OPTICAL AND MAGNETIC PROPERTIES OF CDS NANOPARTICLES PREPARED BY MICROWAVE ASSISTED METHOD

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Abstract - Cadmium sulphide nanoparticles were prepared by microwave assisted method using cadmium acetate as cadmium source and sodium sulphide as sulphur source. The prepared sample is characterized by XRD, FTIR, FESEM, UV-Vis spectroscopy and VSM. X-ray diffraction shows the CdS in cubic phase. FESEM image reveals particle like structure. From the FTIR spectra showed a characteristics Cd-S stretching vibration at 613 cm^{-1}. Optical bandgap of CdS nanoparticles is estimated as 2.58 eV. The second harmonic generation efficiency (SHG) is 2.42 times of KDP. Vibrating sample magnetometer (VSM) provided the hysteresis curve with magnetic saturation value of CdS nanoparticles is 0.022 emu/g.

Keywords: CdS nanoparticles; optical bandgap; SHG efficiency and magnetic studies.

I. Introduction

The synthesis of group II-VI semiconductor has been the focus of recent scientific research due to their important non-linear optical properties, luminescent properties, quantum size effect and other important physical and chemical properties [1]. It has a direct bandgap of 2.5 eV at room temperature. Among these materials, CdS one of the most important II-VI group semiconductor has potential applications for light-emitting diode, solar cells, sensors, non-volatility of data storage and photocatalysis [2]. CdS is one of the most promising materials in II–VI family because of its inherent properties. In present study reports the structural, morphological, optical, nonlinear optical and magnetic studies of microwave assisted CdS nanoparticles.

II. Experimental

Preparation of CdS nanoparticles by microwave assisted method

0.1 M of $Cd(NO_3)_2$ was dissolved in 50 mL of double distilled water and 0.2 M of Na_2S was dissolved in 50 mL of double distilled water and then stirred for 2 hours to obtained pale yellow colour solution. The yellow colour solution was placed in a domestic microwave oven at 453K for 10 min. Microwave irradiated solution was centrifuged at 12000 rpm for 5 min. The centrifuged solution was irradiated for 30 minutes at 453K in domestic microwave oven (2.45 GHz, 750W). The final product was collected and subjected to various studies.

The synthesized compound was identified using XRD on a Riagu Mini Flexell Desktop Diffractometer (CuK_α, λ = 1.5406 Å). The morphology was examined by FESEM on VEGA 3 TESCAN SEM. The molecular structure was confirmed by JASCO 460 plus FT-IR spectrometer by KBr pellet method in the range of 400-4000 cm^{-1}. The linear optical absorption characteristics were recorded using a Perkin Elmer Lambda 25 spectrophotometer. Magnetic study was performed using Vibrating Sample Magnetometer (Lakeshore VSM 740).

III. Results and Discussion

Structural analysis

XRD patterns of the microwave assisted CdS nanoparticles is shown in Fig. 1a which indicates the CdS has cubic structure. The X-ray diffraction pattern revealed the major peaks at 2θ values of values of 26.3, 43.8, 51.9 and 71.5 corresponding to the (1 1 1), (2 2 0), (3 1 1) and (3 3 1) crystal planes respectively. The planes of CdS are well matched with standard JCPDS card no: 65-2887 corresponding to the purity of CdS nanoparticles. The broadened of diffraction peak provides information about the sizes of the particles being in the nano range. The average crystallite size (D) is calculated using Debye-Scherrer's formula [3]

$$D = k\lambda / \beta \cos\theta \quad (1)$$

where

K - is the shape constant (0.9),
λ - is the wavelength of X-ray (1.5406Å),
β - is the full width at half maximum (FWHM)
θ - is the glancing angle.

