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Shifting behavior in photoluminescence spectra of newly synthesized cadmium selenide and ferroelectric liquid crystals nanocomposite

Pritam Saha [a], Tapas Pal Majumder [a,*], Roman Dabrowski [b]

[a] Department of Physics, University of Kalyani, Kalyani 741235, West Bengal, India
[b] Institute of Chemistry, Military University of Technology, Warsaw 00908, Poland

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ABSTRACT

A unique method has been adopted to prepare cadmium selenide (CdSe) nanostructures using isopropyl amine as a reactant. By introducing CdSe nanostructures in ferroelectric liquid crystal (FLC) at room temperature a significant blue shift is observed. Such blue shift is noticed with the variation of concentration of FLC molecules as well as CdSe nanostructures. Photoluminescence spectra are clearly indicating a broad strong peak at lower wavelength side expected to cover a broad spectra region with the variation of FLC molecules as well as CdSe nanostructures in FLC CdSe hybrid nanostructures composites.

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1. Introduction

During the past few decades nano-sized materials have been attracted great attention because of their interesting properties that differ markedly from those of bulk materials [1–4]. Nano scaled semiconductors belonging to II–VI family are well known for their advanced optical and electronic properties [5–9]. Cadmium selenide (CdSe) belonging to II–VI semiconductor group having a direct band gap of 1.24 eV at room temperature, has wide potential applications in solar cells, biological labeling, and so on [10–12] and has been widely used in photovoltaic devices, electroluminescence, and catalysts [13–15]. A variety of techniques like chemical vapor deposition (CVD), molecular beam epitaxy (MBE), metal-organic vapor chemical deposition (MOCVD), organometallic vapor phase epitaxy (OMVPE), solvothermal methods, and hydrothermal methods etc. have been widely used in the synthesis of CdSe nanostructured materials [16–24]. Synthesis of 1-D ME (M = Zn, Cd; E = S, Se) nano-crystals using ethylenediamine (EDA) as both solvent and template has been reported earlier [25]. In this present work we used isopropyl amine (IPA) as both solvent and template. Here we are reporting a single step, straight forward, simple and environment friendly solvo-thermal technique for the synthesis of CdSe nanostructures. We also extensively studied the photoluminescence behavior of FLC-CdSe nanostructures mixed composites with the variation of concentration of both FLC molecules and CdSe nanostructures.

2. Experimental details

2.1. Preparation of CdSe nanostructures

All the reactants were of analytical grade and were used without further purification. In this synthesis process 1.538 g of cadmium acetate [$Cd(CH_3COO)_2 \cdot 2H_2O$] was put into a glass beaker filled with 75 ml of isopropyl amine (IPA) and the mixture was stirred for 5 min at room temperature. Then 0.27 g of selenium (Se) powder was added to the previously prepared clear solution and the mixture was stirred for another 5 min at room temperature. Then 5 ml of $N_2H_4 \cdot H_2O$ was added drop-wise to the mixture under vigorous stirring and the new mixture was stirred for 30 min at room temperature. The color of the solution was deep yellow. Then the solution was put into a Teflon lined stainless steel autoclave. The autoclave was maintained on average at 162 °C for 4 h, and then it was allowed to cool naturally approaching to room temperature. The resulted very dark brown precipitate was filtered, subsequently washed with milli-Q water and absolute ethanol. The products were dried in air at 65 °C for 3 h to obtain a type of CdSe nanostructures. The phase sequences of the ferroelectric liquid crystals (FLC) W-206E are given below:

$$Crystal \xleftrightarrow{19.3\ ^\circ C} SmC^* \xleftrightarrow{86.6\ ^\circ C} SmA^* \xleftrightarrow{92.7\ ^\circ C} N^* \xleftrightarrow{97.2\ ^\circ C} Iso.$$

Since our work was done at room temperature, so the composite system of FLC molecules and CdSe nanostructures was in SmC^* phase. The work was then done only at ferroelectric phase.

* Corresponding author.
E-mail addresses: tpm@klyuniv.ac.in, tpmajumder1966@gmail.com (T. Pal Majumder).

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2.2. Characterization

The morphology of these products was obtained by using scanning electron microscopy (SEM). The SEM photos were taken with EVO, LS 10, ZEISS, 2013. The SEM measurement was done on the glass substrate coated with requisite samples using a programmable spin coater, Apex Instruments Co. with model no. SCU-2008C. XRD analysis was performed on Miniflex 600, Rigaku, 2014. UV–vis scanning spectrophotometer (UV-3600, Shimadzu, Japan) was used to record the electronic absorption spectra of the obtained products at room temperature. Photoluminescence spectra were carried out on a Photon technology, PTI-QM40, Fluorescence spectrometer using excitation source of 230 nm line of a Xenon lamp. Both UV–vis and PL spectra of pure CdSe nanostructures were recorded in solution state with ethanol as solvent. Both UV–vis and PL spectra of CdSe nanostructures and FLC molecules composites were recorded in solution state with chloroform as solvent.

3. Results and discussion

3.1. Morphology

The morphology of the CdSe nanostructures can easily be seen using the low and high magnification of SEM images as shown in Fig. 1. The morphology of the prepared CdSe product (CdSe) is capsule like structure as shown in Fig. 1. The length of the nanostructures is about from 200 to 400 nm and the breadth is about 40 to 50 nm and except those there are few particles observed with particle size about from 40 to 50 nm. EDX pattern confirm the ratio of cadmium and selenium (Cd:Se) is about 76:24% contained in the pure CdSe nanostructures. We did not observe any other impurity in the composition.

