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AUGUST 19, 2020

LID and LeTID Testing

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LID and LeTID

- LID (Light-Induced Degradation) is a well-known phenomenon for crystalline silicon PV cells and modules.
- LID attracted renewed interest with the commercialization of mono-PERC modules, as early products showed LID in excess of 5%.
- Most (but not all) of mono-PERC products in the market now show LID less than 2%, as manufacturers make their products LID-resistant during manufacturing.
- LeTID (Light- and elevated Temperature-Induced Degradation) is a relatively new degradation mode that has been verified in both mono- and poly-PERC products.
- CFV now offers an LID/LeTID testing service, based on the LeTID test sequence possibly to be included into the future versions of IEC 61215.

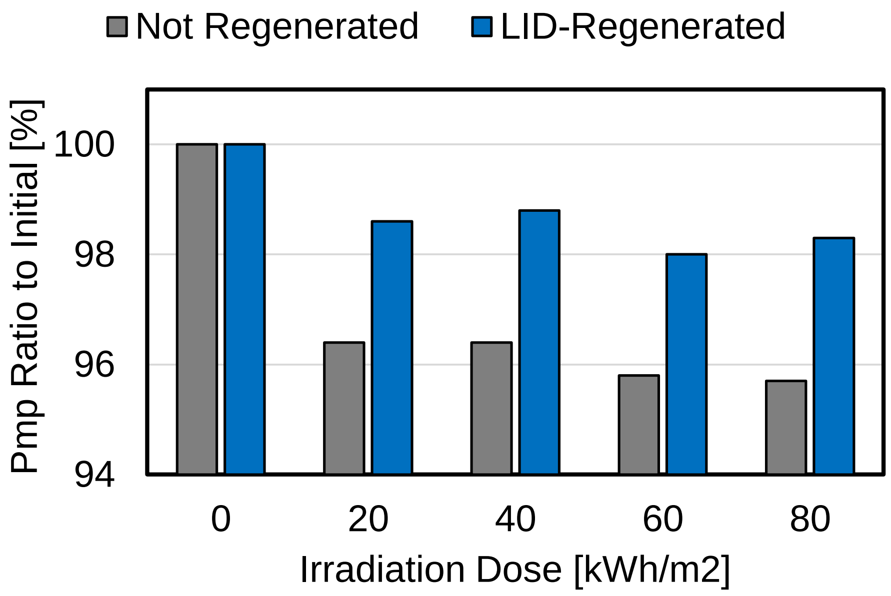
LID (Light Induced Degradation)

- LID is a light-induced loss of performance of photovoltaic (PV) devices, first discovered for crystalline silicon PV cells in 1970s.
- It is primarily caused by boron-oxygen (BO) defects in p-type silicon wafers that get activated by minority carrier injection, either by light or by forward bias.
- The degradation saturates within days of field installation.
- Traditionally, mono-Si (Al BSF) modules had shown LID of ~3%,
  and poly-Si modules had shown LID of ~1%.
- Early mono-PERC products (2011-2013) showed LID in excess of 5%, sparking renewed interest in LID.

LID-Resistant Products

- **LID Regeneration**, a phenomenon and process pioneered by University of Konstanz in 2006, was successfully commercialized after 2013, and most mono-PERC cell manufacturers have now incorporated the process into manufacturing.

  - LID Regeneration during cell manufacturing involves carrier injection at 200-300°C, which results in hydrogen passivation of BO defects.
  - Mono-PERC products currently on the market typically show LID < 2%.
  - A plausible model for the hydrogen passivation mechanism was first proposed in 2013 (UNSW of Australia).



