Investigation of Electrical and Optical Properties of CdS Thin Films Prepared by Physical Vapour Deposition Technique

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Abstract: **Due to its many uses in optoelectronic devices, cadmium sulfide is one of the most interesting semiconducting materials. With the chemical formula CdS, it is a binary compound. It is a semiconductor compound in the II–VI range with a 2.4 eV intermediate energy band gap. Its high sensitivity to light and high absorption coefficient make it useful in the field of renewable energy conversion. Among the many uses for CdS thin films, one is as a window layer in second-generation solar cells, where it produces photon traps and thus quantum efficiency. In this work, the physical vapor deposition technique is used to fabricate CdS thin films on glass substrates, and the electrical and optical properties of the prepared films were investigated. The resistivity of CdS thin film was found to be 36.881 Ω.cm. TCR of the film was observed -0.001948 /°C. The prepared films also exhibits good optical properties.**

Keywords: Cadmium sulfide, binary compound, deposition technique, electrical and optical properties

1. Introduction:

The fabrication of sophisticated electrical devices, optical elements, and several other uses are made possible by thin films, which are essential to the advancement of technology [1]. Scientists and engineers continuously research new materials and deposition techniques to improve the performance and characteristics of thin films [1, 2]. They are crucial in many sectors because of the exact control they have over the thickness and qualities of the film. Substratum layers with thicknesses ranging from nanometers (nm) to micrometers (µm) can be recognized as thin films [3, 4]. These films have several uses in a wide range of technical applications and are frequently placed onto a substrate. Physical Vapor Deposition (PVD) is a category of thin film deposition techniques that involve the physical processes of vaporization and condensation to create a thin film on a substrate. PVD methods are widely used in various industries for applications ranging from microelectronics to optics and decorative coatings. In PVD, the material to be deposited (the source material) is physically vaporized or sputtered from a solid or liquid state into a vapor phase [5-7]. The vaporized material then condenses on a substrate, forming a thin film. PVD is used in a wide range of applications, including the deposition of metal and semiconductor films for microelectronics, the production of optical coatings, decorative coatings on jewelry and watches, and the manufacturing of solar cells. PVD methods are relatively clean and can be performed under vacuum conditions, minimizing contamination. It is essential for preparing thin films with specific properties, and they play a crucial role in the production of various advanced materials and devices [8, 9]. CdS is a semiconductor with a direct bandgap. The bandgap energy of CdS is around 2.42 eV, making it suitable for optoelectronic applications [10]. The electrical properties of CdS thin films are important for various applications, especially in the field of electronics and optoelectronics. The electrical behavior of CdS thin films is influenced by factors such as the deposition method, film thickness, crystallinity, and doping [11, 12]. The different methods of thin films deposition or fabrications are reveals in Fig.1.

