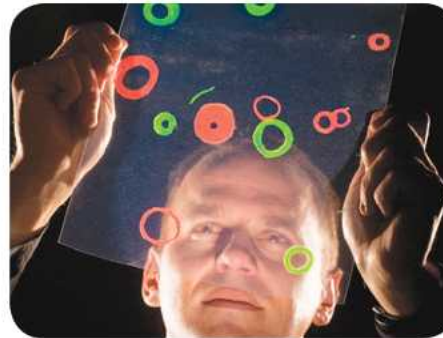


Exceptional service in the national interest



Comparison of Beam-Based Failure Analysis Techniques 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**

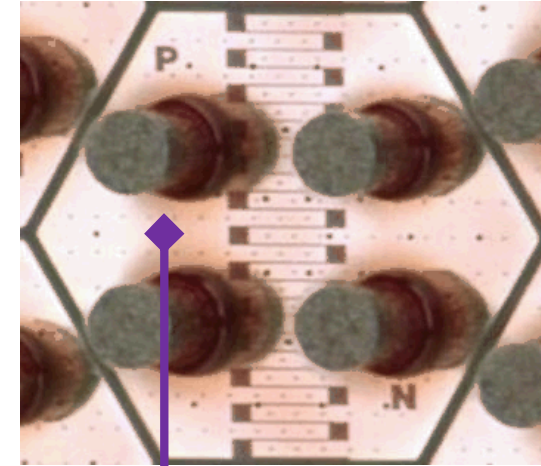
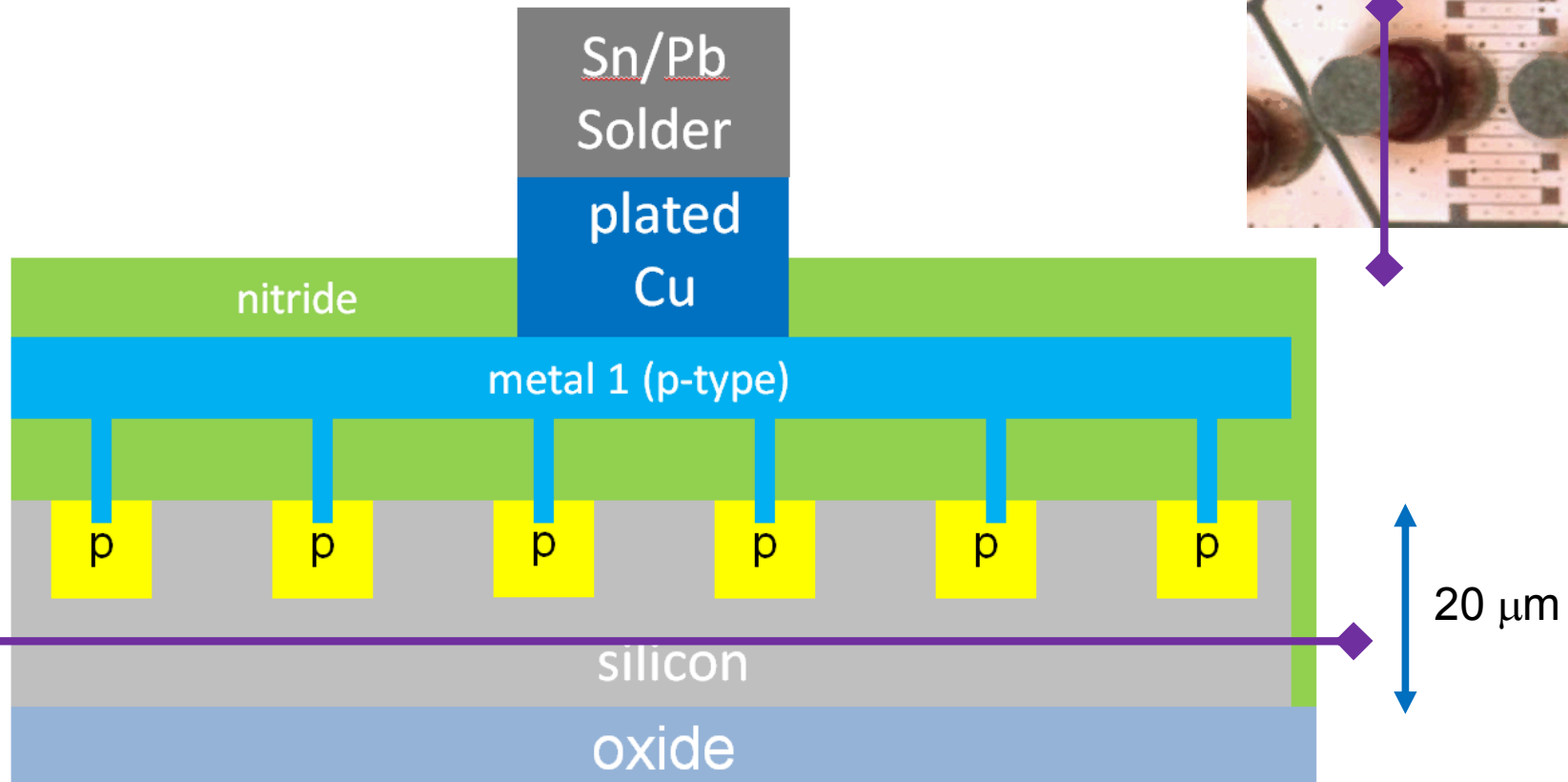
Presentation Outline

- MEPV Overview
- Defect Localization Techniques
- Comparison of Beam-Based Techniques
- Conclusion

What is a MEPV?

MEPV = **m**icrosystems-**e**nabled **p**hotov**v**oltaic

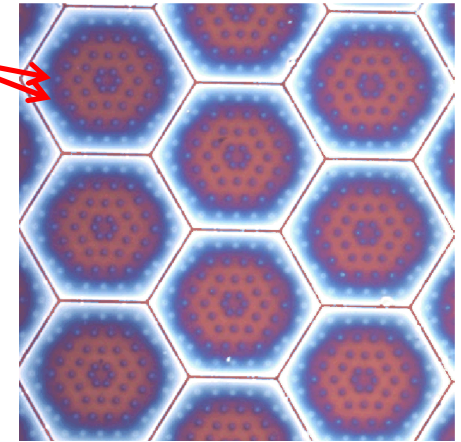
Initial fabrication on silicon-on-insulator wafer



