Potential-induced degradation was firstly described as a power loss mechanism occurring for Sunpower modules operated at high positive potential against the ground [1]. It was called “the surface polarization effect” and was explained by an accumulation of negative charges on top of the silicon nitride layer at the front surface of the back-contact-back-junction n-type solar cells and found to be reversible [1]. During the following years the universal term potential-induced degradation was shaped which includes above described phenomena as well as power degradations observed for modules made from p-type cells of different architecture [2]. PID is not yet explained satisfactorily. In [3], the power drop accompanied by PID is divided into two categories. Both are reversible and both occur after applying a high voltage stress (positive or negative potential) between solar cell and ground; one is PID-s which results in a massive cell shunting; the other one is PID-p related to a degradation of the front surface passivation. In this study we investigate encapsulated n-type IBC solar cells featuring a p⁺ front floating emitter (FFE) in respect to their behavior towards high voltage stress. The FFE is capped by a silicon oxide, silicon nitride stack acting as anti-reflective coating and passivation layer. In contrary to the IBC cells with p⁺ front surface field examined in [1,3], our encapsulated IBC cells with FFE degrade while applying a negative potential against the ground.

### Module assembly

- **glass:** standard 3.2 mm solar glass
- **backsheet:** white, transparent or black Tedlar backsheet
- **encapsulation material:** commercially available EVA or alternative material
- **cells:** p-type IBC solar cells with p⁺ front floating emitter (FFE) and p-type reference cells (Al BSF)

**Assembly process**

contacting: IBC cells by ECA gluing of bare Cu ribbon; reference cells by soldering of SnPbAg coated ribbon

lamination process identical for all modules for one encapsulation material, peak temperature differs by 10 K depending on the encapsulation material

### PID test conditions

**Test conditions**

- **voltage supply:** ±1000V
- **humidity:** 5 % or 55 % ± 5 %
- **temperature:** 25 to 65 °C

**Test procedure**

- **initial characterisation:** IV, SunsVoc, EL
- **module placed face down on Al foil covered metal plate**
- **voltage applied**
- **final characterisation:** IV, SunsVoc, EL

PID test conditions

- PID and regeneration is reversible and repeatable
- magnitude of the power drop in same range
- degradation rate significantly shorter for condition II → used for all further tests

PID test for different encapsulants

- **PID and regeneration observed for all encapsulation materials**
- **extent of power drop different for all materials but cannot be related to volume resistivity of encapsulant**
- **results are reproducible for EVA but not for M1**
- **different degradation time?!**

**PID – origin of power drop**

**EL records of initial state (a), degraded state (b) and degraded state (c)**

Picture b shows homogenous decrease of EL signal → increase in radiative recombination in the degraded state

→ PID for IBC cells with FFE due to degradation of front surface passivation as proposed in [3]?!

front vs. rear power drop after PID

bifacial IBC modules show lower relative power drop for rear side illumination

→ PID for IBC with FFE is a front side effect

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### References


