Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A
This journal is © The Royal Society of Chemistry 2015

Electronic Supplementary Information for "Screening effect on photovoltaic performance in ferroelectric $CH_3NH_3PbI_3$ perovskite thin films"

Daehee Seol[a,#], Gill Sang Han,[a,#], Changdeuck Bae,[b,c] Hyunjung Shin,[b] Hyun Suk Jung,[a,*] and Yunseok Kim, [a,*]

[a] *School of Advanced Materials and Engineering, Sungkyunkwan University (SKKU), Suwon 440-746, Republic of Korea*

[b] *Department of Energy Science, Sungkyunkwan University (SKKU), Suwon 440-746, Republic of Korea*

[c] *Integrated Energy Center for Fostering Global Creative Researcher (BK 21 plus), Sungkyunkwan University (SKKU), Suwon 440-746, Republic of Korea*

[#] D. S. and G. S. H. contributed equally to this work.

[*] Address correspondence to hsjung1@skku.edu and yunseokkim@skku.edu

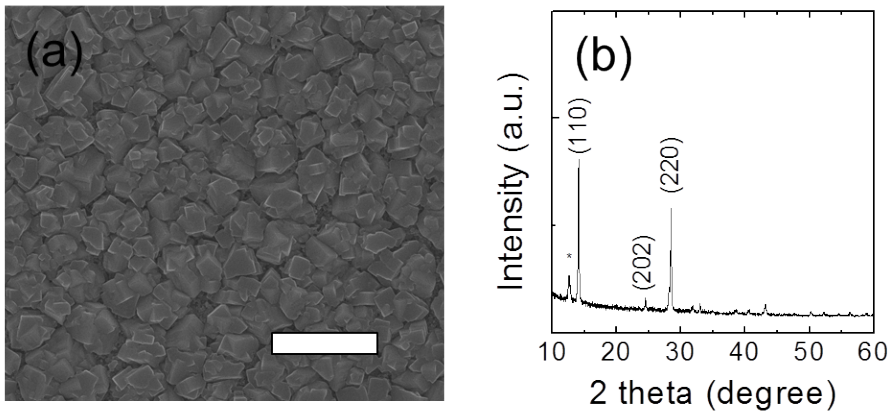

Fig. S1. (a) Field-emission scanning electron microscopy (FE-SEM) image and (b) X-ray diffraction pattern of the $CH_3NH_3PbI_3$ perovskite on TiO_2 compact layer/ FTO substrates. Scale bar is 2 μm.

FE-ESM image shows the MALI PTFs deposited on TiO_2 compact layer/ FTO substrates (Fig. S1a). An average size of the perovskite crystal is about 400 nm. The crystal size of perovskite can be controlled by CH_3NH_3I concentrations in IPA solution. Fig. S1b shows the XRD patterns of the $CH_3NH_3PbI_3$ on TiO_2/FTO glass which is consistent with reported tetragonal $CH_3NH_3PbI_3$ perovskite structure. Each relative intensity of (110) and (220) is obviously higher compared to the other peaks, indicating a highly crystalline perovskite.

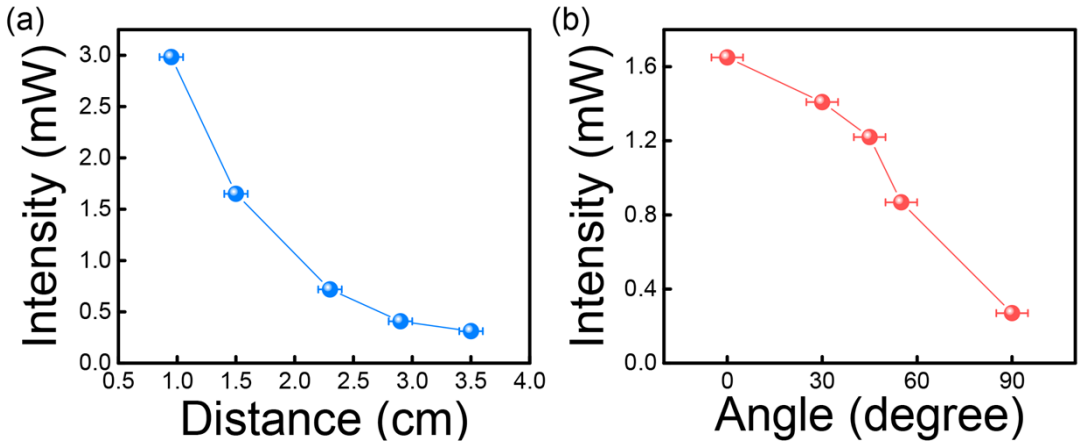

Fig. S2. Power of red light as a function of (a) distance and (b) angle. To measure angle dependence, the distance was fixed as 1.5 cm.

