10th anniversary

ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

RMIT Melbourne

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A STUDY ON THE TOLERANCE OF PEROVSKITE SOLAR CELLS UNDER PROTON RADIATIONS

Dang-Thuan Nguyen (Thuan)

Email: dangthuan.nguyen@anu.edu.au

Australian National University

Perovskite solar cells

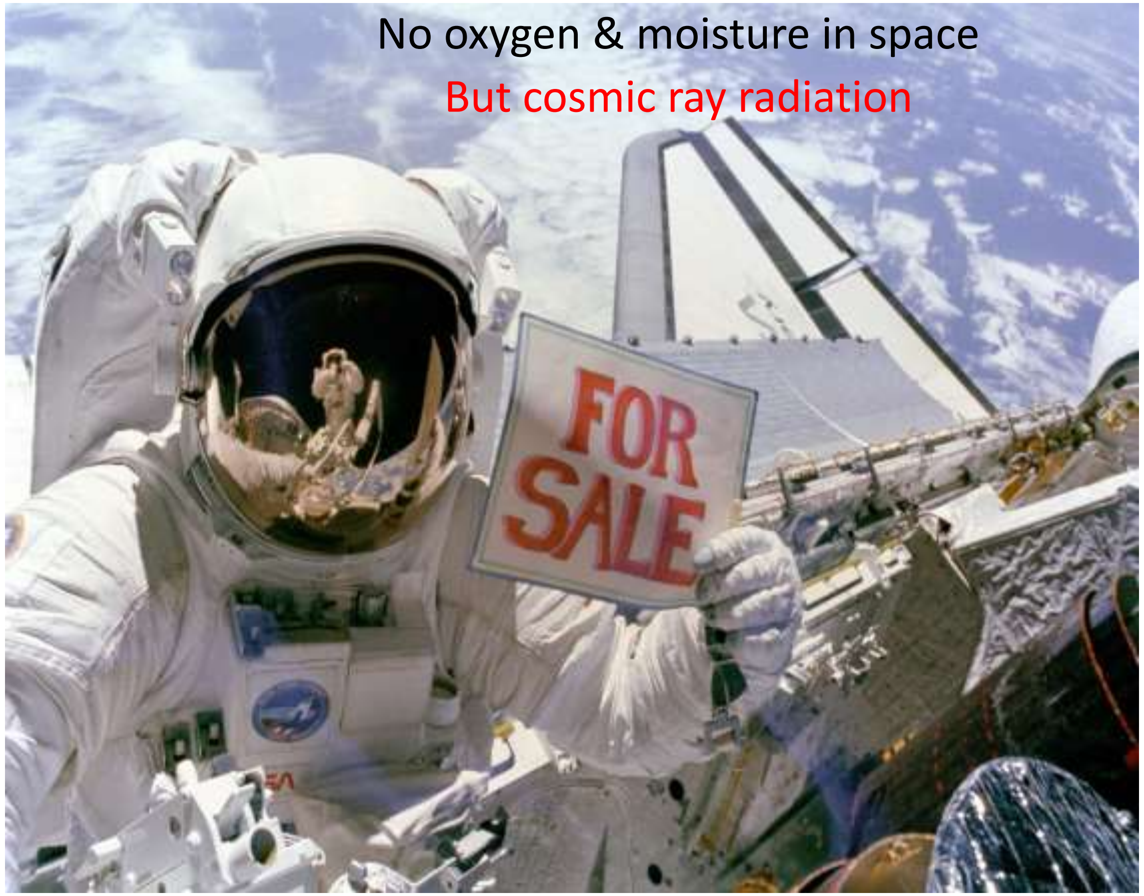
- High power conversion efficiency
- Simple and low cost solution-based processes
- High specific power (power per weight)
- High tolerance under high energy particle radiations

- Unstable at ambient condition (oxygen and moisture)

→ Potential for space applications

Source: Nguyen, D.T. et al. (2023), Adv. Energy Sustainability Res. 2300085

Why space application?



