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Investigation of structural, morphological and optical properties of Zn doped CdS nanostructures synthesized via co-precipitation method

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ABSTRACT

The present work reported the Zn doped CdS nanostructures synthesized via using co-precipitation method from cadmium and sulphide particle arrangements with no ligands at different temperature arrangement and amalgamation time. The as synthesized CdS nanostructures were characterized by XRD, SEM, PL, Raman, FTIR and UV–vis spectroscopy to investigate the structural, morphological, and optical properties. XRD analysis revealed that all the samples were acknowledged the cubic crystal structure and crystallite size is found in 3–9 nm range. SEM analysis exhibits that synthesized material is in nano size range. PL, Raman and FTIR analysis also revealed that the inorganic component in all the synthesized samples is a CdS phase with a cubic crystal structure. An enhancement in optical band gap is observed with increasing Zn doping concentration in CdS nanostructures. The investigation revealed that Zn doping plays a significant role to tuning structural and optical properties of CdS nanostructures, which influence the particle size, band gap and morphology. Therefore, the synthesized CdS nanostructures at different doping concentration of Zn can be used as a window layer for solar cell applications and optoelectronic devices.

1. Introduction

In the recent years, the synthesis and studies of the structural, morphological and optical properties of nanomaterials especially group II—VI have drawn significant attention owing to quantum confinement effect related to small dimension of the nanoparticles that give them novel properties which makes them suitable to be used in LEDS, solar cells, fuel cells, drug delivery, optoelectronic devices and as catalysts for large industrial changes [1–4]. Among the different II—VI semiconductor group materials, cadmium sulfide (CdS) has got great attention in the observations and scientific community because of their wide band gap, high electron affinity and high photoconductivity and has potential applications in different keep records of science and technology such as electronic apparatuses such as thin-film FETs, solar unitsand LEDS [4,5]. Wide band opening in semiconductor materials is really important because of this quality it is possible to fabricate diodes and laser heterostructures for emission in the electromagnetic spectrum of the visible region. In addition, band-gap of CdS nanoparticles enables it to give high conversion efficiency in solar cells and opto-electronic devices. However, for such applications, doping and synthesis method play a significant role to tune the structural, morphological and optical properties. Recently, transition metal doped semiconductors which are known as dilute magnetic semiconductors, have engrossed extensive spread in

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scientific community and forfeit awarness to their prospective applications [6–8]. Doping of transition metals (for example Zn, Cu, Mn, Fe, Co, Ni etc.) into II—VI semiconductors materials has led to unique optical, electrical and electrochemical properties. Moreover, doped semiconductors materials with transition metal ions opens up budding of forming a novel materials and new properties of the materials are expected [9]. Transition metals are very fascinating impurities as they cause introduction of deep levels in the gap region,which can change not only optical characteristics but also the electrical and electrochemical properties thereby affecting their practical applications in various fields of technology [10]. $Cd_{1-x}Zn_{x}S$ draws much consideration in light of its tunable optical properties. The physical and chemical properties of nanocrystalline $Cd_{1-x}Zn_{x}S$ combination is successfully adjusted by monitoring its stage, structure and size and extra structures. This ternary framework has potential application in numerous gadget creations, for example, sun powered cells and level board shows. In this way, the ternary $Cd_{1-x}Zn_xS$ nanoparticles is a fascinating product to inspect, by taking into consideration the energy of seeing new technology what's more, trying to achieve novel applications. In solar cell system, evidences have confirmed CdS films to be functional, the substitution of CdS with the higher band gap $Cd_{1-x}Zn_XS$ alloys has resulted in a decline and reduction of window absorption losses and an enhancement of the short circuit current [11]. The ternary $Cd_{1-x}Zn_xS$ compound is a very handy material to be used as a window material for the production of p-n junctions elite of lattice mismatching in devices which are basis on quaternary materials and have superior efficiency than those of pure CdS and ZnS. Further, transition metal ions doping in CdS can lead to enhancement in their optical properties and can be used as a window layer in solar cell, as a blue laser, and in gas sensors and many other areas. There are various synthesis technique for the prepation of CdS nanoparticles such as such as sol-gel, coprecipitation method, chemical precipitation method, solvothermal, spray pyrolysis and microwave (MW) assisted synthesis [3,4,12–14]. However, synthesis by co-precipitation method offers the advantage like short time reaction and production in bulk amount.

Therefore, keeping in view all the above, we presented a systematic way to analyze the structural, morphological and optical properties of $Cd_{1-x}Zn_xS$ nanostructures at different doping concentrations of zinc (x = 0, 0.1 and 0.3). In this work, $Cd_{1-x}Zn_xS$ nanostructures were prepared by using co-precipitation method from cadmium and sulphide particle arrangements with no ligands at various arrangement temperature and amalgamation time.

2. Experimental

2.1. Chemicals

For synthesis of Zn doped CdS nanostructures, the precursor materials were used as; 0.3M solution of cadmium acetate ($Cd\,(CH_3COO)_2{\cdot}2H_2O$), 0.3M solution of sodium sulphide (Na_2S) and 150 ml of methanol (CH_3OH) and 0.3M solution of zinc acetate ($C_4H_6O_4Z_n$). The chemicals used in the current work are of meticulous grade and can be used without having impurities.

2.2. Synthesis

Pure CdS nanostructures were synthesised through co-precipitation method by using 0.3M solution of Na_2S (Fermont) and 0.3M solution of cadmium acetate ($Cd\,(CH_3COO)_2{\cdot}2H_2O$), which were prepared in 50 ml of methanol. During the experiment, the temperature was maintained at 25 °C. We add cadmium ions slowly into the sulphide ions along with constant stirring. Then, the final solution changed from transparent to yellow colour which gives us the indication about the formation of CdS nanostructures.The process was stopped after 30 min. The precipitate obtained is then washed with 50 ml of methanol which is followed by heating at 150 °C. And for the doping of zinc ((x = 0.1)) into CdS nanostructures, 0.3M solution of cadmium acetate ($Cd\,(CH_3COO)_2{\cdot}2H_2O$), and 0.3M solution of zinc acetate ($C_4H_6O_4Z_n$) were added into 50 ml of methanol with constant stirring. A mixture is obtained which is then added into 50 ml of methanol. During the experiment the temperature was maintained at 25 °C. The process was stopped after half an hour. The precipitate so obtained is then washed with 50 ml of methanol which is followed by heating at 150 °C. The similar procedure was follow up for the remaing Zn doping concentration samples, except the variation of the stoichiometric amount of the dopant Then, all the characterizations are performed to determine its structural, morphological and optical properties.

2.3. Characterization

The as prepared samples were examined by XRD for crystalline nature and phase purity analysis. XRD pattern of the samples were recorded from 20° to 80° with a scanning speed of 2°/min. The surface morphology investigation were carried out by SEM and FESEM. To explore the optical properties of $Cd_{1-x}Zn_xS$ (x = 0, 0.1, 0.3) nanoparicles synthesiszed via co-precipitation method at different doping concentration of zinc, Photoluminescence (PL), Fourier Transform Infrared (FTIR), Raman and UV–vis spectrum were measured at room temperature.