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Research Article

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Preparation and Structural Characterization of Mn^{2+} Doped CdTe Nanoparticles by Co-precipitation

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ABSTRACT

Semiconductor nanoparticles are currently being extensively studied due to their unique size dependent properties. It has been demonstrated by several groups that nanocrystalline II-VI semiconductors show enhanced luminescence, increased oscillator strength and shorter response time. There has been great interest to control the size of nanoparticles using surface capping agents. Polymers are able to achieve surface passivation, prevent particles from agglomeration which are in favour of controlling the particles size and size distribution effectively. Mn^{2+} doped CdTe nanoparticles using PVA as assisting agent were prepared from co-precipitation method. From powder X-ray diffraction studies, the crystal system is indexed to cubic phase and the corresponding lattice cell parameters are evaluated. The evaluated average crystallite size of prepared sample is in nano scale. SEM and TEM micrographs show irregular shaped particle size clusters and EDS analysis confirms the presence of constituent elements of the prepared material.

Keywords: CdTe, Semiconductors, Co-precipitation and Structural properties.

INTRODUCTION

The intense interest in the science of materials confined within the atomic scales stems the fact that these nanomaterials exhibit fundamental unique properties with great potential of next generation technologies in electronics, computing, optics, biotechnology, medical imaging, drug delivery, aerospace and energy etc. [1]. Metal oxides and telluride's play a very important role in many areas of chemistry, physics and materials science. These can adopt a vast number of structural geometries with an electronic structure that can exhibit metallic, semiconductor or insulator character. In technological applications, these are used in the fabrication of microelectronic circuits, sensors, piezoelectric devices [2-10]. Incorporation of semiconductor nanocrystals (NCs) into functional polymers is a highly desirable approach to generate novel materials for use in optoelectronic devices, such as light emitting diodes (LEDs) and photovoltaic cells [11]. Since the discovery that nanocrystalline materials have interesting physical properties, these materials have found many applications. Recently, II–VI compounds synthesized at nanometric scale have been considered as building blocks to construct and design nanoscale photonic devices and sensors [12-14].

Nanoparticles based on II-VI and III-V semiconductors have been the most widely studied systems in the recent decades. Among different semiconductor materials, II-VI semiconductor nanoparticles are considered to be an important group with considerable progress in the synthesis and utilization of their unique properties [15, 16]. II-VI semiconductors are: ZnO, ZnSe, ZnS, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, HgTe etc. Wide – band gap II-VI compounds are expected to be one of the most vital materials for high performance optoelectronic devices such as light-emitting diodes (LEDs) and laser diodes (LDs) operating in blue or ultraviolet spectral range [17-20].

Many fabrication techniques have been attempted for depositing CdTe nanoparticles. Some are controlled atmosphere based techniques like sputtering [21], thermal evaporation [22], e-beam evaporation [23], Molecular Beam Epitaxy (MBE) [24], Co-precipitation [25], Metal-organic chemical vapour deposition (MOCVD) [26]. All these techniques are extremely expensive and require specialized equipment. Among these, co-precipitation is the most convenient method because of its simplicity, low cost, easy to add doping materials and the possibility of varying the film properties by changing composition of starting solution. In the present work, Mn^{2+} doped CdTe nanoparticles were prepared by co-precipitation method. The prepared samples were characterized by XRD, SEM with EDS and TEM studies to collect the information about the structural properties of prepared samples.

