Processing and Laser Scribing Flexible Perovskite Solar Modules for Lunar Application

Grace Salazar, Chemical Engineering, SEMTE
Nicholas Rolston, Assistant Professor, ECEE

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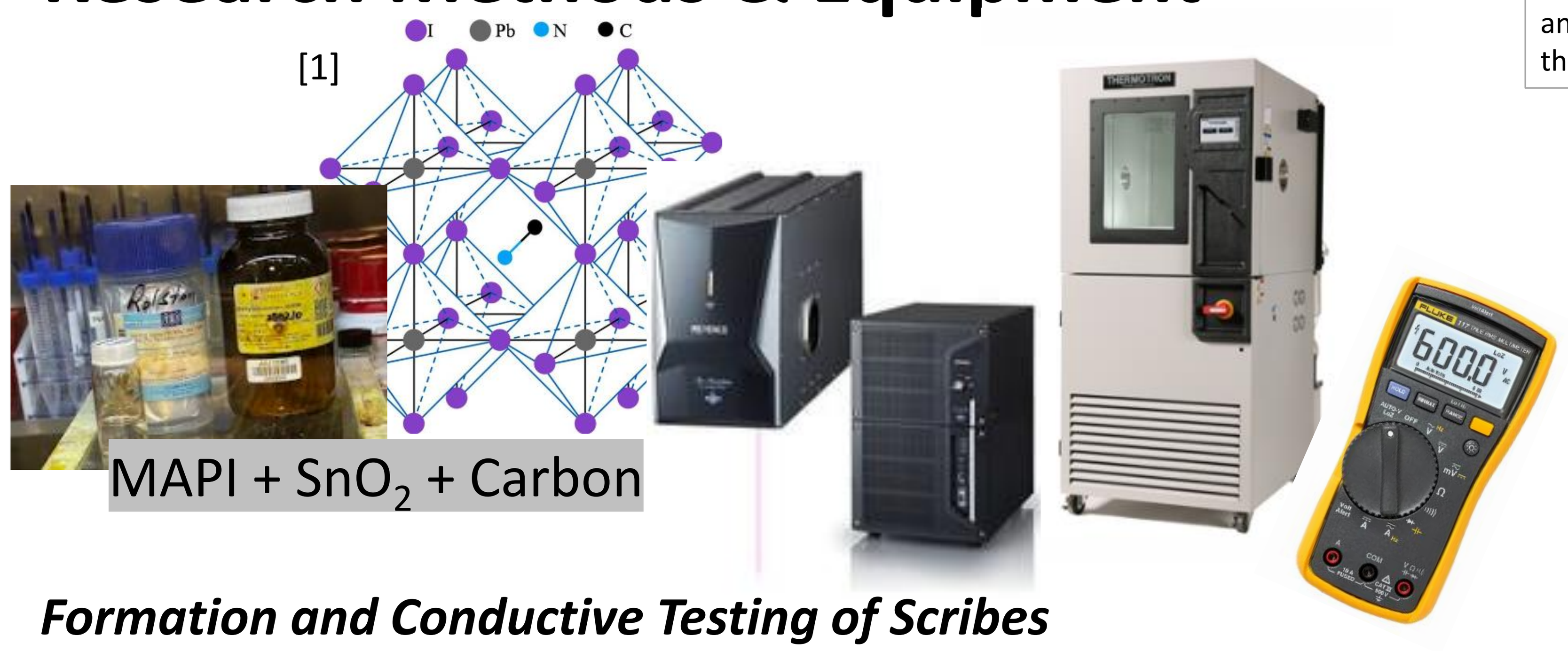
Abstract:

This research effort focuses on the creation of a low-cost, lightweight, flexible perovskite solar modules that can withstand harsh thermal cycling that mimic lunar environments. Further, testing focuses on the comparison between flexible and rigid perovskite solar modules and the scalability of these cells to provide application within a large-scale module consisting of multiple cells monolithically integrated using laser scribing. Results focus on the feasibility of flexible, lightweight solar module usage for lunar application in the near future.

Research Questions

1. How can laser scribing be applied effectively to a flexible substrate Perovskite Solar Module (PSM)?
2. How does thermal cycling and reverse bias testing affect the laser scribing and structure of a flexible Perovskite Solar Module (PSM)?

Research Methods & Equipment



Formation and Conductive Testing of Scribes

1. Adjustments of spot frequency, scan speed, laser power, and repetitions of the laser marker were tested to correctly achieve formation of P1, P2 and P3 patterning scribes.
2. Multimeter testing occurred with voltage measurements taken through the scribe to ensure success without lasering under or over the expected measurement.

