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Passivation of Highly Boron Doped Silicon Surfaces by Sputtered AlO_x and PECVD SiN, a Comparison

T.-T. A. Li[1], A. Cuevas[1*], J. Tan[1], C. Samundsett[1], D. Saynova[2] and B. Geerligs[2]
[1]School of Engineering, College of Engineering and Computer Science, The Australian National University, Canberra, ACT 0200, Australia
[2]Energy research Centre of the Netherlands, Petten, The Netherlands
*Corresponding author: Email andres.cuevas@anu.edu.au

Abstract: We show that boron-diffused emitters can be passivated with AlO_x deposited using RF sputtering of an Al target. The surface passivation achieved so far is inferior to that obtained using an optimised PECDV SiN process that includes a chemically grown SiO_2 interfacial layer. Nevertheless, the levels of passivation obtained, expressed by emitter recombination current densities of J_{0E}=228-349 fA/cm^2 for sheet resistances of 88–210 Ω/□, are already consistent with solar cell with efficiencies in the 20% range.

1 Introduction: An emerging application of aluminium oxide, AlO_x, is the passivation of the front, boron diffused surface of n-type silicon solar cells. Atomic Layer Deposition techniques have given the best results so far [1,2], thanks to a low density of interface states combined with a high negative charge. In this experiment, we investigate the passivation of boron-diffused surfaces using AlOx deposited by RF sputtering of an Al target [3] and compare it to the passivation achieved with an optimised PECVD SiN process [4].

2 Experiment: 4", 10 Ω.cm, (100) Cz n-type silicon wafers were saw-damage etched using a 50% TMAH solution and chemically polished using a 10:1 HNO3/HF solution to a final thicknesses of 370-470μm. The boron diffusions were performed in a quartz tube furnace using BBr_3 at 865^{o}C or at 900 ^{o}C for 60 min. To obtain a wider range of sheet resistances and surface dopant concentrations, some of the wafers were annealed at 1000 ^{o}C in N_2 for 3 h or 18 h, after having removed the boron glass using alternating steps in hot HNO_3 and HF solutions. The boron diffusions with no drive-in step give an "industrial type" emitter, with a high surface doping and a relatively shallow pn junction. Those that underwent a drive-in step give a more optimised, "laboratory type", dopant profile with relatively low surface doping and deep junction.

The 4" wafers were quartered to provide a set of samples for passivation with sputtered AlO_x and another set for passivation with PECVD SiN_x. The latter was performed at the Energy research Centre of the Netherlands (ECN) using a method reported by Mihailetchi et al. [4] that includes the chemical growth of a thin SiO_2 layer using nitric acid prior to the deposition of the SiN_x. We will refer to this as a NAOS/SiN_x stack. AlO_x was deposited at the ANU using a 99.999% pure Al target, reactively sputtered with 2 sccm of O_2 and 20 sccm of Ar at a pressure of 3 mT. The RF power was 298 W, with intrinsic bias voltages of around 120 V.

The samples with sputtered AlOx were annealed in a quartz tube furnace at 425 ^{o}C in N_2 for 30 min. Those having a SiN passivation were "fired" in a conveyor belt furnace at approximately 800^{o}C. The dielectric layers were deposited on both sides of the wafers to create a symmetrical structure in order to extract the values of the emitter recombination current density J_{0E} corresponding to the boron emitter regions using photoconductance characterisation techniques [5].

3 Results and discussion: Fig. 1 shows the measured saturation current density, J_{0E},corresponding to the p+ emitter region (inclusive of bulk and surface recombination) for different boron diffusions and for two types of surface passivation, either a sputtered AlO_x layer (approximately 20 nm thick) or a nitric acid SiO_2/SiN_x stack (NAOS/SiN_x).

