Webinar
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pv magazine webinars

Quantify the impacts of cell cracking in the field

25 May 2020

4 PM – 5 PM | CEST, Berlin
10 AM – 11 AM | EDT, New York
7.30 PM – 8.30 PM | IST, India

Mark Hutchins
Editor | pv magazine

Lou Trippel
First Solar

Tristan Erion-Lorico
PVEL

Anil Kottantharayil
IIT Bombay

Prakash Suratkar
PV Diagnostics

Si PV Modules – Microcracks and Power Loss

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PV Magazine Cell Cracking Webinar – 25 May 2020

National Centre for Photovoltaic Research and Education

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Ministry of New and Renewable Energy (MNRE)

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at

IIT Bombay

In existence since 2010

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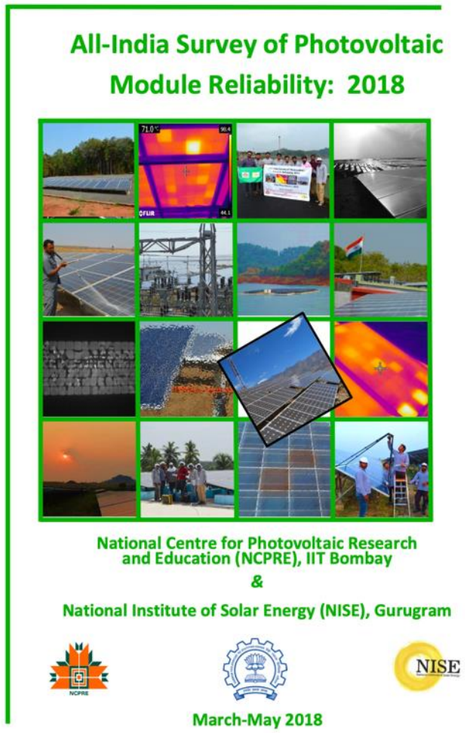
About 156 students working on Solar PV

- Education & Training
- Advanced Si-Solar cell
- Thin Film Devices
- Energy Storage
- Power Electronics
- PV Module Reliability
- Industry Affiliate Program & Industry Interaction

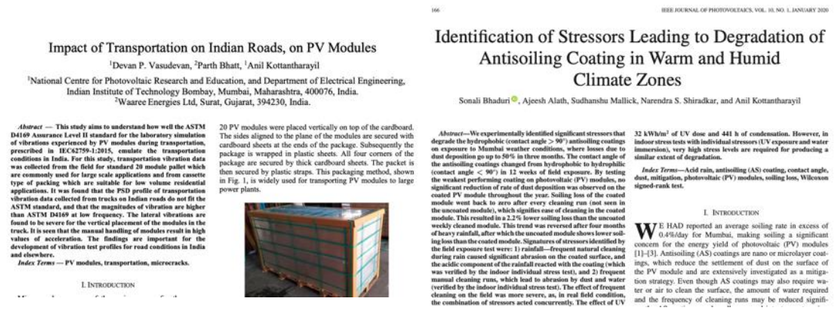
PV Module Reliability @ NCPRE



All India Surveys of PV Module Reliability – 2013, 2014, 2016, 2018

Laboratory and outdoor test facilities for modules

Field test services for industry



Impact of Transportation on Indian Roads, on PV Modules

[1]Devan P. Vasudevan, [2]Parth Bhatt, [1]Anil Kottantharayil

[1]National Centre for Photovoltaic Research and Education, and Department of Electrical Engineering, Indian Institute of Technology Bombay, Mumbai, Maharashtra, 400076, India.
[2]Waaree Energies Ltd, Surat, Gujarat, 394230, India.

Abstract — This study aims to understand how well the ASTM D4169 Assurance Level II standard for the laboratory simulation of vibrations experienced by PV modules during transportation, prescribed in IEC62759-1:2015, emulate the transportation conditions in India. For this study, transportation vibration data was collected from the field for standard 20 module pallet which are commonly used for large scale applications and from cassette type of packing which are suitable for low volume residential applications. It was found that the PSD profile of transportation vibration data collected from trucks on Indian roads do not fit the ASTM standard, and that the magnitudes of vibration are higher than ASTM D4169 at low frequency. The lateral vibrations are found to be severe for the vertical placement of the modules in the truck. It is seen that the manual handling of modules result in high values of acceleration. The findings are important for the development of vibration test profiles for road conditions in India and elsewhere.

Index Terms — PV modules, transportation, microcracks.

I. Introduction

20 PV modules were placed vertically on top of the cardboard. The sides aligned to the plane of the modules are secured with cardboard sheets at the ends of the package. Subsequently the package is wrapped in plastic sheets. All four corners of the package are secured by thick cardboard sheets. The packet is then secured by plastic straps. This packaging method, shown in Fig. 1, is widely used for transporting PV modules to large power plants.

166 IEEE JOURNAL OF PHOTOVOLTAICS, VOL. 10, NO. 1, JANUARY 2020

Identification of Stressors Leading to Degradation of Antisoiling Coating in Warm and Humid Climate Zones

Sonali Bhaduri, Ajeesh Alath, Sudhanshu Mallick, Narendra S. Shiradkar, and Anil Kottantharayil

Abstract—We experimentally identified significant stressors that degrade the hydrophobic (contact angle > 90°) antisoiling coatings on exposure to Mumbai weather conditions, where losses due to dust deposition go up to 50% in three months. The contact angle of the antisoiling coatings changed from hydrophobic to hydrophilic (contact angle < 90°) in 12 weeks of field exposure. By testing the weakest performing coating on photovoltaic (PV) modules, no significant reduction of rate of dust deposition was observed on the coated PV module throughout the year. Soiling loss of the coated module went back to zero after every cleaning run (not seen in the uncoated module), which signifies ease of cleaning in the coated module. This resulted in a 2.2% lower soiling loss than the uncoated weekly cleaned module. This trend was reversed after four months of heavy rainfall, after which the uncoated module shows lower soiling loss than the coated module. Signatures of stressors identified by the field exposure test were: 1) rainfall—frequent natural cleaning during rain caused significant abrasion on the coated surface, and the acidic component of the rainfall reacted with the coating (which was verified by the indoor individual stress test), and 2) frequent manual cleaning runs, which lead to abrasion by dust and water (verified by the indoor individual stress test). The effect of frequent cleaning on the field was more severe, as, in real field condition, the combination of stressors acted concurrently. The effect of UV 32 kWh/m² of UV dose and 441 h of condensation. However, in indoor stress tests with individual stressors (UV exposure and water immersion), very high stress levels are required for producing a similar extent of degradation.

