Effect of concentrations ratios of NiO on the efficiency of solar cell for $(CdO)_{1-x}(NiO)_x$ thin films

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Abstract

CdO:NiO/Si solar cell film was fabricated via deposition of CdO:NiO in different concentrations 1%, 3%, and 5% for NiO thin films in R.T and 723K, on n-type silicon substrate with approximately 200 nm thickness using pulse laser deposition. CdO:NiO/n-Si solar cell photovoltaic properties were examined under 60 mW/cm^2 intensity illumination. The highest efficiency of the solar cell is 2.4% when the NiO concentration is 0.05 at 723K.

Key words

CdO thin film, solar cell, fill factor, conversion efficiency.

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تأثير نسب تراكيز أوكسيد النيكل على كفاءة الخلية الشمسية لاغشية أوكسيد الكادميوم المشوبة بأوكسيد النيكل بدرجة حرارة الغرفة ودرجة 723 كلفن

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الخلاصة

تم ترسيب اغشية أوكسيد الكادميوم المشوبة باوكسيد النيكل على قواعد من السيليكون من النوع السالب بتقنية الليزر النبضي، تم حساب سمك الغشاء لتراكيز معينة هي 1%، 3%، 5% من أوكسيد النيكل لدرجة حرارة الغرفة ودرجة 723 كلفن، وجد 200 نانومتر وتم قياس أيضا كفاءة الخلية تحت شدة ضوء مقدارها 60 ملي واط/سم^2، وتم إيجاد اعلى كفاءة للخلية الشمسية هي 2.4% عند تركيز 0.05 لاوكسيد النيكل في درجة723 كلفن.

Introduction

A solar cell is a large-area p-n junction structure design to convert the sunlight into electric current efficiently[1]. Solar cell uses the photovoltaic effect, where by excess photo generated minority carriers which are separated by a junction with a built-in field [2]. Once separated, they arrive as majority carriers on the opposite sides of the junction. This excess majority carrier concentration is responsible for the creation of voltage cross the external circuit. If a load is attached to this circuit, a current starts to flow and useful work is done [3, 4].

Main structure of solar cell

The solar cell is a structure consisting of two active layers.

1) a thin heavily doped top layer called the emitter or window layer.

2) a thick moderately doped bottom layer, called the base or absorber with opposite doping [5, 6].

Parameter of solar cell

Many parameters are used to characterize solar cell in this section, we will briefly review some of these parameters and how they influence the performance of the device. Fig. 1 shows the I-V characteristics of a solar cell in the dark and under illumination. The I_{sc} and V_{oc} are the short circuit current and the open circuit voltage, I_m and V_m are the current and voltage corresponding to the maximum power point. This point where maximum power can be generated by the device[7, 8].

$$\eta = P_m/P_{in} = FF \times I_{sc}/P_{in} \times 100\% \qquad (1)$$

where: FF is the fill factor, η: the photovoltaic conversion efficiency which is another important parameter. It's a measure of the amount of light energy that is converted into electrical energy [9, 10].

P_m: is the area of the maximum power, and p_{in} is the incident power.

