Physical Properties of Cdo Thin Films Prepared by Spray Pyrolysis Technique

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ABSTRACT

In this paper CdO films of 3.8 μm thickness were deposited onto glass and Si-wafer substrates by spray pyrolysis technique at 250ºC temperature. The structure, optical and electrical properties were investigated. The structure of the films were studied by X-ray diffraction have polycrystalline structure with (111) preferential orientation. The films have good transmittances in visible and NIRregion, with direct optical band gap (2.5eV).The electrical conductivity was measured as function of temperature and theactivation energy was about(0.155and 0.241) eV.The electrical characterization of CdO/Si hetrojunction diode was investigated by current –voltage studied.The reverse current strongly increased with illumination intensity and voltage bias.

Keywords: spray pyrolysis, CdO thin film, physical properties.

الخصائص الفيزيائية لغشاء اوكسيد الكاديوم الرقيق المحضر بطريقة الرش الكيميائي

الخلاصة

في هذا البحث تم ترسيب اغشية اوكسيد الكاديوم بسمك ٣,٨ مايكرومتر على قواعد الزجاج والسيليكون بطريقة الرش الكيميائي عند درجة حرارة ٢٥٠ درجة سيليزية . واختبرت الخصائص البصرية التركيبية والكهربائية للاغشية المحضرة اذ اظهرت الدراسة بأن الغشاء يمتلك نفاذية جيدة عند المنطقة المرئية والمنطقة تحت الحمراء القريبة وانه يمتلك فجوة طاقة $E_g = 2.5$ eV . وقد قيست التوصيلية الكهربائية كدالة لدرجة الحرارة وتبين انها تمتلك طاقتي تنشيط 0.155 eVو0.241 eV واختبرت الخصائص الكهربائية لثنائي الوصلة الهجين CdO/Si من قياس خصائص تيار – جهد وجد ان تيار الاضاءة يزداد بقوة مع شدة الاضاءة الساقطة وجهد الانحياز.

INTRODUCTION

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Thin film technologies play the pivotal role specifically in the field of microelectronics, optical coating, integrated optics and superconductors etc[1].Cadmium oxide (CdO) have face center cubic(FCC)structure with directBand-gap between(2.3 and 2.5) eV is an n-type semiconductor and one of the promising transparent conducting oxides (TCO) with high electrical conductivityand optical transmittance in visible spectralregion [2].Which has foundextensive applications in solar cells[3], low emissive window optical communications, flat panel display, photo-transistors, photodiodes, transparent electrodes and gas sensors[4-8].Varioustechniques have been employed to prepare CdO thin films such as chemical vapor deposition[6], spray pyrolysis [2], solution growth[9], SILAR Deposition Technique[7], pulsed laser deposition [5] and sol-gel method [4].The chemical technique of spray pyrolysiswhich is simple to handle economically viable is used for several decades in glass [10].In the present work, optical and electrical properties have been performed for analysis of the deposited CdO thin films on glass and silicon wafer substrates was studied.

EXPERIMENTAL

The preparation of CdO thin films have been done by spray of an aqueous nitrate solution of 0.1 M concentration in double distilled water at deposition temperature of 250ºC onto the glass substrateand on the single – crystal silicon wafers of p-typewith (111) Orientation.The spray rate was maintained via compressed carrier gas of the order3 ml/min. The nozzle – to- substrate distance was approximately 30 cmand the single spraying time was around 5 sec.Before the deposition process, a glass substrate was cleaned ultrasonically in acetone, and finally dried.The silicon wafer was cleaned by a standardprocess. This waferwas chemically etched in dilute Hydrofluoric acid to remove native oxide then back contact metallization wasaccomplished by thermalevaporation ofAl electrode. The wafer was scribed intoindividual pieces of(0.5*0.5) cm^2 area then sent to spraying apparatus. After the deposition ofCdO, frontal metal electrode is formed by thermalEvaporatingIndium electrode.Characterizedfilms were deposited on both silicon and glass substrates under the same experimental conditions. One of the CdO films deposited on the glass substrate was used for theoptical properties; the other CdO filmdeposited on the p- Si substrate was used for the electrical properties. The optical and electrical measurement included Optical transmission, energy band gap, electrical Conductivity andreverse I-Vcharacteristics under illumination. Film thickness is measured by optical interferometer method using He-Ne laser (632.8nm),thickness is determined using the formula [11]:-

$$d = \frac{\Delta x}{x}.\frac{\lambda}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where x is fringe width, Δx is the distance between two fringes and λ is the wavelength of laser.

