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Potential Induced Degradation of Crystalline Silicone Cells with Various Antireflective Coatings

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Abstract/Summary:

The first experiences with potential induced degradation (PID) of silicon solar cells have been presented in literature since 1989 [1-4]. It has been shown that PID may cause power losses of more than 30% for modules out in the field. Critical issues on the cell level are the SiNx anti-reflective coatings (ARC), their deposition method, the emitter thickness and metallization (thus influencing the electrical series resistance). The leakage current was found as an indicator for the intensity of degradation. Moreover, different test methods to prove the stability or susceptibility of samples have been presented. In this paper we are showing the influence of the anti-reflection coating to provoke PID and the ability of silicon nitrite layers to prevent PID. For each layer structure, at least four different designs have been manufactured and tested for their stability against PID. To do so, it was necessary to find an appropriate test sequence, which would show polarization effects in an adequate time frame, while there is no standard procedure available that addresses this problem for the time being. Furthermore, it has been necessary to develop suitable reference samples to compare the results and to prove the repeatability of the test sequences. The experiment has been divided into two parts: The pre-evaluation has been realized with small onecell mini-modules to probe the adequate testing parameters and to analyze the leakage currents for various prone samples. During the second part, we also investigated the reversibility of PID - depending on the state of degradation of these samples - to check whether PID is one 100% reversible, or whether the degradation mechanism also shows an irreversible part.

For more Information on the topic please contact the R&D Team of PI Berlin.

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Poster:

NextPage

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POTENTIAL INDUCED DEGRADATION EFFECTS ON CRYSTALLINE SILICON CELLS WITH VARIOUS ANTIREFLECTIVE COATINGS

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→ Introduction

The polarization of crystalline silicon solar cells is another aspect of the potential induced degradation (PID) as known from the TCO corrosion at thin film modules. Both effects are induced by sodium diffusion from the glass through the encapsulant. For crystalline silicon it can cause power losses in the field of more than 30%, which are mostly reversible.

In this paper we are showing the influence of the anti-reflection coating to provoke PID and the ability of nitrite layers to prevent PID. The experiment has been divided into two parts: The pre-evaluation has been realized with small one-cell mini-modules to probe the adequate testing parameters and to analyze the leakage currents for various prone samples. During the second part, we also investigated the hot spot risk and the reversibility of PID - depending on the state of degradation of these samples - to check whether PID is one hundred percent reversible or whether the degradation mechanism also shows an irreversible part.

Three different PID tests

(1) Climate condition of **85°C** with a relative humidity of 85% for 48 hours (internal PI-Berlin standard). This PID test shows the fastest degradation
(2) Climate condition of **60°C** with a relative humidity of 85% for 96 hours (proposal for an IEC standard). Shows the same results as for the PI standard test but after 192 hours instead of 96 hours
(3) Climate condition of **25°C** with no specific humidity level control for 168 hours combined with a glued copper foil on the front glass (proposal for a simple PID test setup published during PVSEC 2011). This test shows the same results after 50 cycles à 168 hours .

All tests with negative system voltage against ground and fully contacted with metal foil on the front glass.

Silicon nitride refractive index

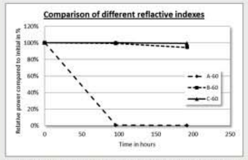

Fig. 1: PID results after two cycles of PID/60/85 of cells with different reflactive index (A=2.03; B=2.2; C=2.3).

Double and triple layer structures

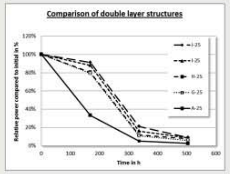

Fig. 2: Different degradation behaviors of various double layer cells (J-G) compared to a standard single layer (A) .

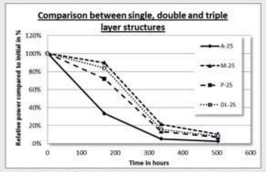

Fig. 3: Different PID behaviors of cells with single (A), double (DL) and triple (M; P) ARC layer during the 168h-25°C-test-method.

Modified layers

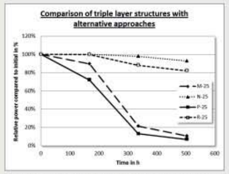

Fig. 4: Cells with triple layer with (N, R) and without (M, P) alternative approaches during the 168h-25°C-test-method.

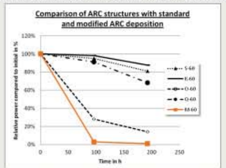

Fig. 5: Different PID behaviour of cells with modified ARC deposition, compared with the best performing standard triple layer "M" (see Fig. 4) during the 96h-60°C-test-cycle.

Hot Spot Risk

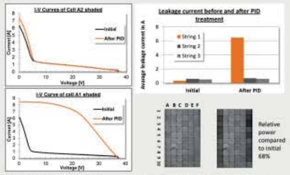

Fig. 6: Hot Spot risk analysis before/after PID treatment.

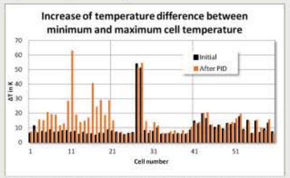

Fig. 7: Increase of the temperature difference between minimum and maximum cell temperature of PID prone (1-20) and PID fix (21-60) cells during a hot spot analysis

Recovery comparison 3 PID Tests

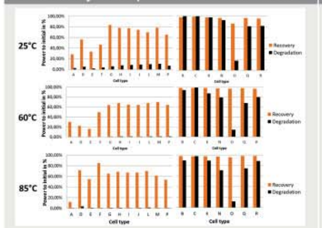

Fig. 8: Comparison between PID degradation and PID regeneration of different cell types (A-R) under different climatic conditions summarized in two groups, one with power under (left diagrams) and over (right diagrams) 15% of the initial power.

Recovery levels

Degradation level	Below 15%		Above 15%	
Time of determination	PID level after Deg.	PID level after Reg.	PID level after Deg.	PID level after Reg.
25°C	6.45%	62.95%	81.58%	95.72%
60°C	0.68%	52.70%	74.83%	98.05%
85°C	0.95%	61.48%	74.82%	97.50%

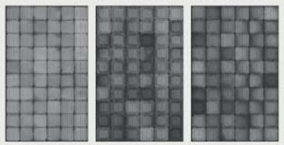

Fig. 9: Electroluminescence images of module GHI after recovery at 25°C (left), 60°C (middle) and 85°C (right)

→ Conclusion

The SiN_x anti diffractive coating has significant influence on the PID stability of the whole module. By applying a second layer, it was possible to slightly reduce the PID effect. By applying a third ARC layer, no further improvement could be monitored. All in all, adding multi-layer-structures to the cells shows an improvement but far too low to be a practical solution for the PID problem.

Alternative approaches to modify the ARC coating to reduce the PID effect were considerably more effective, further experiments will combine and modify the investigated approaches to again enhance the PID stability. Furthermore, it could be shown that PID affected cells can generate a higher risk of developing hot spots than unaffected cells.

It was shown that the 85°C test is two times as burdening as the 60°C test and 50 times more as the 25°C test, if the modules are contacted with metal foil on the whole module front surface.

Activation energies are in the range between 82.60 and 56.14 kJ/mol.

Regarding recovery, it could be shown that modules above a degradation level of 15% can be recovered to a minimum level of 96% and under 15% to 53%. Finally it was observed that the degradation is not completely recoverable depending on the degradation level of the module.