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EXPERIENCES ON PID TESTING OF PV MODULES IN 2012

Sascha Dietrich, Jens Froebel, Matthias Ebert, Joerg Bagdahn

Fraunhofer - Center for Silicon-Photovoltaics CSP
Walter-Huelse-Straße 1, 06120 Halle (Saale)
Telefon +49 (0) 345/5589-408
sascha.dietrich@csp.fraunhofer.de

Motivation

- High voltage stress conditions are identified as a crucial degradation problem for solar cells
- Degradation usually happens quickly (months), large scale and with high magnitude in terms of performance loss
- Na^+ migration through encapsulant and SiN due to potential between the cell and the frame + glass found as root cause
- Type approval test for modules required (IEC NWIP 62804)

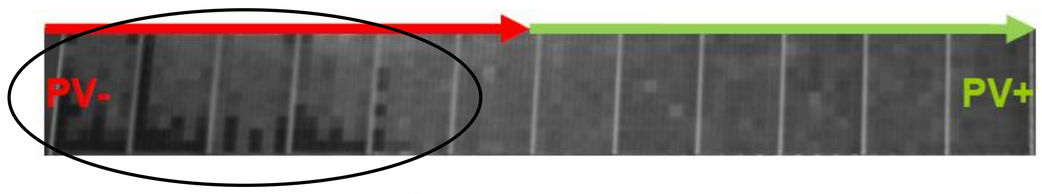

Fig. 1: High voltage stress degradation (PID) along module string in floating ground configuration [1]

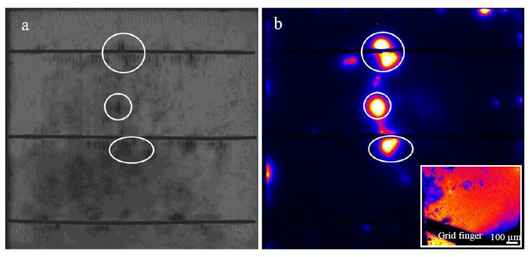

Fig. 2: Shunted regions on solar cell EL-image (left), LIT image (right) [2]

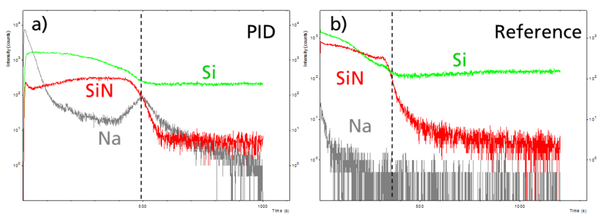

Fig. 3: Na accumulation at SiN / Si interface PID cell (left), reference cell (right) [2]

High Voltage Stress Testing (HVST)

Condition	Setup 1	Setup 2	Setup 3
Relative Humidity	50 %	85 %	50 %
Temperature	50 °C	60 °C	25 °C
Al-foil	yes	no	yes
Test Duration	48 h	96 h	168 h
No. of Modules Tested	77	11	7

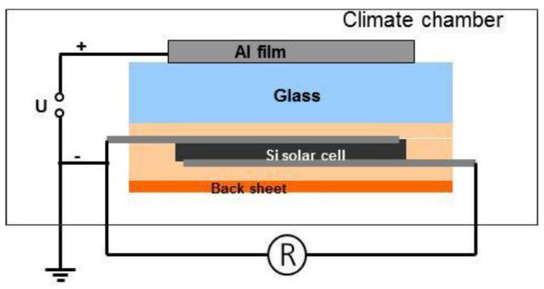

Fig. 4: Scheme of experimental setup 1

Fig. 5: Experimental setup 1 at Fraunhofer CSP with Al-foil covered PVC sheets

Results

- 46 % of modules failed the 5 % loss criteria (Fig. 6)
- scattering of power loss per module type can be very largely (Fig. 7)
  → statistical scattering of PID sensitive cells

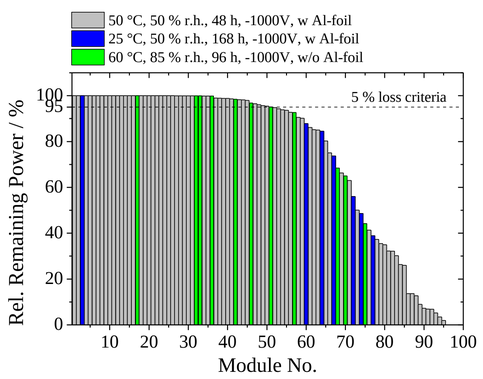

Fig. 6: Remaining power summarized for all tested modules (95 tested modules)

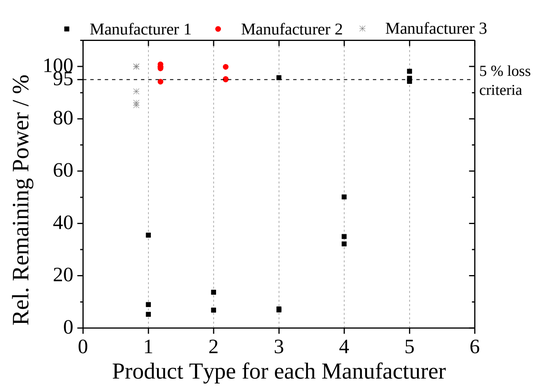

Fig. 7: Rel. remaining power per product type of several manufacturers (test setup 1)

