Re-Evaluating Solar Panel Mechanical Durability Testing: Case Study of Commercial Modules

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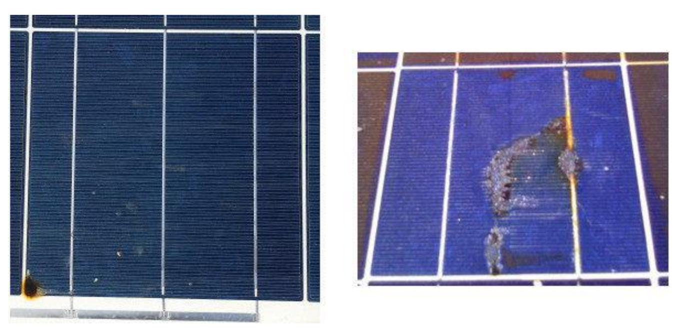
Introduction

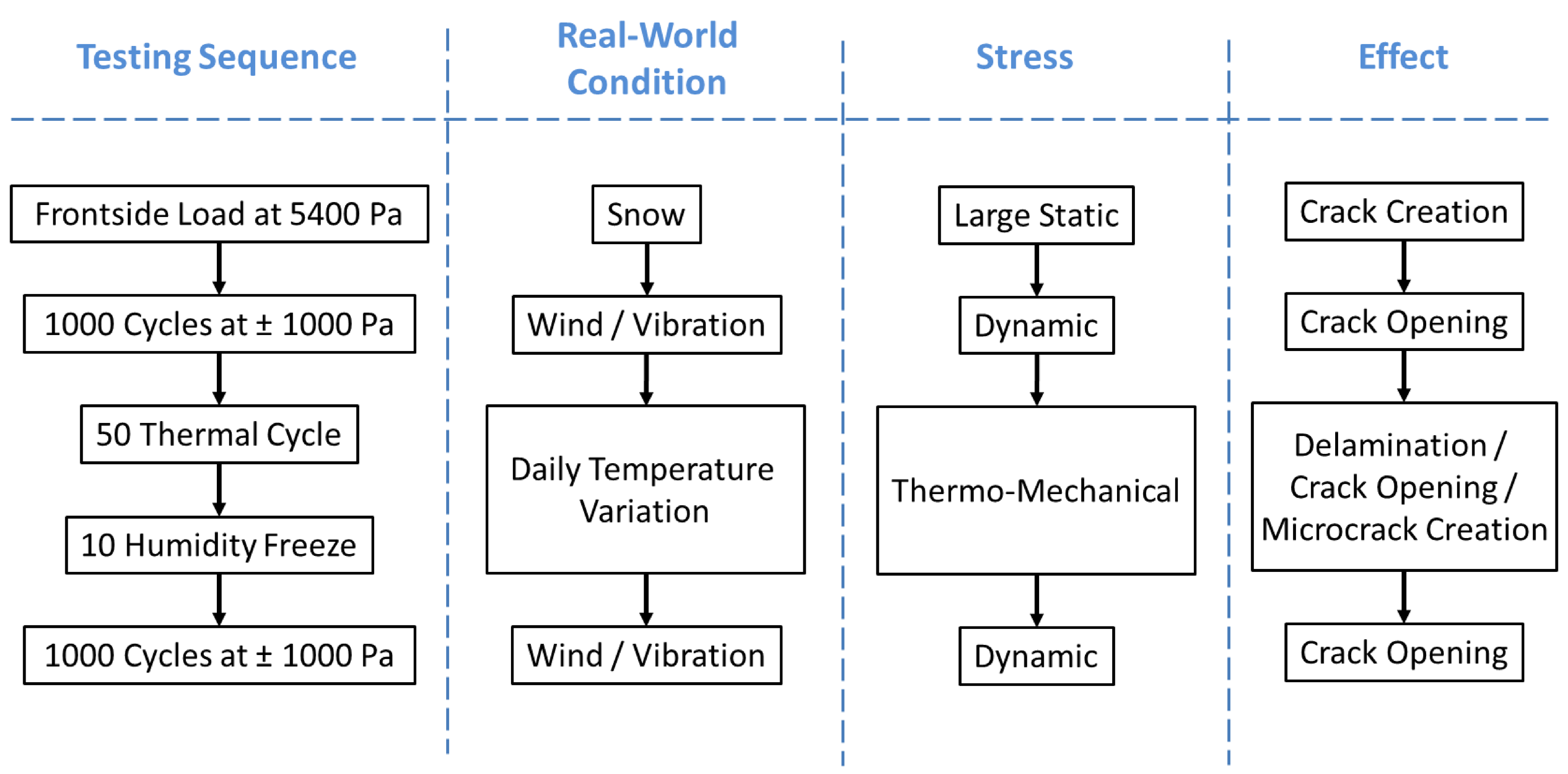
- PV modules experience a wide range of mechanical stressors over their lifetime that may cause cell cracking (e.g. shipping, installation, snow, wind, thermal cycling)
- Cell cracks pose a risk to long term performance
  - Increase in **series resistance**
  - **Shunting** from cracks can lead to reduced low light performance
  - Increase in "dead area" leading to **current mismatch**
  - Potential for **hot spot** generation
  - Severe hot spots are a potential **fire hazard**



