# New Cells, New Issues: Stress Tests For N-Type PV Module Designs


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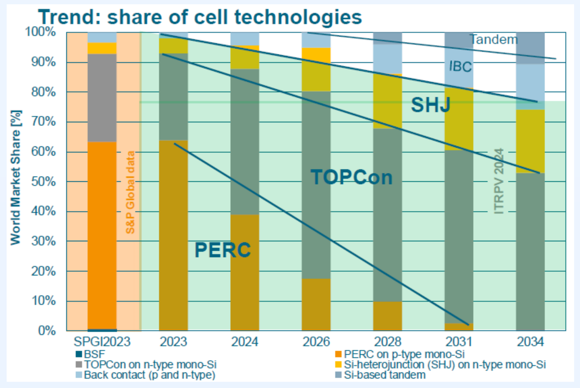
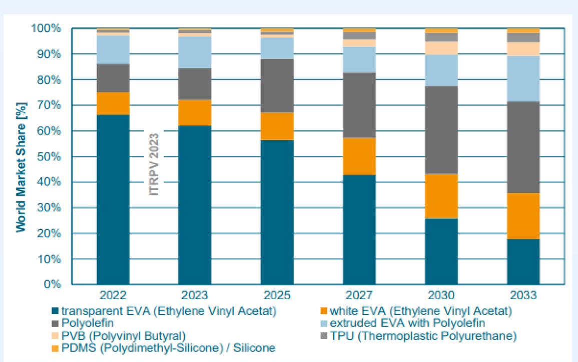
## INTRODUCTION

- Rapid adoption worldwide of n-type cell topologies and new encapsulants.
- Growth is driven by desire for higher efficiency, improved bifaciality, and better resilience to LID LETID.
- These cell types are found susceptible to
  - UV-induced degradation (UVID) - passivation loss
  - Potential induced degradation (PID) – shunting, contact corrosion, delamination
- Higher risk for module performance and warranty, as the first year of degradation may exceed -2%.



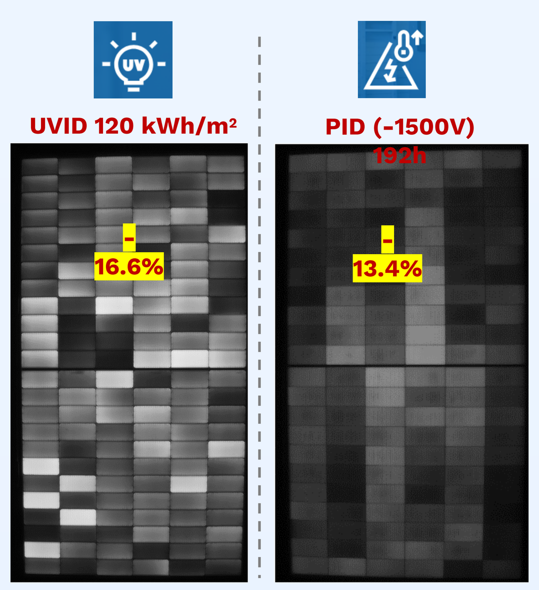
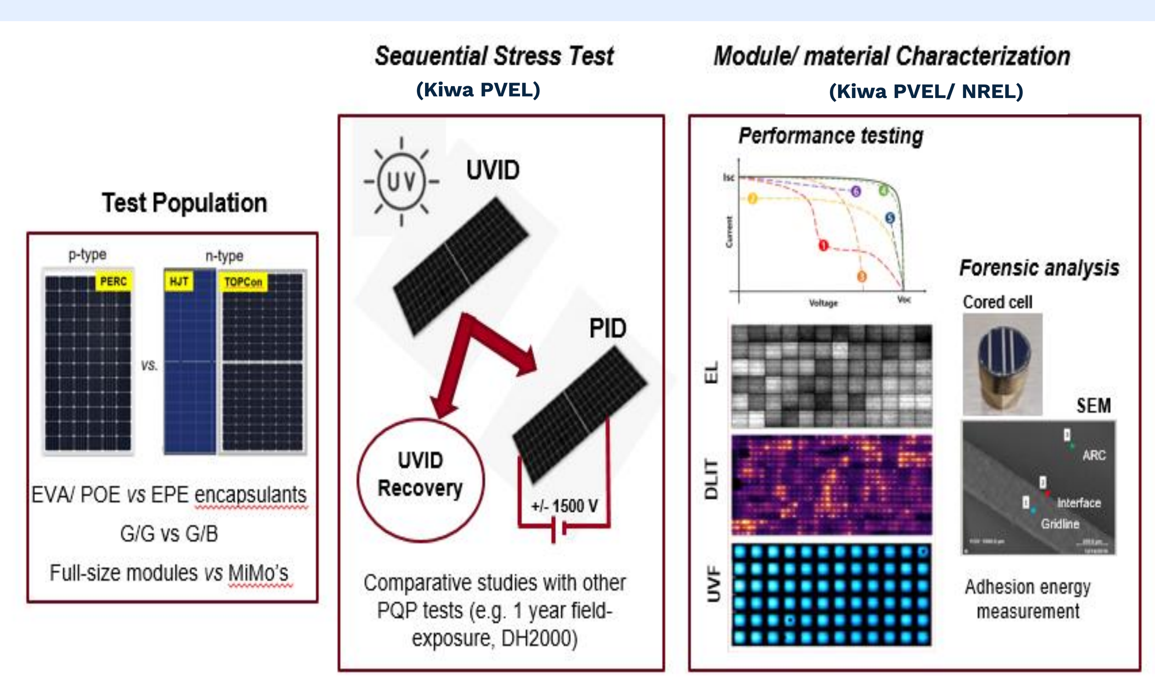



