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Numerical Simulation and Efficiency Improvement of Solar Cell using Multi Layer Anti Reflecting Coating

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ABSTRAC

Efficiency improvement of solar cell has been achieved using design and simulation of anti-reflecting coating. Anti-Reflecting coating helps in deploying new geometries shape for the evaluation of different methods to provide for light trapping in all directions and enables full space utilization when bringing together into device arrays. Efficiency improvement strategies have been discussed using efficient selection of modules and surface texturing using TCAD tools. Significant improvement in yield and minimization of losses was achieved using device simulation and process simulation platform using silvaco tools. Multi-layer anti reflecting coating has been designed which can be studied to analyze the performance of system. It was observed that multi-layer coating helps in improvement of available current for similar light beam under simulation.

***Keywords*---** Anti Reflecting Coating, TCAD, Device Simulation, Solar Cell

I. INTRODUCTION

The term "photovoltaic" combines two terms - "photo" means light, "volta" means voltage. The photovoltaic system in this discussion uses photovoltaic cells to convert sunlight directly into electricity. Made of crystalline silicon. Solar cells are also called photovoltaic (PV) cells. It is a static device with no moving parts. The photovoltaic system is designed to supply power to the load. The load can be AC or DC. It is needed during the day or night or twice. Photovoltaic systems can only provide nighttime supply during the day. We need supplies because we have batteries and electricity can be stored and used. Solar photovoltaic (PV) devices generate electricity directly from sunlight through electronic processes, and this process occurs naturally in certain types of materials, called semiconductors. The electrons in these materials are released by solar energy and can be induced through electrical circuits, powering electrical equipment or sending electricity to the grid.

So far, reducing wafer thickness is an important factor in driving down the cost of silicon-based solar cell. However, moving more than 100 microns may bring significant challenges related to processing [1]

The relative increase in incision loss [2]. Epitaxial silicon growth and layer transfer technology provide methods cntinue to reduce the use of silicon wafers. Of course, silicon provides the perfect seed for epitaxial growth, and various stripping techniques have been studied to reuse expensive silicon substrates. Another method use low cost substrates that remain attached to solar cells, such as display glass or metal foil. Achieve High quality crystalline silicon requires careful selection of seed layers for epitaxial growth on such substrates.

In this work, we focused on customizing the ARC's anti-reflection performance to match the ultra-thin battery structure.

Heterojunction epitaxial crystalline silicon solar cells. Schematic diagram of crystalline silicon heterojunction units

As shown in Figure 1. Various homogenous and heteroepitaxial seeds on glass substrates have been studied [3,4] But for this particular study, n + Si wafers were used as epitaxially grown substrates. Thin In heterojunction solar cells, the conductance in the doped a-Si:H layer is not high enough to be effective Side collection. Transparent conductive oxides (TCO) are often used to solve this problem. TCO must also It has a high transmittance to provide light for the active layer of the battery. Typical TCO has refraction Index , such a layer can also be used as an anti-reflective coating for solar cells.

For all crystalline Si thin film methods, a combination of crystalline material and a very thin active layer making light traps a prerequisite for increasing current density. The goal of all light trapping methods is increase the average path length of incident photons. 1μm thick silicon layer, front side texture and rear. The reflector can thus absorb the same amount of light as the flat 10-μm layer. So using this method is very convenient The effective silicon thickness Te is used to explain arbitrary light trapping structures. Highly effective anti-reflection coatings (ARCs) are important for improving the light collection characteristics of solar cells.All thicknesses. Monolayer ARCs for thick absorbers are well known and their sole purpose is to reduce reflections.It does not absorb light in the ARC. This ARCs need only be optimized, with minimal integrated reflectivity.Respect the AM1.5 spectrum. However, for very thin silicon solar cells, cell thickness and structure are affected