EXPERIMENTAL SECTION

Analytical Reagent (AR) grade of cadmium chloride ($CdCl_2$), Sodium hydrogen telluride (NaHTe), Poly vinyl alcohol (PVA), Manganese Oxide (MnO) were used as starting materials and used without further purification. Double distilled water was used as a solvent in the experiment. 0.045 g of cadmium chloride was added to 2.3 g PVA and volume of the solution was completed to 50 mL by double distilled water. The complete solution was left for 24 hours at room temperature to swell. After that the solution was warmed up to 80°C and stirred for 6 hours until viscous transparent solution was obtained. One milliliter (mL) of sodium hydrogen telluride (NaHTe) was dropped into the solution with gentle stirring and then 0.01 mole % manganese oxide was added to it to get the transparent solution. The prepared solution was casted on flat glass plate dishes. After the solvent evaporation, a thin film containing manganese doped PVA capped CdTe nanoparticles was obtained. The excess of unsoluble salts were removed from the surface of the films by washing the films using de-ionized water before characterization. Powder X-ray diffraction pattern of the prepared sample is recorded on a PANalytical Xpert Prodiffractometer with CuK_α radiation. Scanning electron microscope (SEM) and energy dispersive spectrum (EDS) images are taken on ZEISS EVO 18. Transmission electron microscope (TEM) images are recorded on HITACHI H-7600 and CCD CAMERA system AMTV-600 by dispersing samples in ethanol.

RESULTS AND DISCUSSION

3.1 Powder X-ray Diffraction Studies

XRD pattern of Mn^{2+} doped PVA capped CdTe nanoparticle was shown in Figure 1. The XRD pattern shows the highest intensity diffraction peak at $2\theta = 23.78^\circ$ along with small intensity peak at 40.15° (JCPDS file No. 15-0770). The diffraction data is indexed to a cubic phase and the corresponding lattice cell parameter is a = 0.642 nm with volume V = 26.953 nm.

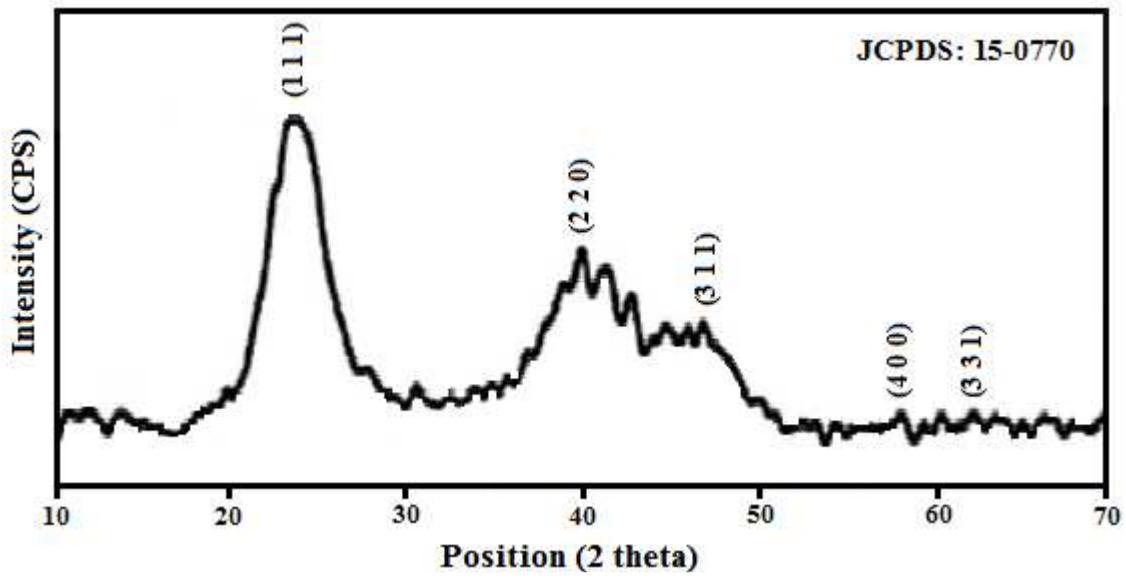

Figure 1: Powder XRD pattern of Mn^{2+} doped PVA capped CdTe nanoparticles

The average crystallite size is calculated from the full width at half maximum intensity of the XRD peaks using Debye - Scherrer's formula,

$$D = (K \lambda / \beta \cos\theta)$$

where D is the mean crystallite size, K = 0.9 is Scherrer constant, λ is the wavelength of the incident beam, θ is the diffraction angle and β is the full width half maximum intensity of the diffraction peak. From the XRD pattern, the calculated value of average crystallite size is 6 nm. The broadening of diffraction peaks indicates the formation of nano-sized particles.