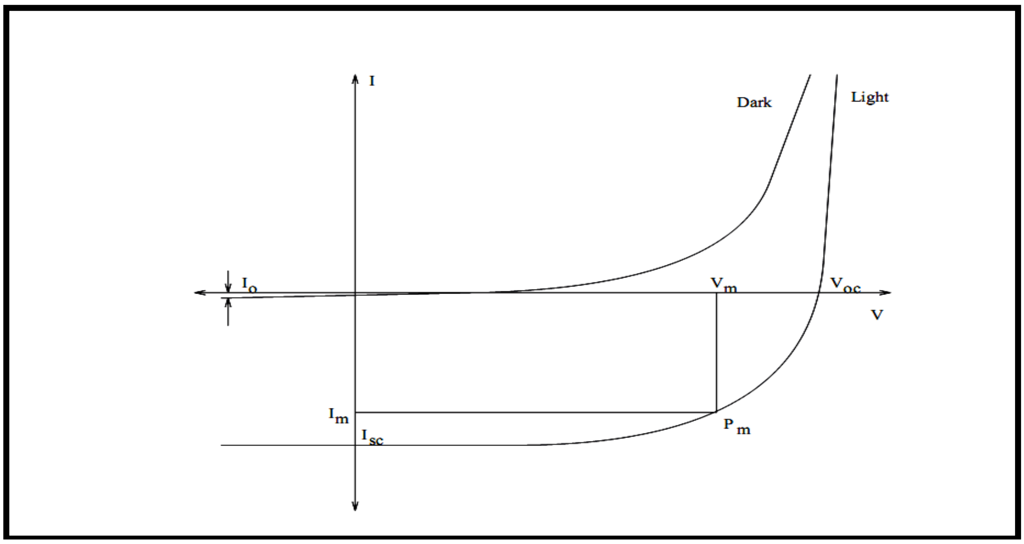

Fig. 1: I-V curve of the solar cell in dark and under illumination [11].

where F.F is defined as the ratio of the maximum power that can be derived from a solar cell to the product of the J_{sc} and V_{oc} occur, no power is generated because the occurrence of one of these parameters means that the other is zero [12, 13].

Experimental work [14, 15]

a- Preparation of pure CdO and CdO:NiO target

pure CdO and doping with NiO content concentrations of high purity (99.999%) pressing under 6.5 tons to target of 2.5 cm diameter and 0.4 cm thickness. it should be dense and homogenous as possible to ensure a good quality of the deposit.

b- Substrate preparation

The behavior of that substrate is extremely important because it greatly influences the properties of the films deposited on it. The cleaning of substrate has strong effect on the adhesion properties of the deposited films.

c- Cleaning procedure of silicon wafer

The etching process is electrode less since there is no applied bias voltage during the etching process.

n-type Si was used as a starting substrate in the etching. The samples were cut from the wafer and rinsed with acetone and methanol to remove dirt. In order to remove the native oxide layer on the samples, they were etched in diluted HF acid (1:10) using ultra sonic bath. The etching time was chosen to be 15 minutes.

d- Pulsed Laser Deposition (PLD) technique

The pulsed laser deposition experiment was carried out inside a vacuum chamber generally at (10^{-3} mbar) vacuum conditions and kept at lower pressure ($8*10^{-2}$mbar) a background gas for specific cases of oxides and nitrides. Photograph of that set-up of laser deposition chamber, which shows the arrangement of the target and substrate holder inside the chamber with respect to the laser beam. the focused Nd:YAG Q-switching laser beam coming through a window was incident in the target surface making an angle of 45° to precipitate more film on the glass slide, with respect to the normal to the target with 500 no. of shots, frequency 6 Hz and energy 500 mJ.

e- Solar cell measurements

The current–voltage characteristics measurements:

The following apparatuses used in studying the I–V characteristics:

1. Digital electrometer (Keithley type 616).
2. Power supply (FARNELL type L30/E).
3. Halogen lamp.
4. Electromotive force (emf) was supplied on both sides of the solar cell, by using the power supply, and then a digital electrometer type "Keithley was used to calculate the output voltage. Another digital electrometer with the same type was used to calculate the output current.
   Measurement of solar cell efficiency:
5. I-V measurement have made for n-CdO:NiO/n-Si hetrojunction when they were exposed to halogen lamp light, philips (60 mW), with intensity (100 mW/cm^2) using Keithley digital electrometer 616, voltmeter and D.C. power supply under reverse bias voltage which was in the range (-2 to 2) volt.

Results and discussions of n-CdO:NiO/Si solar cell thin films measurements

The current–voltage characteristics

In order to determine the performance of a solar cell device, as well as its electrical behavior, current density-voltage (J-V) measurements were performed. The relation between the photocurrent density (J_{ph}) and bias voltage (V) of the CdO:NiO at different concentrations and annealing temperature were presented in Figs. 2-9. The measurements were carried out under power density equal to 60 mW/cm^2.

