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Shallow B-implanted emitters with laser overdoping from AlO_x passivating layers

Thibaut Desrues[a]*, Coralie Lorfeuvre[a], Samuel Gall[b], Yannick Veschetti[a]

[a]*CEA, LITEN, INES, 50 av. du Lac Léman, BP332, F-73370 Le Bourget du Lac, France*
[b]*CEA Tech Pays de la Loire, TechnoCampus EMC², Z.I. du Chaffault, F-44 340 Bouguenais, France*

Abstract

A simple process for the fabrication of selective emitter structures on n-PERT cells is investigated, using shallow Boron emitters obtained by ion implantation. By tuning the emitter doping process parameters, J_{0e} values as low as 10 fA.cm^{-2} have been obtained with highly resistive profiles. Laser overdoping processes from AlO_x passivating layers are tested on these profiles to locally increase the emitter conductivity and allow better contact properties. Through this process the emitter sheet resistance and doping profile may be locally controlled with a limited impact on the J_{0e} values.

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Keywords: n-type PERT solar cells; AlOx; laser doping; selective emitter

1. Introduction

N-type silicon substrates show several advantages to produce very high-performance silicon solar cells, as shown recently by many groups [1-3]. Bifacial PERT (Passivated Emitter Rear Totally diffused) structures involve a simple process, which can be more easily implemented in mass production [4]. Amongst the various approaches for reducing the cost of these solar cells, the use of ion implantation (I^2) to create the emitter and BSF regions is one of the most promising. Many studies have shown that this technique not only reduces considerably the number of process steps, but also allows to reach very low emitter saturation current densities (J_{0e}) [5-7]. To further increase

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* Corresponding author. Tel.: +33 479 792 877.
E-mail address: thibaut.desrues@cea.fr

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the efficiency of n-PERT cells, selective emitter structure may be used to reduce contact recombination ($J_{0,met}$) while increasing current collection. However such devices require more patterning steps than conventional n-PERT cells [8]. We study in this paper the fabrication of lightly doped Boron emitters through I^2 process with laser overdoping from AlO_x passivating layers, in order to fabricate selectively doped devices (Fig.1). We first analysed the impact of I^2 processes on shallow B-emitters to reach the lowest current saturation densities. The possibility to fire the AlO_x layer with laser irradiation and locally decrease the sheet resistance of the emitter is also investigated.

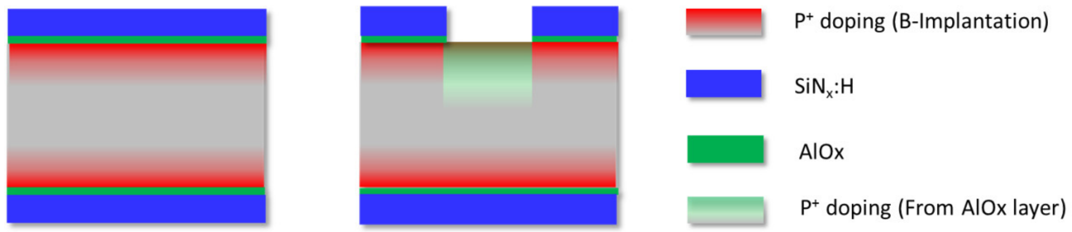

Fig. 1. Sketches of symmetrical samples before and after laser overdoping

2. Experimental

Industrial 156x156mm² n-type pseudo-square Cz wafers were implanted with Boron ions on a VSEA "Solion^{TM}" implanter after a wet chemical polishing step. Implantation doses between 1E14 and 1.17E15 at.cm^{-2} with implantation energies of 8 keV to 10 keV were used. The wafers were then annealed at 950°C or 1050°C with a step of dry oxidation. The emitter sheet resistance (R_{Sheet}) values were measured using a 4-point probe after the annealing step. After an HF dip, 4nm or 8nm thick AlO_x layers were deposited by plasma ALD technique at 250°C on both sides, as well as 75nm thick undoped hydrogenated silicon nitride (SiN_x:H) layers deposited by PECVD at 450°C. Samples underwent a firing step in an IR belt furnace at 800°C to simulate a typical screen printing process. The effective lifetime (and J_{0e} values) of the symmetrical samples were measured using an Inductively Coupled Photo-Conductance Decay (IC-PCD) technique [9]. For the laser doping study the wafers were irradiated with a 15 ps UV laser emitting at 355nm and high frequency (80MHz). Doping process was evaluated through 4-probes sheet resistance and Electro-Chemical Voltage (ECV) measurements using a NH_4F electrolyte and a ring surface of 0.101 cm².

