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Synthesis of Semiconductor ZnO Nanoparticles Using Hydrothermal Method for Polymer Materials

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Abstract

Polymers are macromolecules having a similar chemical arrangement of monomers. These undergo structural deformation and change in properties when subjected to higher temperatures. To overcome these issues, additive materials need to be added into the polymer which makes them as "conductive polymers". One such material is Zinc Oxide(ZnO) and ZnO nanoparticles are successfully synthesized by using hydrothermal method from liquid phase precursor in this study. The nanoparticles were characterized by Scanning Electron Microscope (SEM) and UV-Vis spectroscopy. The results exhibit the morphological structure and absorption peak at around 303nm confirming the presence of prepared ZnO nanoparticles. These ZnO nanoparticles when added into polymers will increase the conductive property of polymer. The developed method was highly favourable for industrial applications for simple processing and cost effective synthesis.

Keywords: *ZnO nanoparticles, Hydrothermal method, conductive polymers.*

1. Introduction

Conducting polymers, now a days have more interest due to its excellent physical and chemical properties in the presence of some additive materials like carbon black, carbon nanotubes, ZnO, TiO_2, SiO_2, etc [1]. The novel properties of conductive polymers have wide commercial applications like high thermal stain withstanding, electrical conductivity and bio-compatibility. Some major advantages of inorganic hybrid conducting are non- toxicity, low cost, structural sustainability and doping with various ions[2].

Zinc oxide is a remarkable semiconductor nanomaterial and has interesting physical properties. The cost effective preparation of ZnO has made quick attraction from industrial resources. Wide applications of ZnO nanomaterials are in energy devices, photoprinting, antimicrobial [3], optical application like LED, sensors and photocatalyst etc. The cost effective synthesis of ZnO nanomaterials via liquid phase techniques include sol- gel, emulsion, homogeneous precipitation[4], aerosol process, sonochemical, mechanochemical process and hydrothermal methods[5].

Solid phase synthesis involves grinding process that makes ways for impurities into the process and non-uniform aggregation of ZnO nanomaterials. Sometimes vapour phase synthesis preferred for high purity ZnO nanomaterials but high energy and temperature is required [6]. The size and morphology of the ZnO nanoparticles was controlled during synthesis, by means of

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three significant surfactants namely, Triton (TX-100), sodium dodecylsulfate (SDS) and cetyltrimethylammonium bromide (CTAB) [7].

In this work, ZnO nanoparticles were successfully synthesized via hydrothermal method. Like in any chemical based synthesis, the parameters to be taken care are the concentration of precursor, stirring time, nature of solvent and temperature of synthesis. The similar work with different concentration of precursor was carried out in another work [8]. This investigation carried out by interpretation of band gap value into Max Planck equation. It has to be noted that the concentration of ZnO nanoparticles needs to be varied better conductive application as the optimum concentration of ZnO nanoparticles in a polymer may not be the same in all cases. This work is mainly focus to increase the interest among the researchers about conductive polymers in commercial applications.

2. Experimental Section

2.1. Materials

Synthesis of Zinc Oxide nanoparticles via hydrothermal method, in this research includes the use of several materials such as Zinc Acetate Dehydrate (Zn $(CH_3COO)_2.2H_2O$) and Sodium hydroxide (NaOH) which were purchased from Sisco Research Laboratories Pvt. Ltd. As per reported procedure all chemicals are used with further dilution using distilled water as solvent medium.

2.2. Synthesis of ZnO nanoparticles

The ZnO nanoparticles are prepared by the following procedure. 2g of Zinc acetate dehydrate was dissolved in 15 ml of distilled water. 8 g of sodium hydroxide was dissolved in 10 ml of distilled water in a separate beaker. Prepared sodium hydroxide solution was titrated against zinc acetate dehydrate solution slowly under constant stirring for about five minutes at room temperature. Obtained solution was stirred for further 1 hour. After the reaction, milky white solution was formed and the solution was filtered using filter paper. Then, filtered precipitate was transferred to hot air oven for 2 hr at 110^0C. Synthesized product was found as white powder.