Example images of severe hot spots caused due to cell cracks [1]

- In this work, a modified mechanical durability test sequence is proposed to evaluate module design with respect to crack durability

Proposed Testing Sequence



Objective: Evaluate a module design with respect to crack creation and crack opening

Module Technologies

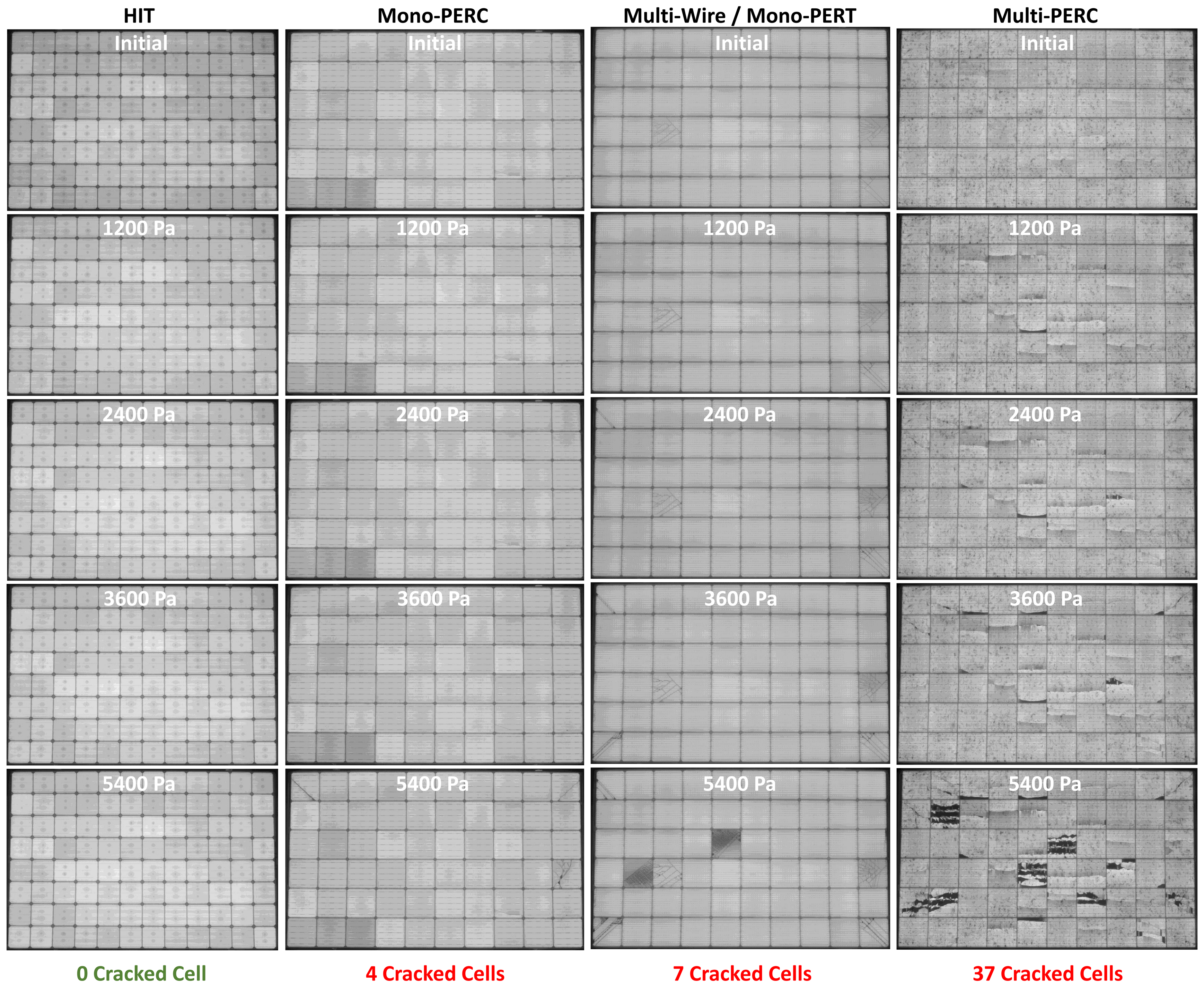
Cell Technology	Interconnect Technology	Cell Size	Number of Cells
HIT	Low Temperature Interconnects	5 inch pseudo-square	96
Mono-PERC	4 Busbar Solder Interconnects	6 inch pseudo-square	60
Multi-PERC	4 Busbar Solder Interconnects	6 inch square	60
Mono-PERT	Multi-Busbar Interconnects	6 inch pseudo-square	60

