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Investigations on structural and electrical properties of Cadmium Zinc Sulfide thin films

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ABSTRACT

Nowadays, II – IV group semiconductor thin films have attracted considerable attention from the research community because of their wide range of application in the fabrication of solar cells and other opto-electronic devices. Cadmium zinc sulfide (Zn-CdS) thin films were grown by chemical bath deposition (CBD) technique. X-ray diffraction (XRD) is used to analyze the structure and crystallite size and scanning electron microscopy is used to study the morphology of Zn-CdS thin film. Optical studies have been carried out using UV-Visible-NIR transmission spectrum. The dielectric properties of Zn-CdS thin films have been studied in the different frequency at different temperatures. The AC conductivity study shows a normal dielectric behavior with frequency which reveals that the dispersion is due to the interfacial polarization.

Keywords: *Solar Cell; Cadmium Zinc Sulfide; XRD; SEM analysis; Dielectric constant and Dielectric loss.*

INTRODUCTION

Semiconductors in the form of thin films find substantially greater technological importance due to their various advantages over bulk crystals. The development of electronic technology has been increasing in the direction of devices utilizing the thin layer of semiconducting material. Among the variety of opto-electronic devices, with rising energy costs, terrestrial photovoltaic solar cells are becoming more attractive as supplementary energy sources. The solar cell fabrication process based on semiconductor thin films during the past has provided an important stimulus for the development of new thin film materials, deposition techniques and equipment.

Semiconductor nanoparticles are widely used in the photovoltaic applications due to their size dependent optical properties and their tunable spectrum in visible to IR.

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Among others, II–VI group semiconductor nanoparticles are widely used in such applications. Cadmium selenide (CdSe) is focused much during recent years for third generation photovoltaics due to its low band gap (1.74 eV in bulk form). In recent years, one dimensional semiconductor nanostructures are more studied due to their advantages than zero dimension structures. Due to the reduced recombination rate, titanium di-oxide nanotubes are very much considered for solar cells and fuel cells. Nanotechnology incorporation into the films shows special promise to enhance efficiency and lower total cost [1-3].

The semiconductor nanoparticles belong to the state of matter in transition between molecules and bulk solids in which the relevant physical dimensions changes on the length of a few to a few hundred nanometers. Recently, many extensive studies are going on in the semiconductor nanocrystals because they exhibit strong size dependent optical properties. These will be the key structural parameters in the fabrication of novel electronic nanodevices and nanocircuits. Semiconductor particles exhibit size dependent properties such as the scaling of the energy gap and corresponding change in the optical properties.

Many nanostructured materials are now being investigated for their potential applications in photovoltaic. As a result much less material is required and costs get decreased. Fuel cells utilize amorphous silicon, which, as its name suggests, does not have a crystalline structure and consequently has a much lower efficiency; however it is much cheaper to manufacture [4-8]. The dielectric constant of a semiconductor is one among its most important properties. Its magnitude and temperature dependence are significant in both fundamental and technological considerations. This paper deals with the preparation of cadmium zinc sulfide thin films, by chemical bath deposition (CBD) technique. The cadmium zinc sulfide thin films were characterized by X-ray diffraction, and scanning electron microscopy (SEM), for microstructure and morphology respectively, while UV-VIS-NIR analysis and dielectric for optical studies.

EXPERIMENTAL

The preparation of cadmium zinc sulfide thin films was carried out by dissolving Cadmium chloride, Zinc chloride, Ammonium chloride and Thiourea in 100 ml of double distilled water in a round bottom flask. The pH was adjusted by the addition of ammonium hydroxide solution with constant stirring. All the substrates were placed vertically inside the chemical bath and the deposition was carried out. Finally the obtained films were sonicated for 5 min and rinsed by double distilled water and dried in air atmosphere. The XRD pattern of the cadmium zinc sulfide thin films was recorded by using a powder X-ray diffractometer (Schimadzu model: XRD 6000 using CuKα (λ=0.154 nm) radiation, with a diffraction angle between 10 and 90º. The crystallite size was determined from the broadenings of corresponding X-ray spectral peaks by using Debye Scherrer's formula. Scanning Electron Microscopy (SEM) studies were carried out on JEOL, JSM- 67001. The optical absorption spectrum of the cadmium zinc sulfide thin films has been taken by using the VARIAN CARY MODEL 5000 spectrophotometer in the wavelength range of 300 to 800 nm. The dielectric properties of the Cadmium zinc sulfide thin films were analyzed using a HIOKI 3532-50 LCR HITESTER over the frequency range 50Hz-5MHz.