$$(Zn(CH_3COO)_2.2H_2O) + 2NaOH \rightarrow ZnO + 2NaCH_3COO + H_2O \quad (1)$$

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3. Result and Discussion

3.1. UV-Vis Spectroscopic Result

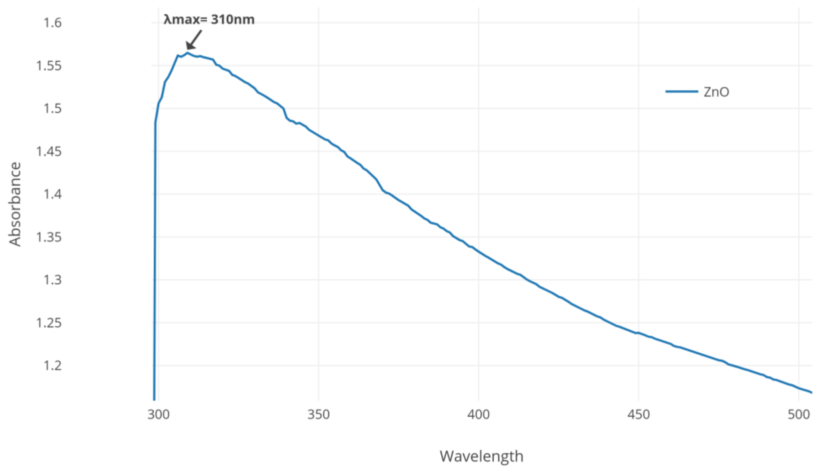

Figure 1: UV-Visible Absorption Spectra Of Zno Nanoparticles

UV Visible spectroscopic analysis of synthesized ZnO nanoparticles was shown in Fig.1. This UV Visible spectroscopy showed the existence of ZnO nanoparticles. The maximum absorbance peak was at **λmax at 310 nm.** The similar experimental work with dissimilar precursor done by Mohd Qasim et al., exhibited different UV-Visbile spectroscopy absorbance in the range of λmax at 300 to 500nm. The change in absorbance can be due to concentration of the precursor, particle size distribution and agglomeration [9].

$$E = \frac{h * c}{\lambda} \qquad (2)$$

The particle agglomeration and size distribution are responsible for the various other smaller peaks in the graph. The optical band gap was calculated by Max Planck equation (2), Planck constant (h) is 6.626×10^{-34} Js and velocity of light (c) is 2.99×10^{8} m/s and the band gap calculated is **4.00 eV**.

ZnO nanoparticles when added into polypropylene resulted in increased breakdown strength and electrical conductivity as reported by Zhao et al [10]. The temperature increase in the ZnO dopant Polyaniline will increase the conductivity and this can be calculated by the following expression ($\sigma(T) = \sigma_0 \exp[(-T_0/T)^{1/4}]$), where, σ is the conductivity, T is the temperature and σ_0 is the conductivity at characteristic temperature T_0 was done in similar work [11]. For the same conductivity test performed using Polypyrrole/ Zinc Oxide Nanocomposite reported increase in electrical conductivity of about 20% than polypyrrole [12]. Studies on LDPE revealed that with addition of ZnO nanoparticles with wide band gap of 3.4 eV increased the dielectric constant of the nanocomposite in a linear fashion [13].

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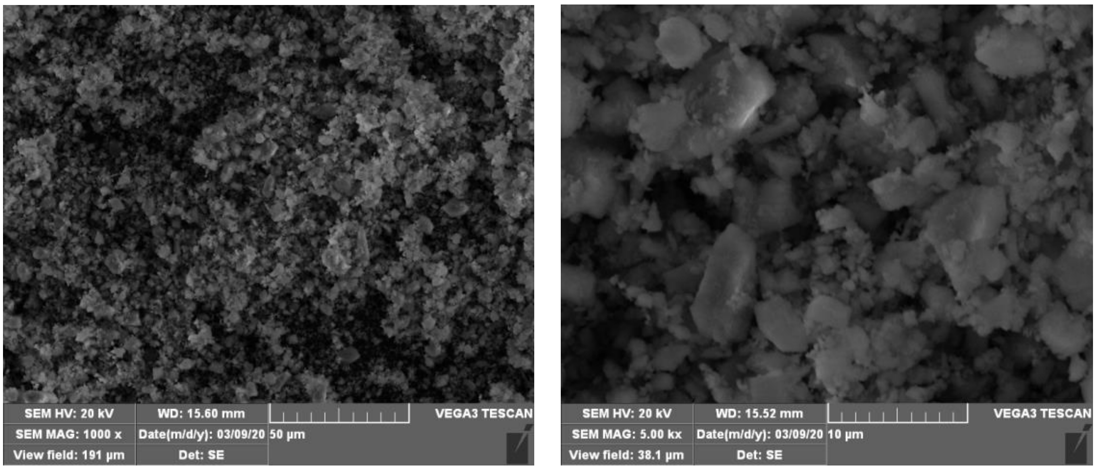

3.2. Surface Morphology

(a) (b)

Figure 2: SEM image of ZnO nanoparticles with (a) 1000X magnification & (b) 5000X magnification

The Scanning electron micrographs of ZnO nano structures are shown in Figure 02. The morphology study of synthesised ZnO was found like aggregate flower structure with high density. This formation can be attributed to higher concentration of precursor than in other methods. This same work did by Lee Sang Duck et al using Zinc acetate as precursor shows smoother and less aggregated of ZnO nanoparticles [14].

4. Conclusion

In this work ZnO nanoparticles were synthesized in cost effective hydrothermal process. The characterized result of SEM and UV-Visible spectroscopy of the nanomaterial was analyzed. The band gap the ZnO nanoparticles in this work was 4.09 eV. In addition to its semiconducting nature, these ZnO nanoparticles when incorporated into the polymer chains, they also increase the mechanical strength of the polymers considerably.

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