Cost effective and Monodispersed Zinc Oxide Nanoparticles Synthesis and their Characterization

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Article Info

ABSTRACT

Zinc Oxide (ZnO) nanoparticles were most widely used in the field of Biotechnology and Nanoelectronics due to their good transparency, high electron mobility, strong room-temperature luminescence and nontoxic. Due to their increasing demand, highly specified and monodispersed nanoparticles formation is a revolutionary field. Here ZnO nanoparticles were prepared by modified sol-gel method and were characterized using UV-Vis Absorption Spectroscopy, X-ray Diffraction and Scanning Electron Microscopy (SEM). Modified sol-gel mediated ZnO nanoparticles were proved to synthesize the highly stable, monodispersed and cost effective nanoparticles which were difficult to obtained from other chemical methods. The nanoparticles synthesized in this work have an average size of 84 nm. The results were quite appreciable and wide band gap - long range ordered ZnO nanoparticles were obtained.

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1.   INTRODUCTION

The field of nanotechnology is one of the most active areas of research in modern material science. Nanoparticles due to their small size and high surface-volume ratio exhibit unique optical, electronic and chemical properties that are significantly different from those of bulk materials [1]. Some of the physical properties exhibited by Nanoparticles are due to large surface atom, high surface energy, spatial confinement and reduced imperfections. Noble metal nanoparticles have found uses in many applications in different fields, such as biocatalysis, photonics and electronics [2]. Nanotechnology is also being utilized in medicine for diagnosis, therapeutic drug delivery and the development of many types of novel products with its potential medical applications on early disease detection, treatment, and prevention [3].

Zinc oxide is a wide gap semiconductor material which has higher electron mobility as well as higher breakdown field strength. ZnO possess many versatile properties for UV electronics, spintronic devices and sensor applications [4]. Also ZnO has been commonly used in its polycrystalline form over hundred years in a wide range of applications. It usually appears as a white powder and is nearly insoluble in water. The powder is widely used as an additive for numerous materials and products including plastics, ceramics, glass, cement, rubber (e.g. car tyres), lubricants, paints, adhesives, sealants, pigments, foods (source of Zn nutrient), batteries, fire retardants, etc [5]. ZnO is present in the Earth crust as a mineral zincite; however, most ZnO used commercially is produced synthetically. ZnO is nontoxic and is compatible with human skin making it a suitable additive for textiles and surfaces that come in contact with human body [6],[7]. The increase in surface area of nanoscale ZnO compared to bulk has the potential to improve the efficiency of the material function. ZnO nanoparticles are used in paints, cosmetics, sunscreens, plastic and

rubber manufacturing, electronics and pharmaceuticals products etc [8]. Sol-gel method is used to synthesize highly pure and well controlled metal oxide nanoparticles.

Due to the increasing applications of ZnO nanoparticles, highly specified and monodispersed nanoparticles formation is a revolutionary field. In the present work, ZnO nanoparticles are synthesized by modified sol-gel method which leads to the formation of highly pure and monodispersed nanoparticles. Sol-gel formation process is cheap, require less energy consumption and less polluted as compared to other methods. ZnO nanoparticles are characterized by using UV-Vis Absorption Spectroscopy, X-ray Diffraction and Scanning Electron Microscopy.

2.   RESEARCH METHOD

For the synthesis of sol gel mediated ZnO Nanoparticles, prepare 0.5M solution of $Zn(CH_3COO)_2$ in 50 ml water and stir it for 30 min. Add 0.15M solution of oxalic acid in 50 ml water dropwise by separating funnel to the above solution and stir the whole solution for 2 hrs. Heat the above solution at 50˚C for 1.5 hrs. Dry the above solution at 90˚C for 2 hour. Heat on 500˚C to evaporate the solvent completely. The properties of the particles so formed are analysed and studied via the UV- Vis, XRD and SEM techniques.

3.   RESULTS AND ANALYSIS

3.1 UV-Vis Absorption Spectroscopy

Fig. 1 shows the UV-Vis curve of the prepared sol gel mediated ZnO nanoparticles. Electrons present in ZnO nanoparticles are excited by the UV-Visible wavelength and according to the excitation energy of band gap, electrons absorbs a specific wavelength from the spectrum to reach in the conduction band. Here peak obtained is sharp because of monodispersed nanoparticles. During the formation process, nuclei are formed and they ripe to grow in nanoparticles, the time for the formation of nuclei and for each nuclei to grow are equal, this causes same sized nuclei in suspension; and hence sharp peak is obtained. It shows a clear absorption peak at 330 nm. With this curve we are herby able to draw exclusive results regarding the formed particles nature and bandgap. The band gap can be calculated by using Tauc's relation which is-

$$\alpha h\nu = A(h\nu - E_g)^n \tag{1}$$

where α is absorption coefficient, h is Planck's constant, ν is frequency of absorption, E_g is band gap energy and n is the transition between the extrema of conduction and valence band.

