# Modeling and Simulation of Antireflecting Layers, Influencing Parameters on the Reflexion and Transmission on the Silicon Solar Cells

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**Abstract**  In our work we focus on the study and implementation of thin films for their different photovoltaic applications. These materials have interesting optical and dielectric properties, they are used as anti-reflection layer. In the same logic, we focus on the theoretical study of antireflective layers (SARC, DARC, MARC). These studies have led us to conclude that there are more of antireflective layers, the greater the efficiency of the solar cell increases. But also thicknesses and refraction indices play an important role in the good performance of the solar cell.

*Keywords: silicon, layer, solar cell, reflection, thickness*

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## 1. Introduction

For ten years, the filing of an antireflection coating is an effective and inexpensive way to ensure low reflectivity and good passivation of silicon photovoltaic cells, but for CAR zero reflectivity can take place only for a single wavelength as the layer acts as a quarter-wave plate depends on the wavelength. For this application to a SCAR a DARC, or MARC combining one or more materials such as $MgF_2$, $SiO_2$, $Al_2O_3$, $TiO_2$, ZnS, and Si3N4 on the front face of the cells is a proposed way to improve their passivation and reflection properties and thus their conversion efficiency.

The following materials are used as antireflection layer: $TiO_2$ (refractive index n = 2.3), $Si_3N_4$ (n = 1.9), $Al_2O_3$ (n = 1.8-1.9), SiO2 (n = 1.4 -1.5), $TaO_5$ (n = 2.1-2.3) [1]. However, using different materials is less profitable because there are often two deposition systems. Well as using the same hardware is beneficial. [2] The ARC is essential to adapt the refractive index and thickness between air or particle (glass) and the substrate to minimize reflection for a given wavelengths, why a good choice of refractive index of the CP and the thickness and operated phenomena destructive interference are required.

The phase difference between the wavelength considered to ARC / substrate interface are in phase opposition in this case the incident wave is completely transmitted or absorbed. [3] The refractive index and thickness of the antireflective layers are used to minimize reflection with the wavelength of 600nm, near the maximum of the emission of sunlight and allow acceptable light penetration photon in silicon [4,5].

In this study, we managed a simulation program that allowed us to find the best combinations of SARC, the DARC, and MARC to minimize reflection.

As we have seen, we have varied the values of the ARC thicknesses and calculated their thinking.
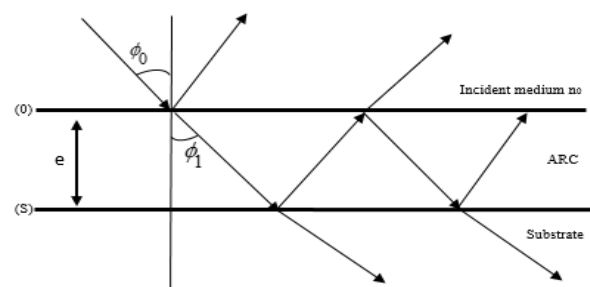
## 2. Model



**Figure 1**. Modeling a glare layer

The theory of the antireflection coating is considered by many authors [6,7]. Matrix calculations determine the spectral transmittance and the reflectivity profile for the multilayer structures on a [8] substrate. Firstly one can describe the characteristic of a single layer matrix .This matrix relates the tangential components of the electric field E (Z) and of the magnetic fields H (Z) on the boundary layers Z = 0 and Z = S [9] .

$$\begin{pmatrix} E(0) \\ H(0) \end{pmatrix} = \begin{pmatrix} E(S) \\ H(S) \end{pmatrix} \qquad (1)$$

The characteristic matrix for a multi-layer is a product of matrices corresponding to a single layer. If (i) is the number of layers, then the first field $Z = Z_0$ and the last $Z = Z_i$ limited are related as follows:

$$\begin{pmatrix} E(Z_0) \\ H(Z_0) \end{pmatrix} = M_1, M_2 \dots M_I \begin{pmatrix} E(Z_i) \\ H(Z_i) \end{pmatrix} \qquad (2)$$

The method of the transfer matrix is used to evaluate the optical properties of a multi-layer system deposited on a substrate. A system of n layers is characterized by the equivalent matrix $M_i$.

$$M_i = \prod_{i=1}^{N} \begin{pmatrix} \cos\varphi_i & \dfrac{j\sin\varphi_i}{n_i} \\ jn_i\sin\varphi_i & \cos\varphi_i \end{pmatrix} \qquad (3)$$

