Study of Optical Properties of Cadmium Telluride (CdTe) Nanoparticles Synthesized by Simple Chemical Co-Precipitation Method

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ABSTRACT : In this work, CdTe nanoparticles has been prepared by Simple Chemical Co-Precipitation Method in which 0.8 mol of Cadmium acetate of AR grade was used as the cadmium source and 0.01 mol of tellurium dioxide of AR grade as the telluride source. Triethanoloamine (TEA) was used as a complexing agent and hydrazine hydrate was used as a reducing agent for tellurium. The synthesized nanoparticle samples was characterized by X- ray diffraction (XRD) and the average crystallite size was found to be 43.52 nm. The band gap energy was calculated from UV-visible absorption spectra and found to be 0.93 eV.

Keywords: Chemical Co-Precipitation, CdTe, Nanoparticles, UV-visible spectroscopy, X-ray diffraction

1. INTRODUCTION.

In recent years, Semiconductor nanoparticles can find applications in nano-metric sized devices such as nano LEDs because of its unique optical and electronic properties that are strongly dependent on their size, shape and surface modification [1-4]. Among the most widely used semiconductor nanoparticles having narrow band-gap, cadmium telluride (CdTe) belonging to II-VI semiconductor nanomaterials has received much attention. Because, it possesses the properties like high absorption coefficient and nearly optimum band-gap energy for the efficient absorption and ability for conversion of solar energy [5-7]. The photoluminescence (PL) quantum efficiencies of CdTe is high. This property in turn makes it an interesting material for use in applications such as light emitting devices, photovoltaic devices and biological labels [8-11]. It also possesses properties such as high resistivity and high absorption (> 104 cm^{-1}) for the visible solar spectrum[12-13]. CdTe nanoparticles are generally prepared through the solution chemistry and organometallic methods [14-15]. The growth of CdTe nanoparticles via physical methods such as ball milling has also been reported and laser ablation. But the organometallic routes has disadvantages due to its properties like toxical nature, expensive providing less stability in air and less reproducibility. However, CdTe nanoparticles synthesized through reactions comprising of aqueous chemistry are environmentally benign. They also have merits like simplicity, reproducibility and stability. So, in the present study, the simple chemical co-precipitation method is employed to synthesize CdTe nanoparticles for investigation of its structural characterization and optical properties.

2. EXPERIMENTAL DETAILS.

Cadmium acetate and tellurium dioxide of AR grade were used as the source for cadmium and telluride ions respectively. 0.8 mol of cadmium acetate was dissolved separately in 50 ml of double distilled water and magnetically stirred to form a clear solution. 0.01 mol of tellurium dioxide was also dissolved separately in 50 ml of hot diluted sulphuric acid and magnetically stirred to form a clear solution. Triethanoloamine (TEA) was used as a complexing agent to form $Cd[TEA]^{2+}$ for controlling growth rate. Hydrazine hydrate [H_2N-$NH_2.H_2O$] was used as a reducing agent for tellurium. The role of hydrazine hydrate is to reduce Te^{4+} ions in TeO2 to Te^{2-}. 25ml of TEA and 8ml of hydrazine hydrate were added to precursor cadmium acetate solution and mixture solution was stirred for 1o min. 25% of ammonia was added to this solution to maintain the pH at 9.96. The solution of tellurium dioxide was added to the mixture solution of cadmium acetate and the resultant solution was stirred slowly until the precipitate is formed. The overall reaction can be represented as follows :

$$[Cd(TEA)n\,]^{2+} + Te^{2-} + 2OH^{-} = CdTe + n(TEA) + H_2O.$$

The precipitates so formed were filtered out and washed four times with double distilled water. The precipitate was finally dried at 100°C for 5 h to obtain the sample. The sample is crushed to obtain the powder samples and the same was annealed at 300°C for 3 h to obtain CdTe nanoparticles.

3. RESULTS AND DISCUSSION

3.1 XRD STUDY

The structural characterization was done by an X-ray diffractometer (Bruker D8 Advance) in the 2θ range (20^0–80^0) using CuKa radiation of wavelength λ = 1.5406A°. The XRD patterns of as synthesized CdTe Nanoparticles is shown in figure 1. The formation of CdTe Nanoparticles is confirmed by the standard reference JCPDS data 82474. The XRD peak shows that CdTe is nanocrystalline with a hexagonal structure with peaks at 2θ = 24.21, 37.81 and 38.59 with the orientations (1 0 1), (0 0 4) and (110) respectively.

The inter planar spacing (d spacing) is calculated by using Bragg's equation,

$$` \mathbf{n\lambda = 2dSin\theta} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where λ = 1.5406A° (wavelength of incident X-ray), θ = Peak position (in radian), n = 1(Order of diffraction), d = inter planar spacing or d spacing (in A°). The lattice parameters for hexagonal system of CdTe nanoparticles is calculated by the equation,

$$\frac{1^2}{d^2} = \frac{4}{3}\left(\frac{h^2 + hk + k^2}{a^2}\right) + \frac{l^2}{c^2} \quad \ldots\ldots\ldots\ldots(2)$$