XRD pattern of CdSe nanostructures is shown in Fig. 2. The synthesized CdSe nanostructured materials is shown to be associated with all the diffraction peaks corresponding to the wurtzite phases of CdSe. The XRD patterns of CdSe nanorods is clearly indicating the characteristic wurtzite planes of (100), (111(002)), (101), (102), (110), (103), (200), (311(112)), (201), (202), (203), (210), (211), (212), (300) and (213) located at 24.03, 25.49, 27.19, 35.29, 42.13, 45.95, 48.99, 49.81, 50.97, 55.95, 64.01, 66.63, 68.05, 72.11, 76.97 and 79.67° as according to JCPDS data card with number 08-0459, respectively, in the 2θ range from 20 to 80° as similar to earlier reported results [26–27]. The average particle size of CdSe nanostructures has been calculated using Debye-Scherrer's relation as given below [28]:

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

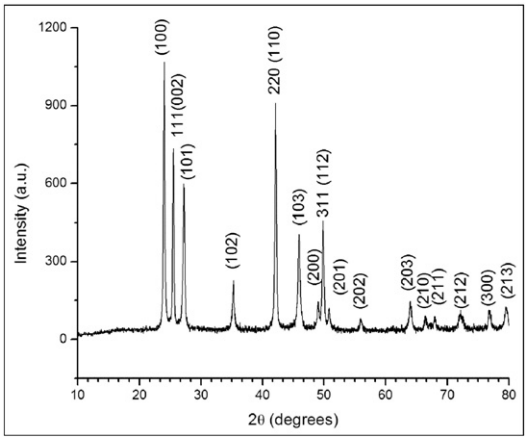

Fig. 2. XRD pattern of synthesized CdSe nanostructures.

K is the constant with the value approximately 0.98, λ is the wavelength of X-ray source in our measurement with the value approximately 1.54 Å. β is full width at half maxima (FWHM) which has been taken from XRD intensity profile at constant peak angle (θ) as shown in Fig. 2. So the average particle size (D) is approximately 40 nm calculated using Debye-Scherrer's relation, Eq. (1).

3.2. Optical properties

The optical properties of semiconductor materials are depending on the size and shape of the particles. The UV–vis spectra, recorded at room temperature of the as prepared CdSe products provides the absorption edge of the CdSe nanoproducts is about 270 nm and the corresponding energy is approximately 2.5 eV. The excitonic absorption features are not very good to present in this manuscript [2L9] because no such distinguish peak was observed but with a hump fall after 270 nm was observed. The photoluminescence spectra of the as prepared CdSe nanocapsule mixed with FLC molecules with different concentration recorded at room temperature for the excitation wavelength 230 nm, is shown in Fig. 3. In the present work the emission property of the as prepared CdSe products and its nanocomposite mixtures with FLC was studied from photoluminescence spectrum in the spectral region from 250 to 700 nm. Photoluminescence spectrum of pure CdSe nanostructures shows several peaks at 420, 451, 469, 484, 495, 559, 599 and 676 nm. Since the photoluminescence spectrum of CdSe nanostructures

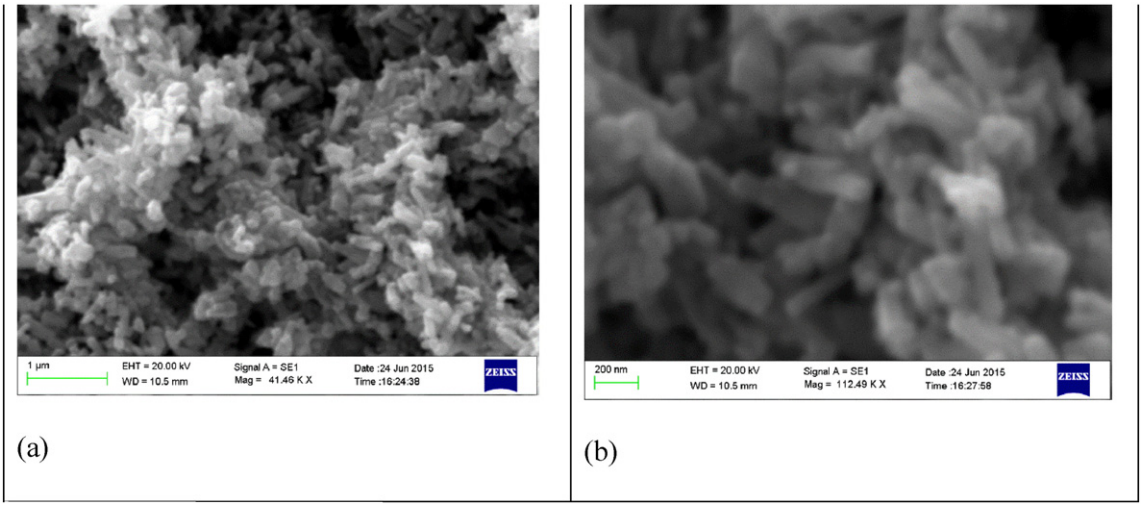

Fig. 1. SEM micrograph of synthesized CdSe nanostructures at different magnification (a) low magnification (1 μm scale) and (b) high magnification (200 nm scale).

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