Digest Journal of Nanomaterials and Biostructures Vol. 14, No. 3, July - September 2019, p. 743 - 750

# THE EFFECT OF EPOXY LAYER SUPPORTED BY CARBON, ALUMINA AND SILICA GRAINS ON THE SOLAR CELL

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In this work, solar cell was fabricated of silicon (p-Type) by depositing of Epoxy layer supported via carbonate, alumina, and silica on the silicon substrate with different volume ratios (5, 15, 25) % with thickness 6 μm. The measurements of I-V, photovoltaic, and the microscopic imaging of the samples have been studied. The results of the I-V measurements showed that the value of reverse saturation current $I_{sc}$ of the compound $Al_2O_3$/p-Si/Al is the maximum value was 7.2 μA compared to other samples. The efficiency of $Al_2O_3$/p-Si/Al found to be the best value was (3.48%) compared to other samples. The microscopic images of the samples showed that they had a uniform distribution on the silicon surface. These results indicate that the silicon surface supported by alumina nanoparticles is a good distributed and homogeneous with different concentrations.

(Received April 12, 2019; Accepted August 30, 2019)

*Keywords:* Electrical properties, Solar cell, Optical spectroscope

## 1. Introduction

Crystalline silicon (C-Si) is an important material of the last century, that has been the corner stone of the semiconductor industry and has spear headed extraordinary technological advancement [1]. The silicon is the basic material for many applications such as electrical and optical devices and has indirect-band gap . Electron-hole pairs are the ones of the mains directions of research in the field of photonic applications is to develop (Si) -based materials which emit light in the visible range [2] Single - or multi-crystalline silicon solar cells have been the workhorse of the photovoltaic (PV) industry since the first practical solar modules [3]. In fact, the study of Epoxy supported by nanoparticles has growing attention which can be exclusively in many applications. Moreover, Epoxy is the most common choice for advanced composite materials such as corrosion protection, higher strength, lower shrinkage, good electrical and fatigue properties [4], better adhesion to fillers, fibers and other materials [5,6]. In the present work, solar cell samples are investigated by electrical properties (I-V), efficiency and optical spectroscope also to study the effect of Epoxy layer supported by Carbon, Alumina and Silica grains on the efficiency of solar cell.

## 2. Experimental

A solar cell was fabricated of silicon (p-type) , resistivity (0.01- 0.02 Ω. cm) and oriented <111>. Epoxy layer (NITOPRIME 25 BASE) with density of (1.2 g/cm$^3$) was added on the surface of silicon. Additionally, Epoxy was mixed with nano grains of $Al_2O_3$ also micro grains of carbon and $SiO_2$ with different concentration (5, 15, 25) %. The electrical properties are shown in Fig. 1. It consists of four probe for Current–Voltage measurements, a (Kithly-112 EAM), a dual Farnel LM 28, and voltage (0 to +30V).

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The thickness (nm) of the films can be calculated using the gravimetric method as the following equation (1):

$$t = \frac{\Delta w}{\rho A} \tag{1}$$

Where $t$ is the film thickness, $\Delta w$ is the various between ( before and after deposition) , $\rho$ is the density of Si film (2.32 gm/cm$^3$) and Epoxy (1.2 gm/cm$^3$), and A is the surface area of the sample. The doped films were determined using the following eq.(2). The layers of Epoxy – supported was obtained over all solar cell layers after several attempts, using the manual surveying method (skimming). The thickness of the layers are (6 µm).

$$Total\ density\ (\rho\ composite) = density\ of\ oxide\ \times it's\ ratio\ in\ composite + doping\ \times it'sratio\ in\ composite. \tag{2}$$

