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## Short Communications

# Effect the Technique of Light Trapping on the Performance of Simple Junction *n-p* Solar Cells Based on GaAs and Si

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Light trapping enhances the absorption of active materials in photovoltaic cells. The use of light trapping results in a thinner active region in a solar cell, which lowers the production cost by reducing the amount of material used, and increases the energy conversion efficiency by facilitating carrier collection and enhancing the open circuit voltage. There are many light trapping techniques have been introduced in order to enhance absorption of the active layer in the thin film solar cell. Antireflective layers reduce reflection losses at interfaces, Light Trap: force the light to stay longer in the layer by changing the structure of interfaces. In the present work we proposed a technique based on closed-form analytical calculation to analyse the effect of light trapping on the performance of simple Si and GaAs np junction solar cells. Particular importance is paid to light reflection. A comparison is carried out between three types of cells, with antireflection coating, with texturing on the front of the cell, and with a lambertinne reflector. The conversion efficiency increased from 23.00 % in a cell with GaAs texturing on the front and a rear reflector (incoherent reflection) to 23.90 % and for Si it passes from 15.05 % to 16.00 %. GaAs solar cell exhibits a maximum efficiency around 28.68 % with a Lambertian reflector. An efficiency of 19.37 % is obtained with Si when a Lambertian reflector is inserted.

**Keywords:** Solar cell, Si, GaAs, Light trapping.

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## 1. INTRODUCTION

To minimize the reflection of light, an antireflection layer is used; the principle of action of anti-reflection coatings is based on the interference of light beams in thin dielectric layers. The principle of multiple reflections own texturing. The relief of the surface causes a decrease in reflection in front: a ray arriving at normal incidence (relative to the plane of the cell) on a pyramid will be reflected on the face of an adjacent pyramid, this double reflection of the pyramids reduces the total reflection coefficient, which is not R but $R^2$. The texturing of substrates of the solar cell increases the photons absorbed in the active layer primarily by decreasing reflectivity over the entire useful spectrum and, to a lesser extent, by increasing the optical path of the wavelength of photons to cells with a rear reflector. Texturing increases the current from the solar cells to 20 %. The minimization of the average reflectivity is obtained by multiple reflections on a non-planar surface generally pyramidal shape that increases the light trapping; the incident rays follow the laws of geometrical optics. This is Eli Yablonovitch offering a first approach based on geometric optics and statistical physics to calculate the maximum absorption edge using randomly textured surfaces. Light trapping by random texture structures or Lambertian is well known and can be applied in solar cell thin layer. By definition area Lambertian randomizes a frilly reflected and transmitted light to all wavelengths. Trapping of light by roughening the active layer, provides support for the total internal reflection occurs at a total internal reflection results therefore in much longer propagation distance inside the material and absorption increased. In 1982, Yablonovitch reported an ideal Lambertian surface and showed a maximum path length of the light $4n^2e$ with ($n$ and $e$ are the refractive index and thickness of the cell) may be obtained by using geometrical optics considerations.

## 2. THEORETICAL MODEL

In this paper, we use a compact summation method based on the simple case of a homo-junction with non-zero front and rear reflectivity to produce a full solution to the analytical model, examining both incoherent reflections. In principle, any digital program capable of solving the semiconductor the basic equations can be used to simulate the solar cell thin films. We use our model at Matlab simulation program to solve the Poisson equation; linking the load to the electrostatic potential, and the electrons continuity equations and holes. Fig. 1 shows the layer structure for the cell and the naming scheme.

The thicknesses of the quasi-neutral region in the emitter and the base are denoted $d_1$ and $d_2$ respectively. The depletion thickness is $w$. The reflectivity of

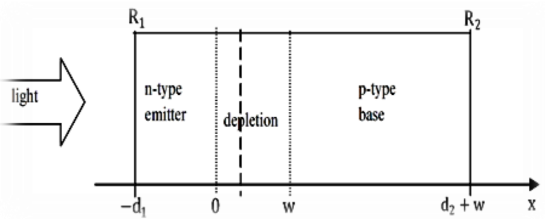

**Fig. 1** – Schematic diagram of the layer structure and naming scheme for the analytical solar cell model

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the front and rear surfaces of the solar cell are denoted $R_1$ and $R_1$ respectively and the total thickness of the solar cell is the sum of the $n$-type, the depletion region and the $p$-type, $P = d_1 + \omega + d_2$.