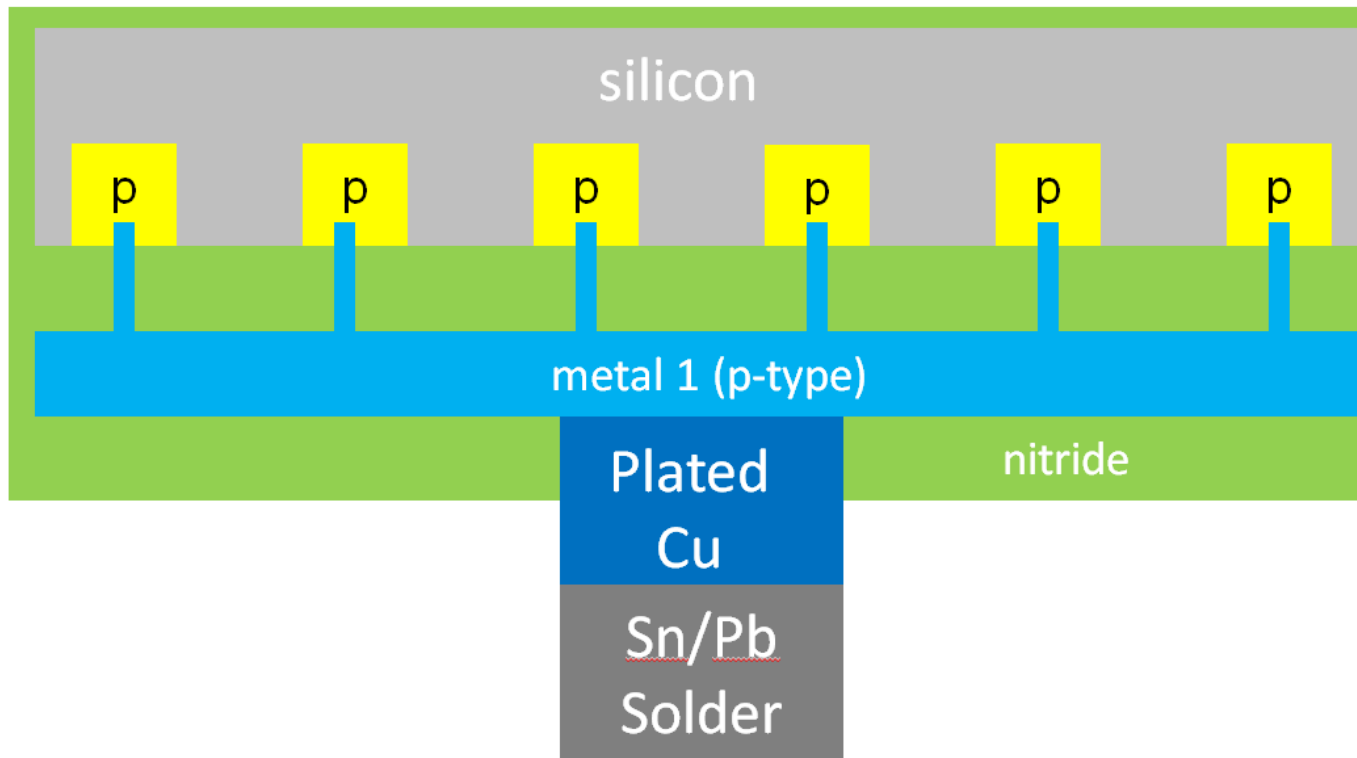
How are MEPVs Made?

