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ScienceDirect

Energy Procedia 124 (2017) 365–370

Energy Procedia

www.elsevier.com/locate/procedia

7th International Conference on Silicon Photovoltaics, SiliconPV 2017

# Impact of the homogeneous junction breakdown in IBC solar cells on the passivation quality of $Al_2O_3$ and $SiO_2$: degradation and regeneration behavior

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**Abstract**

Within the last years, many different approaches for the simplified fabrication of interdigitated back-contact (IBC) solar cells have been developed. Most of those concepts result in emitter and back-surface field (BSF) regions that are in direct contact to each other which leads to a controlled breakdown under reverse bias at the $p^+n^+$ junction. In this work, the influence of the reverse breakdown on the passivation quality of $Al_2O_3$ and $SiO_2$ at the $p^+n^+$ junction is investigated, not only shedding light on the degradation but also on the regeneration behavior of the cells. It was found that cells with $Al_2O_3$ passivation on the back side degrade during reverse breakdown whereas sister cells with $SiO_2$ passivation were rather unaffected. Consequently, the degradation seems to be related to the passivation layer. However, it is shown that the passivation can be regenerated even under normal operation condition. A possible explanation is the discharging of interface traps, which are getting recharged already at room temperature.


Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.

*Keywords:* Silicon; Solar cell; Back Contact; Back junction; Reverse bias; Breakdown; Passivation

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1876-6102 
Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.
10.1016/j.egypro.2017.09.311

## 1. Introduction

Interdigitated back-contact (IBC) solar cells have a very high efficiency potential [1, 2] but typically come along with a complex fabrication process. Several approaches for simplifications of the process flow have been suggested within the last years [3-11]. The simplifications are often based on self-aligning processes, i.e. the masking of one dopant type (or source) by the other dopant type (or source) [3, 7-10]. This inherently leads to a steep doping gradient at the transition from emitter to back-surface field (BSF) with very thin space charge regions on both sides of this $p^+n^+$ junction. Consequently, the junction shows a breakdown at low voltage when reverse biased [3, 4, 12].

SunPower has proven that their IBC solar cells show a non-damaging reverse breakdown that is even beneficial for the module performance compared to standard cell concepts when a part of the module is shadowed [13]. On the other hand, it was found that the reverse breakdown can affect the cell performance even if it occurs homogeneously along the whole $p^+n^+$ junction in a controlled way [12], but the reason is still unknown.

In this work, a direct comparison of identically processed IBC solar cells with either $Al_2O_3$ or $SiO_2$ passivation on the back side (see Fig. 1) is made in order to test the influence of the passivation layer on the solar cell degradation under reverse bias. Additionally, the regeneration at different temperature regimes over time is investigated.

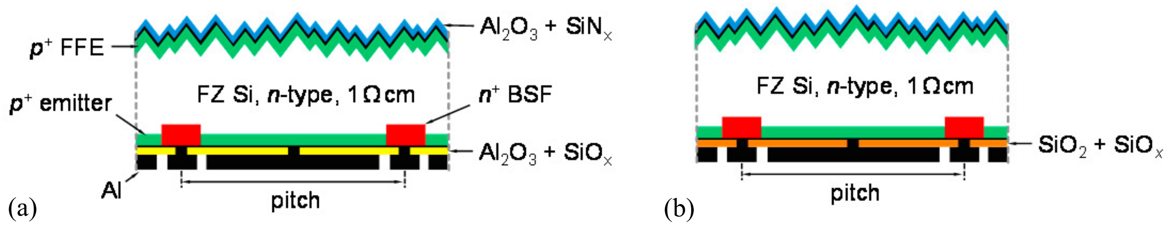


Fig. 1. Schematic of the IBC solar cells with BSF formed by local ion implantation of phosphorus and subsequent $BBr_3$ furnace diffusion to form the emitter and anneal the phosphorus implantation [7]. The pitch is 0.5 mm with 0.4 mm emitter width and 0.1 mm BSF width. The cells were processed identically, but the thermally grown $SiO_2$ was either kept as back-side passivation layer and capped with $SiO_x$ (b) or replaced by an $Al_2O_3$ / $SiO_x$ stack (a). (FFE = front floating emitter)

## 2. Experimental

Solar cells were fabricated on 1 Ω cm n-type FZ silicon wafers with 200 µm thickness. The samples were textured on the front side with KOH forming random pyramids. Phosphorus was implanted locally on the back side ($3\times10^{15}$ $cm^{-2}$, 10 keV) to form the BSF. All the masking in the fabrication was done by a photoresist. Emitter and front floating emitter (FFE) were realized by a full-area $BBr_3$ furnace diffusion (890 °C, 1 h). After removing the boron glass, a ~40 nm thick oxide was grown in a tube furnace at the Australian National University. The thermal oxide was either kept as back-side passivation layer (see Fig. 1b) or removed in HF and replaced by a 10 nm thick $Al_2O_3$ layer (plasma-assisted atomic layer deposition, PA-ALD). The back side (passivated with either $Al_2O_3$ or $SiO_2$) was then capped with 100 nm $SiO_x$ (plasma-enhanced chemical vapour deposition, PECVD) (see Fig. 1a). On the front side, the $Al_2O_3$ was capped with 60 nm $SiN_x$ (PECVD). Before metallization, all samples received a forming gas anneal at 425 °C for 25 min to activate the $Al_2O_3$ passivation. Contact openings on the back side were etched in HF, Al was evaporated and wet-chemically structured. Finally, the finished cells were tempered at 300 °C for 5 min on a hotplate to improve the metal contact.

## 3. Results

### *3.1. IBC solar cells*

The cell parameters of the best solar cells from both groups (either $Al_2O_3$ or $SiO_2$ back-side passivation) are summarized in Table 1. The thermally grown $SiO_2$ offers a very good surface passivation for the ~160 Ω/sq boron emitter with a recombination current density prefactor ($J_0$) of only 13 fA/cm$^2$ on a planar surface (compared to