Journal of Advances in Applied Sciences and Technology

ISSN : 2393-8188 (print)
2393-8196 (online)
www.milliyasrcollege.org.journal.php

ZINC OXIDE NANOPARTICLES FOR PHOTOVOLTAIC APPLICATIONS

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ABSTRACT:

In present era zinc oxide semiconductor crystals are widely used in photovoltaic applications. Zinc oxide nanoparticles are having wide range of optical and electrical properties like large binding energy of 60 meV and large energy band gap of 3.37 eV. In addition, Zinc Oxide is the environmental friendly, having good electron mobility, better photoconduction properties and transparent to entire visible range. Therefore, Zinc Oxide is becoming more and more popular in third generation hybrid solar cells. Present investigation deals with the study **o**f structural and optical characteristics of zinc oxide nanoparticles for photovoltaic applications. Synthesis of zinc oxide nanoparticles was carried out by Sol-gel method. Zinc acetate dehydrate and sodium hydroxide were used as initial materials with methanol as solvent. The structure and morphology of as synthesized zinc oxide nanoparticles was studied using X Ray Diffractometer (XRD) and Scanning Electron Microscope (SEM) respectively. SEM micrographs exhibited the spherical shape of zinc oxide nanoparticles. The UV-VIS absorption spectra indicated blue shift in wavelength. Secondary bending at 663.75 per cm in the FTIR spectra confirms the synthesis of zinc oxide nanoparticles. The synthesis of hybrid solar cell using as produced zinc oxide nanoparticles is under investigation.

KEYWORDS: Zinc Oxide nanoparticles, sol-gel method, XRD, UV visible absorption.

1. INTRODUCTION

Zinc Oxide (ZnO) nanoparticles are popular in Physics, Chemistry and Material Sciences. From past two decades the ZnO nanoparticles are commonly used in gas sensor [1], chemical sensor [2-3], bio-sensor [4-5], cosmetics, optical and electrical devices, window materials for displays and Solar cells [6-10]. ZnO nanoparticles are transparent semiconductor oxide having piezoelectric and dielectric nature. ZnO semiconductor is having wide range of optical and electrical properties with large binding energy of 60 meV and large band gap of 3.37 eV [11-14]. In addition, Zinc Oxide is environmental friendly, hardest of all II-VI semiconductors due to high melting point (2248 K) and having large cohesive energy (1.89 eV) [15]. Hybrid solar cells are comprised of a blend of conjugate polymer and inorganic semiconductor materials with the expectation that the device will integrate the advantages of both the organic and inorganic materials [16]. ZnO is one of the popular inorganic materials used in hybrid solar cell as it is environmental friendly, ease to synthesize and transparent to entire visible range [17].

Different techniques are used to synthesize ZnO nanoparticles including microwave irradiation method [6], chemical method [15], hydrothermal method [18] and sol-gel [9] method. However, sol-gel method is popularly used because it is low cost, less hazardous, environmental friendly, requires simple equipment and provides rigorous control on shape and size of nano particles. In the present investigation ZnO nanoparticles were synthesized by sol-gel method using zinc acetate dehydrate and sodium hydroxide as precursors and methanol as solvent. Characteristics of as produced ZnO nanoparticles were studied from the point of photovoltaic applications.

2. Results and Discussion

Material and Methods:

All the reagents used in the experiments were in analytical grade purchased from Rankem India Pvt. Ltd. and used without any further purification.

0.2M solution of zinc acetate dehydrates in methanol was produced by sonicating the mixture for two hours at 30 degree Celsius. Then 0.2M solution of sodium hydroxide in De-ionized water was added slowly in this solution to attain the pH value approximately 12. Solution was further Sonicated for one hour. The precipitate obtained was filtered and washed thoroughly in methanol. The filtered paste was dried in oven at 80 degree Celsius for 10 hours. The flow diagram of synthesis of ZnO nanoparticles is shown as in figure 1.