Silicon layer is released and reattached to final substrate

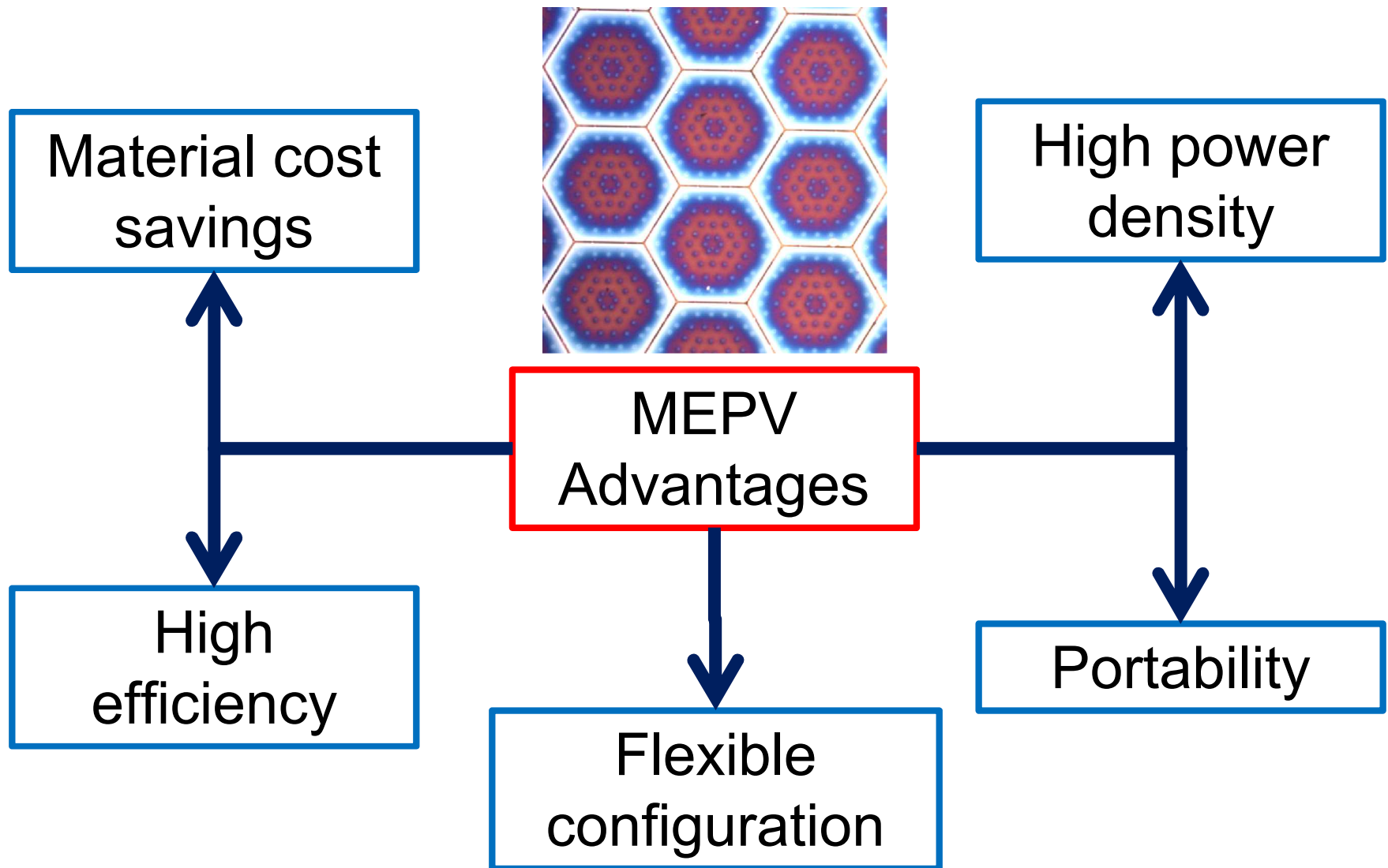
etch release
holes



1 mm

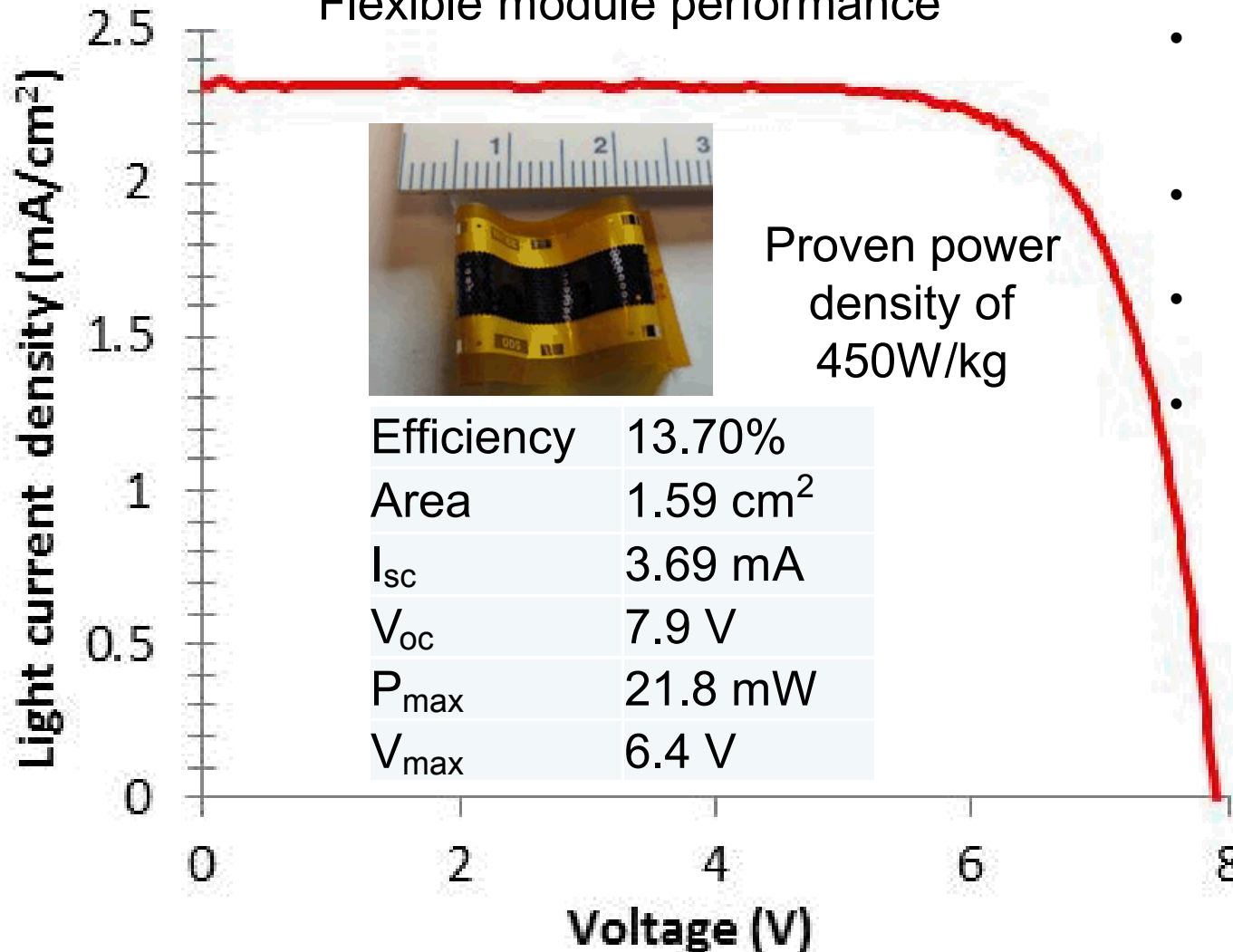


Why MEPVs?



MEPV's have achieved ultra low silicon usage and high power density

Flexible module performance



Proven power
density of
450W/kg

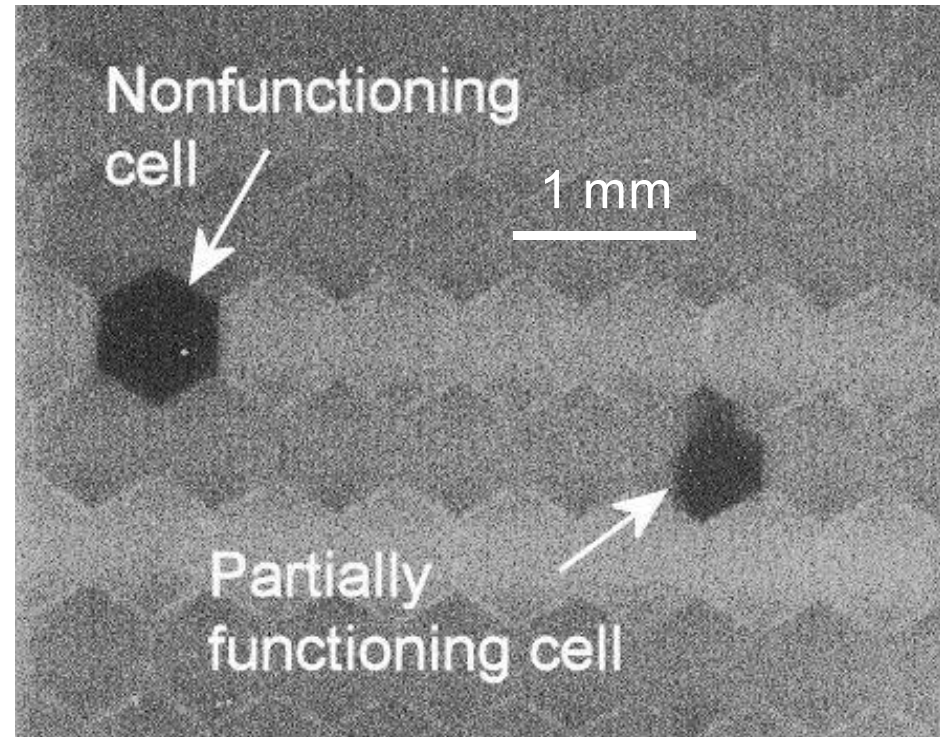
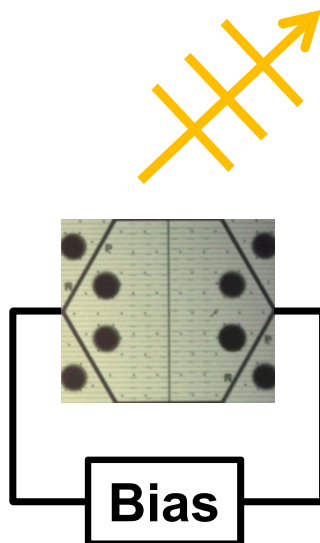
- 15% peak cell performance on rigid substrate.
- 10X improved power density
- 15x less material consumption
- Flexible substrate bend radius ~ 1mm