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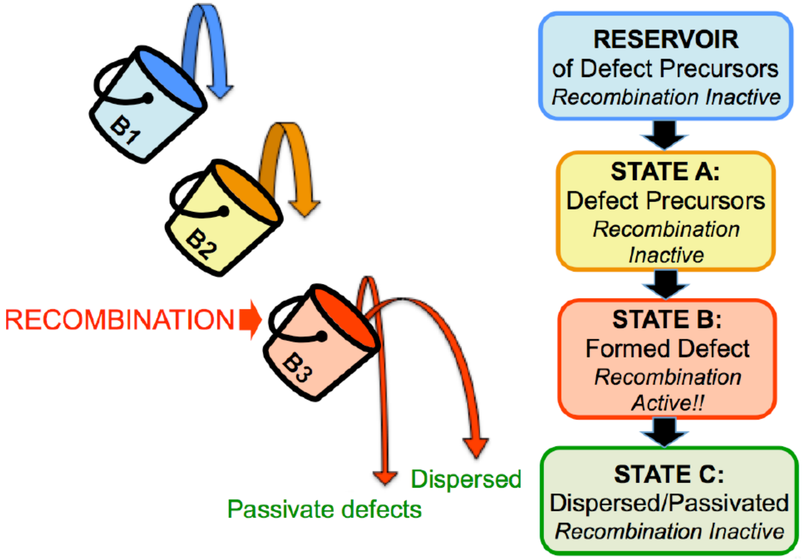
LeTID (Light and elevated Temperature Induced Degradation)

- LeTID is a slow degradation phenomenon first reported in 2015 that requires both carrier injection and elevated temperature to proceed.
  - Hanwha Q Cells study published in 2017 shows LeTID-sensitive modules suffering max 7% degradation after 3 years in Cyprus, and 2.5% in Germany.
- LeTID has been observed in both mono- and multi-PERC products.
- The mechanism is not known, and possible explanations are being investigated.
- In 2018, UNSW proposed a “four-state hydrogen bucket model”, and they describe several hydrogen-induced loss mechanisms that are possible: (1) undesired hydrogenation of contact interfaces, (2) auto-generation of neutral mono-atomic hydrogen and the subsequent ionization, etc.



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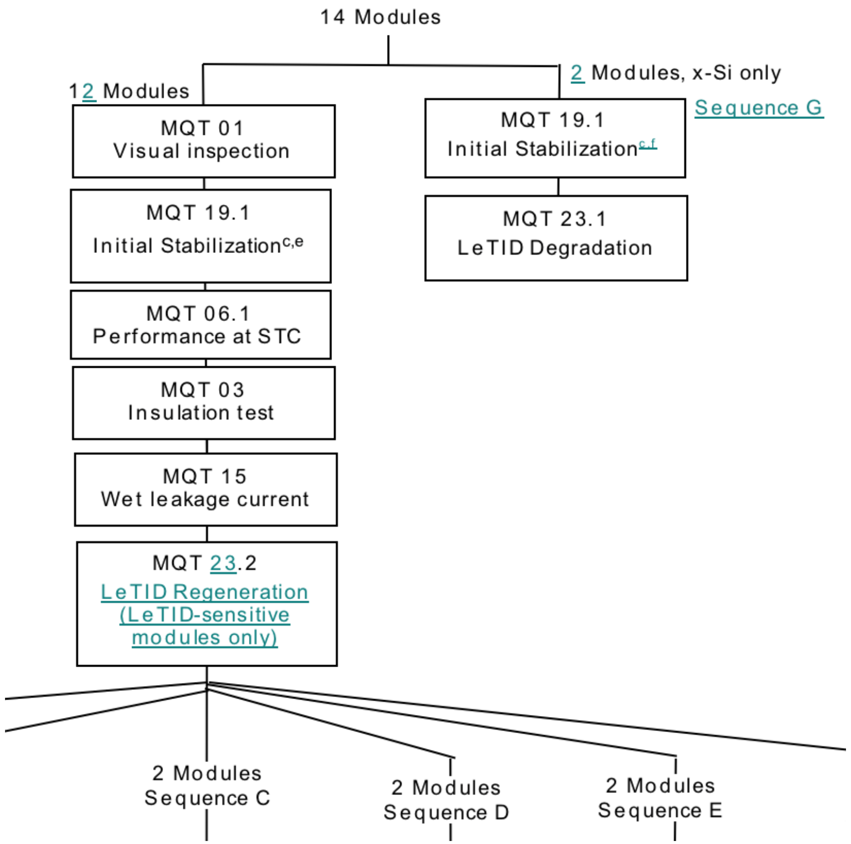
LeTID-Resistant Products?