Image: Kiwa PVEL's PQP testing results

## PROJECT GOALS

- Benchmark state-of-the-art reliability for n-type cells and new encapsulants against UVID and PID of industrial full-size modules.
- Understand the root-cause mechanisms behind UVID and PID.
- Develop UVID recovery techniques.
- Correlate accelerated stress tests with field-exposure and other tests (DH2000, LETID).
- Deposit test results in the DuraMAT DataHub.




## CORE OBJECTIVES

- Disruptive Acceleration Science
- Fielded Module Forensics

## UVID MECHANISMS

UVID mechanism is different from other light-induced degradation modes (BO-LID and LETID). Expected causes:

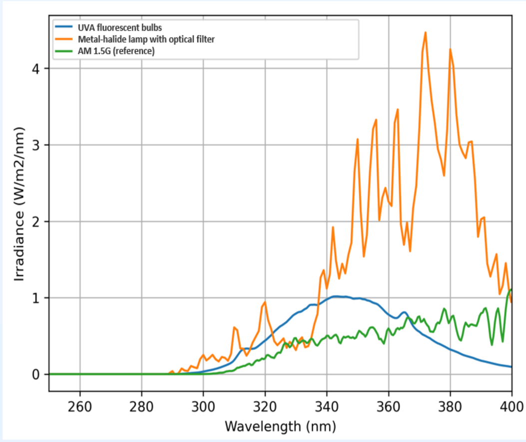
1) **Recombination at SiNy/Si interface** [2]

2) Recombination in Si bulk [3]

3) Hot-carrier effect [4, 5]

