Perovskite material characterization and behavior in space-like environments using slot-die-coated perovskite mini modules

Manoj Rajakaruna, Nadeesha Katakumbura, Zachary William Zawisza, Tyler Brau, Aesha P. Patel, Jaehoon Chung, You Li, Muhammad Mohsin Saeed, Zhaoning Song, Yanfa Yan, Randy J. Ellingson

Wright Center for Photovoltaics Innovation and Commercialization (PVIC), Department of Physics and Astronomy
University of Toledo, Ohio, 43606, USA

Background

- Perovskite solar cells have attained efficiencies of over 25% for small area devices, and due to their low cost and scalability, numerous studies have demonstrated the ability to scale up to fabricate large-area mini modules, achieving efficiencies of over 20% [1]
- Due to their low-cost, high power conversion efficiencies, high specific power, high flexibility, and ease of fabrication, they are regarded as promising materials for terrestrial and space photovoltaic applications. [2]
- This preliminary study aims to investigate the behavior of perovskite solar cells under proton radiation and thermal cycling, with the goal of assessing their suitability for use in space-like environments.

Irradiance-Temperature dependent JVTI measurement system [3]



Figure 1. JVTI testing chamber at PVIC

Optimum parameters	
Convenient temp range	-20C to 120 °C
Temp difference top and bottom of cell	0 to ±5 °C
10 °C step time	3 to 4 minutes
Full range sweep	~60 minutes
Temp tolerance	± 0.1°C (light off) + 3°C (light on)
JV sweep time (FW and RW)	~8 sec
Number of data points	100

Toledo Heavy Ion Accelerator (THIA)

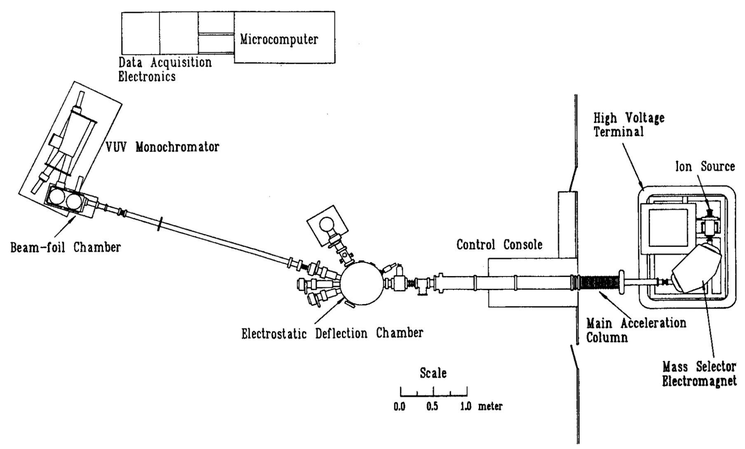


Figure 2. Schematic of general layout of THIA [4]

