

Electroluminescence in Cd_{1-x}Zn_xS Nanocrystals

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Abstract

Cadmium Zinc sulfide ($Cd_{1-x}Zn_xS$) nanocrystals have been synthesized for different values of x (x = 0.0, 0.25 and 0.50) by chemical synthesis route. The structural studies were carried out by using X-ray diffraction (XRD) studies. Diffraction pattern reveal that samples are crystalline in nature having hexagonal (wurtizite) structure. Absorption spectra of specimens have shown blue shift in absorption edge in compared to bulk. Electroluminescence (EL) studies have revealed that EL starts at lower threshold voltage on increasing the Zn content in the ternary compound.

Keywords: Electroluminescence Nano crystals, XRD.

1. INTRODUCTION

II-VI compounds are attracting a great deal of attention because of their potential abilities in the wide spectrum optoelectronic devices [1]. Ternary materials provide a possibility of tailoring their properties as per requirements and hence project themselves as important semiconducting materials for further advancements in the field of device fabrication [2]. Semiconducting nanoparticles, especially sulfides doped with transition metal ions and rare-earth ions, have been studied extensively because of their excellent luminescence properties[3,4] The optical properties of doped nanomaterials differ from the corresponding host nanomaterials as the dopants form deep trap levels and act as luminescence centers.[5,6] Discrete energy states can be introduced in the band gap of semiconducting host by doping with transition metals such as Cu, Ag and Mn.[7] In this regard, the role of Cu as a luminescence activator is of considerable significance for II-VI compound semiconductors. There have been number research groups investigating Cu-doped of ZnS nanoparticles by chemical routes. Datta et al. investigated the effect of Cu incorporation on the phase transition from wrutzite to Cubic structure prepared by solvothermal process.[8] Geng et al. have reported the synthesis of ZnS:Cu²⁺ nanorods through a solution phase thermal decomposition molecule precursor route. They were able to tune the optical properties of the products by changing Cu doping concentration.[9] Unni et al. synthesize the CdS, CdS:Zn²⁺ and CdS:Cu²⁴ and reported the photoluminescence quenching at 15 wt % of Cu.[10] Ternary materials provide a possibility of tailoring their properties as per requirements and hence project themselves as important semiconducting materials for further advancements in the field of device fabrication [11]. Synthesis and Electroluminescence of $Cd_{1-x}Zn_xS$ nanorystals for different values of x= 0.0, 0.25 and 0.50, is reported in this paper.

2. EXPERIMENTAL

2.1 Synthesis of ternary Cd_{1-x}Zn_xS nanoparticles

Single source orgenometallic precursor technique has been used to prepare nanocrystalline $Cd_{1-x}Zn_xS$ particles [12]. CdCl₂, ZnCl₂ and (NH₂)₂CS dissolved in ethanol were used as sources of Cd^{2+} , Zn^{2+} and S^{2-} ions respectively. Sample were prepared in two part, solution X was prepared by dissolving $CdCl_2/ZnCl_2$ and [(NH_2)₂ CS] in 60 ml of ethanol in a flask under magnetic stirring at 60°C in oil bath. Another solution Y was prepared by dissolving sodium Hydroxide (NaOH) in 20 ml ethanol. Solution Y was added into Solution X. The mixed solution was held at 60°C under magnetic stirring. After adding the solution Y into solution X, a white precursor was obtained. The reaction system gradually become transparent and the color changed from white to blue and then to green yellow for x=0 and light brown yellow for x=0.25and 0.50. The solution samples were extracted and centrifuged to found $Cd_{1-x}Zn_xS$ nanoparticles.

2.2 Characterisation

The samples have been characterized by X-ray diffraction (XRD) and UV/VIS absorption spectra.

2.2.1 X-ray diffraction (XRD)

All the samples were characterized at Inter University Consortium (IUC) Indore. The morphologies and sizes of nanocrystalline $Cd_{1-x}Zn_xS$ were determined by X-ray diffraction studies with Cu K α radiation (λ =1.5418 Å). XRD data were collected over the range 20⁰-90⁰ at room temperature. X-ray diffraction patterns have been obtained



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by Rigaku Rotating Anode (H-3R) diffractometer. The particle size was calculated using the Debye-Scherrer formula. The samples have been characterized for their Xray diffraction (XRD). An X-ray diffraction spectrometer usually consists of a generator, water-cooled primary radiation source units, a diffractometer and a measuring electronic unit. X-ray diffraction instruments may vary slightly, depending upon the manufacture. Size of nanocrystals is determined from broadening of XRD peaks.