The crystal structure of thin film were determined by x- ray diffraction using the (Philips model, PW/ 1710) diffractometer, with monochromatised Cu Kα radiation (λ = 0.15418 nm at 40 KV and 30 mA).

Optical transmission of CdO films deposited on micro slide glass were recorded in a UV/Vis in the range (300-1100) is Shimadz3101PC spectrometer. The

electrical resistivity measured through the change of thin film resistance with temperature by putting the sample inside (electrical blast dry box model WG20) attached with thermocouple (digital Multimeter), electrical resistivity determined by equation: [12]

$$\rho = R\frac{bd}{l} \qquad \text{..... (2)}$$

Where l, b and d are length,width and thickness of film respectively, electrical conductivity can evaluate from the equation:

$$\delta = \frac{1}{\rho} \qquad \text{..... (3)}$$

Dark I-Vmeasurementswere done by using a Keithley electrometer automatic system. The illuminated I-V characteristics were measured under a tungsten-halogen lamp light under 80W/cm^{2}intensity by a Keithley 6517A electrometer.

RESULT AND DISCUSSION

a) Structure studies

Figure (1) shows the x-ray diffraction pattern of prepared thin film at temperature 250 C^o from the solution concentration (0.1 M). It shows presence of different strong diffraction peaks which confirm polycrystalline cubic CdO phase formation. All the diffraction peaks of the films are indexed to (111), (200), (220) planes. Also the plane (111) of the phase $Cd(OH)_2$ was appear at angle(29^o) . The sharpness of the peaks show that film has good crystalline nature .relatively stronger intensity of the peaks indicates preferential (111) orientation of the film and similar behavior also reported by other searchers. These result was agree with [13]

b) Optical studies

CdO film about 0.38 μm thickness deposited on microslide glass.The variation of optical transmittance with wavelength λ in range (300 – 900) nm is shown in Figure (2).Figure reveals high transparency andgradually increasing of transmittancein visible and NIRregionsis in good agreement with the reported results for CdO thin film[1]. Theabsorption coefficient (α) is calculated using the equation[7]:

$$\alpha = \frac{1}{d}\ln\frac{1}{T} \qquad \text{..... (4)}$$

Where T is transmittance and d is film thickness. The absorptioncoefficient (α) and the incident photon energy (hν) is related by thefollowing equation [7]:

$$\alpha h\nu = A(h\nu - E_g)^{1/2} \qquad \text{..... (5)}$$

Where hν are photon energy and A constant,E_g optical bandgap.The direct energy gap Eg at 300K is obtained by Extrapolations of the linear portion of the plots of $(\alpha h\nu)^2$ versus hν this plot to $(\alpha h\nu)^2 = 0$, as shown in Figure (3). The linear

dependence of $(\alpha h\nu)^2$with $(h\nu)$ indicates direct band gap. The CdO exhibits direct band gapEg=2.5eV. The obtained value, of direct band gap is in good agreement with the reported results for CdO thin films prepared by other techniques[7, 14].

c) Electrical studies

1- Electrical conductivity

One of the reasons for the application of the CdO thin films in the optoelectronic devices technology is their good electrical conductivity. The temperature dependence of the electrical conductivity of the studied film during temperature range 300-400 K as shown in figure(4).It has been that the conductivity increases as the temperature increased,this is due to the increase in the excitation of the charge carrier which will increase the probability of transition from valence band to conduction band.Figure(5) indicates the relationship between lnσ and 1000/T for CdO thin film the activation energy (E_a) where can be calculated using the following equation[15]:

$$\sigma=\sigma_0 \exp E_a/K_BT \quad \ldots\ldots\ldots\ldots\ldots(6)$$

Where $\sigma_0$constant, KBBoltzmann constant Figure(5) reveal electrical conductivity (lnσ) slowly decreases for the gradually heatedCdO thin filmIt can be recognize two regions in Figure (5) the first regions is low temperature region with value of activation energy equal (0.155 eV) . The second region is high temperature region with value of activation energy (0.241 eV). We can notice that the film has more than one value of activation energy as a result of polycrystalline structure of CdO film.The values of activation energy (E_a) show that Fermi energy level is above the ($E_g/2$) level and it is narrowed to the conduction band whenever the value of activation energies reduced. On the other hand, the activation energy was lower than of optical energy gap of film. The above results are close with the results of the literature [16].

