GROWTH OF NANOSTRUCTURED ZnO THIN FILMS VIA SPIN COATING TECHNIQUE FOR ACETONE SENSING APPLICATIONS AT ROOM TEMPERATURE

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ABSTRACT

This paper reports on the effect of precursor solution on the formation of nanostructured zinc oxide (ZnO) thin films via spin coating technique. The thin films are characterized by X-ray Diffraction (XRD) and scanning electron microscopy (SEM). The optical property of the thin films is also studied. Based on the analytical data, the well grown ZnO nanostructured thin film is subjected to gas sensing applications.

Keywords: Nanostructures, Gas Sensor, Spin Coating, Thin Films, Zinc Oxide

I INTRODUCTION

Varieties of chalcogenides like ZnS, ZnO, CdS, CdTe, etc., are used as chemical/gas sensors [1]. Among them, Zinc oxide (ZnO) gains substantial interest in the research community owing to its novel properties like piezoelectric, luminescent, catalytic, photoconducting, semiconducting as well as its low cost, non-toxicity and chemical stability.[2]. Reports revealed that the semiconducting property of ZnO thin films is highly pronounced in the gas sensing applications [3 - 4]. Acetone, the irritant vapor leads to hepatotoxic effects when inhaled. Long - term exposure to acetone causes kidney, liver and nerve damage. Hence, it is necessary to sense acetone even at its low concentration. Among the commonly adopted techniques for the deposition of ZnO thin films, spin coating [5] is more advantageous due to its capability of producing relatively uniform films. In this work, we report the preparation and characterization of nanostructured ZnO thin films for acetone sensing application.

II EXPERIMENTAL DETAILS

All the chemicals purchased from Rankem were used without further purification. The films were deposited on cleaned glass substrates by spin coating. To study the effect of precursor on the sensing property of the film, three different approaches were carried out. In the first approach (ZnO I), 0.1M aqueous solutions of zinc acetate (ZA) and hexamethylene tetramine (HMT) is mixed with 1% poly vinyl alcohol (PVA) and the precursor solution was spin coated at 2500 rpm. After coating, the film was dried at 400°C for 10 min. The spinning and drying procedure was repeated for 15 cycles to enhance the film growth and was calcined at 400°C for 3 hrs. In the second approach (ZnO II), 0.1 M ZA and HMT were mixed with tetrahydrofuran and the pH of the reaction medium was adjusted to 10 by adding triethanolamine (TEA). The prepared sol is spin coated and calcined as per the above protocol. In the third approach (ZnO III), pH of the solution of precursor used for first approach is adjusted to 10 by adding TEA in drops and used for coating.

The prepared ZnO films were characterized using PANalytical X-ray diffractometer (XRD) for phase identifications and the surface morphology was determined using the JEOL JSM Field emission scanning electron microscopy (FE – SEM). The optical and electrical properties were studied using the absorbance spectra and nyquist plot taken by JASCO – Ultraviolet - Visible (UV-Vis) spectrophotometer and Gamry Reference 600 potentiostat respectively. A set – up for analysing the gas sensing property of the nanostructured ZnO thin films was fabricated (not described in this paper) and an attempt is made to sense acetone. In the present study, the sensitivity (S) of the films is determined using the formula reported elsewhere [6].

III RESULTS AND DISCUSSION

The XRD patterns of ZnO thin films given in Fig.1 are comparable with the standard JCPDS (File No: 36 – 1451), suggesting the formation of wurtzite phase of ZnO [6]. In the case of ZnO II and ZnO III, the Bragg angles at 35.14° (002) and 32.39° (100) correspondingly revealed the orientation of growth along the c-axis [3] and a-axis [7]. The average crystallite size (D) calculated by Scherrer formula [6] as 51.4 nm, 53.9 nm and 137.2 nm respectively for ZnO I, ZnO II and ZnO III.