2.1. Fabrication of shallow B-implanted emitters

We used the I^2 process to reach thin and well controlled doping profiles. As shown in Fig. 2a, R_{Sheet} values ranging from 100 to 800 Ohms/sq. are obtained, with various depths and peak concentrations (not shown here). The AlO_x/SiN_x:H stack used in this study is very efficient to passivate the c-Si surface. Using 8nm AlO_x thickness, we achieve implied V_{OC} values above 730 mV on undoped wafers. Onto a lightly doped emitter, the J_{0e} values increase as expected with the doping level (Fig. 2b). However for the most highly resistive profiles, J_{0e} levels still below 20 fA.cm^{-2} are obtained. Emitter profiles having higher R_{Sheet} values compatible with a standard cells metallization process show J_{0e} values about 50 fA.cm^{-2} and more. Using AlO_x as passivating layer has two advantages for our purpose. Firstly, due to its negative charges it induces an inversion layer in n-type substrates and may therefore decreases the sheet resistance of shallow emitters [10]. Secondly, the Al atoms contained in this material may be used as dopant source for laser irradiation [11].

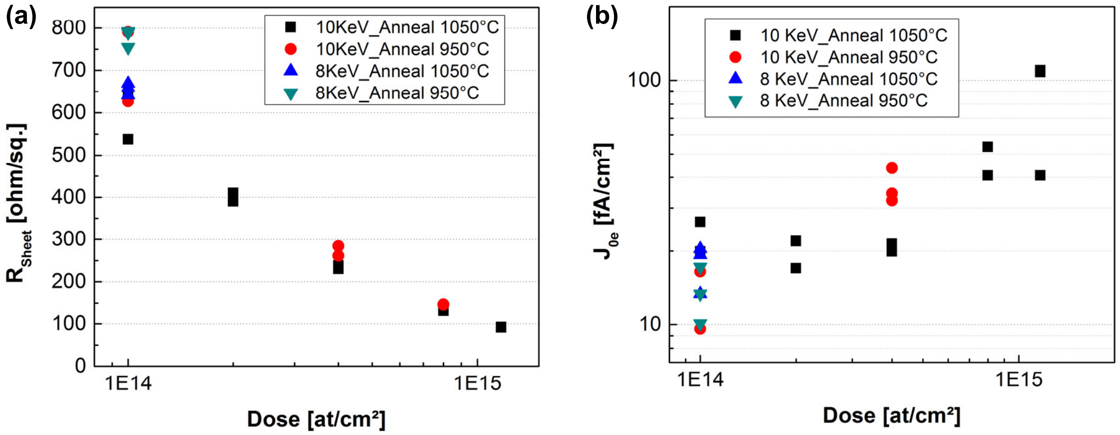

Fig. 2. (a): Sheet resistance values obtained for different doses and annealing temperatures. (b): Related J_{0e} values extracted from IC-PCD measurements.

2.2. Laser overdoping from AlO_x passivation layers

To study the effectiveness of Al doping from the AlO_x layer, substrates with a shallow emitter have been used (10keV, 2E14 at.cm^{-2}, 1050°C, 410 Ohms/sq.). On those substrates 1cm^2 squares have been totally irradiated with different scanning speeds to measure the sheet resistance after laser treatment (Fig. 3). To investigate the effect of laser processes on the surface passivation level, some wafers have been irradiated only on 1% of their surface and lifetime measurements have been performed to extract J_{0e} values. By changing the scanning speed, various energy ranges are reachable with the laser treatment. R_{Sheet} values between 378 to 106 Ohms/sq. from the initially B-doped 410 Ohms/sq. are obtained, indicating an actual doping from Al atoms. Slightly higher R_{Sheet} are obtained by using a thinner AlO_x layer (4nm), probably due to the lowest dopant quantity deposited with those stacks. With deeper profiles, J_{0e} values increase above 50 fA.cm^{-2}, showing the surface degradation after laser doping. Thermal treatments may therefore be needed to heal these degradations and improve the surface passivation in the ablated areas. ECV profiles shown in Fig. 4 indicate that not only the profile depth, but also the peak concentration, can be changed with such a process. This can be of great interest for the doping profile optimization to reach the best contact properties (low contact resistivity and $J_{0,met}$ values).