Figs.2-9 show that the photocurrent density increases with increasing of the bias voltage, i.e. J_{ph} increases with increasing of the depletion region width (W) according to the relation [16];

$$I_{ph} = qa\, G_{ph}\, (L_p + L_n + W) \qquad (2)$$

where G_{ph} is generation rate of photo carriers, L_p and L_n are the diffusion length of holes and electrons. The width of the depletion region increases with increasing of the applied reverse bias voltage, which leads to separate the electron-hole pairs and then increase the photocurrent density. The forward and reverse bias photocurrent density is a function of the generation and diffusion carriers. we can observe from figures below that the photocurrent density increases with increasing of annealing temperature, this is attributed to the increasing in the grain size and reducing the grain boundary and improvement of structure, which leads to the increase of the mobility of electron and increase the photocurrent density as well as the increase of the depletion width which leads to an increase in the creation of electron-hole pairs.

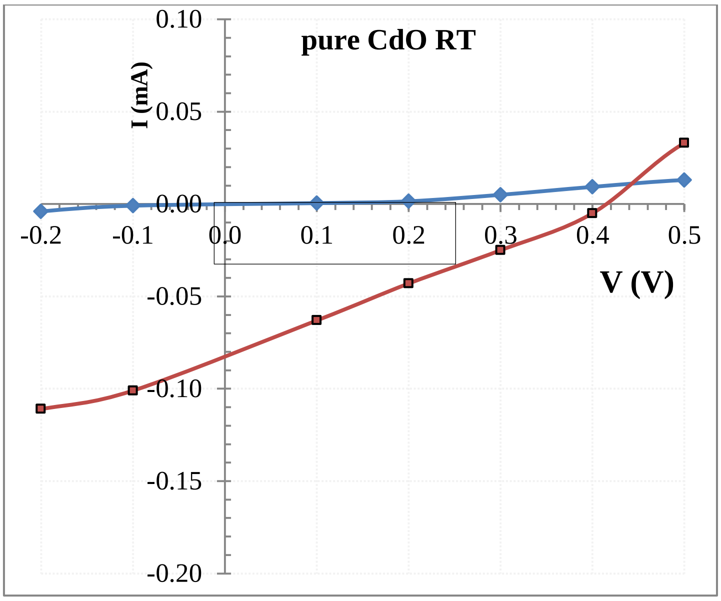

Fig. 2: Current versus voltage for pure CdO at room temperature.

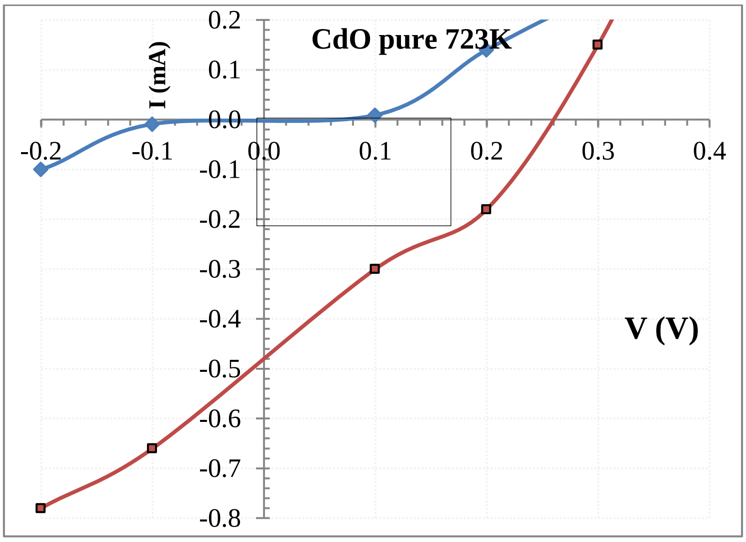

Fig. 3: Current versus voltage for pure CdO at 723K.