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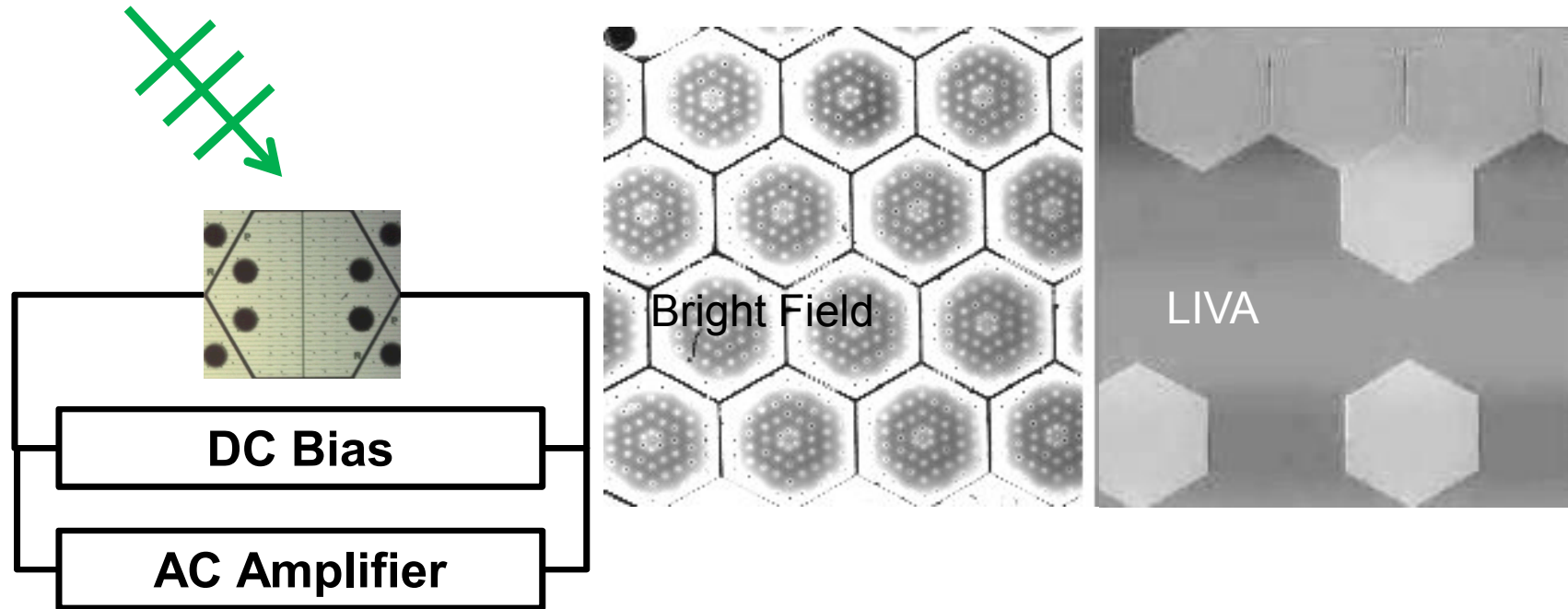
FA Techniques: Electroluminescence

EL image of array of interconnected MEPV



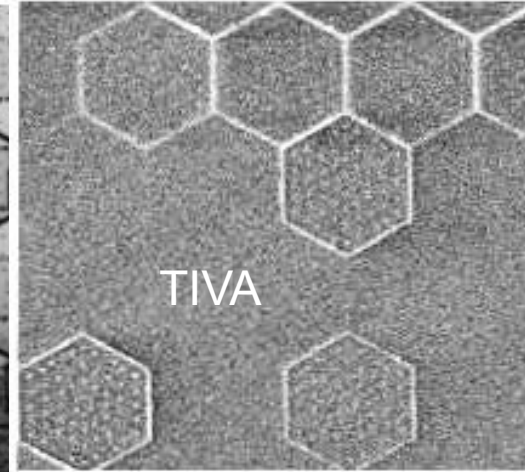
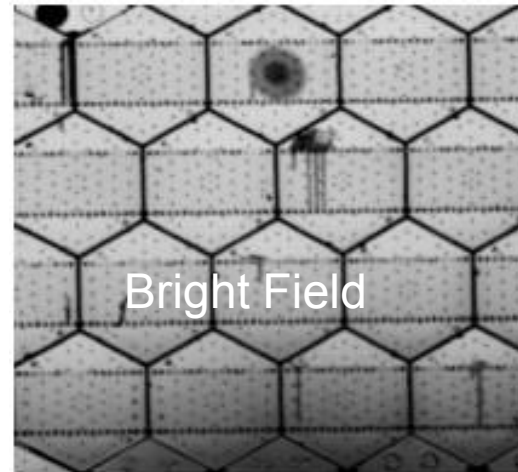
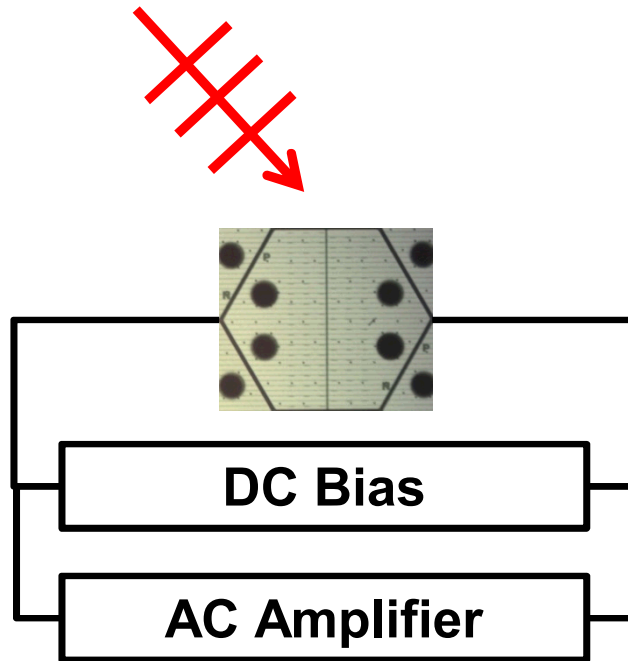
- Operation: Bias device and collect photons
 - **Forward Bias**: determine **functionality**
 - **Reverse Bias**: localize high **leakage currents**

