Energy and Power Engineering, 2022, 14, 550-557
https://www.scirp.org/journal/epe
ISSN Online: 1947-3818
ISSN Print: 1949-243X

Comparative Studies on Reflection Defect between Textured and Planar Surface Based on TCO Materials

Alassane Diaw, Papa Touty Traore*, Awa Dieye

Physics Department, Cheikh Anta Diop University, Dakar, Senegal
Email: alou2045@yahoo.fr, *papatoutytraore@gmail.com

How to cite this paper: Diaw, A., Traore, P.T. and Dieye, A. (2022) Comparative Studies on Reflection Defect between Textured and Planar Surface Based on TCO Materials. *Energy and Power Engineering*, **14**, 550-557.
https://doi.org/10.4236/epe.2022.1410030

Received: July 8, 2022
Accepted: October 17, 2022
Published: October 20, 2022

Abstract

This article presents, on the one hand, the performance of ARC by configurations ITO/Si, MgO/Si, and GeO_2/Si. On the other hand, we study the impact of thickness on the reflection of OCTs, because the thickness of OCTs plays an important role on the optical properties and the variation of the reflection and transmission of TCO/Si heterojunctions as a function of thickness is also sown. And the last part of the paper, we will make a comparative study between the performance of silicon textured on the front side and that of silicon where the front side is planar. These two forms of silicon will be covered with ARC. For this, we will use the following materials ITO, MgO, and GeO_2 and we represent the variation of the reflection of CAR on a planar surface and on a textured surface as a function of the wavelength. The results show that the reflection is low in textured surface compare to the planar surface.

Keywords

Reflection, TCO, Textured Surface

1. Introduction

Transparent conductive oxide (TCO) layers are essential components for a wide variety of photosensitive electronic devices, serving as transparent electrical contacts or electrodes in flat panel displays, touch screens, thin film solar cells, and electrochemical devices [1]. Despite the specific requirements for different applications, two basic conditions are generally accepted to define Metal Oxide OCTs:

- The oxide must have a bandgap energy greater than 3.1 eV, making it transparent at wavelengths above 400 nm, to transmit more than 80% of visible light as a thin film; and

- The metal oxide must be sensitive to degenerate doping so that carrier densities of 1020 - 1021 cm^{-3} can be achieved [2].

TCOs were deposited in thin films using a Spray CVD technique, which is a simple and economical method. Historically, there were two main materials of this type: tin oxides with various doping, or tin-doped indium oxide (In_2O_3: Sn or ITO). Typically, the resistivity ranges of OCTs go down to 10^{-4} Ω·cm, and they can transmit 90% of the visible light for layers about 100 nm thickness.

In this work, we will make TCO/Si configurations. That is, we will use some TCO materials while giving their parameters [3] such as refractive index and thickness for a calibrated wavelength at 600 nm. Then compares the efficiency between a textured surface and planar surface about their reflectivity as shown in **Table 1**.

2. Materials and Methods

To evaluate ARC performance in this part, we use the following configurations ITO/Si, MgO/Si, and GeO_2/Si [4]. **Figure 1** shows the variation in the reflection

Table 1. Parameters of the studied TCO Materials.

Transparents Conducteurs Oxydes (TCO)			
Materials	**ITO**	**MgO**	**GeO_2**
Refractive Index	1.8941	1.7367	1.6076
Thickness (nm)	79.193	86.371	93.307

