DOI: 10.24996/ ijs.2017.58.3C.10

ISSN: 0067-2904

Band Energy Outline of NiO:Au /Si Thin-Film for Solar Cell

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Abstract

In this paper the effects of the contact material on the photovoltaic (PV) characteristics of p-NiO:Au/n-Si solar cells fabricated by using the pulsed laser deposition (PLD) technique had been studied. It shown the p-NiO:Au/n-Si could be successfully used to construct and improve the performance of solar cells by using Au. The conversion efficiency was increased comparable with p-NiO/n-Si solar cells. In this case the NiO:Au layer acts as a hole collector as well as a barrier for charge recombination.

Keywords: NiO:Au thin films , Pulsed laser deposition, Solar Cells**.**

حزمة الطاقة لـلافلام الرقيقية NiO:Au /Si كخلية شمسية

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الخلاصة

في هذا البحث تم دراسة خصائص الخلايا الشمسية المصنعة من المركب NiO:Au/n-Si ومن نوع (P) والمصنعة باستخدام تقنية الترسيب الليزر النبضي (PLD). حيث بين الدراسة ان استخدام عنصر الفضة Au يحسن ويطور من عمل وكفاءة الخلية الشمسية. من خلال البحث وجد ان كفاءة التحويل للخلية الشمسية p-NiO/n-Si تزداد بوجود عنصر الفضة، حيث تعمل طبقة NiO:Au كجامع للفجوات.

Introduction

Nickel oxide (NiO) is the most exhaustively investigated transition metal oxide. It is a NaCl type antiferromagnetic oxide semiconductor. It offers promising candidature for many applications such as solar thermal absorber [1], catalyst for O evolution [2], photoelectrolysis [3] and electrochromic device [4]. NiO is also a well-studied material as the positive electrode in batteries [5]. Pure stoichiometric NiO crystals are perfect insulators [6]. Several efforts have been made to explain the insulating behavior of NiO. Appreciable conductivity can be achieved in NiO by creating Ni vacancies or substituting Li for Ni at Ni sites [6]. Hydrogen gas sensors based on electrostatically spray deposited NiO thin film was studied by Raied et. al.[7 and 8]. Gold (Au) is a soft, yellow metal with the highest ductility and malleability of all the elements, where doping it with NiO can construct high efficiency electrical devices. Pulsed laser deposition (PLD) is a very important and powerful technique for the growth of thin films of complex materials. It consists of three major parts, laser, vacuum system and chamber [9]. Electrical properties of pure NiO and NiO:Au thin films that prepared by PLD has been studied by Raied et al. [10]. A solar cell or photovoltaic (PV) cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect which is a physical and chemical phenomenon. Solar cells are described as being photovoltaic irrespective of whether the

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source is sunlight or an artificial light. They are used as a photodetector, detecting light or measuring light intensity. Recent studies have been shown that NiO thin films can be used successfully as solar cell.

A PV cell may be represented by the equivalent circuit model 2420 [11]. The more important characteristic of PV are conversion efficiency (η) and fill-factor that defined as [11]:

$$\eta = \frac{maximum\, output\, power\,(P_m)}{input\, power\,(P_{in})} \qquad (1)$$

And the fill-factor (FF) is defined as:

$$FF = \frac{I_m V_m}{I_{SC} V_{OC}} \qquad (2)$$

Where P_{in} is the power input to the cell, V_{oc} open circuit voltage, I_{sc} is the short circuit current, and I_m and V_m are the maximum cell current and voltage respectively at the maximum power point, $P_m= I_m . V_m$. Figure-1 illustrates the typical (I-V) characteristic of a Si PV cell, showing I_m and V_m at the maximum power point. Solar cell behavior can conveniently be examined through four main parameters as shown in Figure-1.