The morphology of the as synthesized sample was examined by a Hitachi Model S-300H scanning electron microscope (SEM). The crystal structure of the sample was characterized by Bruker AXS D8 Advance X Ray diffractometer using Cu Kα radiations having wavelength 1.54 A.U. UV-VIS measurements were made by a Shimatzo UV spectrophotometer-1800. The FTIR analysis was carried out using Bruker-Alpha spectrophotometer.

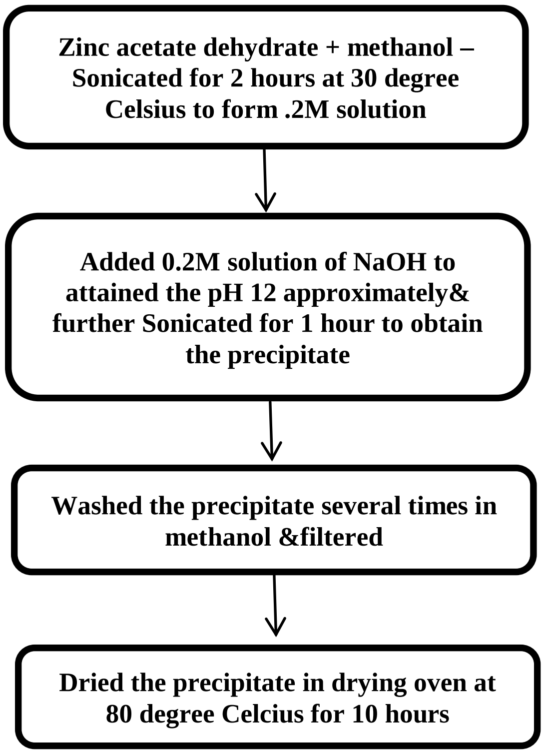

***Figure 1**: Flow diagram of synthesis of ZnO nanoparticles*

2.1 XRD Analysis of Zinc Oxide Nanoparticles

Figure 2 Shows the XRD pattern of ZnO nanoparticles. The diffraction peaks show the hexagonal wurtzite nano-crystalline nature of sample as per JCPDS card no. - PDF#800075ICDSD# 067849. The XRD pattern of synthesized ZnO nanoparticles is identical to the hexagonal phase with Wurtzite structure with space group (C6V=P63mc) and unit cell parameters a = b = 3.253 Å and c = 5.209 Å. Peak characteristics of any impurity were found to be absent. The average grain size of ZnO nanoparticles was determined using Debye Scherrer relation given by the formula

$$d = \frac{0.9\lambda}{\beta cos\theta}$$

where $\lambda = 1.54*10^{-10}$ m is the wavelength of X rays used in XRD investigation, β is full width at half maxima and θ is the diffraction angle in radian. The diffraction angles and calculated d values of sample for different peak are tabulated in table 1. The average size of the ZnO nanoparticles was found to be 16.89 nm.

Table 1 XRD results of ZnO nanoparticles

Peak	2θ	d in nm
1 0 0	32.93	12.62
0 0 2	35.614	19.884
1 0 1	37.404	21.078
1 0 2	48.74	12.446
1 1 0	57.69	21.614
1 0 3	64.06	16.808
2 0 1	69.03	13.794

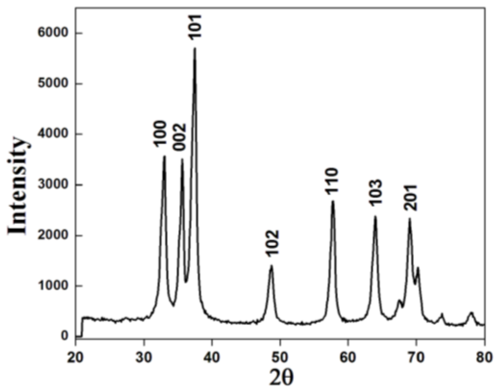

Fig. 1 XRD pattern of ZnO nanoparticles

2.2 SEM Analysis of Zinc Oxide Nanoparticles

Figure 3 shows the morphology of the as prepared ZnO nanoparticles analysed by Scanning Electron Microscope. The medium and high resolution SEM images demonstrate clearly the formation of spherical shaped nanoparticles.