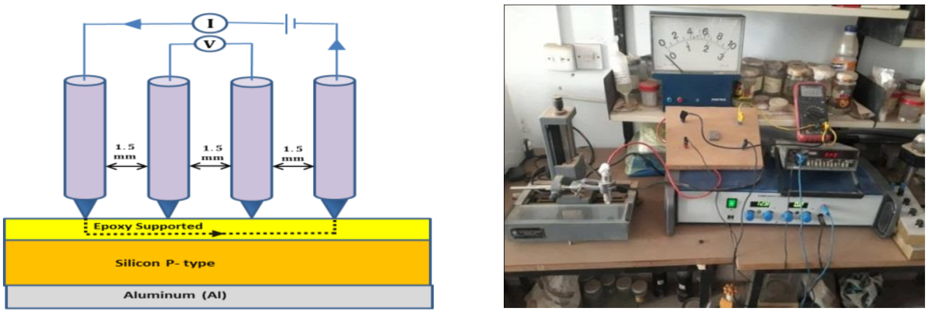



*Fig. 1. Setup of (I-V) characteristic.*

## 3. Results and discussion

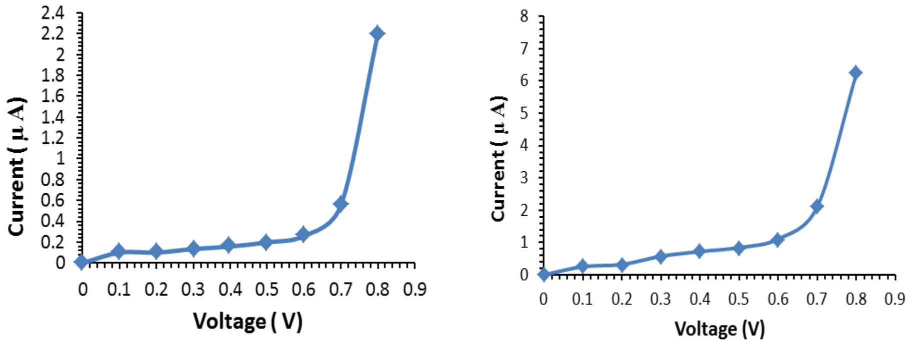
### 3.1. I-V Characteristics

The (I-V) measurements of Epoxy/p-Si/Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si/Al sandwich structure were studied in different concentrations based on the characteristics of p-Si substrate. The current – voltage measurements were achieved. Figs. 2 a & b show (I-V) the characteristics of silicon and Epoxy. It can be seen that all Figures show rectifying behavior. Furthermore Fig. 3 illustrates the (I-V) characteristics of $Al_2O_3$/p-Si/Al sandwich structure device with different concentrations (5, 15, 25)%. Saturation current of $Al_2O_3$/p-Si/Al was higher than the other samples, whereas the Carbon/p-Si/Al and $SiO_2$/p-Si/Al were lower than the $Al_2O_3$/p-Si/Al structure due to high resistance series which lead to a small current passing through the surface with the same applied voltage as Figs. 4 and 5. The (I-V) characteristics have two regions. The one region at low voltage (V< 0.6 volt), this is the case the recombination current is dominant, due to the charge carrier of concentrations are greater than the concentration of intrinsic ($np>ni^2$). Furthermore, each excitation electron from valance band to conduction band will recombine with a hole in valance band. The other region at high voltage (V> 0.6 Volt) represents forward current increases with the voltage due to the applied voltage exceeds the potential barrier. This is called diffusion current [7]. The Table 1, shows comparison between the experimental results of Epoxy /p-Si /Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si /Al samples and the p-Si sample. The fill factor ideality factor and potential barrier are calculated by the following equations (3) and (4) [8]:

$$n = \frac{q}{k_B T}\frac{\Delta V}{\ln\frac{I}{I_S}} \tag{3}$$

$$\Phi_B = \frac{k_B T}{q}\ln\left[\frac{A^{**}T^2}{J}\right] \tag{4}$$

The values of ideality factor as well as potential barrier of $SiO_2$/p-Si/Al were higher than the other samples. The value of ideality factor also potential barrier increase with increasing concentration due to increase interface states at the surface lead to make as centers of recombination.