Price optimization for commercialization

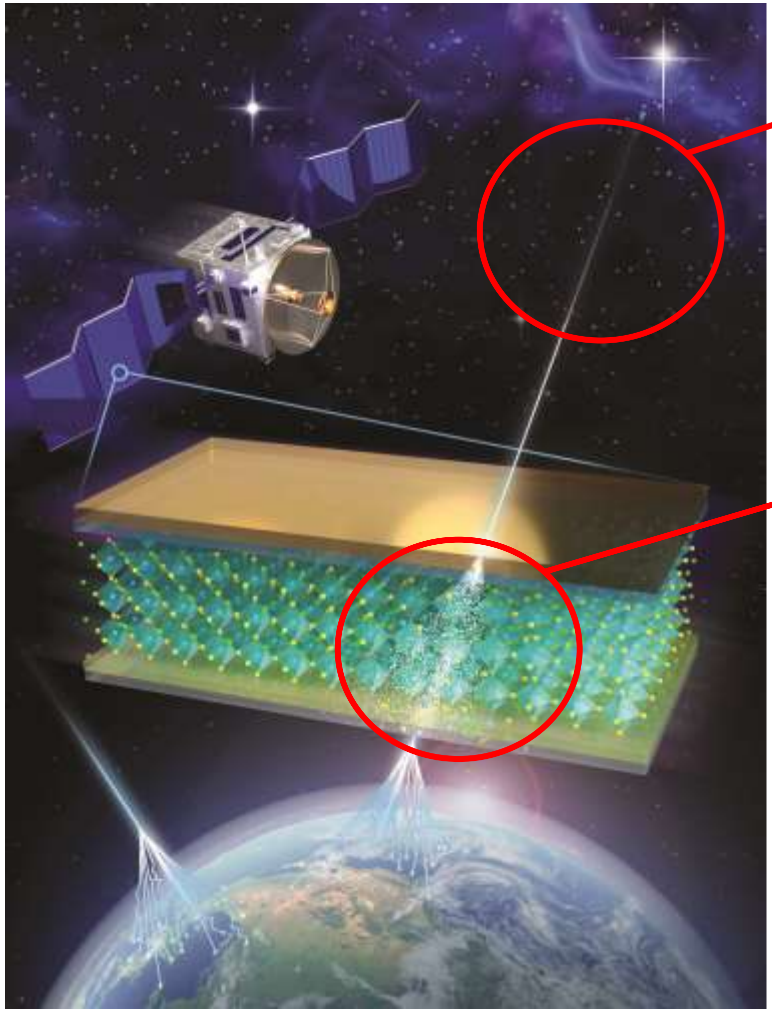
- Unstable with oxygen and moisture

- High tolerance under particle radiations
- Low cost processes → Manufacturing cost
- High PCE
- High power per weight

High PCE and High power per weight → Transportation cost

Manufacturing cost and Transportation cost → Price optimization

High energy particle radiations



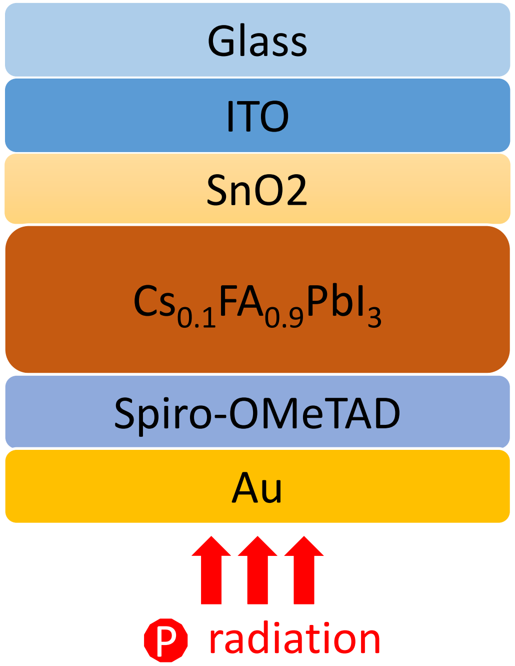
Cosmic rays: γ, e^-, $\mathbf{p^+}$, β^+…

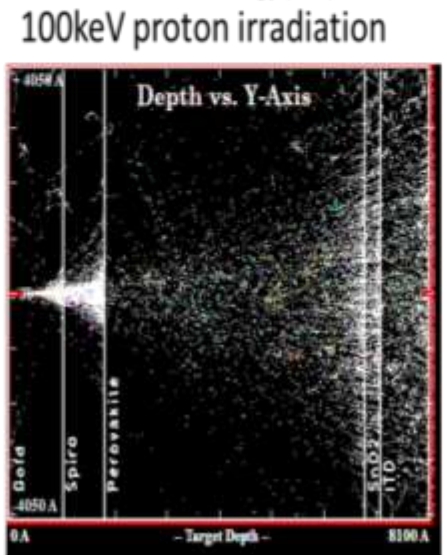
Among them, p+ is the main source of damage due to abundance and energy (mass)

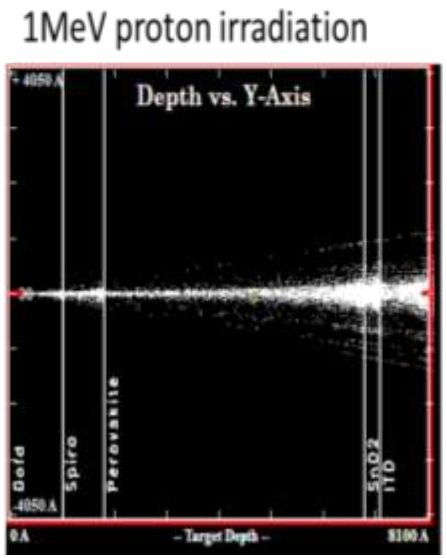
Defect creation within PSC’s functional layers

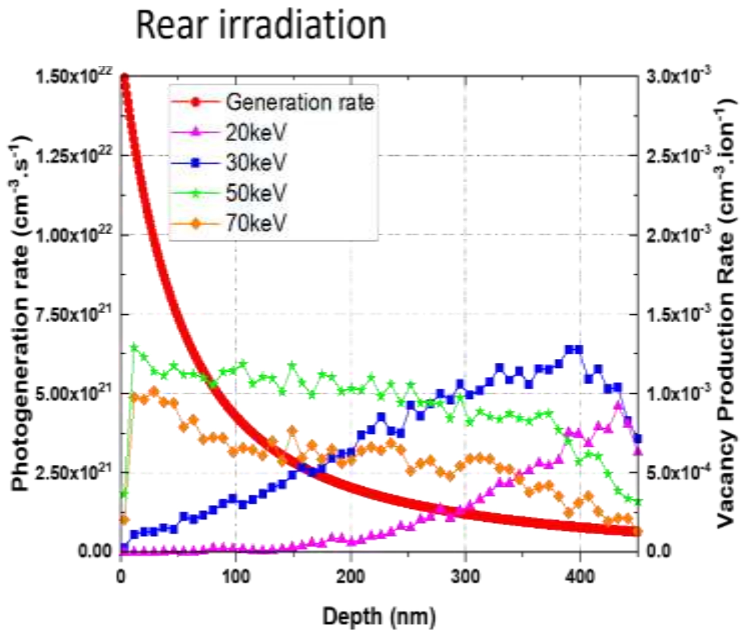
→ This work will focus on defect creation and efficiency degradation under proton radiation