Index Terms—Acid rain, antisoiling (AS) coating, contact angle, dust, mitigation, photovoltaic (PV) modules, soiling loss, Wilcoxon signed-rank test.

I. Introduction

WE HAD reported an average soiling rate in excess of 0.4%/day for Mumbai, making soiling a significant concern for the energy yield of photovoltaic (PV) modules [1]–[3]. Antisoiling (AS) coatings are nano or microlayer coatings, which reduce the settlement of dust on the surface of the PV module and are extensively investigated as a mitigation strategy. Even though AS coatings may also require water or air to clean the surface, the amount of water required and the frequency of cleaning runs may be reduced signifi-

Development of new standards for Indian conditions

Development of tools for testing

SOLAR MARQ

PVDiagnostics

AirProbe

A stethoscope for Solar PV plants

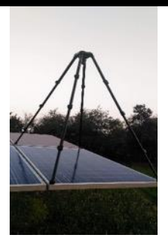
Sun Connect India

Mentoring of startups

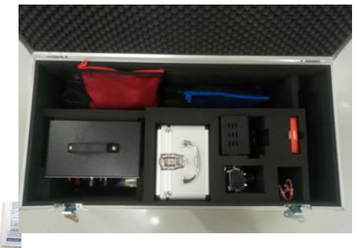
NCPRE

Activities Specific to Microcracks

- On-site in-plant EL measurements



- Developed low cost EL camera and kit

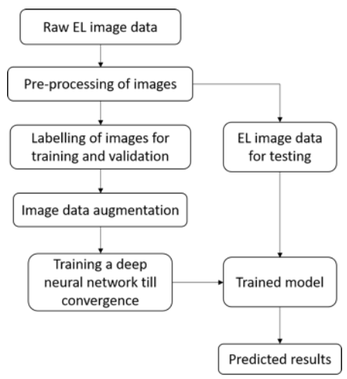


- Developed Dynamic Mechanical Loading test equipment

- Environmental stress after mechanical stress

- Transportation studies

- Machine Learning for crack detection from EL images



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Micro-Cracks in Si PV – How Does It Happen?

- Cell manufacturing processes – e.g. texturization
- Module manufacturing processes – e.g. soldering
- Module handling for test & packaging
- Module transportation
- Installation
- Maintenance – e.g. cleaning of panels
- Hail, wind, snow & sand loading
- Thermal cycling during operation

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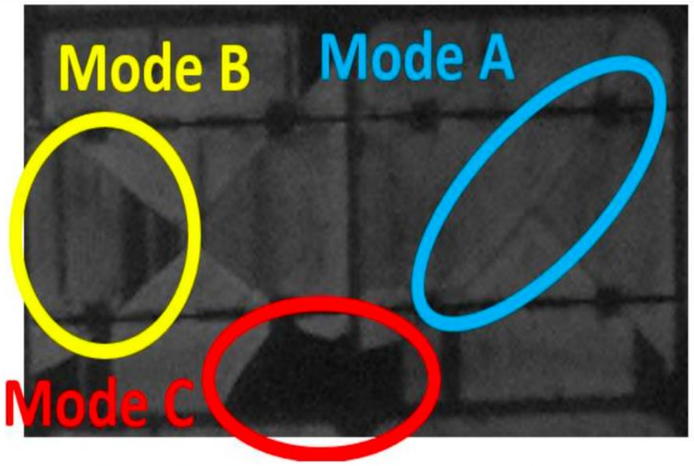
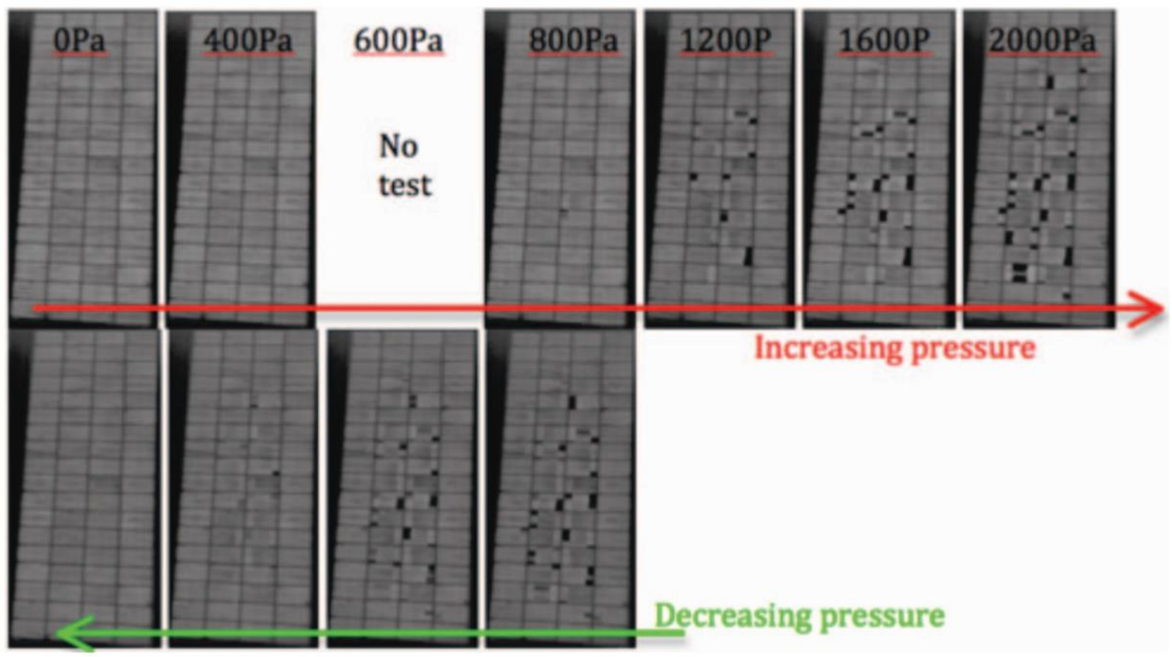
Micro-Cracks in Si PV – Electroluminescence Images



