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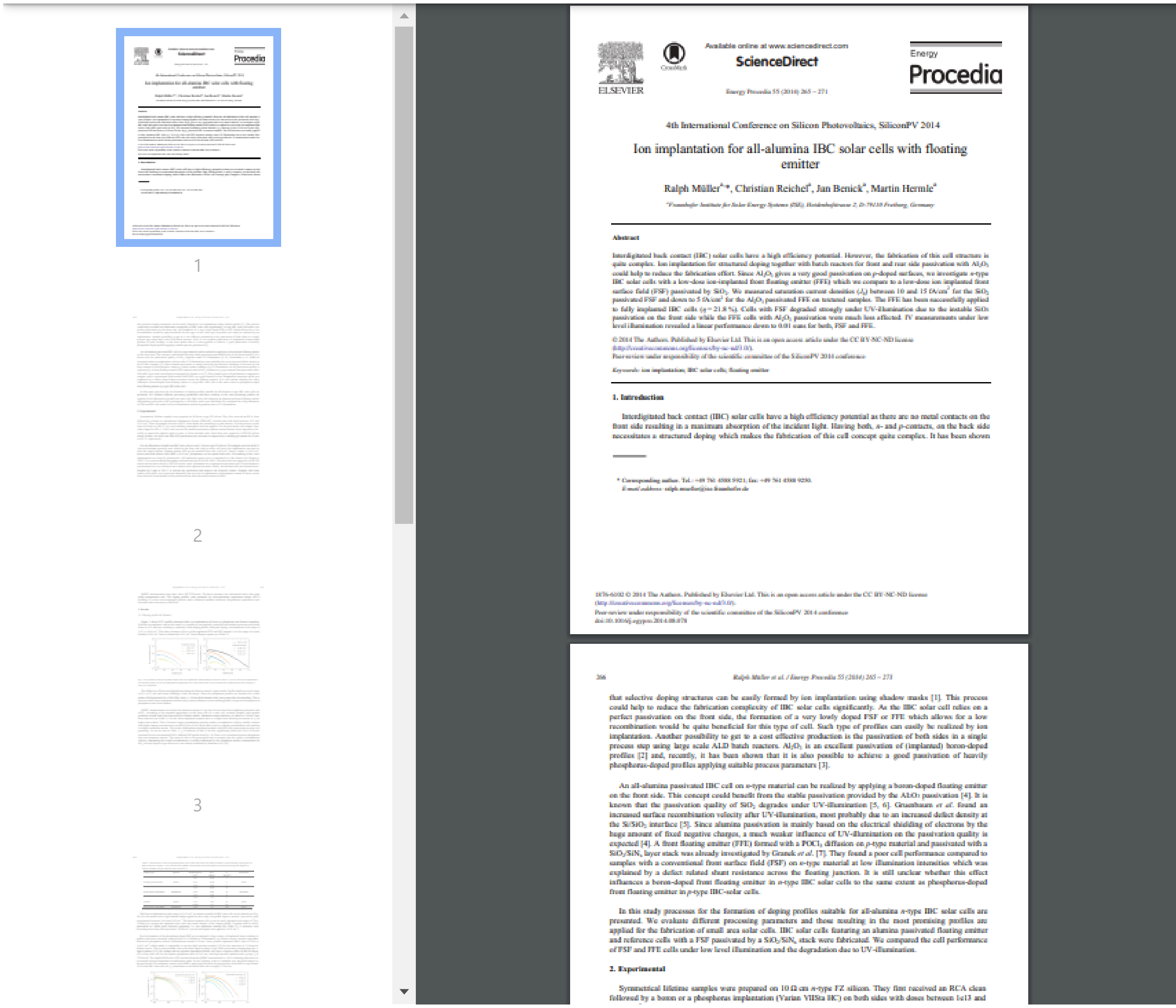

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Ion implantation for all-alumina IBC solar cells with floating emitter

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Abstract

Interdigitated back contact (IBC) solar cells have a high efficiency potential. However, the fabrication of this cell structure is quite complex. Ion implantation for structured doping together with batch reactors for front and rear side passivation with Al_2O_3 could help to reduce the fabrication effort. Since Al_2O_3 gives a very good passivation on *p*-doped surfaces, we investigate *n*-type IBC solar cells with a low-dose ion-implanted front floating emitter (FFE) which we compare to a low-dose ion implanted front surface field (FSF) passivated by SiO_2. We measured saturation current densities (J_0) between 10 and 15 fA/cm^2 for the SiO_2 passivated FSF and down to 5 fA/cm^2 for the Al_2O_3 passivated FFE on textured samples. The FFE has been successfully applied to fully implanted IBC cells (η = 21.8 %). Cells with FSF degraded strongly under UV-illumination due to the instable SiO_2 passivation on the front side while the FFE cells with Al_2O_3 passivation were much less affected. IV measurements under low level illumination revealed a linear performance down to 0.01 suns for both, FSF and FFE.