*a)* *b)*

*Fig. 2. I-V characteristic of (a) p-Si and (b) Epoxy.*

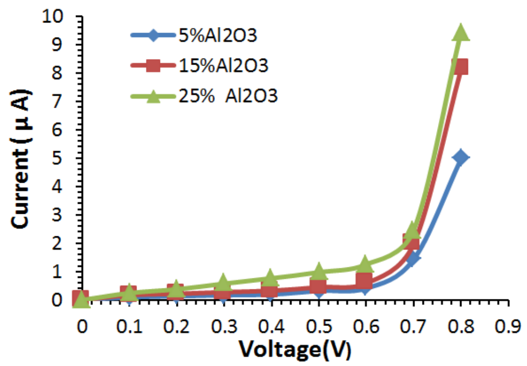



*Fig. 3. I-V characteristic of $Al_2O_3$/p-Si/Al of different concentrations.*

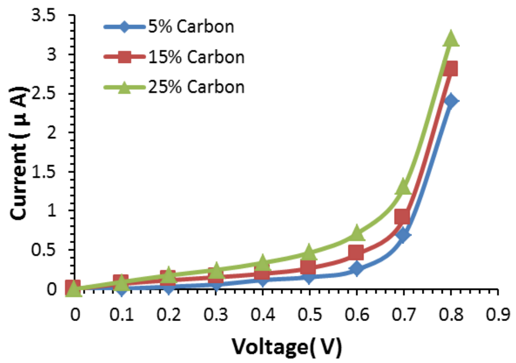



*Fig. 4. I-V characteristic of Carbon/p-Si/Al of different concentrations.*

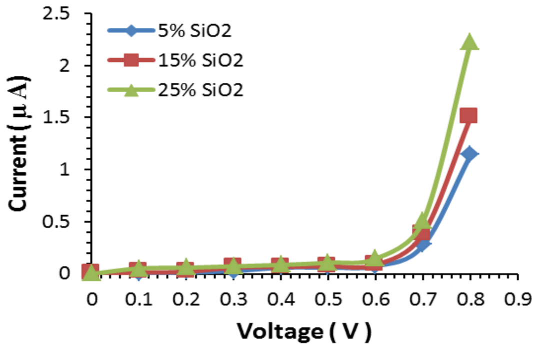



*Fig. 5. I-V characteristic of $SiO_2$/p-Si/Al of different concentrations.*

*Table 1. Saturation current, ideality factor, potential barrier and resistance series for Pure Si, Epoxy /p-Si/Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si/Al sandwich structure of different concentrations.*

| Sample | $I_o$(μA) | n | $\Phi_B$ | Rs(Ω)×$10^4$ |
|---|---|---|---|---|
| Pure Si | 4.32 | 1.82 | 0.691 | 4.7 |
| Epoxy | 1.23 | 3.82 | 0.697 | 112.6 |
| 5% $Al_2O_3$ | 6.84 | 1.621 | 0.682 | 35.9 |
| 15% $Al_2O_3$ | 6.93 | 1.617 | 0.675 | 34.7 |
| 25% $Al_2O_3$ | 7.2 | 1.603 | 0.663 | 33.1 |
| 5% Carbon | 6.53 | 1.692 | 0.691 | 41.6 |
| 15% Carbon | 6.72 | 1.687 | 0.687 | 42.5 |
| 25% Carbon | 6.77 | 1.677 | 0.668 | 43.8 |
| 5% $SiO_2$ | 2.53 | 2.21 | 0.695 | 33.1 |
| 15% $SiO_2$ | 2.83 | 2.17 | 0.694 | 34.7 |
| 25% $SiO_2$ | 3.32 | 2.11 | 0.693 | 35.9 |

