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I-V CHARACTERISTICS OF CDTE/PTNPS/AL$_2$O$_3$/PTNPS/SI THIN FILM SOLAR CELL

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ABSTRACT

The CdTe/PtNPs/Al$_2$O$_3$/PtNPs/Si solar cells have been fabricated on p-Si wafer by thermal evaporation, ALD, and sputtering methods at different thicknesses (time intervals) of Pt Nano Particles (0.5, 0.761, 0.926, and 1.56nm). In this work, the effect of the ultrathin PtNPs layer was studied. The I-V characteristics are studied and interpreted. Gold and indium tin oxide (ITO) are used as back and front contacts, respectively. It was found that the efficiency and filling factor have maximum values at thickness of 0.761nm.

KEYWORDS: Solar Cell, Al$_2$O$_3$, PtNPs, Efficiency, Fill Factor

INTRODUCTION

Recently, inorganic and hybrid light absorbers such as quantum dots and nanoparticles have been studied and applied in fabricating thin-film photovoltaic devices because of their low-cost and potential for high efficiency [1]. Atomic-layer-deposited (ALD) aluminum oxide (AlO$_x$) was successfully applied in the past for the passivation of *p*-type and *n*-type crystalline silicon wafers [2]. Recently, an extremely thin AlO$_x$ layer was implemented as a tunnel layer [3].

The modification of electrodes with nanoparticles has been the subject of thousands of papers but one of the most curious observations is that of nanoparticle mediated charge transfer [4]. This term has arisen for electrode-insulator-nanoparticle constructs. In the absence of the nanoparticles, the insulating layer passivates the electrode. However, upon binding of nanoparticles to the surface of the insulating layer, efficient charge transfer across the insulating layer is observed. Similar observations have been reported with different electrode types including gold [5], platinum [6], and indium tin oxide [7], and with different types of nanoparticles including gold [5], platinum [6], silver [7], and cadmium telluride (CdTe) quantum dots [8].

In the present work, I-V characteristics of CdTe/PtNPs/Al$_2$O$_3$/PtNPs/Si solar cell are investigated as a function of the thickness of PtNPs layer.

EXPERIMENTAL

In this work, a p-type silicon wafer with 0.7mm thickness is used as a substrate. To prepare the silicon wafers for the deposition process, Shiraki cleaning is done then they are itched by HF for one minute to remove the oxide layer from them. The PtNPs layers are deposited on the silicon wafer by sputtering method. The ultrathin Al$_2$O$_3$ layer with thickness of 1.7nm is deposited on the PtNPs layer by ALD method. This oxide layer is sandwiched between two PtNPs layers. The CdTe (1:1) powder from Sigma Aldrich Company is used to deposit 100nm thin film on the second PtNPs layer by thermal evaporation method using [NANO 38] deposition system supplied by Kurt J. Lesker Company. The rate of deposition is set to be about 0.03nm/sec so that the total time of the deposition process takes about one hour. The thickness of CdTe layer is controlled by crystal quartz method. The substrate during the deposition process was not heated. The prepared samples are annealed in air for one hour at 300°C by hot plate. For the back contact, 100nm gold layer is deposited on the back side of silicon substrate by sputtering method. For the front contact, 100nm layer of indium tin oxide, ITO, is deposited on the CdTe layer by sputtering method too. Figure1 illustrates a schematic view of the solar cell layers.

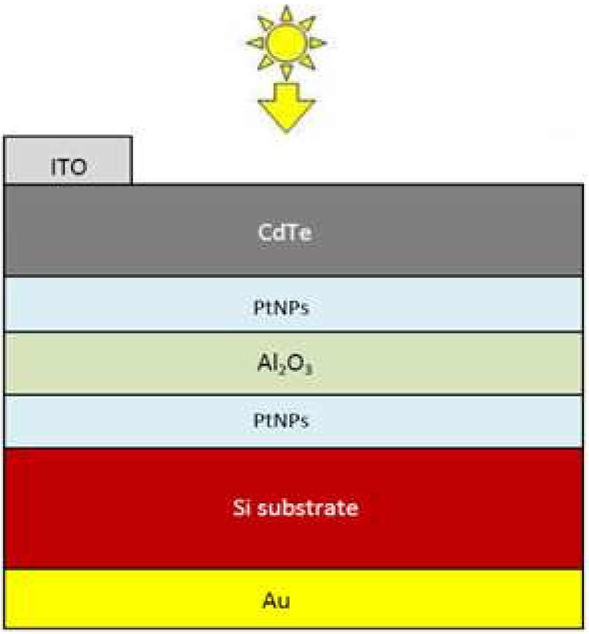

Figure 1: Schematic View of the Prepared Solar Cell

I-V characteristics are measured by KEITHLEY computerized system after contact wires were soldered to each side of samples by indium alloy soldering. This type of soldering guarantees good contacts, as well as its low temperature keeps the structural properties of films unaffected.

