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Stress Factor Assessment for Microsystems-Enabled Photovoltaics

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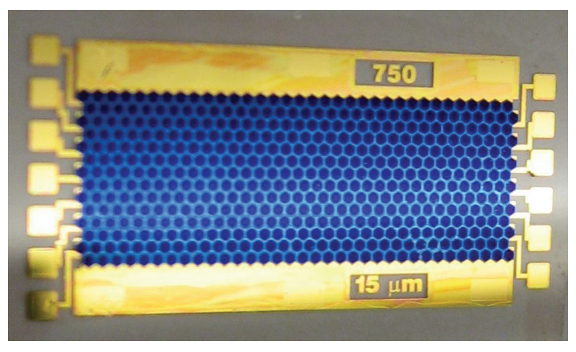
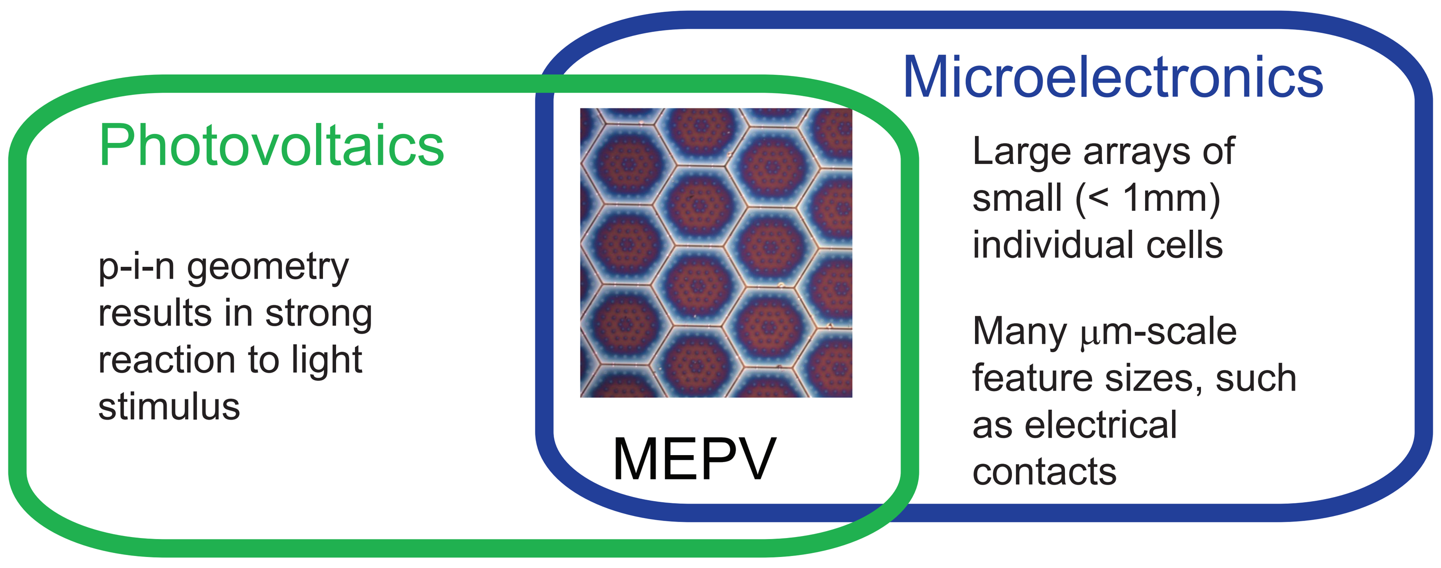
Introduction