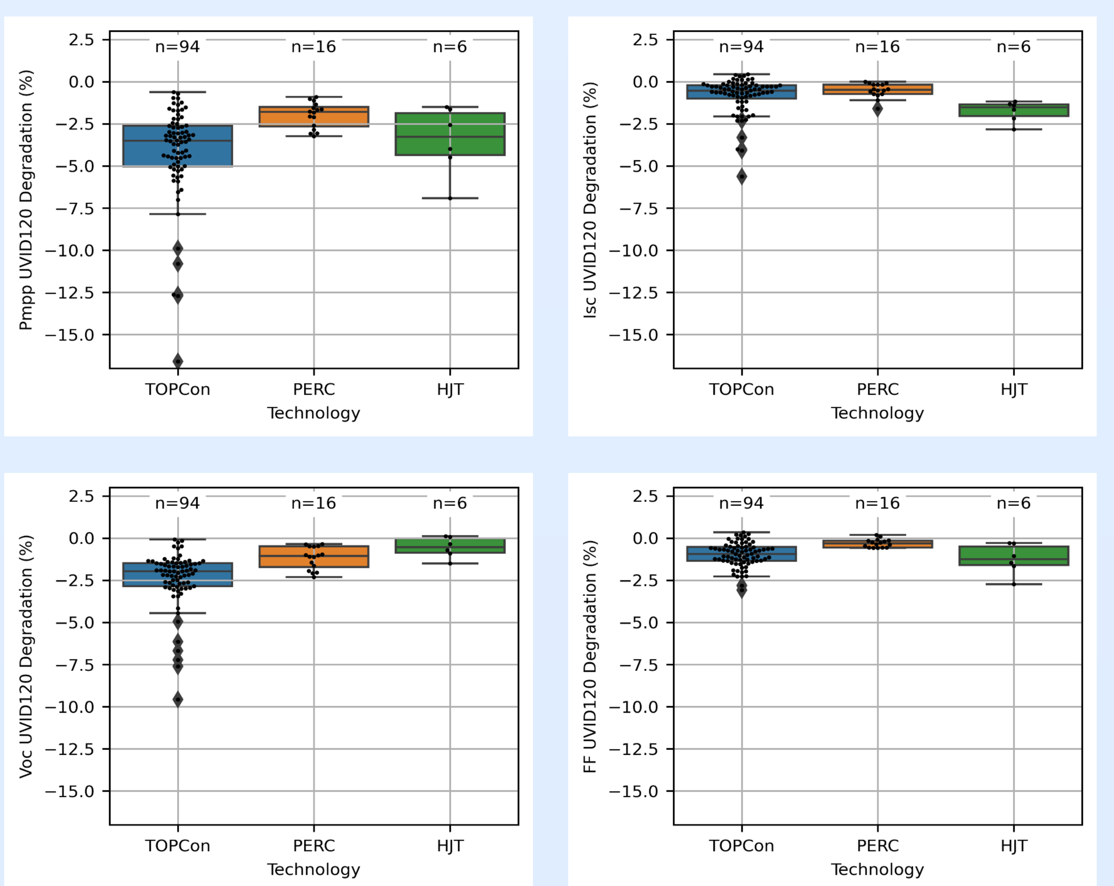
## KIWA PVEL's UVID TESTING

- Modules preconditioned outdoor for LID stabilization.
- Front-side irradiation at module temperature 60°C, under short-circuit condition. Total UV dose is 120 kWh/m² (280-400 nm) when using metal halide lamps. Equivalent dose is ~55 kWh/m² when using UV fluorescent bulbs.
- Total UV dose is equivalent to 1-2 years of outdoor exposure, depending on location.
- Use of MH lamps (Suzhou, China) and UVF bulbs (Napa, USA).
- Test modules are characterized with flash STC front and rear, EL, and wet leakage current test.



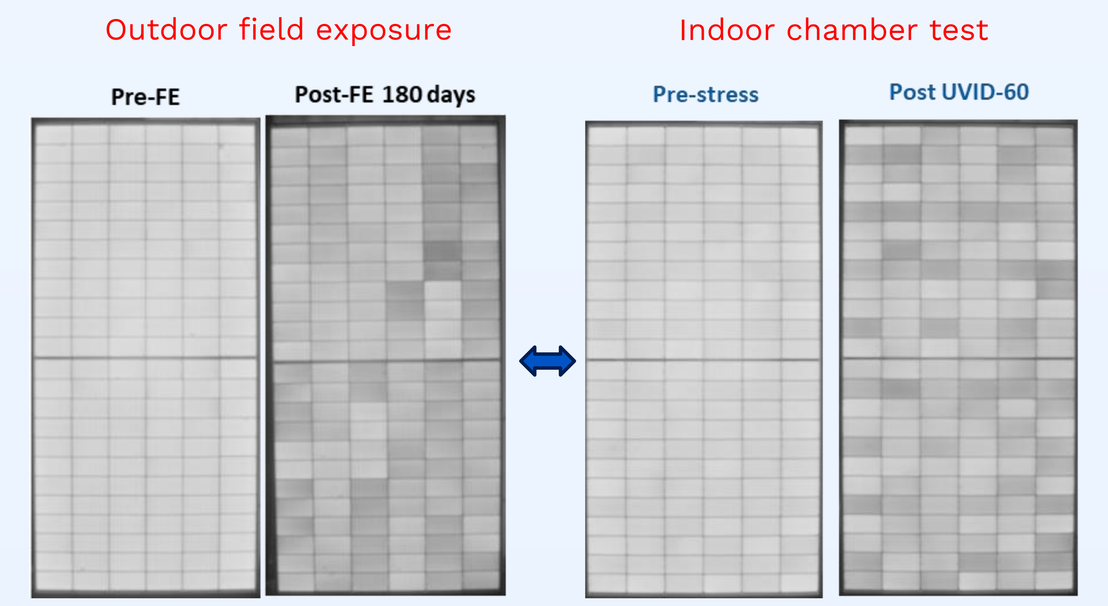

## RESULTS: ACCELERATED UVID TESTING

- More than 100 n-type modules subjected to UVID testing, primarily TOPCon.
  - n-type TOPCon: wide range of power loss -0.8% to -16%.
  - n-type HJT: moderate power loss (-2 to -7%).
  - p-type PERC: lower power degradation (<-3%).
- More than 50% of TOPCon BOMs exhibited power degradation >-3%.
- Degrada is mainly due to Voc loss (passivation loss). Some BOMs showed Isc loss, while FF is stable.
  - Different UVID failure mechanisms occurring concurrently.
- Checkerboard pattern in EL images.