RESULTS AND DISCUSSIONS

The efficiency, η, and the fill factor, FF, are calculated from I-V characteristics diagrams. Figure (2) demonstrates the current vs. the voltage behavior in the dark, while figure (3) demonstrates the light condition, both in the absence of the PtNPs layer. The dark current in the reverse bias is very close to zero which could be considered as an ideal case for diode characteristics. Figures (4) to (7) show the I-V curves in the presence of PtNPs layer with different thicknesses: 0.5nm, 0.761nm, 0.926nm and 1.56nm for light currents.

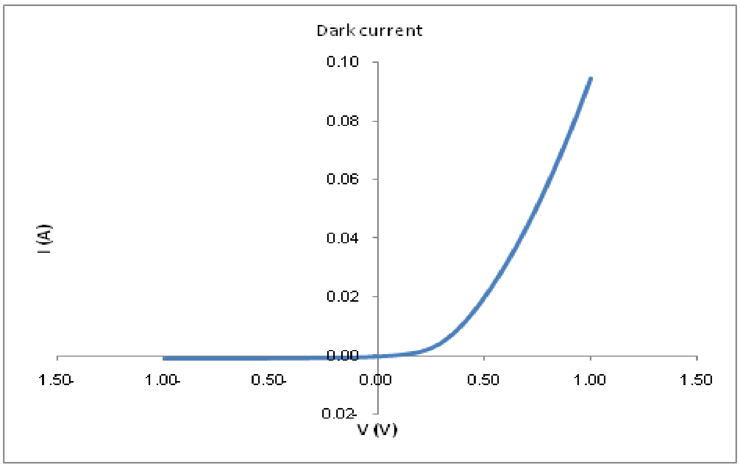

Figure 2: I-V Curve of Dark Current for CdTe/ PtNPs/Al_2O_3/ PtNPs/Si Device in the Absence of PtNPs Layer

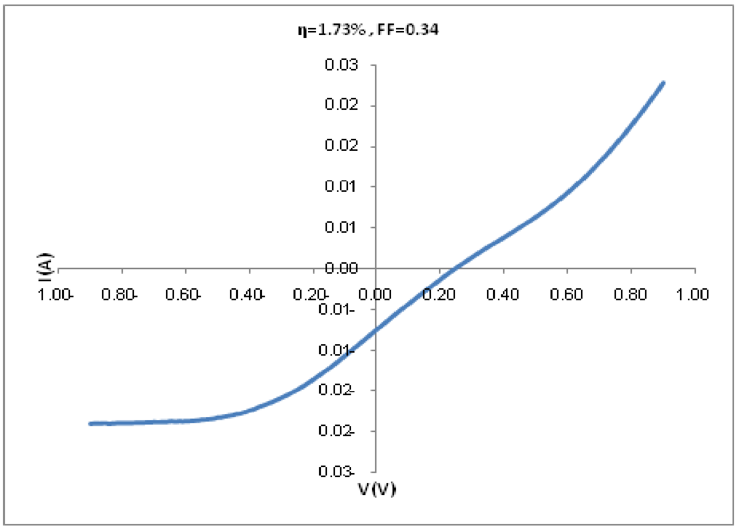

Figure 3: I-V Curve of Light Current for CdTe/PtNPs/Al$_2$O$_3$/ PtNPs/Si Device in the Absence of PtNPs Layer