3.2 Morphological Studies

Figure 2 shows the SEM images of Mn^{2+} doped PVA capped CdTe nanoparticles at different magnifications. The SEM micrographs show uniformly distributed spherical like structures with a little agglomeration. The agglomeration could be induced by densification resulting from the narrow space between particles. Further, the TEM analysis was performed to obtain the microscopic morphology and structural information. Figure 3 illustrates the TEM images of Mn^{2+} doped PVA capped CdTe nanoparticles. The TEM images represents spherical and sphere like structures with the diameter of about 20 nm.

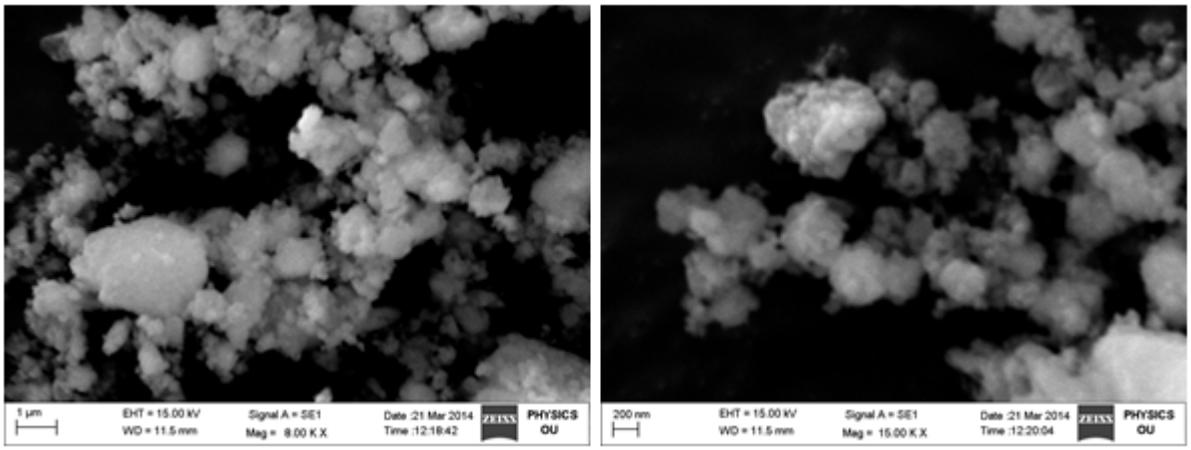

Figure 2: SEM images of Mn^{2+} doped PVA capped CdTe nanoparticles

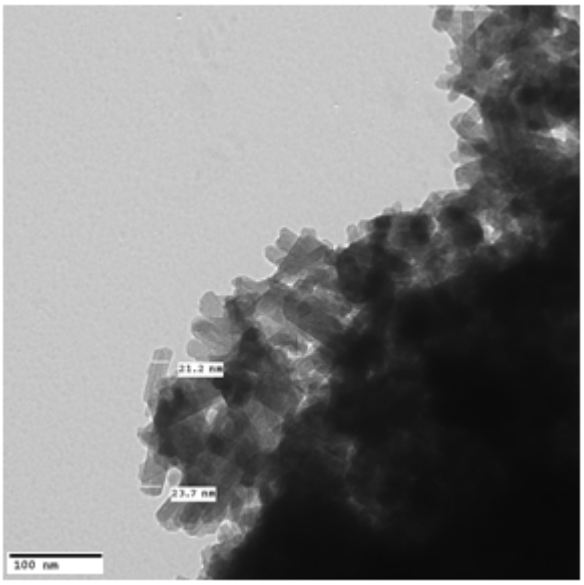

Figure3: TEM images of Mn^{2+} doped PVA capped CdTe nanoparticles

CONCLUSION

In summary, images of Mn^{2+} doped PVA capped CdTe nanoparticle was synthesized by co-precipitation method. Powder XRD pattern confirms the cubic phase of the prepared materials. From diffraction data, crystallite size was evaluated from Scherrer's formula which was in the order of nano size. SEM and TEM analysis showed uniformly distributed spherical like structures.

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