Simulation of defect creation within perovskite







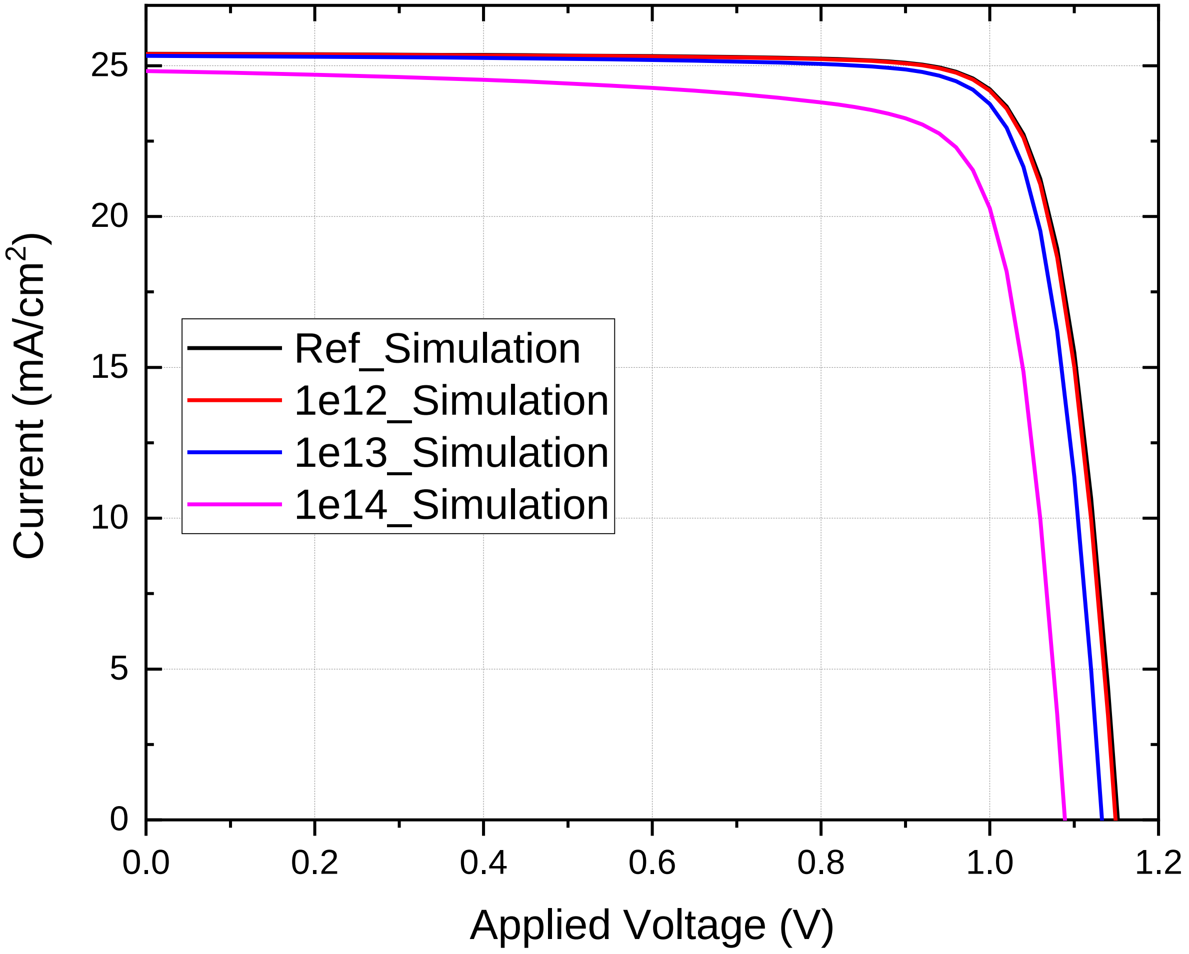


- SRIM simulation for defect production profiles
- COMSOL simulation for JV-curves (with additional defects from SRIM)

For detail, please see Nguyen, D.T. et al. (2023), Adv. Energy Sustainability Res. 2300085

Simulation of efficiency degradation

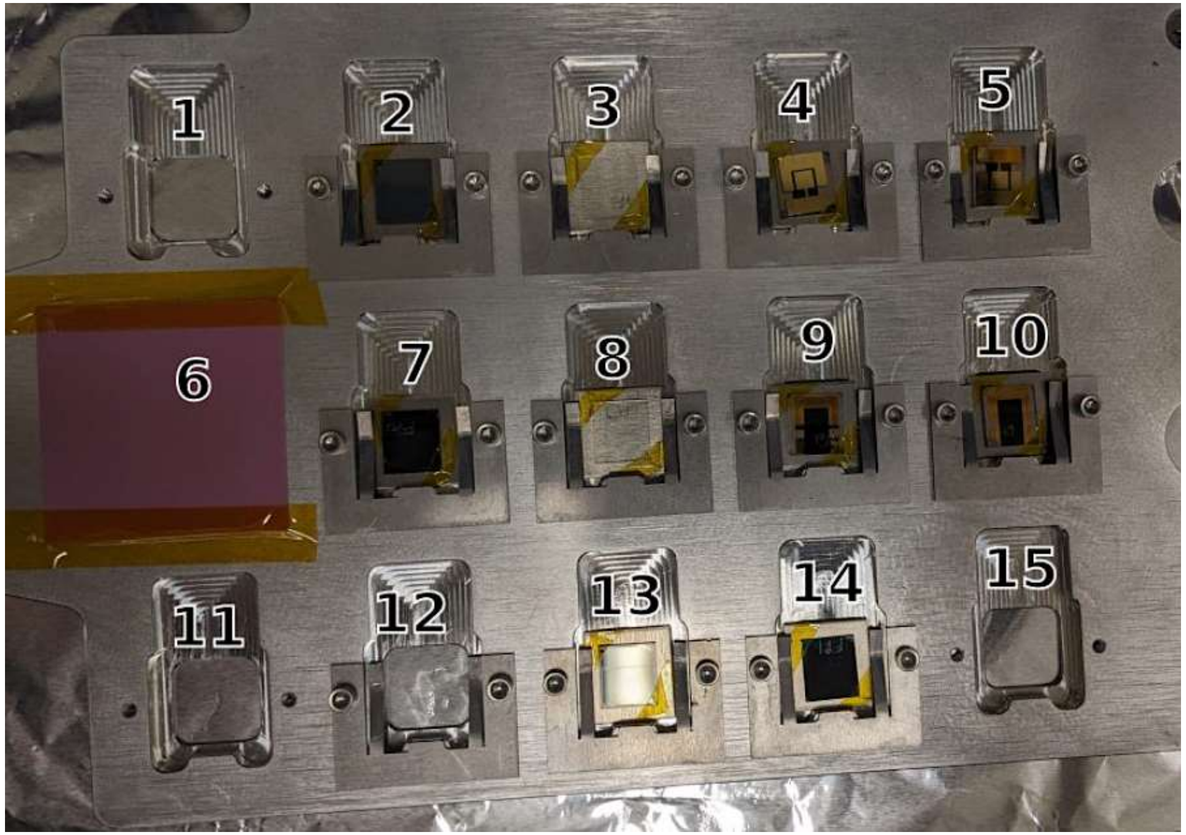
J-V changed under 10MeV proton radiation