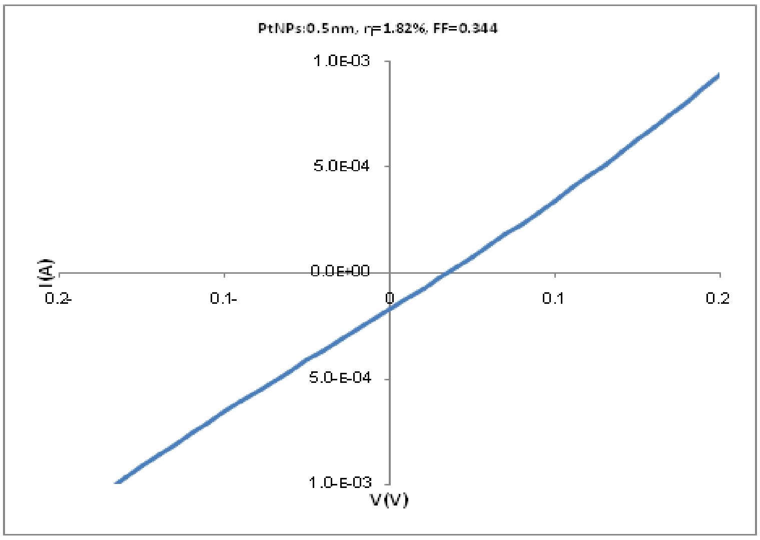

Figure 4: I-V Curve of Light Current for CdTe/PtNPs/Al$_2$O$_3$/PtNPs/Si Device in Which the Thickness of PtNPs Layer Is 0.5nm

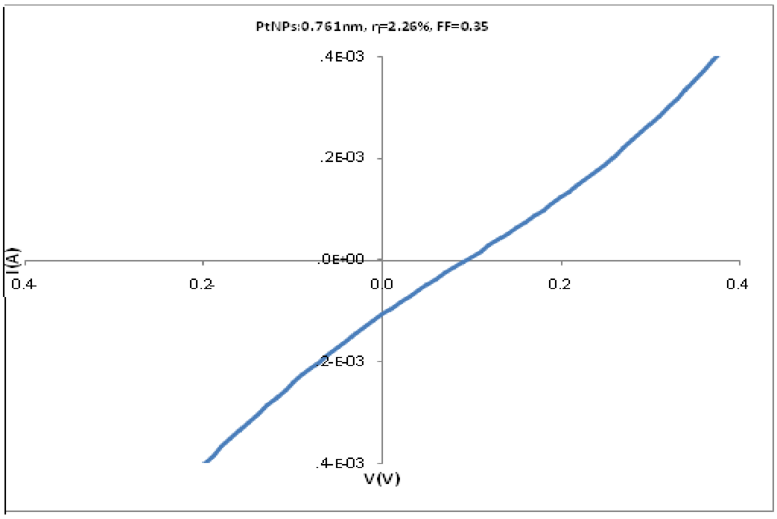

Figure 5: I-V Curve of Light Current for CdTe/PtNPs/Al$_2$O$_3$/PtNPs/Si Device in Which the Thickness of PtNPs Layer is 0.761nm

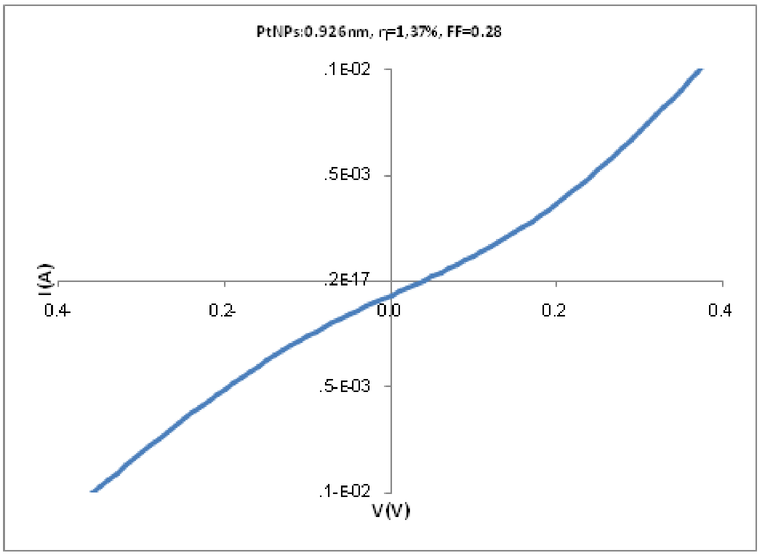

Figure 6: I-V Curve of Light Current for CdTe/PtNPs/Al_2O_3/PtNPs/Si Device in Which The Thickness of PtNPs Layer is 0.926nm