The average crystallite size of microwave assisted CdS nanoparticles is 26 nm. Williamson-Hall method (W-H) suggests a way to calculate the microstrain of the prepared CdS nanoparticles. Modified Scherrer equation is expressed as

$$\beta \cos\theta = (k\lambda / D) + (4\varepsilon \sin\theta) \quad (2)$$

The W-H plot is expected to be horizontal line, parallel to the sinθ axis, whereas in the presence of strain, it has a non-zero slope (Fig. 1b). The dislocation density strongly influences many of the properties of materials [4]. Dislocation density (δ) is calculated using the equation,

$$\delta = 1/D^2 \quad (3)$$

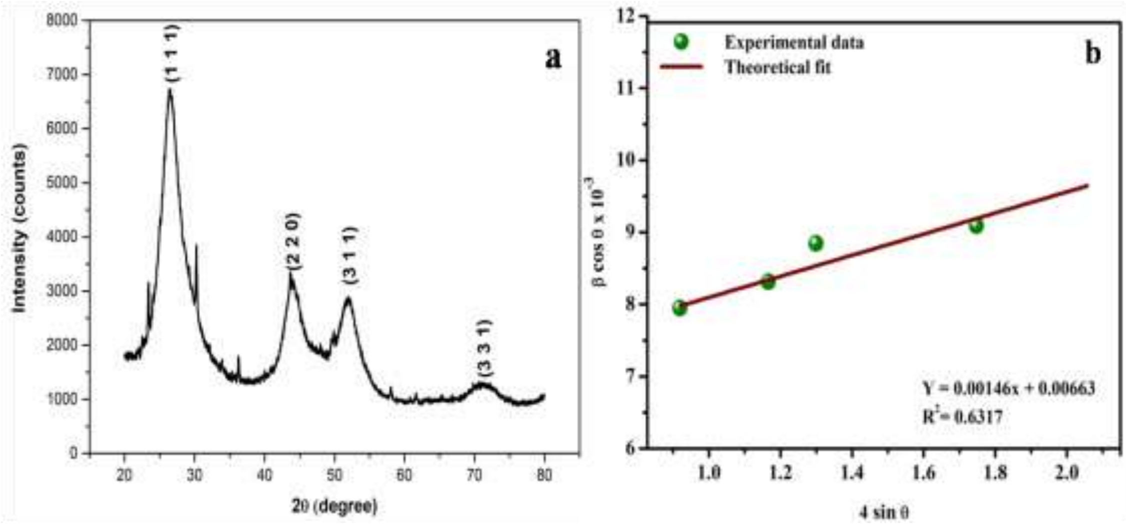

Fig. 1(a) XRD pattern and (b) W- H plot of CdS nanoparticles

The calculated strain and the dislocation density value of microwave assisted CdS nanoparticles are 0.00146 and $14.79X10^{15}$ lines/m^2 respectively.

FT-IR analysis

Fig. 2 shows the FT-IR spectrum of microwave assisted CdS nanoparticles. The broad absorption band at 3459 cm^{-1} is due to O-H stretching vibration of hydroxyl group of the water molecules present in the material. The relatively is intense S-O stretching absorption bands in the 750-1350 cm^{-1} region of IR spectrum. The peak at 2442 cm^{-1} clearly indicates the S-H stretching. The peak organized at 613 cm^{-1} which is due to the Cd-S stretching vibration [5-6].