### 2.1 Short-Circuit Current Density

Basically the relationships governing the operation of a solar cell Si are valid for GaAs [1]. The density of the photocurrent is:

$$J_{ph}(\lambda) = J_{p,ph}(d_1) + J_{n,ph}(d_2) + J_{dr,ph}(\omega) \quad (1)$$

where $J_{p,ph}$ – the hole current density. $J_{n,ph}$ – the emitter current density, $J_{dr,ph}$ – the depletion current density.

### 2.2 Tension *e-n* Circuit-Ouvert

The dark current density is:

$$J_d = J_s + J_{SRH} \quad (2)$$

$$J_s(\lambda) = J_{p,d}(d_1) + J_{n,h}(d_2) \quad (3)$$

where $J_{p,d}$ – the dark hole current density, $J_{n,d}$ – the dark emitter current density, $J_{SRH}$ – the dark current in the depletion region. The dark depletion current density was assumed to be dominated by Shockley–Read–Hall recombination [1]. Note that in our model the overall minority carrier lifetime contains both radiative and nonradiative components, and a Shockley–Read–Hall lifetime was defined for electrons and holes in both the emitter and base regions. The overall minority carrier lifetime is then:

$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_{SRH}} \quad (4)$$

With $\tau_n$ is the radiative lifetime of minority carriers and $\tau_{SRH}$ is the overall minority carrier Shockley-Read-Hall lifetime [1, 2]. The open-circuit voltage $\upsilon_{co}$ can be calculated with using the condition $J = J_{ph} + J_d(\upsilon) = 0$ and letting $\upsilon = \upsilon_{co}$.

### 2.3 Fill Factor and Conversion Efficiency

The output power of $P$ of solar cell is:

$$P = JV = \left(J_{ph} - J_d\right)V \quad (5)$$

The maximum output power $P_m$ can be derived using $\frac{dP}{dV} = 0$.

$$P = J_m V_m = J_{ph}\left[\upsilon_{co} - \upsilon_T\left(1 + \ln\left(1 + \frac{V_m}{\upsilon_T}\right)\right)\right] \quad (6)$$

Where $J_m$ and $V_m$ are the maximum current density and maximum voltage, and $V_m$ can be calculated numerically from the following equation:

$$V_m \approx \upsilon_{co} - \upsilon_T\left(1 + \ln\left(1 + \frac{V_m}{\upsilon_T}\right)\right) \quad (7)$$

The fill factor $FF$ and the conversion efficiency $\eta$ of the cell are defined as:

$$FF = \frac{J_m V_m}{J_{ph} v_{co}} \quad (8)$$

$$\eta = \frac{P_m}{P_{in}} \quad (9)$$

Where $P_{in} = 1000 w / m^2$ is the incidence power at AM1.5.

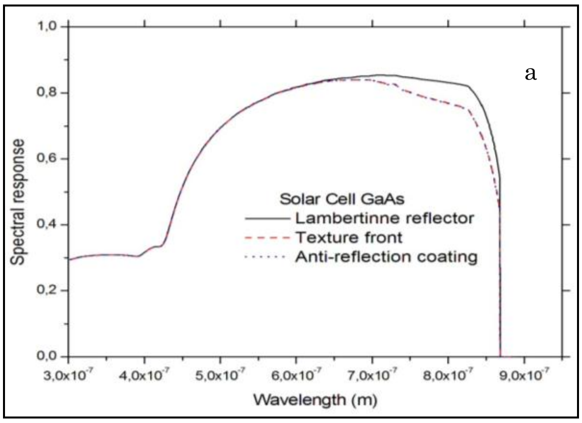
## 3. RESULT AND DISCUSSION

Solar cells which have been studied, is a structure np based on GaAs and Si, without windows without BSF layers. Table 1 includes the physical parameters of solar cells GaAs and Si used in the simulation.

| Parameters | Emitter (μm) | Base (μm) | Donor doping Nd (cm $^{-3}$) | Acceptor doping Na (cm $^{-3}$) |
|---|---|---|---|---|
| GaAs | 0.1 | 1.2 | $5 \times 10^{18}$ | $5 \times 10^{17}$ |
| Si | 0.1 | 15 | $5 \times 10^{18}$ | $5 \times 10^{17}$ |

### 3.1 Comparison Between the Solar Cell with Antireflection Coating, with Texturing on the Front, and with Reflector Lambertinne

We make a comparative study of three cases of solar cells, case an antireflection layer for the GaAs cell , and the solar cell Si ($SiO_2$ with thickness 0.3 μm and refractive index $n = 1.9$ [4]), and a reflector positioned at the rear of the solar cell, usually studying the incoherent reflection. For roughness at the front and the incoherent reflection, and the case of a reflector lambartinne. Fig. 2 (a, b) shows the spectral response curves for solar cells based on GaAs and Si and the curves characteristic $J = f(V)$, shown in Fig. 3 (a, b) for solar cells



