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Fabrication temperature sensing by using ZnO Nanoparticles

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Abstract

A present study is reported for the synthesis and characterization of ZnO nanoparticles and its application as a temperature sensor. ZnO nanoparticles thin film was prepared the by Sol: Gel method and deposition on a glass substrate. Structural and optical properties of ZnO films were studied. Structural investigation including microstructure was carried out by X-ray diffraction (XRD) analysis. The films gave a hexagonal wurtzite structure. Optical properties of the thin films were determined by using UV-Vis spectrometer. It was found the value of the band gap of the thin film is 3.18 eV. The variations in resistance of sensing with different temperatures were recorded. The relative resistance was decreased linearly with increasing temperature over the range (120- 250)°C.

Keywords: ZnO, Sol-Gel, Nanoparticles, Structural properties, Optical properties, Temperature sensing.

تحضير متحسس حراري باستخدام اوكسيد الزنك ذو الجسيمات النانوية

اسامة اسماعيل خضير

مركز الفيزياء التطبيقية– وزارة العلوم والتكنولوجيا

الخلاصة

أفادت دراسة الحالية حول امكانية تحضير ودراسة خصائص جزيئات أكسيد الزنك ذوالتركيب النانوي واستخدامة كمتحسس للحرارة. تم تحضير اوكسيد الزنك ذو التركيب النانوي حضر بطريقة صل – جل ورسب بعد ذلك على الزجاج. تم دراسة الخواص التركيبية للاغشية المحضرة باستخدام حيود الاشعة السينية حيث كان التركيب البلوري هو سداسي. تم دراسة الخواص البصرية باستخدام جهاز الطيف للاشعة الفوق البنفسجية و المرئية حيث تم احتساب فجوة الطاقة وذلك من خلال طيف الامتصاص للغشاء المحضر . تم تسجيل تغير المقاومة مع ارتفاع درجة الحرارة للغشاء المحضر حيث لوحظ ان المقاومة تقل بصورة خطية مع ارتفاع درجة الحرارة للغشاء المحضر

1.Introduction

ZnO is an n-type II–VI semiconductor with wide band gap of 3.37 eV, large exaction binding energy (60 meV). These properties make it a promising material for optoelectronic devices. ZnO has become a chief material for scientific and industrial applications (like: light emitting devices, light detecting devices, gas sensing devices and temperature sensing devices) due to its numerous excellent material performances. Therefore, the synthesis of high-quality ZnO material with a controlled microstructure for optoelectronic and electronic devices is a very important topic [1]. ZnO thin films have been prepared by a variety of thin film deposition techniques, such as pulsed-laser deposition, RF magnetron sputtering, chemical vapor deposition, spray pyrolysis and Sol–Gel processes [2]. Sol–Gel process has distinct advantages over the other techniques due to excellent compositional control, homogeneity on the molecular level due to the mixing of liquid precursors, and lower crystallization temperature [3]. ZnO is one of the promising materials among metal oxides for use in different types of sensors. As the temperature is an important parameter for measuring the different properties of materials. Because of various useful properties of ZnO, it behaves as good material for temperature sensing applications [4].

2. Experimental

Zinc acetate dihydrate (Zn (CH3COO)2_2H2O) was dissolved in a solution of isopropanol and monoethanolamine. The molar ratio of MEA to zinc acetate was 1.0 and the concentration of zinc acetate was 0.7 mol/l. The resultant solution was stirred at 50°C for one hour to yield a clear and homogeneous solution. The solution was finally aged at room temperature for 24 h. ZnO film was prepared on glass substrate by spin coating. Spin coating was performed at room temperature, with a rate of 3000 rpm for 30 sec. After depositing each times, the film was preheated in air at 250 °C for 5 min. After repeating the coating procedure five times for the final film thickness of approximately 200 nm, the film was finally postheated at 500°C for 1 h in air using a furnace. The thickness of the film is measured by using Ellipsometry technique which was found as ~ 200 nm. Silver past electrodes are used for the bottom electrical contact with an electrode gap of ~2 mm. For measuring the optical absorption of thin film, a double beam UV-Vis Spectrophotometer (Camspec-M550) was used. The XRD measurements were carried out using an X-Ray Diffractometer PW 1830 PANalytical which has tube anode; copper using the wavelength 1.54056Å.

3. Results and Discussion

3. 1. Structural properties

The structure of ZnO film was studied using high resolution X-ray diffraction (XRD). XRD spectra of ZnO thin film were showed in Fig. 1. The XRD peaks of 31.48°, 35.26° and 37.17° were corresponding to ZnO (100), (002) and (101) respectively[2]. Theses peaks confirmed that the film was polycrystalline in nature and the type of structural was a hexagonal wurzite. The crystalline size (grain diameter (D)) of the crystallites can be determined using the Scherrer's formula from the full width at half maximum (FWHM) β [5, 6],

$$D=0.94\lambda/\beta\cos\theta \qquad (1)$$

where λ is the wavelength of the X-ray used, β is the FWHM and θ is the angle between the incident and scattered X-ray. The grain size of ZnO was 18.417 nm.