Fig. 2 gives the band gap of the prepared ZnO nanoparticles using the Tauc's relation and it is estimated to be 3.65 eV. This shows that the particles so produces are semiconducting in nature and can be used in the electronic applications.
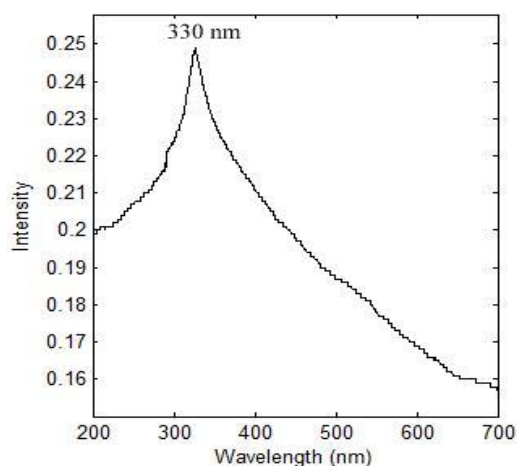

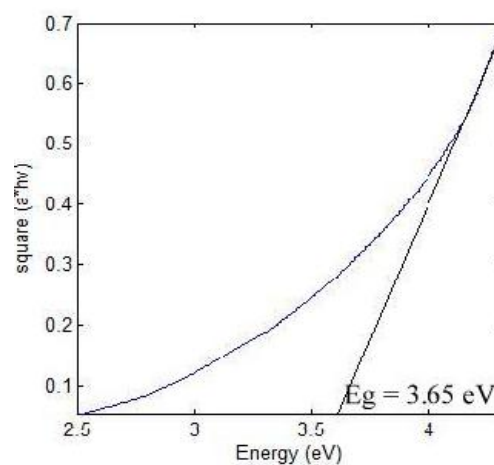
Fig. 1 UV-Visible spectrum of ZnO nanoparticles

Fig. 2 Bandgap estimation of sol gel mediated ZnO nanoparticles

3.2 X-Ray Diffraction

Fig. 3 shows the X-Ray Diffraction of the sol gel mediated ZnO nanoparticles. The X-ray diffraction data are recorded by an X'Pert Pro x-ray diffractometer operated at a voltage of 45 kV and a current of 40 mA with Cu Kα radiation (1.5406 Angstrom). The average grain size of the samples is estimated with the help of the Scherrer equation, using the diffraction high intensity peak. The mean grain size (D) of the particles is determined from the XRD line broadening measurement using the Scherrer Equation-

$$D = 0.89\lambda/(\beta Cos\theta) \tag{2}$$

Where λ is the wavelength (Cu Kα), β is the full width at the half- maximum (FWHM) of the peak and θ is the diffraction angle. Here the λ is 1.54 Å (Cu-Kα) value of β is 0.017 and value of 2θ is 36^0, putting the values particle size obtained is around 85 nm. X-ray diffraction analysis (not shown here) of the samples showed that the particles have a wurtzite structure.
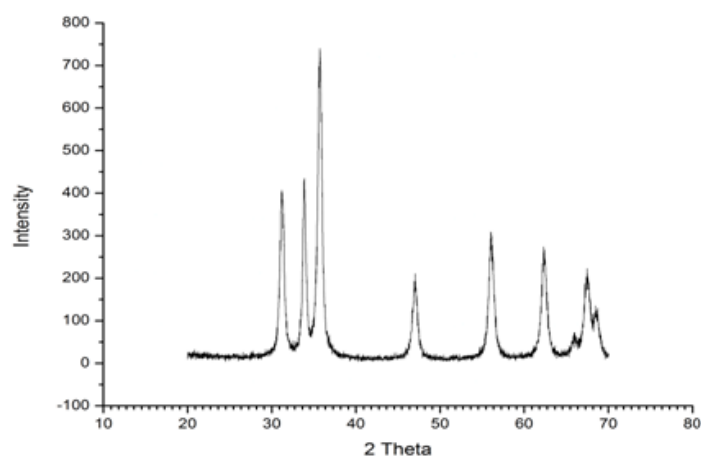