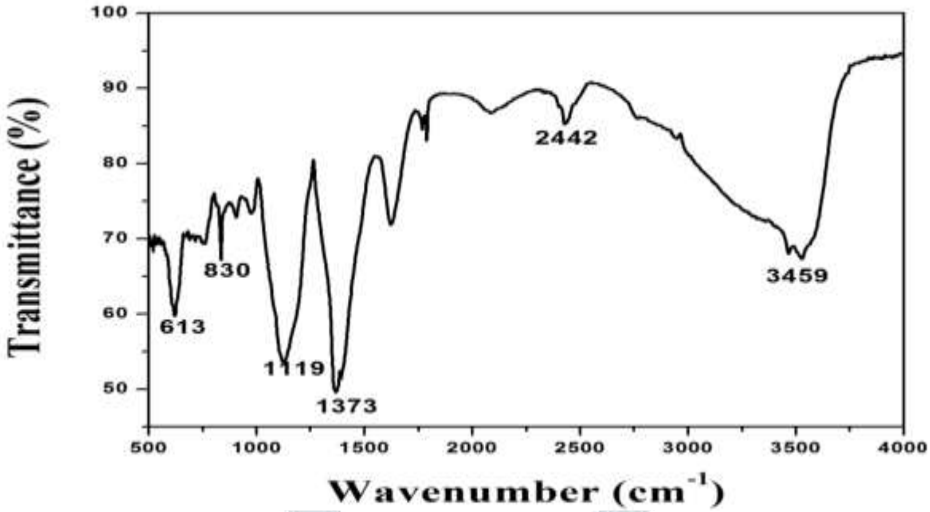

Fig. 2 FT-IR spectrum of microwave assisted CdS nanoparticles

Morphological analysis

Fig. 3a show typical SEM images of prepared microwave assisted CdS nanoparticles which indicate that the particles are in nano sizes. Fig. 3b shows the average particle size of the nanoparticles is 109 nm. The EDS of CdS nanoparticles is displayed in fig. 4, with a separate peak of Cd and S which ensured that the nanoparticles are cadmium sulphide.

