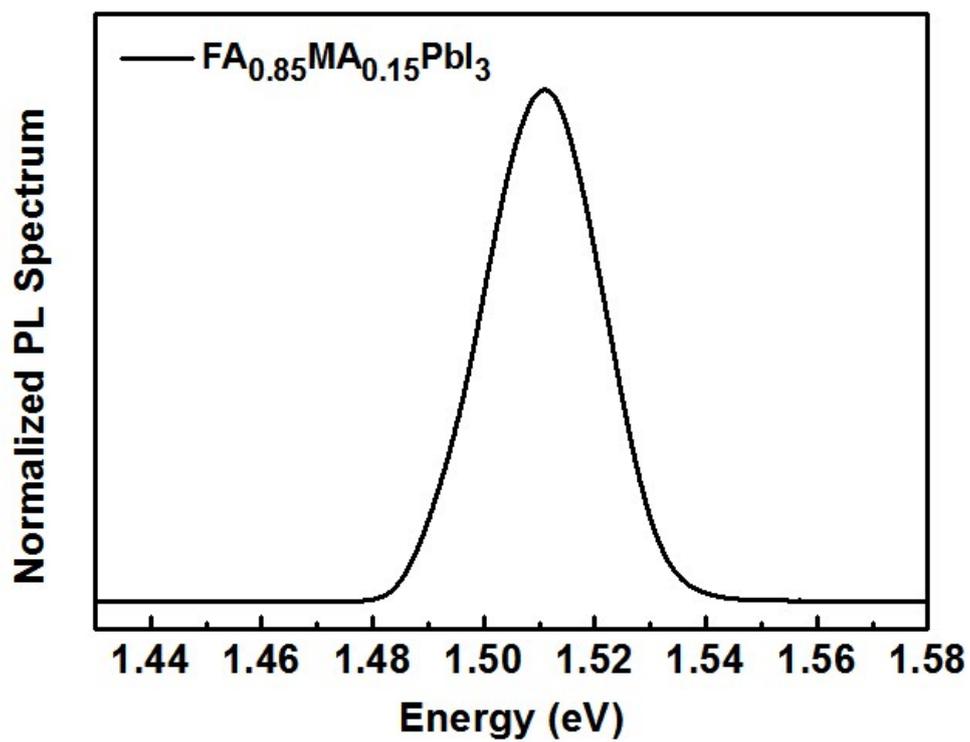


Figure S2. Steady state photoluminescence spectrum of pure $\text{FA}_{0.85}\text{MA}_{0.15}\text{PbI}_3$.

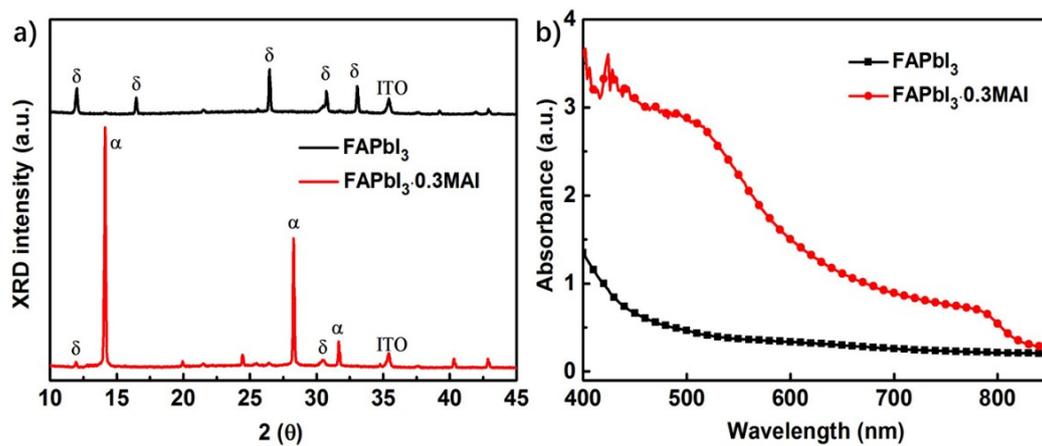


Figure S3. a) XRD patterns of perovskite films prepared with precursor solution FAPbI₃ and FAPbI₃·0.3MAI annealed at 130 °C for 10 min, b) UV-Vis results of films corresponding to Figure S3a.