Experimental setup

- 10MeV proton radiation
- Total irradiation area is 20x20mm which over-scans the sample's size of 12.5x14mm
- Flux 1e9 p/cm2.s to avoid heating
- Fluence: 1e12, 1e13, 1e14 p/cm2; in which 1e14 p/cm2 equivalents to ~5.5 years in LEO or ~100 years in GEO (*)

(*) Calculated based on 10 MeV proton equivalent dose, source: Brandon K. Durant et al. ACS Energy Letters 2021, 6, 7, 2362-2368

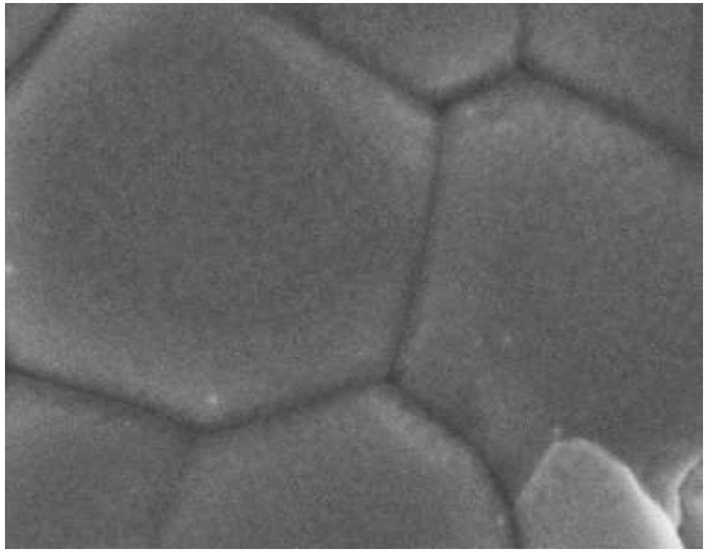


Samples including:

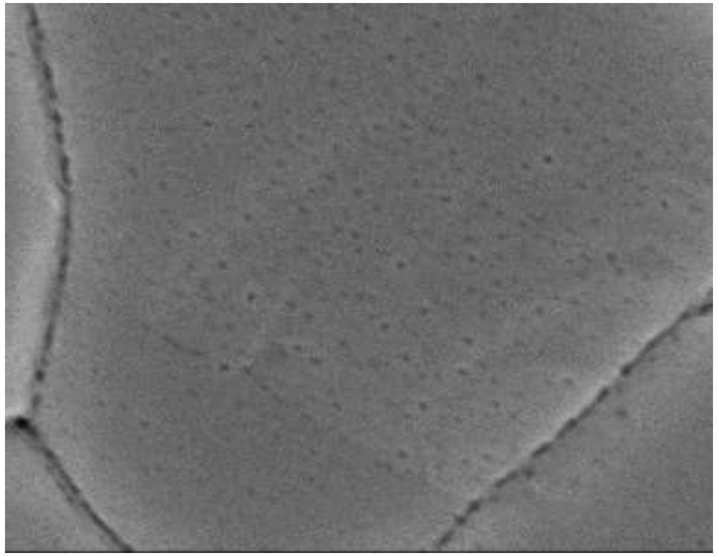
2 cells, 2 films, and one ITO glass for each condition

