Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 77 (2015) 129 – 138

Energy Procedia

5th International Conference on Silicon Photovoltaics, SiliconPV 2015

Simulation study of multi-wire front contact grids for silicon solar cells

Massimo Nicolai[a], Mauro Zanuccoli[a], Paolo Magnone[b], Marco Galiazzo[c], Diego Tonini[c], Matteo Bertazzo[c], Enrico Sangiorgi[a], Claudio Fiegna[a]

[a]*Advanced Research Center on Electronic-System (ARCES), and Department of Electrical, Electronic, and Information Engineering "Guglielmo Marconi" (DEI) University of Bologna, Via Venezia 52, Cesena (FC) 47521, Italy*
[b]*DTG, University of Padova, Stradella S. Nicola, 3 I-36100 Vicenza, Italy*
[c]*APPLIED MATERIALS ITALIA s.r.l., Olmi di S. Biagio di Callalta (TV) 31408, Italy*

Abstract

Multi-wire (MW) front-contact schemes represent a promising alternative to standard H-pattern structure with ribbon busbar (BB) in silicon solar cells. In the case of MW schemes, busbar are replaced by copper wires. MW have been demonstrated to enhance the photo-generation with respect to a standard H-pattern structure with ribbon busbar when solar cells are encapsulated and assembled in modules. However, the influence of the geometrical and optical properties of the encapsulation layers as well as of wires on the optical effective shading is not exhaustively treated by the literature. In this work, we have performed electro-optical simulations of MW and BB based solar cells in order to calculate the effective optical shading factor, the enhancement of conversion efficiency and the saving of contact-paste, with respect to the BB design. Specifically, we have studied by means of a ray-tracing simulation tool the significant impact of the front contact grid geometry, of the encapsulation layer thickness and of the optical properties of the cell front interface on the effective optical shading. The calculated values of effective optical shading are used to determine the enhancement of the figures of merit and the paste saving with respect to the reference silver BB scheme. On the basis of our calculations the adoption of optimized MW designs may enhance the conversion efficiency up to 0.5 $\%_{abs}$, allowing paste saving up to 50 mg per cell.

Peer review by the scientific conference committee of SiliconPV 2015 under responsibility of PSE AG

Keywords: Multi-Wire MW Scheme, Electro-Optical Simulation, Effective optical shading

Peer review by the scientific conference committee of SiliconPV 2015 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.07.020

1. Introduction

Conventional industrial H-pattern silicon solar cells adopt a grid of screen printed busbar and fingers fabricated starting from silver pastes. Inside PV modules, solar cells are encapsulated by a layer stack of glass and a polymeric material.

The total fabrication cost of the module is markedly sensitive to the amount of silver-based paste used for the front-contact grid. With this regard, the silver (Ag) paste consumption of industrial screen-printed crystalline silicon solar cells is within the range 120 mg - 200 mg per wafer [1]. In the recent years, one challenging task for photovoltaic industry is to reduce the consumption of Ag paste. However, paste saving techniques are often associated to an increase of total series resistance leading to Fill-Factor (FF) degradation and significant power loss. Moreover, the front-grid design has a marked impact in terms of light shading losses [2].

Multi-wire (MW) schemes [3,4] represent an alternative option to BB aimed at reducing the silver paste consumption in silicon solar cells. In the case of MW schemes, busbar are replaced by copper wires resulting in paste saving. MW are promising for the silicon solar cell industry. In fact, due to their geometry, MW lead to photo-generation enhancement with respect to standard ribbon busbar [5] thanks to a better light-trapping within the cell layer stack consisting of glass, encapsulant and silicon. Moreover, MW are straightforwardly implementable on existing cells offering a full compatibility with different device architectures. In particular, only a few technical details of the process have to be modified, by using a different kind of cell stringer [3].

Optical simulations of MW can be helpful in order to study the light trapping properties of the MW scheme. Several authors have theoretically and experimentally studied the effective optical shading of encapsulated solar cells featuring aerosol-printed and plated fingers presenting a circular cross-section similar to that of copper wires [6]. They reported that the effective optical shading ranges between one third to half of the wire diameter. Blakers [6] has calculated the effective shading of a rough half-circular encapsulated finger and, by a comparison to reflection measurements, he presented experimental data to support calculations of the effective optical shading. In [5], the effective reflection on different types of metal fingers has been analysed by theory and experiments. However, to our knowledge, one issue that has not been addressed to date is that of the sensitivity of the effective optical shading of wires to their geometry and density, to the thickness of the encapsulant layer as well as to the optical reflectance of the cell front interface. The influence of these parameters on the light trapping enhancement due to MW may have a relevant impact on the cell design.

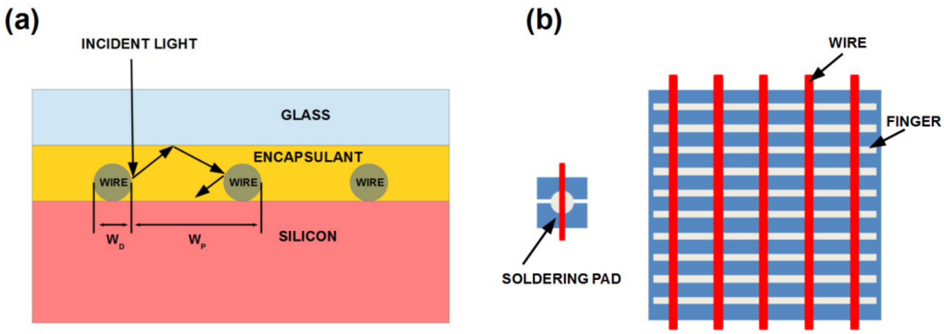

Fig. 1. (a) Sketch of the encapsulated multi-wire solar cell (cross-section, not to scale) and (b) top view schematic of the contacting grid with the detail of a soldering pad.

In this work, we have performed electro-optical simulations of MW and BB based solar cells in order to calculate the effective shading factor, the enhancement of conversion efficiency and the paste saving of the MW scheme with respect to the BB design. In particular, by means of optical simulations, we have analyzed the impact of the geometries of the stack layer, of the wire coverage fraction and diameter, and of cell front reflectivity on the wire