Results

- test setup guides degradation pattern (Fig. 8)
- without Al-foil: strong concentration along the perimeter of the module
- with Al-foil: homogeneous electrode across module surface
- A few degraded cells may lead to high degradation (Fig. 9)
  - cells may be arbitrarily distributed across the module
- cloudy EL-image (local shunting) of a cell typically beginning of degradation

Discussion:

- statistical significance of HVST should be discussed
  → needle in a haystack may be crucial to the result
- low current EL appropriate for qualitative statistical evaluation of progress of degradation

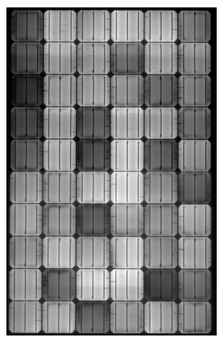

Fig. 8: Typical degradation pattern for different test approaches;
left: setup 1; right: setup2

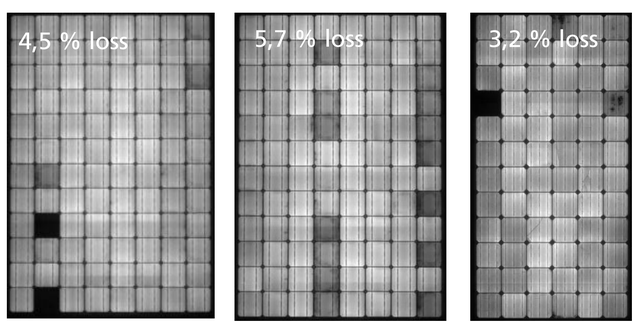

Fig. 9: Example where a few degraded cells with arbitrary distribution lead to rel. high performance los (8 A)

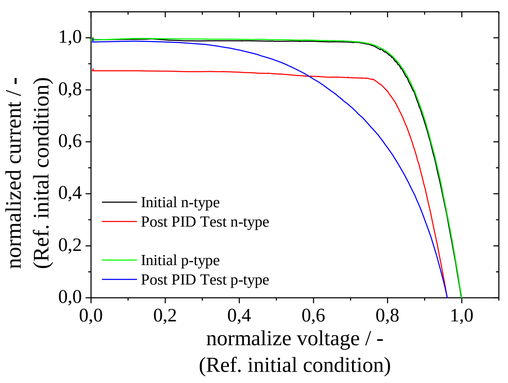

Fig. 10: Typical IV-curves for degraded n-type and p-type modules at -1000 V

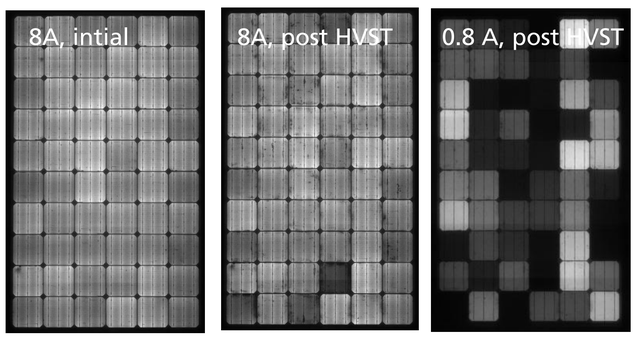

Fig. 11: Local shunting of solar cells leads to cloudy EL image of cells (here: power loss 15 %)

Recovery

- n-type cells show PID effect at negative bias with different degradation characteristic compared to p-type cells
- fast recovery after testing

Discussion:

- How to deal with this type of behavior in terms of testing?
- Definition of time frame for characterization after HVST?
  - e.g. Minimum waiting time before measurement
- Does it come with fast degradation during HVST?

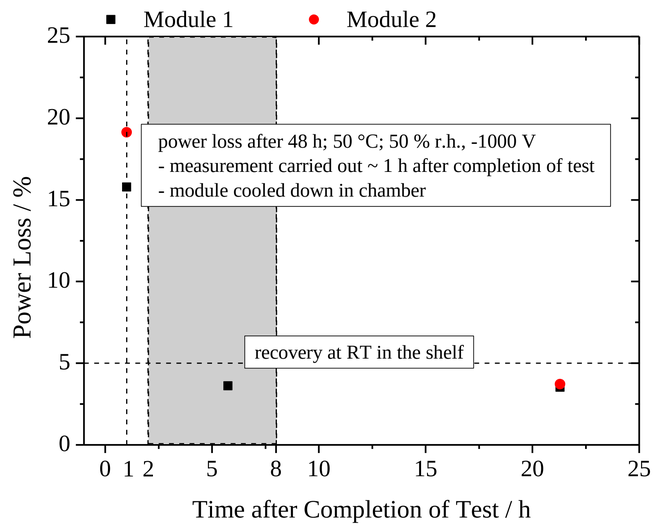

Fig. 12: PID effect on modules with n-type cells + fast recovery at room temperature after completion of the test (same manufacturer)

Bibliography

[1] S. Pingel et al., "Potential Induced Degradation of Solar Cells and Panels," 35th IEEE PVSC, Honolulu, 2010, pp. 2817–2822.

[2] V. Naumann, C. Hagendorf, S. Grosser, M. Werner, J. Bagdahn „Micro Structural Root Cause Analysis of Potential Induced Degradation in c-Si Solar Cells" Energy Procedia, 27, 1 – 6 (2012)