Sb_2S_3 Nanocrystals in glass

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ABSTRACT

In this work conventional quench method was adopted to fabricate Sb_2S_3 nanocrystals in glass. The glass composition was optimized for proper glass host matrix to grow semiconductor Quantum dots. The systematic compositional variation of network former and network modifier oxides can further reveal the effect of matrices on the formation of stibnite quantum dots. The dot sizes and their distributions were modified by heat treatment of glass samples in the temperature range from 500°C to 700°C. X-ray diffraction studies were carried out for size distributions and nanoparticles with size ranging from 25nm to 80nm were obtained. The size distribution of Sb_2S_3 nanoclusters was later confirmed by using transmission electron microscopy. Quantum dots so grown were further characterized by optical absorption and Photoluminescence spectroscopy.

Keywords: Sb_2S_3, photoluminescence, quantum dots, optical properties.

1 INTRODUCTION

Group V-VI compound have potential applications in photoconducting cells, photovoltic cells, optoelectronic devices, thermoelectric coolers, etc [1]. Among V-VI compounds antimony trisulfide is a promising candidate for solar energy as its band gap (1.6-2.2 eV) covers maximum spectrum of the visible and infrared region of the solar energy spectrum. It has the maximum value of the dielectric function of 10.9 and 14.4 for amorphous and crystalline form respectively [2]. Over the past two decades nanostructures compounds have attracted great attention in many scientific areas due to their improved electrical, optical, mechanical and thermal properties with respect to their bulk counterpart. So far a lot of work has been done on Sb_2S_3 thin films[3], nanowires by solvothermal route [4], nanoroads by complex decomposition approach [5],nanoparticles via the benzene thermal reaction of $SbCl_3$ and Na_2S [6]but fabrication of stibnite quantum dots still has major challenges.

Here we report the synthesis of Sb_2S_3 naoparicle in glass matrix by conventional quench method. The Sb_2S_3 nanocrystals are in weak confinement range i.e R= 25 nm to 80nm. Our principle characterization tools are X- ray diffraction, optical absorption and Transmission Electron Microscopy. The goal of this work is to explicate the structural and optical characteristics of nanocrystallites and identify the general growth parameters with the help of characterization tools.

2 EXPERIMENTAL

Different glass compositions were optimised to get a suitable glass composion to fabricate stibnite quantum dots. The optimized glass composition comprises 55% SiO_2, as a glass former 25% Na_2O, 18-20% K_2O as modifier and 2% ZnO. To ensure proper mixing and homogeneity of the composition the base glass constituents were mixed by wet ball milling. 5 wt% Sb_2S_3 of total glass composition was mixed by mortar pestle. The glass batch mixture was kept in an alumina crucible and melted in box furnace at 1300°C for 40 minutes. The glass was quenched in air. A transparent glass was obtained and glass smples were made od small dimension (5mm X 5mm). The heat treatment was done in the temperature range from 500°C to 700°C. X-ray diffraction studies were carried out by Rikaku Miniflex II. Optical absorption and TEM measurements were done by Ocean Optics HR-4000 and FEI TechnaiG^{2}30.

3 RESULTS & DISCUSSION

In annealing process quantum dots can be grown in glass by heating the glass sample at temperature slightly higher than glass trnsition temperature T_g [7]. Figure 1 shows some selected diffraction pattern of Sb_2S_3 doped glass samples, which match well with the reported data for Sb_2S_3 JCPDS file no 060474. X-ray diffractrograms of glass smples were used to calculate the average size of nanoparticles by using Scherrer formula. It is clear from the figure 1 that increase in annealing time and temparature increses the growth mechanism. A- glass sample annealed at 625 °C for 12 hrs has less FWHM value than D- glass sample annealed at 600 °C for 2 hrs. Nanoparticles with size ranging from 25 nm to 80 nm were obtained.

The particle size distribution of Sb_2S_3 nanoclusters was later confirmed by using transmission electron microscopy (Figure 2). TEM microgrph clearly exhibits the un homogeneous size distribution of stibnite quantum dots.

The dots so grown were further characterized for optical absorption. Figure 3 shows the optical absorption spectra of Sb_2S_3 dopted glass samples. We assume that the edge position obtained by interpolating the absorbance at

X- axis to be the band gap of the sample. The results indicate that the absorption in figure 3, curve B and C are attributing at same energy, this is because of the annealing temparature and time. The energies were 2.55eV, 2.43eV, 2.40eV, 2.2eV and 1.7eV for samples A to E.

