Effect of Sputtered Zinc Oxide as Anti- Reflection Coating in Amorphous Silicon Solar Cell

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Abstract: *Amorphous Silicon (a:Si) solar cell structure is modelled and optimized using Lumerical FDTD solution & Lumerical Device. Sputtered Zinc Oxide (ZnO) transparent layer have been used on these Amorphous silicon solar cells as anti-reflecting coating (ARC). Simulation is done and optical properties and electrical characteristics have been investigated. It is found that the less Reflectance and more transmittance with application of Sputtered ZnO proved that it can be used as AR coatings. It is observed that after using sputtered ZnO as an ARC, conversion efficiency of solar cell is increased from its original 9.03% to 11.90 and it is also observed a thickness of 70-90 nm is optimum for use of the Sputtered ZnO as anti-reflection coatings.*

Keywords: Amorphous Silicon (a:Si), Sputtered ZnO, Anti Reflecting Coating(ARC), Conversion Efficiency

1. Introduction

The performance of solar photovoltaic cells depends on its design, material properties, and fabrication technology. Numerical simulation is the best approach for solar cell researchers, which help to find out an optimized structure with good fitted parameters. As a result fabrication complexity, costs, and time reduce significantly. The major objectives of numerical modelling and simulation in solar cell research are testing validity of proposed physical structures, geometry on cell performance, and fitting of modelling output to experimental.

Simulation of amorphous silicon solar cells helps in predicting the behaviour of amorphous solar cell devices. As the complexity in design of photovoltaic cells, it becomes more difficult to obtain analytic solutions for their performance. A combination of optical and electrical simulations which account for these non-ideal processes are necessary to accurately characterize the photovoltaic efficiency of the solar cell.

For Optical Simulation FDTD Solutions is used, which is a high performance optical solver that can be used to simulate the interaction of light with a wide variety of solar cell designs. These designs can range from simple planar geometries to very complex patterning, and can include a wide variety of materials such as organics and metals. The result of the optical simulation is the spatial absorption in the substrate region, from which one can calculate the generation rate. This generation rate can be used in an electrical simulation in DEVICE to determine the responsivity and the photovoltaic efficiency of the solar cell. The CHARGE solver in DEVICE will account for the distribution of dopants that give rise to the built-in electric fields, the mobility of free carriers and the physical processes that result in the recombination of charge[11].

The function of solar cell is to obtain light generated carriers and these collection of light generated carriers generate current and power is dissipated in the load,

2. Methodology

A. Modelling of a:Si solar Cell

In this Section, the detail modelling of a:Si solar unit cell is given and defined different material structure which is used and also defined there geometry as shown in Fig.1. Sputtered ZnO is coated on Glass Substrate which acts Anti Reflecting Coating (ARC). For Simulation in FDTD solution, materials are defined in terms of refractive index and wavelength [12]. It also noted that the thickness of ZnO of 70nm to 90nm will be optimum to use it as ARC. The diffusion doping of N well (n++) is added with concentration of $1x1019$ cm-3 and junction width is 0.4 µm and back diffusion(P++) is added with same concentration of $1x1019$ cm-3 and Junction width is 0.2µm.
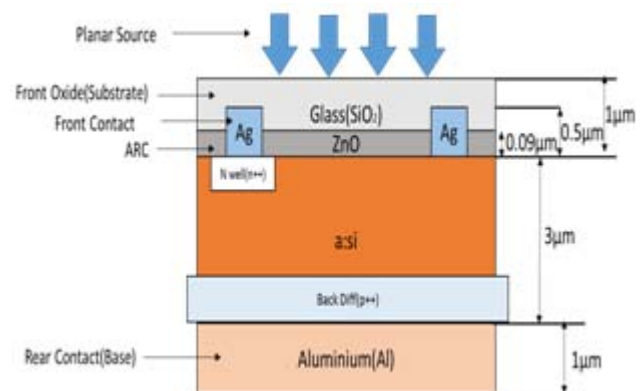

Figure 1: Schematic of a a-Si single-junction solar cell

B. Solar Cell Work flow

The solar cell workflow starts with optical simulations in FDTD Solutions. Taking the solar spectrum into account, the solar generation rate is calculated from the optical absorption and used as a source in the subsequent electrical simulation in DEVICE to calculate the Conversion efficiency.

