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Dielectric properties of CdS-PVA nanocomposites prepared by ultrasound-assisted method

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The electric and dielectric properties of ultrasound-assisted synthesized CdS nanocrystals-PVA mixture were studied in temperature range of 298 K to 498 K and frequency range from 200 Hz to 1 MHz. Scanning Electron Microscopy (SEM) shows that the morphology of CdS nanoclusters are formed in the form of mostly spherical nanoparicles with average size 10 nm. It was found that the nature of polarization processes in pure PVA and CdS-PVA nanocomposites are different. This is due to interfacial polarization in nanocompisites.

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Keywords: CdS, Nanocomposite, Dielectric constant, Dielectric loss, Impedance Spectroscoy

1. Introduction

Nanostructured cadmium sulphide is a technologically important material; possess optical and electrical properties that depend strongly on the size and shape of the nanoparticles. This is due to confinement of the charge carriers in the limited space of the nanocrystal [1-4].

In many cases, the size dependent optical properties can be understood by considering the effects of quantum confinement on the band gap transition, i.e., the electronic transition with lowest energy, and a few other closely related transitions [5].

However, quantum confinement will affect all electronic transitions throughout the entire Brillouin zone and, thus, decide the dielectric function of a semiconductor nanocrystal in a broad energy range. Despite the scientific and technological importance, only a few studies have been published in which the dielectric function of semiconductor nanocrystals is considered [6,7].

Polymers are also excellent host materials as capping agents and stabilizers since they prevent aggloromation and precipitation of the particles. Polymer based semiconductors are also advantageous from point of view of film preparation. The embedding of such semiconductor nanoparticles, polymer matrix can be consider as potential candidates for their use in electronic and optoelectronic devices. Recently, various methods to fabricate such composite films, especially polymeric films containing nanoparticles, have been reported and their electrical and optical properties have been studied by many researchers [8-10].

Among used polymers, polyvinyl alcohol (PVA) is an important polymer having a high dielectric strength (>1000 kV/mm), good charge storage capacity and dopant dependent electrical and optical properties [11].

Further, it should be noted that the study of dielectric relaxation processes in semiconductor polymer nanocomposites help us in understanding the molecular motions and their interactions which are affected by chemical composition, molecular structure and morphology of the sample being examined.

The impedance spectroscopy has proved to be a powerful method to study the charged carrier relaxation and transportation in electronic devices [12-27].

Ultrasound-assisted method, is one of the most effective methods have been used for preparation of nanostructures by many researchers in last decades [28-30].

In this study, dielectric and electrical properties of sonochemically prepared CdS-PVA nanocomposites in the film form have been investigated using Impedance Specctroscopy method.

2. Experimental

For preparation CdS-PVA nanocomposites, 10 ml of 0.2M aqueous solution of cadmium acetate dehydrate, 10ml of aqueous solution of PVA (10%) and 10 ml of aqueous solution of 0.2M sodium sulfide were separately prepared in different flasks. Then all of these materials were simultaneously mixed is a rounded bottom flask and kept under ultrasonic irradiation for 1 hour. After sonication, the solution was rinsed in ultrasonic bath for remove weak bounded materials and get pure materials. SEM image (Fig. 1) shows formation of CdS nanoclusters which aggregated in the form of mostly spherical small nanoparticles with average size 10 nm. In order to preparation of CdS-PVA nanocomposite in the film form, the prepared CdS nanopowders were added to 10 ml of 10% PVA solution in water and kept under ultrasonic irradiation for 30 minute again to obtain homogeneous distribution in surface and volume of composite material as possible. Then a drop of viscous CdS-PVA nanocomposite were dispersed on an ordinary microscope glass and let to dry at room temperature for electrical characterization. A thin layer silver paste was coated on both sides of prepared sample for dielectric measurement. Then the sample was located between metal electrodes as sandwich method. Thickness of film was measured by mechanical micrometer and was 100 micrometer.

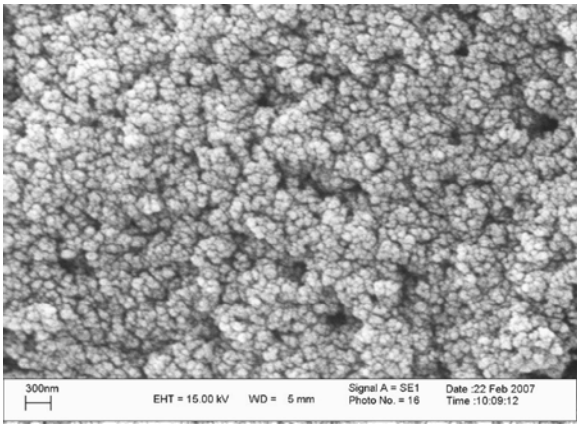

Fig. 1. SEM image of CdS nanoparticles prepared by ultrasound-assisted method.