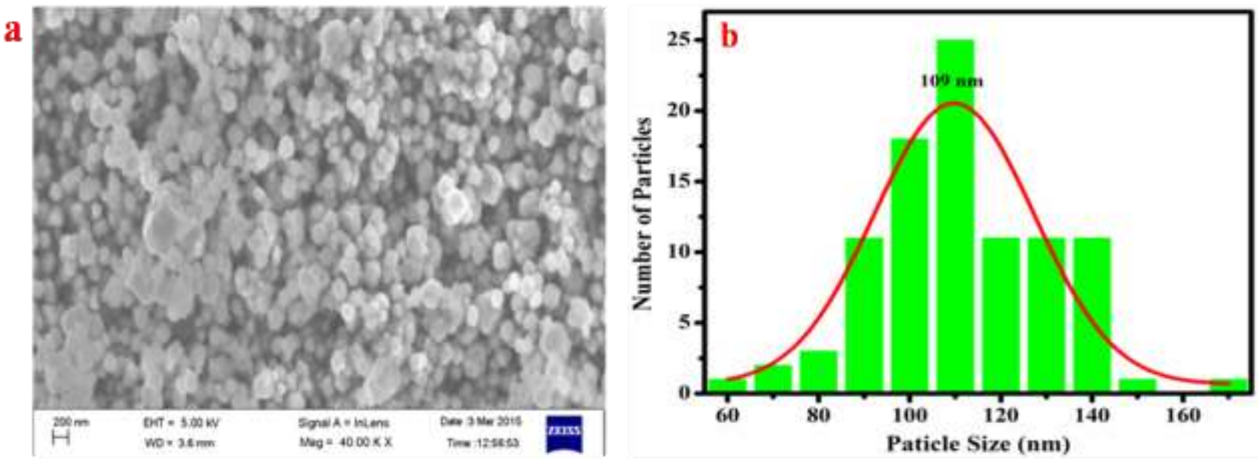

Fig. 3(a) FESEM image and (b) particle size distribution of CdS nanoparticles

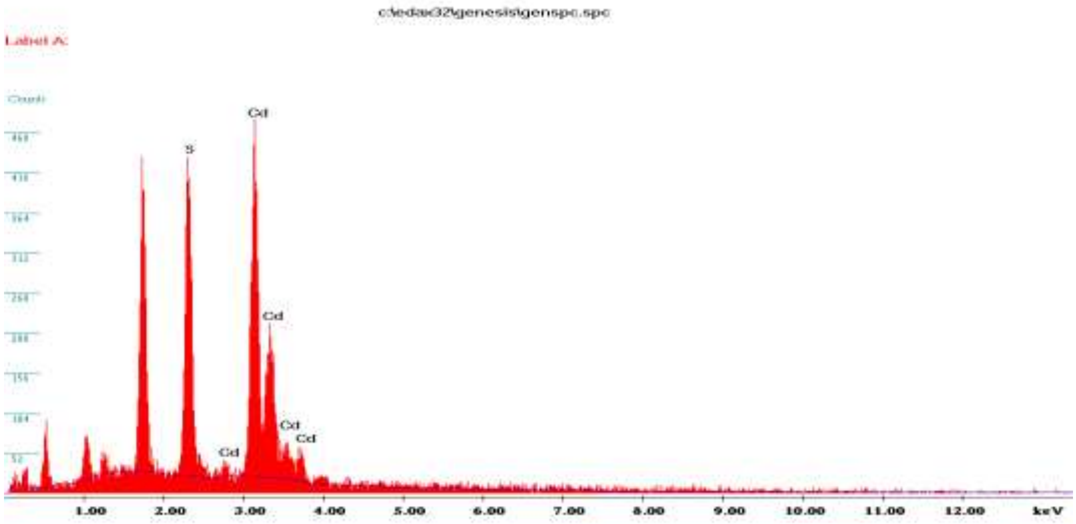

Fig. 4 EDS image of microwave assisted CdS nanoparticles

Optical studies

The relation between the absorption coefficient (α) and the incident photon energy (hυ) for the case of allowed direct transition [7-8]

$$\alpha h\upsilon = A\,(h\upsilon - E_g)^n \qquad (4)$$

where,

A - is the characteristic parameter (free of photon energy),
h -is Planck's constant,
υ -is the frequency of light,
E_g -is the optical energy bandgap
n -is the parameter which characterizes the transition process involved.

The parameter n got the value of 2 for direct allowed electron transition and ½ for indirect allowed electron transition. The plot of $(\alpha h\upsilon)^2$ Vs hυ is shown in fig. 5, from which the optical energy bandgap (E_g) is estimated by extrapolating the linear part up to zero on energy axis. The optical direct bandgap of microwave assisted CdS nanoparticles is 2.58 eV. This can apply these nanomaterials to be applied in photocatalytic activities and optical devices [9-10].