Fig.2 shows the SEM images of the prepared films. SEM image of the ZnO I film shows a uniform distribution of hexagonal shaped grains whereas ZnO II film paves a pillar like morphology for the group of nanorods with almost uniform size distribution. ZnO III film possesses a rock like morphology. These results are in accordance with the growth along a-axis and c-axis obtained from XRD for ZnO III and ZnO II films respectively.

Fig.3 depicts a UV-vis spectrum of the ZnO films in which an absorption peak centered around 315 nm (3.93 eV) for all the three samples resulting in a blue-shift with respect to bulk ZnO. This sharp absorption onset of the films exhibits the optical quality and low concentration of defects such as voids.

Fig.4 shows the nyquist plot of the ZnO films from which the intercept of impedence on the X - axis gives the dc resistance of the films. It is observed that ZnO II shows higher resistance than the other two films.

3.1 Gas Sensing Measurements

In the present study, on careful observation of all the three samples, the film of ZnO II possessed the pillar like structure leading to larger surface area in addition to large number of adsorption-desorption sites [8] which favors the interaction of gas molecules. Hence the sensitivity measurement for acetone was carried out with the ZnO II. Fig.5 represents the sensing characteristics of ZnO film with respect to concentration at room temperature. Acetone is injected in steps of 20 ppm inside the test chamber and the sensitivity is found to increase from 0 ppm to 100 ppm and gets saturated beyond 100 ppm. The mechanism behind the decrease of resistance of ZnO after the injection of acetone is due to the release of electrons on the surface and beyond 100 ppm, the saturation in the sensitivity value is observed due to the formation of multimolecular layers on the film surface.

