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Scanning Transmission Electron Microscopic Analysis of Gamma Ray Exposed Perovskite Solar Cells

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Abstract : Various perovskite materials have surprisingly high resistance towards high-energy electrons, protons, and hard ionization, such as X-rays and gamma-rays. Superior radiation hardness makes a family of perovskite semiconductors an attractive candidate for single- and multijunction solar cells for the space environment and as X-ray and gamma-ray detectors. One of the methods to study the radiation hardness of different materials is by exposing them to gamma photons with high energies (above 500 keV) Herein, we have explored the recombination dynamics and defect concentration of a mixed cation mixed halide perovskite Cs0.17FA0.83PbI1.8Br1.2 with 1.74 eV bandgap after exposure to a gamma-ray source (2.5 Gy/min). We performed an advanced STEM EDX analysis to reveal different types of defects formed during gamma exposure. It was found that 10 kGy dose results in significant improvement of perovskite crystallinity and homogeneous distribution of I ions. While the absorber layer withstood gamma exposure, the hole transport layer (PTAA) as well as indium tin oxide (ITO) were significantly damaged, which increased the interface recombination rate and reduction of fill factor in solar cells. Thus, STEM analysis is a powerful technique that can reveal defects formed by gamma exposure in perovskite solar cells. Methods: Data will be collected from perovskite solar cells (PSCs) and thin films exposed to gamma ionisator. For thin films 50 µL of the Cs0.17FA0.83PbI1.8Br1.2 solution in DMF was deposited (dynamically) at 3000 rpm followed by quenching with 100 µL of ethyl acetate (dropped 10 sec after perovskite precursor) applied at the same spin-coating frequency. The deposited Cs0.17FA0.83PbI1.8Br1.2 films were annealed for 10 min at 100 °C, which led to the development of a dark brown color. For the solar cells, 10% suspension of SnO2 nanoparticles (Alfa Aesar) was deposited at 4000 rpm, followed by annealing on air at 170 ˚C for 20 min. Next, samples were introduced into a nitrogen glovebox for the deposition of all remaining layers. Perovskite film was applied in the same way as in thin films described earlier. Solution of poly-triaryl amine PTAA (Sigma Aldrich) (4 mg in chlorobenzene) was applied at 1000 rpm atop of perovskite layer. Next, 30 nm of VOx was deposited atop the PTAA layer on the whole sample surface using the physical vapor deposition (PVD) technique. Silver electrodes (100 nm) were evaporated in a high vacuum (10-6 mbar) through a shadow mask, defining the active area of each device as ~0.16 cm2. The prepared samples (thin films and solar cells) were packed in Al lamination foil inside the argon glove box. The set of samples consisted of 6 thin films and 6 solar cells, which were exposed to 6, 10, and 21 kGy (2 samples per dose) with 137Cs gamma-ray source (E = 662 keV) with a dose rate of 2.5 Gy/min. The exposed samples will be studied on a focused ion beam (FIB) on a dual-beam scanning electron microscope from ThermoFisher, the Helios G4 Plasma FIB Uxe, operating with a xenon plasma.

Keywords : perovskite solar cells, transmission electron microscopy, radiation hardness, gamma irradiation
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