Analysis of Solar Cell with MGO Anti-Reflective Coating

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Abstract— In general solar PV panel works without coating, its efficiency is only about 10-15 %. When specified coating thickness applied on the solar cells, it get slightly increased. Here Magnesium Oxide (MgO) material is used as an anti-reflecting coating agent on silicon solar cell. The optimized coating thickness is 86nm for single crystalline solar PV cell, the wavelength of the light rays is of order 400nm to 800nm. Theoretical model has been developed to determine the reflectivity, transmissivity and refractive index. The coating material increasing transmissivity compare to without coating material.

Key words: Single Crystalline Solar Cell, Anti-Reflective Coating, Refractive Index, Reflectivity, Transmissivity

I. INTRODUCTION

The sun is the biggest member of the solar system comparing with others which resolve around it. The shape of sun is sphere and it contains hot gases like helium and hydrogen with a diameter of 1.39×10^9 and the average distance of sun is 1.5×10^{11} m from the earth. The solar energy is in the form of light and heat which is the base of sustenance of all living organisms. It is eco friendly, intermittent, pollution free and freely available energy resource. All other renewable energies excluding geothermal resource rely on solar energy. The available total amount of solar energy is ten thousand times more than the actual usage of humans, but the solar energy obtaining from the sun is depends on its location, season so the density of solar energy is low, which is a major problem in utilization of solar energy.

The two types of converting solar energy from the sun is photovoltaic conversion method and solar thermal energy conversion. The difference between these two method is direct or indirect conversion of light energy into electrical energy. Here we are using photovoltaic energy conversion method which is directly converts the heat energy from the sun into electrical energy and which uses the solar PV modules to develop electrical energy by means of array of solar cells. Generally conversion efficiency of solar cell is between 16 to 20% which is depends on PV module and ambient conditions. The PV module utilizes the heat from the sun's maximum solar radiation which is dissipated in the PV module.

In photovoltaic industry, anti-reflection coatings mostly used are metal oxides such as SiO_2, TiO_2, ZrO_2. In a single crystalline silicon solar cell, ZnO was coated by atomic layer deposition method with different thickness range of 600nm – 1000nm. By this anti-reflection coating material the conversion efficiency enhances by 6%. [5]

In a multi crystalline silicon solar cell, SiO_2 was coated by surface passivation technique method to enhance the open circuit voltage and short circuit current with a thickness range of 750nm – 1100nm. By this SiO_2 coating material the conversion efficiency enhances by 0.3% [8] .

Combination of two materials as anti-reflection coatings were also been tried by the researches to improve the conversion efficiency. Such combinations used by researches were Al doped MGO, ITO [1], TiO_2 - SiO_2[3]. Thus in this work MGO as an anti-reflection coating to enhance the optical properties of solar cell.

II. THEORETICAL MODELLING

The equations defined below for theoretical modeling of silicon solar cell anti reflective coating are considered as in Sukhatme S P, et.al.[7]

A. Incident angle and Incident Total Solar Radiation Falling on the Surface

Declination angle can be determined by using the following relation [7],

$$\delta\ (\text{in degrees}) = 23.45 \sin\left(\frac{360}{365}(284+n)\right)$$

For horizontal surface incident angle can be calculated using the following formula,[7]

$$\cos\theta = \cos\theta_z = \sin\phi\ \sin\delta + \cos\phi\ \cos\delta\ \cos\omega$$

B. Refractive Index Calculation for Arc

Refractive index of an Anti-Reflective Coating material

$$n_1 = \sqrt{n_0 x n_2}$$

Where,
n_1 = refractive index of Anti-Reflective Coating material
n_0 = refractive index of surrounding material. (Glass)
n_2 = refractive index of semiconductor material. (Si)
n_0 = 1.5 for glass
n_2 = 3.4434 for silicon

C. Find the optimum thickness of an anti-reflective material ti be coated

Thickness of the Anti-Reflective Coating material can be determined as follows,

$$d_1 = \frac{\lambda}{4n_1}$$

Transmissivity calculation without Anti-Reflective Coating material can be calculated from the following expression,

