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Three-Dimensional Numerical Simulation of Rear Point Contact Crystalline Silicon Solar Cells

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Abstract. High efficiency monocrystalline solar cells commonly adopts rear point contacts of limited extension and passivation of the uncontacted bottom silicon surface region in order to improve performance. Modeling and analysis of advanced solar cells is strategic to optimize the device design and to minimize the losses. Several competing physical mechanisms must be accounted for in order to properly analyze rear point contact solar cells and a three-dimensional (3D) analysis of complex geometries is required. In this work we describe the issues related to the design of the mesh grid for the 3D numerical simulations, the definition of appropriate boundary conditions and the main adopted assumptions. Examples of numerical simulations are reported.

Keywords

Rear point contact solar cells, three-dimensional numerical simulation, advanced solar cells.

1. Introduction

The recombination losses occurring at the rear contact of crystalline solar cell significantly limit the conversion efficiency. Conventional solar cells, which feature a base contact metalization extended over the whole back silicon surface, are affected by significant recombination losses at the metal-semiconductor interface. High-efficiency silicon solar cells usually feature local point contacts at the back surface, allowing the passivation of the uncontacted back silicon surface region (see Fig. 1). This back-contact scheme is commonly adopted by PERC (passivated emitter and rear cell) and PERL (passivated emitter, rear locally diffused) solar cells and enables the fabrication of single-junction cells featuring record conversion efficiency well above 20% [1], [2].

As discussed in [3], the optimum design of rear point contact solar cells requires a trade-off between several effects such as the reduction of the surface recombination velocity at the passivated back interface, the larger bottom effective internal reflectivity of passivated surface compared to metal-contacted region and the enhancement of series parasitic resistances that is mainly due to the back contact-resistance and to the base spreading resistance associated to 3D conduction paths occurring when the extension of the contacted region is much smaller than the cell area.

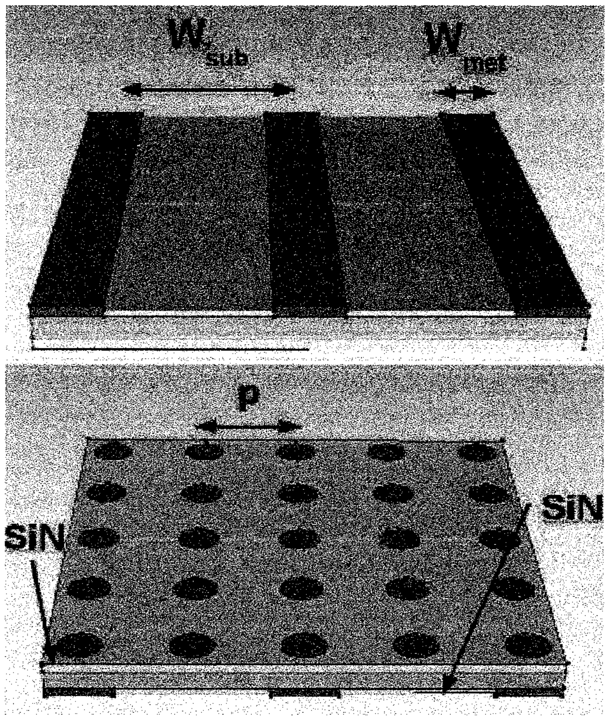

Fig. 1 Sketch of a rear point contact solar cell. On the top side, W_{sub} denotes the front contact pitch and W_{met} the front contact finger width. The figure on the bottom highlights the rear side of the device featuring the holes equally distributed with period *p*. The interface that is not contacted by the metallization is passivated by silicon nitride (SiN) or silicon oxide.

Typical rear point contact solar cells feature circular contacts uniformly distributed on the bottom surface with diameter s and repetition period (pitch) p (see Fig. 1). In the following we denote by f the metallization fraction at the rear side, defined as the ratio of the contacted area to the total cell area and expressed by Equation (1):

$$f = \pi \cdot \left(\frac{s}{2p} \right)^2 \qquad (1)$$

The non-metalized rear surface is typically passivated by using silicon nitride or silicon dioxide in order to reduce the density of surface defects and suppress recombination [3]. Given the complex 3D geometry, modeling of rear point contact solar cells is fundamental in order to optimize the device design.

Previous works were limited to two-dimensional numerical simulation approaches [4] or relied on quasi-