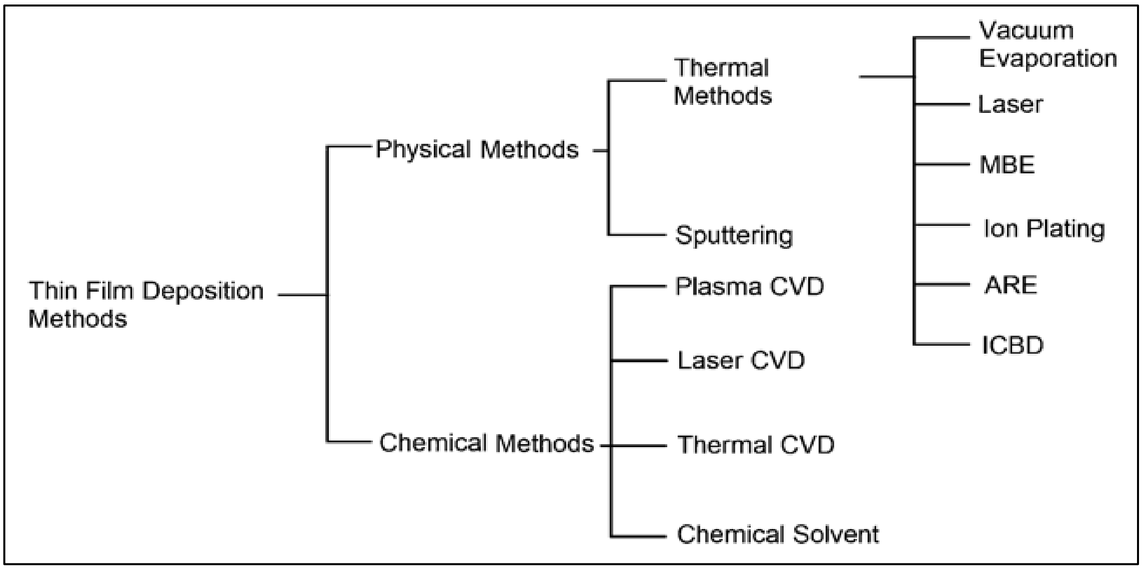

Figure 1: Methods of thin films fabrication

The aim of present research work is to preparation of CdS thin films by Physical vapour deposition technique and investigation of electrical and optical properties of the CdS films.

2. Experimental Work

Commercially available AR-grade CdS nanoparticles were used in this research work. The CdS nanoparticles (NP's) were purchased from Sigma Enterprises, Nashik. All of the films were prepared on glass substrates. For the preparation of thin films, all substrates were washed with acetone and then exposed to an IR lamp for 20 minutes to eliminate other contaminants. The thermal-evaporated technique was used to prepare thin films. The system consists of a vacuum pump system that was evacuated to a pressure of 10^{-5}-10^{-6} mbar. A vacuum was created inside the chamber, and substrates were placed inside the vacuum glass chamber. CdS NP's were retained in a molybdenum boat using a conventional arrangement and a high-voltage power supply provided to the evaporation target. The prepared CdS thin films were annealed at 100 °C for 2 hours in a muffle furnace.

3. Result and discussion

The electrical and optical properties of prepared thin films were investigated using static electrical and photo-luminous optical systems respectively. The standard methods and formulae were used for the calculation of electrical parameters.

3.1 Electrical properties

The electrical properties of prepared CdS thin films were studied using half bridge circuit method. In this method with respective surrounding temperature of the film, the voltage is measure and then converted into the resistance. The DC resistance of the films as a function of temperature was measured using the half-bridge method [12]. The thick film was linked in series with an external load resistor (RL) and a set DC voltage was applied to the circuit. Using a digital multimeter, the output voltage across the RL resistor was measured in order to get the values of the film resistance. A digital temperature display system was utilized to display the operating temperature through the use of a chromel-alumel thermocouple. The temperature coefficient of resistance, activation energy, and resistivity of the prepared thin films were calculated using equations 1, 2, and 3 [12, 13].

$$\rho = \left(\frac{R \times b \times t}{l}\right) ohm - cm \quad (1)$$

Where, R= Resistance of the film at room temperature, t = thickness of the film, b = breadth of the film, l = length of the film.

$$\Delta E = \frac{\log R}{\log\ Ro} \times KT \quad (2)$$

Where,

ΔE = Activation energy,
R = Resistance at elevated temperature,
R_0 = Resistance at room temperature.
K = Boltzmann constant and
T = Absolute temperature.

$$TCR = \frac{1}{R_o}\left(\frac{\Delta R}{\Delta T}\right) \; /^{o} C \qquad (3)$$

Where,
ΔR = change in resistance between temperature T_1 and T_2,
ΔT = temperature difference between T_1 and T_2 and
R_o = Resistance of the film at room temperature.

Fig. 2 shows the plot of temperature versus resistance of the CdS thin films.