Radiation test under 10MeV proton

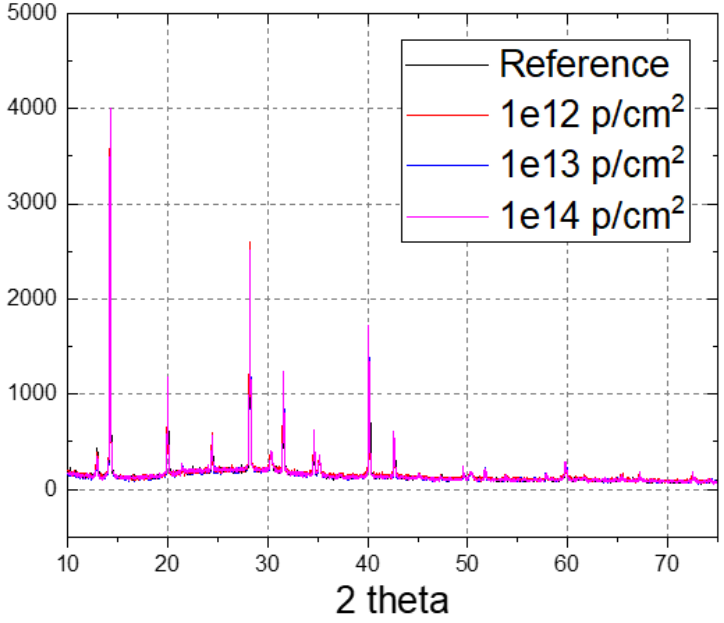
Reference SEM



1e12 p/cm² SEM

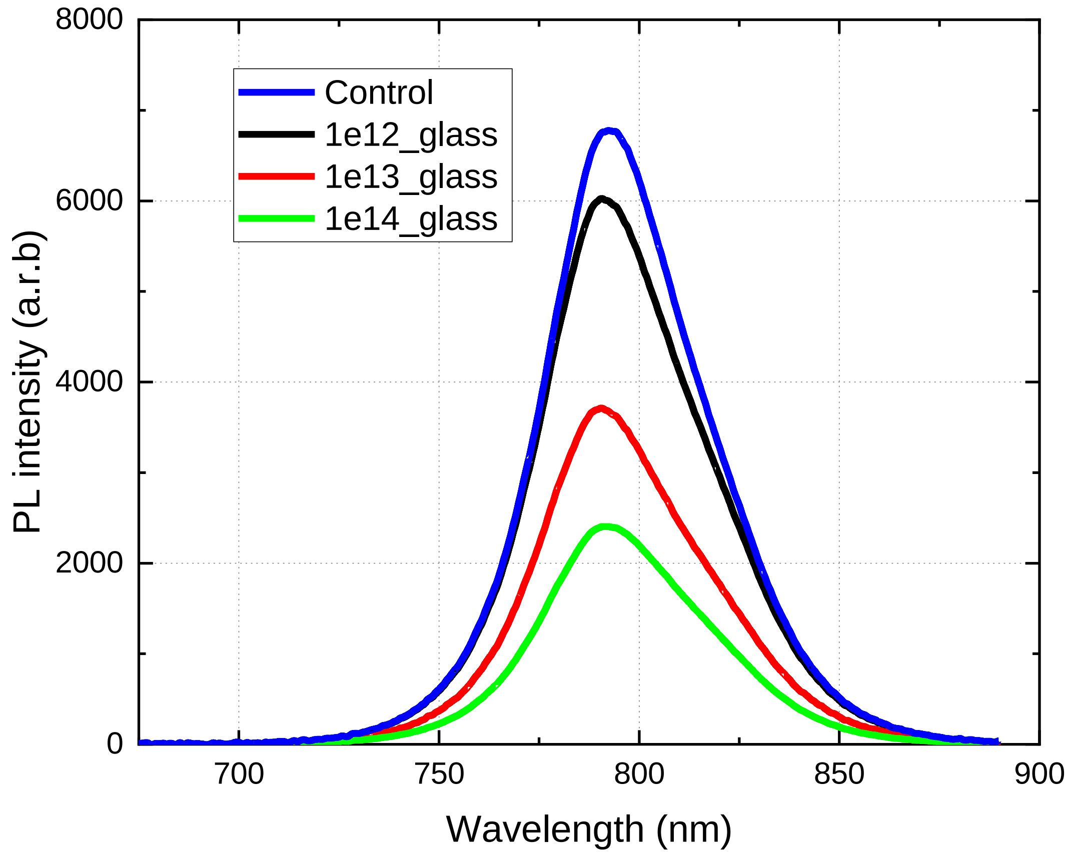


XRD

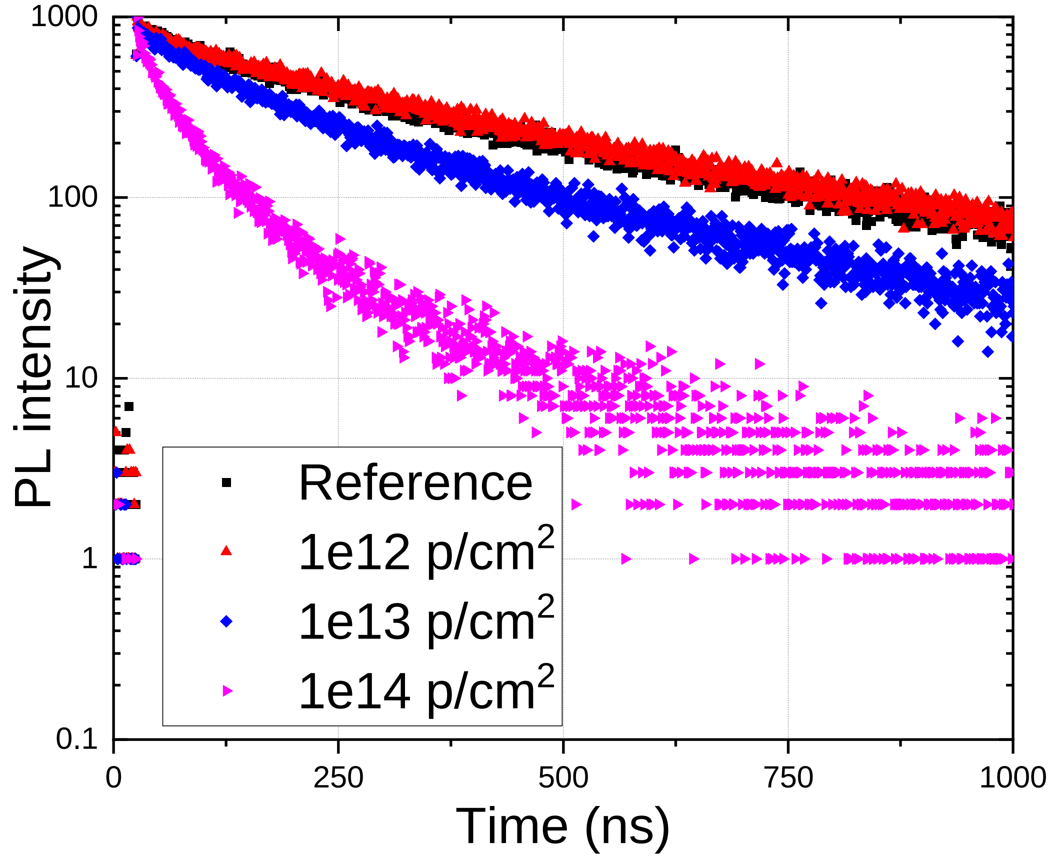


Radiation test under 10MeV proton

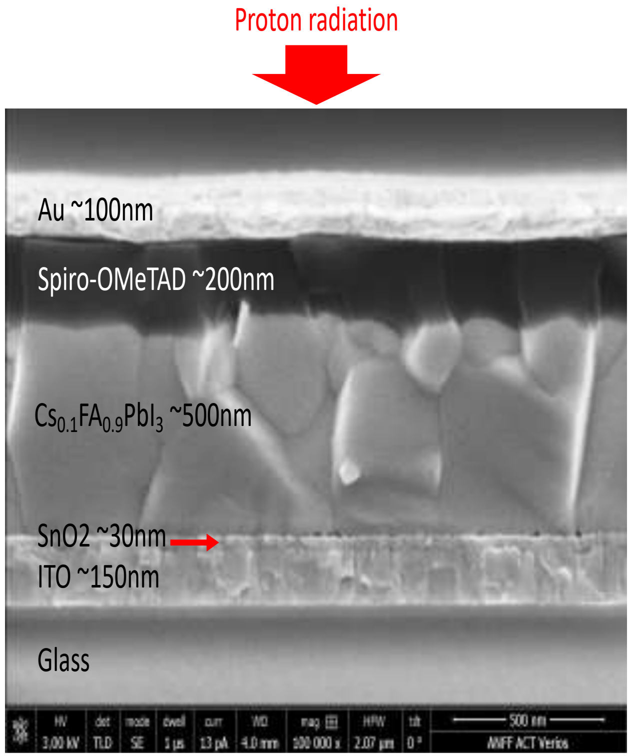
PL



TRPL

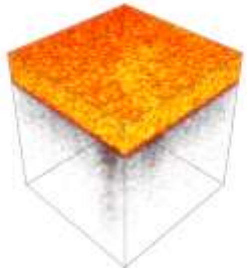


Radiation test under 10MeV proton

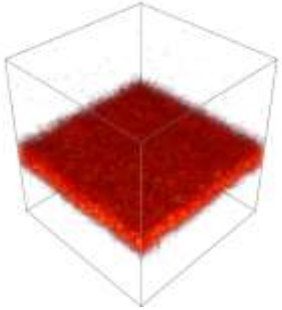


Control | Fluence 1e12

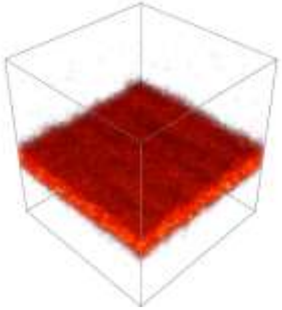
3D Render of Cs_2Au+



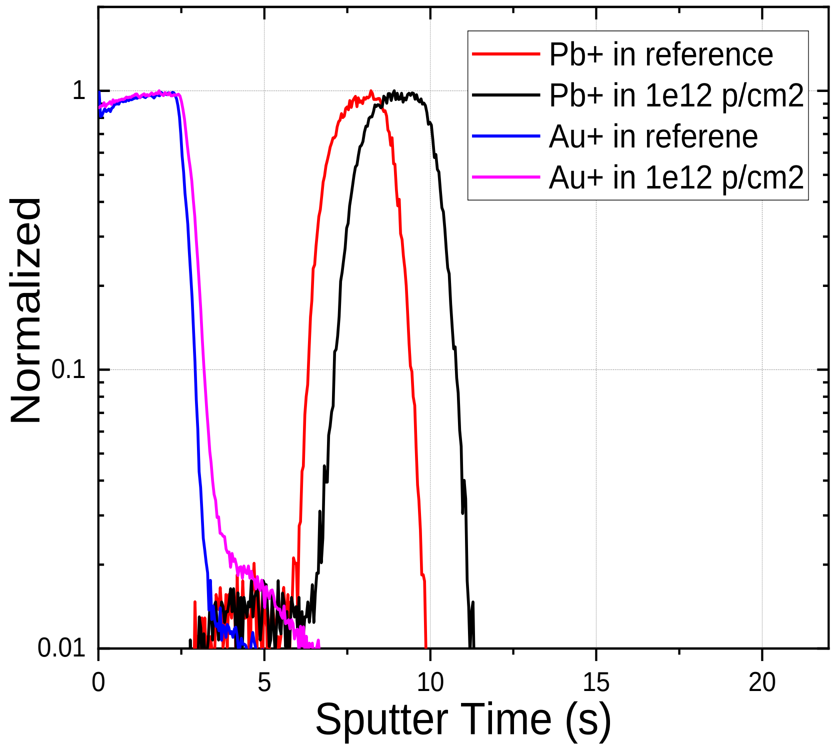
3D Render of Cs_2Au+



3D Render of Pb+

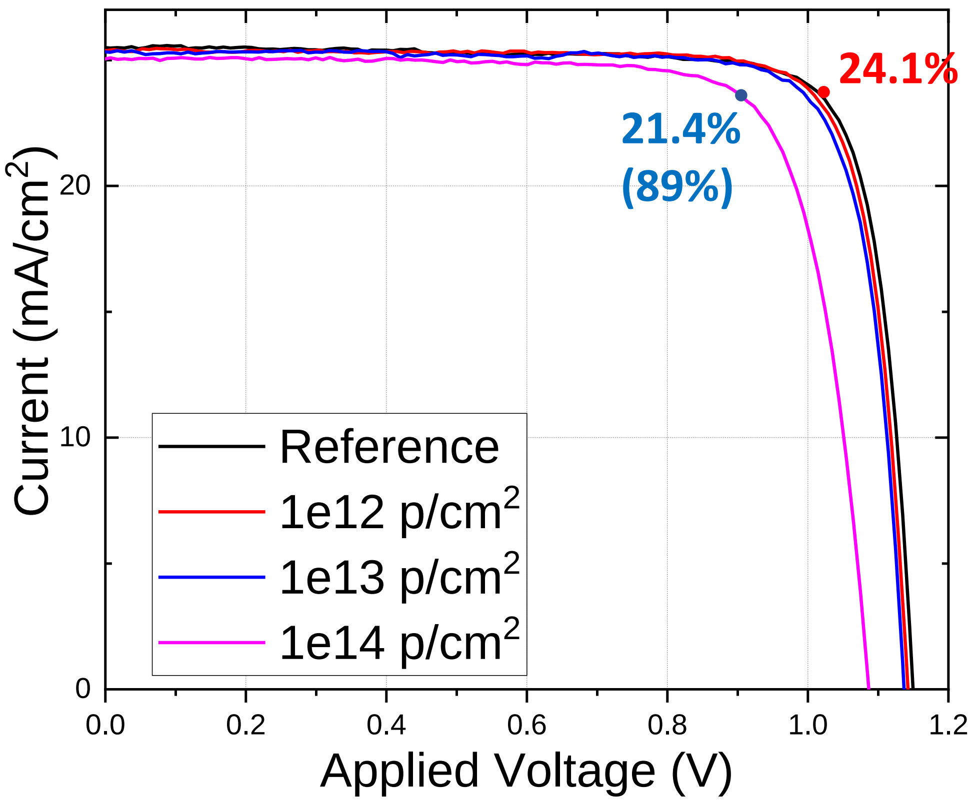


3D Render of Pb+

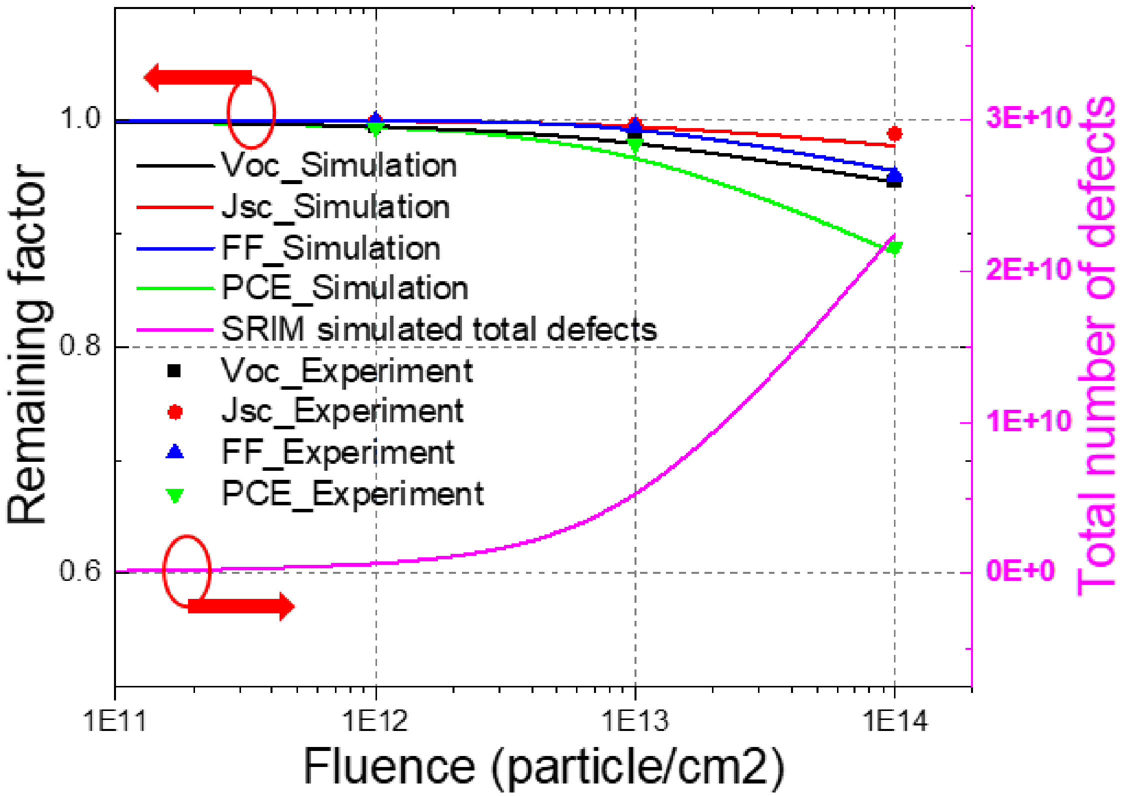


Radiation test under 10MeV proton