### 3.2. Photovoltaic measurements

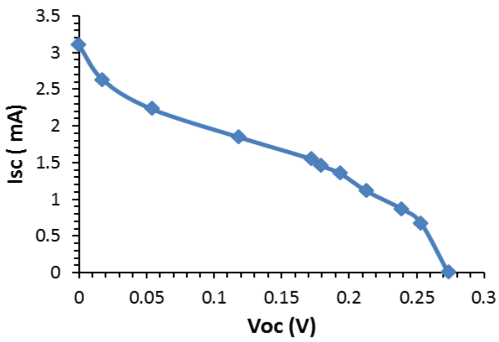
The illumination was applied under (100 mW/$cm^2$) by halogen lamp type (Philips) with 100W power. $V_{OC}$ and $I_{SC}$ were measured in order to calculate the fill factor (F.F.) of the solar cell structure using equation (5) and the efficiency (η %) using equation (6). The fill factor is presented the maximum power output ($P_m$) to the open circuit voltage ($V_{oc}$) and the short circuit current ($I_{sc}$). The fill factor can be calculated by the following equation [9]:

$$FF = \frac{P_m}{I_{SC}\, V_{OC}} = \frac{I_m\, V_m}{P_{in}} \tag{5}$$

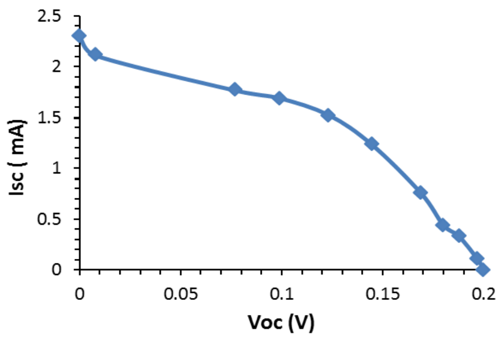
The efficiency of the cell can be also determined from the following equation[10]:

$$\eta = \frac{P_m}{P_{in}} = \frac{FF\, I_{SC}\, V_{OC}}{P_{in}} \tag{6}$$

The photovoltaic characteristics of the pure Si, Epoxy /p-Si/Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si/Al sandwich structure solar cells were prepared with different concentration (5,15,25)%. Fig. 6a & b show solar cell of pure silicon and Epoxy. In addition, it was observed that efficiency of the $Al_2O_3$/p-Si/Al was higher than that of (p-Si) sample and the other samples as Fig. 7. Increasing of concentration leads to increase the conversion efficiency until reaching the optimum value due to reduce of the stress on the surface [11]. While the Figs. 8 and 9 show the photovoltaic characteristics of the $SiO_2$/p-Si /Al samples of the different concentration were lower than the other samples, due to high resistance series of $SiO_2$ layer this lead to low conductivity [12]. In Table 2, we compared the experimental results of Epoxy /p-Si /Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si /Al samples with a p-Si sample. It can be seen that the $Al_2O_3$/p-Si/Al photovoltaic devices have higher $V_{oc}$ and $I_{sc}$ and lower fill factor (F.F) than (p-Si) sample. Light trapping can improve Isc by carrier recombination at the surface lead to enhance efficiency of the solar cell. The nanoparticles of $Al_2O_3$ can also reduce the density of the defects at grain boundary lead to small recombination at the boundary [13].




*a)*




*b)*

*Fig. 6. Isc against Voc characteristics of (a) p-Si and (b) Epoxy.*

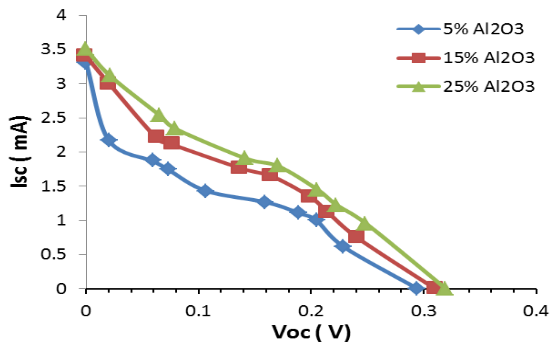



*Fig. 7. Isc against Voc characteristics of $Al_2O_3$/p-Si/Al of different concentration.*

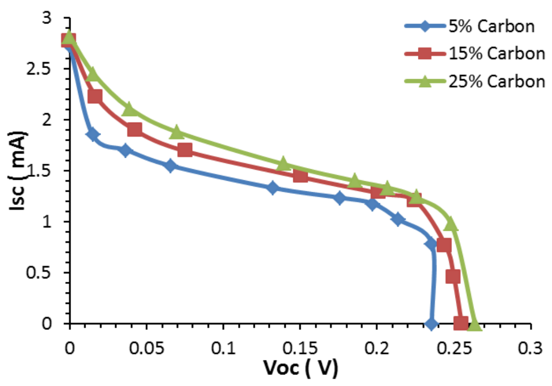



*Fig. 8. Isc against Voc characteristics of Carbon/p-Si/Al of different concentration.*