## OUTDOOR TESTING

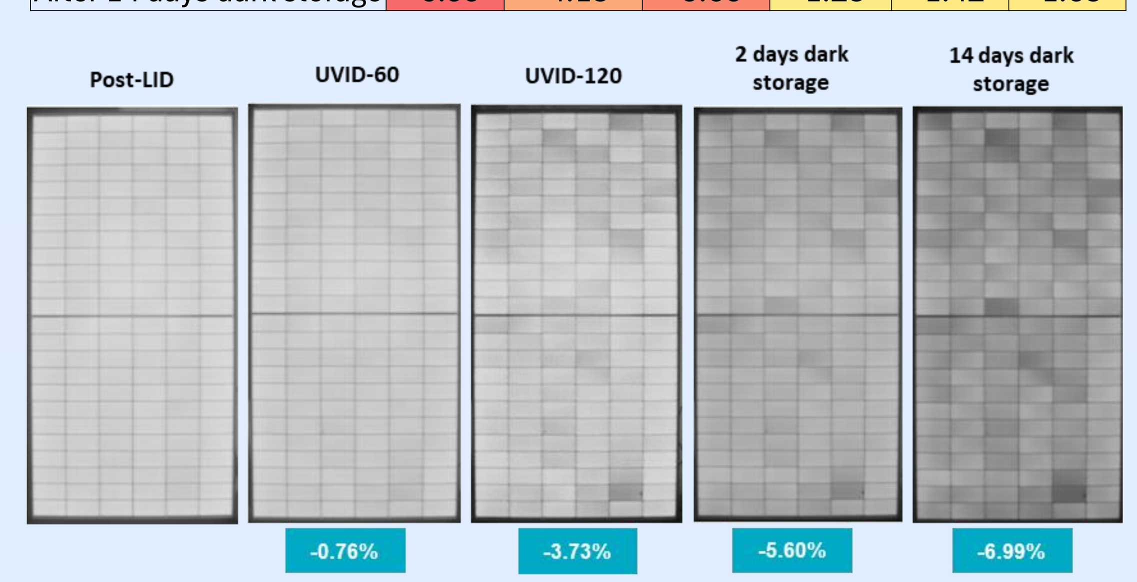
- TOPCon fielded modules at different sites in the US and China showed higher Voc losses in first 5-11 months of deployment.
- Power loss was more prominent on front side.
- Rear-side parameters also severely degraded in some highly sensitive UVID modules.
- Checkerboard patten visible in field-exposed (FE) module is similar to that seen in UVID stressed module, indicating **UVID is a real problem**.




## DARK DEGRADATION & METASTABILITY

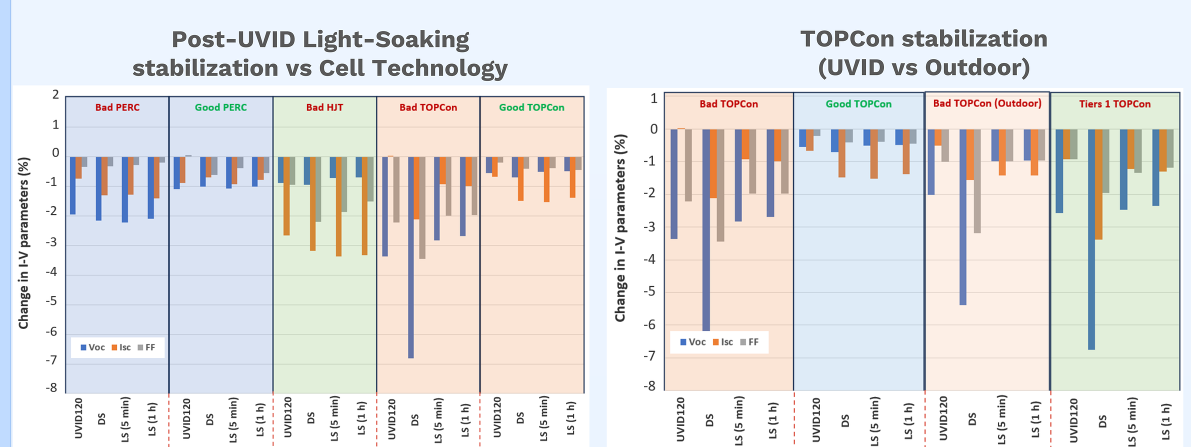
- Post UVID-120 modules stored in dark exhibit significant power degradation – signs of metastability.
- Checkerboard UVID signature in EL images becomes more pronounced with dark storage duration.
- Extent of dark degradation depends on
  - Higher in UVID-sensitive modules.
  - Lower at warmer dark storage room.
- All technologies exhibited dark degradation.
  - TOPCon: Extensive, HJT: Moderate, PERC: Minimal.
  - Parameters affected differently. Greater Voc loss in TOPCon, while HJT suffer from Isc and FF losses.
- Metastability also seen in fielded modules.
- A stabilization step is important to ensure accurate and reliable flash measurements following UVID testing.