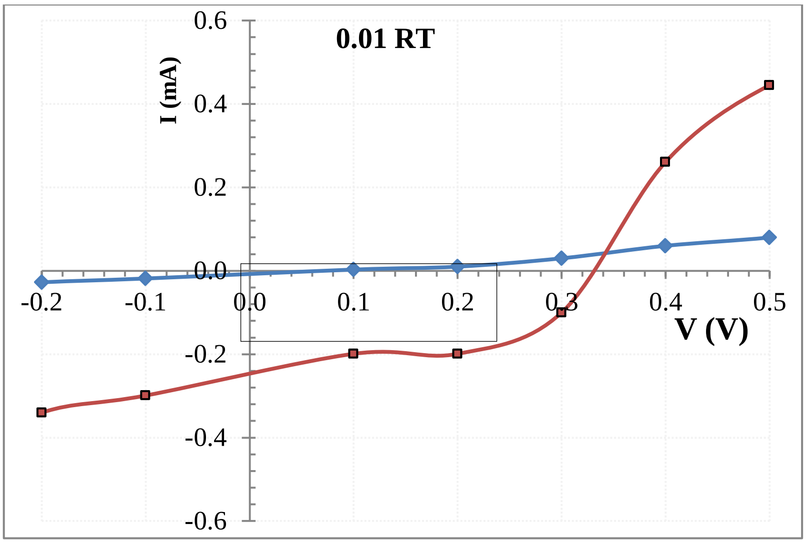

Fig. 4: Current versus voltage for CdO:0.01 NiO at R.T.

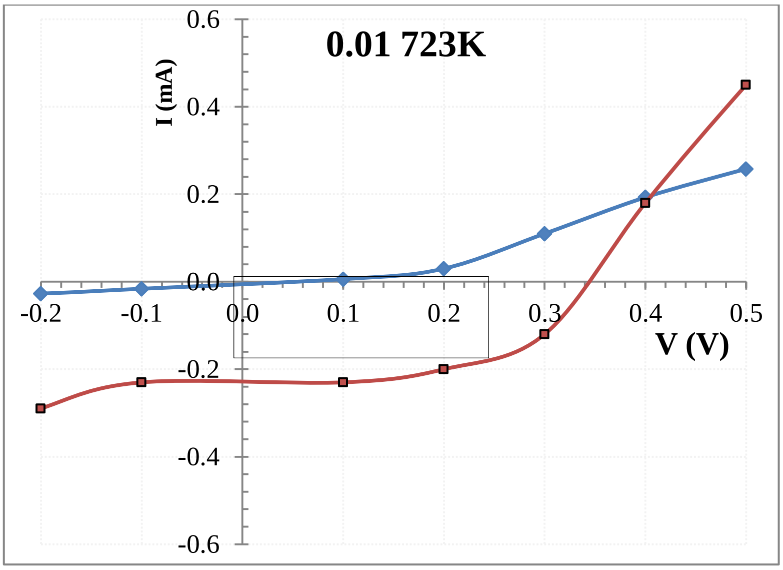

Fig. 5: Current versus voltage for CdO:0.01 NiO at 723K.