[1] "Hot spots: Causes and Effects" *PV Magazine* 2017

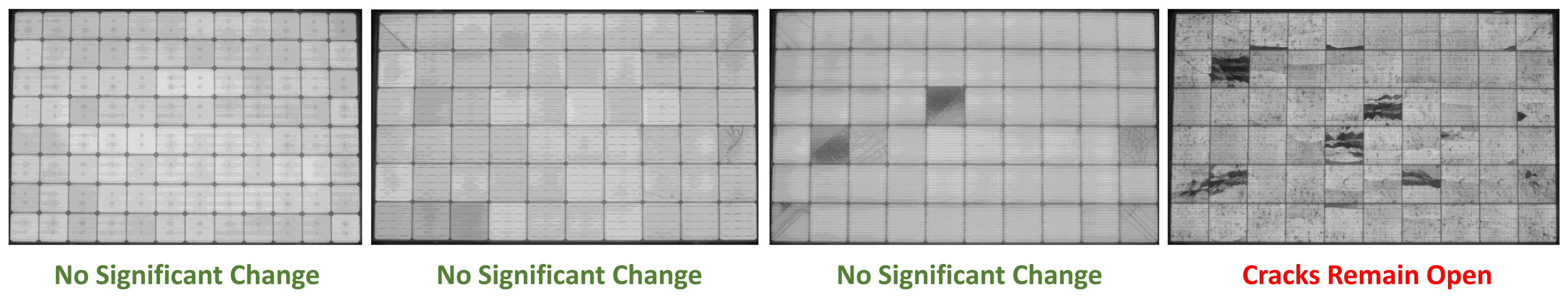
[2] M.W. Rowell, S.G. Daroczi, D.W.J. Harwood, A.M. Gabor, "The Effect of Laminate Construction and Temperature Cycling on the Fracture Strength and Performance of Encapsulated Solar Cells" *45th IEEE PVSC*, pp 3927-3931, 2018

