Growth and Characterization of CdS Thin Films by Chemical Bath Deposition

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Abstract- **T**hin films of cadmium sulfide (CdS) were grown by Chemical Bath Deposition (CBD) technique. Cadmium sulfide, and thiourea were used as the source materials for the preparation of the films. The films were deposited onto the good quality glass plates (75 mm X 25mm) as substrates. To carry out the growth, 1 M Cadmium sulfide solution was prepared and required amount of triethanolamine was added to form a bound stable complex. The substrates (glass plates) were stirred in the solution at the temperature 55ºC with a constant rate of rotation 60 rpm using a DC motor. The pH of the reaction mixture was maintained using appropriate quantities of Sodium hydroxide and aqueous ammonia were added for the film adherence to the substrate support. Thickness of the film gets nearly saturated when the deposition time is above 90 min. Electrical resistivity of the grown CdS film was found to be of the order of 10^6 **Ω**-cm as measured by using Four-Probe method.

Index Terms- Chemical Bath Deposition, Resistivity, UV-Visible, Thin film, energy bandgap.

I. Introduction

Cadmium Sulfide (CdS) is one of the important wide energy gap semiconductors mainly because of its applications in piezoelectric transducers, laser materials and photovoltaic cells [1]. Among the various deposition processes used to grow the thin films, solution grown technique has proved its excellence for large area thin films. These films have many advantages over the films prepared by other techniques, such as large area films and simplicity of the process [2]. Also, the film can be obtained as a pure, doped and or mixed semiconductor component. A variety of substrates of semiconductors and insulators can be deposited by this method since working temperature of the process is quite low and the preparation parameters could easily be controlled. An important application of these films is solar cells which is an important factor for the growing industrialization and need of the energy. World energy generation scenario mostly depends on conventional energy sources. The solar energy has proved its utility amongst all these sources of renewable energy. The solar cell is an important candidate for an alternative terrestrial energy source because, it can convert sunlight directly to electricity with good conversion efficiency [3]. Taking the importance of Cadmium Sulfide material into account, studies are planned to investigate the physical and electrical properties of the thin films cadmium sulfide.

II. EXPERIMENTAL

The chemical bath deposition technique was used to grow thin films of CdS with a varying molarities of the solution. The films were deposited onto a good quality glass plates as substrates (size 75 mm X 25 mm) in which cadmium Sulfide, and thiourea were used as the basic ingredients. When thiourea is added to an alkaline solution of a complex cadmium salt, the solution become turbid and solid phase of CdS is formed by the reaction [4]:

$$[Cd\,(NH_3)_n\,]^{2+} + (NH_2)_2\,CS + 2OH^- = CdS + nNH_3 + H_2NCN + 2H_2O$$

To carry out the growth, 1 M Cadmium sulfide solution was prepared. For each growth of the thin film, 10 ml of 1 M Cadmium sulfide solution was taken into a beaker. Required amount of triethanolamine was added to form a bound stable complex. The appropriate quantities of Sodium hydroxide and aqueous ammonia were added to adjust the pH of the reaction mixture and film adherence to the substrate support. The substrates (glass plates) were stirred in the solution at a constant temperature 55 ºC and rate of rotation 60 rpm using a DC motor.

A. Effect of Stirring

There have been a few studies on the effects of stirring the deposition solution on the deposited film. Overall, stirring affects CBD grown films mainly by preventing deposition of loosely adhering, large aggregates. These loose deposits are readily removed by the stirring action. This is important, since they block the substrate, preventing normal adherent film growth. Such no adherent deposits can also be prevented without stirring by placing the substrate in the bath at an angle. Due this the deposit on the surface towards front side, which will usually be a mixture of adherent and the loosely adherent material, will be removed (by wiping with a reagent that dissolves the film), leaving the film on the back-side surface of the glass plate, which does not collect precipitated deposit. It is reported that the rate of deposition is affected by stirring only at low stirring rates, and the effect is not large. There is no apparent difference between low and fast stirring rates [5]. This implies that, even slow stirring is enough to prevent sticking of large, loosely adhering particles. Apart from deposition rate, the stirring could, in some cases, strongly affect the film quality and the effect of stirring depends on the concentration of ammonia (relative to the Cd).

III. RESULTS AND DISCUSSION

A. Physical/ Surface Observations

Certain physical properties (quantum size effect, color of the film etc.) of thin film semiconductor depend on the thickness of the film. The thickness of the as grown films depends on the time of the deposition as well as the composition parameter. Therefore a series of films were grown by varying disposition time at a constant temperature 55ºC with a constant rate of rotation 60 rpm and the corresponding thickness were measured. The thickness of the films was measured by using wedge shaped film. Figure.1 shows the variation of thickness of the film with the deposition time. The graph shows that the thickness is proportional to the deposition time up to ~ 60 min and the rate of increase of the thickness reduces as time increases.