- Several strategies to achieve LeTID resistance with PERC products have been proposed. Two examples are:
  - Wafer quality control and screening, and
  - Process similar to LID regeneration, but with significantly different process conditions (temperature, carrier injection level, and process duration).
- At the moment, it is difficult to determine without testing if a product from a specific manufacturer is LeTID-sensitive or not.
- In 2018, Fraunhofer CSP of Germany tested 9 module types (6 mono-PERC and 3 poly-PERC) purchased from wholesale distributors. LeTID ranged in 0.2 to 6%.
- A test sequence for LeTID susceptibility does exist, and it may be included into future editions of IEC 61215.

LeTID Test Sequence in Future IEC 61215

- The next edition of IEC 61215 may include a separate sequence to determine if a module type is sensitive to LeTID.
- If the tested samples are found to be LeTID-sensitive, the remaining samples are to undergo "LeTID regeneration" initially.
  - The purpose of this step (>600 hrs. long) is to put LeTID-sensitive modules into the regenerated state, so that there is no LeTID-related performance increase during subsequent stress tests.
- The test sequence is for module certification, but it can be adopted for risk assessment.



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Testing for LID and LeTID

- Both LID and LeTID are induced during the LeTID test. The two degradation modes are difficult to separate out completely.
- A reasonable separation can nonetheless be obtained via a sequence of tests: an outdoor exposure (80-120 kWh/m^2) followed by the chamber-based LeTID test.
  - LID = [Pmp after 80-120 kWh/m^2 outdoor exposure]/[initial Pmp] – 1
  - LID + LeTID = [Pmp after LeTID test]/[initial Pmp] – 1
  - For the outdoor exposure, Pmp is measured after 40, 80, and 120 kWh/m^2 cumulative doses.
- The separate figures for LID and LID + LeTID will provide guidance to the project developers and independent engineers:
  - Projects in cold climates → Use LID
  - Projects in hot climates → Use LID + LeTID
  - Projects in temperate climates → Use a weighted average based on site climate data

CFV Labs LID + LeTID Test Protocol

- CFV's LID + LeTID test protocol is based on the test sequence proposed for the future editions of IEC 61215.
- EL imaging is included at all steps, as it is useful to visualize the cell-to-cell mismatch evolution.

Test Sequence (8 samples)	
Initial Check	Visual Inspection
	STC I-V + EL Imaging
LID Test (120 kWh/m^2 cumulative)	Outdoor Light Soak #1 (40 kWh/m^2) + STC I-V + EL Imaging
	Outdoor Light Soak #2 (40 kWh/m^2) + STC I-V + EL Imaging
	Outdoor Light Soak #2 (40 kWh/m^2) + STC I-V + EL Imaging
LeTID Test	LeTID #1 (75°C, Isc-Imp, 162 hrs.) + STC I-V + EL Imaging
	LeTID #2 (75°C, Isc-Imp, 162 hrs.) + STC I-V + EL Imaging (optional)
	LeTID #3 (75°C, Isc-Imp, 162 hrs.) + STC I-V + EL Imaging (optional)

Summary

- LID and LeTID are different degradation modes.
- Early mono-PERC products showed LID over 5%. Current mono-PERC products are often LID-resistant, but sample testing is nonetheless recommended for the risk assessment.
- LeTID is a newly discovered phenomenon, and it affects both mono- and multi-PERC products. The effect is be most pronounced if LeTID-sensitive modules are installed in hot climates.
- LID and LeTID are difficult to separate out completely, but some separation is possible via a sequence of short outdoor exposure for LID followed by a chamber test for LeTID.
- CFV’s LID + LeTID test protocol based on IEC 61215 working group proposals will give project developers and independent engineers guidance on the minimum and maximum LID + LeTID degradation that can be expected on a module type.

Useful References

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Thank you.

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