

Optical behaviour of CdS nanorods dispersed in liquid crystal

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ABSTRACT

The optical properties of CdS nanorods have been modified in presence of antiferroelectric liquid crystals (AFLC). The effective refractive index of the CdS nanorods has been increased from 2.468 to 2.499 due to presence of AFLC molecules. The change in optical band gap of the CdS nanorods dispersed in AFLC causes the increment of refractive index of the CdS nanorods. The optical band gap of the CdS nanorods has been shifted from 2.61 eV to 2.52 eV due to presence of AFLC. We have also observed the enhanced photoluminescence (PL) intensity and red shift in emissive energy band of CdS nanorods dispersed in AFLC. Copyright © 2015 VBRI Press.

Keywords: CdS nanorods; liquid crystals; optical property.



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Introduction

Over few decades semiconducting nanomaterials have been investigated with intense attention due to their wide field of applications. Among these semiconductors, CdS, one of the best direct band-gap semiconductors of II-VI group, has drawn intense interest due to their wide application in solar cell, light-emitting diodes for flat panel display and photocatalyst for chemical reaction [1-3]. The physical properties of nanostructures are strongly dependent on their size, especially on quantum confinement effects. Therefore, many researchers developed different techniques to control the shape and size of CdS nanostructures [4-7]. Besides the different synthesis techniques various surfactants or polymers like PEG, CTAB, PVA etc. have been used to control the size of CdS nanostructures [8-12]. Yao et al. [13] had successfully tuned the absorption and emission bands by controlling the morphological growth of CdS nanomaterials with assistance of PVA. Recently, liquid crystals (LC) have been used to modify the physical properties of nanomaterials [14-17]. The LC applies their own effect on modification of physical properties of nanomaterials. Kumar et al. [18] observed memory effect in cadmium telluride dots doping with ferroelectric liquid crystals.

In this paper, we report the modification of optical properties of CdS nanorods by simply changing the surroundings medium of the CdS nanorods by W1000 AFLC [19]. We have observed the tuning of the effective

refractive index and emissive bands of the CdS nanorods due to presence of AFLC molecules.

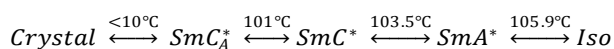
Experimental

Materials

The cadmium acetate, sulfur powder, cetyl trimethyl ammonium bromide (CTAB) and ethylenediamine (EDA) were purchased from Merck Limited. All the chemicals were of analytical grades and used without further purification.

Methods

The CdS nanorods were synthesized by solvothermal method using Cadmium Acetate $[\text{Cd}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}]$ and sulphur powder as reactant, ethylenediamine (EDA) as the solvent and cetyl trimethyl ammonium bromide (CTAB) as surfactant. At first 0.8 g Cadmium Acetate and 0.1 g sulphur powder were dissolved in 40 ml EDA under vigorous magnetic stirring and during stirring 0.2 gm CTAB was added. Then obtained solution was transferred into a 50 ml Teflon-lined stainless steel autoclave and the autoclave was kept at 180°C for 2 hrs and then cooled to the room temperature. Finally, the resultant sample was filtered off and then dried to obtain CdS powder. To prepare the sample for measurements at first 4mg W1000 AFLC was dissolved in 0.25 ml chloroform by ultrasonication. Then the 1 mg as prepared CdS powder was mixed with W1000 solution and the mixture was ultrasonicated until we got homogeneous mixture of CdS and W1000. Finally, very thin layer of the AFLC mixed CdS was coated on quartz plate using a programmable spin coater (Apex Instruments Co., model: SCU-2008C). Similarly, pure CdS sample was coated on quartz plate using acetone as solvent. The phase sequence of W1000 AFLC is given below:



Characterizations

The morphology of the CdS nanomaterials was evaluated by Electron Microscope (TEM). An ultraviolet-visible spectrometer (UV-2401PC, TCC-240A, Shimadzu) was used to identify the absorption band of the sample and Photoluminescence (PL) spectra were recorded on LS55 PerkinElmer fluorescence spectrometer.