2-(I-V) Characteristics

Figure (6) Shows The I–V characteristics of the typical n-CdO/p-Si hetrojunctiondiode measured at 300º K under dark and illumination conditions, notice that, the reverse dark and photocurrentincreases with reverse bias, while photocurrent strongly depends on the bias and incident power density.We observe increase in the photocurrentvalue with voltage bias and power density and that the magnitude of the photocurrent exhibits flat dependence when the voltage value is higher than 3V. At this voltage the structure is Suitable to be used as an efficient photodetector, takinginto account the manufacturing low cost for this structure and good sensitivity of CdO/Si hetrojunction diode for white light[4, 17].

Figure (7) exhibit the linearity response of CdO/Si diode, when it is illuminated by different power density white light. It has found a linear relation between photocurrent and incident light with increase incident power this lead to increase photocurrent value with incident power according to the relation [18]:

$$(I_{ph}, V_{ph}) \alpha P_i^B \quad \ldots\ldots\ldots\ldots\ldots (7)$$

Where B the power of power radiation its value range
Range $0.5 \leq B \leq 1$.

CONCLUSIONS

Transparent and conducting CdO films were deposited on glass and p-Si substrates at 250°C by spray pyrolysis technique. X-ray diffraction, Transmission spectra, electrical conductivity and I-V Characteristics in reverse bias were investigated. XRD pattern confirms CdO phase with preferential orientation along (111). Films have good transmission in UV/Vis region with 2.5eV. The current–voltage characteristicsof the n-CdO/p-Si heterojunction. I-V characteristic show that the device structure is suitable to be used as an efficient photo detector.

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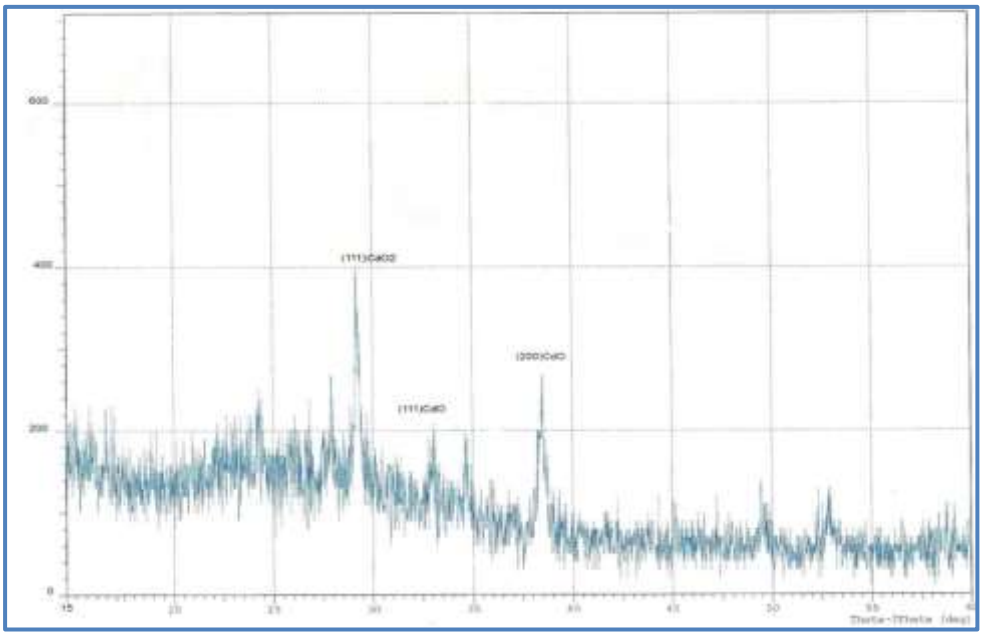


Figure (1): X-ray diffraction pattern of CdO thin film prepared at (250C°).