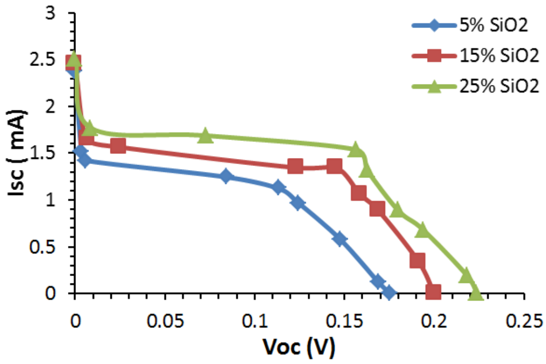



*Fig. 9. Isc against Voc characteristics of $SiO_2$/p-Si/Al of different concentration.*

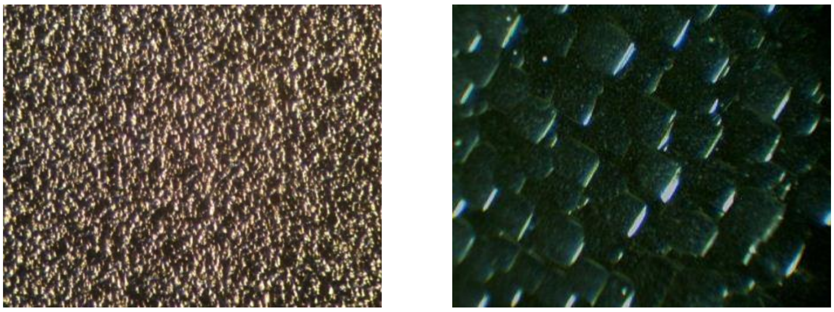
*Table 2. Photovoltaic parameters of Pure Si, Epoxy /p-Si/Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si/Al sandwich structure Solar cell device.*

| Sample | $I_{Sc}$(mA) | Vm (Volt) | Im(mA) | Voc (volt) | F.F | η% |
|---|---|---|---|---|---|---|
| Pure Si | 3.12 | 0.172 | 1.544 | 0.27 | 0.315 | 2.66 |
| Epoxy | 2.3 | 0.123 | 1.522 | 0.2 | 0.393 | 1.87 |
| 5% $Al_2O_3$ | 3.31 | 0.189 | 1.11 | 0.29 | 0.219 | 3.0 |
| 15% $Al_2O_3$ | 3.43 | 1.34 | 1.344 | 0.31 | 1.581 | 3.3 |
| 25% $Al_2O_3$ | 3.51 | 0.2 | 1.455 | 0.319 | 0.261 | 3.48 |
| 5% Carbon | 2.72 | 0.197 | 1.177 | 0.235 | 0.363 | 2.42 |
| 15% Carbon | 2.77 | 0.225 | 1.197 | 0.2553 | 0.381 | 2.69 |
| 25% Carbon | 2.81 | 0.2254 | 1.236 | 0.263 | 0.376 | 2.78 |
| 5% $SiO_2$ | 2.37 | 0.113 | 1.12 | 0.175 | 0.306 | 1.27 |
| 15% $SiO_2$ | 2.45 | 0.145 | 1.344 | 0.21 | 0.388 | 1.95 |
| 25% $SiO_2$ | 2.51 | 0.156 | 1.537 | 0.224 | 0.426 | 2.4 |