Power of red light (wavelength: 650 nm) was measured as a function of distance and angle. In our measurement, red light was illuminated at 1.5 cm and 45 degree from the top side of the sample.

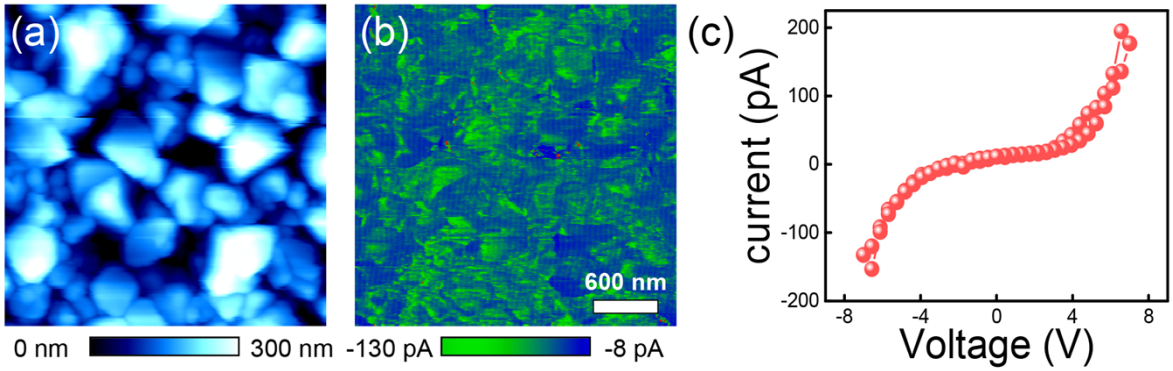

Fig. S3. (a) Topography and corresponding (b) CAFM images. CAFM image was acquired under the -5 V_{dc}. (c) Averaged I-V curve from100 measurements. Scale bar is 600 nm.

In order to investigate conductivity of the MALI PTFs, current AFM (CAFM) and I-V measurements were carried out. In the measurements, dc voltage was applied to the conductive AFM tip. The obtained results in Figs. S3b and S3c show pA level of current flow. This indicates that the resistance of the MALI PTFs in our study is not significantly different from conventional oxide ferroelectrics.

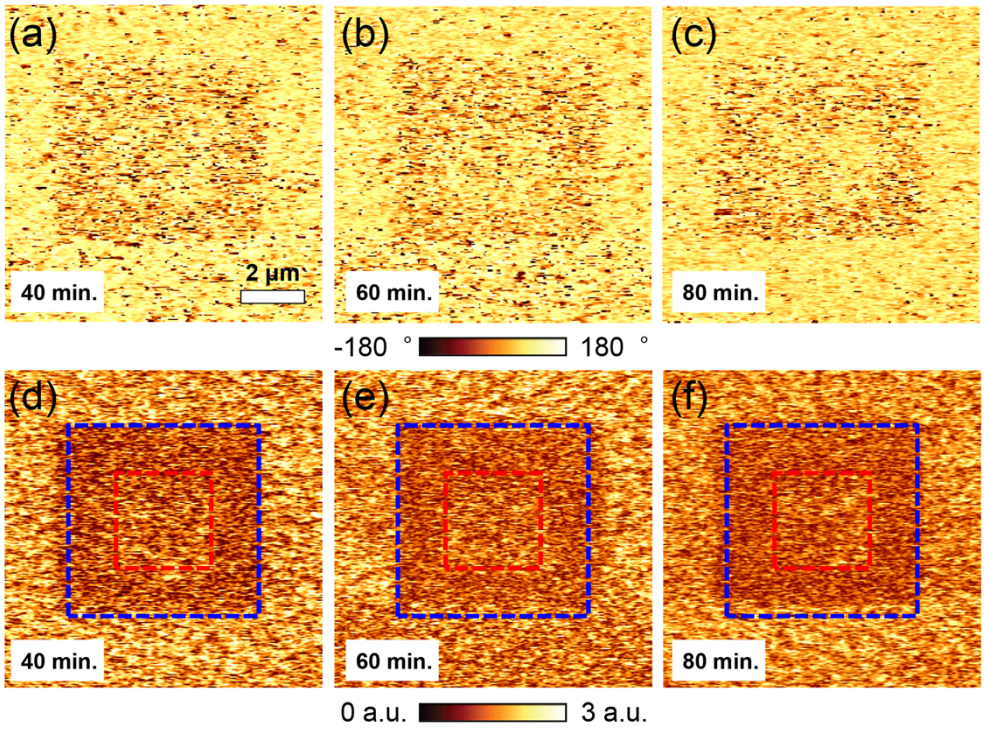

Fig. S4. PFM (a-c) phase and (d-f) amplitude images: (a, d) 40 min, (b, e) 60 min and (c, f) 80 min after poling procedure. Red and blue dotted areas were poled by the applied voltages of -7 V_{dc} and 7 V_{dc}, respectively. Scale bar is 2 μm.