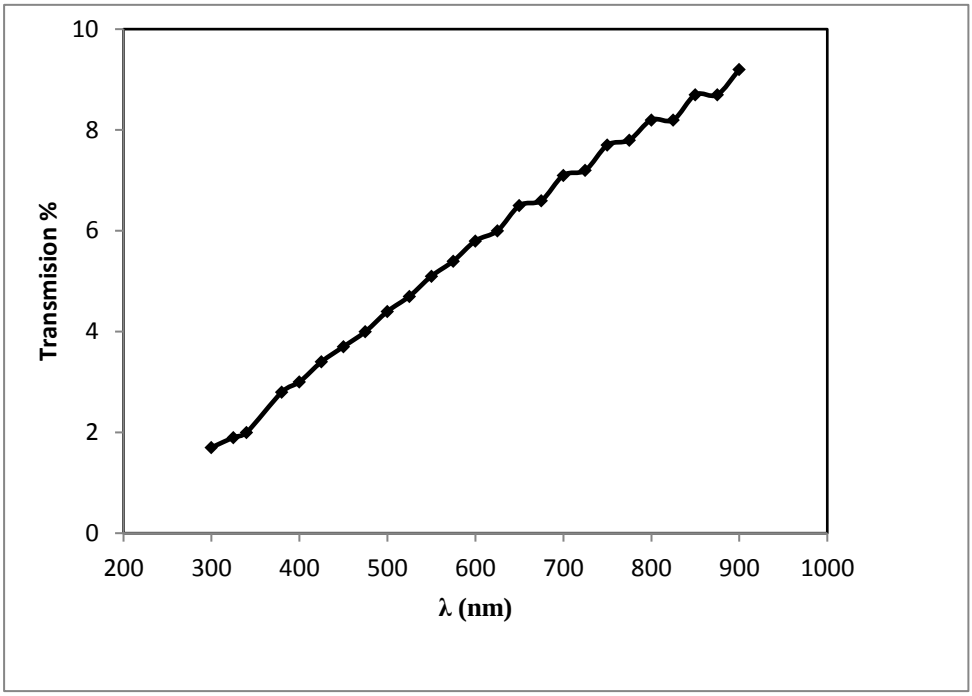


Figure (2): Variation of optical transmission (T) vs wavelength (λ).