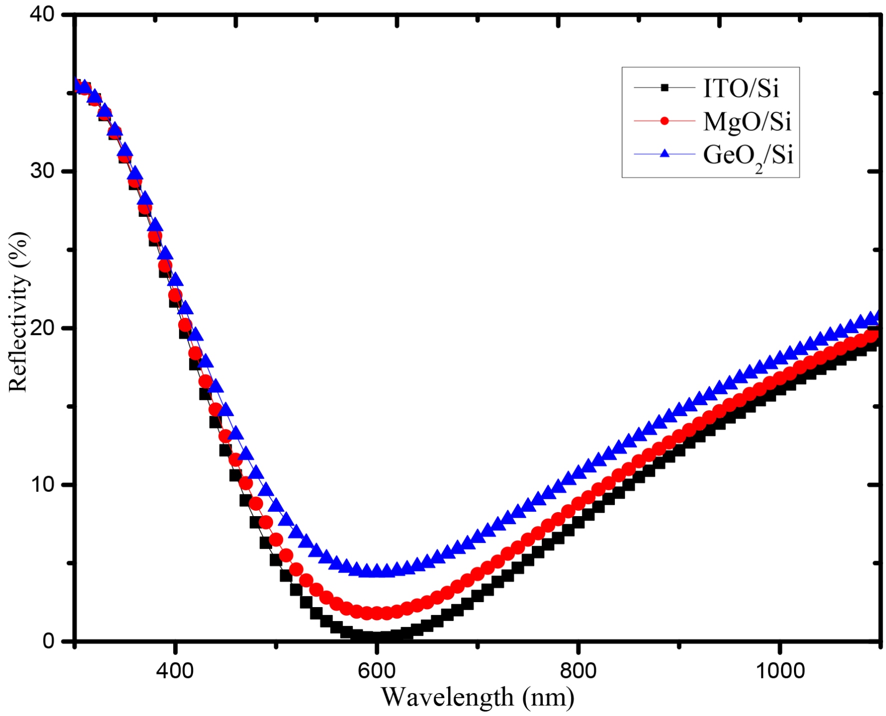

Figure 1. Variation of TCO reflection deposited on silicon as a function of reference wavelength λ_0 (λ_0 = 600 nm).

of the TCO deposited on silicon as a function of the reference wavelength λ_0.

In this figure, we have studied the TCO/Si reflexion and we notice that for low wavelengths the reflection of the TCO/Si decreases rapidly while for long wavelengths we have a rapid increase of the reflection. In addition, we note that at 600 nm the reflection of these TCO/Si is important with a reflection of the ITO/Si configuration that is almost zero. This may be due to the fact that OCT reflect radiation near and far from the infrared because of their free charges. In addition, they have good transparency properties in the visible domain and they play an important role in the passivation of semiconductor interfaces. The TCO used in these different simulations have refractive indices very close to the optimal index of silicon. This leads to massive absorption of light flux in the TCO layer, causing almost zero reflections.

In this part again, we will study the impact of thickness on the reflection of OCTs, because the thickness of OCTs plays an important role on the optical properties. Thus, Figures 2-4 represent the variation of the reflection and transmission [5] of TCO/Si heterojunctions as a function of thickness. For this, we went through the formula (quarter wave blade.) to calculate the reflection and transmission.

In these three figures, the study of the reflection and transmission of the heterojunction TCO/Si was highlighted. Compared to these figures, we notice that for thicknesses between 60 and 80 nm, we have a rapid decrease in reflection. From 100 nm, we note an increase in the latter. In addition, we note that reflections and transmissions are very important for thicknesses between 80 and 100 nm except for the ITO/Si heterojunction which has a near-zero reflection in