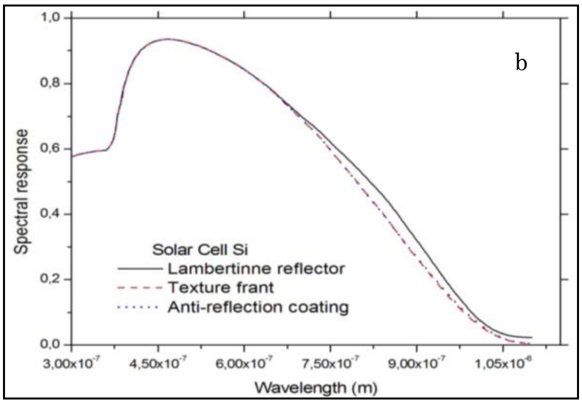


**Fig. 2** – Shows the curves of the spectral response for the solar cells GaAs (a), and Si (b)

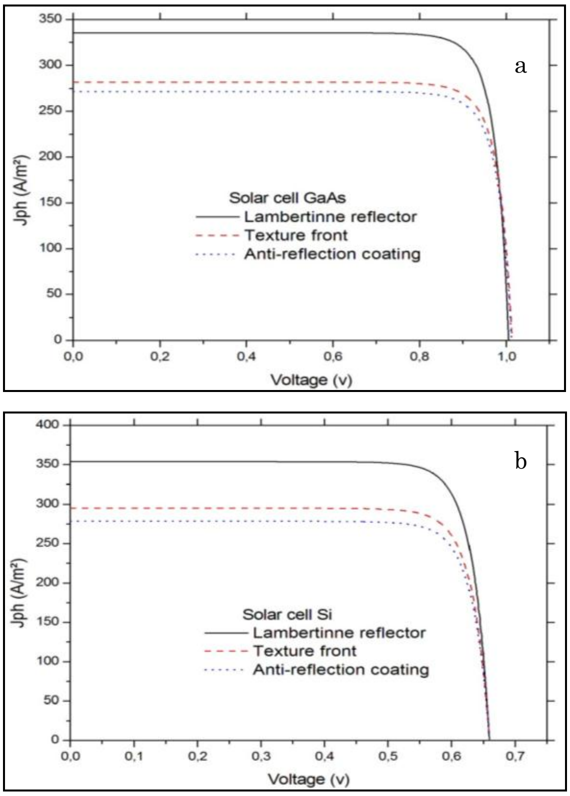


**Fig. 3** – Represented by the characteristic curves $J = f(V)$ for the solar cell GaAs (a), and Si (b)

**Table 2** – Photovoltaic magnitudes of solar cells based on GaAs and Si in the three cases studied

| Solar Cell GaAs | | | | |
|---|---|---|---|---|
| PV parameter | $\eta$(%) | *FF* | $J_{ph}$ (A/m$^2$) | $v_{co}(v)$ |
| Lambertinne reflector | 28.68 | 0.84 | 335.45 | 1.01 |
| Texture front | 23.90 | 0.84 | 281.87 | 1.00 |
| Anti-reflection coating | 23.00 | 0.85 | 271.63 | 1.00 |
| Solar Cell Si | | | | |
| PV parameter | $\eta$(%) | *FF* | $J_{ph}$ (A/m$^2$) | $v_{co}(v)$ |
| Lambertinne reflector | 19.37 | 0.83 | 353.82 | 0.66 |
| Texture front | 16.00 | 0.83 | 294.99 | 0.65 |
| Anti-reflection coating | 15.05 | 0.83 | 278.34 | 0.65 |

based on GaAs and Si, Note that solar cells with lambertinne reflector provide a photo current, a efficiency, a tension, a form factor, more important than any other case of solar cells because of photon guarded the longest time in the solar cell therefore increased absorption. Photovoltaic magnitudes of the three solar cells in the two solar cells GaAs and Si are summarized in Table 2. From this table, we observe that the photovoltaic magnitudes in three solar cells for both solar cells based on GaAs and Si, marking an increase with the different technical trappings of light used in this work.

## 4. CONCLUSION

The incorporation of antireflective coatings or textured surfaces on the front of the cell gives promising results for achieving better electrical performance at reasonable costs. We have shown that the lambertinne structures could induce a significant improvement in the photoelectric current for the two GaAs and Si cells.

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