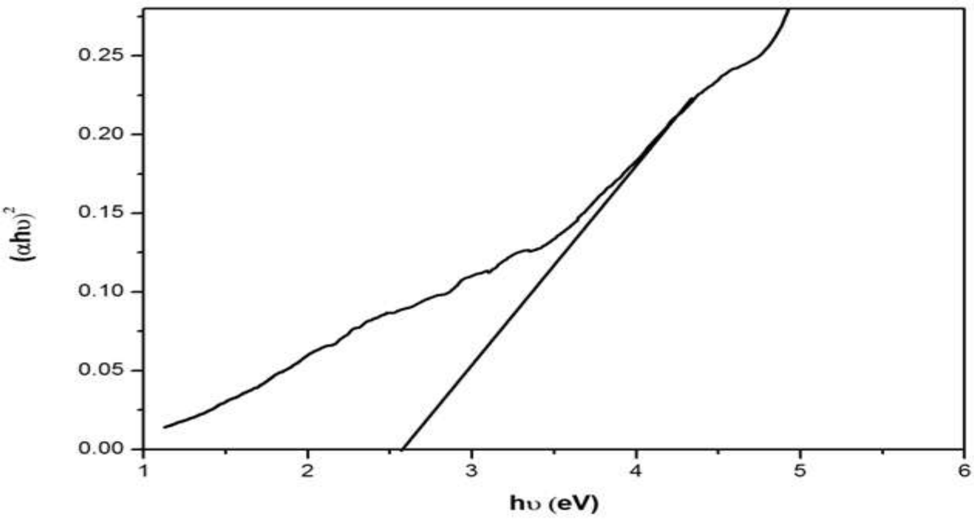

Fig. 5 Optical bandgap of microwave assisted CdS nanoparticles

Magnetic studies

The room temperature VSM measurement of microwave assisted CdS nanoparticles was carried out under the applied magnetic field of 0-15,000 Oe (Fig. 6). The presence of a small hysteresis with coercive field (H_c) of about 215 Oe and saturation magnetization (2.20×10^{-3}emu/g) indicates the weak ferromagnetic behaviour. Spin coupling effects of smaller particle size (26 nm) strongly affect the saturation magnetization of CdS. Particle size, structure, saturation magnetisation and crystallinity influence the magnetic properties of the nanomaterials. Particle size reduction and breaking of exchange bonds have impact on an unusual magnetic behaviour. This room temperature ferromagnetism arises from the creation of a spin-split impurity band at the Fermi level, below the conduction band due to the hybridization between the charge carriers of cadmium and sulphide. The microwave assisted CdS nanoparticles is used in non-volatile storage of memory devices [11].

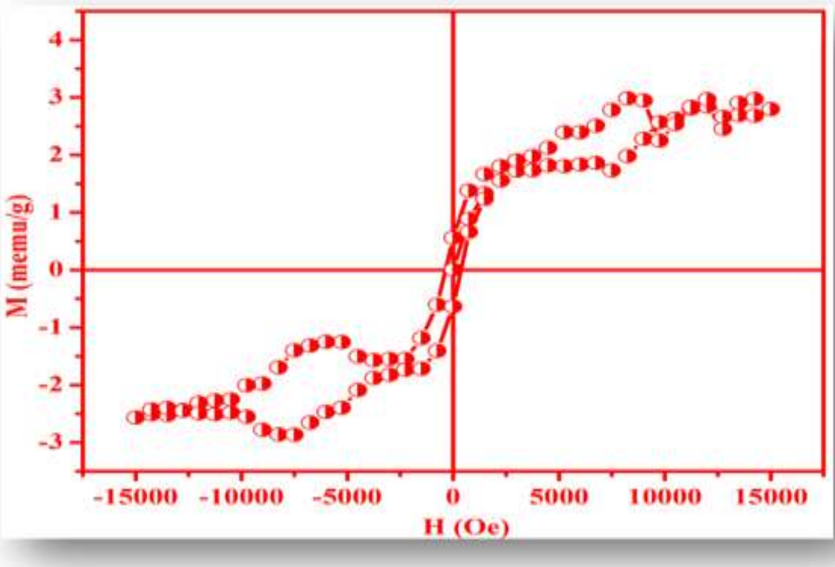

Fig. 6 M-H curve of microwave assisted CdS nanoparticles

Nonlinear optical studies

In the nonlinear optics system, the nonlinear polarization plays as a source for the generation of new waves. In this frequency conversion experiment, the nonlinear polarization is induced in the CdS sample by the Q-switched Nd:YAG laser (1064 nm, 9 ns and 10 Hz). The incident optical waves induce a phased array of dipoles that then radiate waves coherently at emission wavelength of 532 nm by harmonic generation. The relative SHG efficiency of microwave assisted CdS nanoparticles is 2.42 times of KDP [12-13].

Conclusion

In the present work, CdS nanoparticles were prepared by microwave assisted method. The XRD results exhibit the cubic crystalline structure. FT-IR results confirm that the stretching vibration of Cd-S at 613 cm^{-1}. The average particle size is 109 nm through SEM analysis. From the optical studies it is observed that the microwave assisted CdS nanoparticles can be used in photocatalytic applications. Synthesized CdS nanoparticles possess ferromagnetism and the value of the magnetic saturation has been found to be 0.022 emu/g and hence it may be useful in spintronic applications.

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