SAND2013-6776P

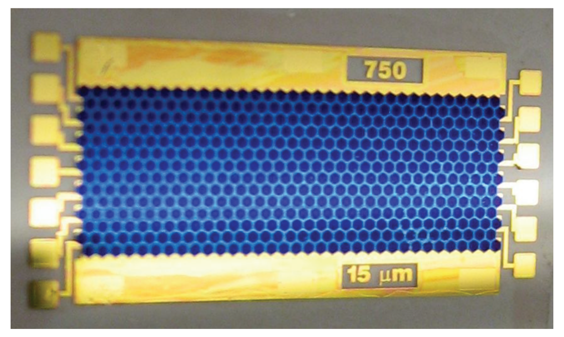
Exceptional service in the national interest

Sandia National Laboratories

Defect localization, characterization and reliability model development for microsystems-enabled photovoltaics

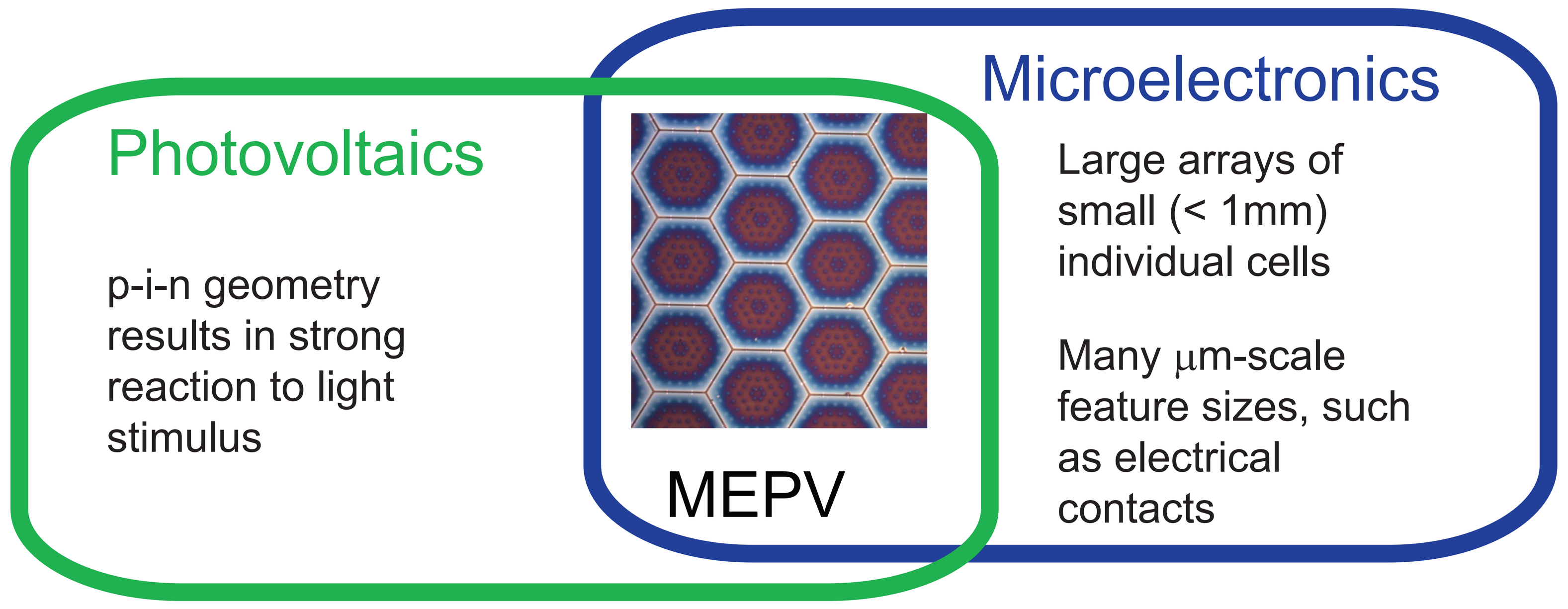
Benjamin B. Yang, Jose L. Cruz-Campa, Gaddi S. Haase, Edward I. Cole Jr., Paiboon Tangyunyong, Murat Okandan, Gregory N. Nielson

Introduction



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

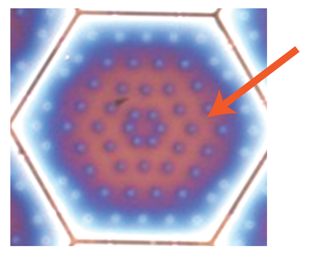
MEPV has unique failure analysis and reliability opportunities because it lies at the intersection of microelectronics and photovoltaics.



In this project, we successfully adapted failure analysis techniques for microelectronics for defect localization in MEPV.