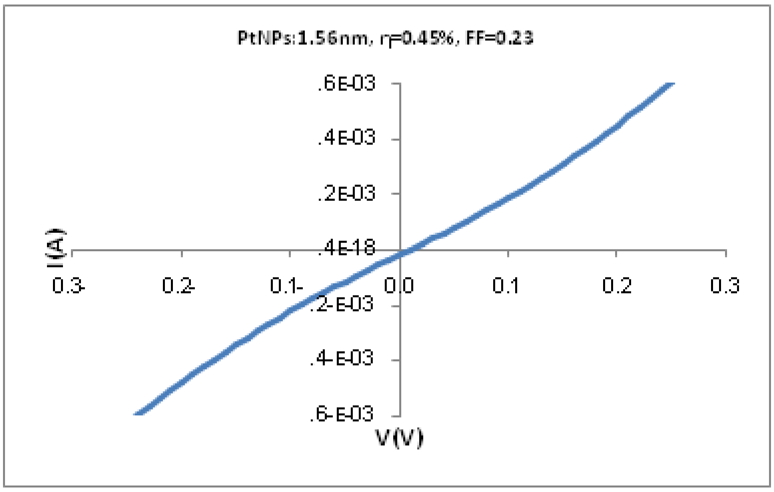

Figure 7: I-V Curve of Light Current for CdTe/PtNPs/Al_2O_3/PtNPs/Si Device in Which The Thickness of PtNPs Layer is 1.56nm

The fabricated solar cell's efficiency was calculated using the following relationship

$$\eta = P_{out}/P_{in} \tag{1}$$

Where P_{in}=0.06 W/cm^2 is the power per area for the halogen lamp measured by power meter.

$$P_{out} = P_{max}/A \tag{2}$$

where A is the effective area of the device in units of cm^2 and P_{max} is the maximum absolute value of the product of ‘I’ and ‘V’ data in the fourth region of coordinates. The filling factor for the solar sell is:

$$FF = P_{max}/\ (V_{oc} * I_{sc}) \tag{3}$$

where V_{oc} is the open circuit voltage and I_{sc} is the short circuit current. The I-V results for all samples are summarized in table (1).

Table 1: Values of H and FF for Fabricated Solar Cells with Different Thicknesses of PtNPs Films

Thickness of PtNPs Layer (Nm)	0	0.5	0.761	0.926	1.56
Quantum efficiency, (η %)	1.73	1.82	2.26	1.37	0.45
Fill factor, FF	0.34	0.344	0.35	0.28	0.23

From table (1) one can conclude that both η and FF increase with increase the thickness of PtNPs layer up to maximum values 2.26% and 0.35 respectively, and then decrease. This behavior shows that the ultrathin PtNPs layer improve the efficiency of the solar cell. When the thickness of this layer accede 0.761nm, the efficiency of the solar cell decrease and it can be concluded that the effect of PtNPs layer can be observed only when this layer is small enough to guarantee the tunneling effect.

Choosing gold for back contact is due to its suitable work function (5.1eV) with respect to electron affinity and energy gap of silicon. The electron affinity of p-Si is 4.05eV and its energy gap at 300K is 1.12eV [9]. The work function of a metal to be a good ohmic contact for some material must be equal or higher than the sum of electron affinity and energy gap of that material. The work function of gold is in the range of 5.1 and 5.47eV which could be ideal for this goal [10].

On the other hand, for n-CdTe thin film, the ohmic contact on the junction is not difficult to be achieved [11]. Although the sum of electron affinity and energy gap of CdTe is 5.73eV [12] which is greater than the work function of ITO, 5.53eV [13], but for n-type semiconductors the case is different. For an n-type semiconductor an ohmic contact means that the work function of the metal must be closer or smaller than the electron affinity of the semiconductor [10]. The most important property of ITO to be chosen as front contact is its transparency. So, in contrary with other conductors, it allows light to pass through it without any problem.

CONCLUSIONS

By varying the thickness of PtNPs film, the efficiency and filling factor of the solar cells increase, reach their maximum values at the thickness of 0.761nm, and then decrease. So, it can be concluded that we have the optimum conditions at 0.761nm. For more than this thickness, the tunneling effect will decrease. Gold at the back side and ITO at front side of devices are suitable contacts for the CdTe/PtNPs/Al_2O_3/PtNPs/Si heterojunction.

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