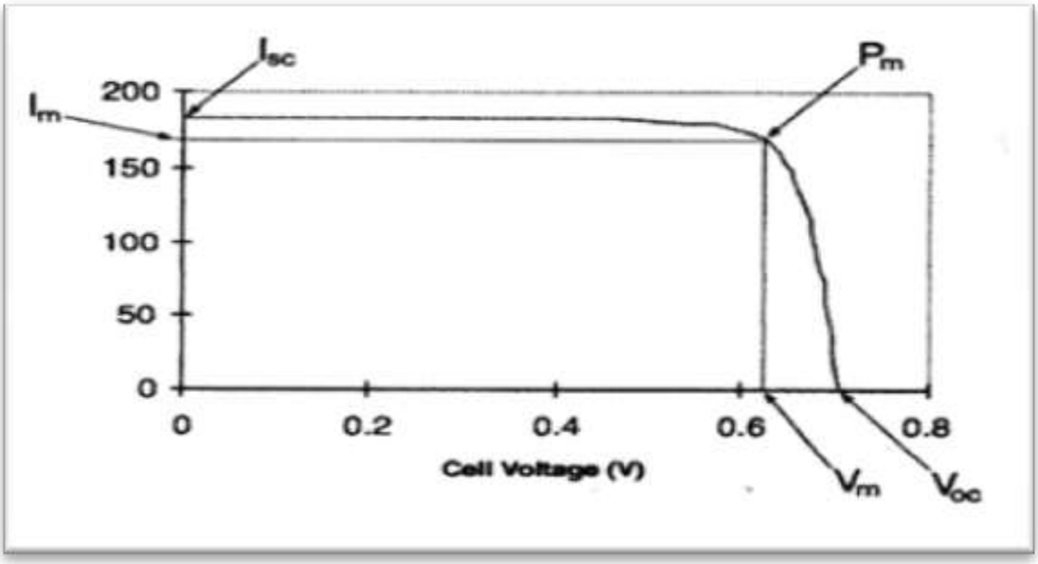

Figure 1- Forward bias I-V characteristic of typical Si PV cell [11].

Experimental procedure

The PLD experiment was carried out inside a vacuum chamber generally at (10^{-3} Torr) vacuum conditions, at low pressure of a background gas for specific cases of oxides and nitrides as represented in reference [12]. The main technical parameters of laser source are 532 nm wavelength, 1000 mJ pulse energy, 10 ns pulse width, 5 Hz repetition frequency and 100 number of shoots. The substrate (Si) was placed in front of the target (NiO with different doping ration of Au) with its surface parallel to that of the target. Sufficient gap is kept between the target and the substrate so that the substrate holder does not obstruct the incident laser beam. The temperature of substrate (Si) was 100 ^{o}C.

This paper describes the heterojunction detector of p-NiO:Au/n-Si device were fabricated by PLD technique with different Au doping ratio (0,1, 2, and 4) wt. % with NiO. The thicknesses of films were around 400 nm for all samples while the areas of it were 1 cm^2. A typical scheme of the fabricated device is shown in Figure-2.

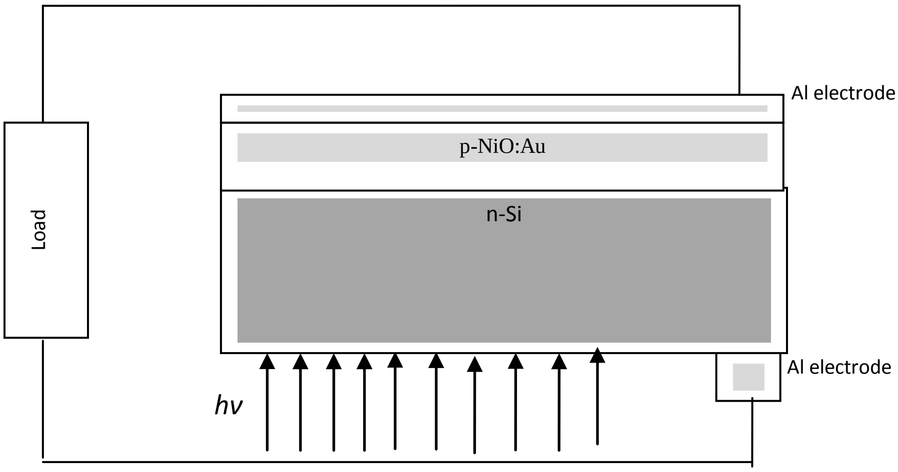

Figure 2- Scheme of fabricated device.