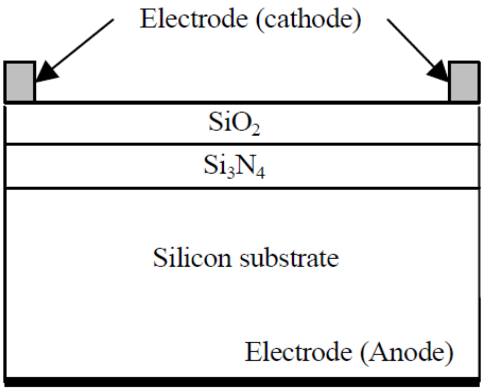

Figure 1.Grid Connected Solar PV System

The best ARC properties are to a large extent. Although the current density increases after application specific ARCs are usually reported [6,7], which does not mean that ARC is optimized current density or battery structure. The modeling of optical properties is mainly using special. Therefore, it is usually separated from the electrical and structural modeling of solar cells. At this we use an efficient weighting function to include internal quantum efficiency (IQE) and effectiveness

The thickness of the active cell layer in optical modeling. So the spectrum transmitted by ARC optimized for efficient use in a given battery structure and can improve solar cell performance.

II. ANTI REFLECTING COATING

Figure 2 shows the boundary conditions. The tangential components of the combined electric and magnetic fields are continuous at the interface. Single crystalline or mono crystalline.

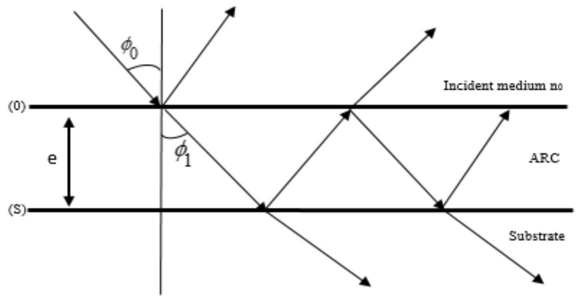

Figure 2 Model of anti-reflective coating

The field component at the first boundary (0) is related to the field component of the next boundary (S) of the first expression.M. C. Troparevskry and P. Kossoboutskyy [7]–[8] studied the tangential components of electric and magnetic fields on two consecutive diopters (0/ARC and ARC/S).First, we will describe the single-layer feature matrix. As mentioned earlier, the matrix shows the tangential and electrical components H(x) and E(x) at the layer boundaries (diopters).

$$\begin{pmatrix} E_0 \\ H_0 \end{pmatrix} = M \begin{pmatrix} E_s \\ H_s \end{pmatrix}$$
(1.1)

The field components to the first border are related to those of the next by the following expressions:

$$E_0 = E_s \cos(\emptyset) + H_s \left(\frac{i\sin(\emptyset)}{Y}\right)$$
(1.2)

$$H_0 = E_s\big(iY\sin(\emptyset)\big) + H_s \cos(\emptyset)$$
(1.3)

$$M = \begin{pmatrix} \cos(\emptyset) & \frac{i\sin(\emptyset)}{Y} \\ iY\sin(\emptyset) & \cos(\emptyset) \end{pmatrix}$$
(1.4)

For a stacking of several layers, instead of a matrix there will be a product of matrix those which can be applied for a double layer studied by C. C. Katsidis and L. Remache [9] - [10]. Y is the optical admittance of radiation with a parallel polarization Y (P) is a perpendicular polarization Y (S) are given by:

,

$$Y^{(s)} = \sqrt{\frac{\epsilon_0}{\mu_0}}\; n\cos(\varphi)$$
(1.5)

$$Y^{(p)} = \sqrt{\frac{\epsilon_0}{\mu_0}}\; n/\cos(\varphi)$$
(1.6)

The reflection coefficient and the total reflection can be expressed as:

$$r = \frac{Y_0 M_{11} + Y_0 Y_s M_{12} + M_{21} - Y_s M_{22}}{Y_0 M_{11} + Y_0 Y_s M_{12} + M_{21} + Y_s M_{22}}$$
(1.7)

$$R = \frac{R_s + R_p}{2}$$
(1.8)

$$R = |r|^2$$
(1.9)

Considering a non-encapsulated structure (n0=1) SiOX/SiNX/Substrate, with variable refractive index, SiOx (1.45≤n2≤1.5), SiNx (1.9≤n1≤2.3) for the photovoltaic cells performance improvements.

III. METHODOLOGY

It is a popular strategy to place an anti-reflective (AR) coating on the photodetector device to increase the quantum efficiency of the device. This coating relies on the destructive interference of the reflected waves to reduce the overall reflectance of the light incident on the detection device. TCAD simulation software for all solar cell technologies. The TCAD modules required for solar cell simulation include: S-Pisces, Blaze, Luminous, Device3D, and Luminous3D.This introduce ray tracing simulation results for conventional silicon photovoltaic modules using different anti-reflection coating materials, EVA and nitride components. We can find the optimum thickness of these materials under different design and operating parameters.