FA Techniques: LIVA



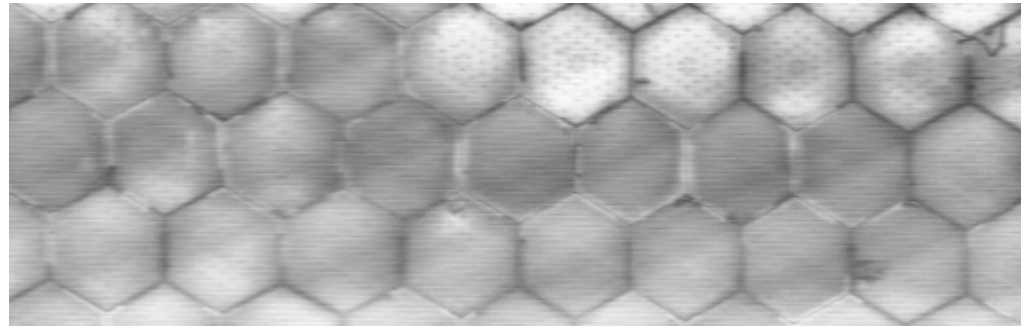
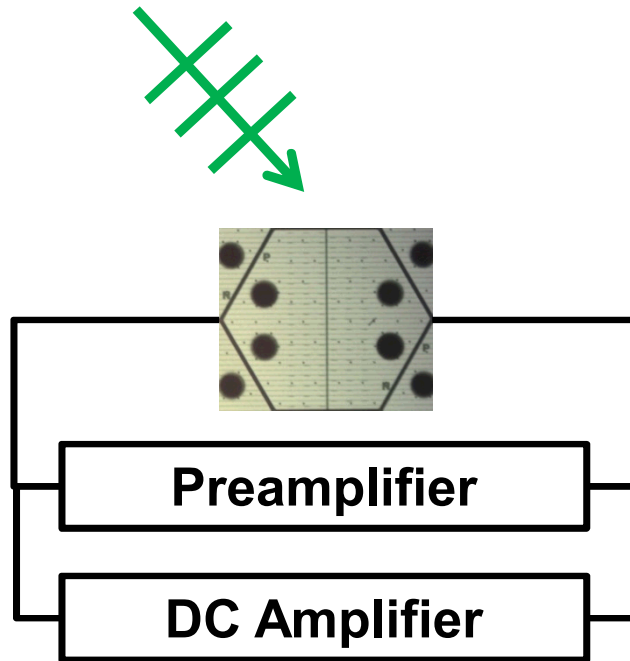
- **Wavelength**: Photon energy $>$ bandgap
- **Operation**: Plot AC amplifier output vs. laser position
- Determines functionality of cell

FA Techniques: TIVA



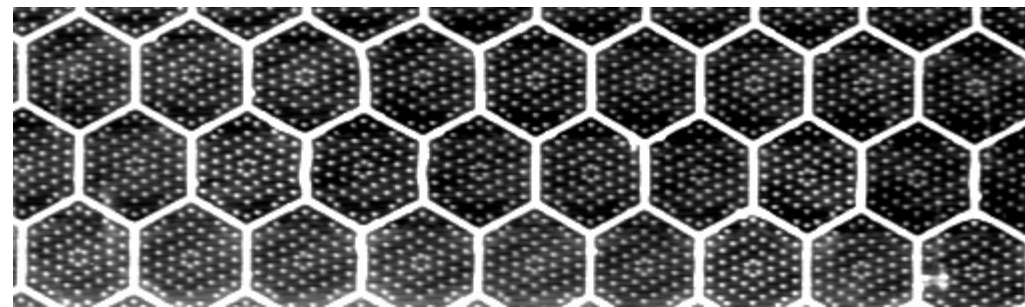
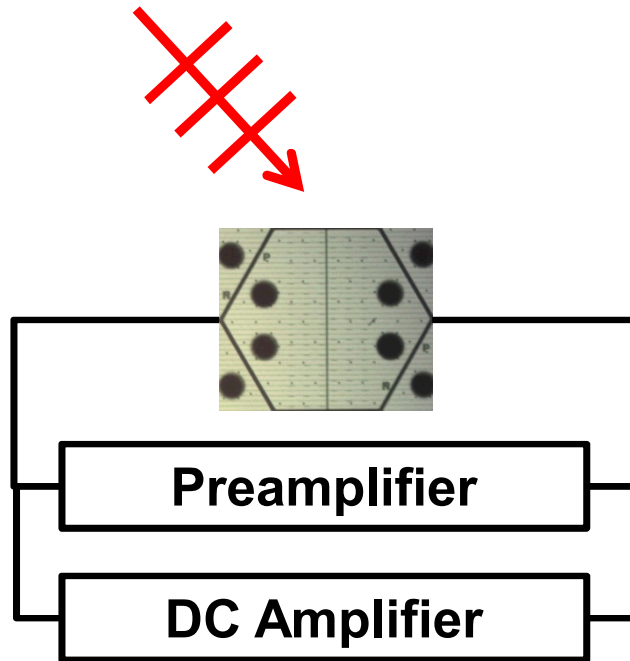
- **Wavelength:** Photon energy $<$ bandgap
- **Operation:** Plot AC amplifier output vs. laser position
- Determines electrical connectivity and identifies leakage paths

FA Techniques: Above-Band-Gap OBIC



- **Wavelength:** Photon energy $>$ bandgap
- **Operation:** Plot **DC amplifier output vs. laser position**
- Determines **localized efficiencies**