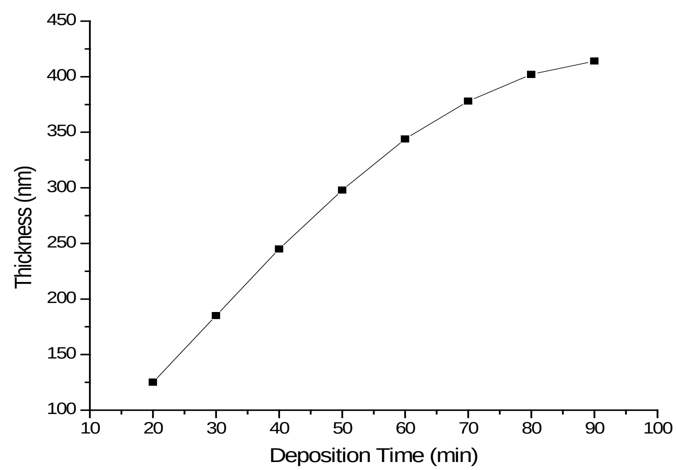

Figure 1: Time dependence of thickness of CdS thin film on deposition time

The as-grown CdS films were thin, uniform, smooth and well adherent to the glass substrate. Color of the as grown film changes with the concentration from greenish yellow to bright yellow. Observation of the film by optical microscopic (figure 2) show that average size of the grains on the as grown film is of the order of 4 -5 micrometer. It also reveals that the films are uniform in thickness and color throughout the film area.

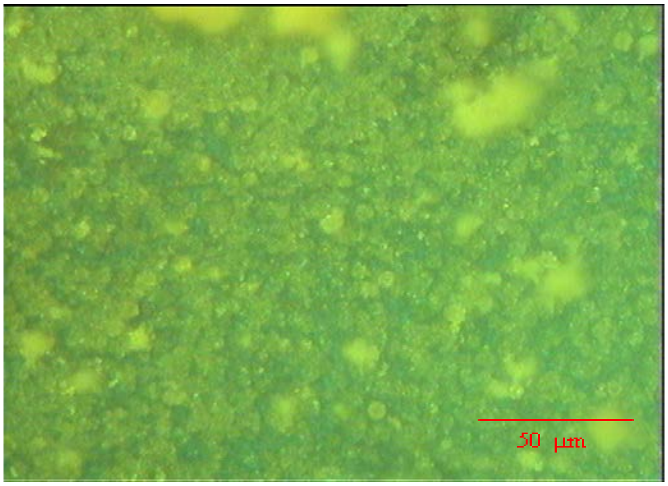

Figure 2:Surface photograph of as grown film using Optical Microscope

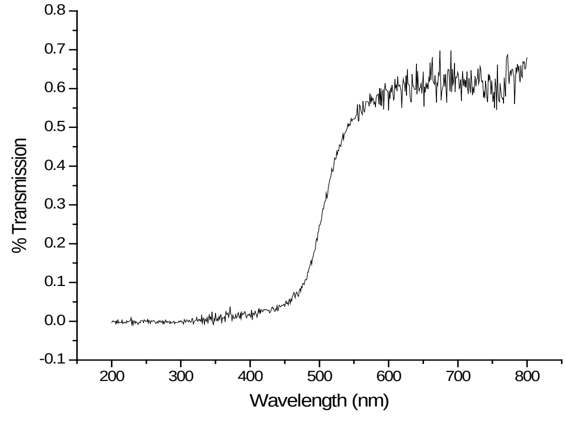

Figure 3: UV-Vis graph of CdS thin film

B. UV-Visible Spectroscopy and Nano-size of CdS Particles

Quantum size effect is one of the most important properties of CdS particles. Some thin films were annealed for 1 hr at 300 ºC to form cohesive mixture of the grains on the as grown film to study the quantum size effect exhibited by the CdS particles [6]. One of the thin film was scanned on UV-Visible in transmission mode and the graph of the transmission response is shown in figure 3. The scan indicate an edge at wavelength 424 nm which corresponds to the emission energy of 2.93ev. The Brus Equation was used to obtain the radius of the quantum dot (R) by using the equation for emission energy of quantum dot semiconductor nanocrystal in terms of the band gap energy (Eg), Planck's constant (h), , the mass of the excited electron (m^*_e), and the mass of the electron hole (m_h^*) given by the following equation [7].

$$\Delta E(R) = E_g(R) + \frac{h^2}{8R^2}\left(\frac{1}{m_e^*} + \frac{1}{m_h^*}\right)$$

The radius of the quantum dot affects the wavelength of the emitted light due to quantum confinement, and this describes the effect of changing radius of the quantum dot on the wavelength emitted. Radius of the nano size CdS particles calculated using above equation was observed to be ~ 3.67 nm.

C. Resistivity Measurement

Since indium is known to be good for ohamic contacts, it was used to make the contacts to the thin films. Four linear contacts with the spacing of 2.5mm were made. Current in the range of microampere was allowed to pass through the film at room temperature. The resistivity of the films was found to be in the range of (8.73 to 11.23) X10^5 **Ω-**cm.

IV. CONCLUSION

Thin films of Cadmium sulfide were deposited successfully on the glass substrate by chemical bath deposition system. The grown films indicated uniform deposition of CdS particles on the substrate. Resistivity of the grown films was of the order of 10^6 **Ω-**cm and calculated size of the CdS nano-particles is ~ 7 nm.

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