RESULTS AND DISCUSSION

Structural studies

The XRD pattern of cadmium zinc sulfide deposited on glass substrate from CBD technique shows broader peaks (Figure 1) indicating that the film is made up of nano-crystallites which are in wurtzite form. The broadened peak shows the nanometer-sized crystallites. The average nano-crystalline size (D) was calculated using the Debye-Scherrer formula,

$$D = \frac{0.9\lambda}{\beta\cos\theta} \quad (1)$$

where λ is the X-ray wavelength (CuKα radiation and equals to 0.154 nm), θ is the Bragg diffraction angle, and β is the FWHM of the XRD peak appearing at the diffraction angle θ. The average crystalline size is calculated from X-ray line broadening peak and Debye-Scherrer equation to be about 12 nm.

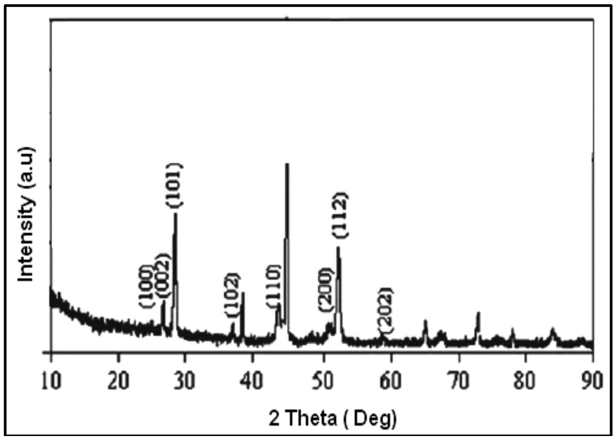

Fig.1. The XRD pattern of the cadmium zinc sulfide thin film.

Surface analysis

Scanning electron microscope (SEM) was used for the study of surface structure and roughness of the cadmium zinc sulfide thin films. Figure 2 shows the SEM image of the cadmium zinc sulfide thin film deposited on glass substrate. The investigated result showed the granular, densely packed surface morphology and more number of grains was observed in small area. The SEM images clearly show that the thin films are uniformly distributed over the entire surface of the substance.

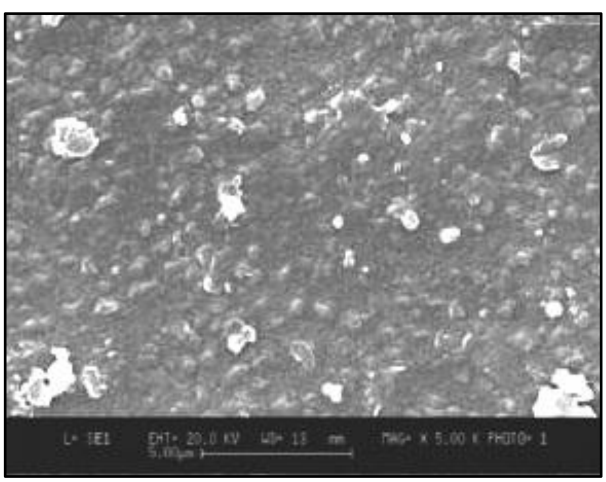

Fig.2. SEM Image of the cadmium zinc sulfide thin film.

Optical properties

Study of materials by means of optical absorption provides a simple method for explaining some features concerning the band structure of materials. The transmittance spectrum of cadmium zinc sulfide thin films in the wavelength range 300 - 800 nm are shown in the Figure 3.The absorbance near infrared domain (300 nm) is very low whereas transmittance is high at the same region. This property of high transmittance (~ 60 – 90 %) and low absorbance near infrared region (~500 –800 nm), makes the film suitable for optoelectronic devices such as window layer on solar cells [9]. Generally, the wavelength of the maximum exciton absorption decreases as the particle size decreases, as a result of the quantum confinement of the photo generated electron–hole pairs. The dependence of optical absorption coefficient on photon energy helps to study the band structure and type of transition of electrons. The observed optical transmittance is around 85 % for cadmium zinc sulfide thin film deposited on glass substrate under the present optimized condition.

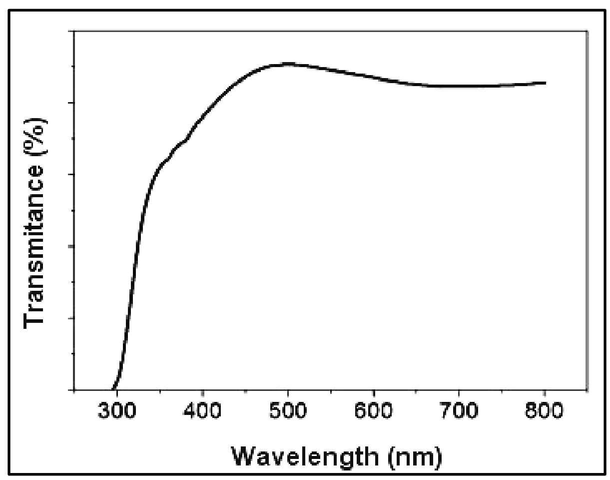

Fig.3. The optical transmittance spectra of Cadmium Zinc Sulfide thin film.

