Fabrication and Study Nanostructure Deposited Thin Films Heterojunction Solar Cell

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ABSTRACT

In the present paper, nanostructure tin oxide (SnO_2) thin films on Si P-type substrates heterojunction solar cell has been made by using a pulsed 532 nm Nd:YAG laser. Deposition of films is achieved at 400 $^{\circ}$C substrate temperatures. The X-ray diffraction (XRD) results show that the deposited films are crystalline with tetragonal rutile SnO_2 structure. The morphology of deposited films were characterized by scanning electron microscope (SEM) and atomic force microscope (AFM), the grain size value (30–50) nm and rms roughness values are (2.8 nm) for thin films deposited at 400°C. Photoluminescence PL spectrum showed good light emission in the visible field. The photovoltaic characteristics included short circuit current (Jsc), open circuit voltage (Voc), where the maximum (Jsc) and (Voc)obtained at AM1 were 14.3 (mA cm^{-2}) and 630(mV), respectively. The fill factor (FF) was (0.68). The fabricated cell exhibits good performance with 7 % conversion efficiency.

تصنيع ودراسة خلية شمسية هجينة بترسيب اغشية رقيقة ذات تراكيب نانوية

الخلاصة

في هذا البحث , تم ترسيب اغشية نانوية لأوكسيد القصدير وترسيبها على قواعد من السليكون الاحادي البلورة من النوع القابل لتصنيع خلايا شمسية هجينة باستخدام ليزر النيودميوم- ياك النبضي ذو الطول الموجي 532 نانو متر تم ترسيب الاغشية عند درجة حرارة قاعدة 400 درجة مئوي. حدد التركيب البلوري باستخدام حيود الأشعة السينية (XRD) اذ أظهرت النتائج تكون طور الروتيل الرباعي لأغشية اوكسيد القصدير البلورية. حددت خصائص طبوغرافية السطح من خلال قياس المجهر الالكتروني الماسح و مجهر القوى الذرية , حيث تراوحت قيمة الحجم الحبيبي (50–30) نانو متر وقيمة خشونة السطح (2.8)نانومتر للأغشية المحضرة بدرجة حرارة قاعدة (400) مئوي. اظهر طيف الانبعاثية الضوئية انبعاثا" جيدا" في المنطقة المرئية. درست الخواص الفولطائية المتمثلة بتيار الدائرة القصيرة (Jsc) وفولتية الدائرة المفتوحة (Voc) بالاضافة لعامل الملئ (FF) ووجد ان اعظم قيمة لكل من (Jsc) و (Voc) لحالة AM1 هي (mA cm^{-2}) 14.3 و ,(mV)630 على التوالي وان قيمة عامل الملئ هي (0.68). الخلية المصنعة اظهرت قيمة كفاءة جيدة بلغت 7%.

INTRODUCTION

These last few years, tin oxide (SnO_2)/silicon (Si) solar cells have been proposed by some authors [2, 3, 4] as low cost photovoltaic devices. The cost reduction obviously will be in the junction formation steps and also in eliminating the anti-reflection layer. SnO_2 is an n-type semiconductor with a wide band gap (Eg = 3.6 eV at 300 K). Tin oxide, in the form of thin films is transparent in the visible region of the solar spectrum, therefore, acts as a window for sunlight. At some wavelengths, the refractive indices of SnO_2 and Si match, SnO_2 acts therefore, as an antireflection coating [5].Tin oxide (SnO_2) is a key functional material, which has multifaceted technological applications including optoelectronic devices [1,6] and gas sensors [7]. A variety of methods, such as sol–gel [8], thermal evaporation [9], wet-chemical synthesis [10], and pulsed laser deposition [11–15] have been used to produce SnO_2 nanoparticles with diameters below 10 nm. The growth of oxide thin films by pulsed laser deposition (PLD) attracted considerable interest during the last years [12]. Indeed, PLD has numerous advantages as compared to classical deposition methods. More precisely, it allows for the control of adherence, crystalline status and stoichiometry of the synthesized material and avoids the incorporation of contaminants in the growing films during the deposition process. In addition, the amount of material evaporated and deposited on the substrate surface can be perfectly controlled by the number and/or intensity of the laser pulses used for irradiations [13]. In this paper, we report the preliminary

results of the fabrication of SnO_2/p-Si heterojunction solar cells of high efficiency made by pulsed Nd:YAG (λ = 532 nm, pulse width 7ns repetition rate 10Hz) laser ablation and investigated their structural and photoluminescence (PL) characteristics.