All India Survey of Photovoltaic Module Reliability 2018, NCPRE, IIT Bombay



A. M. Gabor, et al., IEEE 43rd PVSC, 2016.

Interesting video from NREL:
https://www.youtube.com/watch?v=-qdyxIybmoc

- Appearance of cracks in EL images decided by the pressure on the panel at the time of imaging
- The same applies to impact of cracks on performance

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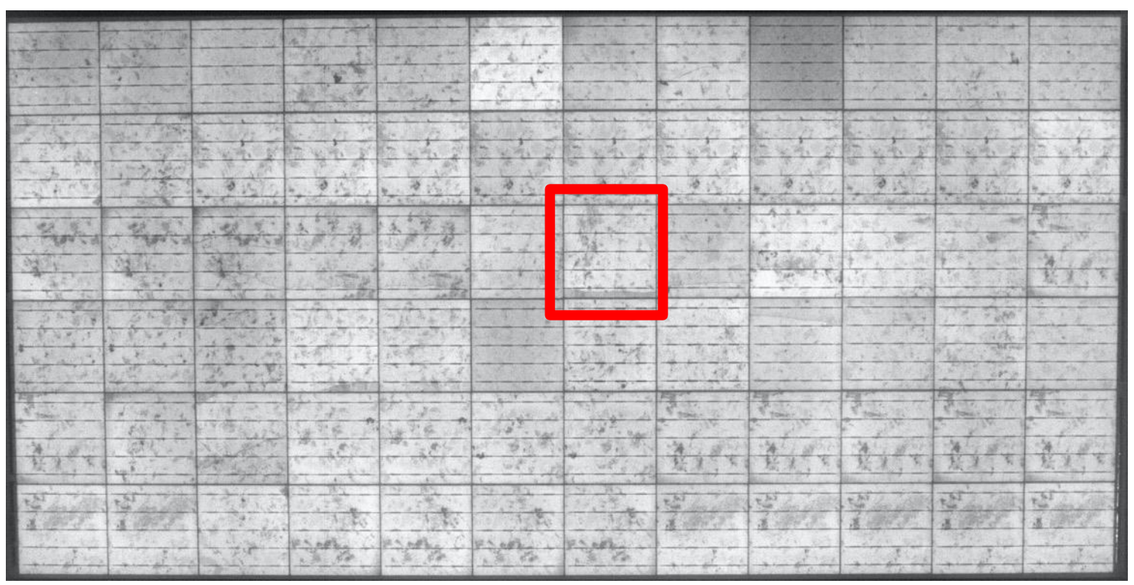
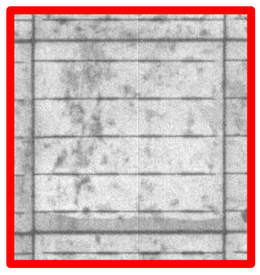
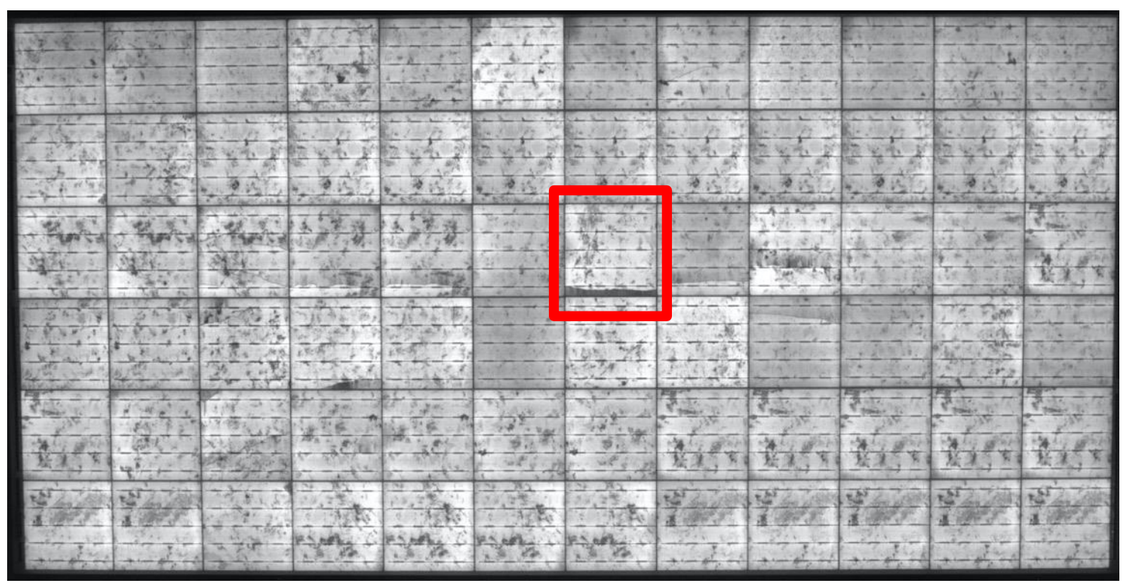
Micro-Cracks in Si PV – Electroluminescence Images

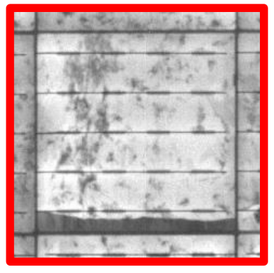
EL at 30% of Isc





EL at Isc: Cracks and other defects are more visible





- Appearance of cracks in EL image is decided by the current at which EL image is taken
- The same applies to impact of cracks on performance