FIGURES

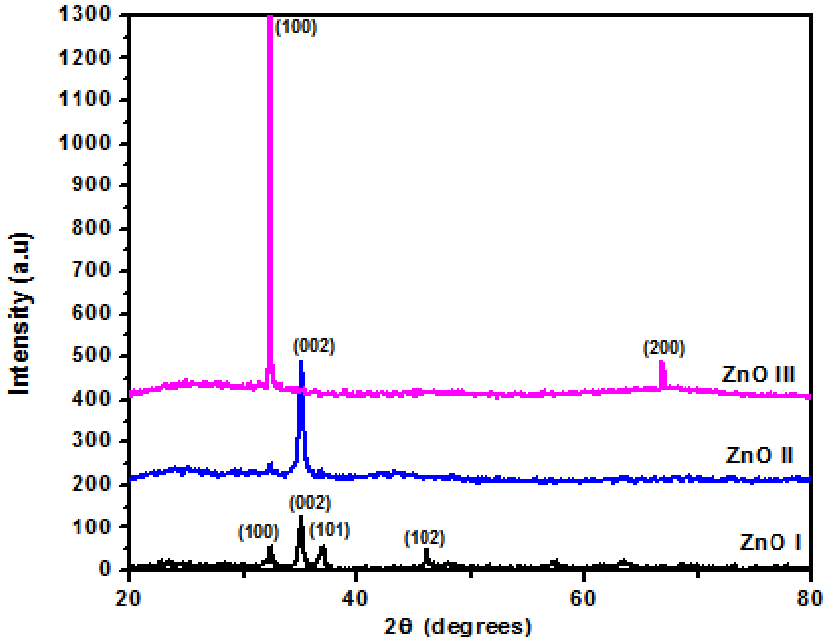


Figure .1 XRD pattern of the ZnO films

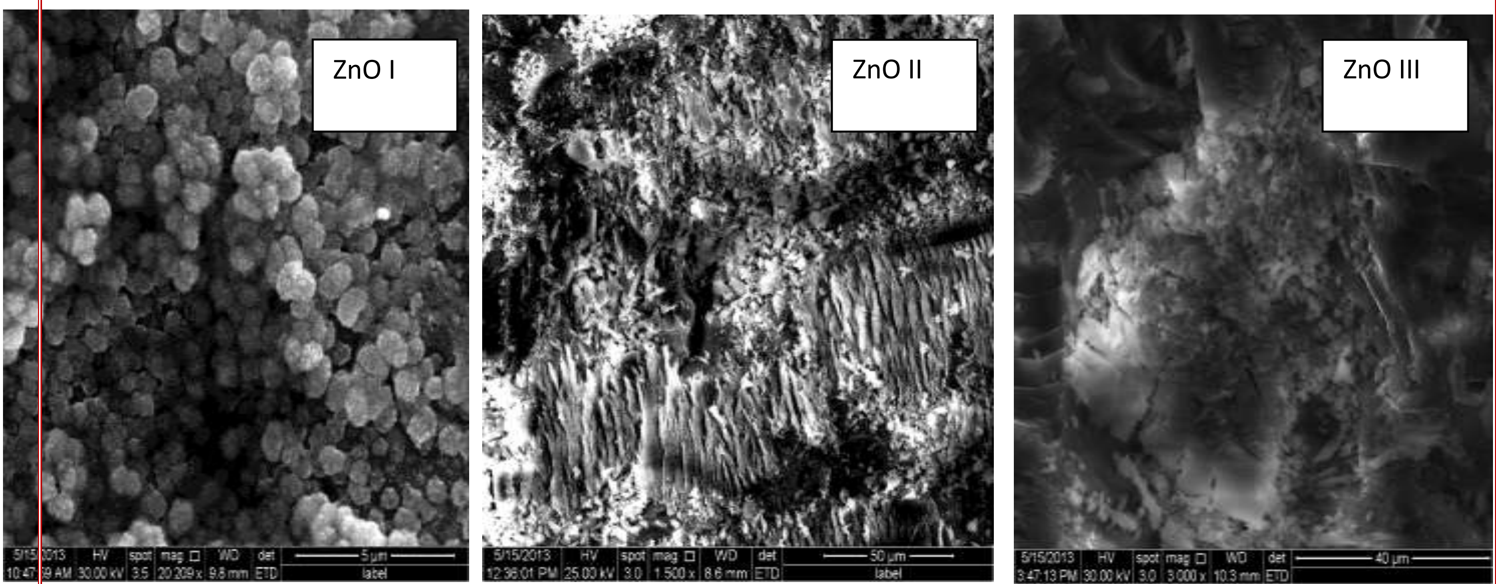
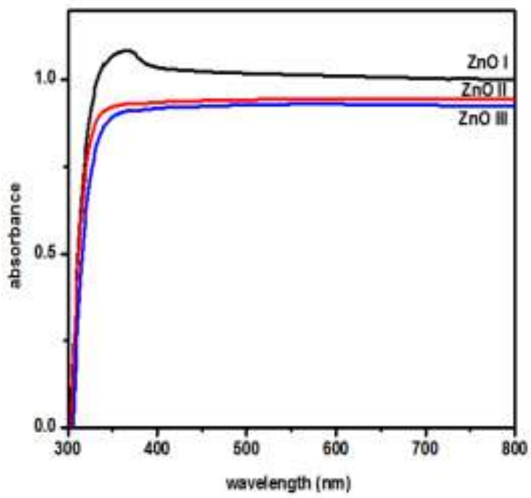


Figure.2 FE-SEM images of the ZnO films



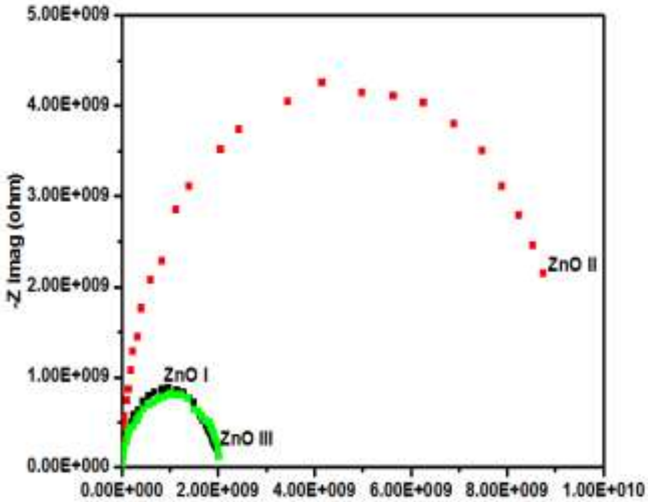


Figure. 3 Absorption spectra of the ZnO films Figure.4 Impedance spectra of the ZnO films