EXPERIMENTAL PROCEDURES
Film preparation

Single-crystal silicon wafers of p-type conductivity with (111) orientation are used as substrates. They have a resistivity in the range of 1-5 Ώ-cm and one face of the wafer is polished to the mirror-like surface. Prior to deposition of SnO_2, these wafers were chemically etched in dilute hydrofluoric acid to remove native oxides. Subsequently, after oxide removing, the wafers were scribed into individual pieces of 0.5 cm^2 sizes, then they were sent to vacuum chamber to fabricate the SnO_2/Si heterojunction. Crystalline SnO_2 films were deposited on cleaned Single-crystal silicon substrates using 10 Hz, 7 ns, Nd:YAG laser at 532 nm. The laser beam was focused on high purity SnO_2 target using 5 cm positive lens. Laser fluence of 1.5 J/cm^2 used for in the ablation. The substrates were placed at 4 cm distance from SnO_2 target. The chamber was kept at vacuum pressure of 10^{-3} mbar. The SnO_2 target was ablated from 10 to 100 pulses (10–20 min) to get single layer thin films. During the deposition the substrate temperatures (Ts) were kept at 400 $^\circ$C. The deposited film had a thickness of approximately 150 nm. The thickness of the film was estimated from cross-sectional scanning electron microscopy (SEM_JEOL 7000) measurement. After the deposition of SnO_2, frontal and back metal electrodes were formed by depositing 200 nm of In and Al respectively. The sensitive area was about 0.2 cm^2. J-V measurements were done under illuminated conditions. The illumination was achieved by halogen lamp type "PHILIPS", 120W, which connected to a Variac and calibrated at AM1 illumination power density by a silicon power meter.

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Film characterization

The structure of the grown films was determined by X-Ray diffraction (XRD) measurements (Philips PW 1050, λ = 0.1542 nm) using Cu-ka source. Film transmission measurement is performed at spectral range 400–900 nm using UV–VIS-PV-8800 (Perkin Elemer Company) spectrophotometer. The surface morphology was examined by scanning electron microscopy (SEM–JEOL 7000) and atomic force microscopy (AFM-Digital Instruments NanoScope) working in tapping mode. PL spectrum was measured at room temperature by a 325 nm He:Cd laser (Perkin Elmer Spectrophotometer Luminescence LS 55 equipped with FL Winlab software).

RESULTS AND DISCUSSION

The XRD result pattern of SnO_2/p-Si thin films prepared at a substrate temperature of 400 $^{\circ}$C for as-deposited sample is shown in Figure 2. The sample shows polycrystalline phase. Reflection peaks from (110) plane, (200) plane, and (211) plane were observed. This orientation corresponds to the tetragonal phase (according to ASTM card No. 7-0214). Accordingly, deposited SnO_2 film shows rutile structure. The lattice parameter of (002)-oriented SnO_2 film from ASTM-Card is 4.738 Å, while that obtained from XRD pattern is 4.74 Å. This will result in strains; the strain calculated from previous results was 0.13%.

The SEM images of the SnO_2/p-Si thin films prepared at a substrate temperature of 400 $^{\circ}$C shows that the SnO_2/p-Si nanoparticle were obtained in an agglomerated state and also the voids take place between the grains (Fig. 3). It is seen in figures that the SnO_2 grain size of the rutile phase thin film is about 30– 50 nm and most particles are polyhedron-shaped with some facets.

The AFM images of the SnO_2/p-Si thin films prepared at a substrate temperature of 400 $^{\circ}$C show a uniform granular surface morphology (Fig. 4). The average grain diameter was evaluated from the plane view image at about 50 nm. The tilted image reveals grain heights of a few tens of nanometers. It is observed that the surface of the film is very smooth. The root mean square (rms) roughness of the films is 2.8 nm.

