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Work towards Simulation Model for the Potential Induced Degradation Effect on Crystalline Silicon Cells

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Abstract/Summary:

The Potential Induced Degradation (PID) effect for p-type silicon cells is known since 2010 [1, 2]. Since then a wide variety of publications [3-6] presented different aspects and influencing parameters of PID. Some papers even showed the possibility of a simple simulation of this effect [7, 8]. This paper will add the newest test results from the actual research work from PI-Berlin. The parameters will be explained in detail and their influence on the degradation process will be discussed. In addition the difference between tests on one cell mini modules and full size modules will be examined, e.g. contact design, the impact of the potential against ground. Furthermore the special conditions in a power plant, for example the degradation phase during the day, which affects the PID degradation time in the field, will be analyzed. This work shows a model which can predict a degradation process, of a specific material composition after it is analyzed and stressed with indoor and outdoor tests. The first outdoor data and their analysis on mini module level will be presented.

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

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WORK TOWARDS SIMULATION MODEL FOR THE POTENTIAL INDUCED DEGRADATION EFFECT ON CRYSTALLINE SILICON CELLS

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→ Approach

The Potential Induced Degradation (PID) effect for p-type silicon cells is known since 2010. Since then a wide variety of publications presented different aspects and influencing parameters of PID. Some papers even showed the possibility of a simple simulation of this effect [7, 8]. This paper will add the newest test results from the actual research work from PI-Berlin. The parameters will be explained in detail and their influence on the degradation process will be discussed. In addition the difference between tests on one cell mini modules and full size modules will be examined, e.g. contact design, the impact of the potential against ground. Furthermore the special conditions in a power plant, for example the degradation phase during the day, which affects the PID degradation time in the field, will be analyzed. This work shows a model which can predict a degradation process, of a specific material composition after it is analyzed and stressed with indoor and outdoor tests. The first outdoor data and their analysis on mini module level will be presented.

PID degradation speed & voltage

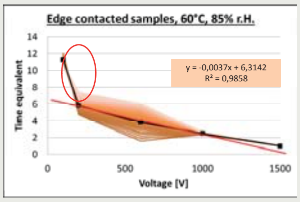


Fig. 1: Calculated curve array (orange) for edge contacted samples, which shows the time equivalent of different degradation levels for different voltages. The regression line (red) is showing a linear correlation between degradation speed and the voltage above.

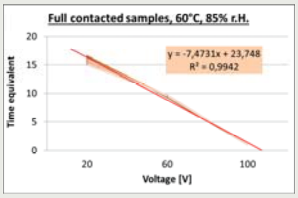


Fig. 2: Calculated curve array (orange) for full surface contacted samples, which shows the time equivalent of different degradation levels for low voltages. The regression line (red) shows a linear correlation between degradation speed and applied voltage

PID degradation level and voltage

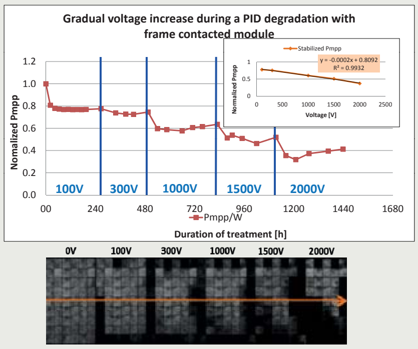


Fig. 3: Degradation progress of P_{MPP} shows a step like behavior with increasing voltage. The regarded electroluminescence images show a development of the PID affected cells from the edge to the center with increasing voltage (bottom). With plotting the voltage against the degradation level of P_{MPP} a linear correlation could be found (top right).

Comparison mini & full size module

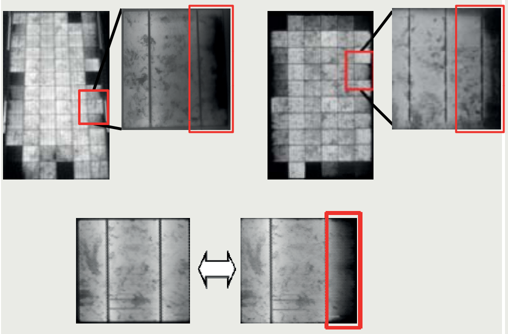
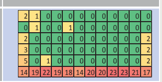
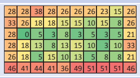
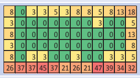
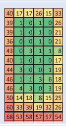


Fig. 4: Electroluminescence images of a cell degraded in a frame grounded field module (left), in a full size frame grounded module stressed in the laboratory (right) or in edge grounded mini module show the same pattern .