Processing and Endurance Testing of Scribing under Lunar Conditions

1. Film and Device samples sent through a Thermotron to thermal cycle the scribes and sample at temperatures ranging from -40°C to 80°C with constant humidity.
2. Measurements were taken every 50 cycles for 3 repetitions, with conductivity testing was performed with standard deviation as measurements of effectiveness. Varying micron distances and additions of PMMA to both flexible and rigid substrates were the variables examined.

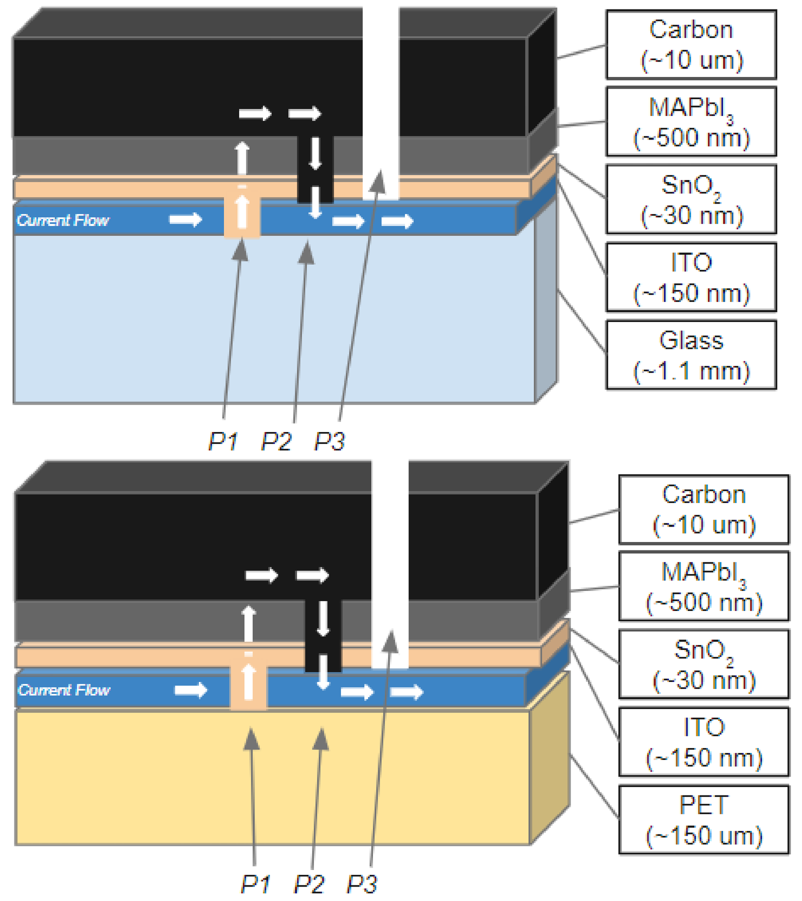


Figure 1. Depiction shows the contents of the MAPI Perovskite Solar Cell that was created for both Rigid (Glass) and Flexible (PET) substrates. Labels for each scribe and their designated current flow are given.