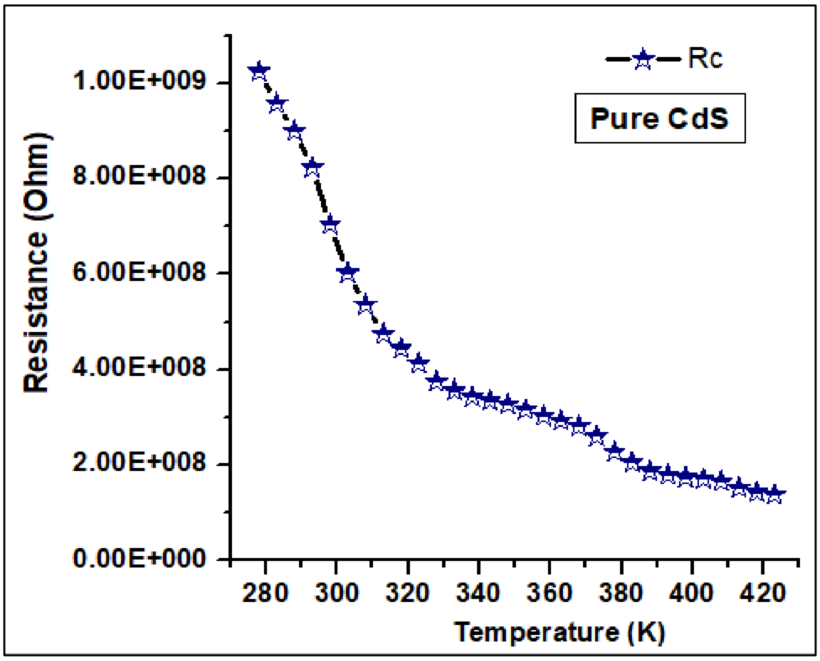

Figure 2: Plot of temperature versus resistance of the CdS thin films

It is found from Fig. 2 that the resistance of the film decreases as the surrounding temperature of the film rises. The decline in resistance of the films with increases in surrounding temperature is attributed to the semiconducting nature of the film. The bandgap energy of a semiconductor tends to decrease with an increase in temperature. This reduction in bandgap can result in more carriers being promoted from the valence band to the conduction band, contributing to increased conductivity [12, 13]. The energy needed for charge carriers, such as electrons or holes, to migrate from the valence band to the conduction band and so affect electrical conduction, is known as the activation energy of CdS thin films. This activation energy is related to the temperature dependency of carrier mobility and conductivity in the environment of semiconductors. The activation energy experimentally, one would typically measure the conductivity of the CdS thin film at different temperatures and then analyze the data using the Arrhenius equation [13, 14]. By plotting the natural logarithm of resistance against the reciprocal of temperature as shown in Fig. 3. The summary of estimated electrical parameters of CdS thin films are tabulated in Table 1.

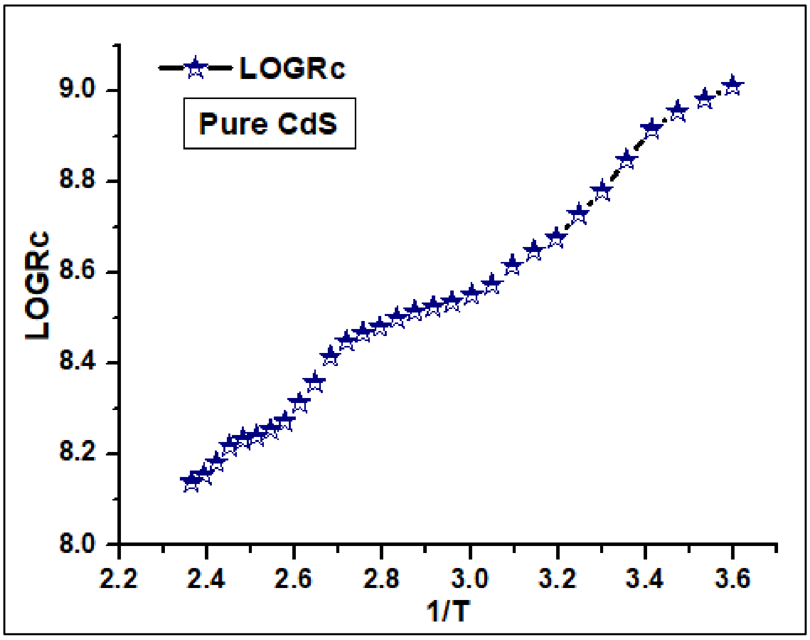

Figure 3: Arrhenius plot of the CdS thin films

Table 1: Summary of estimated electrical parameters of CdS thin films

Sample	Thickness (nm)	Resistivity (Ω.cm)	TCR (/ºC)	Activation Energy (eV)	
				HTR	LTR
CdS	72	36.881	-0.00195	0.2532	0.1808

