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Pattern of partial rear contacts for silicon solar cells

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Abstract

Partial rear contacts solar cells, which are passivated and locally contacted on their rear side, are widely used for their higher performances, especially in open-circuit voltage. If the distance in between two contacts has been optimized, the best geometry of a contact lattice remains unclear. So far, the most widely explored geometry is the square lattice. This work aims to explore, by the mean of numerical simulations on both PERL and PERT architectures, the consequences of different lattice geometries, and more specifically triangular and hexagonal patterns. This study was extended to the variation of a set of material and process parameters in order to observe the consequences on conversion efficiency for each contact pattern. Once the simulations performed, it has been demonstrated that even though these three geometries show the same optimal efficiency when varying the distance in between two contacts, the triangular contact pattern is clearly more robust with the variation of this distance, which makes it a good candidate for fully optimized solar cells. Moreover, the variation of material and process parameters shows the interest of the triangular contact pattern in case of degraded parameters.

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1. Introduction

Surface recombination is responsible for a large drop of open-circuit voltage (V_{oc}) in silicon solar cells, inducing a loss of efficiency. In order to address this problem at the rear side of a cell, one can use Partial Emitter Rear Locally diffused (PERL) or Passivated Emitter Rear Totally diffused (PERT) architectures, which consist in

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depositing an insulating and poorly recombinant layer at the rear side of the absorber, then making a local ablation in order to contact the absorber with metal by point contacts regularly spread onto the surface [1]. This solution leads to a higher V_{oc}, although it also decreases the fill factor (FF) by lengthening the majority carrier path in the semiconductor. The optimization of the distance in between two localized contacts (pitch) has been widely studied [2-4], and brought to a high increase in efficiency.

These optimizations have been made assuming a square pattern for the contact lattice. However, the available ablation techniques (optical lithography [1] or ultra-violet laser [5, 6]) give the possibility of using different patterns, like the three regular ones, triangular, square and hexagonal. For a given pitch, the different lattices will change both the maximum majority carrier path (which drives the V_{oc}) and the ratio between the contacted area and the rear side surface (which drives the FF), also called metallization fraction. Therefore, the aim of this work is to compare the influence of different rear side contact patterns on the electrical performances of both PERL and PERT solar cells. After a qualitative analysis of contact patterns, complete solar cell simulations are performed for the different patterns and for different pitches. Then, the influence of different material and process parameters is studied.

2. Geometrical considerations

A scheme of the simulated device, as well as the three possible contact lattices disposed in regular patterns and the simulation domains is presented in Fig. 1. The choice of contact pattern can influence two electrical parameters: open-circuit voltage (V_{oc}) and fill factor (FF). More specifically, the V_{oc} is degraded with an increase of metallization fraction [3], called f. Furthermore, the FF being linked to the series resistance into the cell, and considering a constant resistivity over the substrate, one can conclude that the FF will decrease as the pitch increases. More precisely, one can find, for each contact pattern, the maximal distance p_{max} that a charge carrier can be from its closest contact on the rear contacts surface. If this distance is minimized, then the substrate resistance from this critical position to the electrode is minimized, and so the resistance for every point on the rear contacts surface is minimized, since every charge carrier will be closer to a contact than this distance. This result can be extrapolated to the charge carriers that are not onto the surface, because p_{max} will be reduced in the same way for these. Hence, the computation of f and p_{max} for the different geometries can enlighten the pertinence of these contact patterns.

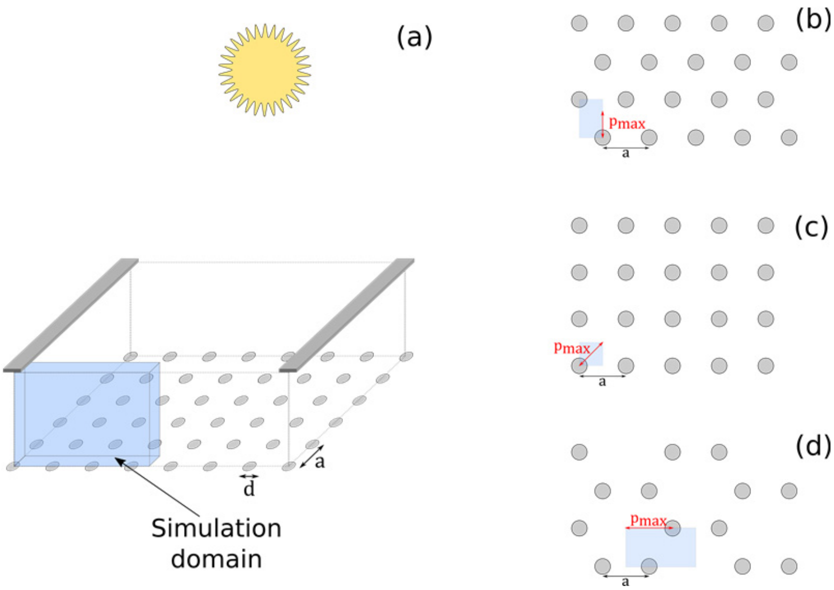

Fig. 1. (a) Sketch of the simulated device. d is the rear contact diameter and a the rear contact pitch. (b) Triangular, (c) square, (d) hexagonal rear contact patterns. Blue rectangles are the reduced simulation domain.