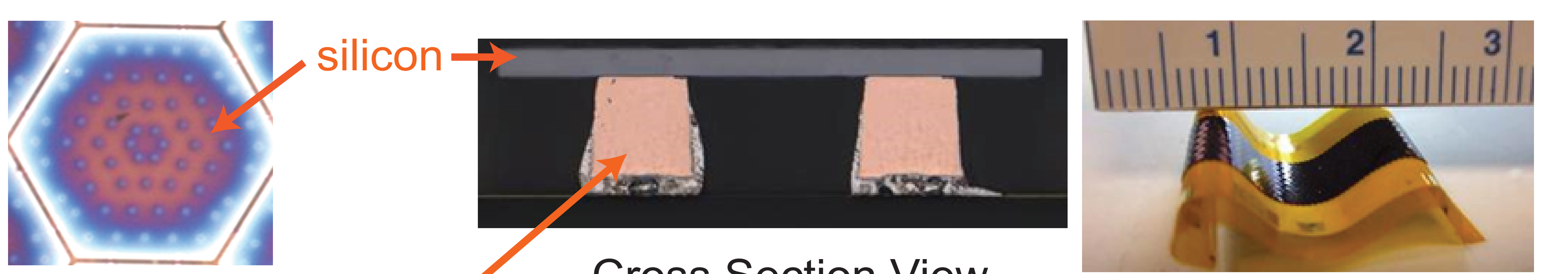


Microsystems-enabled photovoltaics (MEPV) is a microfabricated photovoltaic (PV) device [1].

This project evaluates their robustness to reverse bias, light, and temperature cycling.



MEPV Overview

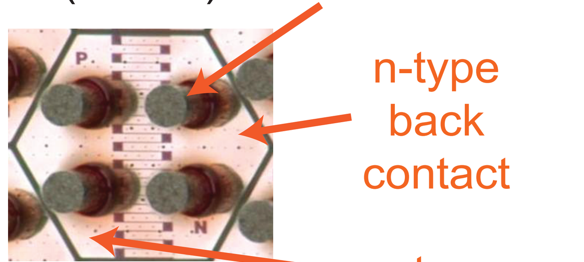


Top View (silicon)

metal pillar to substrate

Cross Section View

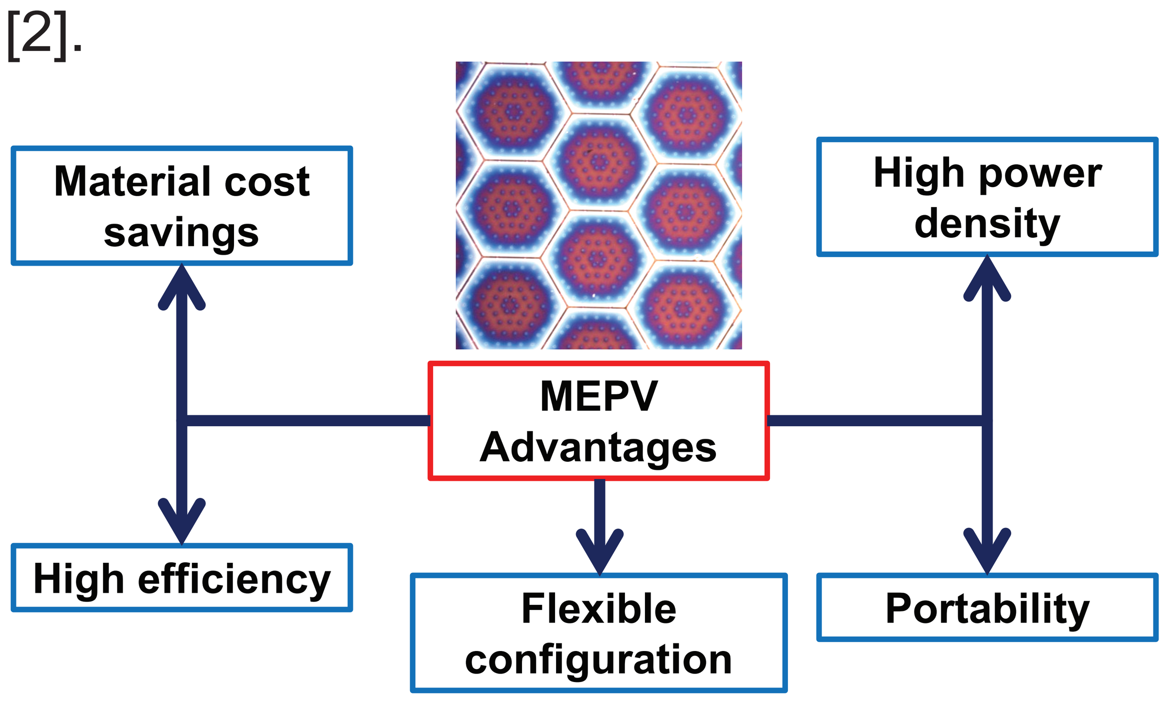
MEPV on flexible substrate (ruler in cm)