Devan Vasudevan, NCPRE, IIT Bombay

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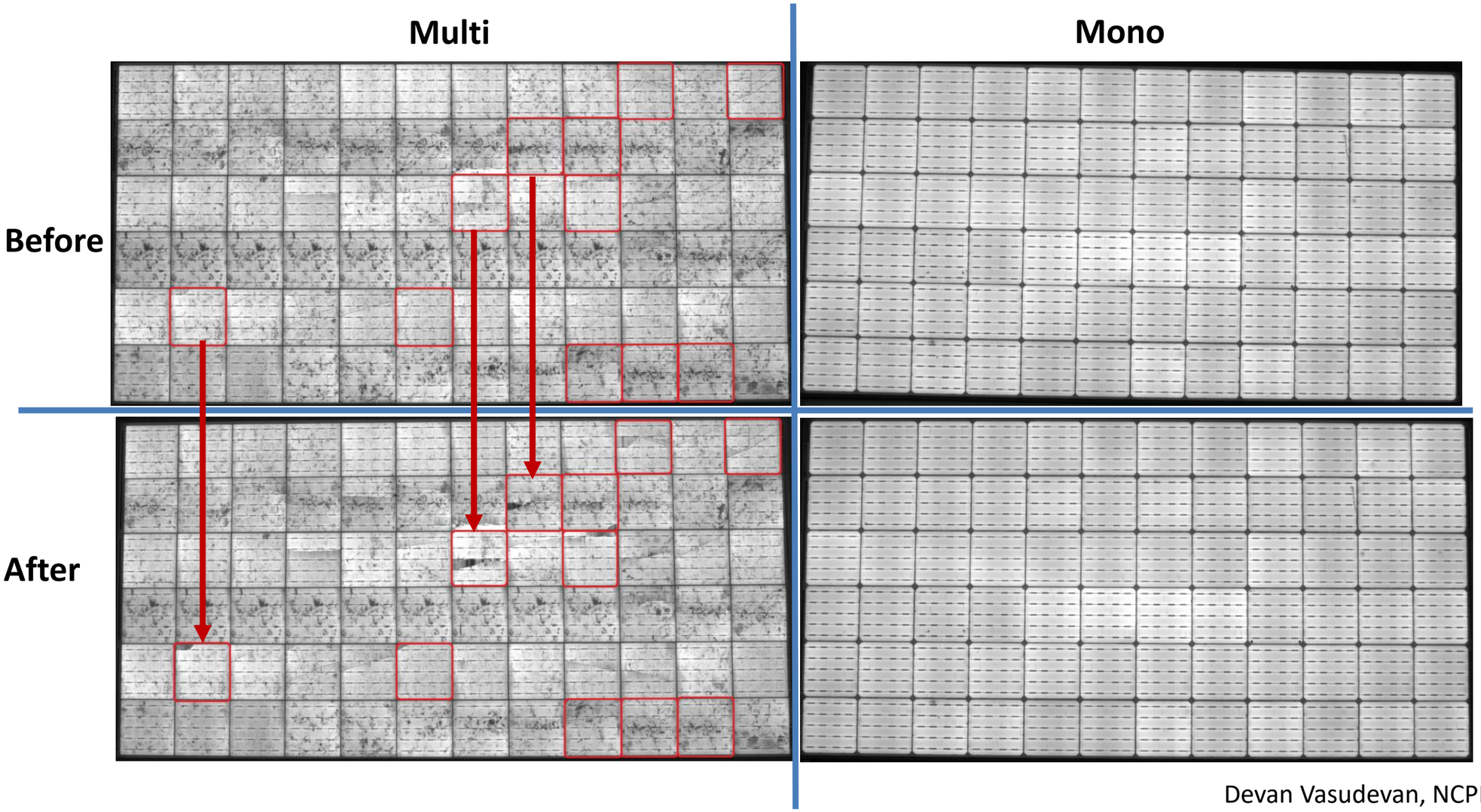
Mono versus Multi Crystalline Silicon

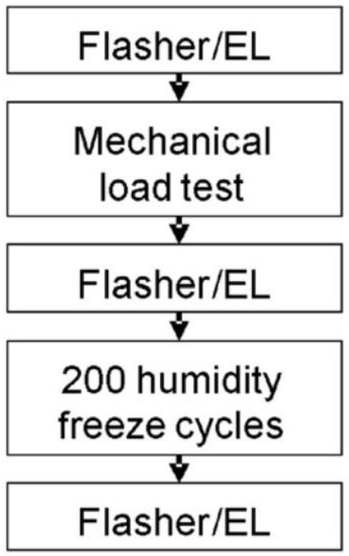
Modules subjected to identical transportation stress.