With $j^2 = -1$, or the refractive index of the $i^{th}$ layer, $\varphi_i$ is the phase shift between the wave reflected by i and i + 1.

$$\varphi_i = \frac{2\pi}{\lambda} n_i e_i \cos\varnothing \qquad (4)$$

$\varnothing$ is the wave propagation angle in the layer. A detailed derivation of r amplitude reflection coefficients and transmission coefficients t amplitude is given in [10]. The resultant expressions are shown in the following equations:

$$r = \frac{n_0 M_{11} + n_0 n_s M_{12} + M_{21} - n_s M_{22}}{n_0 M_{11} + n_0 n_s M_{12} + M_{21} + n_s M_{22}} \qquad (5)$$

$$t = \frac{2n_0}{n_0 M_{11} + n_0 n_s M_{12} + M_{21} + n_s M_{22}} \qquad (6)$$

In terms of components of the transfer matrix, r and t can be written by the following relationship [11].

$$r = \frac{M_{12}}{M_{22}} \qquad (7)$$

$$t = \frac{1}{M_{22}} \qquad (8)$$

$I_j$ are the elements of the characteristic matrix of the multilayer. The intensity coefficients (reflection, transmission) are given by:

$$R = |r|^2 \qquad (9)$$

$$T = \frac{n_s}{n_0}|t|^2 \qquad (10)$$

## 3. Results and Discussion

Good anti reflection layer is essential for the performance of solar cells because it provides an increase in the photocurrent by reducing the reflectivity at a minimum, the difference with other optoelectronic devices, the function of the solar cells with a range of length d 'exhausted wave from 300-1100nm, it means they need a CAR with a broadband [12]. The Figure 2 shows the variation of the reflection coefficient and transmission of bare silicon as a function of wavelength.
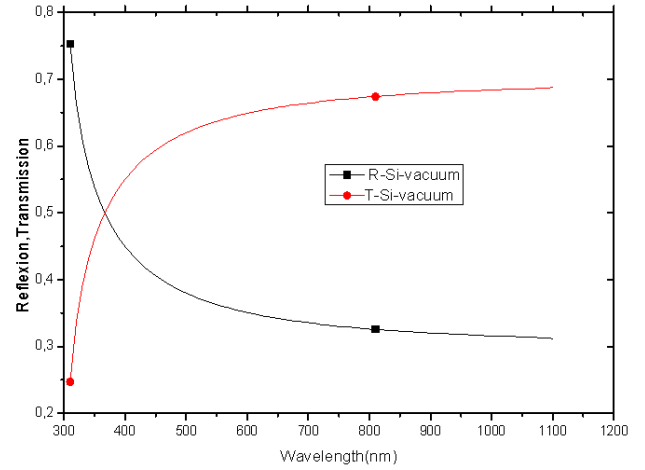


**Figure 2.** Change of reflection and transmission of the bare silicon based on the calibrated wavelength $\lambda_{Re}f = 600nm$

The Figure 2 shows the first variation of the bare silicon of the reflection as a function of the wavelength. On a wavelength between 300 nm and 600 nm range, a rapid decrease in the silicon of the reflection coefficient is noted nude 75.15% to 35.19%. Secondly there is the variation of the bare silicon of the transmission as a function of the wavelength. The latter is believed to a wavelength between 300 nm and 600 nm with a coefficient which varies from 24% to 65%. For higher values at 600 nm, a slight decrease of the reflection coefficient and increased transmission is noted. This shows that for large wavelengths, the reflection of the bare silicon is between 31% and 35%. That is to say, the reflection coefficient is not negligible, and transmission is between 65% and 68%. Therefore the cell is less efficient.

The Figure 3 shows the variation of the reflection coefficient and transmission of silicon with a SCAR depending on the wavelength.
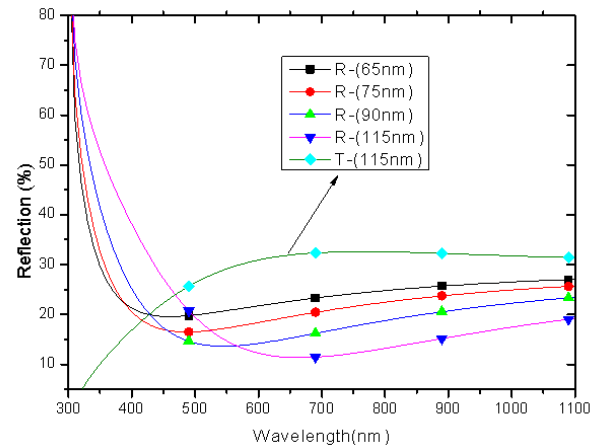