After negative and positive poling procedure, the PFM measurements were sequentially performed over an area of 10 × 10 μm^2. The obtained PFM results in Fig. S4 show that poled states of the MALI PTFs are retained above 1 hour. This indicates that the poled states are intact during the subsequent measurements.

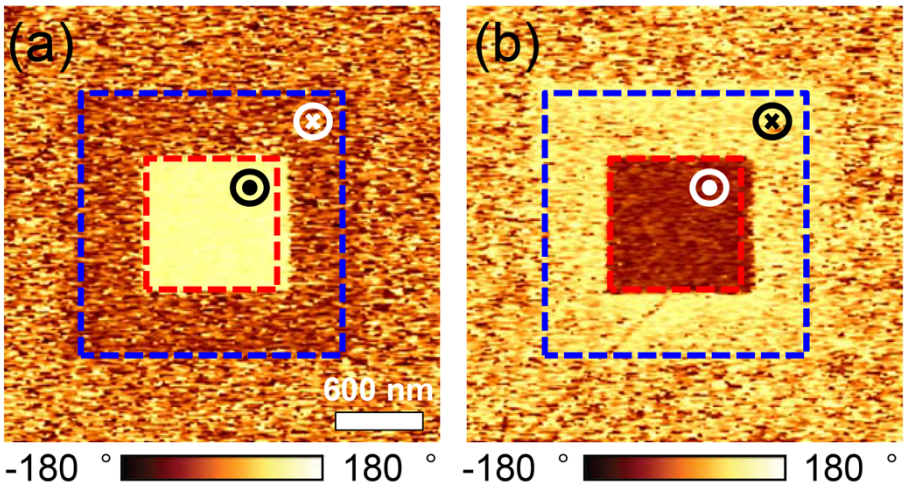

Fig. S5 PFM phase images after poling processes in (a) P(VDF-TrFE) and (b) $Pb(Zr,Ti)O_3$ thin films. Blue and red dotted areas represent poled areas by application of 7 and -7 V_{dc}, respectively. Scale bar is 600 nm.

In order to confirm the sign of piezoelectric coefficient of MALI PTFs, P(VDF-TrFE) and $Pb(Zr,Ti)O_3$ thin films are used as reference samples. Under the positive bias (blue dotted area), polarizations are switched as downward. In contrast, in a case of negative bias (red dotted area), upward polarization is induced. As clearly seen in Fig. S3a and b, PFM phase images of the P(VDF-TrFE) and $Pb(Zr,Ti)O_3$ thin films are exactly opposite to each other and the poling results of the MALI PTFs show the same tendency with those of the P(VDF-TrFE) thin films. It indicates that the MALI PTFs has negative piezoelectric coefficient.

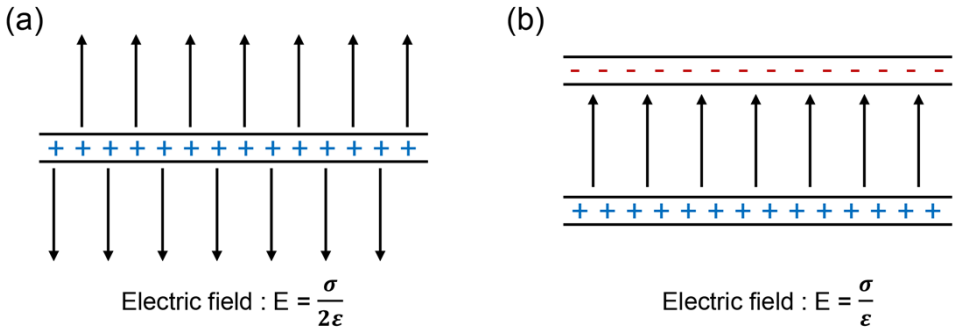

Fig. S6 The electric field in parallel charged plate model: (a) a single charged plate and (b) two charged plates model. E, σ and ε represent electric field, surface charge density and dielectric constant, respectively. Here, single charged plate model was used for calculation electrostatic force.

In order to calculate electrostatic force caused by surface screening charge, *i.e.* excess positive charges, on the MALI PTFs surface, their surface was assumed as a single charged plate model (Fig. S4a). In the as-grown state, surface charge density was calculated as 0.058 μC/cm^2 and then, effective electric field became 1.31×10^6 V/m (here, dielectric constant of MALI PTFs is 25). The electrostatic force is acquired through a simple equation:

$$F = qE$$

where F, q and E are electrostatic force, electric charge and electric field, respectively. Thus, electrostatic force caused by surface charge is calculated as 2.09×10^{-13} N.