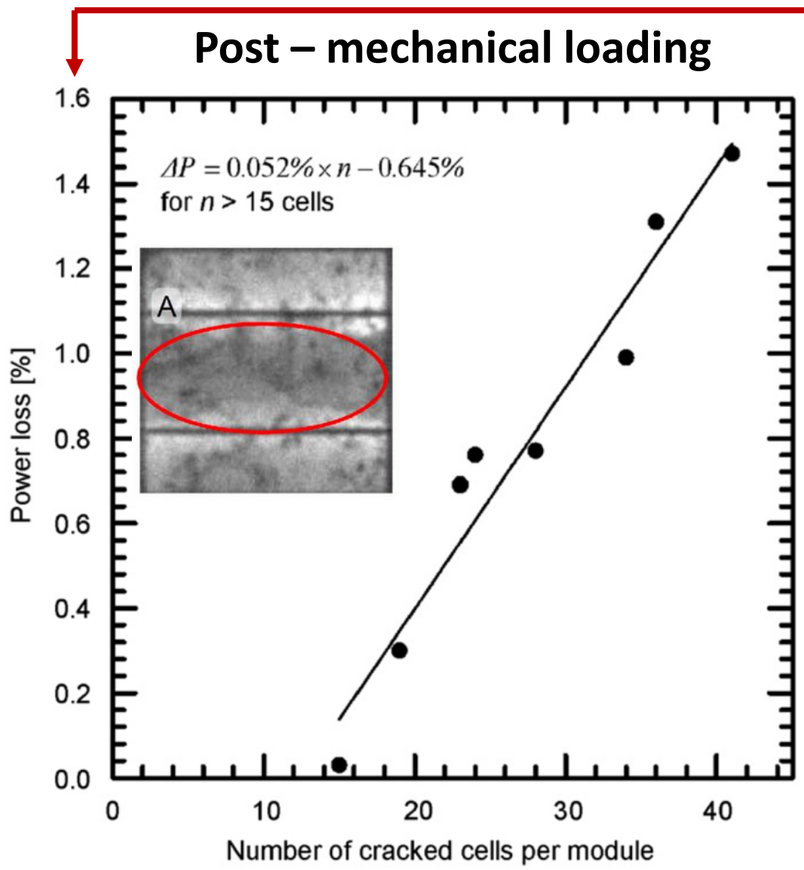


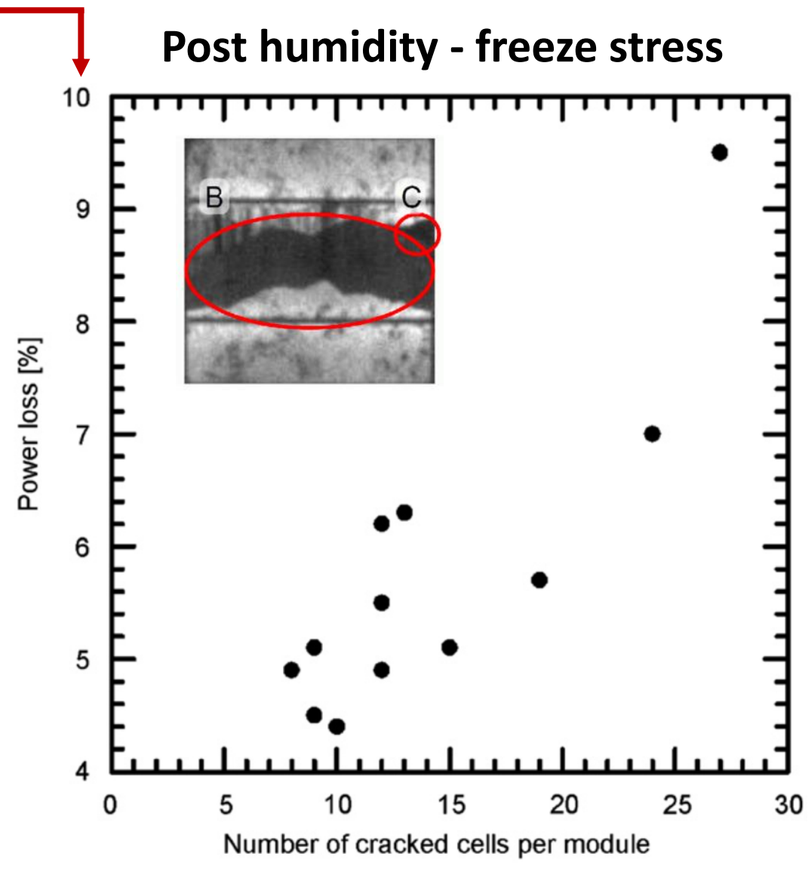
Devan Vasudevan, NCPRE, IIT Bombay

- Mono is more robust to mechanical stress
- Indian market share of mono in 2017 was 5% (www.pv-tech.org, Sep. 2019.)

Post Crack Generation Stress Enhance the Cracks and Their Impact on Performance







M. Köntges, Solar Energy Materials and Solar Cells, 2011.

- A-type cracks converted to B- and C-type with larger area after HF stress
- Leading to significant powerloss enhancement after HF stress

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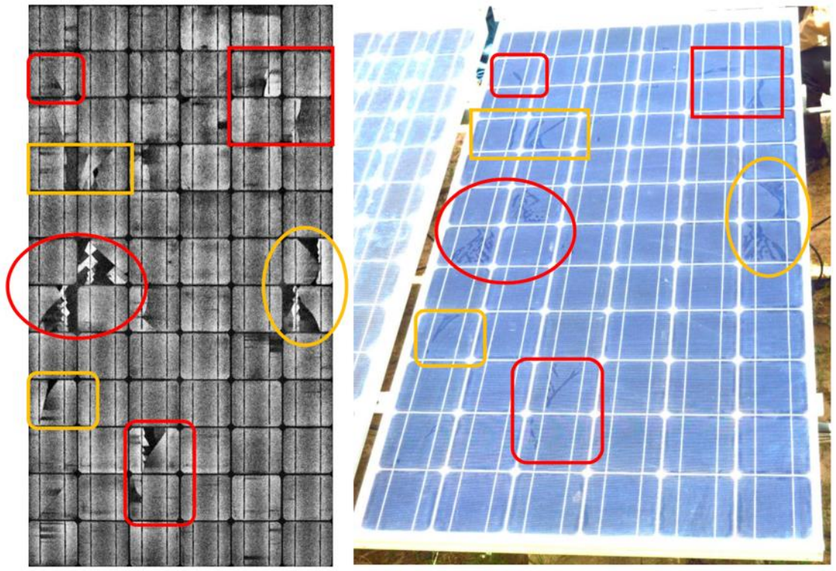
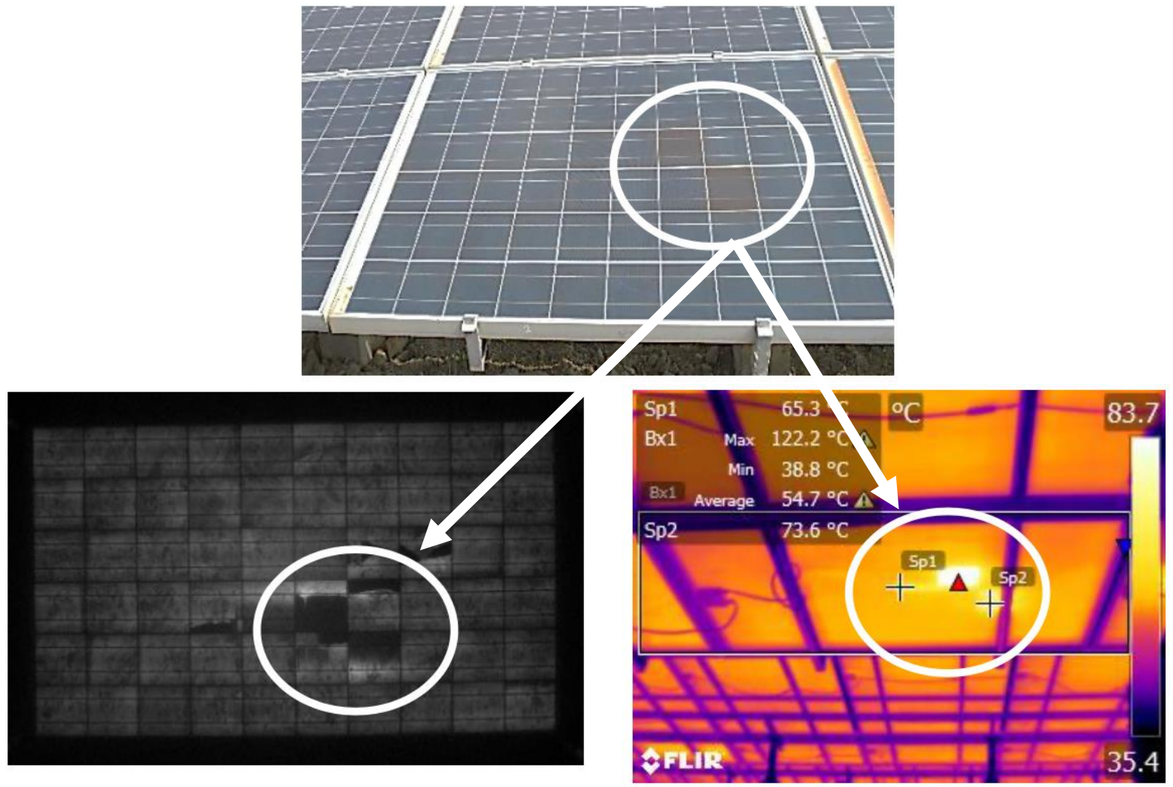
Cracks and “Other” Defects