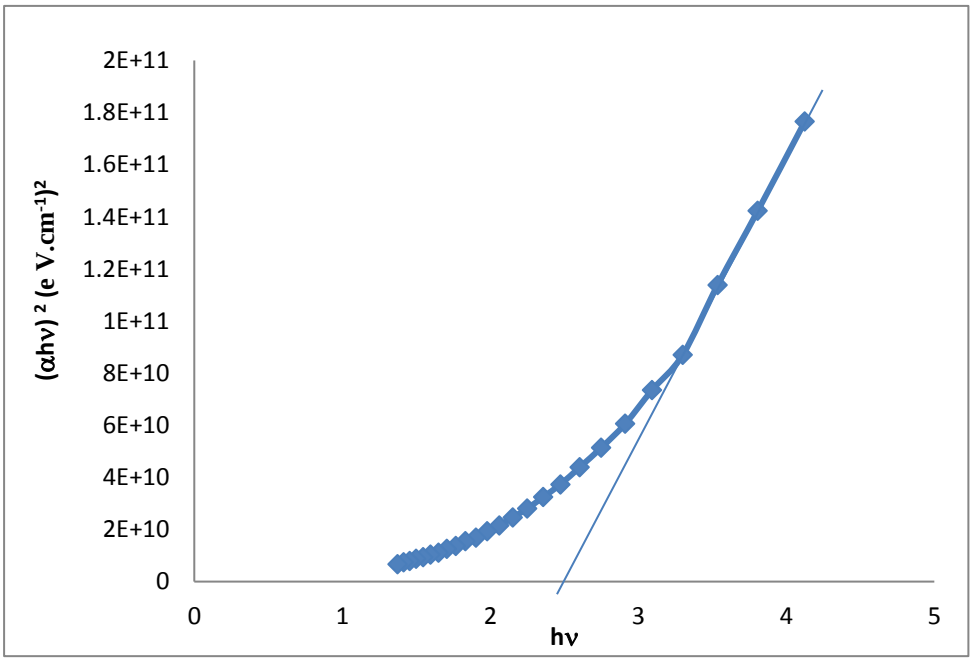
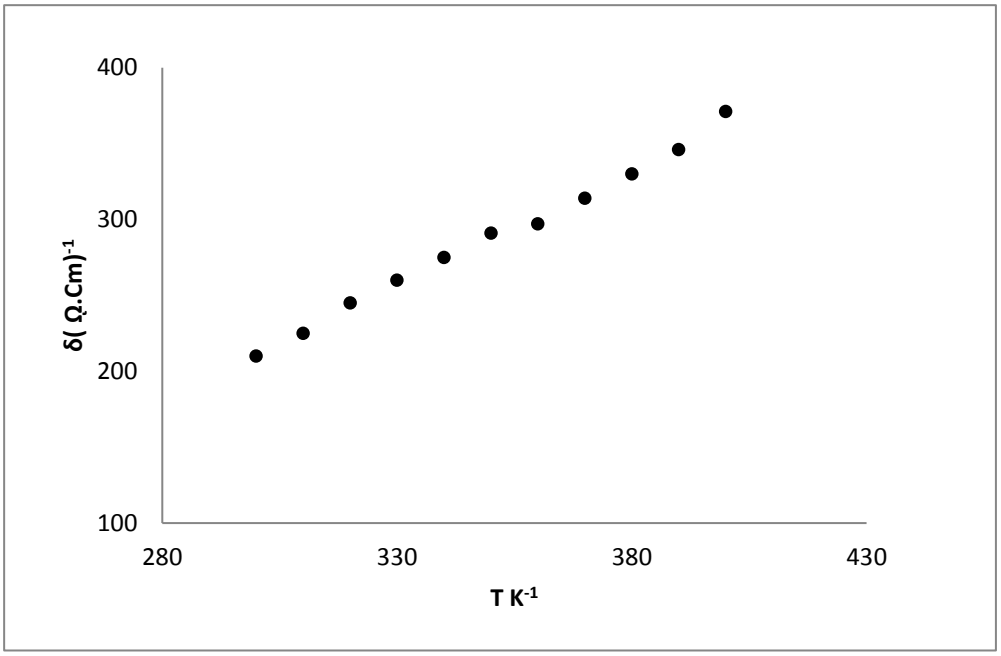
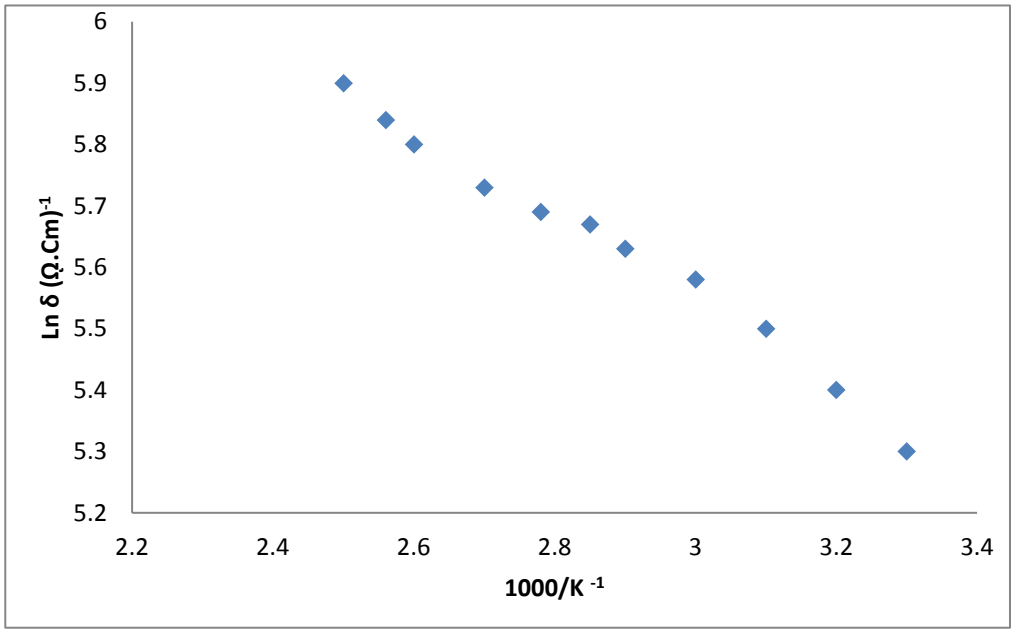


Figure (3): Variation of (hν) vs (αhν)2 (Eg= 2.5 ev)of CdO film.



Figure(4): The temperature dependence of the electrical conductivity of the CdO film.



Figure(5):Variation of Lnδ withinverse temperature for CdO thin film.