A digital muitimeter victor VC97 was used to measure the current flow in a detector, manufactured from the prepared structure in dark condition. Voltage was applied from a KIETHLEY power supply at arrange of (0-5V) in forward and reverse biasing. This characterization was used to determine the conversion efficiency (η) and fill-factor (FF), where the power input (P_{in}) to the cell of 50 mW.

Result and discussion

The morphology of thin films of pure NiO and with doping deposited on Si substrate by PLD at 100 ^oC temperature ware examined using SEM. Figure-3 shows that all films are homogeneously distributed, very smooth and the crystallites are very fine.

Table-1 shows the effect of doping ratio on conductivity (σ) and energy gap (Eg) of NiO. From the result, one may conclude that adding a small amount of Au in NiO material enhances the conductivity of the NiO because the conductivity of Au is higher than NiO, moreover the energy gap of NiO will be decrease.

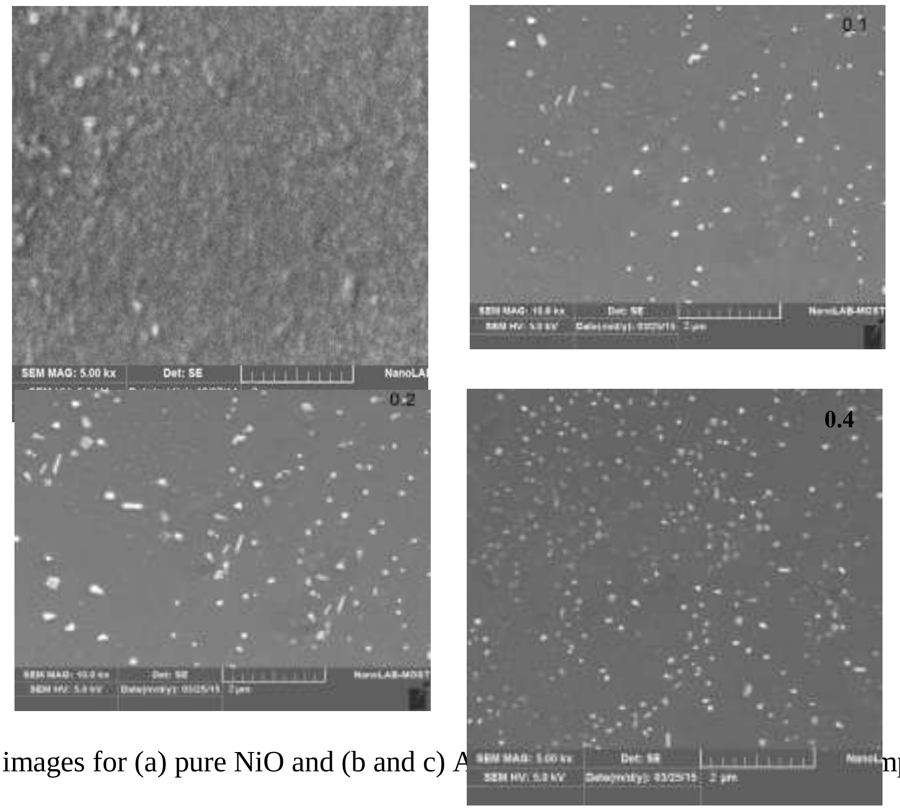

Figure 3- SEM images for (a) pure NiO and (b and c) A mperature.

Table 1-Illustration the effect of doping on conductivity and energy gap of NiO.

