Simultaneous optimization and simulation of a-Si$_{1-x}$C$_x$ layers on n-type silicon solar cells

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Abstract

We have applied Rosenbrock's optimization algorithm to obtain the optimized efficiency of a solar cell and its structural parameters. To obtain these parameters, we have developed a computer program for simultaneous optimization and simulation of the solar cell. We have used experimental data on the electrical and optical properties of a-Si$_{1-x}$C$_x$ layers, put them into the written code and obtained the optimized parameters of this solar cell. The maximum efficiency is 6.32% which is close to one experimental result.
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1. Introduction

In the past, experimental iterations for device fabrication were economically acceptable to engineers and device designers but nowadays the cost makes this approach unacceptable. The main goal of device modeling techniques is to relate their electrical performance to the materials properties. This approach does not provide an optimum structure. Thus to obtain the best simulation result the modeling should be implemented by changing and optimizing the device parameters [1].

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When device modeling techniques are put into an optimization cycle, the value of all structural parameters is adjusted at the same time under several constraints, until the requirements are satisfied. When we write a computer code for this problem and implement it, the optimized device structure will be obtained [2].

In this paper, we first describe the general optimization problem and review the Rosenbrock's optimization algorithm, which we have used for our work. We apply this technique, which was used by Chen [2] and his coworker, to optimize silicon solar cell structures. The algorithm which they used was slightly different from the constrained Rosenbrock's algorithm. We introduce a simulation technique that has been successfully used for simulation of MOSFET [3] and LDD MOSFET [4]. Then a-$Si_{1-x}C_x$ alloys and their optical and electrical properties, which we will optimize for cell fabrication, are introduced. Finally, we will report our results of optimization and simulation of a-$Si_{1-x}C_x$/n-Si solar cells.

2. Optimization technique

The general optimization problem can be express mathematically as

$$
\begin{aligned}
&\text{Max} \qquad f(\vec{x}) \\
&\text{subject to} \quad g_i(\vec{x}) \leqslant 0 \quad i = 1, 2, \ldots, m \geqslant n,
\end{aligned}
\tag{1}
$$

where x is a vector of n parameters to be optimized in the design space, $f(\vec{x})$ is the object function which is desirable to be minimized and $g_i(\vec{x})$'s are the constraints that stem from structure limitations, properties of materials which are being used to fabricate the cell. Even the level of current technology or operating costs of fabrication of the cell could be considered. These constraints define a design space [5], and the only acceptable values for the design vector are those that do not violate constraints.

2.1. Rosenbrock's constraints optimization technique

This algorithm is based on the direct search method by rotating the coordinate system. Each stage of maximizing is in such a way that, one axis is always oriented toward the locally estimated direction of the maximum, and the other axes are normal to it and mutually orthogonal. For the constrained case, when the number of constraints is small, the constraints are defined as follows [5]:

$$
l_i \leqslant x_i \leqslant u_i \quad (i = 1, 2, \ldots, m \geqslant n),
\tag{2}
$$

where $x_1, x_2, \ldots, x_n$ are the independent variables, l_i and u_i are lower and upper limits, respectively, corresponding to each independent variable. If there is no particular constraint imposed on u_i (or l_i), then a convenient limit should be imposed by the user. A boundary width of $10^{-4}(u_i - l_i)$ associated with each pair of constraints as in Eq. (2) is defined, so that a variable x_i ($i = 1,2,\ldots,m$) is within its boundary region if