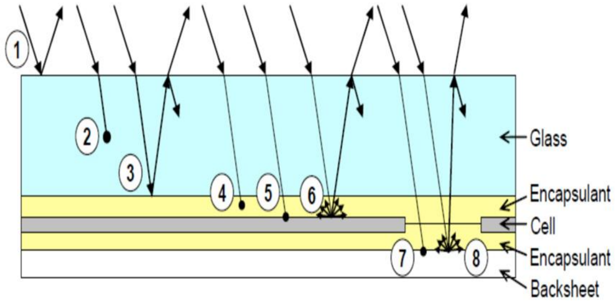

Figure 2. Cross-sectional diagram of a PV module

Accurate optical evaluation of PV modules is not easy. As shown in Figure 1, the incident light is reflected from the interface between the air glass (1), the glass package (3), the package unit (6) and the package backplane (8); in the latter two cases, the reflection is usually diffuse, Causes some of the reflected light to totally reflect at the glass-air interface and then return to the unit. In addition, the incident light is absorbed by the glass (2), the package (4), and the antireflection coating or metal finger (5) and negative film (7). The eight interactions depend on the incident wavelength and angle of incidence of the light. Therefore, ray tracing applications will contribute to a comprehensive optical assessment.

Table 1-Parameters for Simulation

Parameter	Value
Cell Width	100 μm
Cell Depth	200 μm
Substrate Concentration	1e17 /cm^3
Diffusion Concentration P-type	5e20 /cm^3
Light Source	AM1.5
Work function	Al- 4.4 e V, Ag- 5.0 eV
Diffusion Temperature	790°C

The solar cell parameters we have defined are listed in Table 1. Other parameters are used by default in Silvaco TCAD tools.

IV. SIMULATION & RESULT

Optical performance reference is taken from material datasheet. Figures 3 shows the simulation results. We find that the optimum thickness of the nitride is 0.7 um. In addition, we also found that the minimum reflectance value will change as the thickness of the ARC increases. In Figure 2, we can find that the maximum value of anode current (Isc) using comparative analysis of two-layer coats and three-layer coating respectively. There is significant improvement of optical efficiency in multiple layers anti reflecting coating which is evident by increase in value of current with respect to incident radiation. We have also included the parameter change of wavelength in order to ensure effective use of solar spectrum and calculation of spectral efficiency. This method will enhance the operating efficiency of solar cell with respect to incident radiation and it can be considered as an important aspect in design and development of high efficiency solar cell.

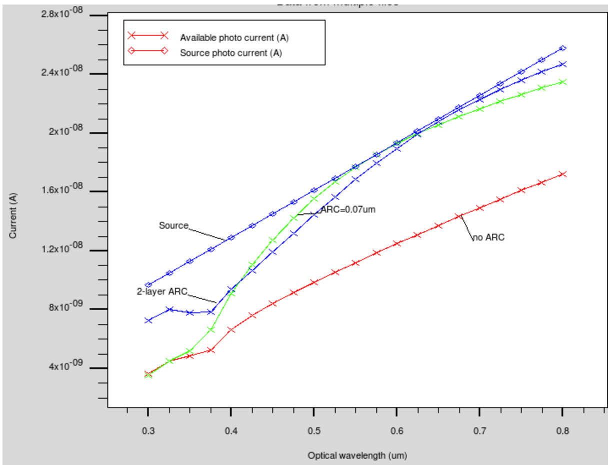

Figure 3. Comparative Analysis of Current with respect to optical wavelength

V. CONCLUSION

It was found that the antireflection effect of SiOx/SiNx double-layer ARC is better than that of a single anti-reflective layer SARC. For DARC, the optimal antireflection effect is obtained with thicknesses e4=110nm and e3=90 nm.The results reported in this study can be used as a significant tool for efficiency improvement in thin film silicon solar cells on glass. In summary, TCAD tools provide a complete solution for solar cell technology. In this article, it helps us to study ARC thickness and materials. We can find the best design conditions for arc thickness, EVA is 0.1um and nitride is 0.07um. It also enables researchers to study all operating and design parameters of silicon solar cells.

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