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Supplementary Information

Room Temperature, Air Crystallized Perovskite film for High Performance Solar Cells

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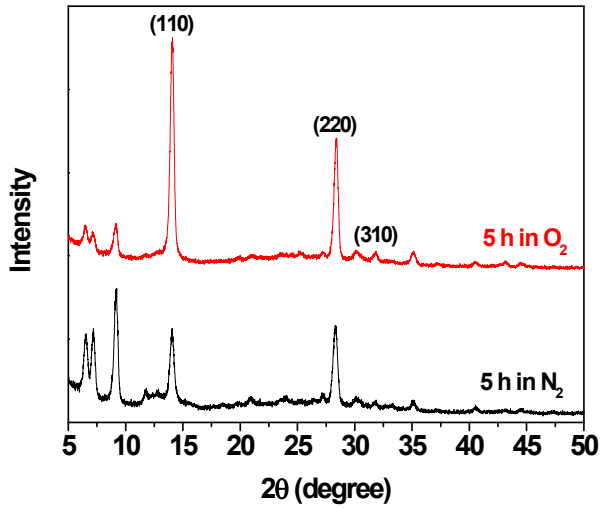
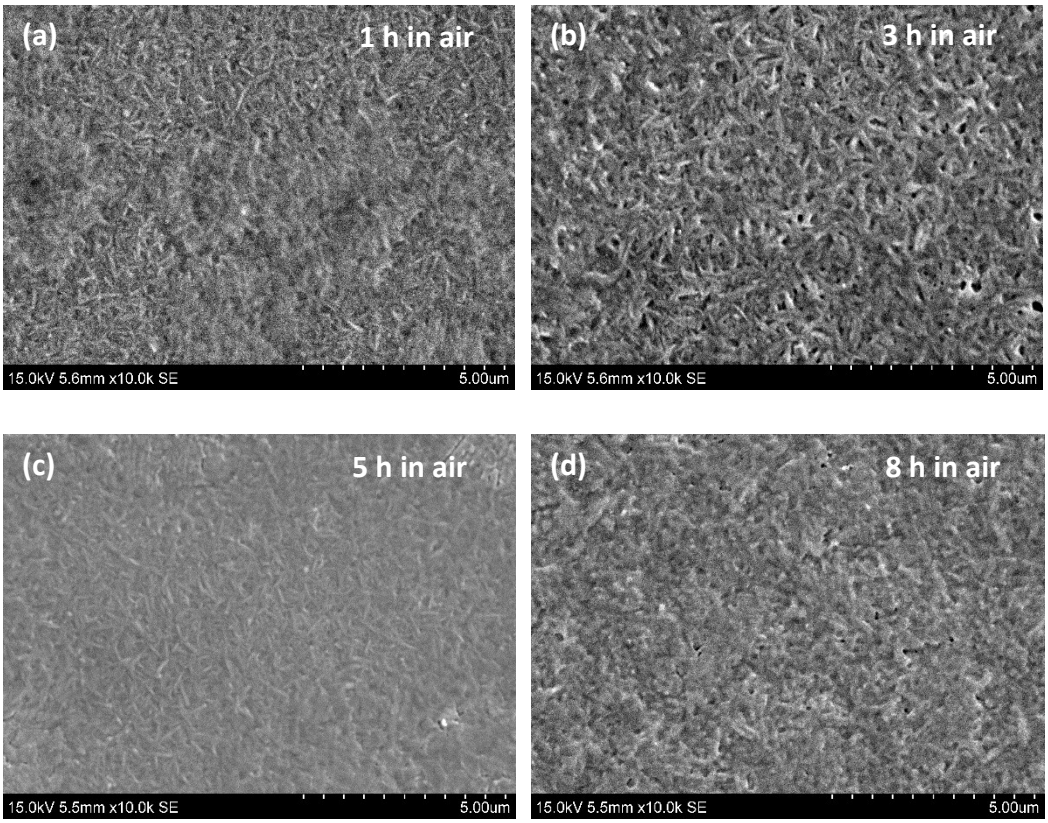


Figure S1. XRD spectrum of perovskite films crystallized in oxygen ambient and nitrogen ambient for 5 h.

Since ambient air contains high percentage of moisture, the room temperature crystallization of deposited perovskite nanorod film with time could be assisted with moisture present in atmosphere. In order to gain further insight into the role of ambient air in crystallization of perovskite film in first 5 hours, we performed an experiment where we grow perovskite films crystallized in oxygen and nitrogen environment having very little moisture (< 20% RH), for the optimized duration (5 hours) of perovskite crystallization time. XRD patterns (figure S1) of 5 h O_2 and N_2 ambient (having less than 20% RH) crystallized perovskite films showed (110) and (220) perovskite peak intensity along with intermediate phase peaks at low angle (5-10 degrees), suggesting that the absence of appropriate moisture led to persistence of intermediate phase. The presence of (110) and (220) perovskite peaks along with low angle intermediate phase peaks in 5 hour O_2 and N_2 ambient crystallized film could be because of the presence of a small percentage of moisture (< 20% RH) in our oxygen and nitrogen filled chamber, which might have led to slow crystallization of perovskite film. Our experiment clearly demonstrates that moisture plays an important role in crystallization of perovskite films in ambient air by conversion of DMSO based intermediate phase into crystalline perovskite phase. On the other hand, XRD spectrum of perovskite film annealed inside N_2 filled glove box, showed pure perovskite phase peaks (110) and (220), without any intermediate phase, which suggest complete crystallization to perovskite phase (figure 3a). The peak intensity for 5 h air crystallized film was seen to be higher than annealed

