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Studies on optical, structural and thermal properties of CdS:PEO nanocomposite solid films having different molar concentration

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ABSTRACT

Cadmium Sulphide (CdS) nanoparticles were incorporated in PEO matrix. No capping agent was used other than the polymer to reduce the size of the CdS particles. The optical properties of the CdS:PEO nanocomposites were analysed and the transmittance of the solid films was found to be above 80%. The structural analysis of the nanocomposites was carried out using Transmission Electron microscope (TEM) and Atomic force microscope (AFM) and the particle size variation for different concentrations of CdS:PEO nanocomposites and the size distribution of CdS particles incorporated in the polymer matrix was analysed. The thermal properties of CdS:PEO nanocomposites were analysed using Differential scanning Calorimetry (DSC). The melting point shift of PEO matrix and the thermal stability of the matrix after incorporating CdS were found.

1. Introduction

Semiconductors in nanocrystalline form are focused by many researchers owing to their potential applications in the area of optoelectronics and nanoelectronics [1,2]. The unusual physical and optical properties of these materials make them good candidates for variety of applications. Semiconductor materials often change their properties dramatically when their dimensions are reduced to the nanometer length range. Semiconductor nanomaterials have interesting physical and chemical properties and useful functionalities when compared to conventional bulk counterparts and molecular materials [3,4]. These novel properties of semiconducting nanomaterials have attracted significant attention in the area of emerging technologies such as nanoelectronics, nanophotonics, energy conversion, non-linear optics, miniaturized sensors and imaging devices, solar cells, catalysis, detectors, photography and biomedicine [5].

Cadmium sulphide (CdS) is a direct band gap semiconductor which belongs to II–VI group of semiconductors. A band gap of 2.4 eV corresponding to the wavelength of 515 nm is the characteristic feature of bulk CdS at room temperature [6]. The properties of CdS nanoparticles are driven mainly by two factors i) the increase in the surface to volume ratio and ii) a drastic change in the electronic structure of the material due to quantum mechanical effects with decreasing particles size. This means that the band gap of CdS semiconductor can be tuned by changing the size of the particles. This tunable property arises due to the quantum confinement effects when the particle size approaches 10 nm or less [7]. Semiconductor

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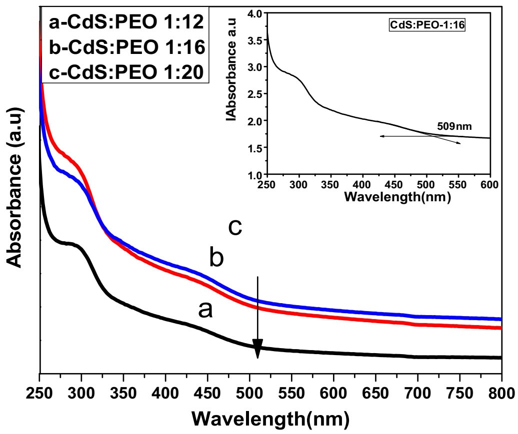

Fig. 1. Absorption spectra of CdS:PEO composites (1:121:161:20).

CdS nanoparticles are widely studied and synthesized as quantum dots, because of their unique properties which can be utilized even in photoreactivity and photocatalyst applications [8].

Another advantage of CdS that makes it a popular choice in photoelectric applications is that the particles absorb the visible part of the electromagnetic spectrum. The applications that make use of this property include solar cells, photodiodes [9], light emitting diodes, optical switches, optical sensors, electro luminescence devices and biomedical tags [10]. In this aspect, not only size tunability plays a major role, but also control over surface properties, control of aggregation and stability of the particles are essential qualities for device applications. Hence, semiconductor nanocomposites can be prepared to achieve the above said properties. Polymers can act as co-ordination sites for the incorporated nanoparticles and the polymer itself can prevent the particles from agglomeration. In the present article, CdS nanoparticles has been incorporated in Poly(ethylene Oxide) (PEO) matrix to control the size of the particles, control over agglomeration and for good surface properties.

Based on the literatures, we have reported the optical, structural and thermal properties of CdS:PEO nanocomposite solid films of different molar concentrations prepared via solution casting route. The novelty of the work was the preparation of solid films of CdS:PEO by simple and cost effective solution technique without any capping agent other than the polymer. Also the band gap was tuned by reducing the size of the CdS particles incorporated in the polymer matrix and the optical property of the nanocomposites was enhanced.

2. Experimental method

Poly (ethylene oxide) ($M_W = 4 \times 10^5$ g/mol) and cadmium nitrate $Cd(NO_3)_2.4H_2O$) were supplied by Aldrich and have been used for the preparation of nanocomposites. In the initial case, the molar ratio of Cd $(NO_3)_2$: PEO was taken as 1:121:16 and 1:20 for solid films of higher CdS concentration. After studying the properties of the prepared films, to improve the quality of the solid films, the concentrations had been changed as 1:100, 1:200, 1:300, 1:400, 1:500 and 1:600 M concentration. PEO was dissolved in 50 ml of acetonitrile and stirred continuously using a magnetic stirrer. After rigorous stirring for 3 to 4 h, Cd $(NO_3)_2{\cdot}4H_2O$ was added to the same PEO solution and stirred further for the homogeneous distribution of $Cd(NO_3)_2$ in PEO matrix. Now, the salt was completely dissolved in the solvent containing PEO. The solution obtained was then transferred to petri dish and dried in ambient temperature to form thin solid films by completely evaporating the solvent. The dried films were then exposed to H_2S gas for controlled flow of gas from a Kipp's apparatus for half an hour. The films slowly changed from white color to yellow which was the indication of the formation of CdS. The simple reaction mechanism for the formation of CdS particles in the matrices was

$$Cd(NO_3)_2 + H_2S \rightarrow CdS + 2HNO_3\uparrow$$

The thickness of CdS:PEO solid films of different concentrations was found using interferrometric technique and the average thickness of solid films having higher CdS concentrations (1:12, 1:16, 1:20) was around 25 μm–30 μm. For other molar concentrations (1:100, 1:200, 1:300, 1:400, 1:500 and 1:600), the average thickness of the solid films was around 10 μm.

3. Results and discussions

3.1. Optical properties

The optical properties of the CdS:PEO composites were studied using the absorption spectra. Fig. 1 shows the absorption spectra of CdS:PEO composites having higher CdS concentration (1:12, 1:16, 1:20). The band edge was measured by taking the intersection of the tangents drawn on the horizontal region between 500–600 nm and the inclined region between