Fraunhofer CSP

HTWK Leipzig

FRAUNHOFER CENTER FOR SILICON PHOTOVOLTAICS CSP

INVESTIGATION OF POTENTIAL INDUCED DEGRADATION ON THE REAR SIDE OF BIFACIAL PERC+ SOLAR CELLS

K. Sporleder[1,2,*], V. Naumann[2], J. Bauer[2,3], M. Turek[2], C. Hagendorf[2]

1 | HTWK Leipzig University of applied sciences | Karl-Liebknecht-Straße 134 | 04277 Leipzig | Germany
2 | Fraunhofer CSP Center for Silicon Photovoltaics | Otto-Eissfeldt-Strasse 12 | 06120 Halle (Saale) | Germany
3 | Anhalt University of Applied Sciences, 06366 Köthen (Anhalt), Germany
* | phone: +49 (0) 345 5589-5070 | mail: kai.sporleder@csp.fraunhofer.de

Supported by: Federal Ministry for Economic Affairs and Energy — on the basis of a decision by the German Bundestag
Supported by: Federal Ministry of Education and Research — on the basis of a decision by the German Bundestag
FORSCHUNG AN FACHHOCHSCHULEN

INTRODUCTION AND MOTIVATION

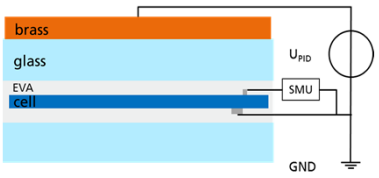
- PERC+ cell concept [1] successfully introduced to mass production
- bifacial gain facilitates reduced LCOE
- absence of full cover rear side metallization: potential of solar cells no longer shielded versus grounded frame or glass on rear side [2]

Is rear side of bifacial PERC cells prone to PID ?

EXPERIMENTAL

Samples and testing conditions

- three types industrially produced PERC+ cells in test
- batches **A**, **B**, **C**, two cells per batch
- 20 cm x 20 cm one cell modules built from each cell type
- material stack: 3 mm glass / EVA / cell / EVA / 3 mm glass

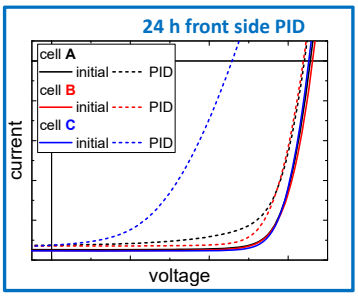


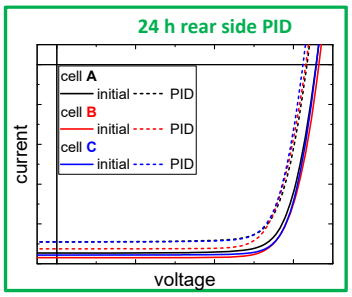
- module stressed under U_{PID} = +1000 V applied to brass plate, cell at ground level
- test duration = 24 h to 96 h, cell temperature 60°C
- dark IV curve measured in 5 min interval during degradation using source meter
- time, temperature voltage according to SEMI PV75-1016

PID sensitivity tested for front and rear side

OVERVIEW: DEGRADATION IN CELL PARAMETERS

Illuminated I-V characteristics – on LED solar simulator (STC)





PID-s for front side under test

- ΔI_{sc} = -2.4% (-2.5%, -3%)
- ΔV_{oc} = -2.3% (-3.5%, -29.8%)
- ΔFF = -9%$_{rel}$ (-1.9%$_{rel}$, -39.8%$_{rel}$)
- main impact on FF for **A** and **C** typical for PID-s [3]

PID-p for rear side under test

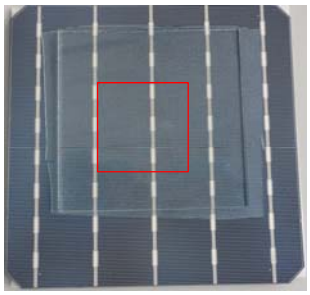
- ΔI_{sc} = -5.9% (-4.6%, -6.9%)
- ΔV_{oc} = -3.5% (-5.0%, -5.1%)
- FF not affected

all cells in test are prone to degradation from the rear side, so called PID-p causes passivation failure

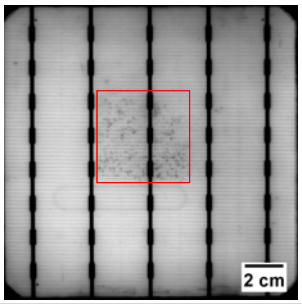
Parts of this work are funded through the German Ministry of Economics within project "PID-Recovery" (FKZ 0324184A).

LATERAL INHOMOGENEOUS PID-p DISTRIBUTION

- local PID test on PIDcon [4]



photograph of cell with rear side up: locally PID stressed at highlighted area

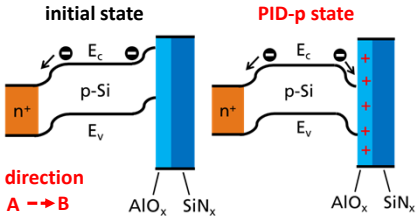


photoluminescence image after 96h PID stress at 1000V bias voltage, rear side up

Hypothesis:

- positive ions enrich in AlO_x layer, reducing field effect passivation [5]
- structural defects or stacking faults in Si or AlO_x facilitates PID-p [6]

PID-p BAND DIAGRAM MODEL



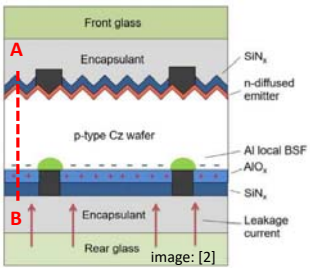


image: [2]

- rear side passivation by field effect of negative charges in AlO_x layer
- **initial state**: electrons repelled from fixed negative charges in AlO_x
- **PID-p state**: positive ions, e.g. Sodium, overcompensate AlO_x layer [6]

break down of field effect passivation can explain PID-p

SUMMARY

1. PERC+ cells in glass/glass module suffer from PID at rear side
2. PID-p type reduced open circuit voltage and current, rather than fill factor
3. lateral inhomogeneous degradation: structural defects facilitate PID-p
4. presumably PID-p relates to local breakdown of field effect passivation of AlO_x layer caused by in-diffusion of positive ions

REFERENCES

[1] Dullweber, T., et al.; Progress in Photovoltaics: Research and Applications 24.12 (2016): 1487-1498
[2] Luo, W., et al.; Progress in Photovoltaics: Research and Applications (2018).
[3] Nagel, H. et al.; 26th EUPVSEC. 2011. S. 3107-3112.
[4] www.pidcon.com
[5] To be shown in forthcoming publication
[6] Naumann, V., et al.; Solar Energy Materials and Solar Cells 120 (2014): 383-389.

Parts of this work are funded through the German Federal Ministry of Education and Research in project "FuzzySun" (03FH024PX5) within "FHprofUnt"