film, suggesting a greater crystalline fraction for 5 h air crystallized film (figure 3b). This indicates that among ambient air crystallized perovskite film and thermal annealed crystallized film, the air crystallized film lead to higher crystalline fraction with complete crystallization of perovskite film.

Figure S2, shows time dependent morphology evolution for perovskite film crystallized in ambient air and control sample crystallized by thermal annealing. SEM images clearly shows the evolution in air growth perovskite morphology till first 5 h leading to rod shape perovskite features. Beyond 5 h the rod shaped morphology were not distinctly clear, indicating degradation of perovskite nanorod features. The 5 h air crystallized perovskite film showed pin-hole free morphology, suggesting volume expansion of nanorod features to form dense and compact film. Thermally annealed control sample showed small features with lot of pin holes.



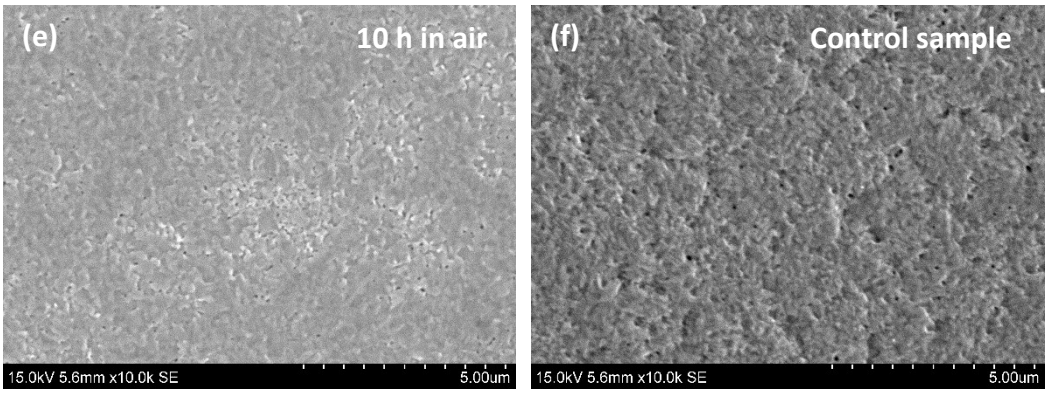


Figure S2. Scanning electron microscope (SEM) images (a-f) of perovskite films crystallized in air for 1, 3, 5, 8, 10 h and control sample crystallized by thermal annealing.

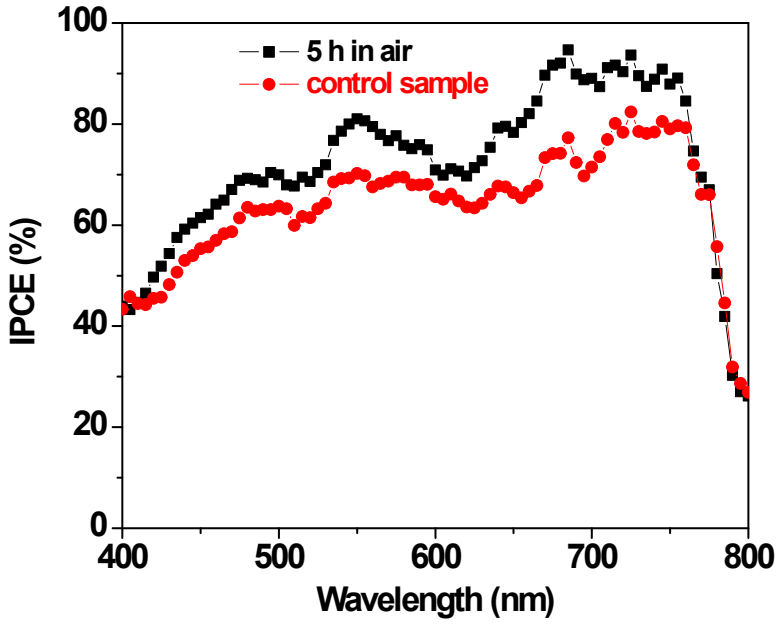


Figure S3. IPCE (%) vs wavelength spectra for devices made from 5 h air crystallized perovskite film and control sample (annealed perovskite film).