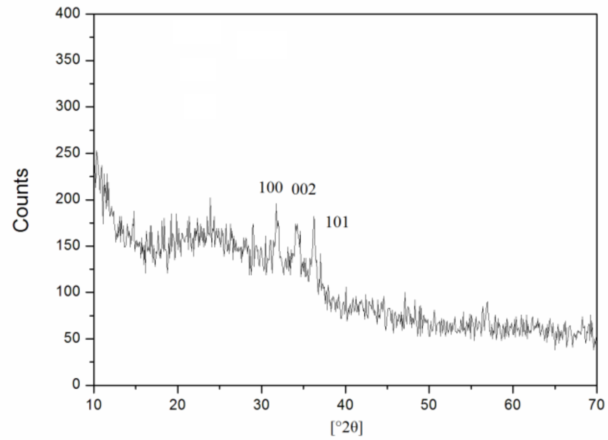

Fig. 1 : XRD of ZnO thin film.

3.2. Optical properties

The optical absorption spectra of ZnO thin film deposited onto a glass substrate was studied at room temperature. Figure 2 shows the variation of absorbance with wavelength (λ). It can be seen that the ZnO thin film has a strong absorption in the UV area, while the absorption is weak in visible region. The absorption edge is about 390 nm, corresponding to a band gap of 3.18 eV, which is very close to the intrinsic band-gap.

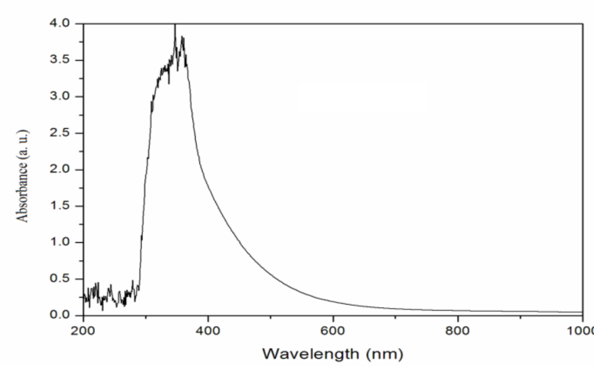

Fig. 2: The variation of absorbance with wavelength (λ) for ZnO thin film.

The value of optical band gap 'Eg' is calculated using the following relation [7and 8];

$\alpha = A (h\nu - Eg)\ n/h\nu$…………………(2)

where A is a constant and n is equal to 1/2 for direct band gap semiconductors. The plot of $(\alpha h\nu)$ 2 versus hν is shown in Fig. 3 for ZnO thin films.

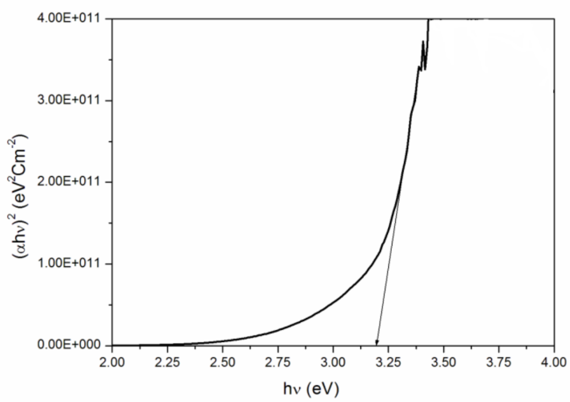

Fig. 3. Plots of $(\alpha h\nu)^2$ versus hν for ZnO thin film.

3.3. Resistance-temperature characteristics (temperature sensitivity)

The sensitivity of a temperature sensor can be defined as [9],

$S = \Delta R/\Delta T$, (MΩ/°C)………………..(3)

Where ΔR is the change in resistance in MΩ, and ΔT is change in temperature in °C of the sensing material. The variations in the resistance with the increase in temperature for the sensing elements prepared at room temperature, are shown in Fig. 4. It is found that the resistances of ZnO thin film is decreased when the temperature is increased and finally it approaches to an almost constant value. The average sensitivity for ZnO is found as 0.8 MΩ/°C. The decrease in resistance of the ZnO thin films with the increase in temperature may be regarded as due to the thermally activated mobility of the carriers, rather than thermally activated generation of these [9,10].

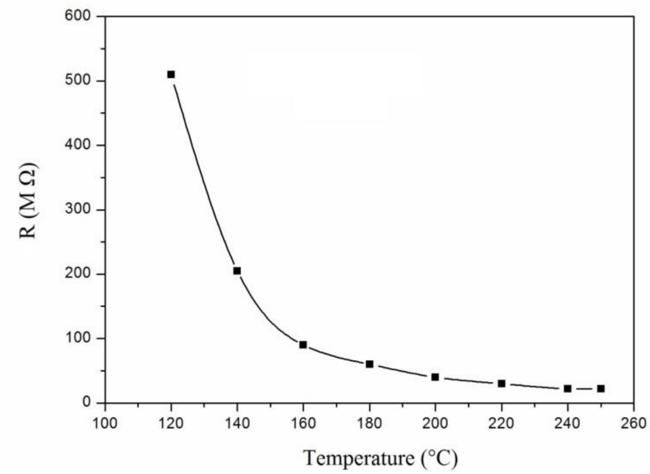

Fig. 4: Variations in resistance with temperature for ZnO.

4. Conclusion

A temperature sensor was fabricated using ZnO nanoparticles on glass substrate. The ZnO nanoparticles were prepared by the Sol-Gel method. From optical properties of the thin film the optical band gap was calculated and is found as 3.18 eV. The resistance of thin film decreased when the temperature increased.

The temperature sensor fabricated with the ZnO nanoparticles proved to be better sensing device for temperature measurements as it has the highest average sensitivity.

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