RHINO
Realization of High efficiency Industrial N-type sOlar cells

Project duration: from 01.2018 to 03.2021
Report submitted: 10.2021

Publishable Summary

This project targeted the development of an industrially feasible manufacturing approach for an n-type cell structure that has demonstrated above 25% efficiency in a cleanroom environment. Key elements of the cell structure are an advanced or selective boron-doped emitter and a full area passivated rear contact, fabricated by low-pressure chemical vapour deposition of an in-situ phosphorous doped polysilicon layer on top of a thermally grown interface oxide. For these key elements, production capable processes and high throughput production tools have been developed and implemented in a lean solar cell production process. Both the implementation of the passivating rear contact and reducing the front carrier recombination losses by the development of advanced emitter from BBr3 diffusion increased the efficiency of the developed industrial solar cell from 21% to 22,3% while using screen printed metallization and established production equipment.

The formation of a selective emitter structure, which is realized by laser-doping from the borosilicate glass, which is present on the wafer surface after thermal diffusion, has been intensively studied. A low contact resistance below 2 mΩcm² and a junction depth of > 1 µm could be demonstrated. However, within the project it was not possible to demonstrate an advantage of the laser-doped selective emitter over advanced homogeneous emitters with increased junction depth. High reflection losses at the laser-treated area was identified as one of the main challenges. Instead, advanced homogeneous emitters were developed. These diffusion processes enable recombination parameters of J0e < 15 fA/cm² (textured, Al2O3/SiNx-passivated) at industrially relevant process times of 2 hours. Further optimization of the BBr3-process yielded a junction depth > 1 µm, which effectively reduces metallization induced recombination and these processes were successfully implemented in the solar cell process.

Test modules fabricated from these bifacial cells demonstrated high bifaciality factors of ~85%, still outperforming current passivated emitter and rear (PERC) modules in terms of bifacial properties. Modelling of bifacial module operation enabled a reliable prediction of energy yields depending on system configuration and ambient conditions.

The project contained partners from a research institute, a manufacturer of diffusion and polysilicon deposition furnaces, a laser system specialist and a module manufacturer. They all brought into this project their expertise that enabled to reach almost all the project goals. Based on the project results, follow-up projects were able to further push the development of industrial TOPCon solar cells at Fraunhofer ISE and the industry partners leading to current solar cell efficiencies of up to 23,8% at Fraunhofer ISE. Further exploitation is under way at Fraunhofer ISE with planned industry projects to transfer the developments.

Project consortium

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Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	2	1'475'857	1'005'111
The Netherlands	1	647'000	313'478
France	1	130'142	58'564
Total	*4*	*2'252'999*	*1'377'153*

Funding agencies involved and contracts

Funding Agency	**Contract N° and Title**
PTJ	0324224A and 0324224B "Verbundvorhaben: RHINO - Realisierung von hocheffizienten industriellen n-Typ-Solar-Zellen, Teilvorhaben: Selektiver Emitter und Prozessintegration"
RVO	TESOL17007
ADEME	1805C0014

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