Cracks in cells can lead to snail trails, indicating moisture ingress through the crack.



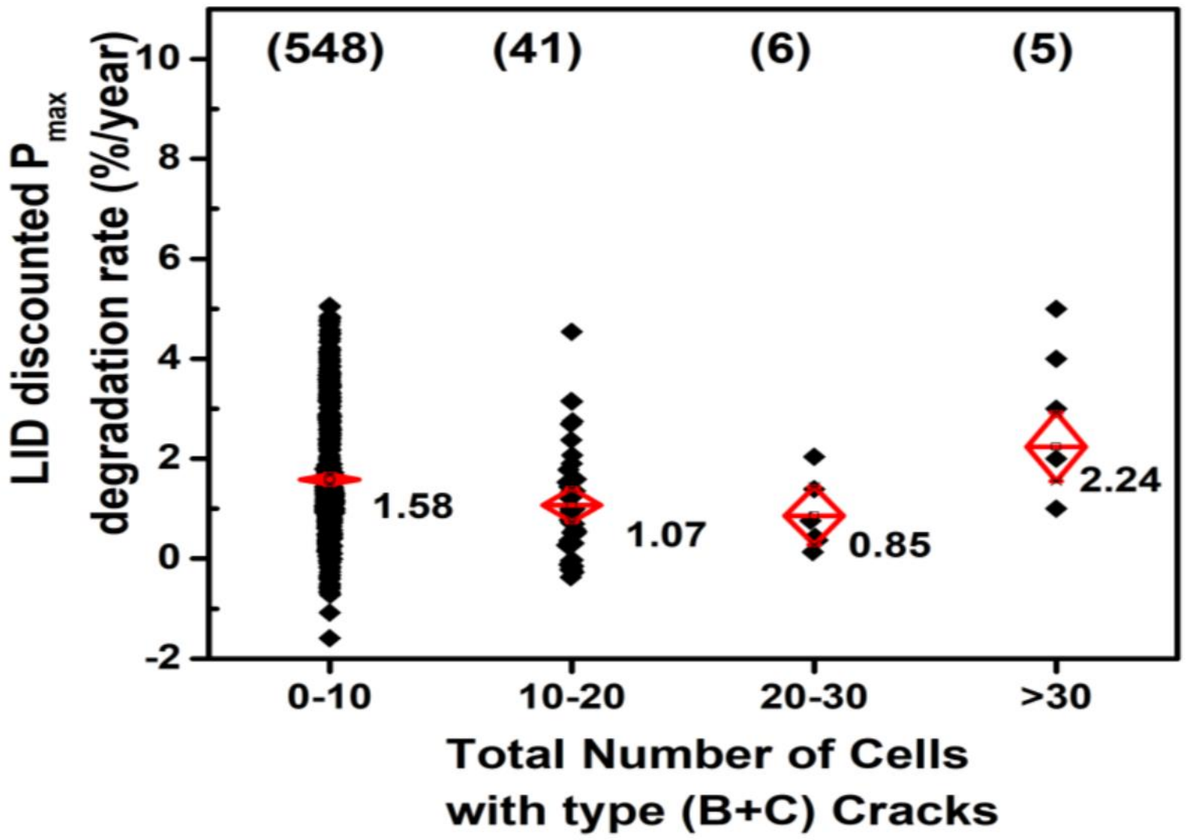
Severe cracking of cells in a module can lead to hot-spots and related problems.