The dielectric properties of CdS-PVA nanocomposites were measured in the frequency range 200 Hz – 1 MHz using Immitansa E7-20 model Impedance spectrometer and the temperature was adjusted and measured Keithley system electrometer 6514.

3. Results and discussion

In this section the temperature and frequency dependence of polyvinyl alcohol (PVA) and CdS polyvinyl alcohol (PVA) nanocomposites were characterized in the temperature range from 298 K to 498 K and frequency range from 200 Hz to 1 MHz.

The dielectric constant of pure PVA and CdS-PVA nanocomposite was calculated from following equation:

$$C = \frac{\varepsilon\varepsilon_0 S}{d} \tag{1}$$

Where, C is capacitance, ε is dielectric constant, d is the thickness of film ε_0 is the vacuum permittivity and S is the area of used electrodes.

The ac resistance is given by:

$$R = 1 \big/ (\omega C \tan\delta) \tag{2}$$

Where ω is the angular frequency and C the capacitance of the sample in Farad. The real part of ac conductivity σ_{ac} was calculated as:

$$\sigma_{ac} = t \big/ (AR) \tag{3}$$

where t is the thickness of the sample in cm and A the cross-sectional area in cm^2. The real part of dielectric constant ε' was calculated as:

$$\varepsilon' = (tC) \big/ A\varepsilon_0 \tag{4}$$

Fig. 2(a) and 2(b) shows the variation of dielectric constant of pure PVA and CdS-PVA nanocomposites with different frequencies and temperatures. It shows also dielectric constant decreases with increase of frequency at all temperatures in the case of pure PVA and CdS-PVA nanocpmposites. The increase in values of dielectric constant with temperature is connected with the increasing of rotation intensity processes of dipoles in CdS-PVA nanocomposites. The rate of increase of dielectric constant in both of temperatures and frequencies indicates of CdS-PVA nanocomposite is noticeable. In this case too possible reasons are considerable. The first in the present of CdS nanoparticles, the conductivity of sample increased and second the influence of existence of small particles can affect on energy shift in band structure of sample. The result of this process is affect on the conductivity of samples.

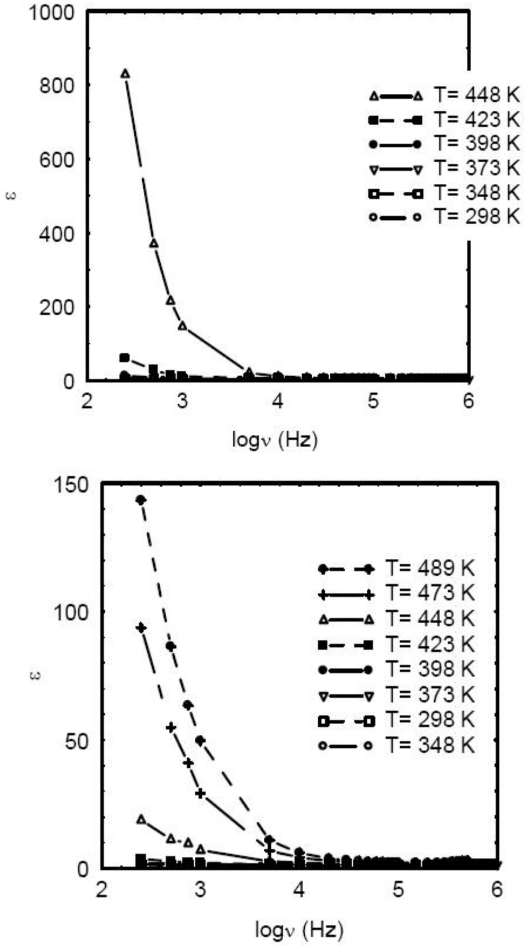

Fig. 2(a,b). Dielectric constant versus frequency a)CdS-PVA nanocomposite, b)Pure PVA.

Figs. 3(a) and (b) shows the variations of dielectric loss with logarithms of frequencies for pure PVA and CdS-PVA nanocomposites. Dielectric loss in the case of pure PVA has a small value at temperature 298 K and it decrease with frequency with temperature from 298 K to 429 K. In the case of CdS-PVA nanocomposites the rate of variations being smaller than pure PVA. These figures also indicate that dielectric loss picks are shifts toward lower frequency regimes as temperature goes down by increasing of temperature.

Figures clearly show that the value of dielectric constant in CdS-PVA is higher than its value in pure PVA. But the rate of increasing by varying of temperature and also frequency for CdS-PVA nanocomposites being larger than pure PVA.