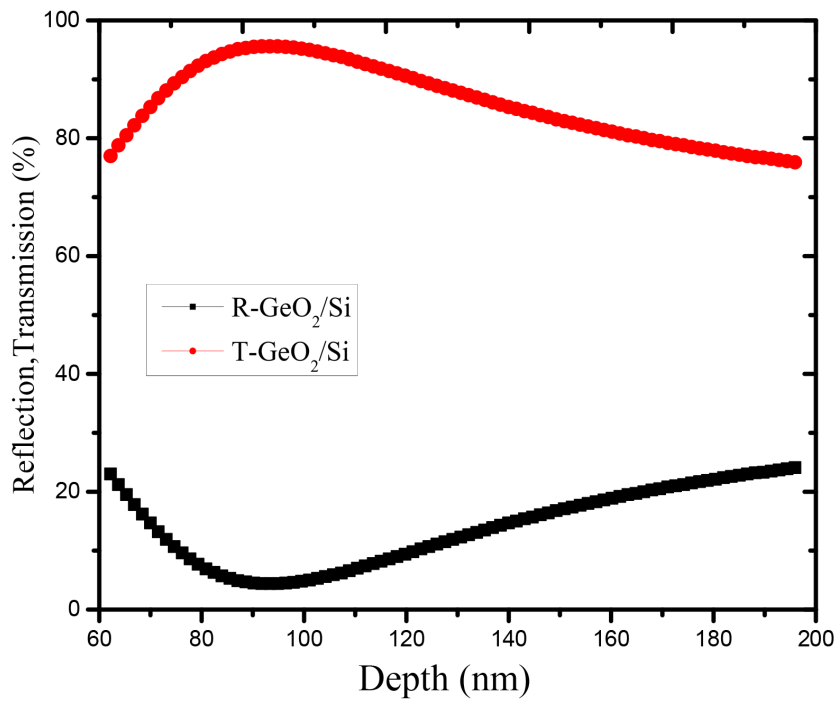

Figure 2. Variation of reflection and transmission of GeO_2/Si solar cell with thickness.

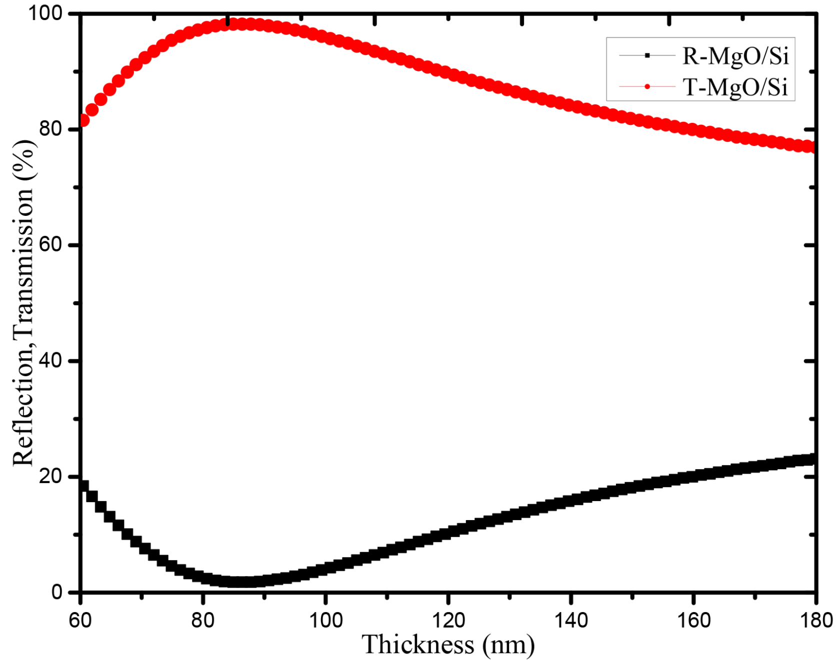

Figure 3. Variation of reflection and transmission of MgO/Si solar cell with thickness.

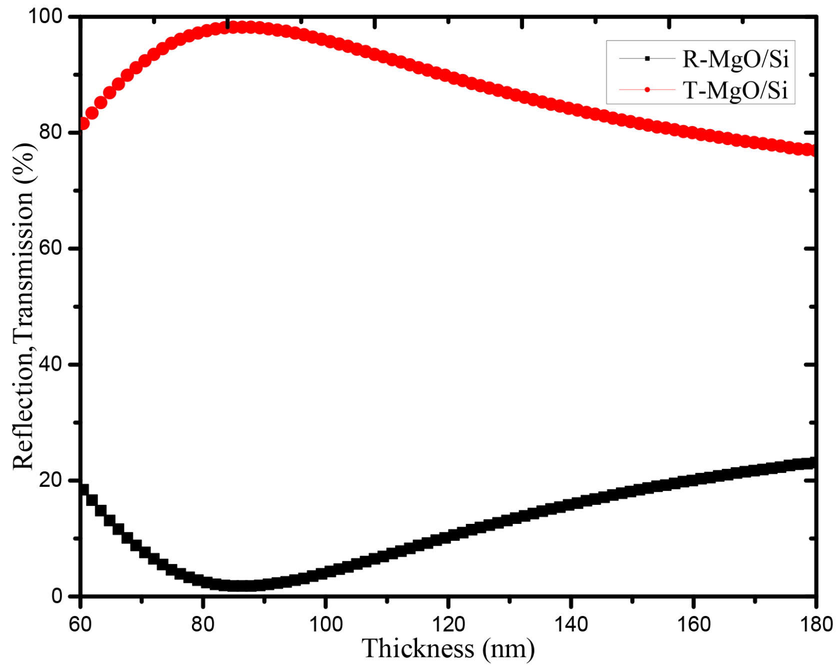

Figure 4. Variation of reflection and transmission of ITO/Si solar cell with thickness.

