Synthesis of Zinc oxide nanostructures by a simple wet chemical method

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Abstract

In this work Zinc Oxide (ZnO) nanostructures have been successfully synthesized by a simple co-chemical precipitation technique in distilled water medium. The syntheses procedures were performed at room temperature. The nanostructures samples were then characterized by X-Ray Diffraction (XRD) analysis. The obtained XRD patterns confirms that the samples are of hexagonal phase and having wurtzite crystal structure. The samples were found to have average crystalline (grain) size 14.89 nm as calculated by the line broadening of the X-ray diffraction pattern.

I. Introduction

Nanoparticles have been a research pursuit for more than a decade now. Among the different nanostructures Zinc Oxide (ZnO) is a well-known semiconductor material with a wide direct band gap of 3.37eV [1-6]. There are several reports available in literature regarding the synthesis, characterization and potential application of zinc oxide nanostructures [1-6]. Becheri et al. [1] have reported the synthesis of zinc oxide nanostructures at high temperature using zinc chloride and sodium hydroxide through a homogeneous reaction process. Nghia et al. [2] has synthesized Zinc Oxide nanostructures by a hydrothermal method. Then the samples were characterized through Scanning Electron Microscopy (SEM) and it was found that the nanostructures are rod shaped. There are several reports of doped zinc oxide materials also. Silver-doped Zinc Oxide nano crystals were prepared by the UV-photo reduction method after which the resulting Ag-doped ZnO were characterized XRD, Raman spectroscopy, UV-visible, and UV photoreduction spectrophotometer. The main aim of these study was to determine the crystalline phases and optical absorption of the sample. The doping of Ag ions in the zinc site of crystal structure induces an increment in the size of nanostructures in comparison of the undoped Zinc oxide. The other properties of the material which also got remarkably improved due to the doping were photocatalytic and photoluminescence. Chakraborty et al. [3] have reported the synthesis and optical properties of flower-like ZnO nanostructures. The results of XRD analysis revealed that the ZnO possesses a hexagonal wurtzite structure. After the data analysis of UV–visible optical absorption, it came into light that the UV absorption edge in the sample is present at ~260 nm. The room-temperature photoluminescence (PL) spectrum shows a violet emission band and also a near-band edge emission at ~360 nm. Also, a sensible growth mechanism is suggested for the genesis of ZnO nanoparticles having flower like

shape. Chauhan et al. [4] have reported the synthesis of both undoped and doped ZnO nanostructures through the chemical co-precipitation method. The crystalline structure, optical properties and band gap found out by X-Ray Diffraction (XRD) analysis and UV-visible spectroscopy analysis. XRD analysis reveals the resultant sample possess hexagonal wurtzite phase. By controlling the reaction temperature particle size were varied. Also, it was reported that with the increase in heating temperature, the average size of nanoparticle was increased and decreased with the increase in doping percentage of metals. The highest peak of absorption showed up at nearly ~260 nm. The band gap values of resultant undoped and Ag-doped samples were observed to be inversely proportional to the temperature. The data analysis of the optical absorption indicated the red shift in absorption band edge after doping of Silver. Rare earth doped zinc oxide has been discussed in details by Daksh et al [5]. Review on the antibacterial properties of Zinc oxide nanoparticles has been reported by Sirelkhatim et al. [6].

II. Experimental details

Here a simple wet chemical co-precipitation method has been adopted for the synthesis of Zinc oxide nanostructures. The chemicals were used as received without any further purification. Firstly, in 50 ml double distilled water 0.034M Zinc nitrate hexahydrate was dissolved. Then in other beaker 7 gm. of potassium hydroxide (KOH) pellets was dissolved in 100 ml distilled water. After that KOH solution was added in Zinc nitrate hexahydrate solution drop-wise with continuous magnetic stirring at 820 rpm at room temperature till the pH of the resulting solution comes to 8. Then the solution is left for few hours to obtain the precipitate. Then the solution is filtered using distilled water and washed off continuously till the pH value of the resultant precipitate reached back to 7. Then the obtained precipitate was allowed to dry for 2 days. Then the dried precipitate was heated at 100°C on a hot plate with to remove the moisture and then grinded it to fine powder.

III. Results and discussion

The X-ray diffraction pattern (Figure 1) of the sample was collected by using Powder diffraction (Bruker Instrument) technique with Cu-Kα radiation with wavelength λ= 1.54060Å. The pattern was matched with the ICSD code 23616 confirming the presence of hexagonal zinc oxide (ZnO) Hexagonal structure with space group P63mc. The corresponding diffraction peaks are labelled in the figure below.