All India Survey of Photovoltaic Module Reliability 2018, NCPRE, IIT Bombay

2018 All India Survey Results – Micro Cracks

Multi : Mono ~ 9:2

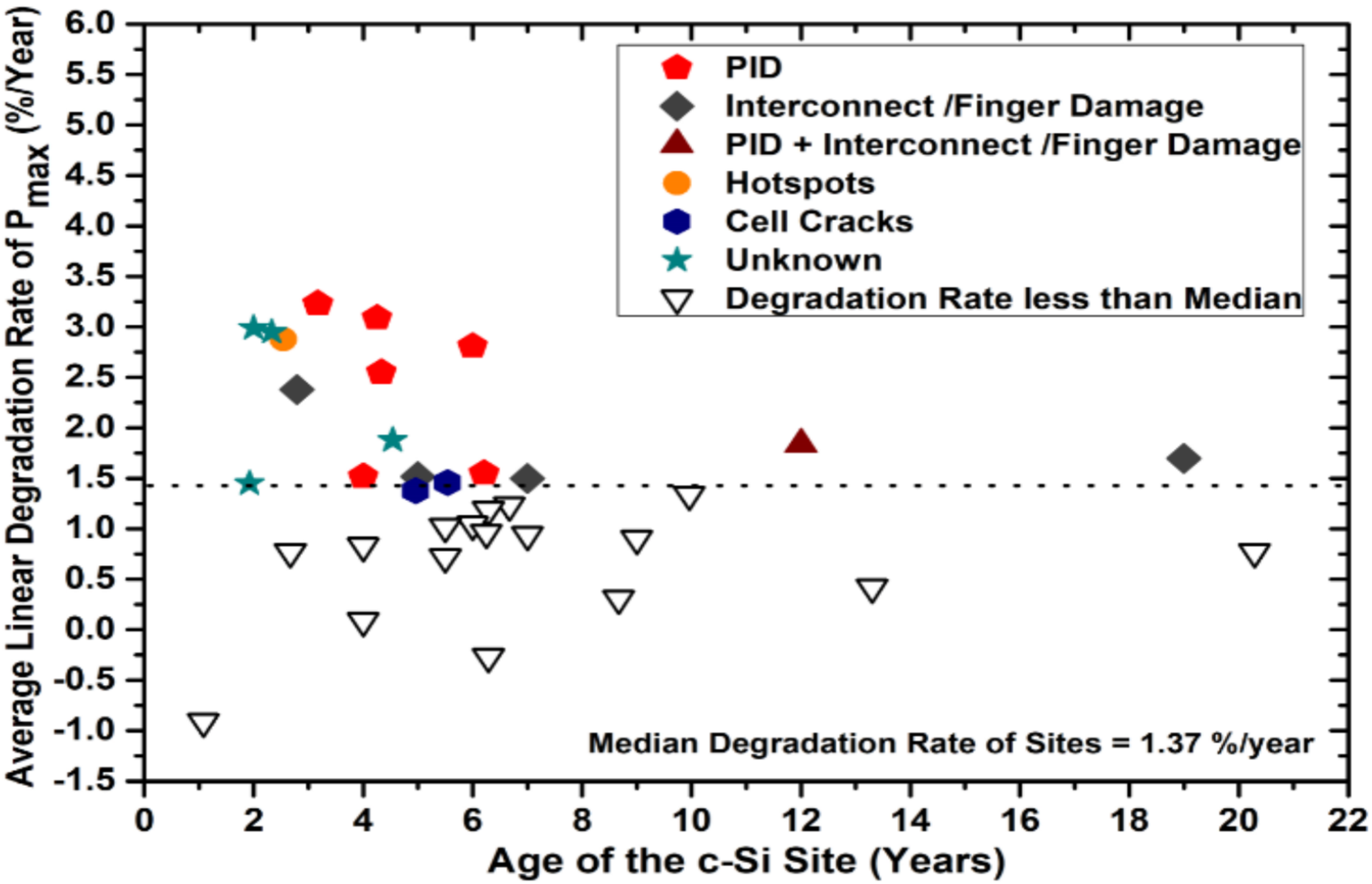
Percentage of cells with different types of cracks				
	Mode A	Mode B	Mode C	No. cells checked
Ground Mounted	8.90%	4.81%	1.12%	31368
Roof Mounted	5.13%	2.01%	0.82%	5712



No clear correlation was observed between number of cells with cracks and STC power degradation in field survey.

All India Survey of Photovoltaic Module Reliability 2018, NCPRE, IIT Bombay

2018 All India Survey Results – Micro Cracks (2)



35 sites in total

In 2, dominant degradation mechanism is microcracks

Survey sites where microcracks were the dominant degradation mode had degradation rates similar as the median of all modules surveyed.

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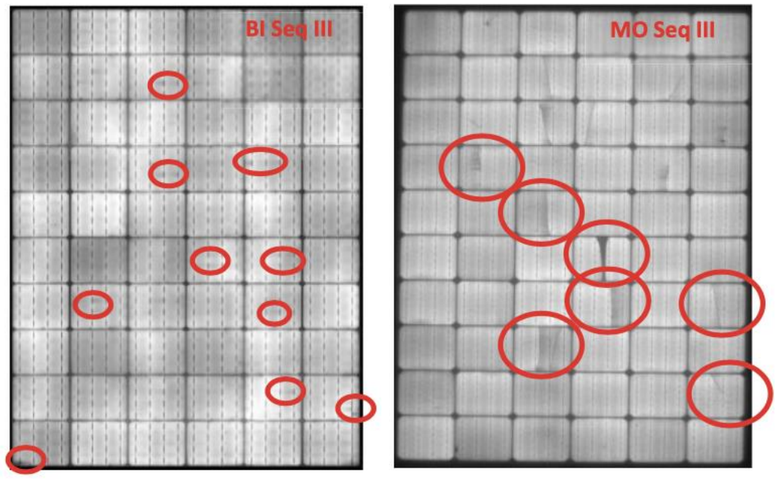
Looking Ahead: Bifacial Modules