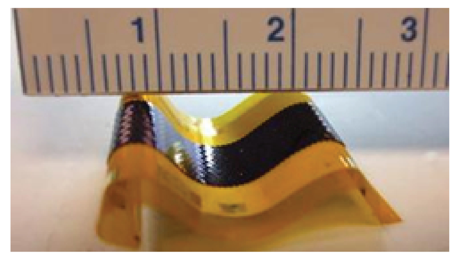
These techniques form a set of tools for building the first reliability model for MEPV, as demonstrated a case study establishing MEPV's robustness to reverse bias stress.

MEPV Overview



Top View (silicon)

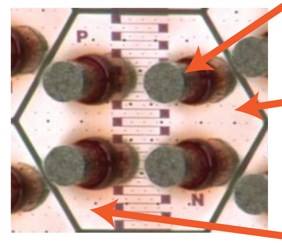
Cross Section View



MEPV on flexible substrate (ruler in cm)

silicon

metal pillar to substrate



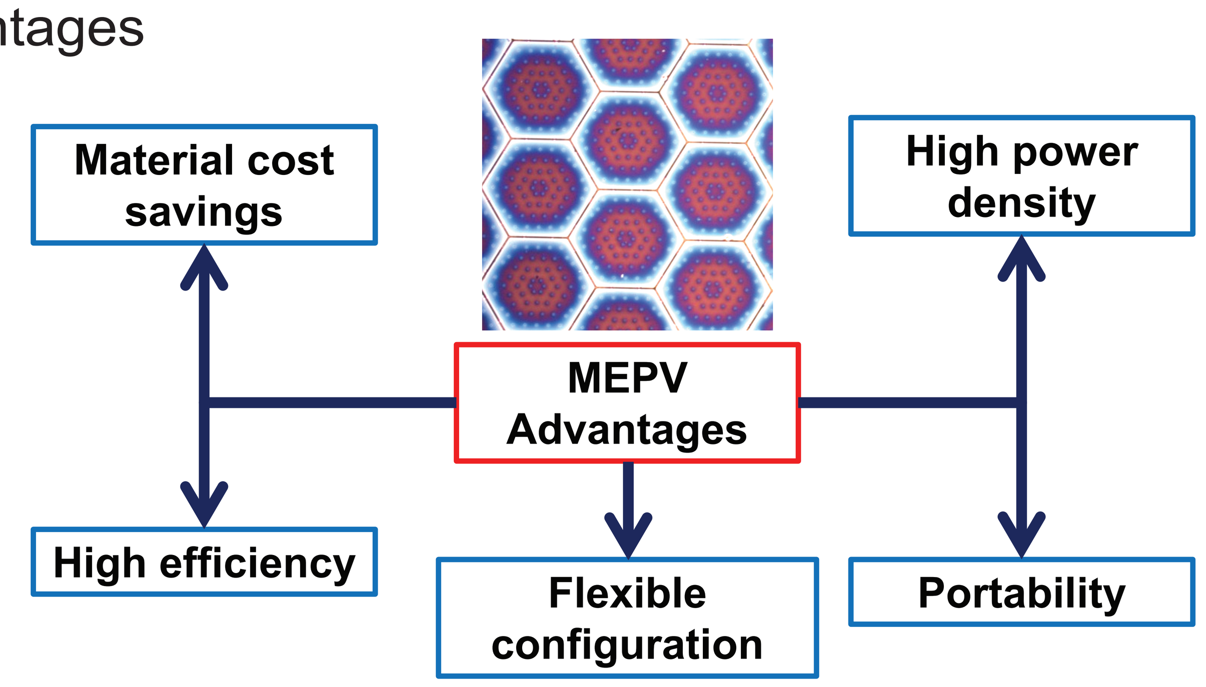
Bottom View (metal back contact)

n-type back contact

p-type 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.

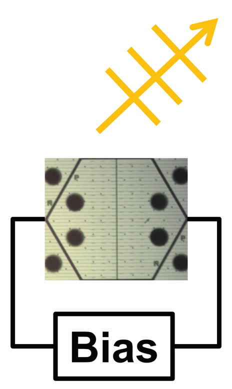
Scaling effects of the MEPV approach leads to several advantages



Failure Analysis Techniques

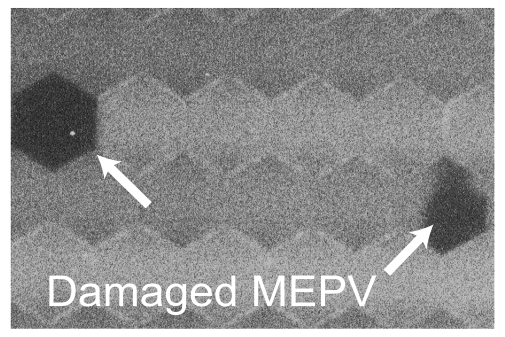
The following defect localization techniques were effective for MEPV:

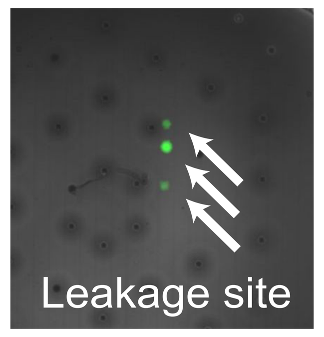
Electroluminescence (EL)



Forward Bias: Evaluates *cell functionality*

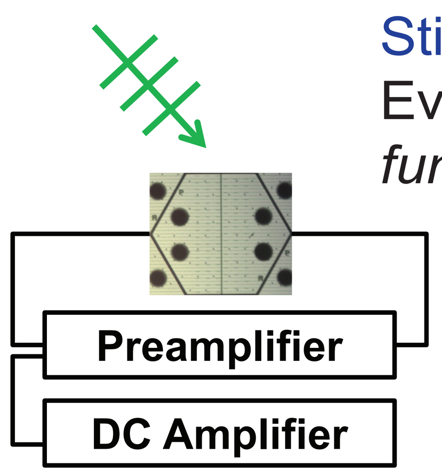
Reverse Bias: Localizes *avalanche breakdown* sites





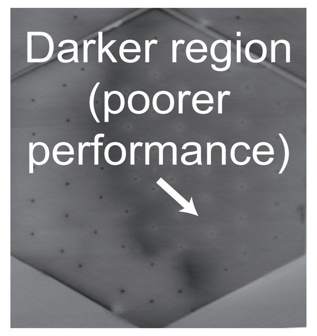
Optical Beam Induced Current (OBIC)

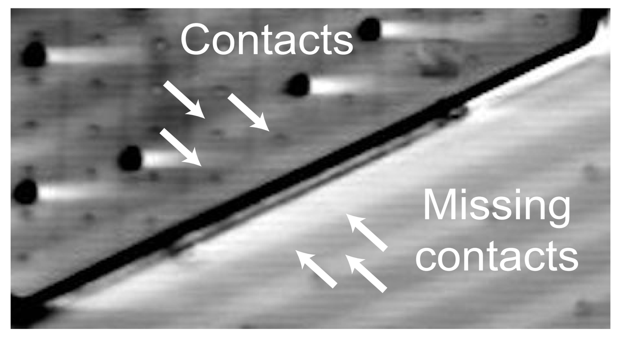
Discovered that DC amplification resulted in better performance than traditional AC filtering.



Stimulus > Band Gap: Evaluates *localized functionality* within cell

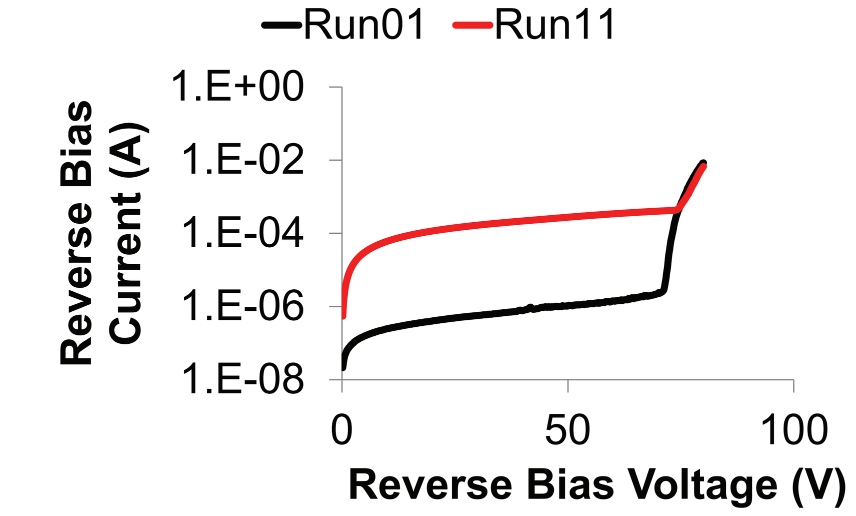
Stimulus < Band Gap: Evaluates *electrical contacts* and *leakage paths*

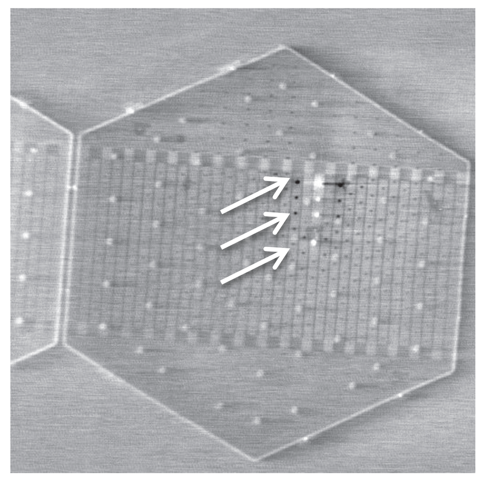




Reverse Bias Case Study

Found breakdown did not occur after > 10 reverse bias voltage sweeps up to 80V. Breakdown voltage found to be 75V.