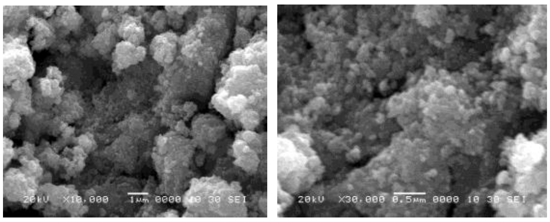

Fig. 3*: SEM images of ZnO nanoparticles*

2.3 UV VISIBLE ANALYSIS OF ZNO NANOPARTICLES

UV visible absorption curve of ZnO nanoparticles is shown in figure 4, it can be seen that the sample is transparent to the entire visible range of the spectrum so useful in producing the hole blocking layer in solar cells.

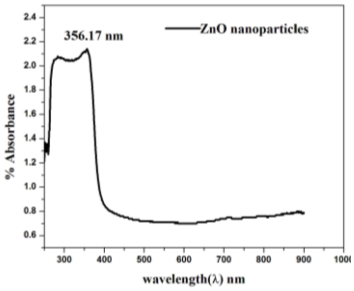

Figure 4*: UV visible spectra of ZnO nanoparticles*

An absorption peak at 356.17 nm is observed, the band gap energy of the ZnO nanoparticles can be obtained by extrapolating the Tauc's curve. The Tauc's curve is the curve between photon energy hν and $(\alpha h\nu)^2$ where h is Planck's constant, ν is frequency of incident radiations and α is the absorption coefficient. The curve is as shown in figure 5

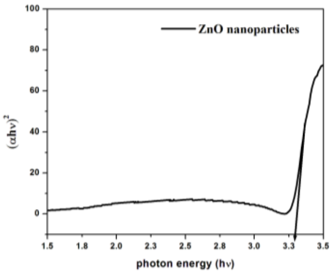

Figure5*: Extrapolation curve showing the band gap energy of Zinc Oxide nanoparticles*

From the figure 5 the band gap energy of ZnO nanoparticles is blue shifted shortly and it was observed to be equal to 3.397eV. Of course the quantum confinement blue shifted the band gap from 3.37 eV to 3.397eV.

2.4 FTIR ANALYSIS

The FTIR spectrum of as produced ZnO nanoparticles is shown in figure 6. The secondary stretching of Zn-O bond is observed at 662 per cm. Many other functional groups also exist. The functional groups at 1400 to 1700 approximately are corresponding to C-O symmetric and anti-symmetric stretching modes, 3500 to 3800 vibrations may correspond to first overtone of fundamental stretching mode of O-H group. This indicates that water molecules are bounded to surface of nano particles. And the peak observed at 2359 may correspond to C-H stretching mode.

3. CONCLUSIONS

The ZnO nanoparticles were synthesized by sol-gel method and the characteristics of as produced ZnO nanoparticles were studied. FTIR spectrograph confirmed the format-ion of ZnO nanoparticles. SEM spectrographs show the granular nature and spherical shape of the ZnO nanoparticles. XRD investigation confirms the wurtzite hexagonal structure of the ZnO nanoparticles.

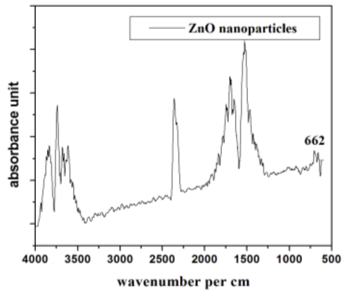

Fig. 6: *FTIR spectrograph of ZnO nanoparticles*

Average size of the ZnO nanoparticles is found to be 16.89 nm. The blue shift observed in absorption of ZnO nanoparticles must be due to quantum confinement effect. The use of synthesized ZnO nanoparticles in hybrid solar cell is under investigation.

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