PL spectrum carried out at room temperature is shown in (Fig. 5). Visible emissions with a peak wavelength position of around 560–600 nm (corresponding to 2.07–2.22 eV) is dominantly observed. The visible light emission is known to be related to defect levels within the band gap of SnO_2, associated with O vacancies or Sn interstitials that have formed during the synthesis process [8]. Several researchers have previously reported similar emissions from SnO_2 nanoparticle [10] .

The I-V under illumination condition of different illumination power of the sample is shown in (Fig. 6). The sample was illuminated by halogen lamp, the photocurrent strongly depends on the bias voltage we observe increase in the current value with power density. (Figure 7) shows the short circuit current density J_{sc} Vs. illuminating power at low levels of illuminating powers we noted that the J_{sc} have a linearity behavior with increasing power. But at high levels of illuminating power J_{sc} have a exponentially behavior that explained to the saturate in carriers.

The photovoltaic performance is shown in Fig. 8 in which the power can be extract from the cell form this curve we obtained the open circuit voltage (Voc) is 630mV while shot circuit current density (Jsc) is 14.3 mA/cm^2 and fill factor (FF=0.68). The high fill factor is probably due to high shunt resistance. The higher short circuit

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current density may be because the photons is due to carriers that are generated deep in the bulk of the silicon.

Figure 9 demonstrates the variation of the output power (the power generated by the cell under simulated (AM1) versus voltage across the load resistance, this figure reveals that deposited nanoparticle of SnO_2/p-Si heterojunction is a suitable device to produce a high efficient solar cell with conversion efficient of 7 %.

CONCLUSIONS

SnO_2/p-Si nanostructure heterojunction solar cell formed by using a pulsed 532 nm Nd:YAG laser. Results of these cell showed that this technique is an appropriate to fabricate highly efficient solar cells with a conversion efficiency about (7%) and fill factors about (0.68). This is because of the window effect taken place between these combinations, which reduces the role of the surface recombination effects. The variation of J_{sc} with illumination intensity showed the exponantly behavior in AMl, lumintion that explained to the saturate in carriers. The concept of a SnO_2 heterojunction solar cell comprised a transparent conducting window material on an active semiconductor substrate, offers the possibility of manufacturing low cost solar cells suitable for large scale terrestrial applications.

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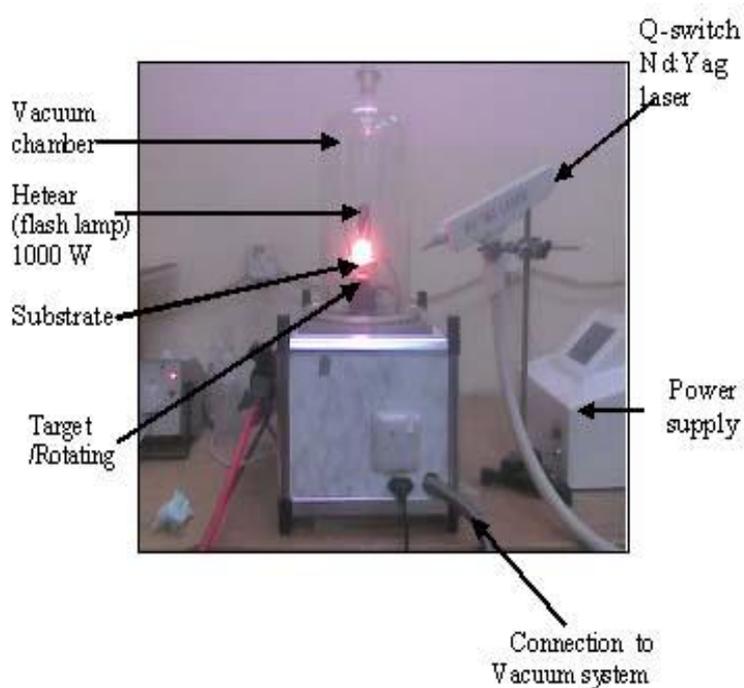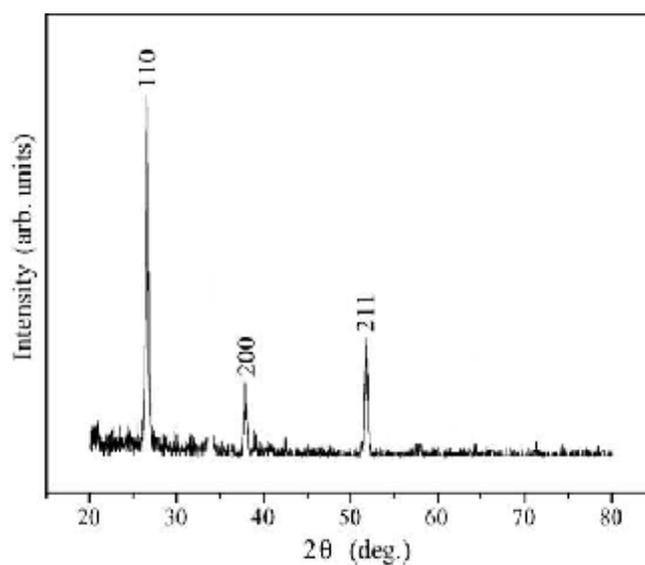