Table S1 Device performance of PVSCs fabricated with NSPS $\text{FA}_{0.85}\text{MA}_{0.3}\text{PbI}_3$ adopting different annealing time.

Annealing time (min)	V_{oc} [V]	J_{sc} [mA/cm²]	FF [%]	PCE
3	0.95	12.9	55	6.7
5	0.96	16.4	65	10.2
8	0.96	21.6	72	14.9
10	0.96	21.1	73	14.8

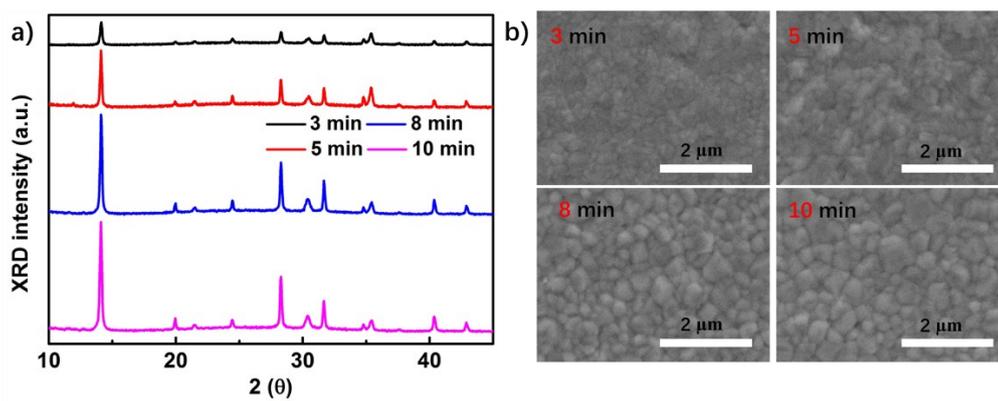


Figure S4. a) XRD patterns of MOCs prepared with NSPS FA_{0.85}MA_{0.3}PbI₃ annealed at 130 °C for 3, 5, 8 and 10 min, respectively. b) SEM results of MOCs corresponding to Figure S4a.

