Nanostructure NiO films prepared by PLD and their optoelectronic properties.

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Abstract

NiO thin films have compounded by pulsed laser deposition on glass and silicon (111) substrates, employing Q-switching Nd:YAG laser. Structure, grain size and optical properties have analyzed by using FTIR, AFM and UV-VIS spectroscopy. FTIR spectra conformed of NiO bonding. AFM images show the particle size about ~66nm. The optical transmission results premiered the transparency of the NiO films is greater than 70% in the visible region with optical band gap 3.85eV. The current voltage characterization of NiO/Si heterojunction has good rectifying.

Keywords : NiO thin film, photodetector, Characterization of NiO

اغشية اوكسيد النيكل النانوية المحضرة بطريقة الترسيب بالليزر النبضي وخصائصها الكهروبصرية

الخلاصة

اغشية اوكسيد النيكل الرقيقة تم تحضيرها بواسطة الترسيب بالليزر النبضي على قواعد من الزجاج والسيليكون ذي الاتجاهية (111)، باستخدام ليزر النديميوم ياك بتقنية عامل النوعية. التركيب، الحجم الحبيبي والخصائص البصرية تم تحليلها باستخدام تحليلات فورير للاشعة تحت الحمراء(FTIR)، مجهر القوة الذرية والتحليل الطيفي للاشعة المرئية وفوق البنفسجية. اظهرت نتائج طيف (FTIR) وجود اصرة اوكسيد النيكل وبينت صورمجهر القوة الذرية ان الحجم الحبيبي حوالي 66 نانومتر. واظهرت الاغشية نفاذية عالية اكبر من 70% للمنطقة المرئية وبفجوة طاقة 3.85 الكترون فولت. خصائص تيار – جهد للثنائي NiO/Si تمتلك تقويم جيد.

INTRODUCTION

NiO is defined as antiferromagnetic material and a metal deficient p-type semiconductor with a wide range from 3.6 to 3.8 e.V band gap [1,2]. At now, transparent conducting oxide films, such as tin oxide, indium oxide, and zinc oxide are periodically used electronic devices [3]. These materials have been attracted a great attention because of i) low cost of these material, ii)their excellent chemical stability [1] iii) promising ion storage material in terms of high stability [4].These properties make its an important material in several scientific and technological applications [5] such as p-type transparent conducting film [6], anode of organic light

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emitting diodes [7], electro chromic display devices [8], gas sensors [9] and as cathode material for alkaline batteries quite reasonable for possible switching applications [10]. NiO exhibits an FCC structure with Ni atoms occupying Octahedral sites with 6O atoms roundedit, the lattice parameter is 4.177A°[11]. These materials have been fabricated using several physical and chemical techniques such as pulsed laser deposition [12], spray pyrolysis [13], DC reactive magnetron sputtering, thermal evaporation, spin coating, sol-gel [4-7]. Pulsed laser deposition (PLD) is a versatile process. This technique is used mainly due to its stoichiometric transfer between the target and deposition film and thus good controllability of the film composition [14].In this study, electrical, optical and structural properties of NiO thin films prepared by PLD method were investigated.

Experimental work

NiO thin films were deposed by pulsed lased deposition with Q-switched second harmonic generation SHG Nd-YAG laser of 532 nm (repetition frequency 6 Hz, pulse width 7 nsec) on porosilicate glass and silicon (111) substrates with incident laser fluence 1.6 J/cm^2 on target surface. The films were prepared at oxygen pressure 2×10^{-1} mbar at 200 C° substrate temperature by using halogen lamp with 40 laser pulses. NiO powder from Fluka company with high purity (99,99%) used to form a target with 2.5 cm diameter and 0.4 cm thickness which pressed by 5 ton. The thicknesses of films 0.3µm were determined by optical interferometer (Fizeau method). Microstructure surface topography was speculated using AFM (Digital Instruments Nanoscope II, AA 3000) and FTIR spectra were recorded with (8400S, Shimadzu) spectrometer. The optical measurements were studied by using UV-visible spectrophotometer (UV-1650 UV-visible recording spectrophotometer) to measure optical transmittance films in the range (200-900) nm. The dark and photocurrent measurements of NiO/Si heterojunction were employing a 8010 DMM Fluke digital multimeter. Farnell, LT30-2 power supply was used to initialize the bias voltage 0-5V.

Results and discussion

The FTIR spectra of NiO thin film deposited at 200C° substrate temperature is illustrated in figure (1). The bond at ≈2800 cm^{-1} and at≈ 2700 cm^{-1} can be tasked to CH_2 vibration. The peaks at≈ (1600, 1500, and 1400) cm^{-1} corresponds to O-H bonding vibration in the water due to absorbed hydrated [15, 16]. The peaks at (426.27, 634.58, and 644.22) cm^{-1} corresponds to the stretching vibration of Ni-O bond of nickel oxide nanoparticles. These results are in a good agreement with references [17-19].