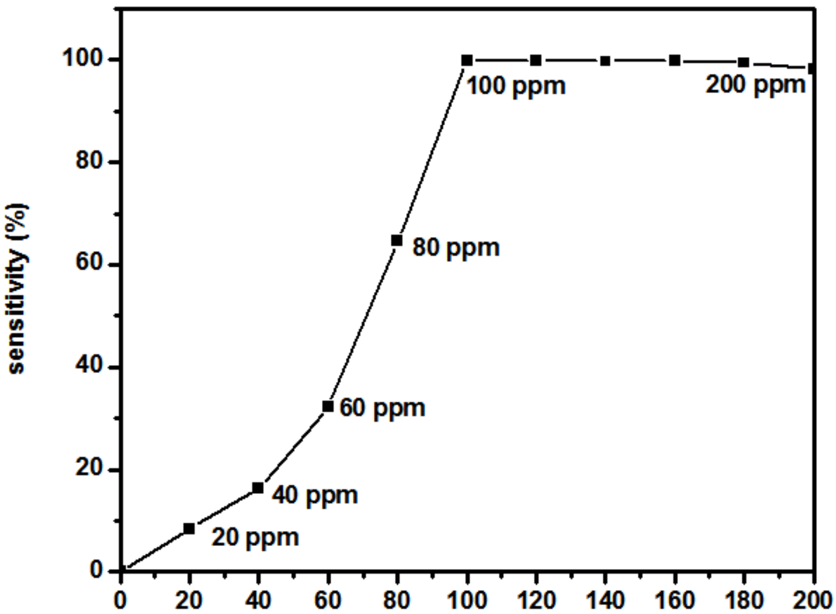


Figure.5 Sensitivity of ZnO II film when exposed to acetone

IV CONCLUSION

The effect of precursor on the ZnO thin films were characterized by XRD and SEM. The uniformly grown ZnO nanorods (ZnO II) along the c-axis plane is tested towards the sensing of acetone and it is found that, the film is active between 20 and 100 ppm.

REFERENCES

[1] Tsiulyanua D, Mariana D, Liess HD and Eisele I, Chalcogenide based gas sensors, *Journal of Optoelectronics and Advanced Materials, 5,2003* 1349 – 1354.

[2] Lokhande CD, Gondkar PM, Mane RS, Shinde VR and Han SH, CBD grown ZnO – based gas sensors and

dye-sensitized solar cells, *Journal of Alloys and Compounds, 475, 2009,* 304 –311.

[3] Hardan NHA, Abdullah MJ, Aziz AA, Ahmad H and Low LY, ZnO thin films for VOC sensing applications, *Vacuum, 85, 2010,* 101 – 106.

[4] Suchea M, Christoulakis S, Moschovis K, Katsarakis N and Kiriakidis G, ZnO transparent thin films for gas sensor applications, *Thin Solid Films, 515, 2006,* 551–554.

[5] Nam GM and Kwon MS, Al-doped ZnO via sol-gel spin-coating as a transparent conducting thin film, *Journal of Information Display, 10, 2009,* 24 – 27.

[6] Sahay PP and Nath RK, Al-doped zinc oxide thin films for liquid petroleum gas (LPG) sensors, *Sensors and Actuators B 133, 2008,* 222 – 227.

[7] Bhole MP and Patil DS, Deposition of non-polar a-axis nanocrystalline ZnO thin films for light emitting applications, *Optoelectronics and advanced materials – rapid communications,1, 2007,* 672 – 676.

[8] Cheng XL, Zhao H, Huo LH, Gao S and Zhao JG, ZnO nanoparticulate thin film: preparation, characterization and gas-sensing property, *Sensors and Actuators B 102, 2004,* 248 – 252.