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Determination of the intrinsic diode parameters of polymer solar cells

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Abstract

Polymer solar cells offer a promising low cost alternative in photovoltaics if the expensive ITO electrode can be omitted. Recently an alternative based on highly conductive PEDOT:PSS in combination with current collecting grids was developed.[1] Electrical modeling is carried out to optimize the grid pattern in these polymer solar cells. The basic inputs for this type of modeling are the resistivity of the materials, film thicknesses and the diode parameters of the solar cell. The diode parameters are often determined by fitting the experimental current-voltage measurements to a one-diode model. This gives the well-known dark saturation current density (J_0), diode ideality factor (n), photocurrent density (J_L), shunt resistance and series resistance. However, the fitted parameters do not always correspond with the intrinsic solar cell parameters, i.e. those that correspond to an infinitesimally small diode, but they are actually lumped parameters containing information of the heterogeneity of the system. For this reason, two one-diode fits corresponding to two different systems (in size and geometry) can yield different intrinsic diode parameters. The reason for this can be found in the heterogeneity of the system.
We show an approach to determine the so-called intrinsic diode parameters, by fitting the experimental IV curve against a simulated IV curve that is obtained from a model in which the experimental solar cells are explicitly modeled in 3D.
This model provides a simple basis to determine the intrinsic solar cell parameters that can be used for the optimization of grid patterns for polymer solar cells.

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1. Introduction

Modeling of solar cells is a powerful tool in the optimization of cell performance. Various reports have been written on the optimization of solar cells.[2-5] Among them a few can be found on optimization of polymer solar cells in particular.[6] In most cases the optimization is done using input parameters like the diode parameters and sheet resistances of the materials in the cell. In those cases, the result strongly depends on the accuracy of these input parameters. Often the diode parameters are obtained by fitting a 1-diode model to experimental data or a measured current and voltage at maximum power point is used. However, in these parameters also the device lay-out plays a role and it only gives the correct diode parameters if the cell is infinitesimally small, not measured using an illumination or aperture area mask[7] and if the series resistance in the cell is very small. More often the fitted parameters are actually lumped parameters containing information of the heterogeneity of the total system. Firstly, the distributed series resistance effect results in a voltage distribution across the solar cell in the lateral direction, which causes that all notional diodes operate at different voltages. Secondly, aperture area masks are used when accurate IV measurements of organic solar cells are carried out. In that case, the intrinsic diode parameters may differ for the illuminated and shaded areas and, moreover, the shaded area will deprive current from the illuminated zone, resulting in lower open-circuit voltages.

Although there are discussions on whether organic solar cells can be described with a 1-diode equation, several groups have reported on fitting of organic solar cells using an (adapted) 1-diode model.[8-11] We will show a simpler approach, based on the standard 1-diode equation, to determine the so-called intrinsic solar cell parameters, i.e. without the influence of the contacts. This is done by simultaneously fitting simulated I-V curves from a 3D finite element model to the experimental data of cells with different geometries. These intrinsic solar cell parameters can then be used for optimization of grid patterns for cells and modules.

2. Models

In electrical optimization of solar cells, the diode parameters of the solar cell without the resistance influence of the contacts must be used, i.e. the intrinsic diode parameters. Most of the time current-voltage experiments are fitted with a one-diode model to obtain the diode parameters and the series resistance of the cell. This gives the well-known dark saturation current density (J_0), diode ideality factor (n), photocurrent density (J_L), shunt resistance and series resistance. However, the fitted parameters do not always correspond with the intrinsic solar cell parameters, but they are actually lumped parameters containing information of the heterogeneity of the system. For small cell sizes and/or cells with a small series resistance, this one-diode model with lumped series resistance can be used. Cells with a high series resistance must be modeled with a one-diode model with distributed series resistance, which needs a finite element method (FEM).

2.1. One-diode model with lumped series resistance

In the one-diode model with lumped series resistance it is assumed that each part of the cell experiences the same voltage, see Fig.1. This is only true if the cell is infinitesimally small or has a very small series resistance. As a result, a fit to the diode equation (Eq. 1) gives only correct ‘intrisic’ cell parameters for very small cells and cells with a very small series resistance.

$$J(V) = J_{ph} - J_0\left(e^{\frac{q(V-R_S J)}{n\cdot kT}} - 1\right) - \frac{V - R_s J}{R_{sh}} \qquad (1)$$