Proton Radiation Hardness of Antimony Chalcogenide Solar Cells

Alisha Adhikari,[1] Joel Blodgett,[1] Vijay Karade,[1] Zachary W. Zawisza,[1] Randy J. Ellingson,[1] Zhaoning Song,[1] and Yanfa Yan[1]

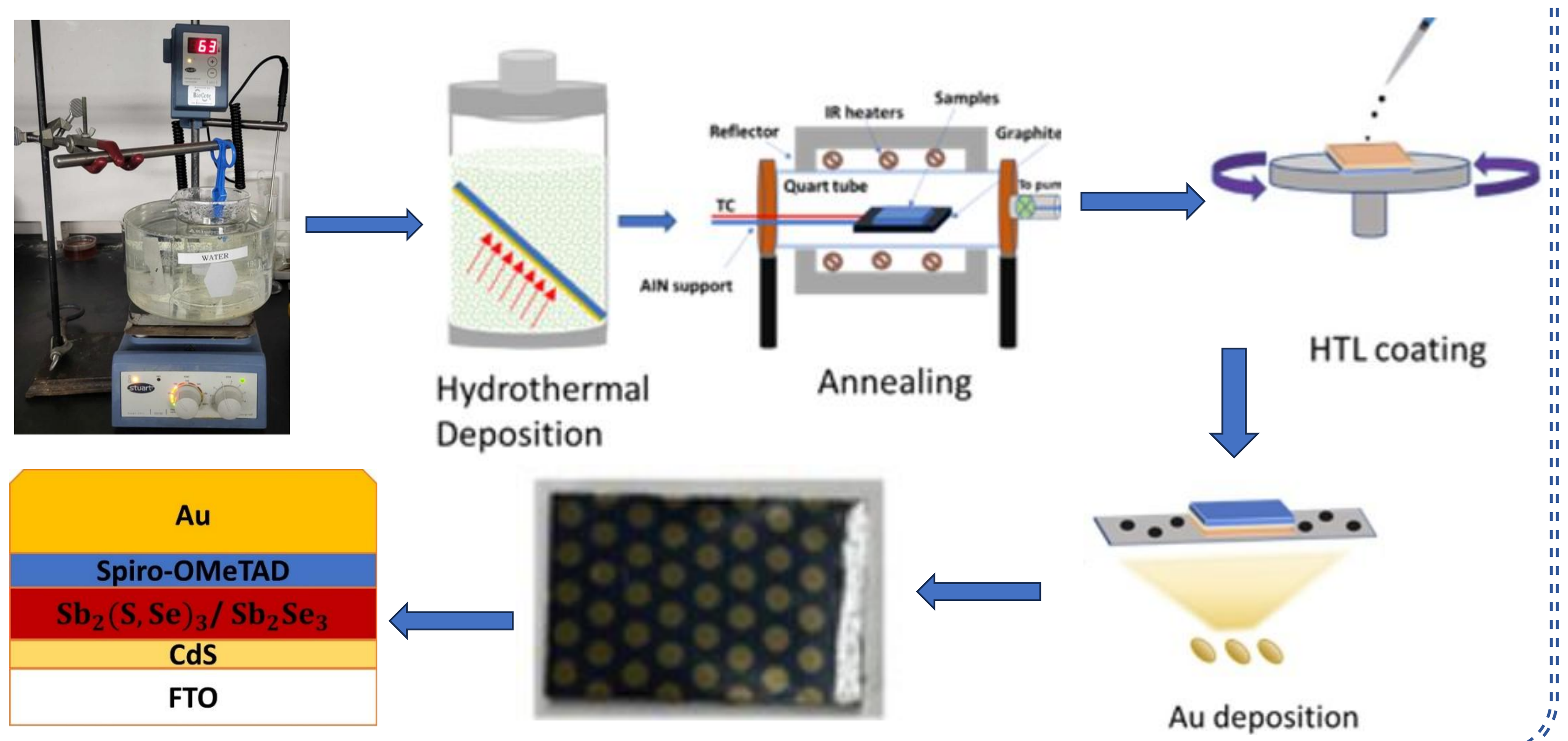
[1]Wright Center for Photovoltaics Innovation and Commercialization, Department of Physics and Astronomy, University of Toledo, Toledo, OH, 43606, USA

Background

- To utilize solar cells for space power applications, studying their proton radiation hardness is pivotal.
- Antimony chalcogenide-based thin-film solar cells have received immense attention for terrestrial and space photovoltaic (PV) applications due to their low cost, ease of synthesis, and material robustness.
- This study aims to understand the effect of proton irradiation on the PV performance of antimony chalcogenide-based solar cells fabricated via hydrothermal method.