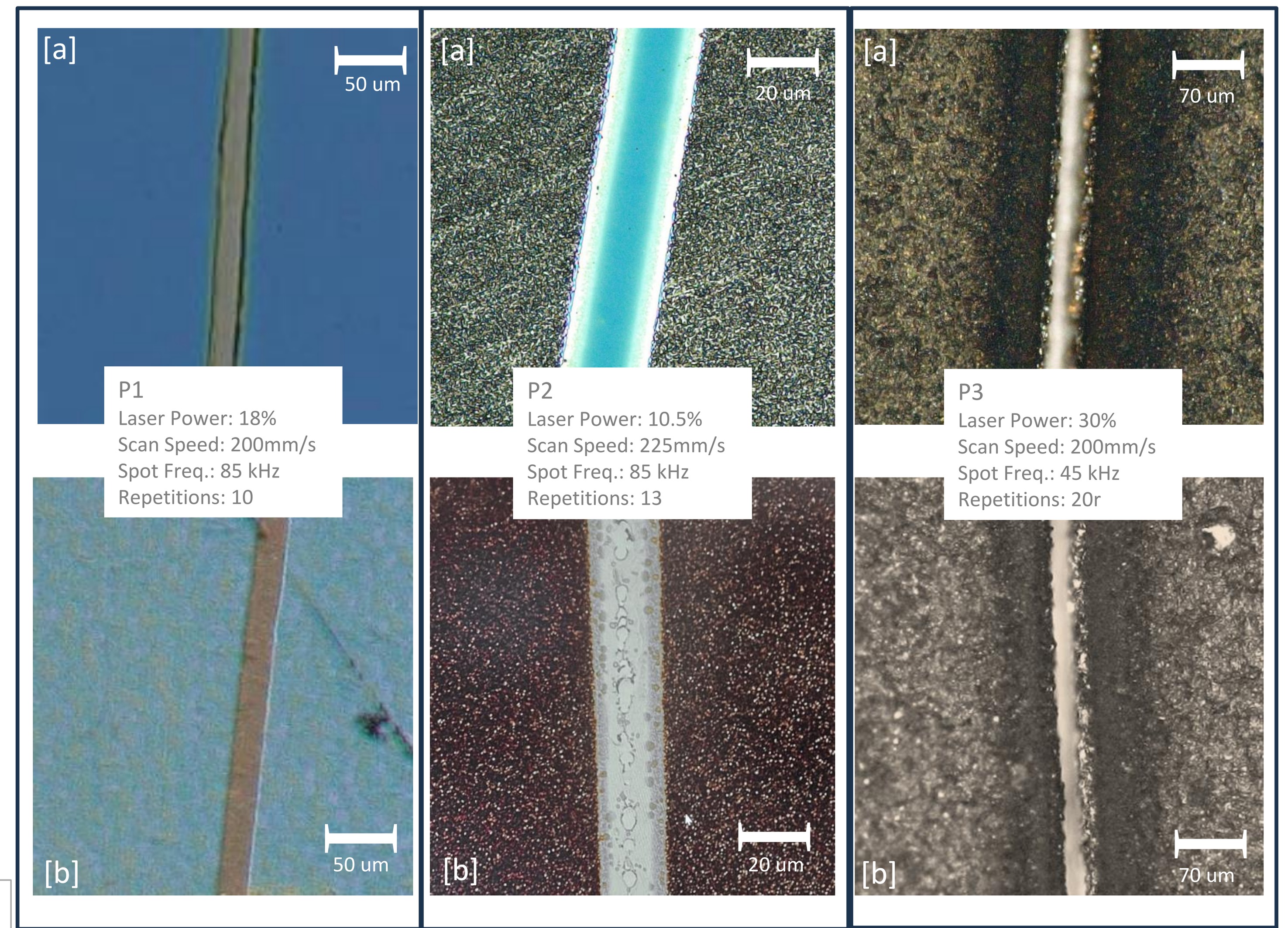


Figure 2. The three different patterning scribes are seen above, with *[a]* displaying the rigid substrate results, and *[b]* displaying the flexible. Multiple trial and errors led to the conclusion that, with the layers being of equal width besides substrate, that the scribing power, speed, frequency and repetition were identical.