Figure (2) shows 2D, 3D distribution of the surface morphology image of NiO film at 200C° substrate temperature which studied by AFM. This figure demonstrates the homogeneity in grain distribution. The grain size calculated from AFM image at the deposited temperature was 66nm.

The optical transmission of NiO thin film on glass substrate is shown in figure (3). Notice that the film has transmittance higher than 70% in visible region, this is due to the absorptivity dependence on crystalline state. From the transmittance data the absorption coefficient (α) was by using the equation [20]:

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

Where (d) is the thickness of thin films(0.3µm) and (T)is transmittance.

To calculate the band gap of NiO film,the absorption coefficient (α) was used by using the relation [17]:

$\alpha h\nu = A\ (h\nu - E_g)^m$ ….(2)

Where *(A)* is a constant, E_g is energy band gap of NiO film, $h\nu$ is the incident photon energy, and (m=1/2) for direct allowed transitions and (m=2) for the indirect allowed transition. The variation of $(\alpha h\nu)^2$ versus the photon energy ($h\nu$) shown in figure (4). Extrapolation of linear part to α=0 gives band gap width which equal to 3.85eV.

The I-V characteristics in the dark for NiO/Si heterojunction is clarified in figure (5). The results exhibits that the current in the forward bias has two regions: the first, at low voltage idealize recombination current, which established one the concentration of the generated carriers above the intrinsic carrier concentration n_i, i.e $n*n>n_i^2$ the recombination method for mass is low occurrence . The second region portrayed the diffusion current at high voltage. In reverse bias, also there are two regions the first is that they generate wherever the reverse current is increased with voltage and this tends to generation of electron-hole pairs at low bias. In the second region, major increases within the reverse bias are often recognized. During this case, the current resulted from the diffusion of minority carriers through the junction[21].

The current-voltage (I-V) measurement in the illumination for NiO/ Si heterojunction is illustrated in figure (6),we could professed the photoelectric behavior of the device under illumination condition. It is comprehended that photo electric redounds result from light-induced electron-hole generation of the device and especially in the depletion region of the P-type silicon. Under external converter bias, the depletion region of the device extends and as a result, more episode photons will contribute to the electron-hole pairs age group that gabbed in the depletion region. The internal electric field in the depletion region where fores the electron-hole pairs to discrete from each other and this bias gets larger with exogenous bias is applied. From this figure, we can see the increase in the photo-current with increasing incident light intensity, where the large intensity refers to a great number of incident photons and hence a large number of separated electron-hole pairs [22].

Conclusion

NiO thin film can be deposite by PLD on silicon substrate at a 200C° substrate temperature. The film deposited at laser flunce 1.6 J/ cm^2. FTIR result shows that the formation of NiO at (426.27, 634.58, and 644.22) cm^{-1}, while the optical properties reveal a high transmittance up to 70% in the visible region with optical band gap 3.85eV. The current voltage characterization of NiO/Si heterojunction has good rectifying.

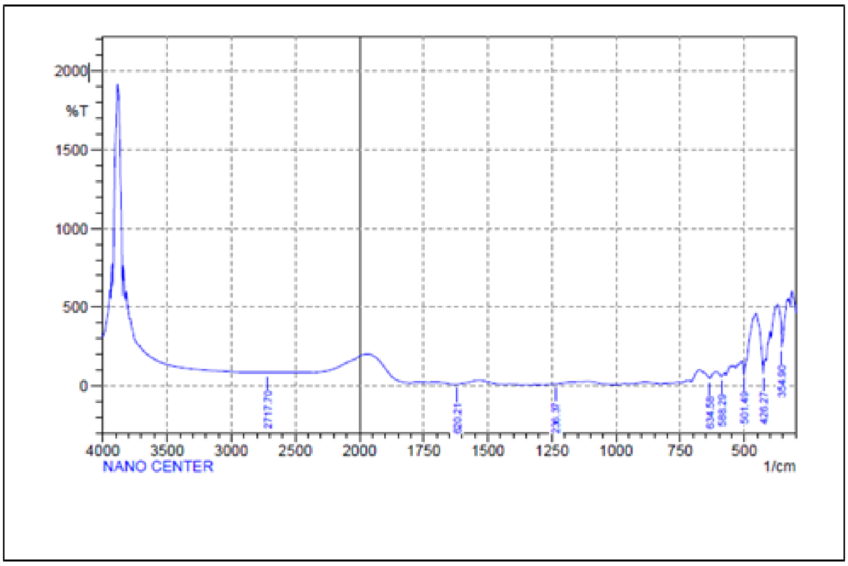
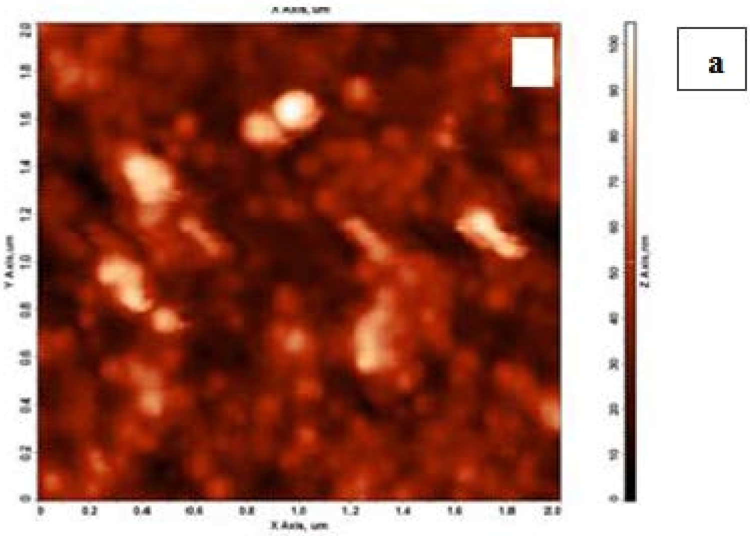


