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Model based continuous improvement of industrial p-type PERC technology beyond 21% efficiency

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Abstract

In this work, we present our progress in the industrial p-type PERC technology [1, 2]. Based on device simulations we continuously develop an efficiency roadmap for a steady improvement of our PERC (passivated emitter and rear cell) process. Following this simulation based approach, we effectively improve the front side metallization and the emitter characteristics. Currently, our best prototype process has reached a conversion efficiency well over 21% which enables the manufacturing of a 60-cell based module with a power of 310W. Our best cell so far has a conversion efficiency of 21.5% which has been confirmed by the calibration laboratory of Fraunhofer ISE. This is to our knowledge the highest efficiency reported for industrial-size silicon solar cells with screen-printed metal front and rear contacts.

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1. Roadmap

In recent publications we have developed methods to simulate the efficiency distribution for a cell concept under different scenarios with a combined statistical and TCAD model [3]. Based on this approach we derive the efficiency

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roadmap for our PERC technology (see Fig. 1). Starting from an average production efficiency of 20.2% we aim at continuously improving the manufacturing processes for front side metallization, emitter diffusion, passivation and rear contact formation. Regarding the module technology, the multi bus-bar design is assumed to be the main optimization step. With these optimization steps, we expect 22.5% efficient p-type solar cells with PERC technology available in the market within the next few years.

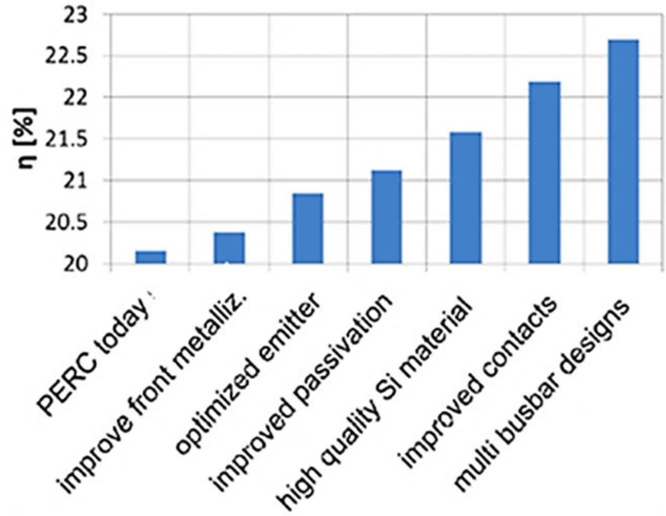

Fig. 1. Efficiency roadmap for our PERC technology; based on device simulations.

2. Technological optimizations

2.1. Front side metallization

According to our roadmap, the first step is the optimization of the front side metallization. We used standard single-print screen printing technology to circumvent the higher process complexity of double printing, hence busbars and fingers are printed within one squeegee stroke. The grid layout consisted of 90 fingers as well as 3 busbars with optimized design to reduce paste consumption and shadowing. Starting from 55µm finger screen opening, we compere 49-µm to 45-µm finger openings for this investigation. Both groups consisted of about 50 solar cells each. The resulting grid lines and IV-data are displayed in Fig. 2 left and right, respectively. The smallest screen opening allowed for a fired gridline width of remarkable 48 µm. This leads to slightly higher J_{SC} due to reduced shading compared to the cells printed with the wider finger opening. However, the higher series resistance of the cells with lower finger width could not be compensated by the higher J_{SC} in this experiment, resulting in a slight efficiency drop of 0.04%abs. Improved pastes and screens are necessary to benefit from the lower finger opening.