Studying the Effect of Scattering Layers on the Efficiency of Thin Film Solar Cells

Zhabiz Rahimi
Department of Computer Science 10
Friedrich-Alexander-Universität Erlangen-Nürnberg
Nürnberg, Germany
Email: Zhabiz.Rahimi@fau.de

Christoph Pflaum
Department of Computer Science 10
Friedrich-Alexander-Universität Erlangen-Nürnberg
Nürnberg, Germany

***Abstract*—Thin film silicon solar cells are optimized in order to increase light absorption. Studying solar cells using experiments requires depositing different layers and building the thin film solar cell, which is usually time consuming and prone to error. Numerical simulation has shown promising results for the calculation of quantum efficiency of thin film solar cells with rough interfaces.**

I. Introduction

Thin film silicon solar cells are optimized in order to increase light absorption. One technique to more efficiently utilize the incident light is increasing the path length of light within a solar cell using textured interfaces. We deposited a sol-gel derived scattering layer between glass and TCO (ZnO) layer as an alternative to the usually applied rough TCO substrates. We analyzed the influence of this scattering layer on external quantum efficiency (EQE) using cell processing and numerical simulations. These surface textures were described by AFM scan data. Complete a-Si:H/μc-Si:H tandem solar cells were simulated, in order to obtain accurate EQE results. The simulated EQE for an a-Si:H/μc-Si:H tandem solar cell with surface textures are presented and compared with experiments. To obtain accurate simulation results, large computational domains of size $5\mu\text{m}\times5\mu\text{m}\times4\mu\text{m}$ were needed. This leads to a high computation time. Therefore, high performance computing with more than 500 processors was required.

II. Numerical Method

We used a three-dimensional finite integration technique FIT in this work. The formulation of this numerical technique is based on the FDTD method [4] and is explained in various publications [5]. Our numerical method uses a rigorous full three-dimensional model for optical simulation. We extended and adapted the finite integration technique, so that the interface between different media in a thin film solar cell can be precisely calculated. Specially, when interfaces between layers contain random surface roughness (see [2] and [3]). The advantage of using the FIT method is that it is highly parallelizable and facilitates the simulation of large three-dimensional domains using parallel computers. In fact, discretizing a large domain with surface textures results in a large number of grid points up to the order of 10^9, which requires the distributed memory parallel computing.

In order to analyze the influence plasmonic effects at the silver back contact, a suitable discretization method is needed. Since standard FDTD method cannot be applied in case of negative permittivity, we developed a discretization method for the time harmonic Maxwell's equations, which is stable for positive and negative permittivity (see [1]). This discretization method is called time harmonic inverse iteration method (THIIM), since it performs a back iteration at grid points with negative permittivity. Using this discretization, time harmonic Maxwell's equations could be discretized for wavelength larger than 350nm for which the permittivity of silver is negative.

We present the simulated quantum efficiency (EQE) for a tandem solar cell with a a-Si:H, a μc-Si:H and a TCO layer with surface roughness at interfaces. The aim of this work is to characterize the influence of surface textures, specially the dielectric SiO_2 scattering layer, on light trapping inside the solar cell. A comparison was made with the corresponding experimental measurement.

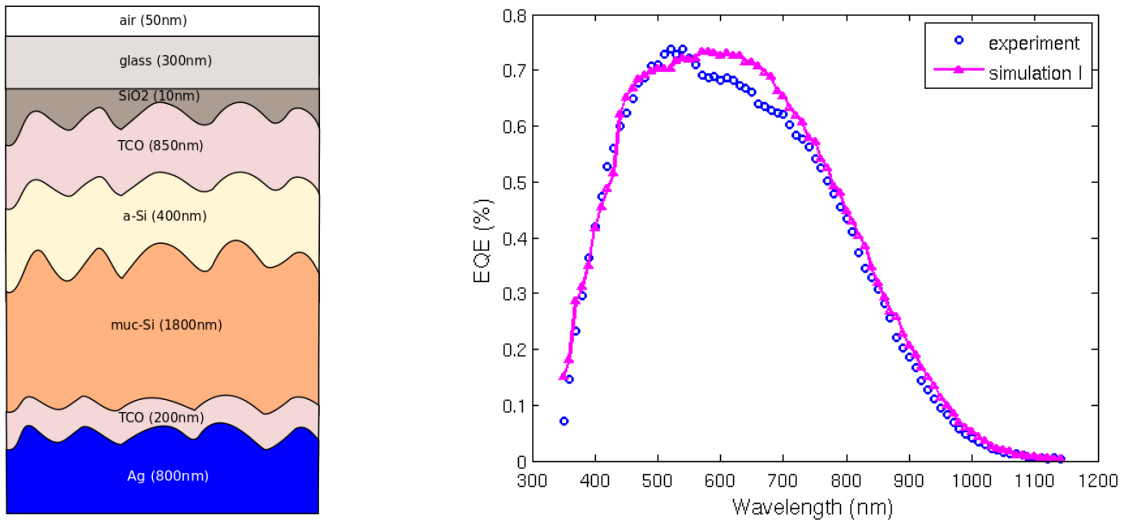
III. Results

We performed separate simulations for 80 different wavelength in order to cover the relevant the solar spectrum from 300nm to 1100nm. Quantum efficiency of the thin film solar cell is calculated for each wavelength. The structural setup of the tandem solar cell is depicted in Fig. 1a. Fig. 1b plots the result of EQE calculations together with experimental data. A comparison between two plots shows a good match in larger wavelengths. A good agreement is also achieved within the wavelength range of 350nm to 500nm. As the wavelength increases, simulation and experiment results diverge. The difference between these two results is more pronounced between from 550nm to 700nm. In fact, this spectrum range is a region where the transparency of the a-Si:H layer gradually increases and the absorption of μc-Si:H gets larger. Simulation results get closer to the experiment for wavelengths larger than 800nm.

Acknowledgment

The help of Jürgen Hüpkes (FZ Juelich) and Arne Jansen (Leybold Optics) in preparing the AZO and Si coatings is gratefully acknowledged. The work was supported by the German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety (grant 0325299).

978-1-4799-3682-3/14/$31.00 ©2014 IEEE



(a) geometry

(b) quantum efficiency

Fig. 1: Simulation of quantum efficiency of a thin film solar cell.

REFERENCES

[1] C. Pflaum and Z. Rahimi. An iterative solver for the finite-difference frequency-domain (FDFD) method for the simulation of materials with negative permittivity. *Numerical Linear Algebra with Applications*, 18, 2011.

[2] Z. Rahimi, A. Erdmann, and C. Pflaum. Method for modeling optical waves in lithography masks. Proceedings of ICEAA Conference, page 809 to 812, 2009.

[3] Z. Rahimi, A. Erdmann, and C. Pflaum. Characterization of the scattering effect of complex mask geometries with surface roughness. Number 7717 in Proceedings of SPIE, 2010.

[4] Allen Taflove and Susan C. Hagness. *Computational Electrodynamics: The Finite-Differnce Time-Domain Method*. Artech House, Boston, London, 2000.

[5] T. Weiland. A discretization method for the solution of maxwell's equations for six-component fields. *Electronics and Communications AEUE*, 31(3), 1977.