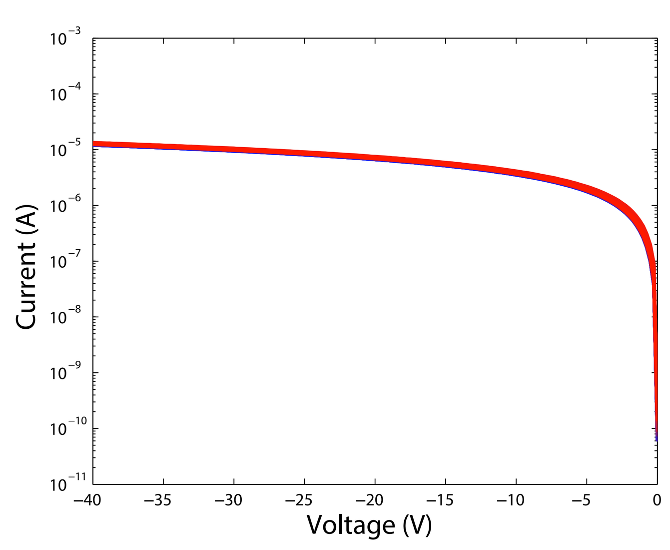
Bottom View (metal back contact)

MEPV uses semiconductor techniques to fabricate silicon solar cells that are 20 µm thick and 500 µm to 720 µm in diameter that can be interconnected into an array on a flexible substrate.

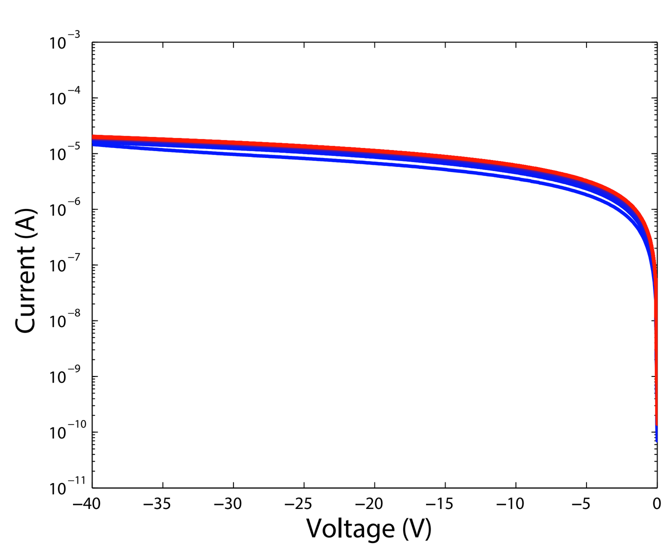
Scaling effects of the MEPV approach leads to several advantages [2].



Reverse Bias Results



Reverse bias IV of during -60 V stress over 300 hours, taken every two hours (blue = first trace, red = last trace). There was an 11% increase in reverse bias leakage current at -40 V.

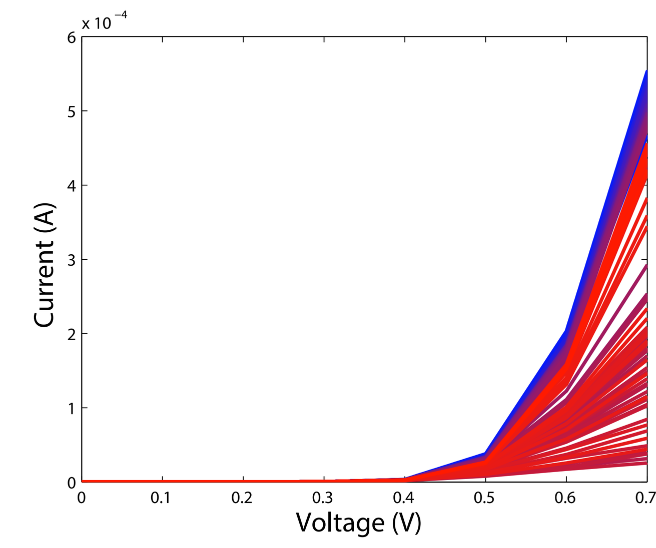


Reverse bias IV of during -55 V stress over 450 hours, taken every two hours. There was an initial increase in reverse bias leakage within the first 50 hours, followed by a slower and steady 11% increase after.