Sample	σ (Ω. cm^{-1})	Eg (eV)
Pure	$4.17x10^{-6}$	3.60
0.1	$3.35x10^{-4}$	3.50
0.2	$2.34x10^{-3}$	3.45
0.4	$8.46x10^{-2}$	3.4

Heterojunctions between p-type (NiO) with different doping ratio and n-type (Si) is prepared by PLD technique. The dark I-V curve in the forward and reverse bias for cell constructed with NiO:Au/Si is shown in Figures- (4,5,6 and 7). The ratio of doping wt %, short circuit current (I_{sc}), the open circuit voltage (V_{oc}), maximum power points (V_m, I_m), fill-factor (FF) and efficiency value were listed Table-2. It is concluding from this table that best value of conversion efficiency was at 0.4 wt % doping ratio. The device had an open circuit voltage c of (0.21V), a short-circuit photocurrent (I_{sc}) of (185mA), and maximum power points (0.08V, 115mA). The conversation efficiency (η) derived from the Figure-7 is (18.4%). The solar cell made without Au give less value of (η) at the same illumination intensity where was equal (0.84%).

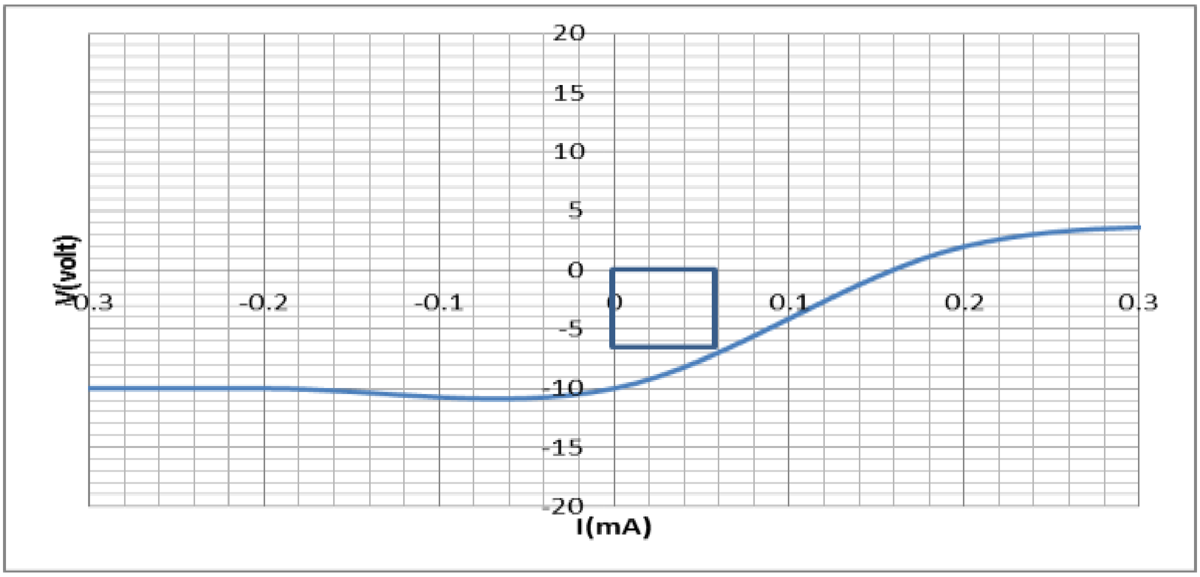

Figure 4- I-V curve for pure NiO/Si solar cell.