Figure (1): FTIR spectra of NiO film deposit at 200C° substrate temperature



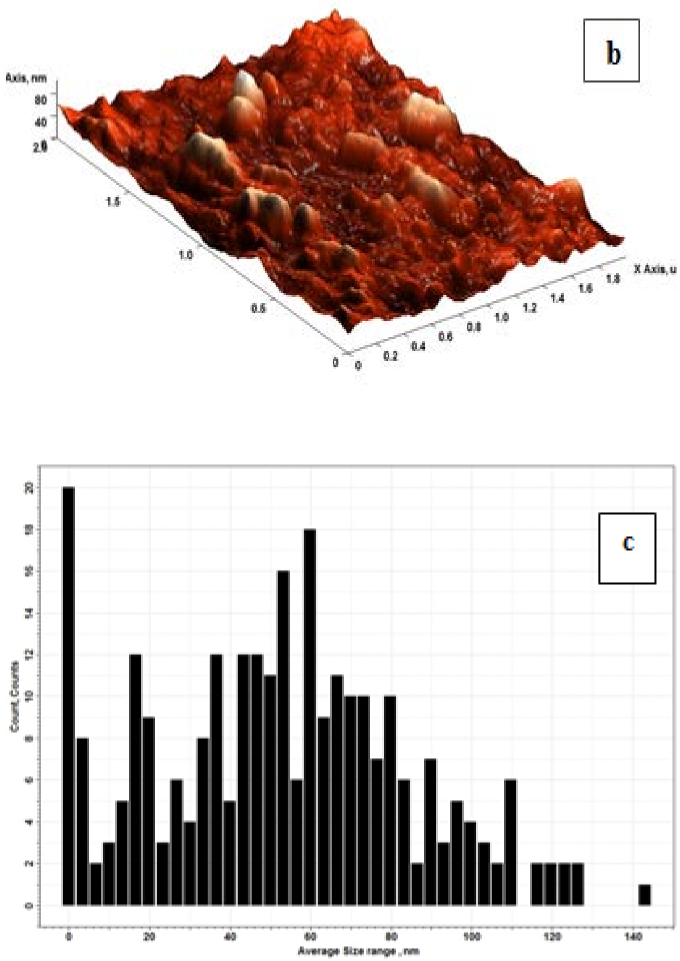


Figure (2): AFM image of NiO thin film at 200C◦substrate temperature a) 2D AFM image, b) 3D AFM image and c) distribution of particle size.

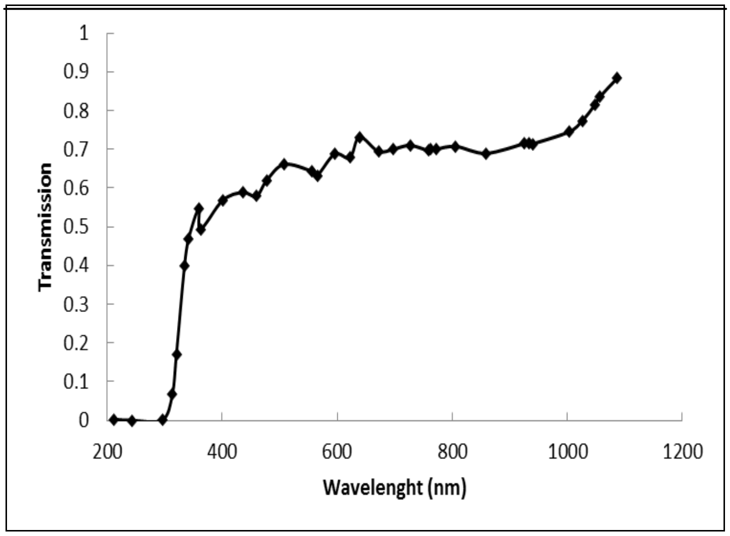


Figure (3): Optical transmission spectra of NiO film grown on glass substrate for 200C° substrate temperature.