| Step# | Pmp% | Voc% | Vmp% | Isc% | Imp% | FF% |
|---|---|---|---|---|---|---|
| Post-LID | | | | | | |
| UVID-60 | -0.76 | -0.84 | -1.02 | 0.60 | 0.31 | -0.52 |
| UVID-120 | -3.73 | -2.31 | -3.24 | -0.17 | -0.45 | -1.29 |
| After 2 days dark storage | -5.60 | -3.39 | -4.98 | -0.47 | -0.60 | -1.83 |
| After 14 days dark storage | -6.99 | -4.18 | -5.66 | -1.28 | -1.42 | -1.68 |



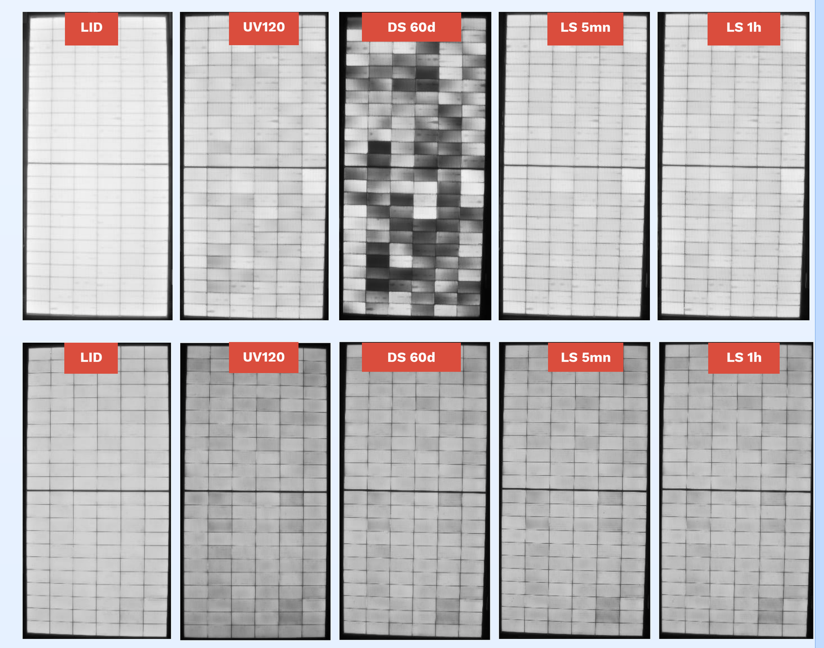

## UVID RECOVERY METHODS

- Experimented different recovery methods on UVID modules using current injection and light exposure.
  - Light exposure method offers faster recovery.
- Results show white LED/ UVF/outdoor sunlight (or full spectrum) can cause significant power recovery.
- Recovery observed with front illumination, suggesting the degradation occurs near passivation/Si interface.
- Recovery is only partial with some degree of permanent damage remaining.
- Module degrade again when left in the dark.




**TOPCon:** Significant improvement after a very short light exposure. Checkerboard pattern is vanished

**HJT:** No obvious changes on EL image, except slight increase in brightness




- Kiwa PVEL's proposed stabilization method involves post UVID-120 test modules to undergo full-spectrum light-soak indoor or outdoors for 0.1 kWh/m² (for TOPCon) and 0.5 kWh/m² (for HJT).

## SUMMARY & FUTURE WORK

- Few TOPCon and HJT BOMs exhibited high susceptibility to UVID as evidenced by both lab and field test data.
- Growing concerns exist regarding their metastability behavior in the dark. Stabilization method needs to be standardized.
- Forensic analysis of UVID samples will be performed using coring and advanced characterization.
- Testing and data analysis will be employed to assess the PID-sensitivity of different BOMs.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