Exploitation of Zinc Oxide nanoparticles as a Humidity Sensors

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Abstract

Zinc oxide nanoparticles were readily synthesized through Co- Precipitation method and dipped in Aluminium chloride ($AlCl_2$) for 1 & 2 min. Zinc Acetate used as a precursor for preparation. In this present work, samples were prepared by spin coating technique in the form of thin films. The ZnO Nanoparticles were characterized by using X-Ray diffraction and humidity sensing, hysteresis characteristic, electrical dc conductivity, Arrhenius plot and activation energy of nanoparticles material studied.

Keywords : ZnO, nanoparticles, co-precipitation, humidity sensors, electrical dc conductivity.

Introduction

Nanotechnology has quite high impact in developing new classes of materials with enhanced functionality and a wide range of applications [1]. The properties of ZnO include it's wide band gap (3.37eV), high exciton binding energy (60meV) [2,4]. Other favourable aspects of ZnO are that it is non-toxic, cheap, relative abundant source materials and chemically stable. [3-6]. ZnO probably has the richest family of nanostructures, 1-D ZnO nanorods are potentially useful for various nano devices such as light emitting diode (LEDs), chemical sensors, solar cells, and piezoelectric devices, because of their high aspect ratio and large surface area to volume ratio ensure high efficiency and sensitivity in this applications.Furthermore, ZnO is bio-safe and biocompatible and may be used for biomedical applications without coating [4-8]. In the present work, ZnO Nano-material dipped under Aluminum chloride ($AlCl_2$) solution at different time, samples were tested for humidity sensing properties.

Experimental

In the present work, synthesis and structural characterization of ZnO nanoparticles by using liquid phase method with large surface area in short reaction time at room temperature and this method is the simplest, cost effective, eco-friendly method. It is also probed for its effect on nanocrystalline size structure via XRD studies of ZnO nanoparticles. [6]

- **Method of Preparation**

Zinc Oxide nanostructure was synthesized by using co-precipitation method. In order to prepare, 2 g of Zinc Acetate Dihydrate and 8 g of Sodium Hydroxide were weighted using a weighting balance. Then, 10 ml and 15 ml of distilled water were measured by a measuring cylinder. After that, 2 g of zinc acetate dihydrate was dissolved with a 15 ml of distilled water and 8 g of sodium hydroxide was dissolved in a 10 ml of distilled water. The solutions were stirred with a constant stirring for about five minutes each. After well mixed, sodium hydroxide solution was poured to the solution containing zinc acetate with a constant stirring by magnetic stirrer for about five minutes. Then, a burette was filled with 100 ml of ethanol and titrate drop wise to the solution containing both sodium hydroxide solution and zinc acetate. After the reaction, white precipitate was formed. [5]

- **Dipping Method:**

Aluminium chloride ($AlCl_2$) is the main compound of Aluminium and chlorine. The compound is often cited as a Lewis acid. In the dipping method, we have used Aluminium chloride for the dipping method. We first prepare 0.01 M solution of Aluminium chloride making up 100 ml by pouring 0.013 mg.

As we prepared the 0.01M solution of $AlCl_2$ then we dipped the thick film of Zinc Oxide for different time parameters. We take 1, 2 minutes dipping and after firing these slides for 1 hour at 500°C finally the two thick films slides for different dipping time is prepared and one thick film taken for pure [7,8]. Series of a sample in which ZnO nanomaterial films were dipped in Aluminium Chloride for different dipping time for 0, 1, 2 minutes samples namely ZS-0, ZS-1, ZS-2 respectively.