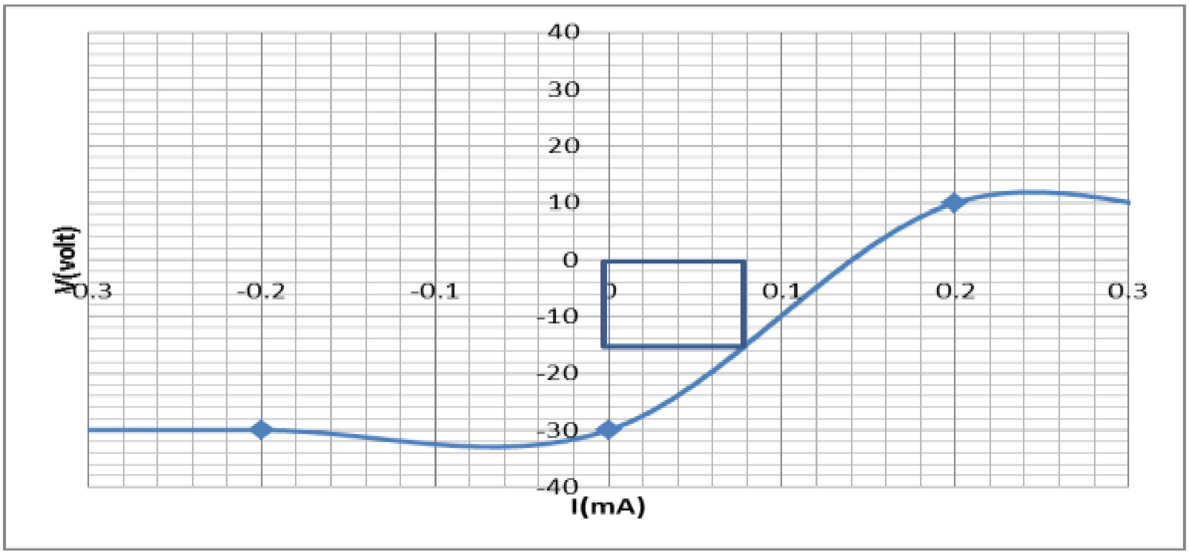

Figure 5- I-V curve for NiO:Au/Si at ratio doping 0.1 solar cell.

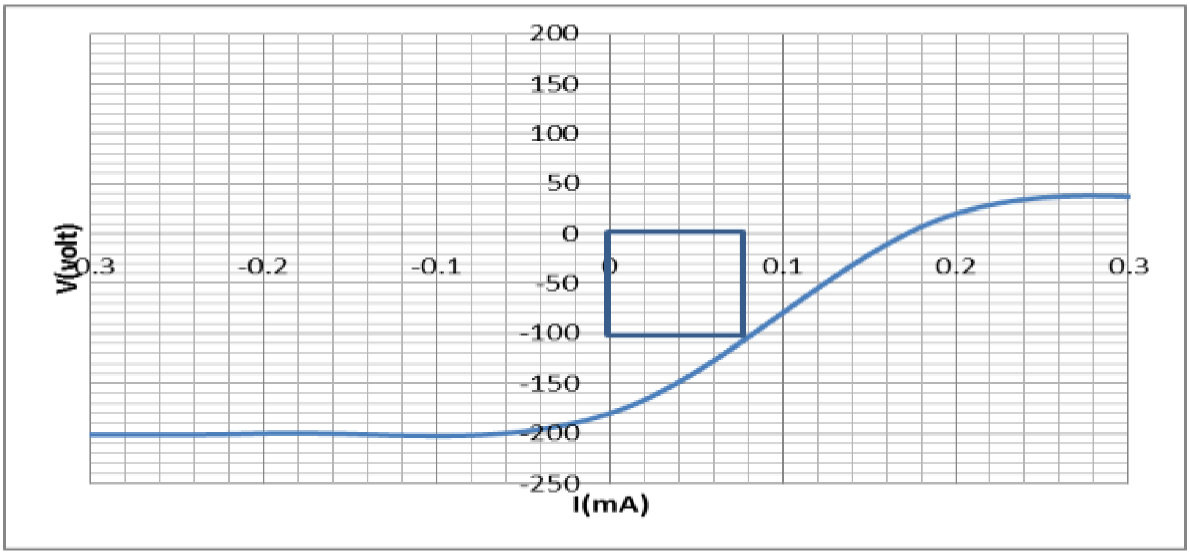

Figure 6- I-V curve for NiO:Au/Si at ratio doping 0.2 solar cell.