### 3.3. Optical spectroscope

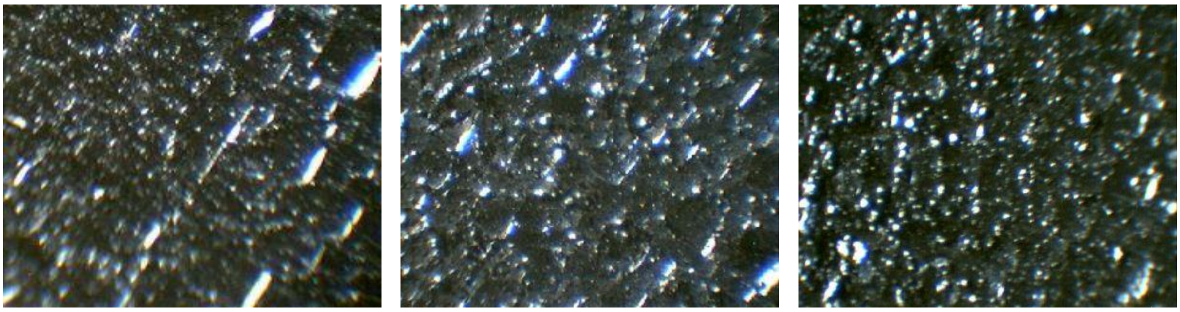
Spectroscopic images are investigated of Epoxy/p-Si/Al, $Al_2O_3$/p-Si/Al, Carbon/p-Si/Al, $SiO_2$/p-Si/Al sandwich structure in different concentrations based on the characteristics of p-Si substrate. Figs. 10 a & b show pure silicon and Epoxy images. Figs. 11 a, b & c show regular and homogeneous distribution on the surface of silicon due to small grain size of $Al_2O_3$.. This leads to a good adhesion process [14] [15].

Figs. 12a, b & c note presence of some stress on the surface due to increase of grin size with increasing concentration. Additionally. Figs. 13 a, b & c show non-uniform distribution with some vacancies on the surface of silicon.



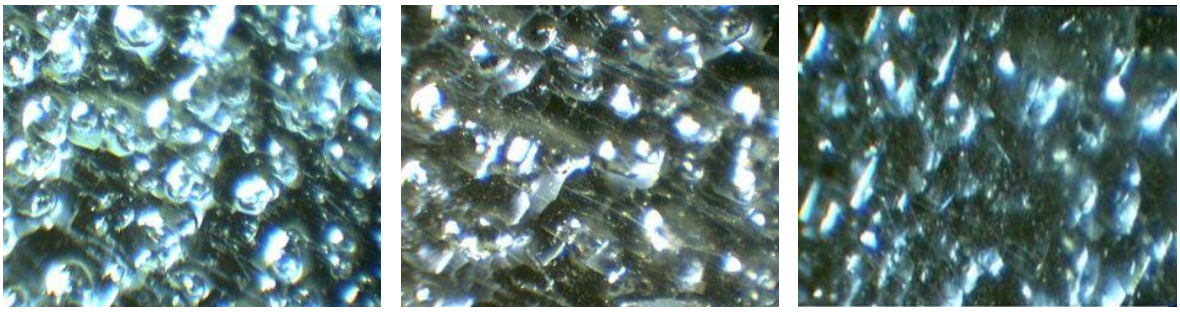
a) b)

*Fig. 10. Spectroscopic images of (a) pure Si and (b) Epoxy.*



a) b) c)

*Fig. 11. Spectroscopic images of Carbon/p-Si/Al of concentration (a) 5%, (b) 15% and (c) 25%.*



a) b) c)

*Fig. 12. Spectroscopic images of $SiO_2$/p-Si/Al of concentration (a) 5%, (b) 15% and (c) 25%.*

## 4. Conclusions

In summary, we have fabricated the solar cell composited from Epoxy layer and mixed using carbon, nano alumina and silica grains of different concentrations. The samples were characterized by electrical and solar cell properties using I-V, photo voltage measurements and optical spectroscopy. The results reveal that the best efficiency was $Al_2O_3$/p-Si/Al structure. Moreover, the efficiency found to be 3.48% at concentration 25% compared to silicon ( p-type) also the efficiency is directly proportional to the concentration rate. Whereas the $SiO_2$/p-Si/Al was minimum efficiency compared to the other samples.

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