Using Accelerated Aging Protocols for Validating the Stability of Carbon-Backed Perovskite Solar Cells

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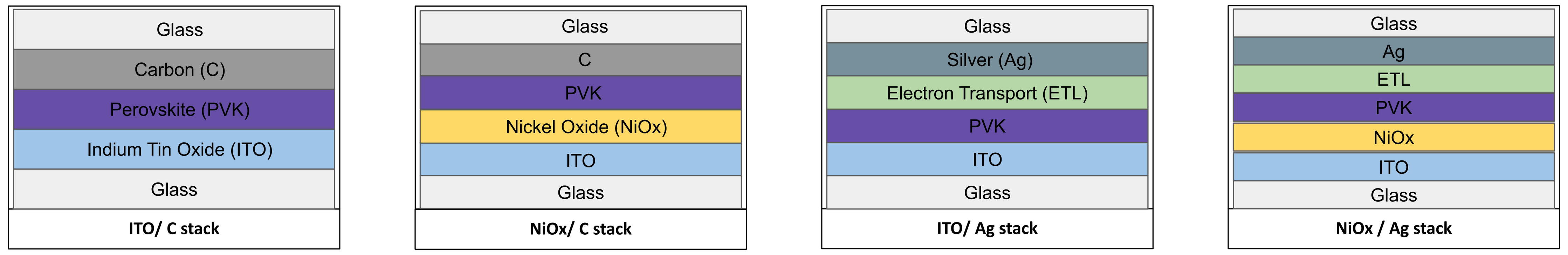
Background

- **Perovskite semiconductors** offer a low-cost, U.S.-manufacturable alternative for solar panels.
- However, they suffer from **rapid degradation** due to environmental stressors (light, heat, moisture).
- **Carbon electrodes** show promise in improving stability thanks to their **chemical inertness** [1].
- Despite known benefits, **quantitative data on carbon vs. metal electrodes** under stress is limited.
- This study compares perovskite devices with carbon vs. silver electrodes **under light and thermal cycling**.
- Results aim to inform the design of **more durable and commercially viable** perovskite solar panels.

Materials

Device Preparation:

Four device stacks were fabricated in quadruplet, with all stacks encapsulated with UV-curable resin and a top cover glass.



Stress-Testing Protocols

Two Pathways Tested:

1. Thermal Cycling → Illumination
   - Thermal Cycling: -40C to 85C, 200 Cycles
   - Followed by 200 hours of illumination
2. Illumination → Thermal Cycling
   - 100 hours of illumination
   - Followed by 300 thermal cycles

Characterization Techniques

Initial Characterization:

1. Photoluminescence (PL) imaging
2. Optical Microscopy

Final Characterization:

1. PL
2. Optical Microscopy
3. X-Ray Diffraction (XRD)

Conclusion and Future Directions

Photoluminescence Shifts:

- Minimal to no shifts in carbon containing samples.
- Lower quality PL data from interface interactions, thereby excluding ITO/Ag samples.

Microscope Images:

- NiOx/Ag exhibited a consistent brown hue across both pathways, indicating worse degradation than other stacks

XRD:

- Similar degradation regardless of the order in which it occurred.
- NiOx is necessary for certain degradation pathways with Ag, not seen in carbon samples

Overall Conclusion:

- Carbon is a good inert electrode
- Carbon helps to maintain good interfaces between layers

Future Directions:

- Extend testing to longer durations
- Integrate alternate Hole Transport Layers (HTL's) compatible with carbon contacts
- Evaluate laser-scribed carbon and Polyethylene Terephthalate (PET)/ITO flexible substrates

Results

Pathway 1

Microscope Images of Delaminated Stacks

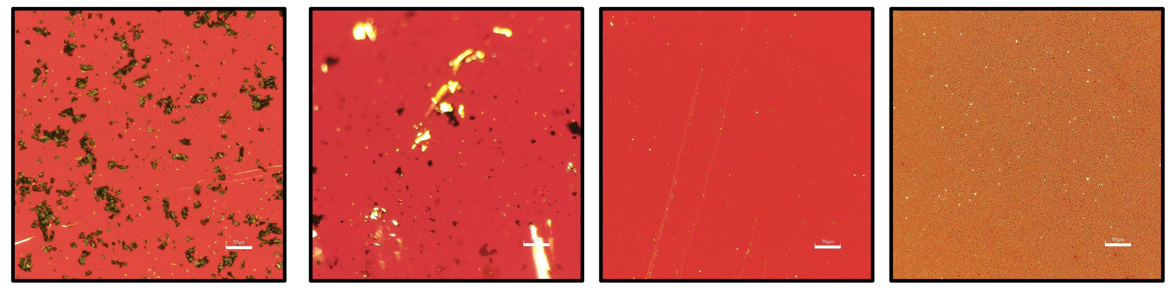


Fig 3. from left to right: ITO/C, NiOx/C, ITO/Ag, NiOx/Ag

PL Data

	NiOx/C	NiOx/Ag	ITO/C
Uncycled (1)	800 nm	819 nm	788 nm
Cycled → Illuminated (1)	798.5 nm	826.5 nm	789.5 nm

Table 1. Peak PL wavelengths for applicable unaged and aged samples across device architectures.