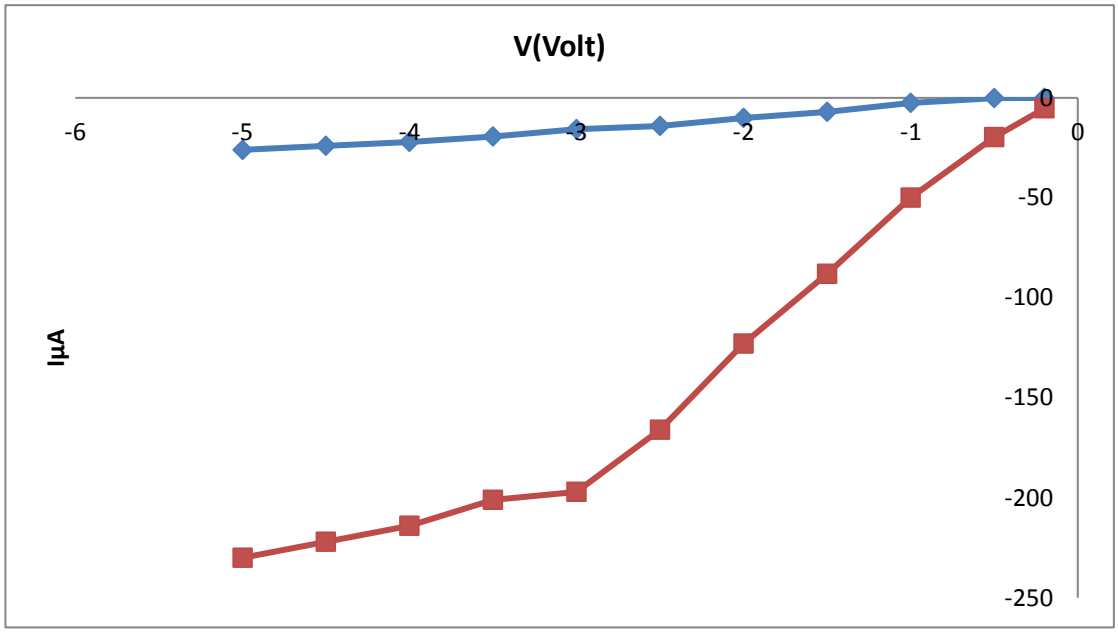


Figure (6): Current-voltage in dark and illumination condition for characteristicsCdO/Si heterojunction.

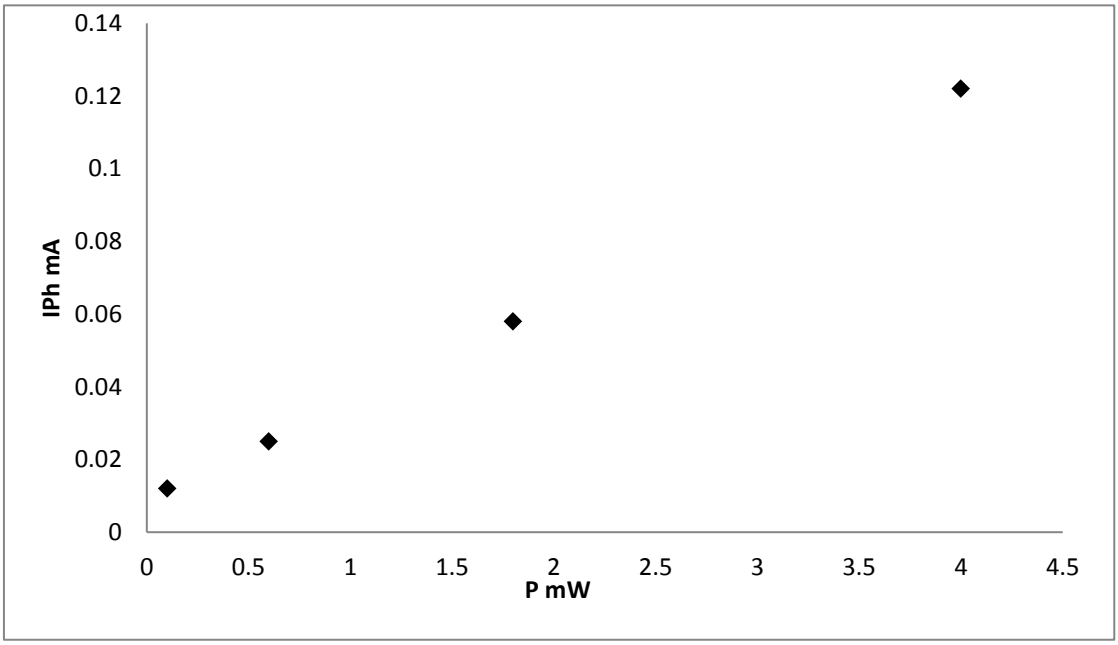


Figure (7): The Relation of photocurrent with incident power.