2.2.2 Absorption spectra

The absorption spectra of the sample have been studied by Perkin Elemer λ -12 spectrometer. UV/VIS spectroscopy is the measurement of the attenuating of a beam of light after it passes through a sample. Ultraviolet /Visible light are energetic enough to promote outer electrons to higher energy levels. This more qualitative application usually requires recording at least a portion of the UV-VIS spectrum for characterization of the optical properties of materials. The increase in the effective band gap has been estimated from blue shift in the absorption edge and the particle size is computed using effective mass approximation model.

2.3 Electroluminescence (EL) Study

For electroluminescence (EL) investigations, Cd₁₋ _xZn_xS layer is placed between SnO₂ coated glass plate and aluminum electrodes. A piece of mica sheet having a window of 2×2 mm is placed over the conducting glass and the sample powder is placed within this window and fixed with adhesive. An aluminum strip is fixed over the sample along with conducting gel in order to obtain good contact. For luminescence studies, the prepared EL cell is connected to AC EL power supply. The EL cell is placed at the slit of PMT (Photo Multiplier Tube) which is connected with the high voltage power supply and the picoammeter is connected for corresponding current, which record the output of the PMT. The EL excitation source was a low distortion audio generator coupled with an electroluminescence power supply (Wide Band Amplifier), AC Voltage at different frequencies was applied and EL brightness at different voltages was measured at each frequency, with the help of photomultiplier tube connected to a picoameter. The corresponding current was recorded by a multimeter, which is connected in series with the EL cell. A particular frequency is set in the audio generator and gradually voltage applied to the EL cell was increased and corresponding current and EL brightness were recorded.

3. **RESULTS AND DISCUSSIONS**

The XRD patterns of $Cd_{1-x}Zn_xS$ nanocrystalline samples are shown in Fig 1. From the figure it can be seen that the XRD pattern of sample (x=0.0) can be consistently indexed on the basis of the hexagonal, wurtzite structure, in which the prominent peaks at 20 values of 26.76° , 43.86° , 47.30° and 51.48° angles corresponds to the reflections at (002), (110), (103) and (112) planes.



Figure 1 XRD pattern of Cd_{1-x}Zn_xS nanocrystals

It was observed that on increasing Zn content in ternary alloy, peaks shift to higher angles. The crystalline size has been estimated from the broadening of the diffraction peaks using Debye-Scherrer formula. The size computed from XRD is in the range of 3 to 15 nm.





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Figure 2(a) Shows the absorption spectra of $Cd_{1-x}Zn_xS$ for x= 0.0, 0.25 and 0.50. The absorption edge shifts toward lower wavelength side with the increase of Zn concentration.

The energy band gap has been determined using absorption spectra. Figure 2(b) shows the plot of $(ahv)^2$ against the photon energy (hv) for samples with x=0.0, 0.25 and 0.5 respectively. The direct band gap of these nanoparticles was determined by taking an extrapolation of the linear region of a plot of $(ahv)^2$. Determined values of band gap of samples with (x=0, 0.25 and 0.5) are found 2.65, 2.93 and 3.21eV respectively.



Figure 3 Voltage-Brightness characteristics of Cd_{1-x}Zn_xS nanocrystals

Figure 3 shows EL brightness versus voltage curve for nanocrystalline $Cd_{1-x}Zn_xS$ powder samples. It is observed that EL starts at a threshold voltage and then increases first slowly and then rapidly with increasing voltage. The lower threshold and higher brightness have been observed with increasing Zn content. As voltage is increased, more electrons and holes are injected into the emission layer and their subsequent recombination increases the EL brightness. It is observed that at higher frequencies, light emission starts at lower threshold voltages, and electroluminescence brightness increases with increasing frequency.

4. CONCLUSION

 $Cd_{1-x}Zn_xS$ can be synthesized by environment friendly chemical synthesis technique. X-Ray diffraction analysis shows the hexagonal (wurtizite) structure for all the samples. Particle size was calculated by Debye-Scherer formula and found to be in range of 3-15 nm. The effective band gap energy has been determined from the absorption spectra and particle size is computed from the effective mass approximation (EMA) model. The particle sizes obtained by this method are in agreement with those from XRD. On increasing Zn content in $Cd_{1-x}Zn_xS$ nanocrystalline ternary compound the EL starts at lower threshold voltages and higher intensity is observed. This shows ternary $Cd_{1-x}Zn_xS$, by tailoring its properties, may be used as materials for further advancements in the field of device fabrication.

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