XRD Data

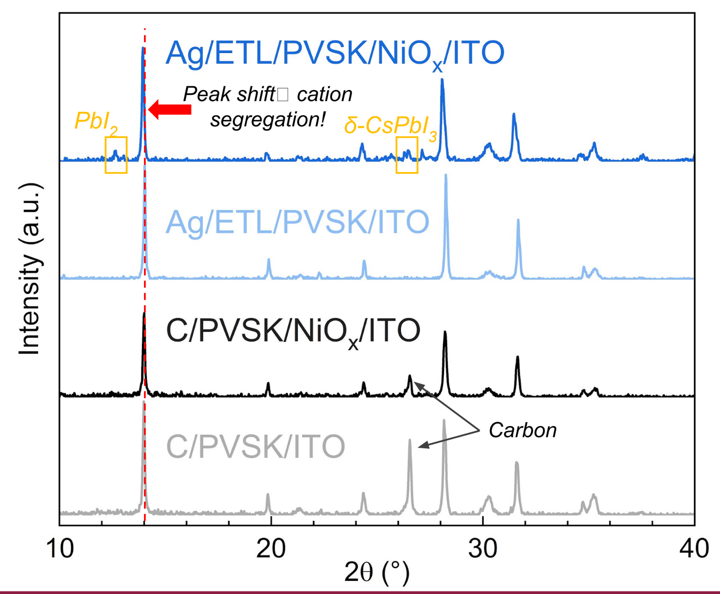


Fig.5 PbI_2 is a degradation product from perovskite, generally happens with reactions with Ag.

Pathway 2

Microscope Images of Delaminated Stacks

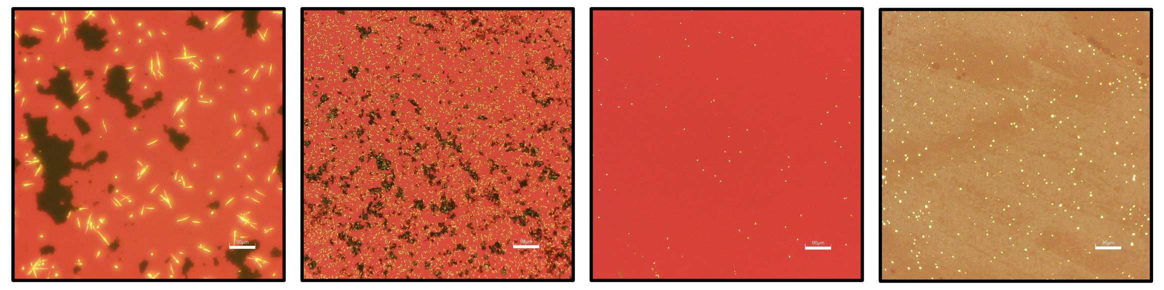


Fig 4.from left to right: ITO/C, NiOx/C, ITO/Ag, NiOx/Ag

PL Data

	NiOx/C	NiOx/Ag	ITO/C
Uncycled (2)	797 nm	815 nm	788 nm
Illuminated → Cycled (2)	796.5 nm	824 nm	789.5 nm

Table 2. Peak PL wavelengths for applicable unaged and aged samples across device architectures.

XRD Data

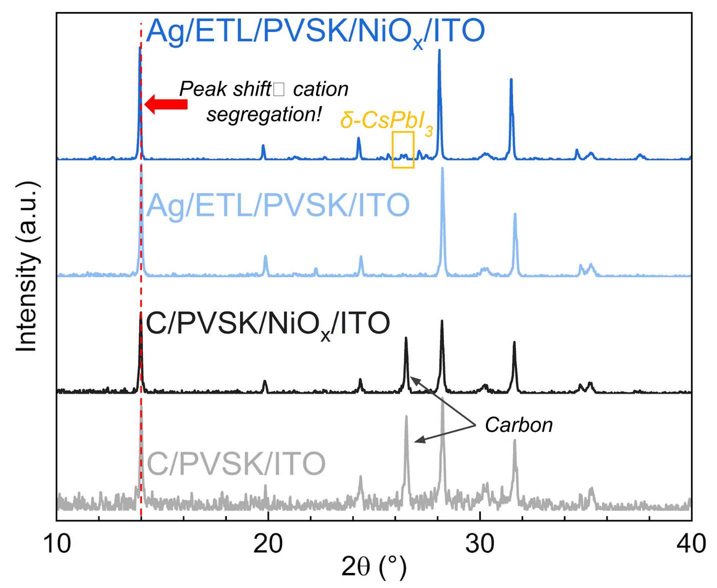


Fig.6 *δ-$CsPbI_3$* forms from cation segregation in which $Cs_{0.2}FA_{0.8}PbI_3$ separates into delta-phase $CsPbI_3$ and partially into alpha-$FAPbI_3$.

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References:

[1] M. Que, B. Zhang, J. Chen, X. Yin, and S. Yun, "Carbon-based electrodes for perovskite solar cells," *Mater. Adv.*, vol. 2, no. 17, pp. 5560–5579, Aug. 2021, doi: 10.1039/D1MA00352F

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