Area 1: Crystalline and Thin Film Silicon PV

PASSIVATING CONTACTS BASED ON LAYERS OF SILIOCN-OXIDE AND CARBIDE FOR CRYSTALLINE SILICON SOLAR CELLS

F.-J. Haug[1], P. Wyss[1], G. Nogay[1], J. Stückelberger[1], A. Ingenito[1], I. Mack[1], C. Allebé[2], J. Horzel[2], M. Despeisse[2], P. Löper[1], C. Ballif[1,2]

[1]EPFL, PV-Lab, Switzerland, [2]CSEM, PV-Centre, Switzerland

Passivating contacts are a key to high open circuit voltage in crystalline silicon solar cells. If made from an interfacial silicon-oxide and layers of doped polycrystalline silicon, they offer the additional advantage of being compatible with high processing temperatures such as those encountered during the diffusion- or firing-steps of solar cell processing.

We present recent results using doped layers of silicon-oxide (SiOx) and silicon-carbide (SiCx). The increased bandgap in the former makes them attractive for application at the front of the device, the carbon addition in the latter was found to increase their adherence to the substrates during thermal processing and their chemical stability. Our contact stacks consist of an interfacial oxide prepared in hot nitric acid (denoted chem-SiOx) and doped layers deposited by plasma-enhanced chemical vapour deposition (PE-CVD). Subsequently, they are annealed in order to crystallize the deposited layers and, depending on the temperature profile, to diffuse dopants across the chem-SiOx into the underlying silicon-wafer.

For contacts based on SiCx:B layers and annealing for 5 min, Figure 1 shows that the implied Voc reaches values higher than 710 mV for dwell temperatures between 800 and 850°C whereas lower or higher annealing temperatures generally yield inferior results. Figure 1 also suggests a minor dependence on the boron content in the precursor-gas mix. The contact resistivity strongly decreases with boron content as well as annealing temperature. The optimum conditions were applied in demonstrator cells as rear contact in combination with an n-type front heterojunction. The best of these hybrid devices shows a Voc of 707 mV, a FF of 79.9% and an efficiency 21.9%, demonstrating excellent passivation and current extraction [1].

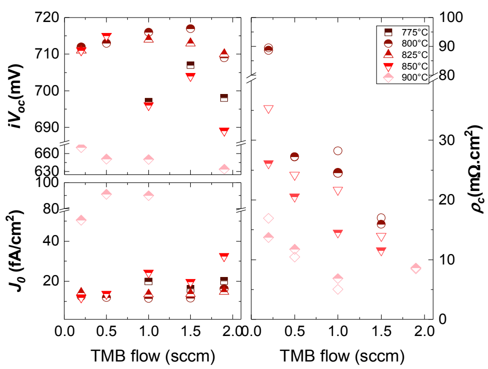

Figure 1: Implied Voc, j_{sat}, and contact resistance of SiCx:B contacts after annealing for 5 min at temperatures between 775 and 900°C.

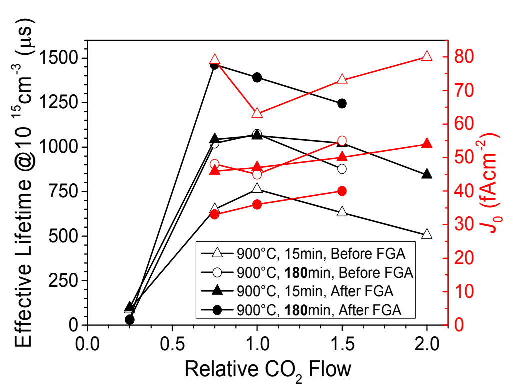

Figure 2: Effective lifetime and saturation current density of SiOx:B contacts after annealing between 15 and 180 min at 900°C.

Integration with one of the high-temperature steps of standard cell production such as the emitter diffusion or the drive-in anneal makes it nevertheless desirable that the contact resists higher thermal budget. Based on results with SiOx:P layers for use as passivating contact at the front, we started investigating B-doped SiOx layes [2]. Compared to SiCx, the incorporation of oxygen by adding CO2 to the precursor gas mix is useful to further reduce parasitic absorption in the layer. Figure 2 shows that even small additions of CO_2 yield a remarkable improvement of the effective lifetime and the saturation current density. A comparison between dwell times of 15 and 180 min at 900°C suggests that this type of passivating contact is compatible with a wide variation of elevated thermal budgets. In combination with a SiOx:P at the front, we could demonstrate a device with co-annealed SiOx passivating contacts on both sides, reaching a FF >78%.

[1] G. Nogay et al., accepted for publication in Sol. En. Mat.

[2] J. Stuckelberger et al., Sol. En. Mat. 158, p2 (2016)