Results and discussion

The morphology of the prepared CdS nanomaterials was evaluated by Transmission Electron Microscope (TEM). The prepared high quality uniform CdS nanorods are shown in **Fig. 1**. The average diameter of the nanorods is 25 nm. An ultraviolet-visible spectrometer (UV-2401PC, TCC-240A, Shimadzu) was used to identify the absorption band of the sample and Photoluminescence (PL) spectra were recorded on LS55 PerkinElmer fluorescence spectrometer at room temperature (300K). The UV-visible absorption spectra of pure CdS nanorods and AFLC mixed CdS nanorods are shown in **Fig. 2**. The pure CdS sample and AFLC mixed CdS sample give absorption peaks at 482 nm

and 490 nm respectively. The absorbance band of CdS nanorods was shifted by 8 nm towards longer wavelength due to presence of AFLC. The optical band gap of CdS nanorods are determined by the following equation:

$$\alpha h\nu = A(h\nu - E_g)^{1/2} \quad (1)$$

Where α is the absorption coefficient, E_g is the optical band gap, A is constant and depends on type of transition.

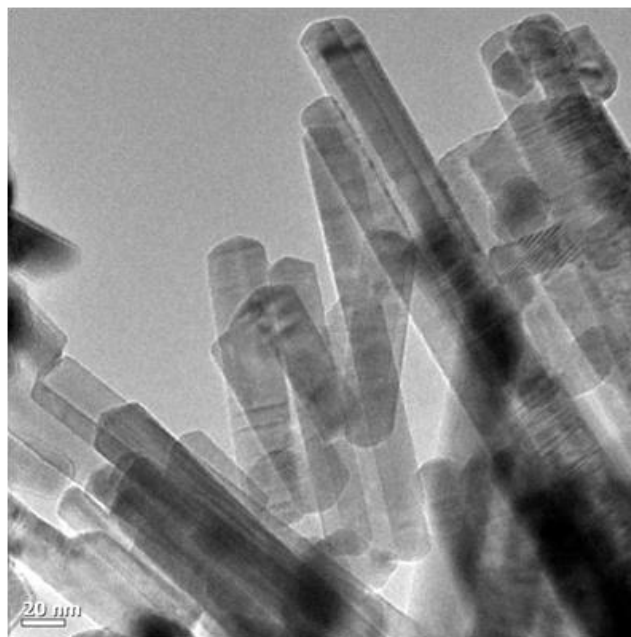


Fig. 1. TEM image of the prepared CdS nanorods.

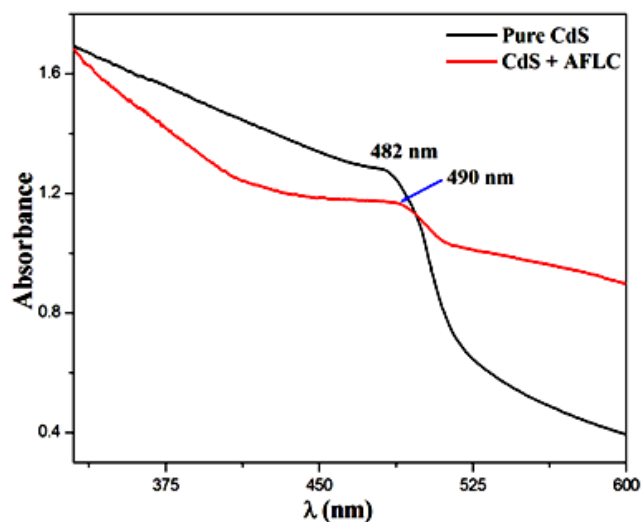


Fig. 2. UV-Visible absorption spectra (recorded at room temperature) of pure and AFLC mixed CdS nanorods.

The band gap are determined by extrapolating the linear portion of $(\alpha h\nu)^2$ vs $h\nu$ plot to the energy axis as shown in **Fig. 3**. The obtained band gaps from **Fig. 3** are 2.61 eV and 2.52 eV for CdS nanorods and AFLC mixed CdS nanorods respectively. The band gap decreases by $\Delta E_g = 0.09$ eV and that may be due to the strong electrostatic interaction between CdS nanorods and AFLC molecules. Lahiri et al. [20] theoretically accounted of such possible interactions

among composite constituents of a nanoparticles doped ferroelectric liquid crystal. The similar result was observed in case of PL spectra (shown in Fig. 4). The emission peak of CdS nanorods was shifted from 523 nm to 528 nm. The shift in absorption and emission spectra were observed due to change of surroundings medium of CdS nanorods in presence of AFLC. The AFLC molecules covered up CdS nanorods and changed the effective refractive index of CdS nanorods. The effective refractive index of CdS nanorods AFLC mixed CdS nanorods can be calculated using the following relation between refractive index (n) and optical band gap (E_g) of the material [21]:

$$n = KE_g^C \quad (2)$$

where, $K=3.3668$ and $C=-0.32234$ are the constants.