C. Simulation Method

Using Symmetry of the device, 2D simulation is performed, Using periodic nature of top electrodes, we focused on only one electrical period instead of the whole solar cell, smaller unit cell is chosen in FDTD and by simply repeating this unit

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cell by periods of 18, the behaviour of whole solar cell can be modelled.
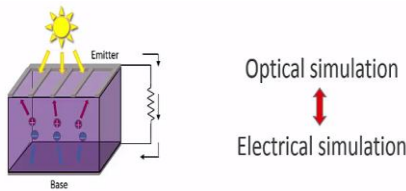

Figure 2: Demonstration of Simulation Methodology

Optical simulation is done using Lumerical FDTD solutions ver 8.12.631. After running simulation, Reflectance of solar cell w.r.t wavelength, Transmittance of solar cell w.r.t wavelength, Solar Generation Rate spectrum and Total optical absorbed w.r.t wavelength are plotted.
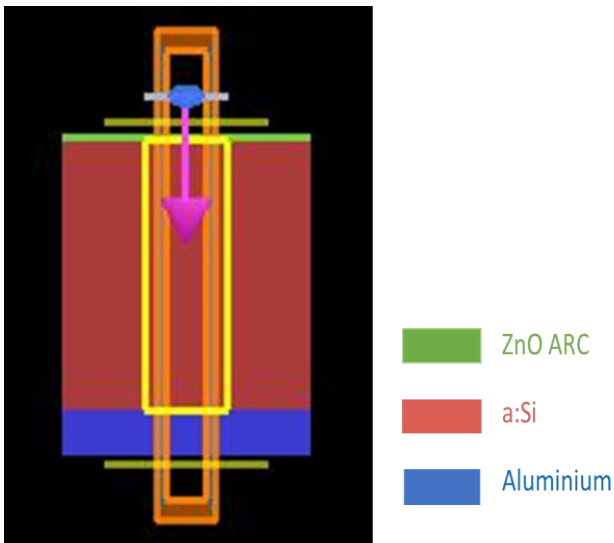

Figure 3: View of a: Si unit solar cell in FDTD Analysis

Electrical Simulation is done using Lumerical Device ver 5.0.697 and by Importing Solar Generation Rate as source, obtained electrical characteristics such as P-V Characteristics, short circuit current, open circuit voltage, maximum power obtained, fill factor and solar cell conversion efficiency is calculated for both with and without application of sputtered zinc oxide as Anti reflecting Coating.
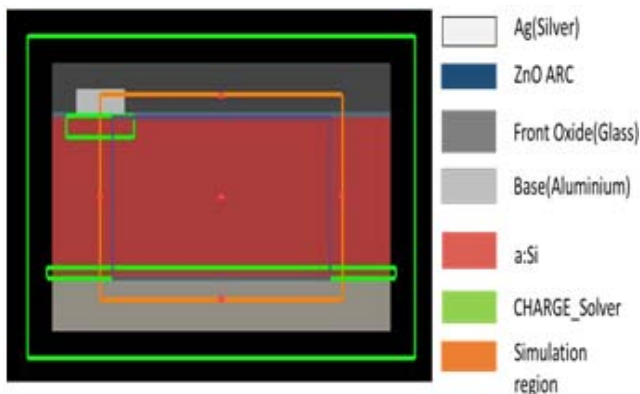