these thickness ranges. The opposite phenomena are noted for the transmission of these TCO. This may be related to the fact that in the thickness interval 80 up to 100 nm corresponds to the interval where the optimum thicknesses of the TCO are found. That's why reflection and transmission are important there. In addition, the fact that the ITO/Si cell has zero reflection compared to the others can be interpreted to the fact that the material (TCO) is transparent to the photons leading to a high absorption, that is to say a large transmission and reflection.

3. Comparative between Planar and Texturized Silicon Surface

Silicon surfaces generally reflect more than 30% of incoming light. To reduce these reflectivity losses, surface texturing becomes important in addition to the standard anti-reflective coatings (ARC) [6]. Its purpose is to create the roughness of the surface. On the surface, it increases a micrometric relief generally pyramidal in shape. The incident rays follow the laws of the geometric optics, because the wavelength of the incident light is lower than the dimensions of the realized structures. These phenomena will be illustrated by **Figure 5**.

In this part of the paper, we will make a comparative study between the performance of silicon textured on the front side and that of silicon where the front side is flat. These two forms of silicon will be covered with ARC. For this, we will use the following materials ITO, MgO, and GeO_2 [7]. **Figures 6-8** represent the variation of the reflection of ARC on a flat surface and on a textured surface as a

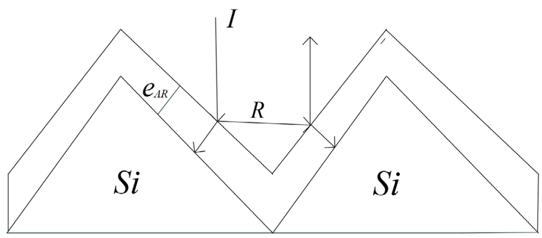

Figure 5. Texturing of the silicon surface in pyramidal form.

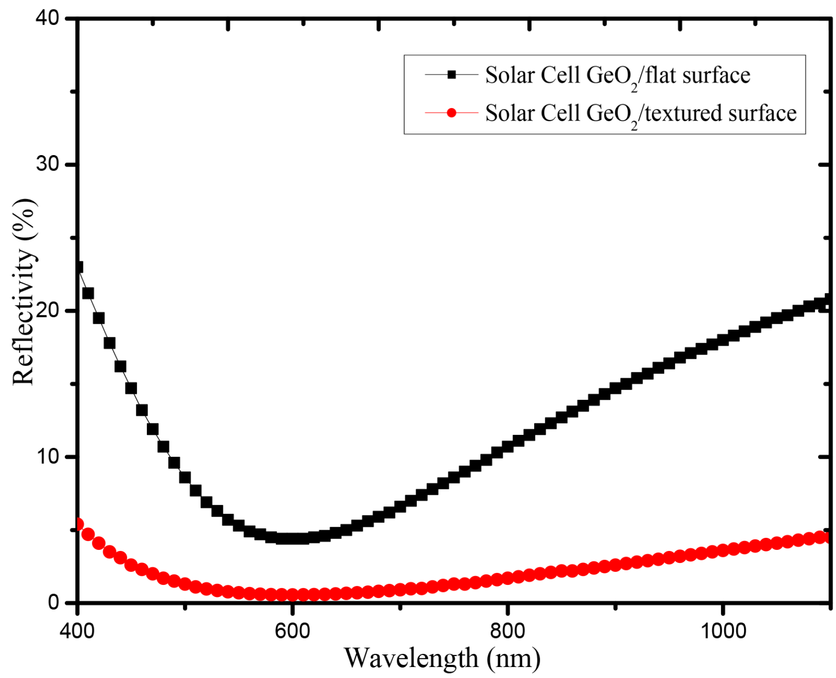

Figure 6. Variation of the reflection of GeO_2/flat surface and GeO_2/textured surface solar cells as a function of wavelength.