Thermal Cycling for unit cells

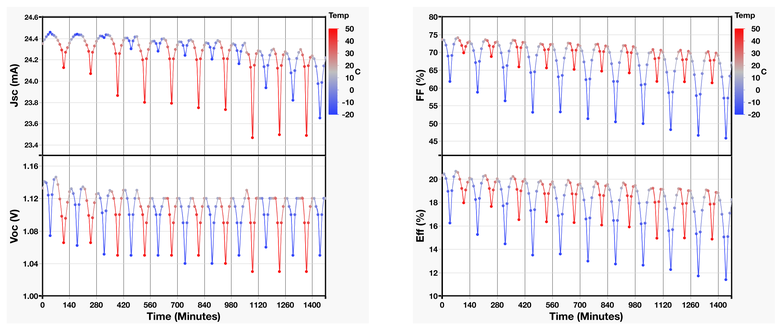


Figure 3. Thermal cycling of unit cell under AM1.5G from -20 °C to 50 °C

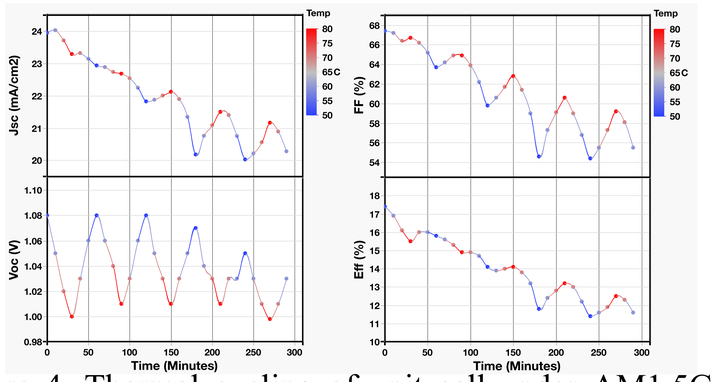


Figure 4. Thermal cycling of unit cell under AM1.5G from 50 °C to 80 °C

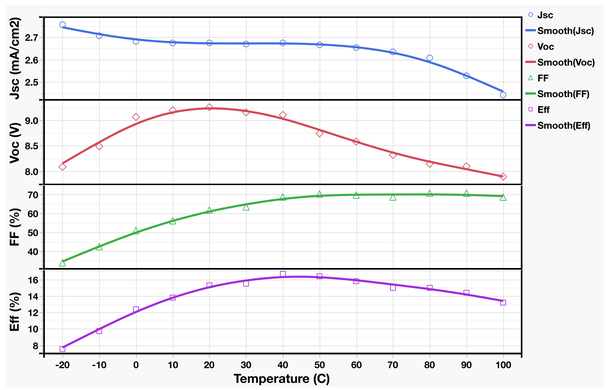


Figure 5. Temperature dependent PV parameters of a mini module (32cm^2) under AM1.5G from -20 °C to 100 °C

Acknowledgements

This material is based on research sponsored by Air Force Research Laboratory under agreement number 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-2023-0096.

Proton Radiation Test

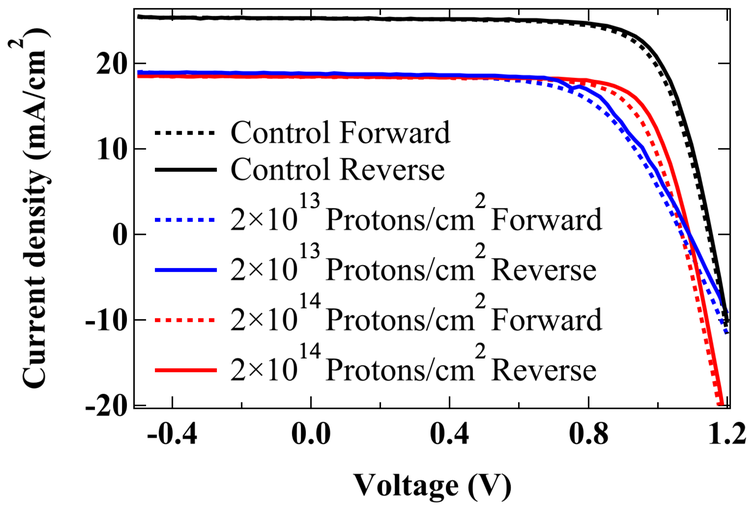


Figure 6. Current Vs. Voltage curves with different proton fluxes

Dosage (Protons/cm^2)	Scan	Voc (V)	Jsc (mA/cm^2)	Fill Factor (%)	Efficiency (%)
Control (N/A)	Forward	1.14	25.49	69.61	20.18
	Reverse	1.15	25.49	72.10	21.07
2×10^{13}	Forward	1.07	18.75	63.67	12.76
	Reverse	1.09	18.83	68.18	14.01
2×10^{14}	Forward	1.07	18.40	72.60	14.35
	Reverse	1.09	18.42	74.79	15.08

Conclusion

- Thermal cycling showed 30-hour stability in a temperature range of -20 °C to 50 °C. However, further increasing the temperature to 80 °C. We attributed the degradation at elevated temperatures to the damage of the Spiro-OMeTAD hole transport layer and the perovskite absorber layer
- We performed proton radiation tests of perovskite PV devices, indicating they are vulnerable to even 2x10^{13} proton/cm^2 radiation flux. This is mainly due to the direct exposure to proton radiation that damages the perovskite absorber

References

[1] T. Bu *et al.*, "Lead halide–templated crystallization of methylamine-free perovskite for efficient photovoltaic modules," *Science,* vol. 372, no. 6548, pp. 1327-1332, 2021.
[2] Z. Yang *et al.*, "Slot-die coating large-area formamidinium-cesium perovskite film for efficient and stable parallel solar module," *Science Advances,* vol. 7, no. 18, p. eabg3749, 2021, doi: doi:10.1126/sciadv.abg3749.
[3] N. Katakumbura *et al.*, "Irradiance and Temperature Control Chamber for Testing Solar Cell Performance," in *2021 IEEE 48th Photovoltaic Specialists Conference (PVSC)*, 2021: IEEE, pp. 1813-1820.
[4] R. R. Haar et al., "The Toledo heavy ion accelerator," Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, vol. 79, no. 1, pp. 746-748, 1993/06/02/ 1993, doi: https://doi.org/10.1016/0168-583X(93)95458-H.