**Figure 3.** Reflection and Transmission of silicon with a SCAR according to the calibrated wavelength $\lambda_{ref} = 600nm$

The Figure 3 shows that for wavelength values ranging from 400nm to 800nm in the visible range is noted a rapid decrease in the silicon reflectance 20% to 12%. From our analysis we can say that the more the thickness of the SARC the greater the reflection coefficient is small. For wavelength values comprised between 400 nm to 800 nm was rapid growth of transmittance of the silicon which is the reverse of the reflection for the same thickness

(115nm). Our overall analysis allows us to say that the greater the thickness, the greater reflection decreases, which increases the transmission. Therefore the solar cell is effective.

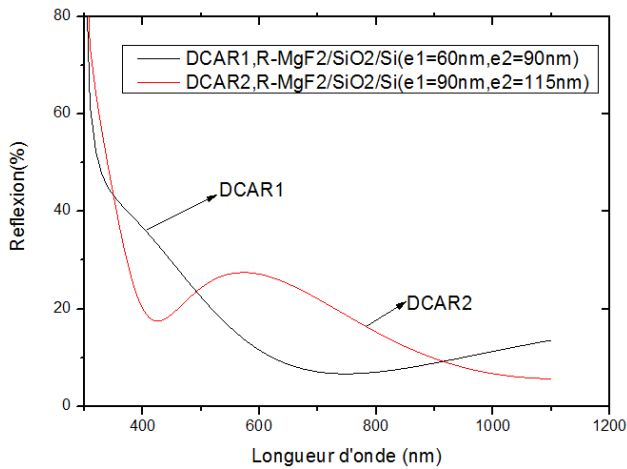The Figure 4 shows the variation of the DARC reflection coefficient as a function of the wavelength.



**Figure 4.** Reflectance DARC a function of the reference wavelength

The Figure 4 shows That for wavelength values between 400 nm and 600 nm was a decrease in the reflection coefficient of DARC1 of 35.72% to 11.65% for thicknesses between 60 nm and 90 nm and increase in the reflection coefficient of DARC2 18.48% to 27.12% for thicknesses of between 90nm and 115nm.

For values of wavelength greater than 600nm wave, the reflection coefficient of the DCAR1 increased to 13.43% and the reflectance of the DCAR2 reached 5.40%. This is due to the deposited materials, and it can be said that the materials are important when obtaining a good performance of solar cells.

The Figure 5 shows the variation of the reflection coefficient as a function of the wavelength.
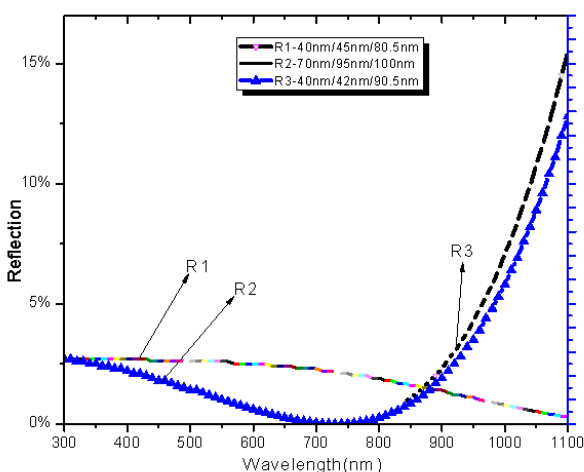


**Figure 5.** the reflection coefficient off TARC as a function of the reference wavelength

For wavelength values between 300nm and 600nm
However the necessary thicknesses to achieve this RAFT are relatively large, which can cause problems

when making contact through it. It is therefore important to minimize advantage of the reflectivity of the RAFT.

The solution of the reflectivity curve R3 is from this direction. This leads to a reflectivity of 2.5% promotes a good efficiency of the solar cell.

## 4. Conclusion

In this work, we have shown the importance of different -anti-reflective layers on the reflection and transmission.

These vary according to the refractive index and thickness of the layer. Thus we can say that the importance of anti-reflective layers is to minimize reflection while providing an important solar cell performance. The anti-reflective effect for optimal thicknesses of 90nm and 115nm in the visible range. In addition, it allowed us to know that the materials used for antireflective layers are important parameters regarding the minimization of reflection.

Indeed this contribution we have just performed on the antireflective layers opens new perspectives that take into account the impact of the thickness, index of refraction, and angle of incidence on the antireflective layers.

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