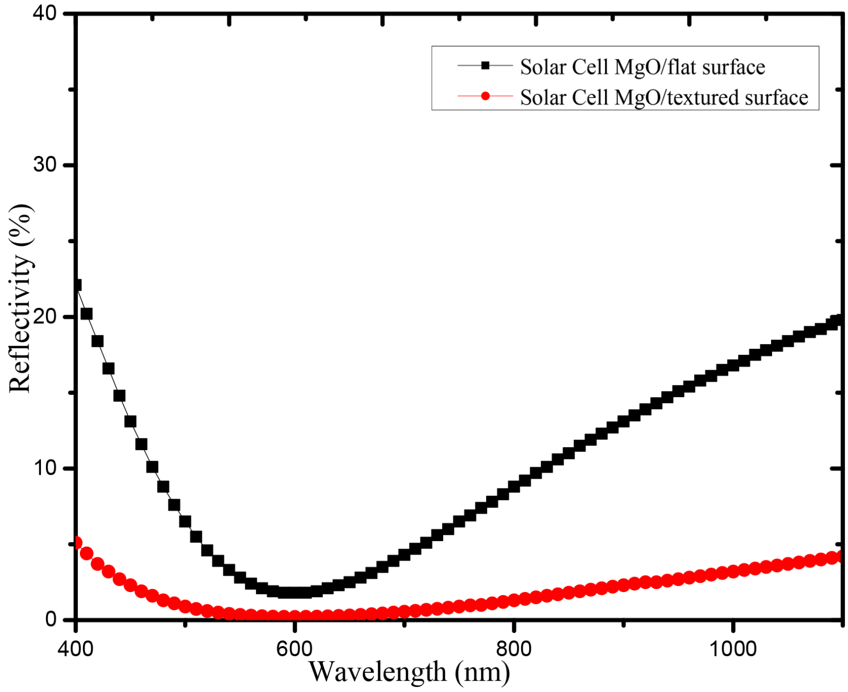

Figure 7. Variation of reflection of MgO/flat surface and MgO/textured surface solar cells as a function of wavelength.

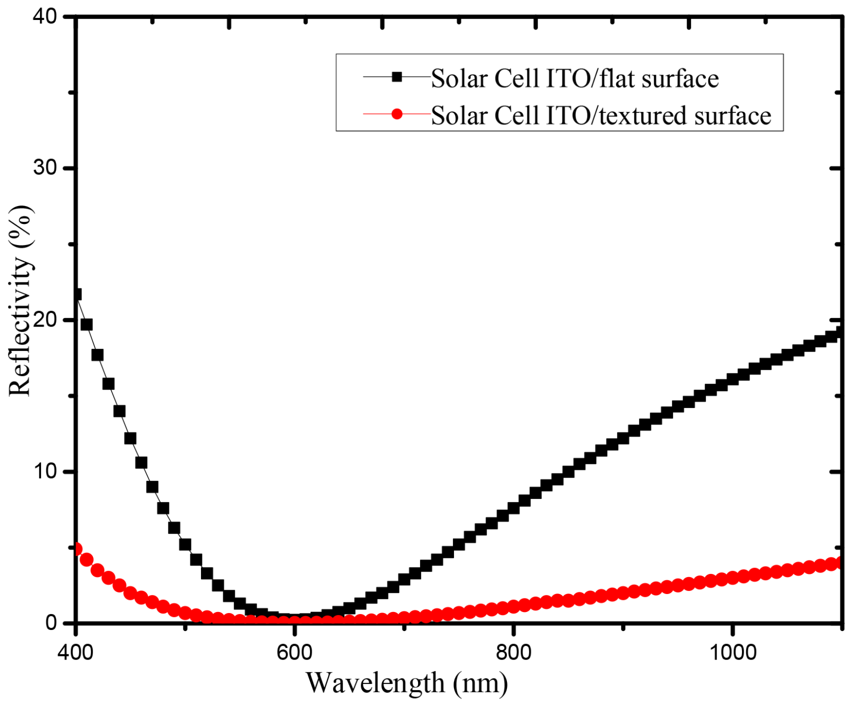

Figure 8. Variation of the reflection of ITO/flat surface and ITO/textured surface solar cells as a function of wavelength.

function of the wavelength.