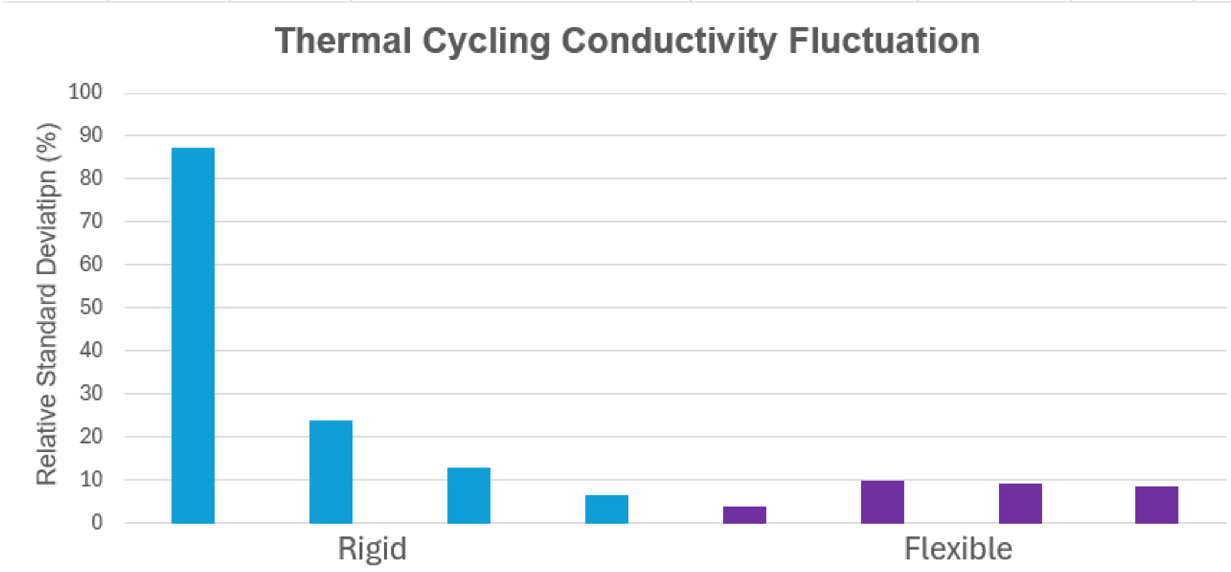


Figure 3. Comparisons between Flexible and Rigid Perovskite Solar Cells were made using Relative Standard Deviation to determine stability. As seen below, averages of the flexible substrates maintained a lower overall conductivity variance, proving a better stability over the course of 200 thermal cycles.

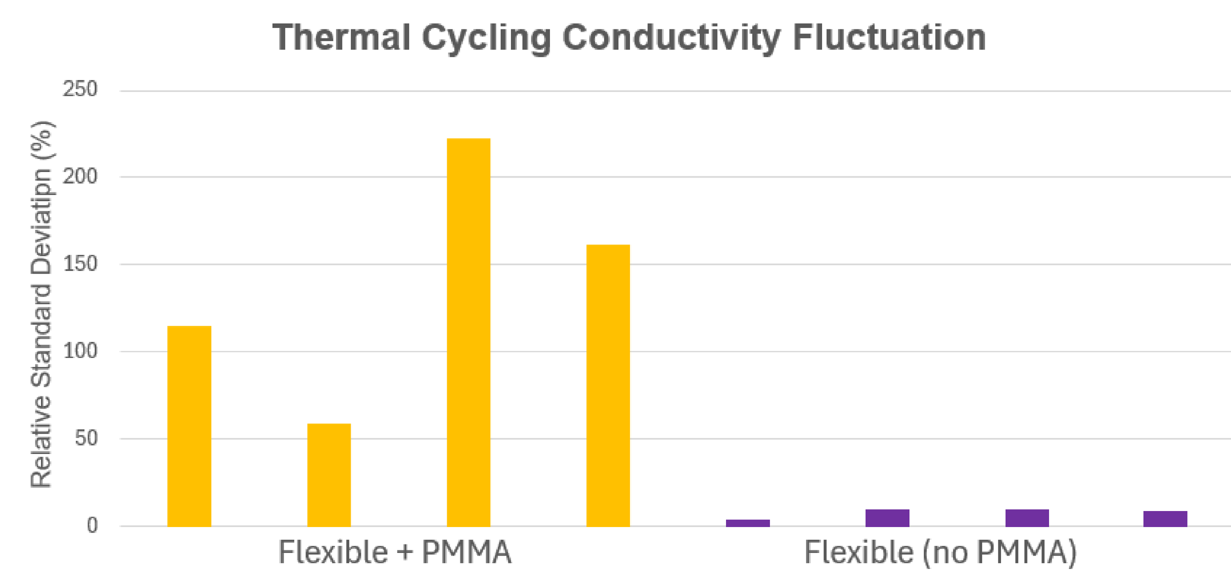


Figure 4. Similar to the figure above, comparisons were then made between the flexible substrates with and without PMMA. Results remained consistent with what was the expected outcome, in which the PMMA created much less stable PSCs, likely due to the reaction that occurred with the Carbon top layer.

Discussion

Scribing and Processing Challenges

- The PET substrate had a natural bend, causing inaccuracy of scribing location and consistency. This was reduced by taping PET to a glass slide to flatten.
- Inaccuracies with blade coating carbon onto the device occurred as well due to the bend. Flattening could not fully solve issue due to small surface area.
- Addition of PMMA atop the Carbon layering reacted to form a uniform paste, altering the scribe lines, resulting in larger conductivity variance.
- P3 Patterning scribes required a lot of adjustments and testing to verify successful scribes due to the depth of the scribe. Examinations couldn't occur with a microscope on the same scope.

Main Takeaways

- Scribing power and adjustments were identical for PET and Glass substrates with successful spin coating, meaning the thickness for the layers remained consistent as well.
- Conductivities of the PET without PMMA remained the most consistent, with degradation of carbon being near nonexistent.

Future Application

Furthering with reverse bias testing: Use of reverse bias testing to further with lunar application.

Creation of Large PET modules: Larger surface area layered with blade coating could reduce bend, improving scribe location accuracy and precision.

Flexible Array Modeling: Adaptation of a system for maximizing efficiency could be implemented from what was discovered. This would consist of formations for transportation and final implementation.

References

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ASU Ira A. Fulton Schools of Engineering
Arizona State University