FA Techniques: Below-Band-Gap SEI

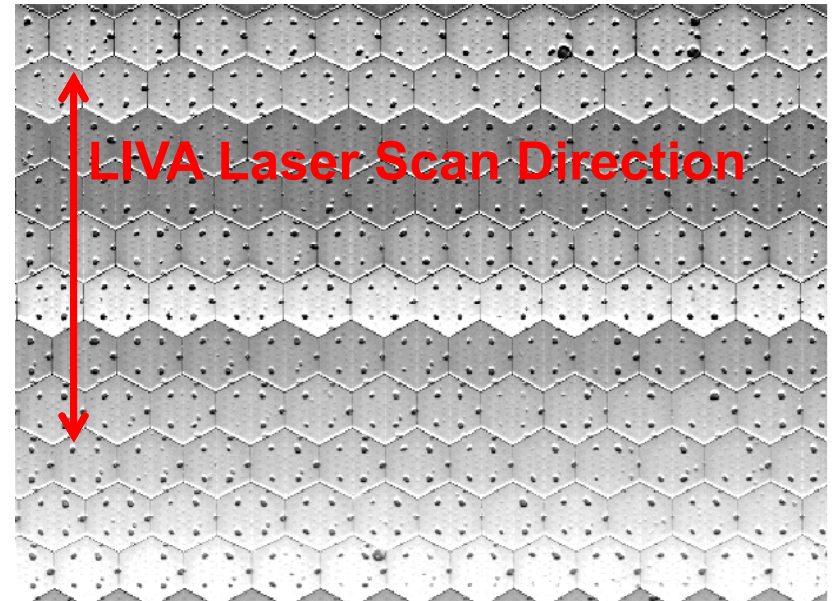
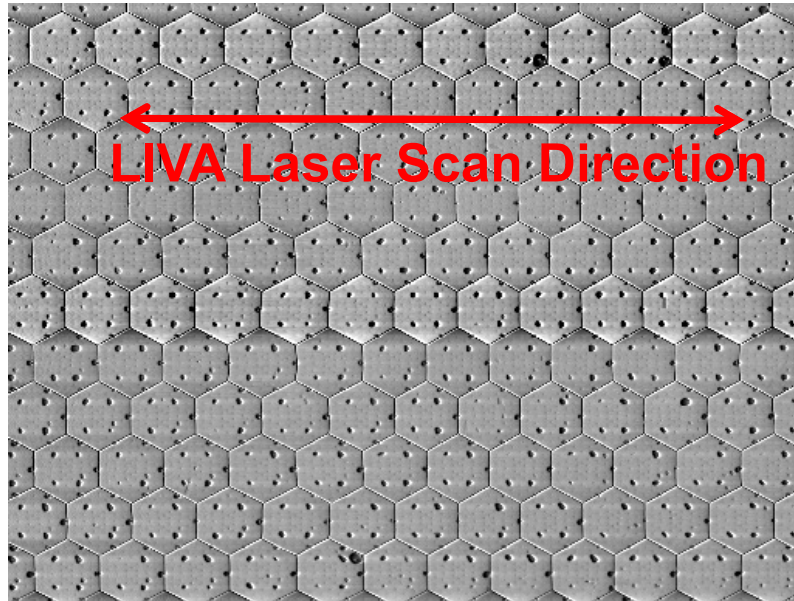


- **Wavelength:** Photon energy $<$ bandgap
- **Operation:** Plot AC amplifier output vs. laser position
- Determines electrical connectivity and identifies leakage paths

Presentation Outline

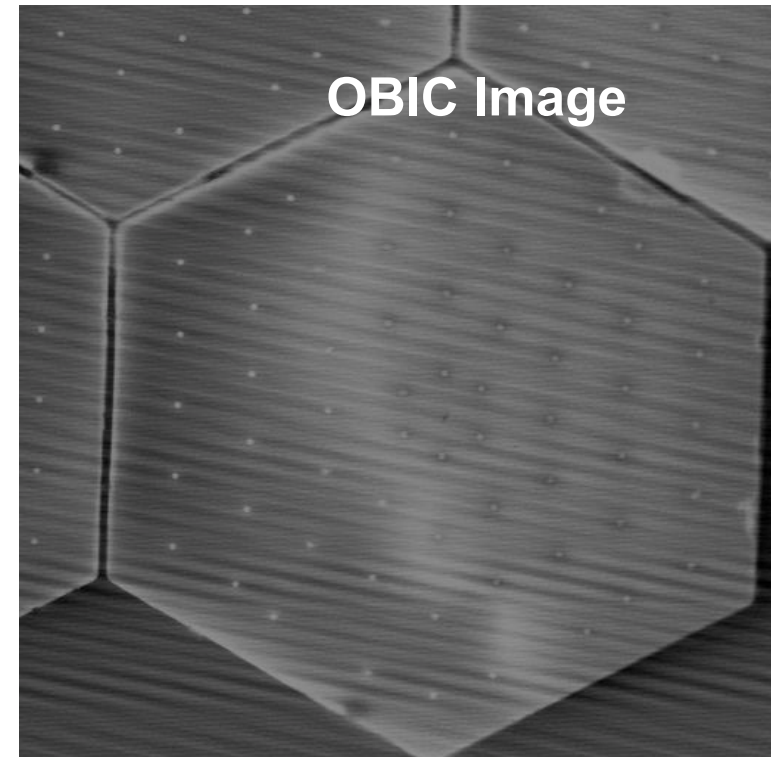
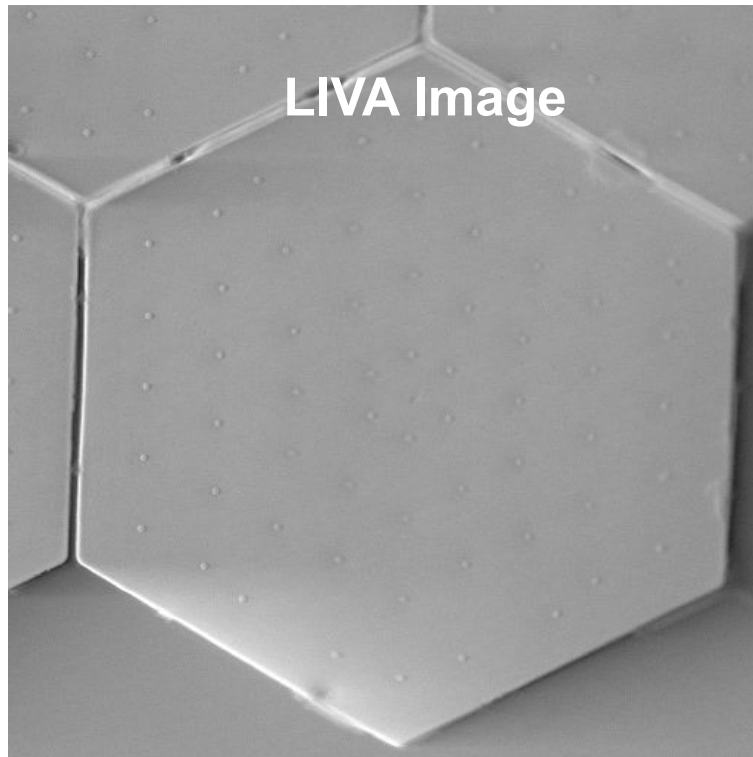
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Downside of LIVA



- LIVA's ability to identify different performance depends on scan direction.
- Above-band gap OBIC does not have this issue.