J-V measured after radiated

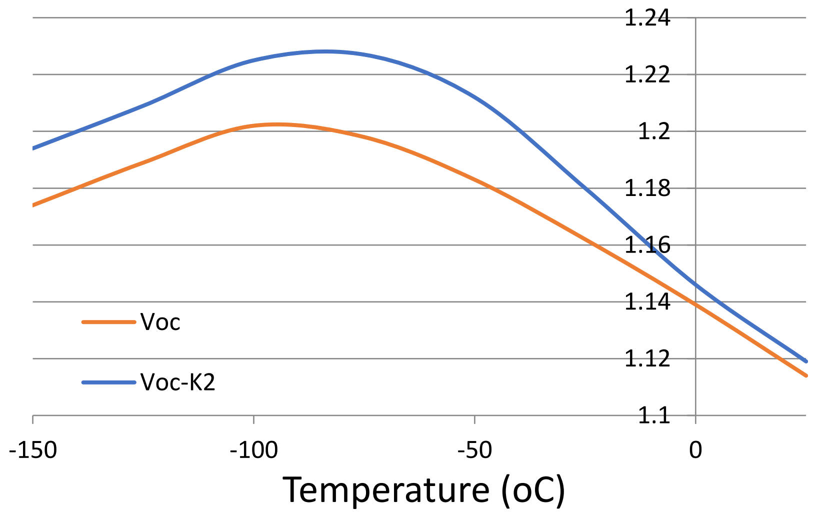


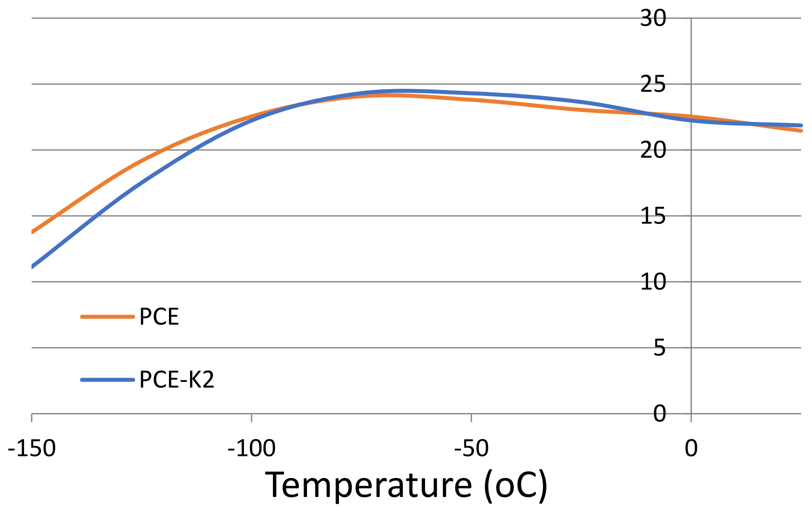
Simulation vs. Experiment



Conclusion

- ➡ Mechanical damage and ions invasion into next layers after being irradiated
- ➡ Samples remain 89% of their initial efficiency after ~100 years in GEO
- ➡ Experiment well matches simulation results
- ⁉ Further study in space applications: **<u>low light & low temperature (deep space)</u>**





THANK YOU!

Contact Us

Dang-Thuan Nguyen[1], Anh Dinh Bui[1], Khoa Nguyen[1], Daniel Walter[1], Klaus Weber[1], Thomas White[1], The Duong[1]*

School of Engineering, The Australian National University

Email (*): dangthuan.nguyen@anu.edu.au (D-T. Nguyen)

(Paper under preparation)