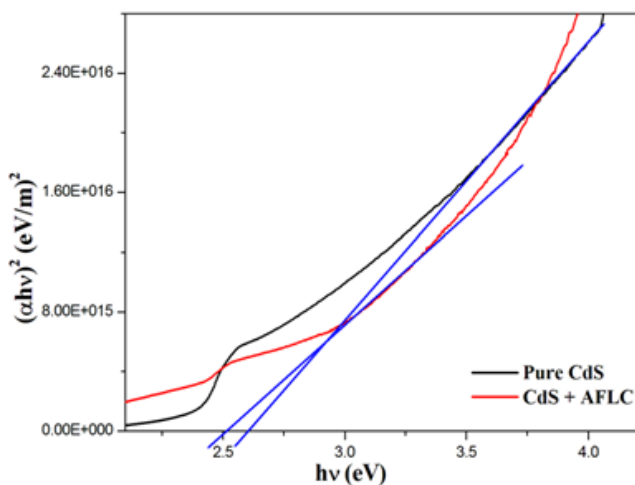


Fig. 3. Plot of $(\alpha hv)^2$ vs hv of pure and AFLC mixed CdS nanorods.

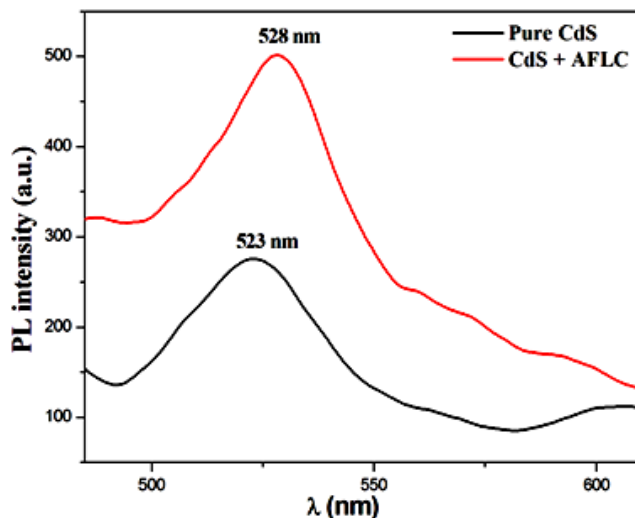


Fig. 4. Room temperature (300K) PL emission spectra of pure and AFLC mixed CdS nanorods excited at 450 nm.

Kumar et al. [21] established the above relation which gives better agreement with the experimental values than the models proposed by earlier workers [22, 23]. We have obtained the value of refractive index 2.468 (n_1) and 2.499 (n_2) for CdS nanorods and AFLC mixed CdS nanorods respectively using equation (2). The ratio between two

refractive indices is $n_2/n_1 = 1.013$, which indicates a little bit denser medium obtained due to the introduction of AFLC molecules. So the deviation of radiation is higher and its velocity is less in compare to pure CdS nanorods and eventually, red shift in emission peak is expected. It is worth to notice here that not only PL emission band is shifted towards higher wavelength side but the PL intensity is enhanced. The PL spectra are recorded at room temperature (300K) and the AFLC material possesses highly light scattering smectic C_A^* phase at room temperature as shown in phase sequence of AFLC and hence incident photons get scattered to excite more CdS nanorods and we get enhance PL counts. It has been reported earlier that the PL intensity can be enhanced by light scattering liquid crystalline phase [24].

Conclusion

We have presented the optical behaviour of CdS nanorods dispersed in AFLC. The absorption and emission bands of the CdS nanorods have been shifted in longer wavelength side by changing the effective refractive index of the CdS nanorods. We have also observed the enhancement in PL intensity of CdS nanorods dispersed in AFLC. The underlying mechanism of our obtained results has been described clearly. Our observations open up the new ways to fabricate smart optoelectronics devices. The sensitivity of the emission maxima of the CdS nanorods to the medium refractive index may be useful for practical applications such as solid-state lighting.

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