Optimization of the efficiency of a photovoltaic cell by means of a genetic algorithm

Giuseppe Alì[1,2], Francesco Butera[1], and Nella Rotundo[1]

[1] Dipartimento di Matematica, Università della Calabria, Arcavacata di Rende I-87036, Cosenza, Italy
giuseppe.ali@unical.it, francesco.butera@unical.it, nella.rotundo@unical.it
[2] INFN, Gruppo collegato di Cosenza, Arcavacata di Rende I-87036, Cosenza, Italy

Summary. We consider an optimization problem for a photovoltaic cell, modeled by the drift diffusion equations, modified to include optical effects. In order to optimize the efficiency of the cell, first we determine the most relevant parameters, such as the number of fingers in a channel or the initial concentration. Then we use a genetic algorithm to determine the sets of parameters which optimize the efficiency of the cell.

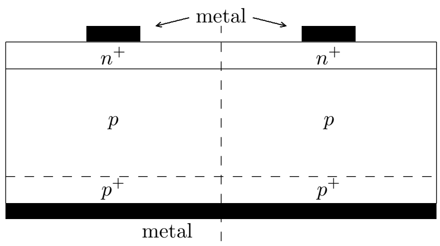

Fig. 1. Geometry of the test photovoltaic cell

1 Introduction

The current efficienciency of photovoltaic cell panels is around 20% [1]. Higher values of efficiency (around 23%) can be achieved by selecting more expensive types of silicon crystals [2], but their use is limited to those cases in which cost is not an issue.

By constrast, commercial panels often fail to reach even the 20% limit of accuracy, falling closer to a value around 15% [3]. Raising the efficiency of commercial panels to values higher than 20% would be an important goal, both scientifically and technologically. An immediate increase of the efficiency of solar panels is possible by following two distinct paths: selecting materials with higher Energy gaps and increasing the area of the exposed solar cells.

In most commercial solar cells, the soldering contacts and the connections between the wafers that compose the cells themselves are on the same side of the surface which is exposed to the sun. Moving the contacts and the soldering connection on the back of the wafers offers is one of the possible way to increase the surface exposed to the sun. Solar cells constructed using this technique are usually referred to as ”Back-contact silicon solar cells” [4].

2 The photovoltaic cell model

We consider a simplified test model of a photovoltaic cell, corresponding to a transversal section of a solar panel. In order to include the effect of the number of fingers in a channel, that is, the distance between two fingers, we consider a block comprising two cells, as in figure.

The cell is modeled by the drift-diffusion equations, implemented in the commercial simulator Sentaurus Device. Thus, we neglect all thermal effects, and assume that two carriers are responsible for the diode's output current, that is, electrons with negative charge $-q$, and holes with positive charge q. The behavior of the device in the test cell, denoted by Ω, is described in terms of number densities of electrons and holes, denoted by $n(x,t)$, $p(x,t)$, quasi-Fermi potentials for electron and holes, denoted by $\phi_n(x,t)$, $\phi_p(x,t)$, current densities for electrons and holes, denoted by $j_n(x,t)$, $j_p(x,t)$, and electrostatic potential, denoted by $\phi(x,t)$. These variables satisfy the following drift-diffusion system [5],

$$-\nabla\cdot(\varepsilon\nabla\phi) = q(N+p-n), \tag{1}$$

$$-q\frac{\partial n}{\partial t}+\nabla\cdot j_n = qR, \qquad j_n = -q\mu_n n\nabla\phi_n, \tag{2}$$

$$q\frac{\partial p}{\partial t}+\nabla\cdot j_p = -qR, \qquad j_p = -q\mu_p p\nabla\phi_p, \tag{3}$$

where $(x,t)\in\Omega\times[t_0,t_1]$. The densities n, p, are related to the quasi-Fermi potentials by relations derived from the Fermi statistics,

$$n = n_i\gamma_n\exp\left(\frac{\phi-\phi_n}{U_T}\right),\ p = n_i\gamma_p\exp\left(-\frac{\phi-\phi_p}{U_T}\right),$$

where n_i is the intrinsic concentration, and γ_n, γ_p are complicated functions of the unknowns, which reduce to 1 for Maxwell-Boltzmann statistics. In (2), (3), $N(x)$ is the doping profile, μ_n, μ_p are the mobilities for electrons and holes, respectively, and R is the recombination-generation term. For the mobilities we use the PHUMOB model present in Sentaurus. We consider Shockley-Read-Hall and Auger recombination-generation terms, combined with a radiative model. The system (1)–(3) is supplemented with appropriate boundary conditions.

3 Optimization

Our goal was to maximize the efficiency of Back-contact silicon solar cells. We used an optimiziation strategy based on a genetic algorithm applied to some physical parameters of the solar cell. In particular we focused on optimizing the doping concentrations of the bulk and of the emitter.

The Sentaurus device simulator was interfaced with a genetic algorithm written in C, via a wrapper capable of restarting Sentaurus with given physical parameters.

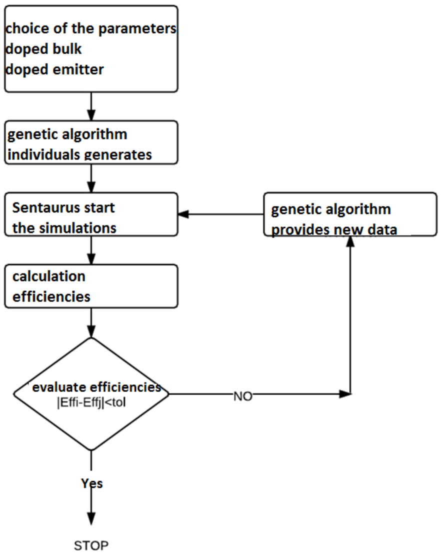

Fig. 2. flow chart simulator device and genetic algorithm

The coupling between Sentuarus and the genetic algorithm was controlled via an euristic algorithm, in which the difference between the computed efficiency in two consecutive steps was used to determine wether the entire optimization process could be stopped.

A wrapper written in C supervises the communication between Sentaurs and the genetic algorithm. The entire process was run under Linux, which provides an ideal platform for these kinds of algorithms.

References

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