Enhanced Proton Radiation Tolerance in Halide Perovskite Solar Cells via Cerium Incorporation for Space Applications

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Abstract:

The development of radiation-resistant solar cells is critical for space applications due to intense proton flux in the cosmic environment. In this study, we explore the incorporation of cerium oxide (CeOx) into the perovskite layer as a strategy to enhance proton radiation tolerance. Proton irradiation tests were performed on reference (Ref) and CeOx-incorporated (OC) perovskite solar cells across fluences from $2 * 10^{12}$ to $2 * 10^{14}$ protons cm^{-2} using 0.05 MeV protons. Structural changes were analyzed via X-ray diffraction and X-ray photoelectron spectroscopy, while electrical properties were assessed using current–voltage measurements and Kelvin probe force microscopy. At a fluence of 2×10^{14} protons cm^{-2}, the OC devices retained 90% of their open-circuit voltage and 83% of their initial power conversion efficiency, whereas the Ref devices showed pronounced degradation in both structure and performance. CeOx incorporation was found to suppress proton-induced defect formation, preserve chemical bonding environments, stabilize grain boundaries, and maintain carrier lifetimes. These findings highlight the efficacy of targeted defect passivation in enhancing the intrinsic radiation tolerance of perovskite devices. While the approach directly addresses the challenges of extraterrestrial operation, it also provides a broadly applicable framework for improving the environmental durability of perovskite solar cells in terrestrial applications.

Conflicts of Interest

There is no conflict of interest.

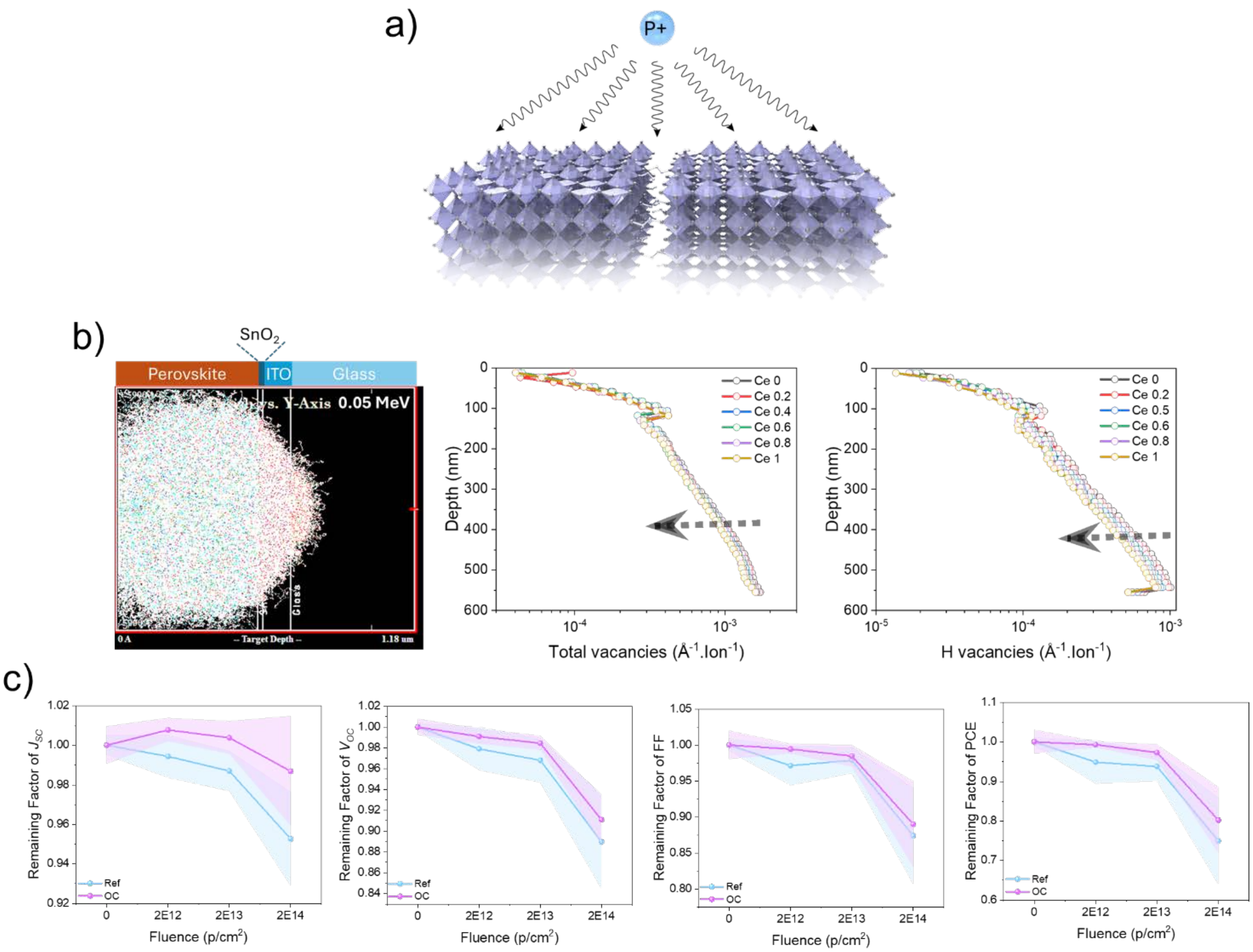

Figure. a) Schematic illustration of proton irradiation on the perovskite structure. b) SRIM/TRIM simulation showing the effect of CeOx incorporation in the perovskite layer under proton irradiation. c) Remaining device performance factor as a function of proton fluence ranging from $2*10^{12}$ to $2*10^{14}$ protons/cm^2 at 0.05 MeV.