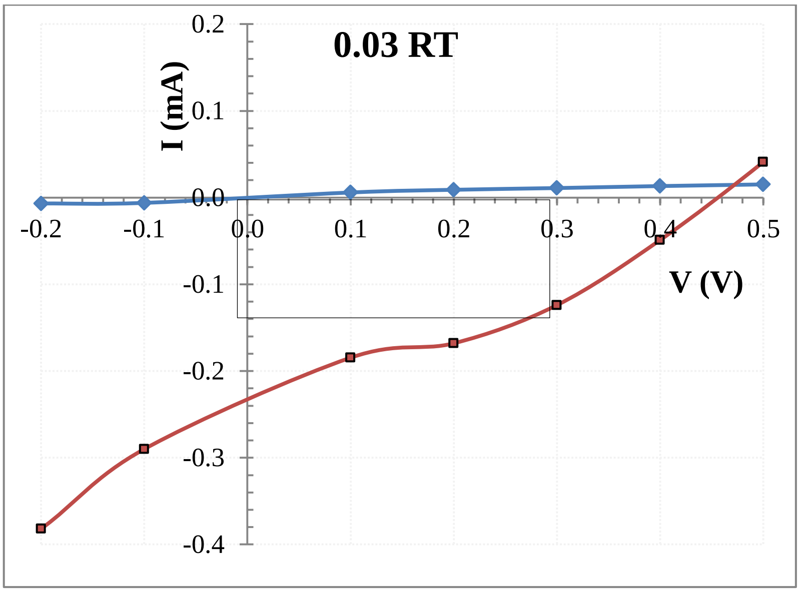

Fig. 6: Current versus voltage for CdO:0.03 NiO at R.T.

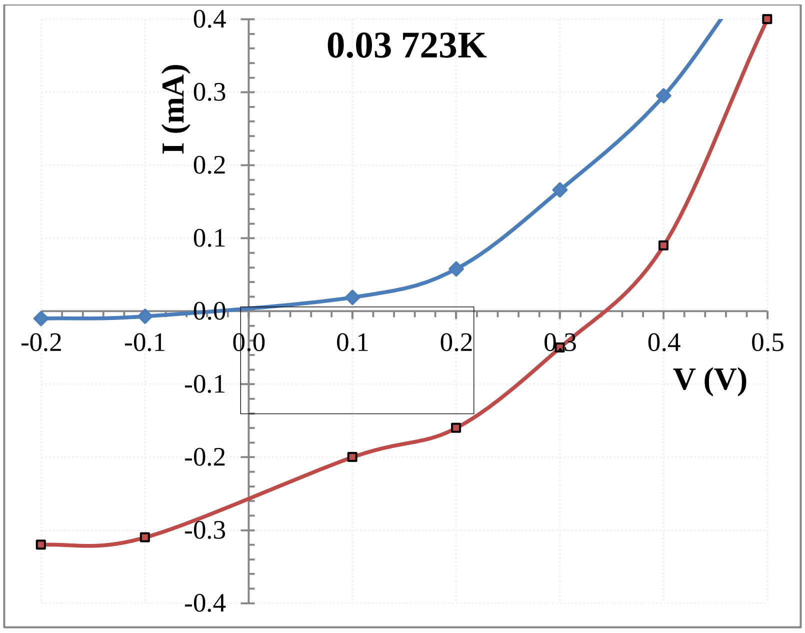

Fig. 7: Current versus voltage for CdO:0.03 NiO at 723K.

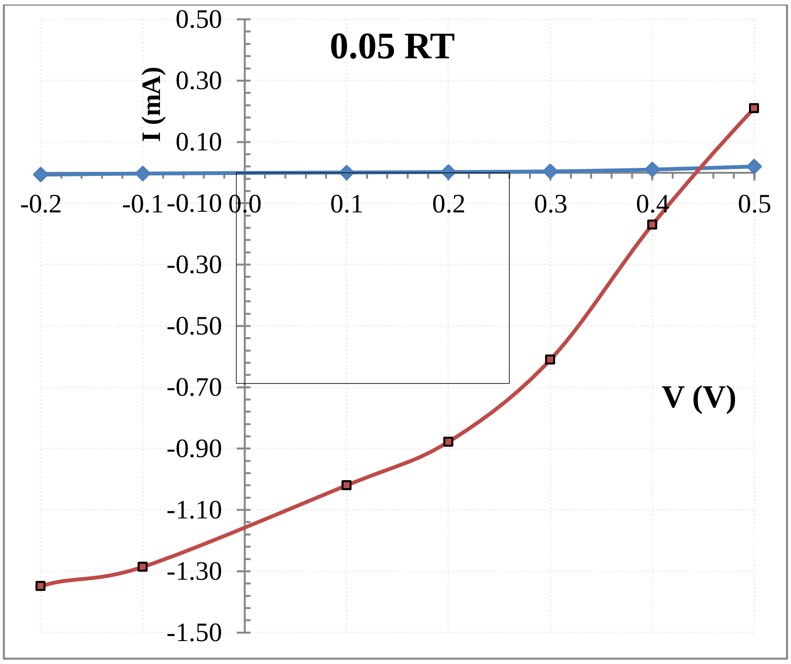

Fig. 8: Current versus voltage for CdO:0.05 NiO at R.T.