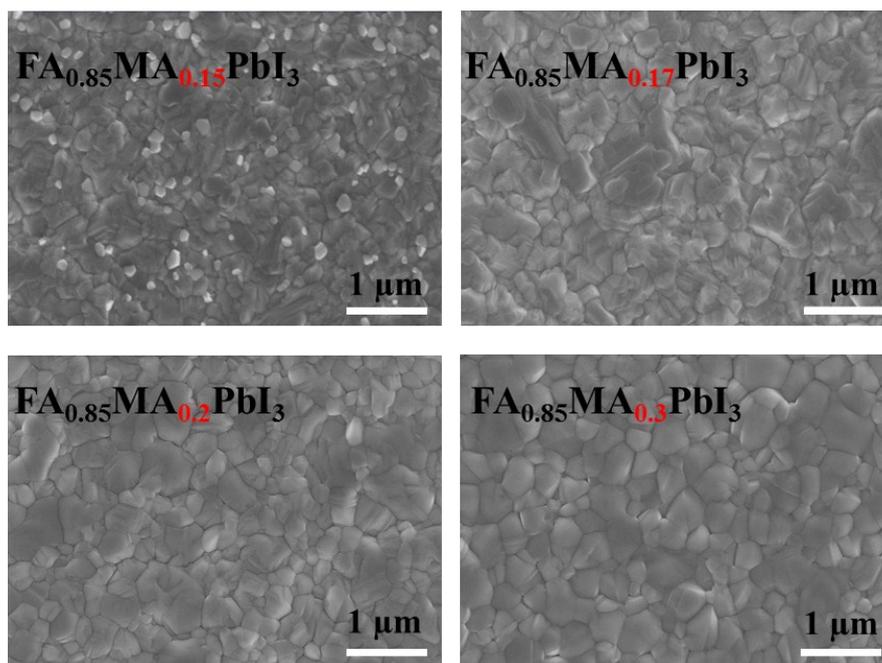


Figure S5. Top view SEM images of MOCPs prepared with precursor solution of $\text{FA}_{0.85}\text{MA}_{0.15}\text{PbI}_3$, $\text{FA}_{0.85}\text{MA}_{0.17}\text{PbI}_3$, $\text{FA}_{0.85}\text{MA}_{0.2}\text{PbI}_3$, $\text{FA}_{0.85}\text{MA}_{0.3}\text{PbI}_3$, respectively, the scale bar is 1 μm .

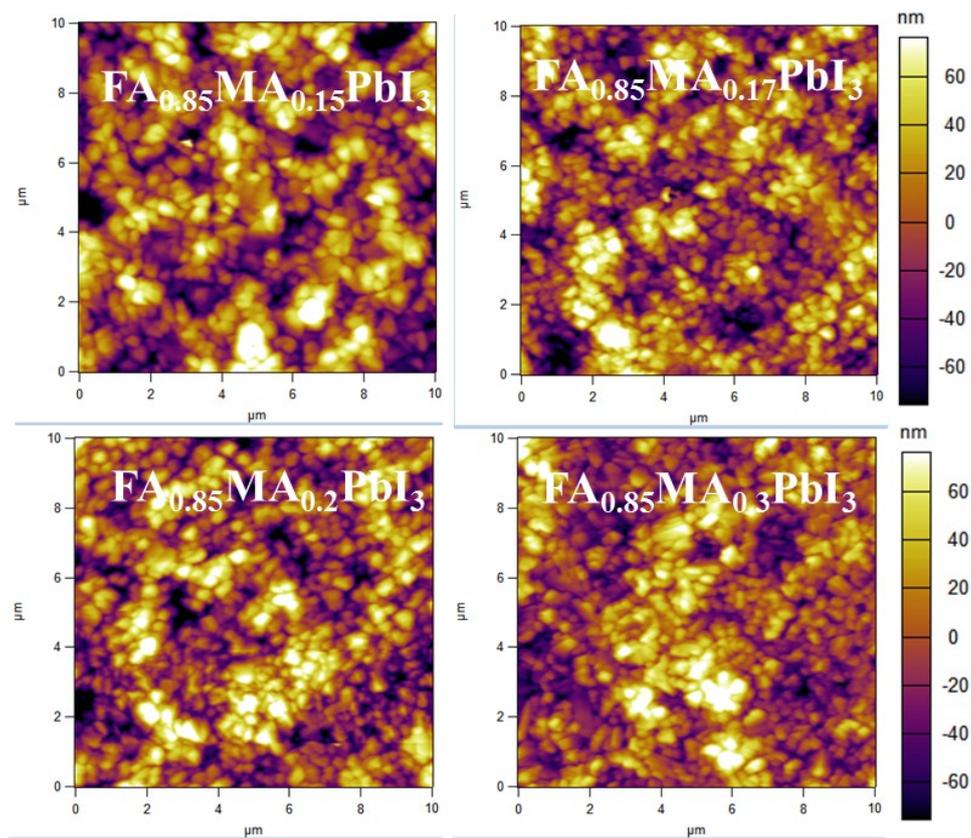


Figure S6. AFM images of MOCPs derived from $\text{FA}_{0.85}\text{MA}_x\text{PbI}_3$ precursor solutions, x ranges from 0.15 to 0.3, the roughness (root mean square (RMS)) is decreased from 39.9 nm (MOCP prepared with SPS $\text{FA}_{0.85}\text{MA}_{0.15}\text{PbI}_3$) to 31.7 nm (MOCP prepared with NSPS $\text{FA}_{0.85}\text{MA}_{0.3}\text{PbI}_3$).