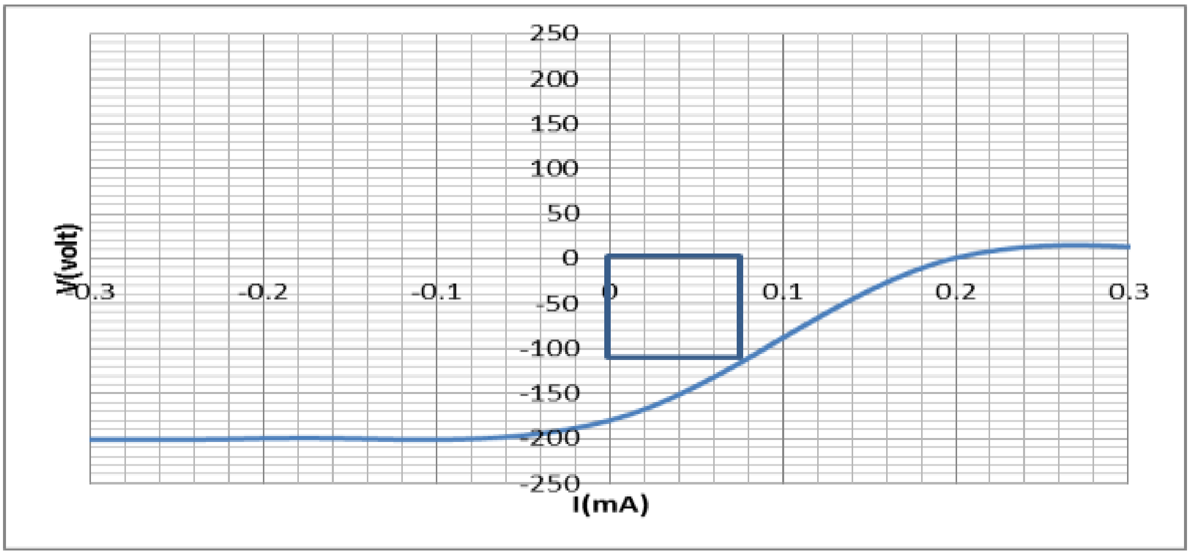

Figure 7- I-V curve for NiO:Au/Si at ratio doping 0.4 solar cell.

Table 2- Illustration the cell parameters for NiO:Au /Si solar cell.

N	Area (cm^2)	P_{in} (mW)	I_{sc} (mA)	V_{oc} (V)	I_m (mA)	V_m (V)	Fill-factor F.F	Efficiency η%
Pure	1	50	10	0.16	7	0.06	0.262	0.84
0.1	1	50	30	0.14	14	0.08	0.266	2.24
0.2	1	50	180	0.178	105	0.078	0.255	16.38
0.4	1	50	185	0.21	115	0.8	0.252	18.4

From the results presented above, it is clearly seen that the NiO:Au layer on Si acts as a hole collector, so this kind of solar cell can be improved for a future work to give much higher efficiency. To illustrate the relationship between the conversion efficiency with doping ratio, Figure-8 showing the increasing gradually in conversion efficiency at 0.1% doping ratio, this increasing become great respectively after this value to reach (16.38%), finally slightly increasing in conversion efficiency to reach the maximum value at 0.4%. The effect of doping on open circuit (V_{oc}) and short circuit current (I_{sc}) is shown in Figure-9, where both characters increase with increase the doping ratio.