Figure (l) Experimental setup.

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Figure (2) XRD pattern of the Products
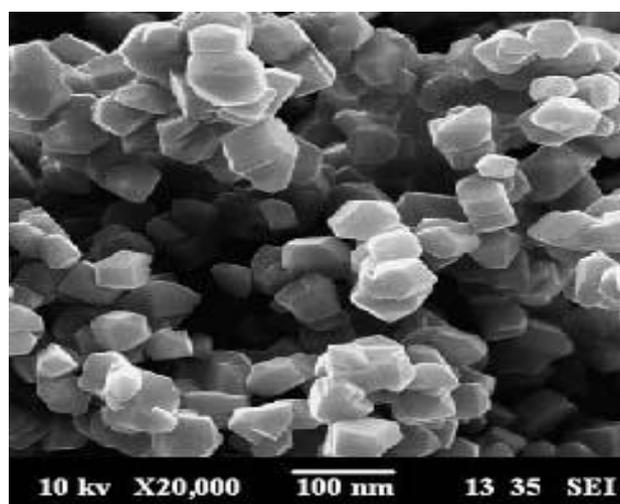
Figure (3) SEM image of the products.

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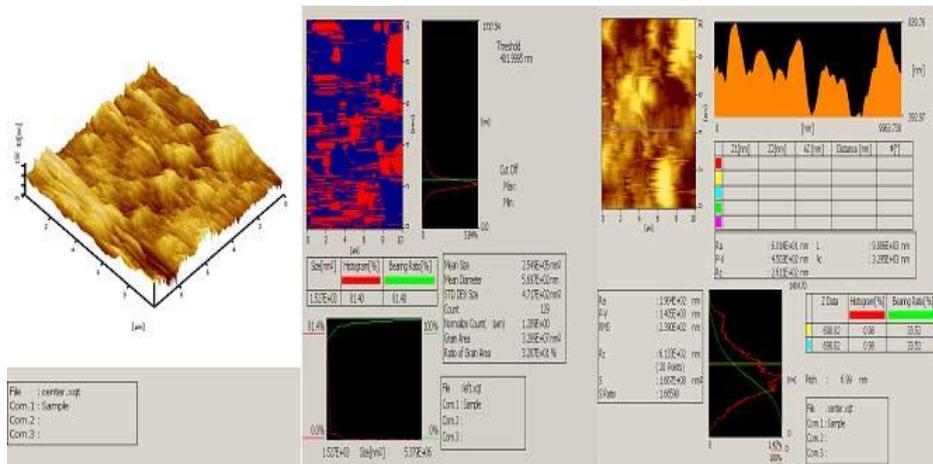**Fabrication and Study Nanostructure
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Figure (4) AFM image of the products.
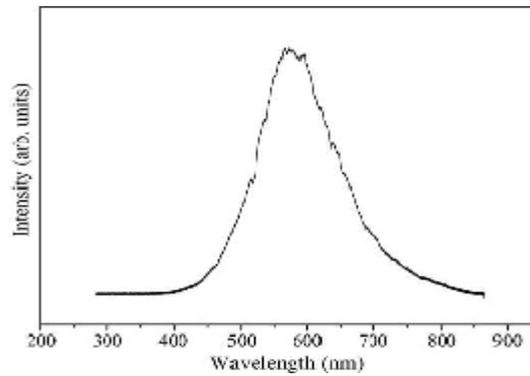
Figure (5) PL spectrum of the products with an excitation
Wavelength at 325 nm.