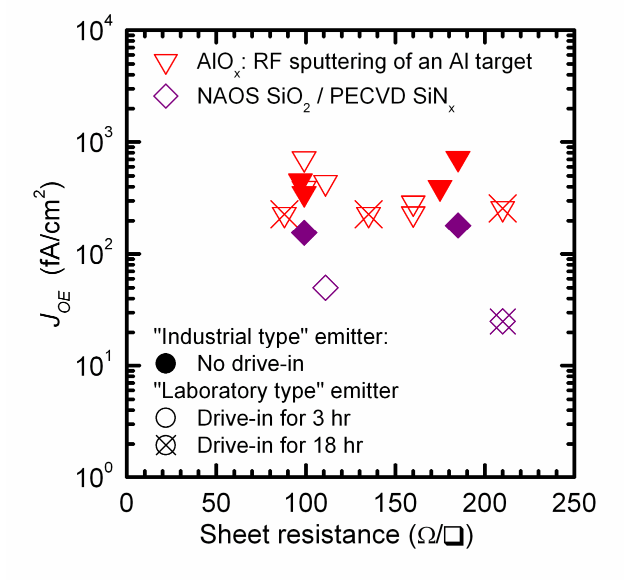

Fig. 1. Recombination (saturation) current density J_{0E} of surface passivated boron-diffused emitters as a function of their sheet resistance.

For the “industrial type” emitter, the best value of J_{0E} using sputtered AlO_x is 349 fA/cm^2 at a sheet resistance of 100 Ω/□. This is consistent with achieving open-circuit voltages of up to 655 mV in n-type (1 Ω.cm) solar cells. Its corresponding sister sample that had been passivated with the NAOS/SiN_x stack achieved a J_{0E} of 155 fA/cm^2. This indicates that further optimization of the “industrial type” emitter profile is needed, since the values achieved by Mihailetchi et al. [4] for a similar sheet resistance are much lower. The results do, nevertheless, prove that sputtered AlOx is capable of passivating boron diffused surfaces.

For the “laboratory type” emitters, the best value of J_{0E} using sputtered AlO_x is 228-257 fA/cm^2 for a range of sheet resistances between 88 Ω/□ and 210 Ω/□. This is consistent with achieving open-circuit voltages of up to 665 mV in n-type (1 Ω.cm) solar cells. The control samples that had been passivated with the nitric acid SiO_2/SiN_x stack achieved a a very low value of J_{0E} = 25 fA/cm^2 at 210 Ω/□, indicating that in this case the surface passivation achieved with sputtered AlOx are not limited by the boron profile itself and that further optimisation of the sputtering process is required.

Table 1: Emitter saturation currents measured for different boron diffusions and passivations.

sample		**NAOS /SiN**	**NAOS/ AlO_x**	**AlO_x**
Diffusion temp (C)	**Resist. ohm/sq**	**J_{oe} fA/cm^2**	**J_{oe} fA/cm^2**	**J_{oe} fA/cm^2**
900/1h	**100**	**155**	**477**	**349**
900/1h +1000/3h	**112**	**50**	**873**	**237**
865/1h	**184**	**180**	**868**	**716**
865/1h +1000/18h	**210**	**25**	**542**	**257**

3 Conclusions: This work has demonstrated a reasonable level of passivation of various boron-diffused surfaces using AlO_x deposited by RF sputtering of an Al target. J_{0E} values as low as 228 fA/cm^2 across sheet resistances of 88–210 Ω/□ have been achieved in this initial experiment; better surface passivation can be expected with the optimisation of the boron diffusion and AlO_x deposition.

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References

[1] B. Hoex, J. Schmidt, R. Bock, P. P. Altermatt, M. C. M. van de Sanden and W. M. M. Kessels, ‘Excellent passivation of highly doped p-type Si surfaces by the negative-charge-dielectric Al2O3’, Applied Physics Letters, 91 (11), 112107–3 (2007).

[2] J. Benick, B. Hoex, M. C. M. van de Sanden, W. M. M. Kessels, O. Schultz and S.W. Glunz, ‘High efficiency n-type Si solar cells on Al2O3-passivated boron emitters’, Appl. Phys. Lett., 92 (25), 253504–3 (2008).

[3] T.-T.A. Li and A. Cuevas, ‘Effective surface passivation of crystalline silicon by rf sputtered aluminum oxide’, Physica Status Solidi - Rapid Research Letters, 3(5),160-162 (2009).

[4] V. D. Mihailetchi, Y. Komatsu and L. J. Geerligs, ‘Nitric acid pretreatment for the passivation of boron emitters for n-type base silicon solar cells’, Appl. Phys. Lett., 92 (6), 063510–3 (2008).

[5] D. E. Kane and R. M. Swanson, 18th IEEE Photovoltaic Specialists Conf, Las Vegas, USA, pp. 578 – 583 (1985).