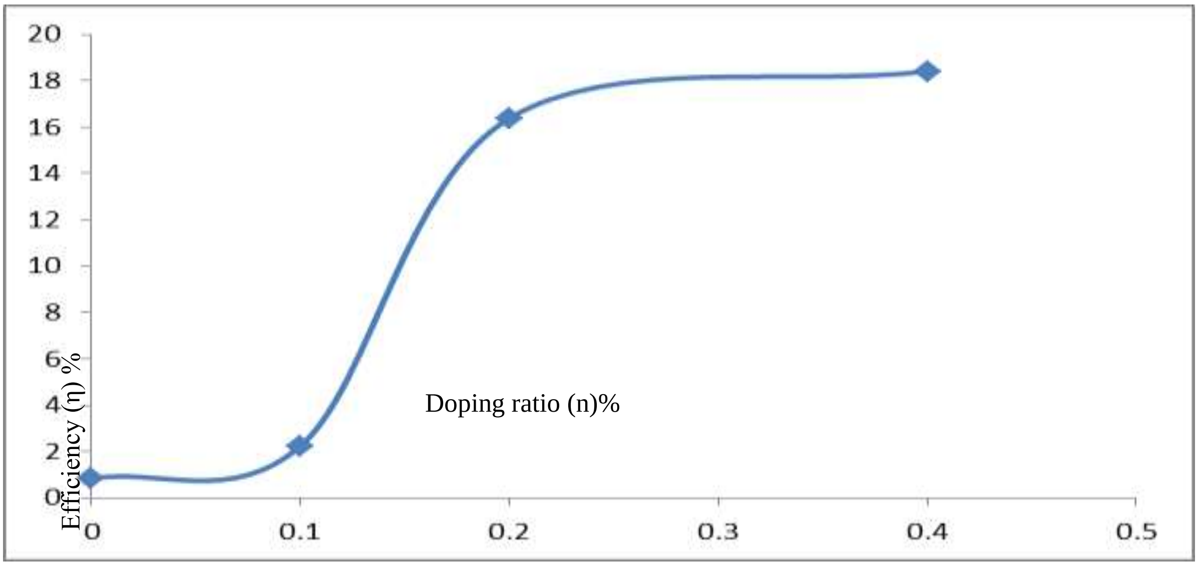

Figure 8- Conversion efficiency% vs. doping ratio %.

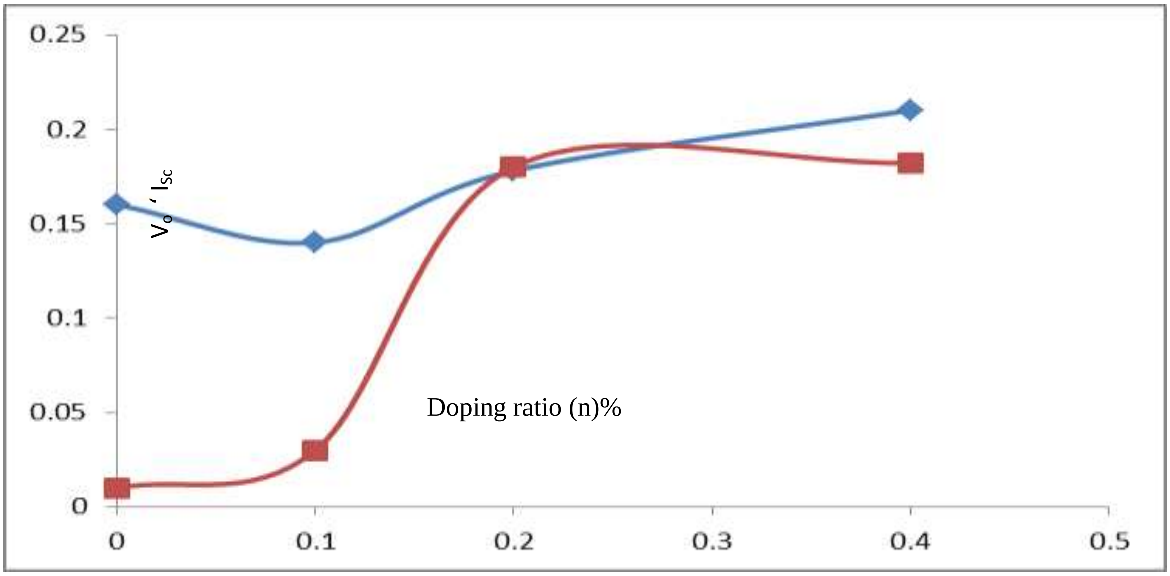

Figure 9-V_o (blue line) and I_{Sc} (red line) vs. doping ratio %.

Conclusion

It shown the p- NiO:Au/n-Si could be successfully used to construct and improve the performance of solar cells by using Au. According to results presented in this work, we conclude that ability to fabrication of NiO:Au /Si thin film as solar cell, where the best value of efficiency (η) was at 0.4 wt% doping ratio. The NiO:Au acts as a p-type oxide layer on Si, So it can be used as a hole collector in construction of our device.

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