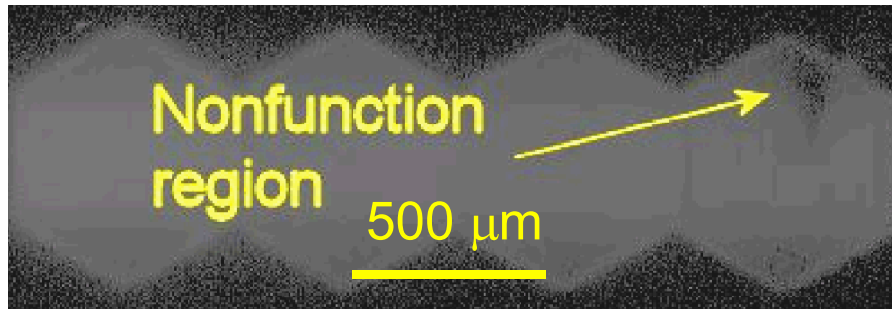
LIVA vs. Above-Bandgap OBIC



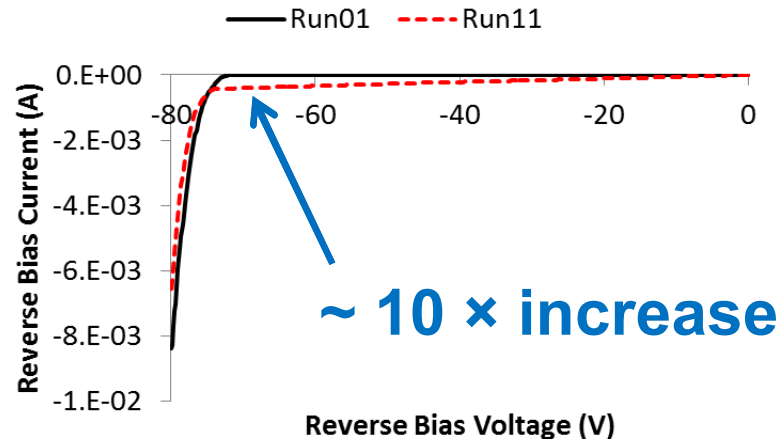
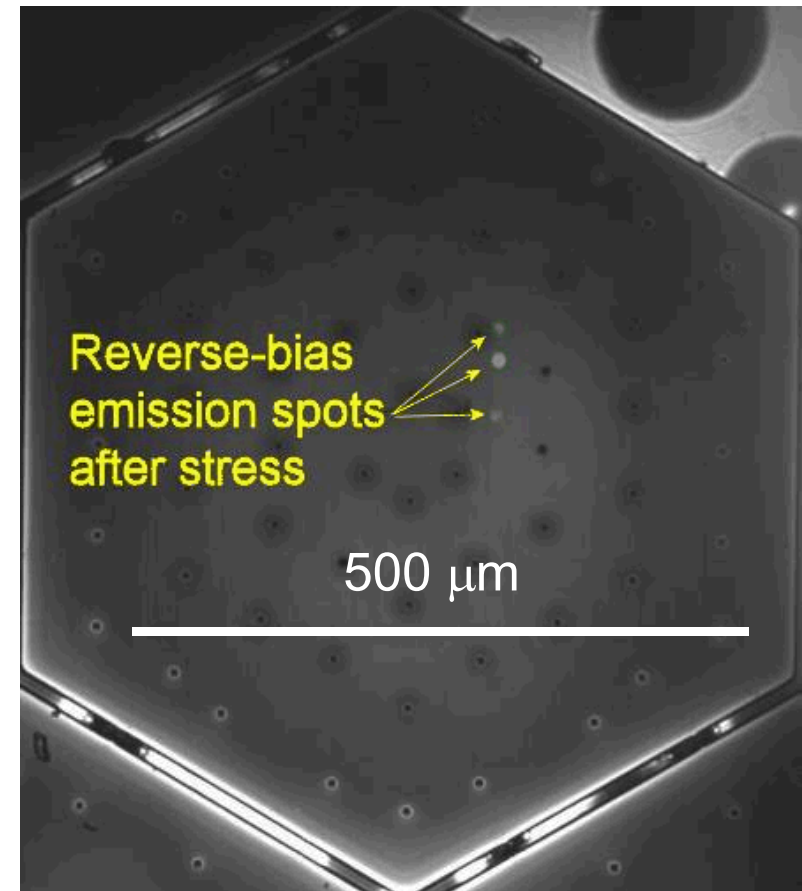
- **LIVA** can only confirm **cell functionality**.
- **Above-bandgap OBIC** is able to **discern localized efficiency** within the cell.

High Reverse Bias Stress: Post-Stress FA

Forward Bias EL

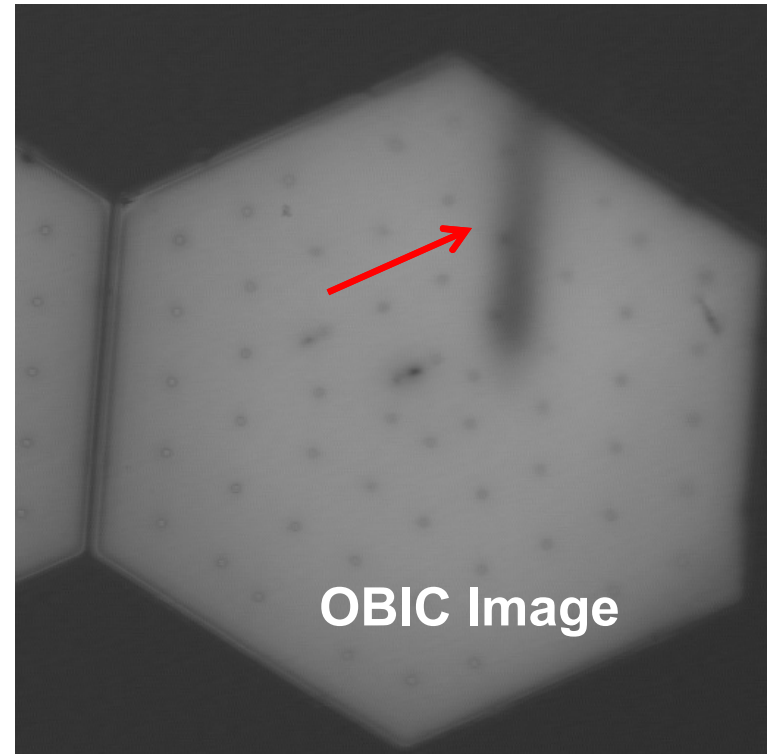
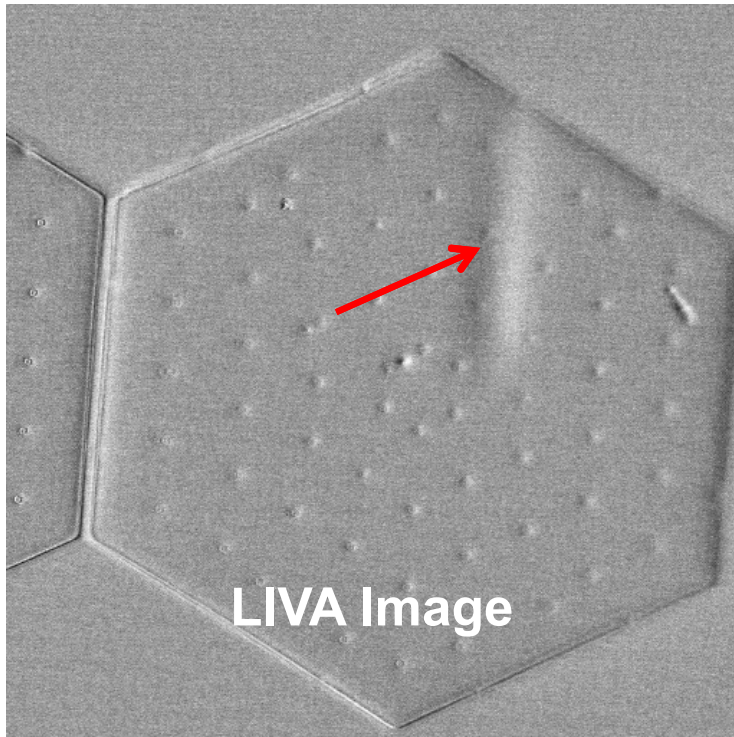