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Keywords: ion implantation; IBC solar cells; floating emitter

1. Introduction

Interdigitated back contact (IBC) solar cells have a high efficiency potential as there are no metal contacts on the front side resulting in a maximum absorption of the incident light. Having both, *n*- and *p*-contacts, on the back side necessitates a structured doping which makes the fabrication of this cell concept quite complex. It has been shown

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that selective doping structures can be easily formed by ion implantation using shadow masks [1]. This process could help to reduce the fabrication complexity of IBC solar cells significantly. As the IBC solar cell relies on a perfect passivation on the front side, the formation of a very lowly doped FSF or FFE which allows for a low recombination would be quite beneficial for this type of cell. Such type of profiles can easily be realized by ion implantation. Another possibility to get to a cost effective production is the passivation of both sides in a single process step using large scale ALD batch reactors. Al_2O_3 is an excellent passivation of (implanted) boron-doped profiles [2] and, recently, it has been shown that it is also possible to achieve a good passivation of heavily phosphorus-doped profiles applying suitable process parameters [3].

An all-alumina passivated IBC cell on *n*-type material can be realized by applying a boron-doped floating emitter on the front side. This concept could benefit from the stable passivation provided by the Al_2O_3 passivation [4]. It is known that the passivation quality of SiO_2 degrades under UV-illumination [5, 6]. Gruenbaum *et al.* found an increased surface recombination velocity after UV-illumination, most probably due to an increased defect density at the Si/SiO_2 interface [5]. Since alumina passivation is mainly based on the electrical shielding of electrons by the huge amount of fixed negative charges, a much weaker influence of UV-illumination on the passivation quality is expected [4]. A front floating emitter (FFE) formed with a $POCl_3$ diffusion on *p*-type material and passivated with a SiO_2/SiN_x layer stack was already investigated by Granek *et al.* [7]. They found a poor cell performance compared to samples with a conventional front surface field (FSF) on *n*-type material at low illumination intensities which was explained by a defect related shunt resistance across the floating junction. It is still unclear whether this effect influences a boron-doped front floating emitter in *n*-type IBC solar cells to the same extent as phosphorus-doped front floating emitter in *p*-type IBC-solar cells.

In this study processes for the formation of doping profiles suitable for all-alumina *n*-type IBC solar cells are presented. We evaluate different processing parameters and those resulting in the most promising profiles are applied for the fabrication of small area solar cells. IBC solar cells featuring an alumina passivated floating emitter and reference cells with a FSF passivated by a SiO_2/SiN_x stack were fabricated. We compared the cell performance of FSF and FFE cells under low level illumination and the degradation due to UV-illumination.

2. Experimental

Symmetrical lifetime samples were prepared on 10 Ω cm *n*-type FZ silicon. They first received an RCA clean followed by a boron or a phosphorus implantation (Varian VIISta HC) on both sides with doses between 1e13 and

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References

[1] C.E. Dubé, B. Tsefrekas, D. Buzby, R. Tavares, W. Zhang, A. Gupta, R.J. Low, W. Skinner, J. Mullin
High efficiency selective emitter cells using patterned ion implantation
Energy Procedia, 8 (2011), pp. 706-711
View PDF View article View in Scopus Google Scholar

[2] J. Benick, N. Bateman, M. Hermle
Very low Emitter Saturation Current Densities on Ion Implanted Boron Emitters

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in: Proceedings of the 25th European PV Solar Energy Conference, Valencia, Spain (2010)

Google Scholar ↗

[3] S. Duttagupta, F.J. Ma, S.F. Lin, T. Mueller, A.G. Aberle, B. Hoex
Progress in surface passivation of heavily doped n-type and p-type silicon by plasma-deposited AlO x/SiNx dielectric stacks
IEEE Journal of Photovoltaics, 3 (2013), pp. 1163-1169

View in Scopus ↗ Google Scholar ↗

[4] J. Schmidt, A. Merkle, R. Bock, P.P. Altermatt, A. Cuevas, N.-P. Harder, B. Hoex, R. van de Sanden, E. Kessels, R. Brendel
Progress in the surface passivation of silicon solar cells
in: Proceedings of the 23rd European Photovoltaic Solar Energy Conference, Valencia, Spain (2008)

Google Scholar ↗

[5] P.E. Gruenbaum, R.A. Sinton, R.M. Swanson
Light-induced degradation at the silicon/silicon dioxide interface
Applied Physics Letters, 52 (1988), pp. 1407-1409

View in Scopus ↗ Google Scholar ↗

[6] F. Granek, C. Reichel
Back-contact back-junction silicon solar cells under UV illumination
Solar Energy Materials and Solar Cells, 94 (2010), pp. 1734-1740

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[7] F. Granek, M. Hermle, S.W. Glunz
Analysis of the current linearity at low illumination of high-efficiency back-junction back-contact silicon solar cells
Physica Status Solidi RRL, 2 (2008), pp. 151-153