The crystallite size of CdTe nanoparticles is calculated by using Scherrer's formula

$$D = \frac{K\lambda}{\beta \cos\theta} \quad \text{..................(3)}$$

where K is a constant (= 0.94), β is the full width at half maximum (FWHM) in radian at 2θ. The d-spacing corresponding to corrected crystal planes (1 0 1), (0 0 4) and (110) are found to be 3.68 Aº, 2.37 Aº and 2.33 Aº respectively. The lattice parameters are found to be a = 4.66 Aº and c = 9.48 Aº which is comparable with the reports of earlier workers [16]. The average crystallite size of the as synthesized CdTe nanopartciles was found to be 43.52 nm

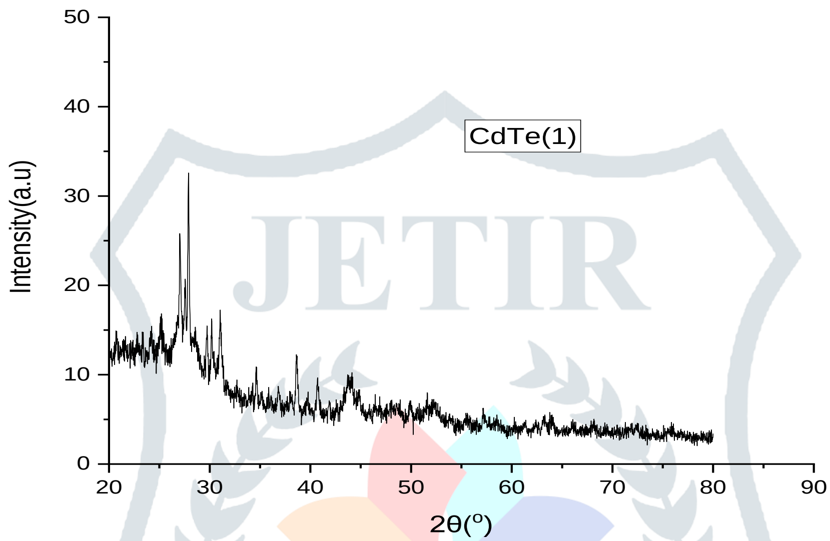

Figure 1. XRD pattern of as synthesized CdTe Nanoparticles

4. OPTICAL STUDY.

The optical property of CdTe nanoparticles is studied with the help of UV-Visible Spectroscopy. The UV absorption spectrum of CdTe nanoparticles taken at room temperature are shown in Figur 2(a). The absorption coefficient α associated with the strong absorption region of the sample, absorbance (A) and the cuvette thickness (t) are related as below [17- 19].

$$\alpha = 2.303\, A / t \quad \text{............(4)}$$

The absorption coefficient of direct band gap semiconductor is given by [30]

$$\alpha = c\,(h\nu - E_g)^{1/2} / h\nu \quad \text{.................. (5)}$$

where α is absorption coefficient, c is a constant, hν is incident photon energy and E_g is the band gap energy. Graph between hν vs $(\alpha h\nu)^2$ is plotted and shown in Figure 2(b). The intercept of the extrapolated straight line at the $(\alpha h\nu)^2 = 0$ axis gives the value of the E_g of the material. The values of E_g so obtained is found to be 0.93

eV which is very small as compared to value in bulk state(1.44 eV) [20]. Such a material having reduced band gap energy may be suitable for use in nanowire-dye sensitized solar cells [21].

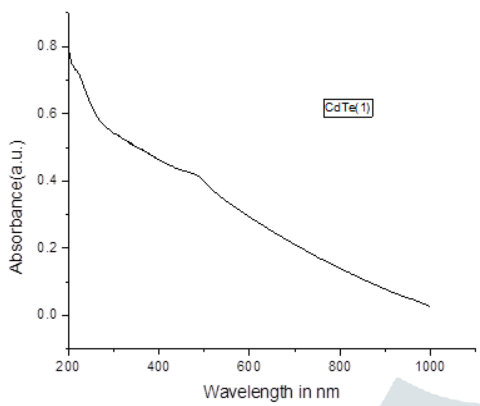

Figure. 2(a). Absorption spectrum of CdTe naoparticles

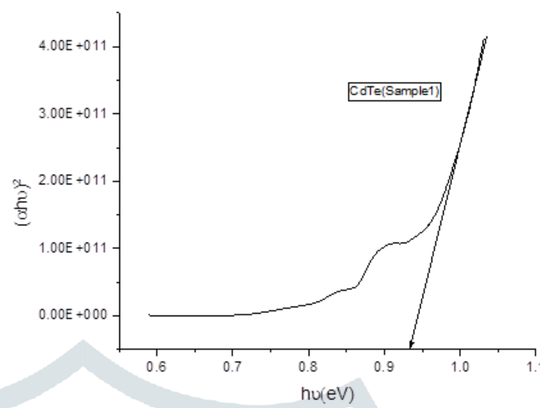

Figure.2(b). Plot of of hν vs (.αhν)^2 of CdTe nanoparticles

5. CONCLUSION.

We have demonstrated the preparation of CdTe nanoparticles by simple co-precipitation method. The nanoparticles so synthesized are characterized by XRD and UV-Visible Spectrometer. The average crystallite size is found to be 43.52 nm. The Energy Band Gap of CdTe NPs synthesized by this method is found to decrease at 0.93 eV. The materials having such band gap energy may find many applications in nanowire-dye sensitized solar cells.

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