Figure (6) the output power
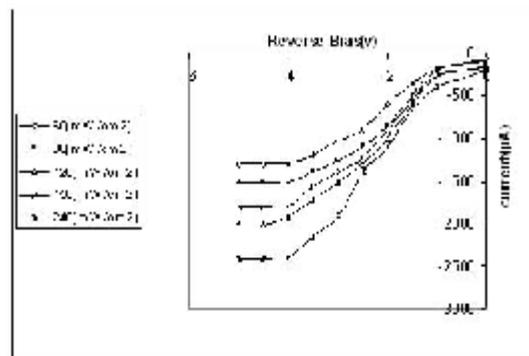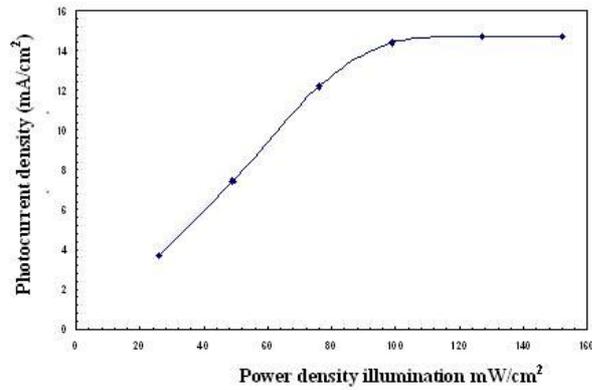
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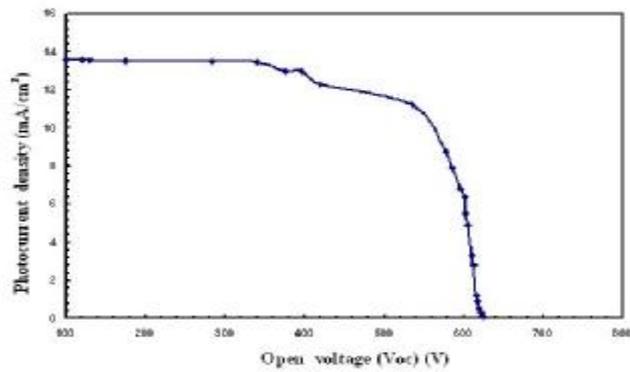Solar Cell**

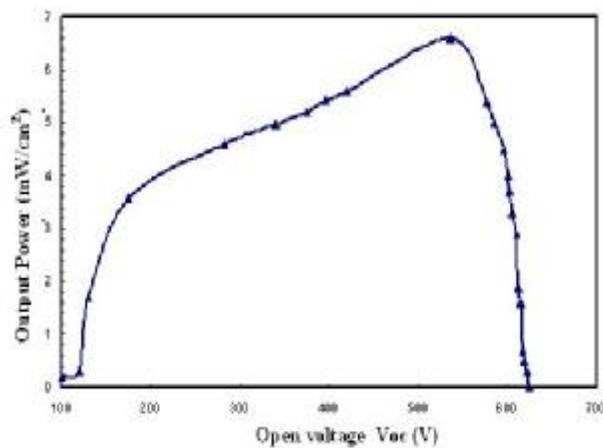**Figure (7) Jsc vs. illumination plot.**

Figure (8) The Photovoltaic Performance

Figure (9) The Output power

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