Experimental Details

Device stacks and fabrication methods



Takeaways

- Antimony selenide (Sb_2Se_3) solar cells exhibited high remaining factors in PV performance after being exposed to lower fluences of protons and showed a decreased performance with increasing fluences.
- Antimony sulfoselenide ($Sb_2(S,Se)_3$) solar cells suffered from significantly reduced device performance after proton irradiation, regardless of fluences and proton energies. This result suggests that sulfur anions are susceptible to proton radiation, causing overall degradation in the device performance of $Sb_2(S,Se)_3$ solar cells.

Results and Discussions

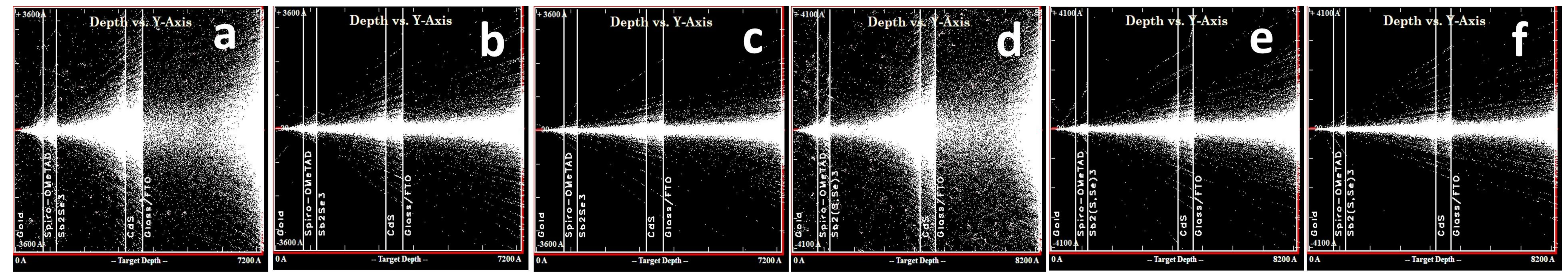


Fig 1: Damage profile in antimony chalcogenide solar cells simulated from SRIM; Sb_2Se_3 exposed to (a) 150, (b) 650, and (c) 1000 keV; $Sb_2(S,Se)_3$ exposed to (d) 150, (e) 650, and (f) 1000 keV

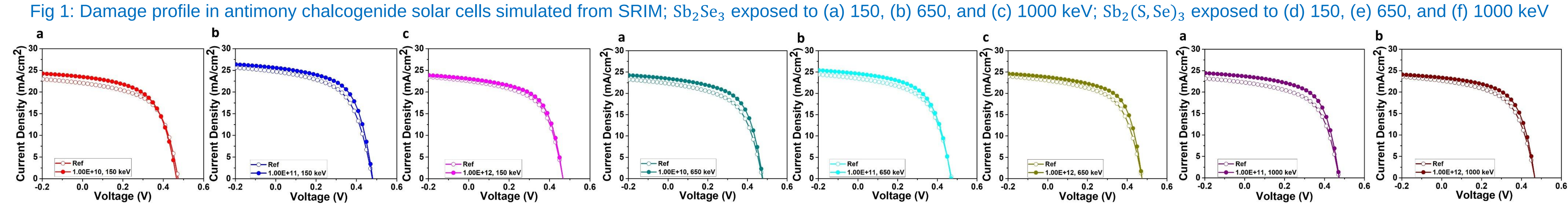


Fig 2: JV curves of champion Sb_2Se_3 devices exposed to 150 keV Fig 3: JV curves of champion Sb_2Se_3 devices exposed to 650 keV Fig 4: JV curves of champion Sb_2Se_3 devices exposed to 1000 keV