Figure 4: View of a:Si unit solar cell in Device

3. Results & Discussions

Solar cell performance data before and after antireflective coating application for amorphous solar cells is shown from Fig.5 to Fig.9. After application of the sputtered zinc oxide layer the short circuit current density (Jsc) shows a significant increase for in cell due to the AR effect of the coatings. The Voc also increases by a similar amount. The improvement of the short-circuit current density due to the ZnO AR coatings can be seen and is reflected in the total optical power absorbed plot. Power absorbed curves for amorphous silicon solar cell before and after anti-reflective coating application are shown in Fig 9 (a) and (b), respectively.
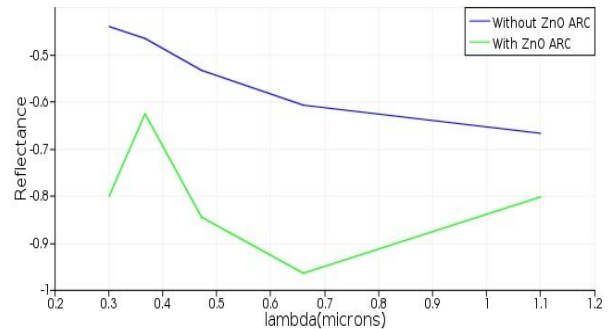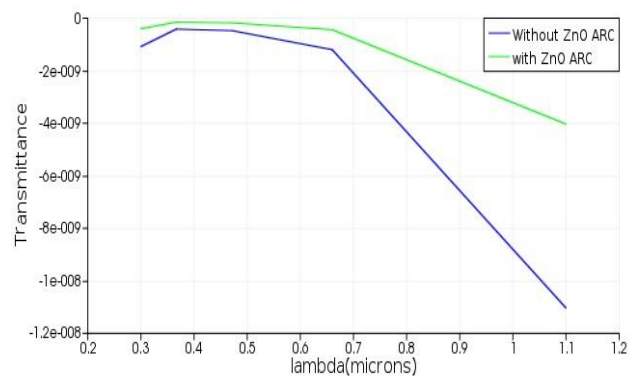

Figure 5: Reflectance of a:Si
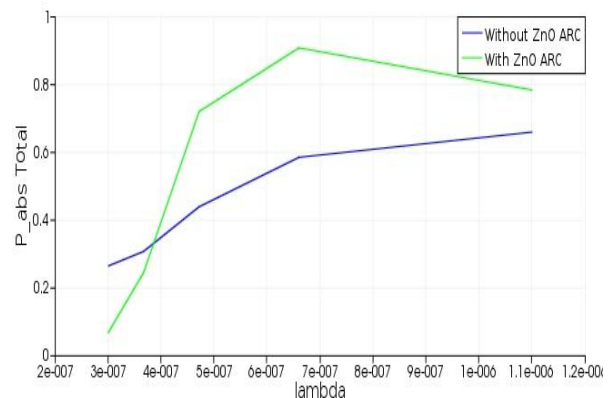

Figure 6: Transmittance of a:Si

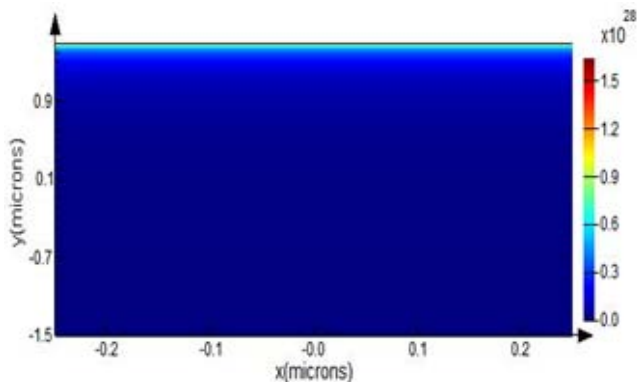**Figure 7:** Total Optical Power absorbed by a:Si Unit Cell

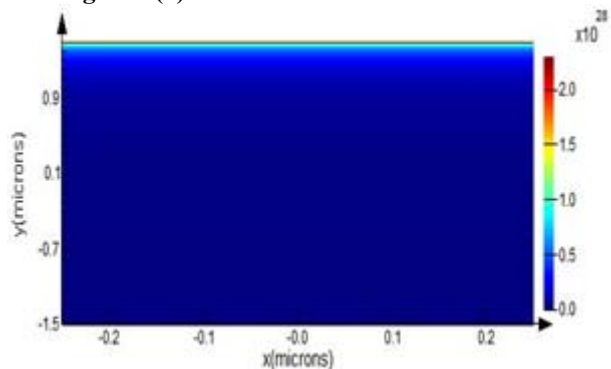**Figure 8(a):** Solar Generation rate without AR