Reverse Bias EL



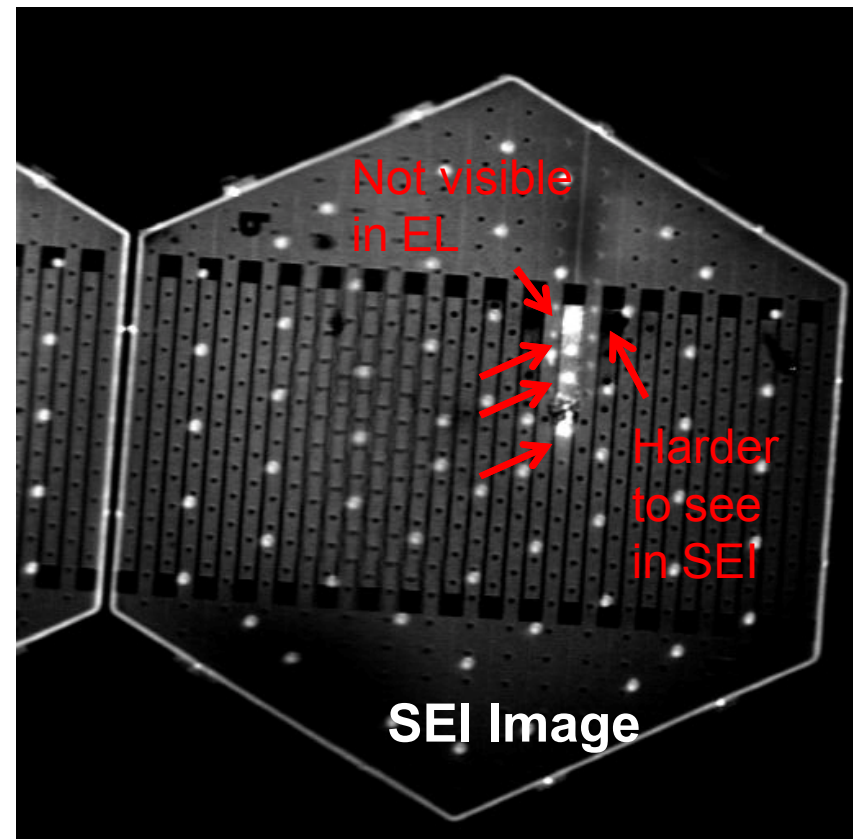
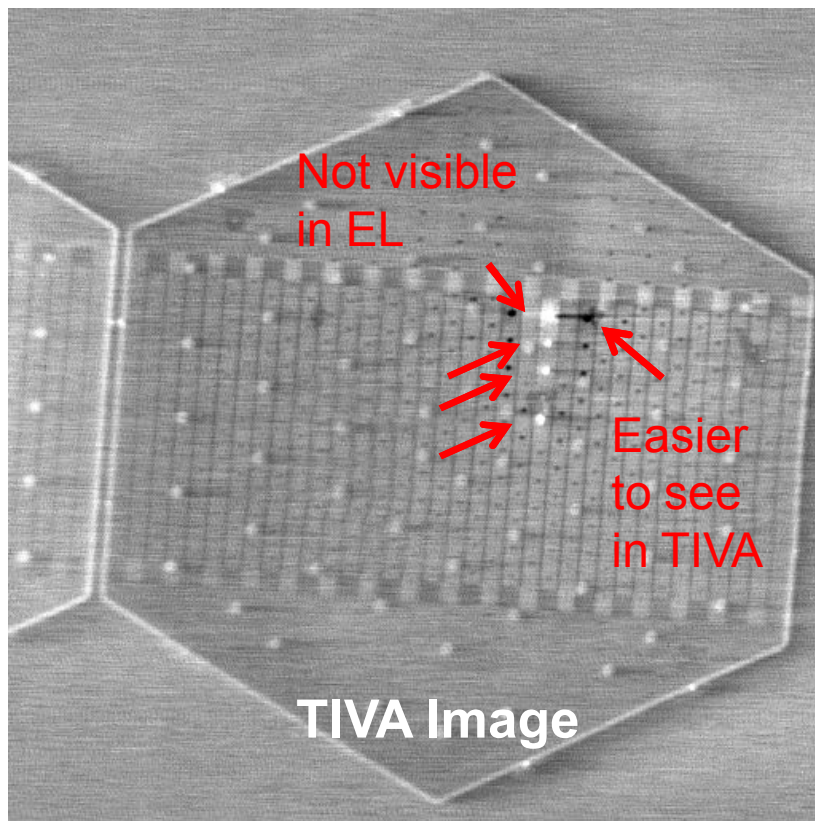
- Breakdown site localized with EL.
- Strong EL signal suggests avalanche breakdown.

LIVA vs. Above-Bandgap OBIC



- Both LIVA and Above-Bandgap OBIC were able to identify defect.
- Matches Forward-Bias EL result.

TIVA vs. Below-Bandgap SEI



- Both **TIVA** and **Below-Bandgap SEI** were able to identify more leakage paths than reverse bias EL
- Additional contact damage more visible in TIVA.

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Conclusions

- MEPV is a microfabricated solar cell with dimensions suitable for CMOS FA
- In general DC amplification (OBIC/SEI) more effective than AC amplification (LIVA/TIVA)
 - Possibly due to lack of transistor amplification
 - Some defects more visible in TIVA than SEI
 - OBIC offers additional fidelity compared to EL, LIVA does not.
- Beam-based techniques coupled with EL are effective defect localization methods for MEPV