Analysis of PID field modules

Power plant	Distribution of PID cells
Power plant 1	
Power plant 2	
Power plant 3	
Power plant 4	

Tab. 1:
- PID distribution of 4 different power plants generated from EL images taken in the field
- The modules are illustrated in the same orientation as mounted in the field
- The percentage of PID affected cells of all analyzed modules is given in the squares
- All modules show the highest rate of PID cells on the lower edge of the modules

Outdoor PID of mini modules

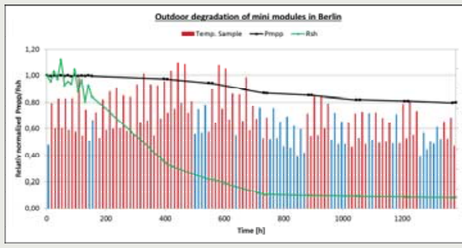


Fig. 5: Progress of the PID degradation during the summer in Berlin. The black line is representing P_{MPP}, the green line R_{SH} and the bars are representing the average day and night temperature. Red bars representing clear days and blue bars are standing for days with rain.

Investigations of PID outdoor degradation

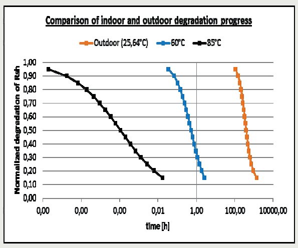


Fig. 6: Comparison between indoor degradation at 85°C and 60°C with the outdoor degradation progress at an average temperature of 25.64°C

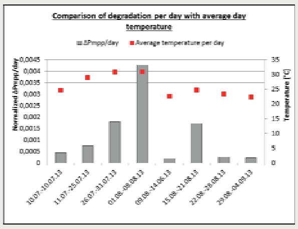


Fig. 7: Comparison between the PMPP degradation per day (grey bars) during the phase according to Figure 9 and the average day temperature (red squares).

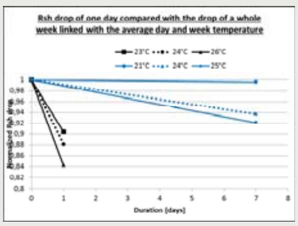


Fig. 8: R_{SH} drop during one day (black) compared to the drop during a week of PID stressed mini modules under outdoor conditions.

Irradiation & PID degradation

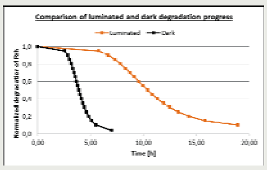


Fig. 9: PID degradation progress of an illuminated (orange) and non-illuminated mini module.

→ Conclusion

The impact of the negative potential against ground was investigated on the PID degradation speed and on the degradation level which was shown to be linked with the contact area. An analysis of PID affected modules showed the preferential direction on the lower edge of the modules and additionally introduced an exception.
Soiled modules seem to create an extensive contact area on the front surface and therefore do not show preferential direction.
Studies about outdoor degradation processes in Berlin were presented. It was shown that the degradation progress matches to those which were generated with a climate chamber. Furthermore it was illustrated that the temperature is the main driving factor during outdoor degradation. In a comparison between the RSH drop during one day with the drop over a whole week with the same average temperatures a typical regenerating factor of 92% could be calculated.
The influence of the irradiation could be observed and the time equivalent between samples without illumination of 500W/m² and with illumination could be determined as 2.7.
Finally, a sigmoidal behaviour of the power degradation vs. shunt resistance was found for all investigated PID test scenarios.
In the next step, we will develop a model for the PID degradation degree and speed as a function of humidity, temperature, soiling and irradiation.