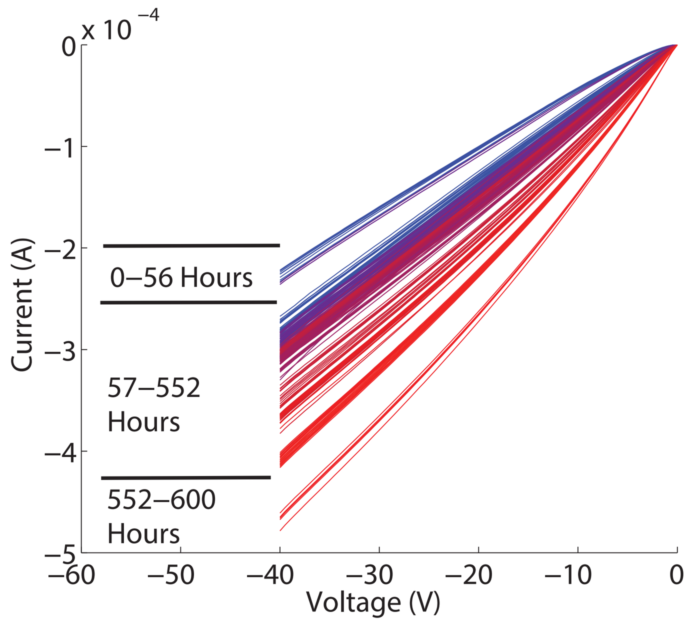




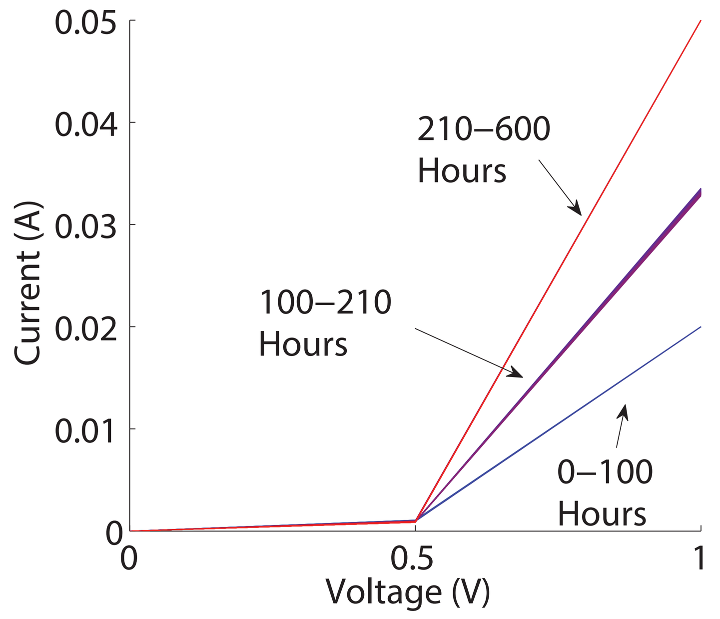
Resulting leakage sites can be identified through below band gap OBIC.

Strong reverse bias EL signal suggests avalanche breakdown.

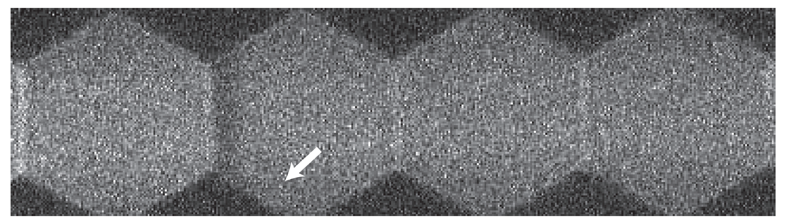
Repeated stress at lower voltages showed good resiliance to reverse bias stress.



Reverse bias IV



Forward bias IV



Each abrupt increase in forward bias current corresponds with new dark region under forward bias EL.

Summary

Microelectronic failure analysis techniques were succcessfully adapted for MEPV.

MEPV was demonstrated to have good robustness to reverse bias stress.

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2013

This project was supported by the Sandia National Laboratories Early Career Laboratory Directed Research and Development Program (EC LDRD).