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

$$\theta_2 = \sin^{-1}\frac{\sin\theta_1}{\left(\frac{n_2}{n_1}\right)}$$

Reflectivity when no anti-reflection coating,

$$\rho_i = \frac{\sin^2(\theta_2 - \theta_1)}{\sin^2(\theta_2 + \theta_1)}$$

$$\rho_{ii} = \frac{\tan^2(\theta_2 - \theta_1)}{\tan^2(\theta_2 + \theta_1)}$$

$$\rho = \frac{1}{2}(\rho_i + \rho_{ii})$$

Transmissivity between air - glass medium and glass – Si wafer can be evaluated from the following,

$$\tau_{r1} = \frac{1 - \rho_i}{1 + (2M - 1)\rho_i}$$

$$\tau_{r2} = \frac{1 - \rho_{ii}}{1 + (2M - 1)\rho_{ii}}$$

$$\tau_r = \frac{1}{2}(\tau_{r1} + \tau_{r2})$$

Total transmissivity $\tau = (\tau_r x \tau_a)$

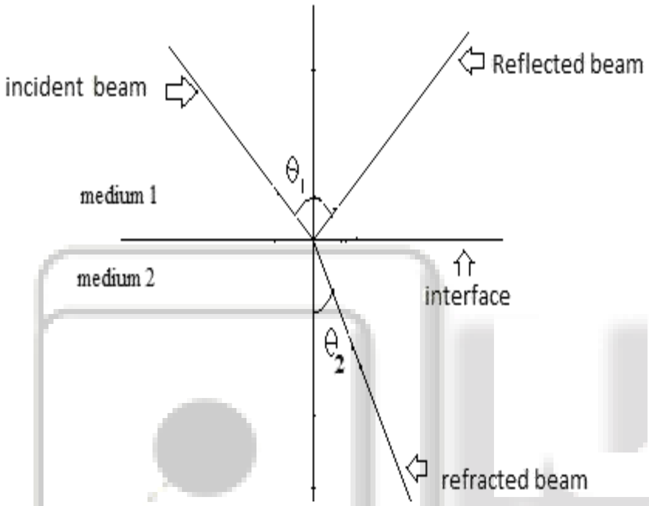

Fig. 1: Reflection and refraction at the interface of two media

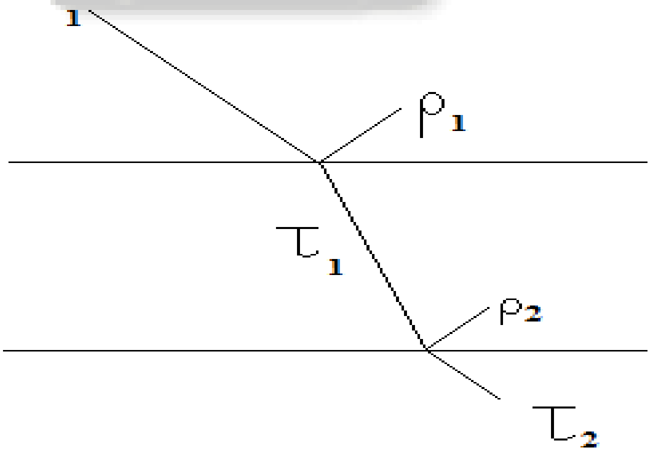

Fig. 2: Ray diagram of reflection and transmission

III. Result and Discussion

The refractive index of anti-reflective material is 2.2726 for optimum transmission of light into the silicon substrate. For the above value of refractive index, an effective anti-reflection coating has been identified. The transmissivity and reflectivity of the glass to silicon are 0.7324 and 0.1546 respectively.

	without coating	with coating
Angle of incidence(θ1)	19.9467	19.9467
Angle of refraction (θ2)	8.5435	9.9078
Reflectivities of polarization 1(ρ1)	0.1715	0.1227
Reflectivities of polarization 2(ρ2)	0.1378	0.0950
Transmissivities of polarization 1(τ1)	0.7072	0.7814
Transmissivities of polarization 2(τ2)	0.7577	0.8264

Table 1:

Based on the optimum value of the refractive index of the anti-reflective coating material calculated.Based on that anti reflection coating material (MgO) is selected.

IV. Conclusion

From the above analysis, I selected magnesiumoxide(MgO) as a antireflective coating material. It improves the transmissivity of the solar cell 9% , compare to the bare panel and reduce reflectivity of the panel to 30% compare to the normal solar cell.

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