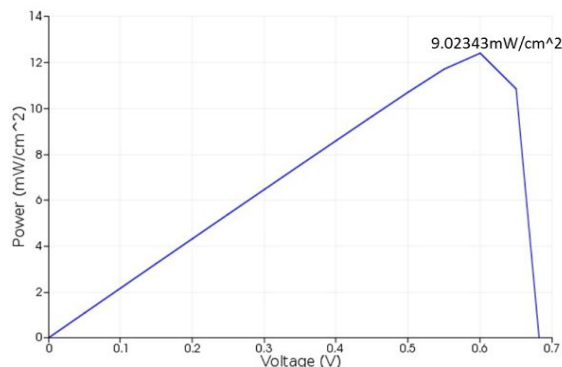**Figure 8(b):** Solar Generation rate with AR

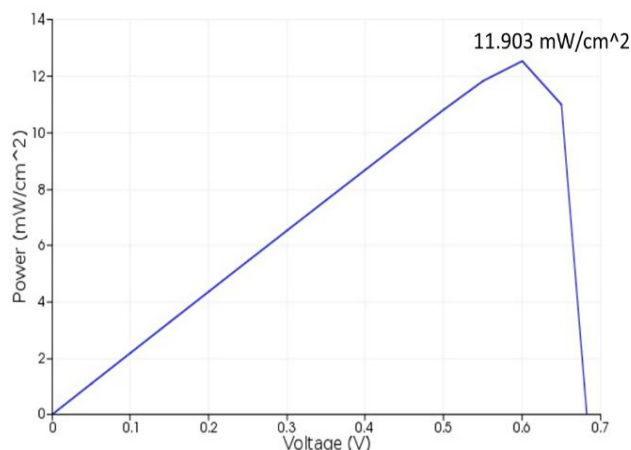**Figure 9(a):** P-V characteristics without AR

Figure 9(b): P-V characteristics with AR

Table 1: a:Si Solar Cell Parameters

Parameters/With and without ARC	Jsc (Ideal) mA/cm^2	Short Curcuit Current(Jsc) in mA/cm^2	Open Circuit Voltage (Voc)In Volts	Fill-factor	Photovoltaic efficiency(η)
Without ZnO ARC	259.372	17.7057	0.611984	83.27%	9.02343%
With ZnO ARC	359.692	21.4117	0.616237	90.2%	11.903%

4. Conclusion

After investigating the optical and simulation result of a:Si solar cell with and without ZnO, it is found that the less Reflectance and more transmittance with application of Sputtered ZnO proved that it can be used as AR coatings more efficiently and henceforth making use of the advantages of sputtered Zinc Oxide. The improvement of the short-circuit current density due to the ZnO AR coatings can be seen and is reflected in the total optical power absorbed plot. It is observed that after using sputtered ZnO as an ARC, conversion efficiency of solar cell is increased from its original value 9.03% to 11.90% and it is also observed a thickness of 70-90 nm is optimum for use of the Sputtered ZnO as anti-reflection coatings

5. Comparison with Previous Studies

The conversion efficiency of ZnO:Al as ARC in Crystalline silicon is found to be increased from 10.68% to 13.10% [2], so in the same way, the effect of sputtered ZnO as ARC is conducted on Amorphous silicon solar cell and it is found that conversion efficiency increased from 9.03% to 11.90%. and also the conversion efficiency of a:Si is found to be on average 9.88% in previous studies and hence concluding that

the optimized design made using Lumerical software is found to be efficient and promising.

Compliance with Ethical Standards

6. Conflict of Interest

We authors declare that we have no conflict of interest.

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