In Figs. 3(a) and (b) dielectric loss pick is shifts toward lower frequency regime as temperature goes down by increasing of temperature, the motion of charge carries become easier and thus can be relaxed even a higher frequency. But some of peaks is not observed at lower temperatures appear at lower frequencies, that's way they don’t seen in measured frequency regions. In the case of pure PVA only one peak was observed at 423 K and the relaxation time was $0{,}207\times10^{-3}$ sec. The conductivity of polymer nanocomposites were increased with temperature this expression arises of observed in decrease in dielectric loss.

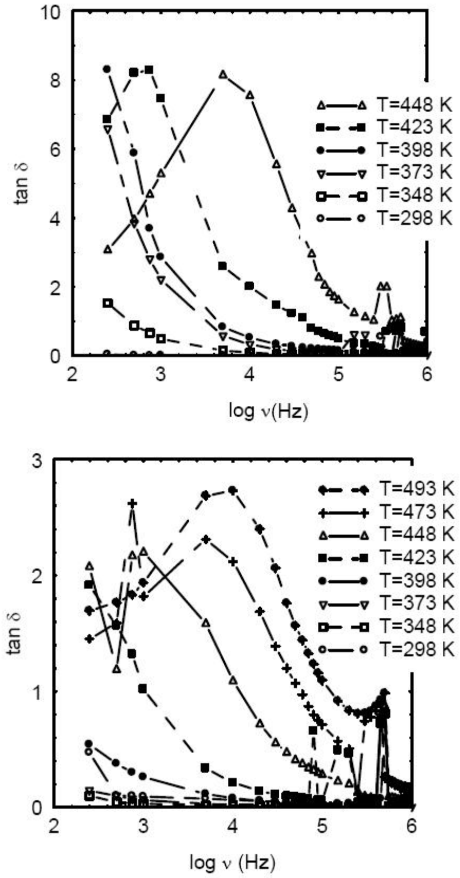

Fig. (3a). Temperature and frequency dependence of dielectric loss for pure PVA and (3b) CdS-PVA nanocomposites.

Fig. 4a and 4b shows that the conductivity (σ) of both of samples is found to increase linearly with frequency. σ increases at a low rate with temperature initially and more rapidly in higher temperatures. Comparison of two figures a, b shows that at a given temperature and frequency, conductivity of pure PVA is less than CdS-PVA nanocomposites. The observed nature in relaxation character is due to the inability of dipoles orientation by alternating electrical field. The increase in values of dielectric constant with temperature is also connected with the increasing of intensity rotation processes of dipoles. This means that the increase of temperature allows rapidly rotate of dipoles.

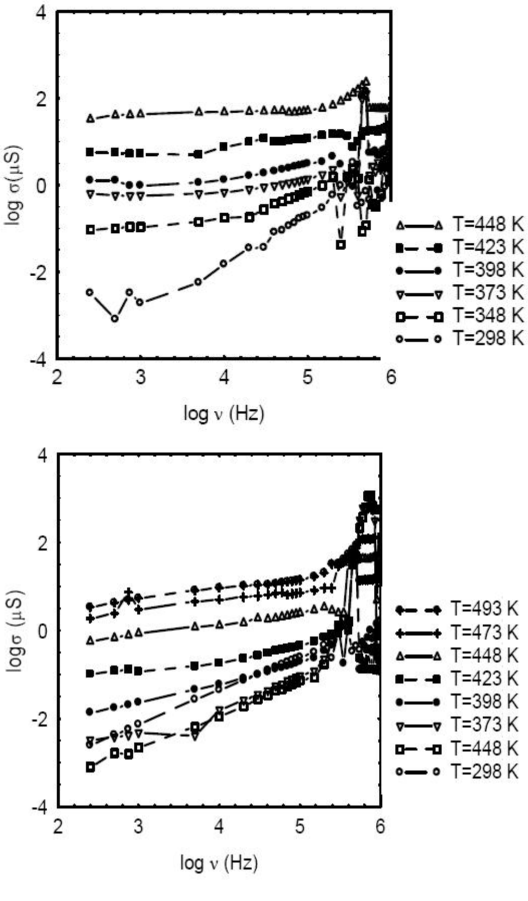

Fig. (4a). Temperature and frequency dependence of electrical conductivity for pure PVA and (4b) CdS-PVA nanocomposites.

The conductivity (σ) of both of samples is found to increase linearly with frequency. σ increases at a low rate with temperature initially and more rapidly in higher temperatures. At a given temperature and frequency, conductivity of pure PVA is less than CdS-PVA nanocomposites.

4. Conclusions

In this paper the dielectric properties of pure PVA and CdS-PVA nanocomposite are characterized. The dielectric constant decreases with increase of frequency at all temperatures for both pure PVA and CdS-PVA nanocomposite. The values of dielectric constant in CdS-PVA nanocomposite are large and this is connected with small size of CdS particles.

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