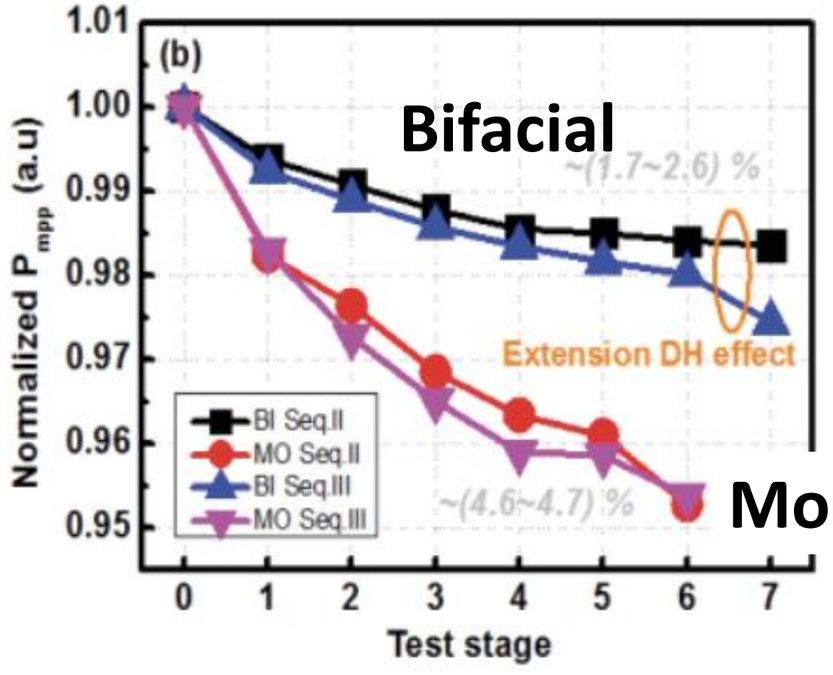
Glass – glass modules are expected to be more robust to mechanical stress, and moisture/O_2 ingress.

C. Lien et al., IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC), 2018.

Seq. II	Precon. 15kWh/m^2	UV 80℃ 15kWh/m^2	DML acc. to IEC TS 62782	TC 50	HF 10	DH 85/85 (1000 h)	DH 85/85 (1000 h)
Seq. III	Precon. 15kWh/m^2	UV 100℃ 15kWh/m^2	DML acc. to IEC TS 62782	TC 50	HF 10	DH 85/85 (1000 h)	DH 85/85 (1000 h)



Bifacial **Monofacial**



Glass – Glass bifacial modules are more robust to cracking.

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Key Takeaways

- Severity of cracks in EL images and impact on performance depends on
  - Current through the module
  - Mechanical stress at the time of measurement
- Mono crystalline cells are more robust to cracking than multi
- Cracks transform to higher severity during long term operation/environmental stress
- Cracks are sometimes the underlying cause of hot-spots and snail trails
- In NCPRE - NISE 2018 All India Survey:
  - 8.3% of cells were found to have cracks
  - No clear correlation was observed between number of cracks and power degradation
  - In 2 out of 35 sites, micro cracks were found to be the dominant module degradation mechanism
- Glass to glass bifacial modules are more robust to cell cracking

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Thank you for your attention!

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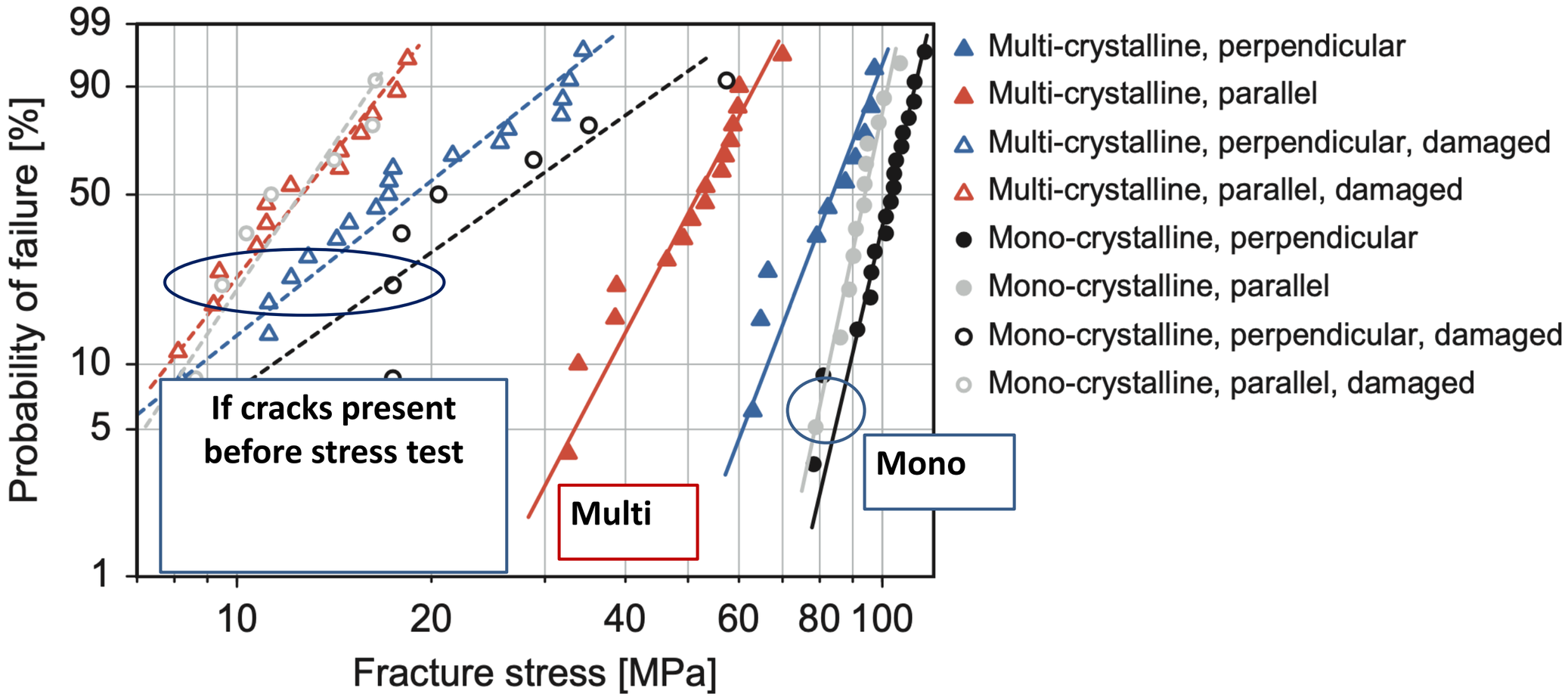
Backup Slides

Cracks robustness of Mono and Multi Silicon Modules



M. Sander et al., Solar Energy Materials and Solar Cells, 2013.