Reverse bias stress produced minor increases in reverse bias leakage current.

Rate of reverse bias leakage increase varies for different stress levels.

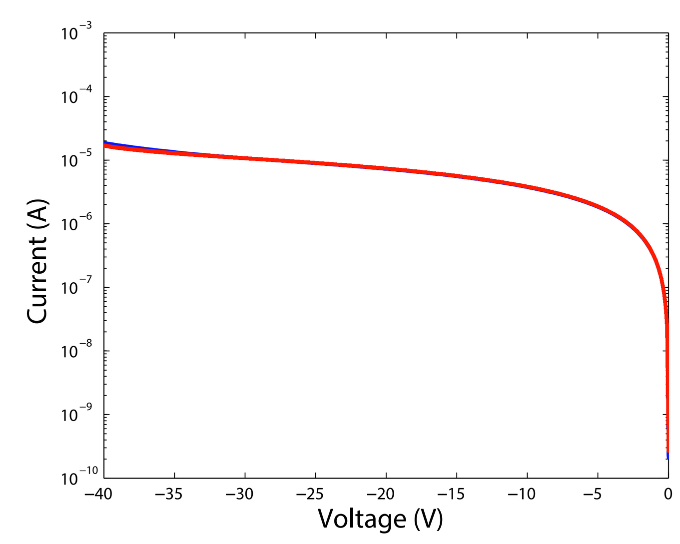
The forward dark IV indicates that, despite minor changes in reverse bias leakage, there may be a decrease in performance.



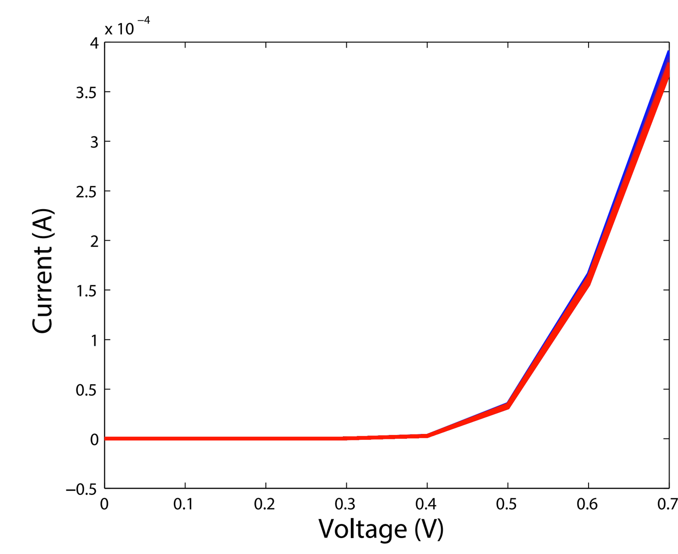
Forward bias IV measurements of -55 V reverse bias stress indicate potential decrease in fill factor.

Light-Induced Degradation Results

500 hours of exposure to a laser offering ~850X higher photon energy at 405 nm compared to AM1.5 revealed no significant changes in dark IV.



No change in reverse bias IV after 500 hours exposure to a 4.5 mW (~ 750W/mm^2) laser.