Dielectric Properties of cadmium zinc sulfide thin film

The dielectric studies show the effects of temperature and frequency on the conduction phenomenon in nanostructured materials. Dielectric behavior can effectively be used to study the electrical properties of the grain boundaries. The dielectric properties of materials are mainly due to contributions from the electronic, ionic, dipolar and space charge polarizations. Among these, the electronic polarization, present in the optical range of frequencies form the most important contribution to the polycrystalline materials in bulk form. Space charge polarization arises from molecules having a permanent dipole moment that can change its orientation when an electric field is applied. The product of the dielectric constant and the power factor is called the loss factor and it is proportional to the energy absorbed per cycle by the dielectric from the field. The dielectric analysis is an important characteristic that can be used to fetch knowledge based on the electrical properties of a material medium as a function of temperature and frequency. Based on this analysis, the capability of the storing electric charges by the material and the capability of transferring the electric charge can be assessed. Dielectric properties are correlated with electro-optic property of the materials.

The variations of the dielectric constant and dielectric loss of the cadmium zinc sulfide thin film at frequencies of 50Hz to 5 MHz and at different temperatures of 40 ºC - 80ºC are displayed in Figures4 and 5. The dielectric constant is calculated using the formula,

$$\varepsilon_r = \frac{Cd}{\varepsilon_0 A} \quad (2)$$

ε_r is used to evaluate the dielectric constant, where *d* is the thickness of the sample and *A* is the area of the sample. The results suggest that the dielectric constant and dielectric loss of the cadmium zinc sulfide thin film strongly depends on the applied frequency and the temperature. The dielectric constant is high at lower frequencies due to the contribution of the electronic, ionic, dipolar and space charge polarizations, which depend on the frequencies [10]. Space charge polarization is generally active at lower frequencies and indicates the purity and perfection of the nanoparticles [11]. Figure 4 shows the plots of dielectric constant against log frequency. The dielectric constants at low frequencies depend on the excitation of bound electrons, lattice vibrations, dipole orientations and space-charge polarization. At very low frequencies all four contributions may be active. It is observed that the dielectric constant decreases with increase in frequency. The large value of dielectric constant at low frequency is due to the presence of space charge polarization.

The Figure 4 shows the variation of dielectric constant as function of frequency and temperature. It is clear from Figure 4 that dielectric constant increases with the increase in temperature. This increase in dielectric constant as a result of increase in temperature can be explained on the basis of the phenomenon that as the temperature increases, the dipoles relatively become free and they respond to the applied electric filed. Consequently the polarization increased and hence dielectric constant also increases with the increase in temperature. The variation of dielectric constant with frequency may be explained on the basis of space-charge polarization phenomenon [12]. According to this, dielectric material has well conducting grains separated by highly resistive grain boundaries. On the application of electric field, space charge accumulates at the grain boundaries and voltage drops mainly at grain boundaries [13]. The dipole moment can easily follow the changes in the electric field, especially at low frequencies as most of the atoms in the nanocrystalline materials reside in the grain boundaries, which become electrically active as a result of charge trapping. Hence, the contributions to the dielectric constant increase through space charge and rotation polarizations, which occur mainly in the interfaces. Therefore, the dielectric constant of nanostructured materials should be larger than that of the conventional materials.

In nanophase materials, inhomogeneities like defects and space charge formation in the interphase layers produce an absorption current resulting in a dielectric loss. Figure 5 shows the variation of the dielectric loss with respect to the logarithm of frequency at different temperatures of 40-80ºC. It is also observed that as the temperature increases, the dielectric constant also increases to a considerable value as seen in Figure 4. The same trend is observed in the case of dielectric loss versus temperature as well given in Figure 5.The larger value of the dielectric loss at lower frequency may be attributed to the space-charge polarization owing to charge lattice defect. The characteristic of low dielectric constant and dielectric loss with high frequency for a given sample suggests that the sample possesses enhanced optical quality with lesser defects and this parameter is of vital importance for various electro-optic devices and their applications.

The high values of dielectric loss at low frequencies could be related to the charge lattice defect of the space charge polarization [14]. The value of dielectric loss measures the loss of electrical energy from the applied electric field into the samples at different frequencies. It is observed that the tan δ shows a decreasing trend with increasing frequency. The ratio of the loss or resistive current to the charging current of the sample is the loss tangent (tan δ). Also it is known that there is a strong correlation, between the conduction mechanism and the dielectric constant behavior (polarization mechanism) in cadmium zinc sulfide thin film. It is observed that the tan δ showed a decreasing trend with increase in frequency which is normal behavior of any materials.