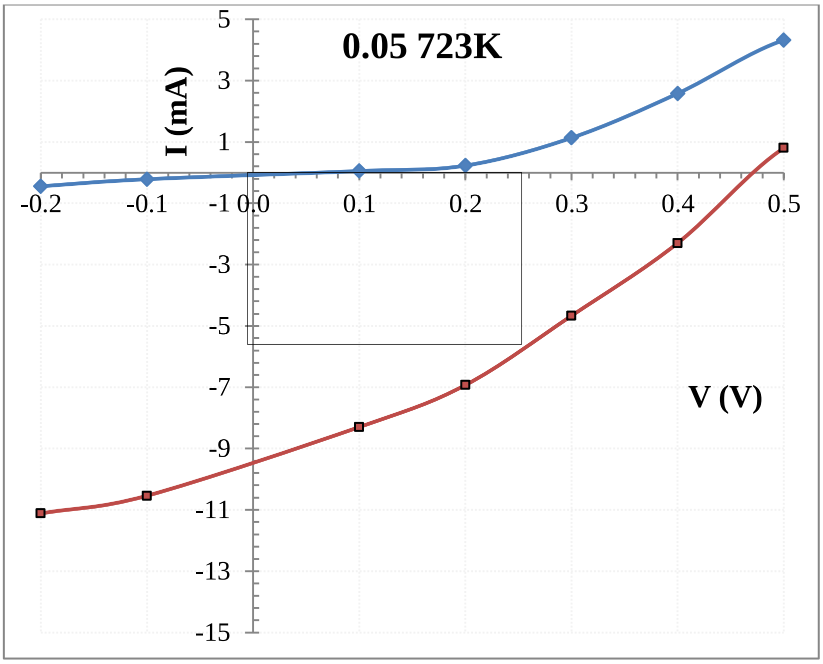

Fig. 9: Current versus voltage for CdO:0.05 NiO at 723K.

Table1: The fill factor and solar efficiency for CdO pure and CdO:NiO at R.T and 723K.

Target	Isc (mA)	Voc (V)	Im (mA)	Vm (V)	F.F	β	%η
CdO pure R.T	0.080	0.320	0.035	0.260	0.355	4.011	0.015
CdO pure 723K	0.480	0.260	0.220	0.180	0.317	5.00	0.066
CdO:0.01NiO R.T	0.240	0.330	0.180	0.250	0.568	3.966	0.075
CdO:0.01NiO 723K	0.240	0.340	0.180	0.250	0.551	3.415	0.075
CdO:0.03NiO R.T	0.230	0.460	0.130	0.300	0.369	15.157	0.065
CdO:0.03NiO 723K	0.260	0.340	0.140	0.230	0.364	4.311	0.054
CdO:0.05NiO R.T	1.300	0.440	0.700	0.270	0.330	4.132	0.315
CdO:0.05NiO 723K	9.400	0.470	5.600	0.260	0.330	2.564	2.427

Conclusions

An n-CdO:NiO thin films was successfully deposited on a n-Si substrate to yield a solar cell by pulse laser deposition technique. The solar cell conversion efficiency (n-CdO:NiO/n-Si) with different doping concentrations 0.01, 0.03 and 0.05 in R.T and 723K under a 60 mW/cm^2 illumination condition was found 0.06, 0.075 and 0.075 for R.T and films annealing was found 0.054, 0.315 and 2.47 the highest efficiency of the solar cell is 2.4% when NiO concentration is 0.05.

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