Results And Discussion

- **X-ray diffraction (XRD)**

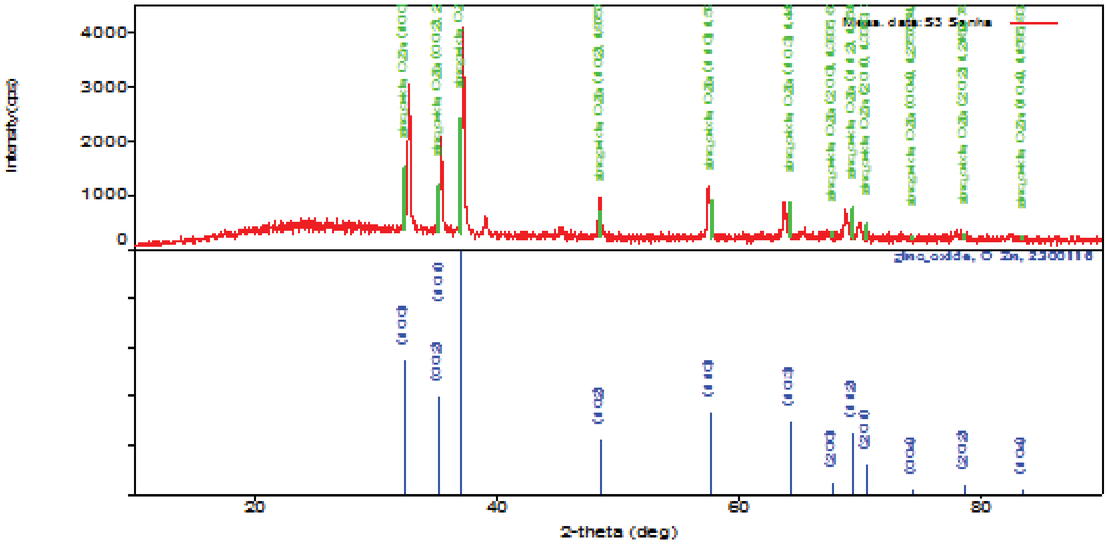

Figure 3.1 – XRD of pristine ZnO nanomaterial

Figure 3.1 shows XRD pattern of pristine ZnO nanocrystalline material respectively. The XRD pattern of pristine Zinc Oxide (ZnO) nanostructure synthesized by liquid phase method via co-precipitation method calcinated at 500 ^{o}C. The crystalline nature with 2θ peak lying at (100),(002),(101),(102),(110),(103) and (112) planes. All the peak match well the standard hexagonal wurtize structure of Zinc Oxide (ZnO). All the peaks are perfectly matched with pure ZnO structure, which indicates the purity of the obtained ZnO particle. The average crystalline size was found to be 48.86 nm calculated by Debye-Scherrer formula. [5,9]

- **Hysteresis characteristics:**

In our present work, humidity sensing with ZnO nanomaterial thick films of pure sample ZS-0 of ZnO nanoparticles and series of a samples which is ZnO nanomaterial film ZS-1, ZS-2 dipped in Aluminium Chloride for different dipping time i.e for 1&2 minutes as shown in figure 3.2.1 respectively. Hysteresis plot shows variation between resistance of sample with respect to relative humidity in increasing order of 40 to 80 % RH. The resistance measurement was done with Keithley 2400 source meter. From this hysteresis plot it is clearly seen that there is very small hysteresis is present during forward (increasing) %RH. It is observed that there is very significant average change in value of resistance of sample in the range of 10^4 to 10^1 MΩ. From 40 to 80 % RH except in the sample ZS-2 (2 minutes) change in value of resistance from 10^4 to 10^0 MΩ. There is noticeable change in the value of resistance of sample ZS-2 at constant temperature 40^{o}C to 80^{o}C.