View at publisher ↗ CrossRef ↗ View in Scopus ↗ Google Scholar ↗

[8] C. Reichel, F. Granek, M. Hermle, S.W. Glunz
Back-contacted back-junction n-type silicon solar cells featuring an insulating thin film for decoupling charge carrier collection and metallization geometry
Progress in Photovoltaics: Research and Applications, 21 (2013), pp. 1063-1076

View at publisher ↗ CrossRef ↗ View in Scopus ↗ Google Scholar ↗

[9] P. Saint-Cast, A. Richter, E. Billot, M. Hofmann, J. Benick, J. Rentsch, R. Preu, S.W. Glunz
Very low surface recombination velocity of boron doped emitter passivated with plasma-enhanced chemical-vapor-deposited AlOx layers
Thin Solid Films, 522 (2012), pp. 336-339

View PDF View article View in Scopus ↗ Google Scholar ↗

[10] P.P. Altermatt, J.O. Schumacher, A. Cuevas, S.W. Glunz, R.R. King, G. Heiser, A. Schenk
Numerical modeling of highly doped Si:P emitters based on Fermi-Dirac statistics and self-consistent material parameters
Journal of Applied Physics, 92 (2002), pp. 3187-3197

View in Scopus ↗ Google Scholar ↗

[11] D.E. Kane, R.M. Swanson

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Measurement of the emitter saturation current by a contactless photoconductivity decay method (silicon solar cells)

in: Proceedings of the 18th IEEE Photovoltaic Specialists Conference, Las Vegas, Nevada, USA (1985)

Google Scholar ↗

[12] B. Hoex, M.C.M. van de Sanden, J. Schmidt, R. Brendel, W.M.M. Kessels

Surface passivation of phosphorus-diffused n+-type emitters by plasma-assisted atomic-layer deposited Al_2O_3

Physica Status Solidi RRL, 6 (2012), pp. 4-6

View at publisher ↗ CrossRef ↗ View in Scopus ↗ Google Scholar ↗

Cited by (23)

Low-breakdown-voltage solar cells for shading-tolerant photovoltaic modules

2022, Cell Reports Physical Science

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> …Although high degradation (up to 10% relative) has been reported in homojunction IBC cells after prolonged operation in strong reverse bias,54 those testing conditions did not occur during the outdoor experiments presented in this work. Considering that at least two of the blocks of cells in the IBC module in Figure 6 were mostly unshaded, it is likely that different effects (other than operation in reverse bias) also contributed to the degradation of the tested solar cells.55,56 The device-level simulation results presented in this article suggest that it is possible to reduce the BDV in TOPCon IBC solar cells by reducing the distance between the emitter and the BSF without creating a shunt.…

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2022, Solar Energy Materials and Solar Cells

> *Citation Excerpt :*
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> …The implementation of patterning technology (such as photolithography) [17,18] and contact technologies (such as a combination of Physical Vapor Deposition (PVD) and electroplating) [19,20] makes the manufacturing of this cell concept very complicated. In this work, in order to reduce the manufacturing complexity while maintaining high device performance, we employ the FFE to replace the FSF so that it could reduce the electrical shading effect and increase the process tolerance [21,22]. Moreover, a simplified process sequence was used to fabricate large-area IBC solar cells based on an industrial equipment, which requires no more than two high-temperature steps.…

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...Ion implantation for solar cell applications has been of interest since the 1980s due to its capability for single side doping, which reduces the number of process steps and complexity in the fabrication of various cell designs such as interdigitated back contact (IBC), passivated emitter and rear totally diffused (PERT), passivated emitter and rear contact (PERC), and passivating contacts [1–4]....

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2016, Solar Energy Materials and Solar Cells

Citation Excerpt :

...However, in some IBC cell designs, an even simpler plasma immersion ion implanter (PIII) can be utilized for significant capEx and production cost savings [4]. Recently an interdigitated back contact cell was introduced using c-Si/SiO2/poly-Si passivated contacts formed by ion implantation [5–9] with a record 23.9% efficiency achieved by Rienäcker et al. [10] In this cell configuration, the ions are implanted into a-Si or polycrystalline-Si (pc-Si) layers separated from the c-Si wafer by a thin oxide layer, instead of directly into the c-Si wafer. This eliminates the end-of-range damage such as dislocation loops [11] to the wafer, which in turn, lowers the post implantation thermal budget needed to activate and diffuse dopants in the pc-Si layer, rather than anneal out induced defects in the c-Si....

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...The excellent passivating ability of intrinsic amorphous silicon (i-a-Si) has been shown through the great success of HIT solar cells [16]. On the other hand, front surface field (FSF) and front floating emitter (FFE) have been proved to be capable of improving front surface passivation and reducing lateral resistance [17,18]. Many previous studies have been done concerning the optimization of the diffused FSF of IBC solar cells, such as diffusion profile, sheet resistance and UV stability [19–23]....

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