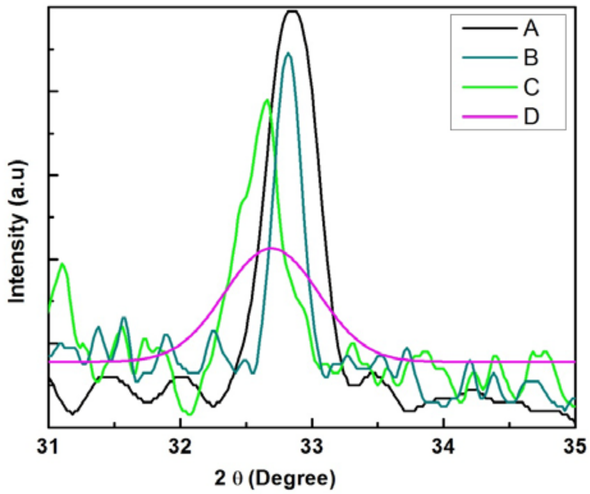

Figure 1. X-ray diffraction pattern of some selected glass samples (A- glass sample annealed at 625 °C for 12 hrs, B- glass sample annealed at 600 °C for 10 hrs, C- glass sample annealed at 600 °C for 6 hrs, D- glass sample annealed at 600 °C for 2 hrs).

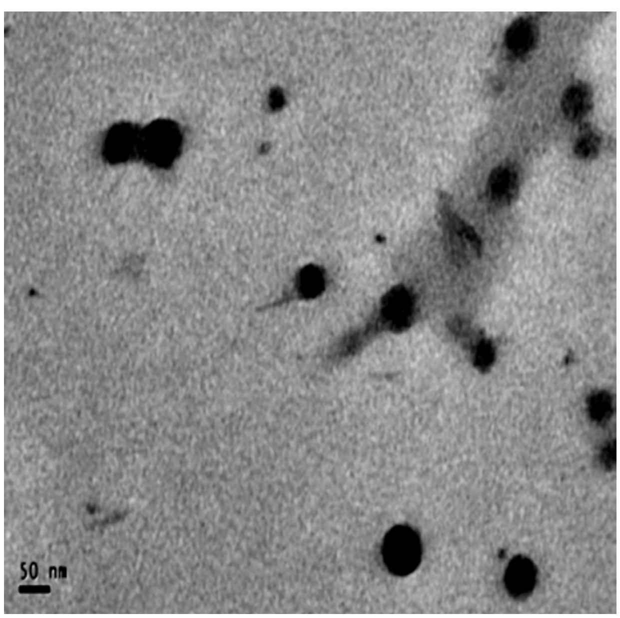

Figure 2. TEM micrograph for a glass sample annealed at 600 °C for 6hrs

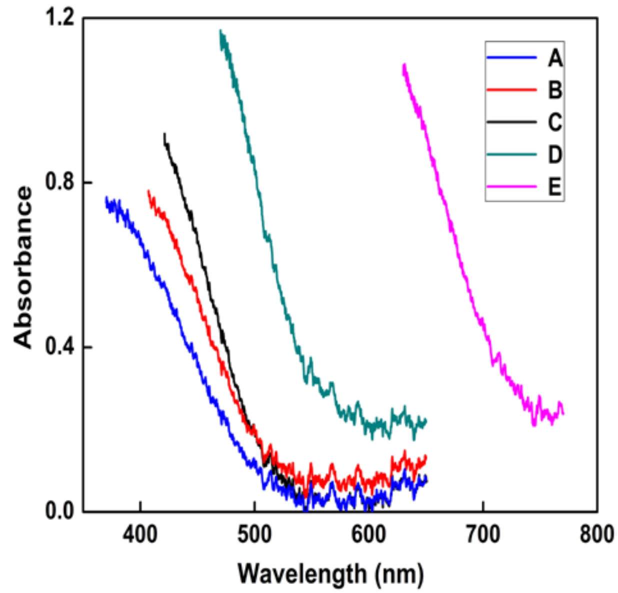

Figure 3. Representative optical absorption spectra measured at room temperature for Sb_2S_3 doped glass samples annealed at (A) 600 °C for 2 hrs, (B) 600 °C for 6hrs , (C) 625 °C for 4 hrs, (D) 600 °C for 10 hrs and (E) 625 °C for 12 hrs.

Absorption spectra show blue shift of absorption edge which is clearly a quantum confinement effect for glass samples with band gap increases from 1.7 eV to 2.55 eV.

4 CONCLUSION

Sb_2S_3 quantum dots were fabricated in glass matrix Glass samples were annealed at different temperature for various time duretion to grow quantum dots. X-ray diffraction study was carried out to calculate average size of nanocrystals. Nanoparticles with size ranging from 25 nm to 80 nm were obtained. TEM analysis confermed the size distribution obtained from XRD. Optacal absorption spectra shows the blue shift of absorption edge energy and band gap energy was obtained in range 1.7eV -2.55eV.

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