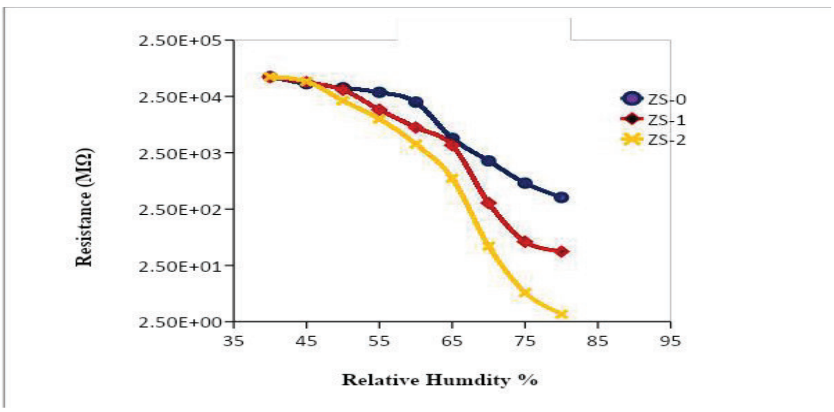

Fig 3.2.1 Hysteresis plot of samples

- **Activation Energy**

Figure (3.3.1) shows the Arrhenius plot of conductivity with (1000/T) at 50, 60, 70 % RH for the sample ZS-2. However, the Arrhenius plot for all the samples found to be linear and by using the equation (ΔE=K x Slope/e) the activation energy ΔE is calculated and tabulated in the table (3.1)

RH %	50%	60%	70%
Sample Code	**ΔE eV**	**ΔE eV**	**ΔE eV**
ZS-0	8.63E-04	8.17E-04	1.23E-03
ZS-1	9.98E-04	9.53E-04	1.13E-03
ZS-2	5.40E-04	7.20E-04	1.36E-03

Table 3.1: Activation energy

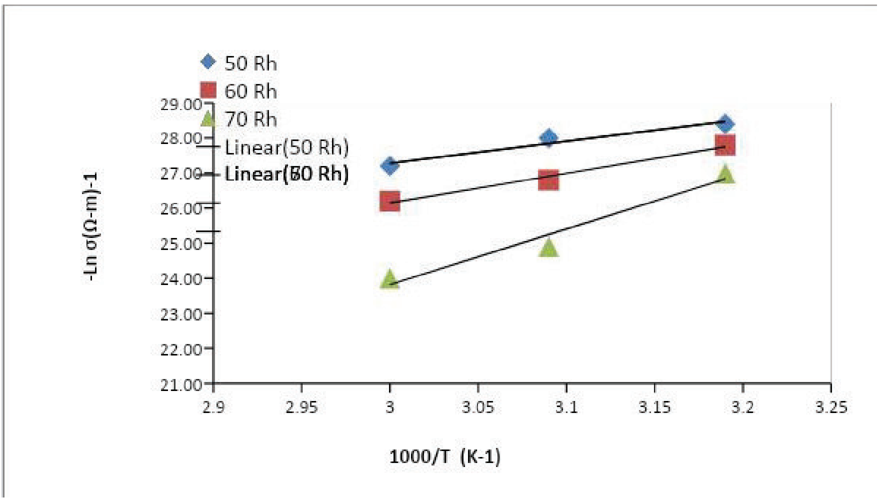

Fig 3.3.3: Arrhenius plot of sample ZS-2

For all samples the activation energy is found to be quite reasonable for the electrical conduction the values of activation energy for the pristine ZnO which is more smaller at constant different RH. This shows that the smaller amount of energy is required for the conduction of electrons due to absorption of water molecules there by increasing the number of donor electrons.

Conclusions

It is observed that the XRD analysis of samples shows that all the peaks are perfectly match with pristine ZnO nanostructure, which indicates that Pristine ZnO nanoparticles obtained. No other peaks were detected in spectrum within detection limit of XRD instrument, indicating the pure pristine ZnO Nanomaterial is synthesized.

The hysteresis plot of all samples were observed that there is very significant average change in value of resistance of samples in the range of 10^4 to 10^1 MΩ. There is noticeable change in the value of resistance of sample ZS-2 in the range of 10^4 to 10^0 MΩ at constant temperature 40^0C to 80^0C.

The Arrhenius plot for all the samples was found to be linear and activation energy ΔE was calculated for all the samples and is found to be quite reasonable for the electrical conduction. The smaller amount of energy is required for the conduction of electron due to the adsorption of water molecules.

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