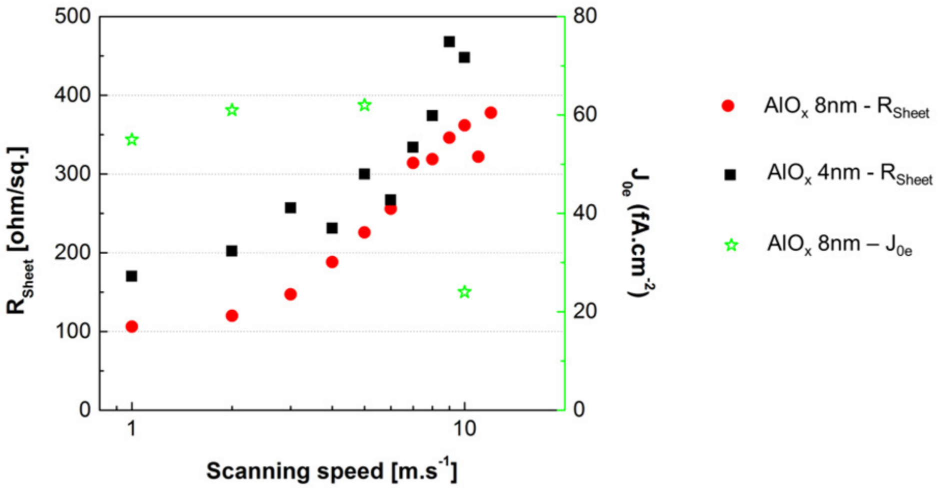

Fig. 3. Sheet resistance and J_{0e} values obtained for different laser scanning speeds and AlOx layers thickness.

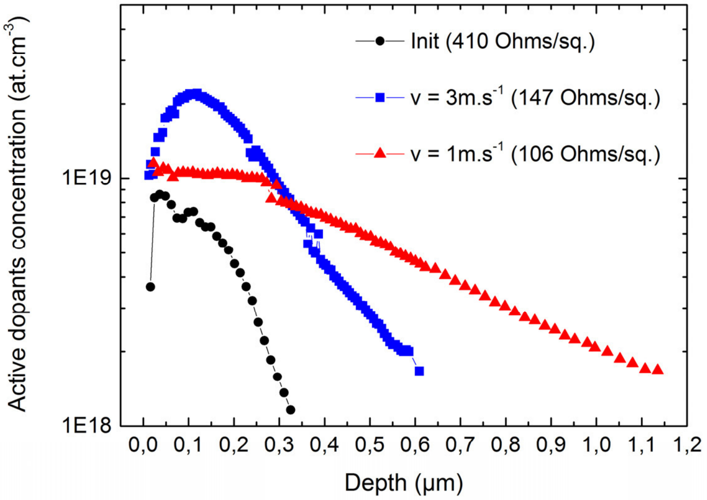

Fig. 4. ECV profiles obtained for different laser treatments and an AlO_x layer thickness of 8 nm.

2.3. Conclusion

The possibility to fabricate n-PERT cells with selective doping was investigated, using shallow B-emitters obtained by ion implantation and laser overdoping from AlO_x passivating layers. Through this processes, various emitter doping profiles may be obtained and used for the cells structure optimization. Shallow profiles from I^2 process show very low J_0 values, whereas more conductive regions are obtained after laser irradiation of the AlO_x/SiN_x:H stack. Improvements of this process are possible using thicker AlO_x layers to obtain lower R_{Sheet} values as well as better surface passivation levels. Further investigations will include SIMS measurements for these different profiles to confirm the effectiveness of Al-doping, as well as contact resistivity and $J_{0,met}$ characterizations.

Acknowledgements

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