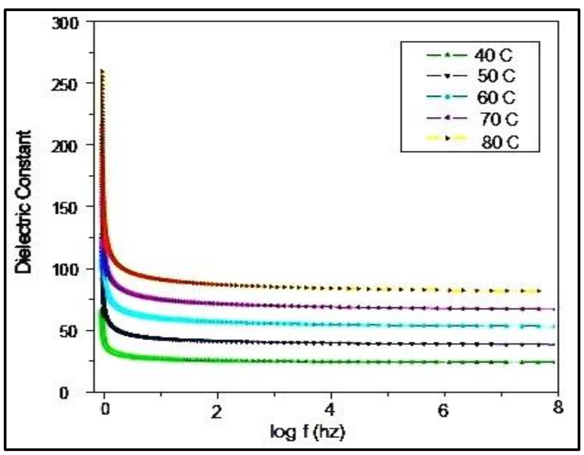

Fig.4. Dielectric constant of cadmium zinc sulfide thin film.

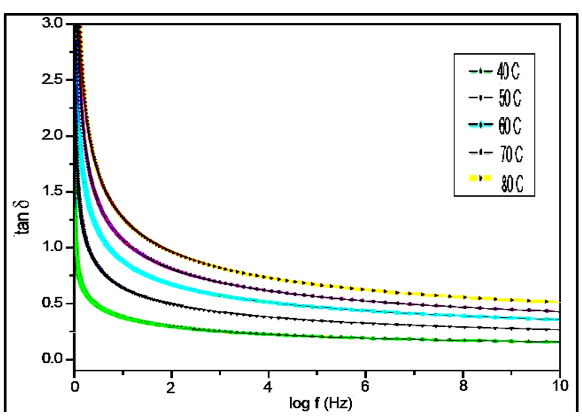

Fig.5. Dielectric loss of cadmium zinc sulfide thin film.

AC Conductivity of cadmium zinc sulfide thin film

The temperature dependent AC electrical conductivity measurement was carried out. The temperature dependent AC conductivity of the cadmium zinc sulfide thin films is shown in Figure 6. Conductivity is the physical property of a material which characterizes the conducting power inside the material. The electrical conductivity in cadmium zinc sulfide thin film is mainly due to the hopping of electrons between the ions of the same element present in more than one valence state. Therefore, Arrhenius type conductivity behaviour is exhibited by the cadmium zinc sulfide thin films in the temperature range investigated. It is seen that the value of ac conductivity increases with increase in frequency. At low frequency range the AC conductivity was nearly independent of the frequency and it increases with increase in frequency. These charge carriers take part in the conduction phenomenon thereby increasing the AC conductivity. The frequency dependent conduction is attributed to small polarons [15].

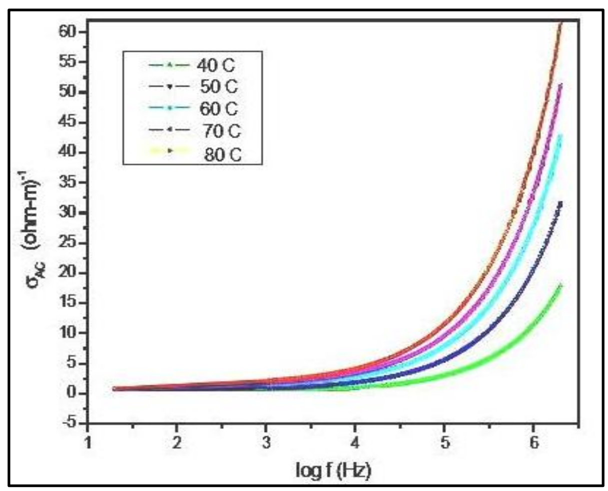

Fig.6. Variation of AC conductivity with log f.

CONCLUSIONS

Cadmium zinc sulfide thin film was deposited on the glass substrate by chemical bath deposition (CBD). Structural and morphology the Cadmium zinc sulfide thin films were investigated by XRD and SEM. The XRD studies shows, the well crystallized and cubic structure of Cadmium zinc sulfide thin films. Optical properties of the cadmium zinc sulfide thin films were investigated by using UV-Vis spectroscopy. The dielectric constant and dielectric loss of the Cadmium zinc sulfide thin films are calculated in the different frequency and temperatures. AC conductivity measurement indicates that conductivity increases linearly with frequency in Cadmium zinc sulfide. AC conductivity increases linearly with frequency which suggests that the conduction in the present system may be due to the polaron hopping mechanism.

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