Experimental Results

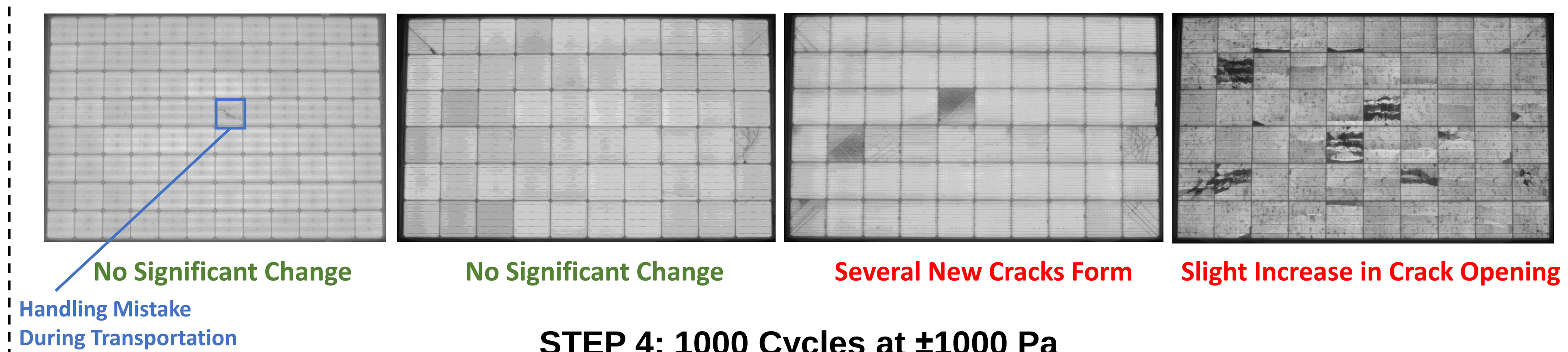
STEP 1: Frontside Load up to 5400 Pa



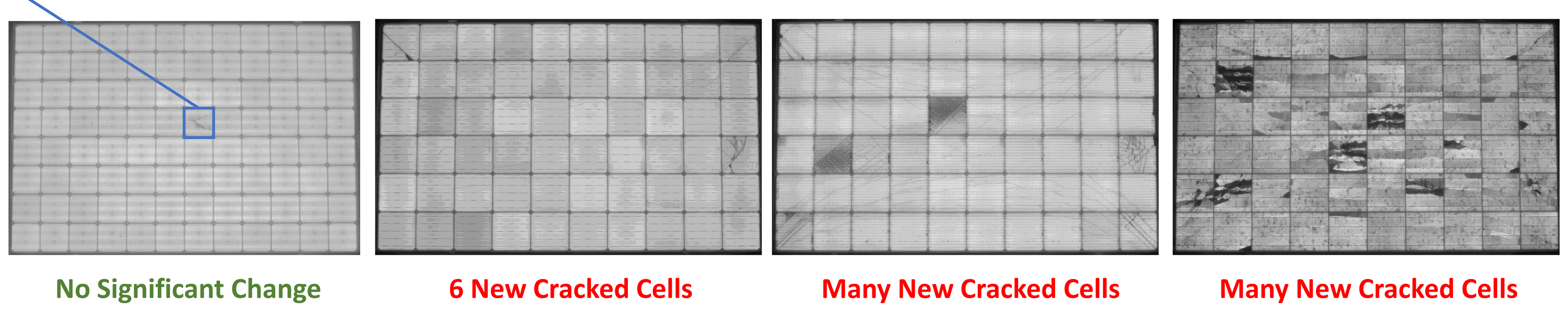
STEP 2: 1000 Cycles at ±1000 Pa



STEP 3: 50 Thermal Cycles / 10 Humidity Freeze Cycles



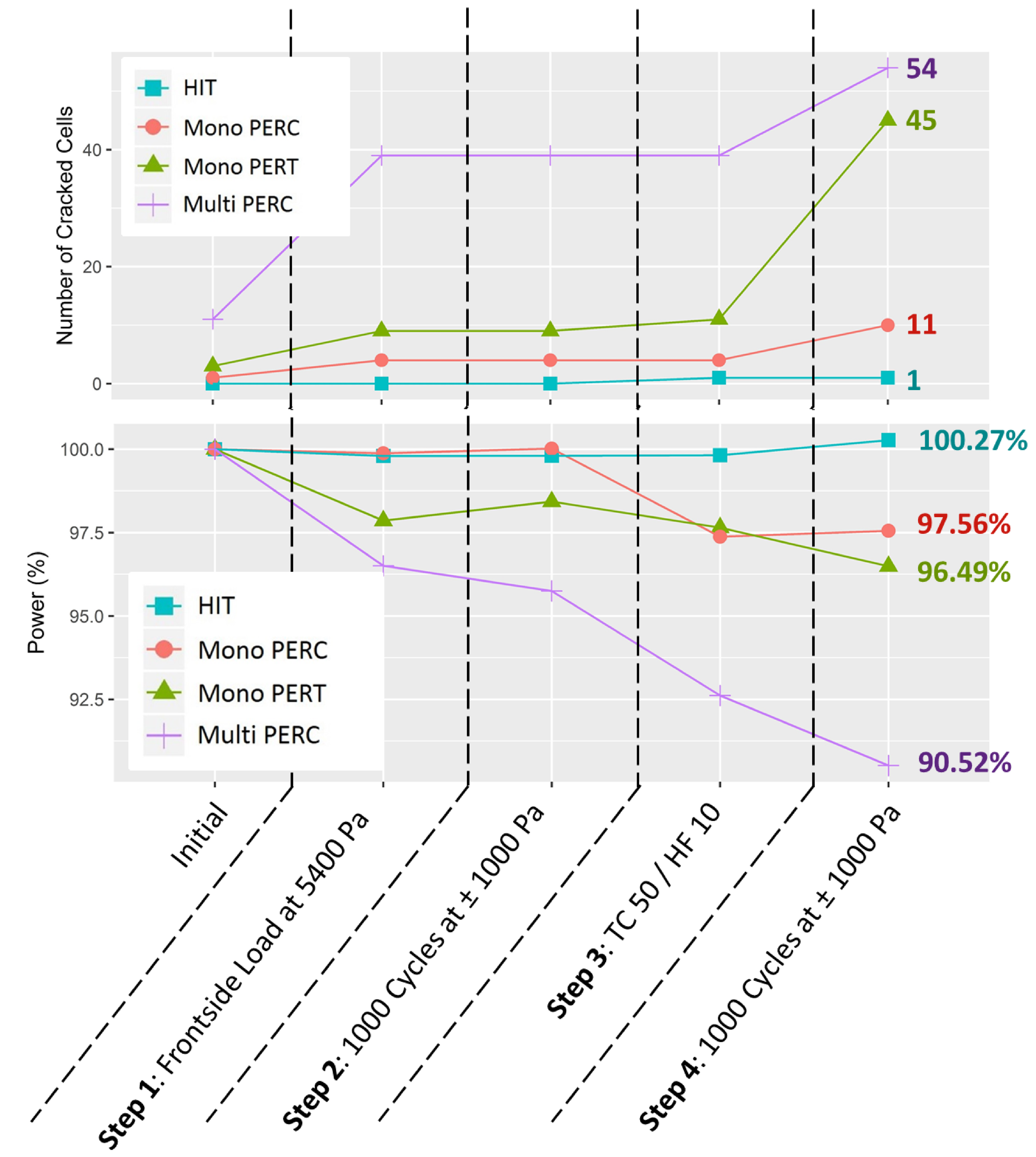
STEP 4: 1000 Cycles at ±1000 Pa



- Thermal Cycling has a major impact on the creation of new cell cracks
- Cell cracks appear to initiate near busbars and propagate with only a mild load of 1000 Pa
- The low temperature interconnect process is the likely reason for superior performance of Heterojunction modules with respect to crack formation. The interconnect geometry and packaging materials may also limit microcrack formation during TC/HF. [2]

Experimental Results

I-V data was captured to assess the impact on performance due to each exposure step. In addition, the number of cracked cells was counted to identify which exposure steps contributed to cell cracks.



Conclusions

- A modified testing sequence was proposed to evaluate module design with respect to crack durability
  - A large front side static load is used to create cracks
  - Subsequent cyclic loading and thermal cycling is used to open cracks
  - Dynamic mechanical loading after TC/HF exposes microcracks that develop during thermal cycling
- Testing sequence replicates stressors that could occur in real-world operation

Snow → Wind / Vibration → Daily Temperature Variation → Wind / Vibration

Key Takeaways

1. Large variation in crack durability across commercially available modules
2. Mechanical loading after thermal cycling causes a significant number of new cracks for modules with solder interconnects
3. Heterojunction modules, utilizing a symmetric cell structure and low temperature interconnect process, exhibit high durability with respect to crack generation

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