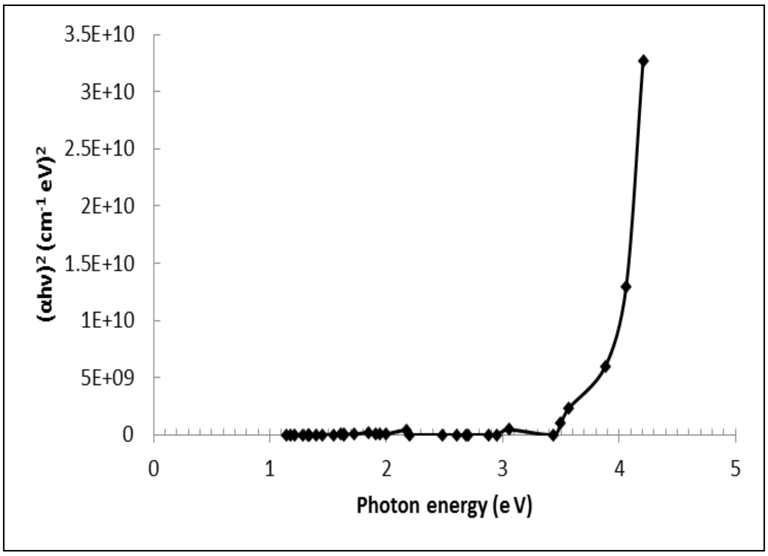


Figure (4): The variation of $(\alpha h\upsilon)^2$ with photon energy for NiO thin film prepared at 200C° substrate temperature.

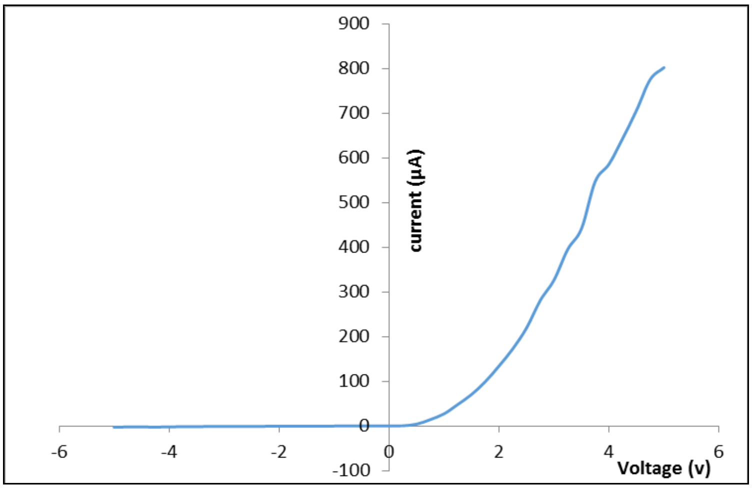


Figure (5): I-V characteristic of NiO/Si heterojunction.

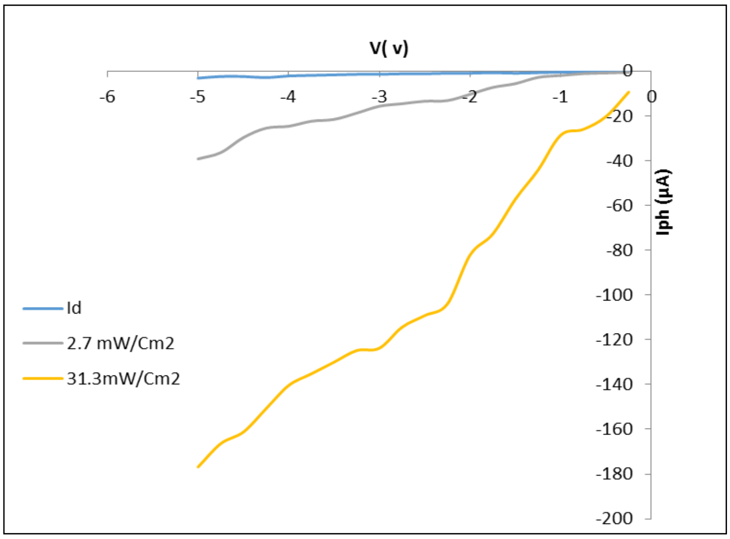


Figure (6):Dark and photo currentsNiO/Si heterojunction.

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