Circuit Simulations to Understand Monograin Membrane Solar Cells

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Introduction:

Monograin Membrane Solar Cells as developed by crystalsol and the Tallinn Univ. of Technology consist of a large number of micro-solar cells connected in parallel. As complex electrical circuits their behavior can be modeled using a combination of a physics-based electrical equivalent circuit and an abstract mathematical model using fit parameters allowing to emulate e.g. current/voltage curves and their dependence of physical boundary conditions such as light intensity, temperature etc. In this first paper on results based on CZTS monograin membrane solar cell measurements the general approach and first results will be discussed.

General Approach:

From an electrical point of view a model consists of two parts, the mathematical equations describing the behavior and the equivalent circuit (EC) according to those model equations. For solar cells various ECs have been published, among which the standard is a one-diode equivalent circuit as shown below. In other publications the EC has been modified by adding diodes and/or resistors in parallel or series to describe the solar cell in more detail. However, the same EC also allows for different model equations, thus different parameters, which again are leading to better or worse descriptions of the behavior of the solar cell. The used parameters have to be extracted or calculated to receive a set of parameters suitable for further investigation of the solar cell. Finally investigating the dependence of these parameters on the physical conditions such as illumination intensity or temperature allows to test the physical relevance.

Details:

The simple EC (fig.1) used here consists of a diode D_{spice} (Shockley equation with Parameters I_S (saturation current) and n (ideality factor)), a voltage dependent series resistor $R_s(V)$ and a voltage dependent parallel resistor $R_p(V)$, a global shunt resistance R_{p2} as well as an independent current source $I_{light}(V)$ modelled with a hyperbolic tangent function (*tanh*) according to [1] and [3]. The resistors $R_s(V)$ and $R_p(V)$ are also modeled with hyperbolic tangent functions, given below. The global shunt resistance R_{P2} takes into account losses across the whole solar cell [2].
Through least-mean-square methods, analytical methods based on either Lambert-W function or conventional methods, the different parameters of the equations of the model, given in the equations below, and those for the diode and the global shunt resistance have been extracted.

Results and Discussion

All the parameters (except those for the current source I_{light}) are extracted from a dark measurement, and the parameters for the current source I_{light} are extracted from different light measurements. The extracted parameter values for I_{light} (A_{IL}, C_{IL}) again can be related in a linear way to the intensity of light. The resulting simulations (variing only the intensity of light) are nearly congruent with the measurements at different light intensities. The model as well as the extraction procedure is suitable for certain combinations of materials, organic as well as inorganic.

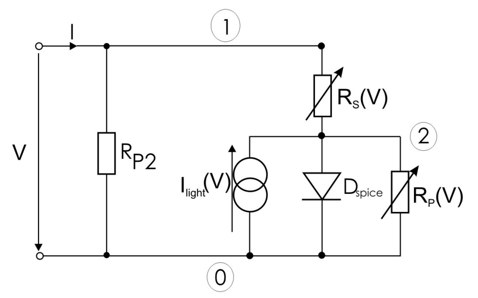

fig.1: equivalent circuit for a solar cell

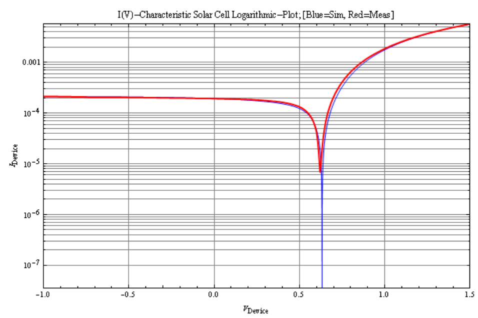

fig.2: simulation results compared to a measurement

Model equations for the series resistor Rs(V), parallel resistor Rp(V) and current source Ilight(V):

$$R_P = A_{RP} \times \tanh[B_{RP} \times (C_{RP} - V(1,0))] + D_{RP} \qquad R_S = A_{RS} \times \tanh[B_{RS} \times (C_{RS} - V(1,0))] + D_{RS} \qquad I_{light} = A_{Il} \times \tanh[B_{Il} \times (C_{Il} - V(1,0))]$$

References

[1] P. Schilinsky, C. Waldauf, J. H. Hauch, and C. J. Brabec, Journal of Applied Physics, vol. 95, no. 5, pp. 2816-2819, March 2004.
[2] A. Moliton and J.-M. Nunzi, Polymer International, vol. 55, pp. 583-600, 2006.
[3] M. Sams, C. Lackner, T. Ostermann, International Semiconductor Device Research Symposium ISDRS 2007, pp. 1-2