Thermoluminescence of Undoped and Cu Doped CdS Nanoparticles

Subhajit Chakraborty, Ranjit Singha, Binapani Goswami

Abstract: In this paper an attempt has been made to synthesize undoped and 1wt% Cu doped CdS nanoparticles through chemical co-precipitation method. Prepared particles were characterized to explore their structural and thermoluminescence properties. The X-ray diffraction analysis reveals a hexagonal crystal structure at room temperature. The particle sizes are determined by Scherer formula for both undoped and doped CdS nanoparticles of various concentrations. The average grain size of undoped and Cu doped nanoparticles is found to be 32.81 nm and 22.3 nm respectively. The thermoluminescence studies of these above samples show TL peaks occurring at temperatures 379, 428, 471, 510 and 550 Kelvin corresponding to activation energy 0.7 eV, 0.9 eV, 1.2 eV, 1.4 eV and 1.3 eV respectively.

Keywords: Activation Energy, Chemical Co-Precipitation, Nanoparticles, Scherer Formula, Thermoluminescence X-Ray Diffraction.

I. INTRODUCTION

Cadmium Sulphide (CdS) is a group II-VI semiconductor with a direct band gap of 2.42 eV at room temperature. Due to the strong size effect the electrical and optical properties of these nanoparticles vary significantly with their size [1-3]. CdS nanoparticles show high luminescence efficiency and have a potential for their use in several optoelectronic devices. It is an attractive material for a green light emitting diode [4] used as photo conducting, photovoltaic or optoelectronic materials. Thermoluminescence (TL) is the phenomenon in which substances like semiconductors or insulators irradiated with radiations like X-rays, v-rays etc emit light when heated gradually. The graph drawn between emitted light intensity verses temperature is known as “Thermoluminescence glow curve”. With the help of these glow curves we can find out different parameters of trapping states. In the present work an effort is made to study the morphological and thermoluminescence properties of the CdS nanoparticles prepared by chemical co-precipitation method. This method is a simple and inexpensive technique to obtain homogeneous and stoichiometric CdS nanoparticles.

II. EXPERIMENTAL

A. Preparation of Undoped and Cu Doped CdS Nanoparticles

Solutions of 0.1M CdSO₄, 2% PVA, and 0.1M Thiourea are prepared by magnetic stirring. For Cu doping a solution of 1wt% CuSO₄ is prepared. Temperature is maintained at a fixed value of 70 degree Celsius. CdSO₄ and CuSO₄ solution is mixed together under constant stirring to which PVA is added. pH of the solution is controlled by addition of ammonia solution. Finally Thiourea is added to get CdS particles as precipitate. The precipitate is then filtered and washed with distilled water and absolute alcohol.

B. Characterization of the Sample

The structural investigation of as prepared CdS nanoparticles are carried out using X-ray powder diffractometer (Model: Bruker D8 Advance powder diffractometer) with CuKα radiation (λ=0.15406 nm). The morphology of the particles are investigated by transmission electron microscope (TEM) [Model: JEOl JEM 100 CX-II] operated at accelerating potential 100 kV. Thermoluminescence glow curves are recorded by Nucleonix TLD Reader TL1009I.

III. RESULTS AND DISCUSSIONS

A. TEM Analysis

The morphology and the dimension of the prepared sample are determined by TEM and High Resolution Transmission Electron Microscopy (HRTEM) [Figure 1(a) and Figure 1(b)]. The TEM image shows the formation of cluster of nanoparticles nearly of equal size. The TEM image shows that most all the particles are nearly spherical in shape. The average diameter of the undoped CdS nanoparticles are found to lie between 30nm to 40nm while those for CdS:Cu(1wt%) lie between 20nm to 30nm. The result obtained from TEM analysis are found to be in agreement with the XRD (X-ray Diffraction) result. The SAED (Selected Area Electron Diffraction) pattern of the CdS nanoparticles shows polycrystalline nature of the particles in case of both undoped and doped samples.
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B. XRD Analysis