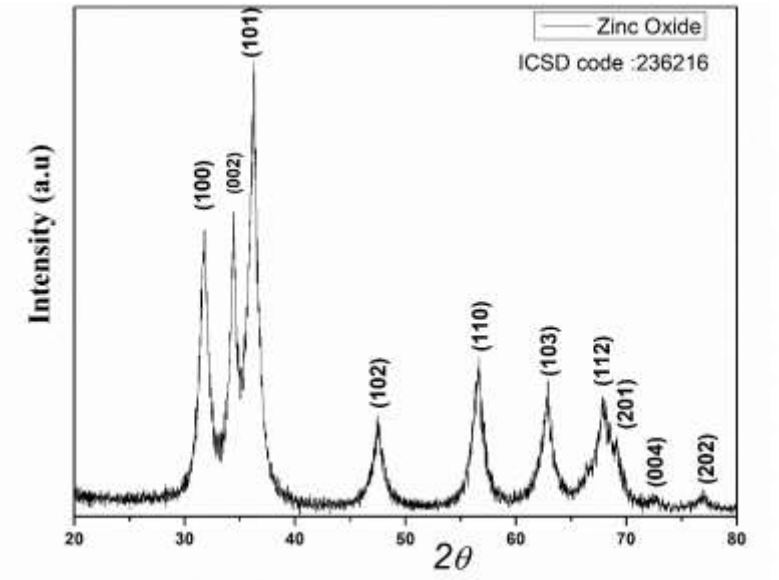

Figure 1: *X-ray diffraction pattern of the undoped zinc oxide nanostructures*

The XRD pattern is usually gets broadened due to the smaller particle size, here the diffraction pattern of our sample also broadened indicating the formation of the nanoparticles. In order to calculate the average crystallite size, we have considered this line broadening (Figure 2) and used the Debye Scherrer equation [7]

$$D = \frac{K\lambda}{\beta cos\theta} \qquad (1)$$

where D is the average particle size, K is the Scherrer constant, λ represents the wavelength of the radiation used, β is the full width at half maxima located at angle θ.

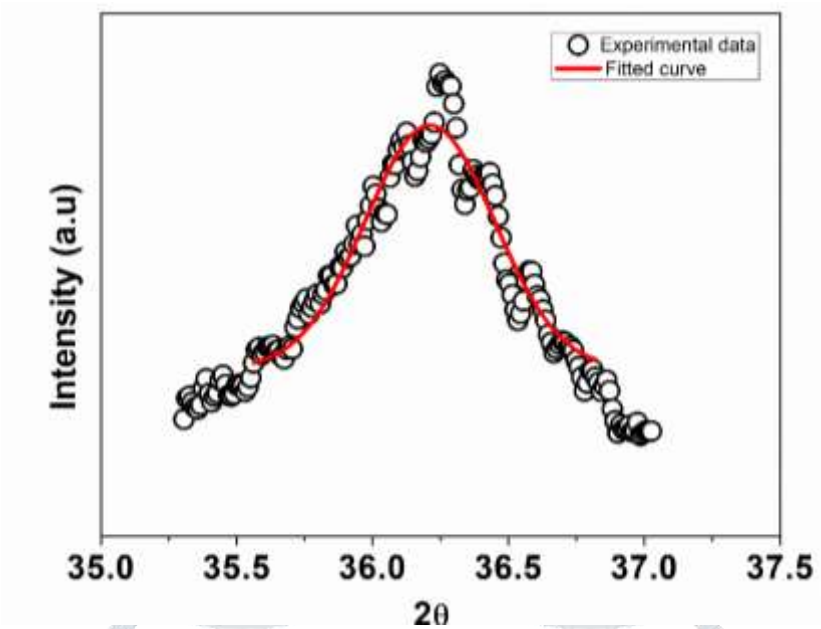

Figure 2: *Calculation of full width at half maxima (FWHM) by Gaussian fitting of the (101) peak*

The value of Scherrer contact we have considered here is 0.9 considering spherical particles. The average crystallite size comes out to be 14.89 nm, confirming the synthesis of zinc oxide nanostructures.

IV. Conclusions

In this work, Zinc oxide nanostructures were successfully synthesized by a simple, low-cost chemical co-precipitation method at room temperature. Double distilled water has been used as the reaction medium. The pristine zinc oxide sample was investigated by X-Ray diffractometer. The obtained information of the XRD pattern shows that the resultant Zinc oxide nanostructures possess a hexagonal wurtzite crystal structure having fine crystalline quality with an average crystallite size 14.89 nm. In future, the prepared nanoparticles can be incorporated in suitable polymer matrix for the preparation of polymer nanocomposites for flexible electronics. The applicability of the prepared zinc oxide nanoparticles for micro bacterial activity can also be studied.

8. References

1. Alessio Becheri, Maximilian Durr, Pierandrea Lo Nostro, Piero Baglioni. Synthesis and characterization of zinc oxide nanoparticles: application to textiles as UV-absorbers. Journal of nanoparticle research 2008; 10:679–689.

2. Nguyen Van Nghia, Tran Nam Trung, Nguyen Ngoc Khoa Truong, Doan Minh Thuy Preparation and Characterization of Silver Doped ZnO Nanostructures. Open Journal of Synthesis Theory and Applications 2012; 1:18-22.

3. S. Chakraborty, A.K. Kole, P. Kumbhakar. Room temperature chemical synthesis of flower-like ZnO nanostructures. Materials Letters 2012; 67:362-364.

4. Ruby Chauhan, Ashavani Kumar and Ram Pal Chaudharya. Synthesis and characterization of silver doped ZnO nanoparticles. Archives of Applied Science Research 2010; 2:378-385.

5. Daksh Daksh and Yadvendra Kumar Agrawa, Rare Earth-Doped Zinc Oxide Nanostructures: A ReviewReviews in Nanoscience and Nanotechnology Vol. 5, pp. 1–27, 2016.

6. Amna Sirelkhatim, Shahrom Mahmud, Azman Seeni, Noor Haida Mohamad Kaus, Ling Chuo Ann, Siti Khadijah Mohd Bakhori, Habsah Hasan & Dasmawati Mohamad, Review on Zinc Oxide Nanoparticles: Antibacterial Activity and Toxicity Mechanism, Nano-Micro Letters volume 7, pages 219–242(2015).

7. B.D. Cullity and S.R. Stock, Elements of X-ray Diffraction, Third Edition 2001.