With these figures, we made a comparative study of the reflection between a combination of a ARC/silicon flat surface and ARC/silicon textured surface. For all these three curves, we notice that the reflection of a ARC on a textured silicon is more important than that of a ARC on a flat silicon. In addition, we notice that the surface Texturing of a cell can reduce the reflectivity by up to three compared to the flat surface. This can be related to the fact that the maximum of light is trapped causing a reduction of the losses related to the reflectivity and leading to an improvement of the efficiency [8] of the solar cell. There is also that the ARC (well optimized) [9] combined with a good Texturing on the front and back surfaces of the cell reduces the reflection losses while creating constructive interference.

4. Conclusion

In this paper, we showed that textured surface has less reflection than planar surface. This can be related to the fact that the maximum of light is trapped causing a reduction of the losses related to the reflectivity and leading to an improvement of the efficiency. We can enlarge the study by doubling the TCO layers in order to study the reflectivity on the two different surfaces.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Guillén, C. and Herrero, J. (2011) TCO/Metal/TCO Structures for Energy and Flexible Electronics. *Thin Solid Films*, **520**, 1-17. https://doi.org/10.1016/j.tsf.2011.06.091

[2] Minami, T. (2005) Transparent Conducting Oxide Semiconductors for Transparent Electrodes. *Semiconductor Science and Technology*, **20**, S35. https://doi.org/10.1088/0268-1242/20/4/004

[3] Katsidis, C.C. and Siapkas, D.I. (2002) General Transfer-Matrix Method for Optical Multilayer Systems with Coherent, Partially Coherent, and Incoherent Interference. *Applied Optics*, **41**, 3978-3987. https://doi.org/10.1364/AO.41.003978

[4] Diaw, A., Mbengue, N., Diop, M.M., Ba, O., Barro, F.I. and Ba, B. (2015) Modeling and Simulation of Antireflecting Layers, Influencing Parameters on the Reflexion and Transmission on the Silicon Solar Cells. *Physics and Materials Chemistry*, **3**, 37-39.

[5] Kanda, H., Uzum, A., Harano, N., Yoshinaga, S., Ishikawa, Y., Uraoka, Y., Fukui, H., Harado, T. and Ito, S. (2016) Al_2O_3/TiO_2 Double Layer Anti-Reflection Coating Film for Crystalline Silicon Solar Cells Formed by Spray Pyrolysis. *Energy Science and Engineering*, **4**, 269-276. https://doi.org/10.1002/ese3.123

[6] Nositschka, W.A., Voigt, O., Manshanden, P. and Kurz, H. (2003) Texturisation of Multicrystalline Silicon Solar Cells by RIE and Plasma Etching. *Solar Energy Materials & Solar Cells*, **80**, 227-237. https://doi.org/10.1016/j.solmat.2003.06.003

[7] Sarker, Md.S., Khatun, M.F., Ahmed, S.R.A. and Hossain, J. (2019) Optimization of Multilayer Antireflection Coatings for Improving Performance of Silicon Solar Cells. *International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering* (*IC4ME2*), Rajshahi, 11-12 July 2019.

https://doi.org/10.1109/IC4ME247184.2019.9036677

[8] Ma, Q., Zhiang, W.J., Ma, D.H., Fan, Z.Q. and Ma, X.B. (2010) Optimal Design of Quadruple-Layer Antireflection Coating Structure for Conversion Efficiency Enhancement in Crystalline Silicon Solar Cells. *International Journal for Light and Electron Optics*, 1-12.

[9] Diop, M.M., Diaw, A., Mbengue, N., Ba, O., Diagne, M., Niasse, O.A., Ba, B. and Sarr, J. (2018) Optimization and Modeling of Antireflective Layers for Silicon Solar Cells: In Search of Optimal Materials. *Materials Sciences and Applications*, **9**, 705-722. https://doi.org/10.4236/msa.2018.98051