Australian National University

ACAP

ARENA
Australian Government
Australian Renewable Energy Agency

Supporting slide

Structure	Energy	Fluence	Initial effi.	Remaining	Ref.
ITO/TiO_2/$MAPbI_3$/P3HT/Au	150keV	1e12	4.8%	95%	1
		1e13		80%	
		1e14		70%	
ITO/c-TiO_2/mp-TiO_2/$MAPbI_{3-x}Cl_x$/P3HT/Au	50keV	1e12	4.8%	100%	2
		1e13		104%	
		1e14		110%	
ITO/polyTPD/PFN-Br/$FA_{0.8}Cs_{0.2}PbI_{2.4}Br_{0.6}Cl_{0.02}$/C60/$SnO_x$/ZTO/ITO/$Al_2O_3$	50keV	1e12	5.6%	77%	3
	300keV		5.8%	147%	
	2.5MeV		5.4%	117%	
ITO/SnO_2/$Cs_{0.15}FA_{0.85}PbI_3$/PTAA:Spiro/Au	7MeV	1e13	16.3%	48%	4
ITO/SnO_2/$Cs_{0.15}FA_{0.85}PbI_3$/PTAA/Au			14.9%	57%	
ITO/SnO_2/$Cs_{0.15}FA_{0.85}PbI_3$/PTAA:C8BTBT/Au			18.0%	57%	
ITO/polyTPD/PFN/$FA_{0.6}Cs_{0.3}DMA_{0.1}PbI_{2.4}Br_{0.6}$/LiF/C60/PEIE/ AZO/ITO/PEDOT:PSS/$FA_{0.75}Cs_{0.25}Sn_{0.5}Pb_{0.5}I_3$/C60/BCP/Au	68MeV	2e12	15.6%	97%	5
		1e13		94%	
ITO/PEDOT:PSS/$MAPbI_3$/PC61BM/BCP/Ag	68MeV	1e12	4.7%	121%	6
ITO/SnO_2/$Cs_{0.1}FA_{0.9}PbI_3$/Spiro/Au	10MeV	1e12	24.1%	99%	This
		1e13		98%	
		1e14		89%	

Self-annealing

[1] Y. Miyazawa et al., 2015 IEEE 42nd Photovolt. Spec. Conf. PVSC 2015, pp. 4–7, 2015.
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[3] B. K. Durant et al., ACS Energy Lett., vol. 6, no. 7, pp. 2362–2368, 2021.
[4] Tang, S. et al., (2023), Adv. Energy Mater., 13: 2300506.
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[6] . V. Brus et al., Adv. Electron. Mater., vol. 3, no. 2, 2017.