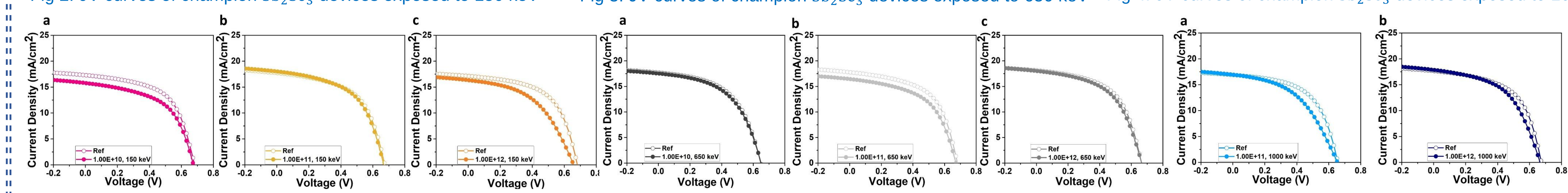


Fig 5: JV curves of champion $Sb_2(S,Se)_3$ devices exposed to 150 keV Fig 6: JV curves of champion $Sb_2(S,Se)_3$ devices exposed to 650 keV Fig 7: JV curves of champion $Sb_2(S,Se)_3$ devices exposed to 1000 keV

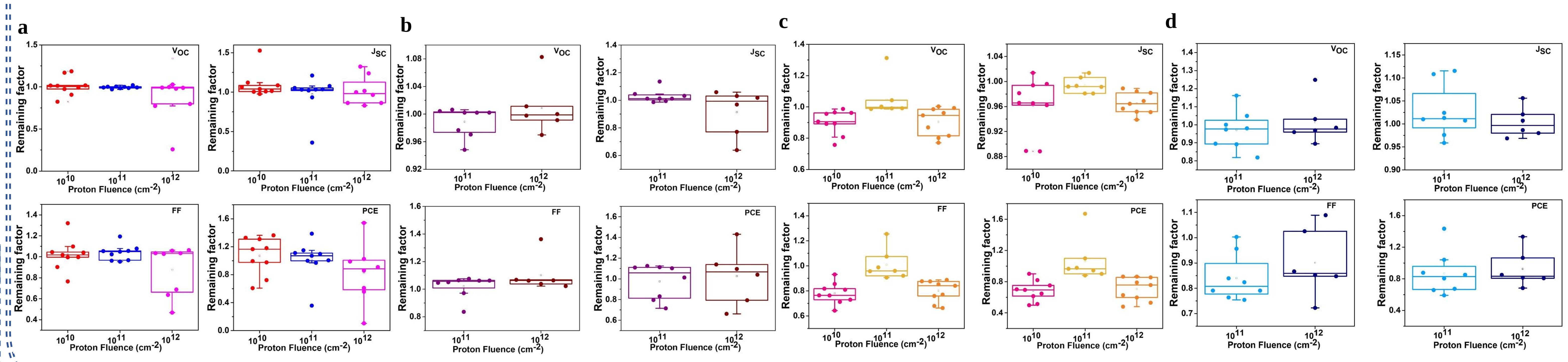


Fig 8: Remaining factor of Sb_2Se_3 devices exposed to (a) 150 keV and (b) 1000 keV; $Sb_2(S,Se)_3$ devices exposed to (c) 150 keV and (d) 1000 keV

Acknowledgments

This material is based on research sponsored by Air Force Research Laboratory under agreement numbers FA9453-19-C-1002 and FA9453-21-C-0056. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon. The views expressed are those of the authors and do not reflect the official guidance or position of the United States Government, the Department of Defense or of the United States Air Force. The appearance of external hyperlinks does not constitute endorsement by the United States Department of Defense (DoD) of the linked websites, or the information, products, or services contained therein. The DoD does not exercise any editorial, security, or other control over the information you may find at these locations. Approved for public release; distribution is unlimited. Public Affairs release approval # AFRL-2025-1891

Reference

- Khanal, M. N., Whiteside, V. R., Parashar, M., Merckx, T., Sharma, M., Kuang, Y., ... & Sellers, I. R. (2024). Radiation versus environmental degradation in unencapsulated metal halide perovskite solar cells. *Journal of Physics: Energy*.
- Cho, S., Ahn, S. H., Cho, I. J., Kim, Y. H., Jeong, J. U., Yoon, M. S., ... & Song, J. Y. (2019). Radiation hardness of cadmium telluride solar cells in proton therapy beam mode. *PLoS One*, *14*(9), e0221655.