Fig. 3 XRD pattern of sol gel mediated ZnO nanoparticles

3.3 Scanning Electron Microscopy

Fig. 4(a) and 4(b) shows the SEM images of the sol-gel mediated ZnO nanoparticles. Scanning Electron Microscopic (SEM) analysis was done using Hitachi S-4500 SEM machine. Scanning electron microscope was used to decide size, location and shape of the Zinc Oxide nanoparticles. These images demonstrated that zinc oxide nanoparticles were spherical in shape. The maximum probability of the size was around 84.89 nm. The other particles were also formed around 146.1 nm which had less probability. Fig. 4(b) shows the clear view of the shape of the nanoparticles and gives an evidence of the formation of well formed nanoparticles.
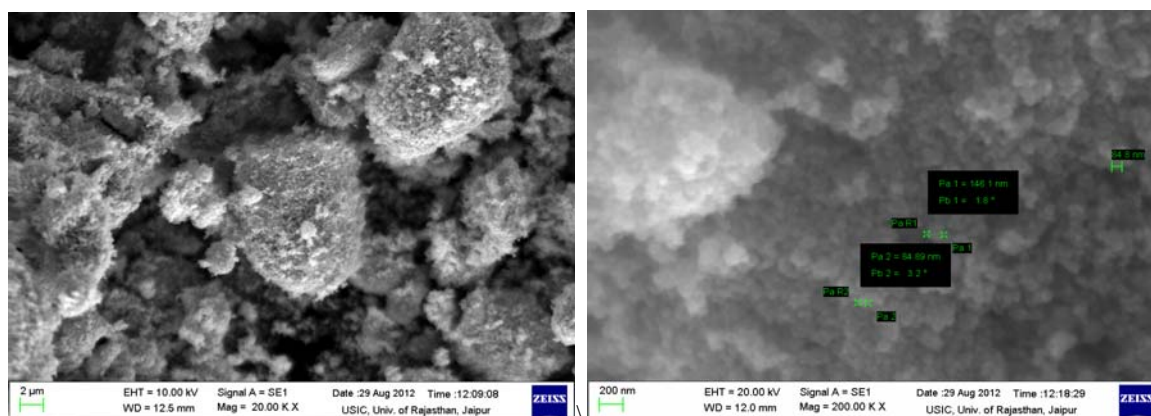

Fig. 4(a) and Fig. 4(b) shows the SEM images of sol-gel mediated ZnO Nanoparticles

4.   CONCLUSION

This synthesis procedure leads to the formation of highly pure and monodispersed ZnO nanoparticles. Highly stable and resistant to photo oxidation nanoparticles were obtained. UV-Visible Spectroscopy studies confirms the semiconducting nature of the nanoparticles by estimating their band gap to be 3.65 eV and it also confirms the synthesis of monodispersed ZnO nanoparticles. XRD studies gives the average particle size of the nanoparticles to be 85 nm. Finally, SEM analysis gives the shape and size of the particles which is tetragonal and around 84 nm (maximum probability). In this way, sol-gel mediated ZnO nanoparticles are synthesized which are of low cost and are stable for longer duration.

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REFERENCES

[1]   Hahn H. *Unique Features and Properties of Nanostructured Materials*, Vol/Issue: 9(3), 1997.
[2]   Schaffer, C. B.; Jamison, A. O.; Mazur, E. *Applied physics letters*, Vol. 84. Pp. 1441, 2004.
[3]   Hwang, C. Y. "Nanomedicine", *Nanotechnology and Medicine*, Vol. 3. Pp. 95-101, 2007.
[4]   Thakkar, K. N.; Mhatre, S. S.; Parikh, R. Y. "Nanomedicine", *Nanotechnology, Biology and Medicine*, 2010.
[5]   Matejka, P.; Vlckova, B.; Vohlidal, J.; Pancoska, P.; Baumruk, V. *The Journal of Physical Chemistry,* 1992.
[6]   K. Sobha, K. Surendranath and V. Meena. *Biotechnology and Molecular Biology Reviews*, Vol/Issue: 5(1), 2010.
[7]   U. Abhulimen. *Mater.Res.Soc.Symp.Proc,* Vol/Issue: 1(27). Pp. 1, 2005.
[8]   M. A. Shah and M. Al-Shahry. *JKAU: Sci* ,Vol. 2. Pp. 61, 2009.

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