3.2 Optical properties

Photoluminescence studies of CdS thin films are valuable for characterizing the material's optical and electronic properties, understanding defect states, and optimizing the fabrication process for various applications such as solar cells, light-emitting diodes (LEDs), and photodetectors. The photoluminescence study of CdS thin films involves investigating the emission of light (photons) by the material when it absorbs photons of higher energy (shorter wavelength), typically through the process of absorption followed by re-emission [15, 16]. This phenomenon provides valuable information about the optical and electronic properties of the CdS thin film. Examining the way the material's electrical characteristics alter in response to light, especially in relation to its behavior as an insulator or semiconductor, is one way to study the optical features of CdS thin films. CdS thin-film photoresponse research may reveal important details about the material's behavior under light and its potential for a range of photovoltaic uses. Furthermore, the findings might further knowledge of its electrical characteristics and prospective applications in modern technology. In this study, we investigated the light-dependent conductance variations of prepared CdS thin-films as a potential optical sensor or photovoltaic device [16, 17]. Fig. 4 illustrate the intensity (light) versus photocurrent plot of CdS thin-films. Photoluminescence study shows the prepared CdS films shows maximum response to blue filter compare to other selected filters.

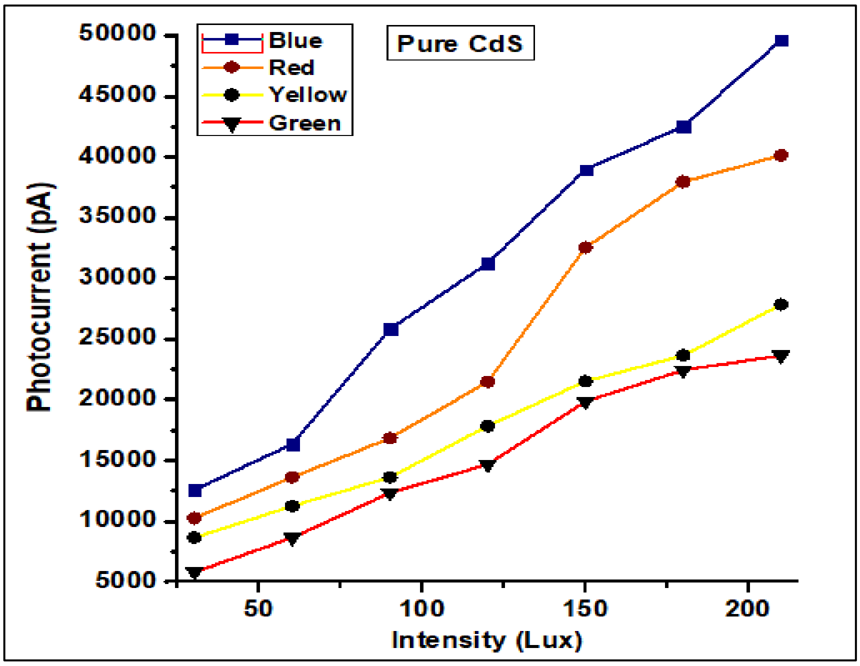

Figure 4: Intensity versus photocurrent plot of CdS thin-films

Conclusions and Future Scope

1. The thin films of CdS successfully prepared by physical vapour deposition technique.
2. The prepared CdS films shows semiconducting nature.
3. The resistivity was found to be for prepared CdS films is 36.881 Ω.cm
4. The optical properties of prepared CdS films were studied.
5. Photoluminescence study shows the prepared CdS films shows maximum response to blue filter compare to other selected filters.
6. The CdS thin films could be useful for fabrication of photodetectors as well as photovoltaic cells.

Acknowledgment

The authors thank to Principal, L. V. H. College and Head of Research Centre in Electronic Science, Panchavati, Nashik, India, for providing necessary lab facilities for current research work. I would like to also thank to my guide for their valuable guidance for the present research work.

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