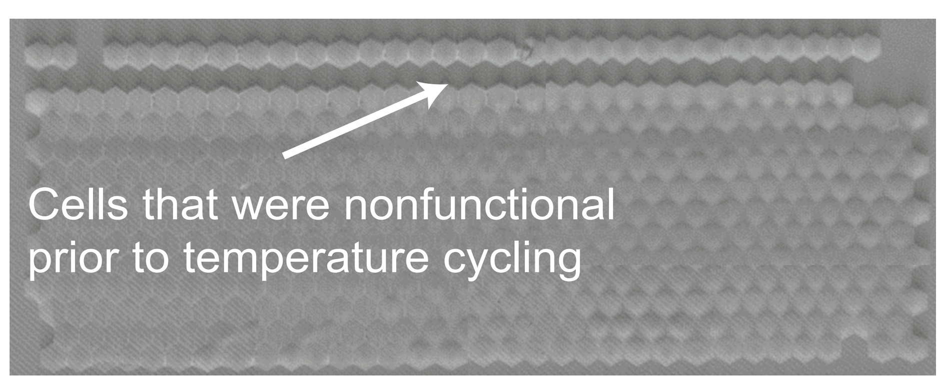
Slight decrease (5% lower output current at 0.7 V) in forward bias IV after 500 hours laser exposure.

Temperature Cycling Results

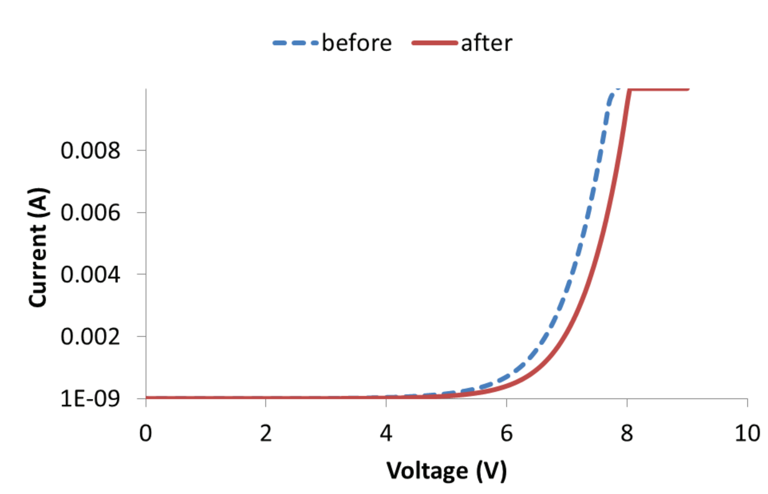
LIVA (a technique similar to OBIC [3]) was used to evaluate the functionality of over 400 MEPV cells before and after 250 cycles from -20°C to 50°C.

All cells were found to be functional after temperature cycling.

There was a slight improvement in overall module fill factor, potentially due to annealing that occured during high-temperature test steps.



LIVA image found no new failures after temperature cycling.



There was minor improvement in fill factor after temperature cycling.

Conclusions

MEPV was found to have good robustness to reverse bias stress, light-induced degradation, and outdoor-like temperature cycling.

Additional tests that evaluate module efficiency in-situ is needed to better understand the effects of the stress factors in this study.

Results of these and additional tests and different stress levels can be used to develop a reliability model associated with the stress factors in question.

[1] J. L. Cruz-Campa, G. N. Nielson, P. J. Resnick, C. A. Sanchez, P. J. Clews, M. Okandan, T. Friedmann, and V. P. Gupta, "Ultrathin Flexible Crystalline Silicon: Microsystems-Enabled Photovoltaics," IEEE Journal of Photovoltaics, vol. 1, no. 1, pp. 3 –8, Jul. 2011.

[2] G. N. Nielson, M. Okandan, J. L. Cruz-Campa, A. L. Lentine, W. C. Sweatt, V. P. Gupta, and J. S. Nelson, "Leveraging scale effects to create next-generation photovoltaic systems through micro- and nanotechnologies," Proceedings of SPIE, vol. 8373, pp. 837317–837317, May 2012.

[3] B. B. Yang, J. L. Cruz-Campa, G. S. Haase, E. I. Cole, P. Tangyunyong, P. J. Resnick, A. C. Kilgo, M. Okandan, and G. N. Nielson, "Failure Analysis Techniques for Microsystems-Enabled Photovoltaics," IEEE Journal of Photovoltaics, vol. 4, no. 1, pp. 470–476, Jan. 2014.vol. 4, no. 1, pp. 299–303, Jan. 2014.

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