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ScienceDirect

Energy Procedia 124 (2017) 131–137

Energy Procedia

www.elsevier.com/locate/procedia

7th International Conference on Silicon Photovoltaics, SiliconPV 2017

Loss analysis of 22% efficient industrial PERC solar cells

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Abstract

The efficiency record of industrial type PERC solar cells exceeded 22% at the turn of the year 2015 to 2016. Our best screen-printed PERC solar cell reached 22.04% efficiency while the best cell batch showed a very narrow efficiency distribution. A detailed electrical and optical loss analysis of those industrial type high efficiency PERC solar cells is carried out which enables further optimization and strategic improvements. A variety of characterization data allows for a recombination current density, resistance and optical loss analysis based on numerical device simulation, analytical calculations and raytracing, respectively. The main recombination losses at maximum power point (MPP) occur in the homogenous and selective diffused regions of the emitter. A series resistance loss analysis is analytically performed. The emitter contribution to the lumped series resistance dominates the series resistance losses. The optical loss analysis performed with raytracing shows main reflection and absorption losses in the rear metal layer which is partly due to the light trapping capability of the PERC cells.

Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.

Keywords: PERC; loss analysis; device simulation

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1876-6102
Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.
10.1016/j.egypro.2017.09.322

1. Introduction

As one of the first groups, SolarWorld Innovations hit the efficiency of 22% for industrial type PERC solar cells [1] while only Trina Solar showed a slightly higher efficiency some weeks earlier [2,3]. Recently, the record has been set to 22.61% efficiency for industrial screen-printed PERC solar cells [4]. This shows the high potential for the PERC solar cell technology in future mass production where an estimated potential of 24% PERC cell efficiency [5] may be achievable. For further optimization and strategic improvements detailed electrical and optical loss analyses of those industrial type high efficiency PERC solar cells have to be carried out. A variety of characterization data allows for a recombination current density, resistance and optical loss analysis based on numerical device simulation, analytical calculations and raytracing, respectively. Such loss analysis is presented below which guides future cell development at SolarWorld.

2. Experimental results

The high efficiency screen-printed PERC solar cells are produced at the SolarWorld Innovations pilot line [6]. The independently measured highest efficiencies are summarized in Table 1.

Table 1. Experimental and simulated IV parameters (*independently measured by ISE CalLab).

Cell	Area [cm²]	j_{SC} [mA/cm²]	V_{OC} [mV]	FF [%]	P_{MPP} [mW]	η [%]
1	242.86	39.90	679.0	81.31	5350	22.03*
2	242.86	39.94	679.3	81.23	5352	22.04*
3	242.86	39.93	678.4	81.34	5351	22.03*
4	242.86	39.96	679.3	81.09	5346	22.01*
Sim	1.00	39.97	680.6	81.42	22.15	22.15

The efficiency distribution of the latest record cell batch is shown in the histogram in Fig. 1 which features a very narrow efficiency distribution and thus good process stability. This enables the preparation of test structures in separate experiments for the complete loss analysis.

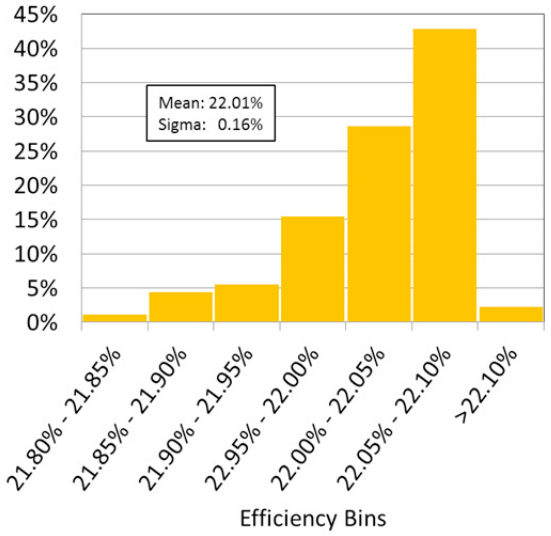

Fig. 1. Histogram – Cell efficiency distribution of a batch of 100 cells fabricated in the PERC pilot line at SolarWorld Innovations.