The XRD peaks are found to be very broad which indicates the very fine size of the grain. The XRD patterns (Fig. 2) exhibit the prominent peaks at 2θ value of 23.4028°, 30.274°, 36.26°, and 43.60° which corresponds to (100) [5], (200) [6], (102) [5], (220) [8] and (311) [8] respectively. The particle size was determined from the width of XRD peaks using Scherrer’s formula $D = \frac{(0.95\lambda)}{\beta \cos \theta}$ where β is the full width half maximum(FWHM), θ is the diffraction Angle, D is the average crystallite grain size and λ is the wavelength of X-rays [9]. The average grain size for undoped CdS nanoparticle is found to be 32.81 nm. The average grain size for CdS:Cu(1 wt%) is found to be 22.3 nm.

C. Thermoluminescence Analysis

X-ray irradiated thermoluminescence glow curves of CdS and Cu doped CdS nanoparticles are shown in figure 3(a) and 3(b) respectively. 10 minute X-ray exposure is obtained from Cu target operated at 30KV at 8mA.

The CGCD (Computerized Glow Curve Deconvolution) [9] of TL glow curves using Kittı’s equation resolve the TL peaks into four components as shown in figure 4(a) and 4(b). Undoped CdS nanoparticles show peaks occurring at temperatures (Tm) 379K, 428K, 469K and 508K, corresponding to activation energy (E) 0.7 eV, 0.9 eV, 1.2 eV and 1.4 eV respectively, with b values 2, 2, 1.8, and 2. Whereas, Cu doped particles gives peak at 386K, 556K, 608K, and 642K having thermal activation energies 0.3 eV, 1.3 eV, 1.1 eV, and 1.3 eV respectively with order of kinetics $b = 1.9, 2, 1.3,$ and 2 respectively. It is evident from the above data that a large shift of TL peak towards higher temperature region occurred due to Cu doping in the particles. TL parameters of CdS and CdS:Cu nanoparticles are shown in Table I.
IV. CONCLUSION

CdS nanoparticles both doped and undoped are prepared successfully in the laboratory through chemical co-precipitation method. Prepared particles are characterized for their structural and morphological properties using XRD and TEM, which confirms the formation of nanosized particles. The average grain size for undoped CdS nanoparticle is found to be 32.81 nm and for CdS: Cu (1 wt%) nanoparticle is found to be 22.3 nm. The TEM images of undoped CdS and Cu doped CdS nanostructure show that the particles exhibit approximately hexagonal structures. SEAD pattern reveal the polycrystalline nature of particles. The thermoluminescence studies of these above samples show a large shift of TL peaks towards higher temperature region when doped with Cu.

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REFERENCES


Table 1. TL parameters of CdS and CdS:Cu

<table>
<thead>
<tr>
<th>Sample</th>
<th>Peak Name</th>
<th>Tm (K)</th>
<th>E(eV)</th>
<th>b</th>
</tr>
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<td>CdS Undoped</td>
<td>Peak I</td>
<td>379</td>
<td>0.7</td>
<td>2</td>
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<td></td>
<td>Peak II</td>
<td>428</td>
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<td></td>
<td>Peak III</td>
<td>469</td>
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<td>Peak IV</td>
<td>508</td>
<td>1.4</td>
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<tr>
<td>CdS:Cu (1wt%)</td>
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<td>386</td>
<td>0.3</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
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<td>556</td>
<td>1.3</td>
<td>2</td>
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<tr>
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<tr>
<td></td>
<td>Peak IV</td>
<td>642</td>
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Invited Talk:
Invited talk on “Physics of the archaeological dating methods” National Seminar on Physics for Cultural Heritage on 25th and 26th May, 2012 at D.M. College Imphal.

Reviewer: Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy (Elsevier publication)

Binapani Goswami:
Educational Qualification: M.Sc Physics from Gauhati University, Ph.D from Assam University, Silchar.
Specialization: Condensed Matter Physics & Spectroscopy.