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Structural Analysis of Chemical Bath Deposited Cadmium Sulphide Thin Film

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Abstract— Cadmium Sulphide thin film was deposited by using Chemical Bath Deposition Method. Chemical Bath Deposition Method is most easy, simple and cost effective method of thin film deposition. CdS thin film was deposited using Cadmium Sulphate as a source of Cd^{+2} ions and Thiourea as a source of S^{-2}ions. Aqueous Ammonia was used to maintain the p^H of the reaction mixture and Triethylamine as a complexing agent. Yellowish Orange CdS thin film of 484 nm thickness was deposited. X-ray diffraction analysis of the deposited thin film revealed a mixture of hexagonal and cubic crystal structure. The standard d values well agreed with the observed d values.

Keywords-*Chemical bath deposition, Cadmium sulphide, Thiourea, X-ray diffraction.*

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I. INTRODUCTION

Cadmium Sulphide is an inorganic chemical compound that has the formula CdS. It is yellow in colour and is a semiconductor of electricity. CdS is used as light Dependent Resistors and Solar Cells.Thin films of Cadmium Sulfide can be piezoelectric and have been used as transducers which can operate at frequencies in the GHz region.[1]Cadmium sulphide can be used as a potential material in thin film solar cells. Semiconducting nanostructures are promising candidates for future electronic and photonic devices. They have unique physical and chemical properties and can be used as elementary units of optoelectronic devices [2,3,4,5].

There are number of physical and chemical techniques used for the deposition of thin films of the semiconducting material. The choice of technique depends on the material to be deposited, nature of substrate, required film thickness of thin film, application were the film used etc. The techniques used for the deposition of a semiconducting material are classified as physical and chemical techniques. Chemical techniques are relatively economical and easier as compared to physical methods.

Chemical bath deposition (CBD) is a solution growth process used for depositing thin films of compound materials. An aqueous solution of a metal complex, when mixed with a solution of chalcogen bearing compound, precipitation of the chalcogenide occurs under certain condition. When the precipitation is controlled, compound gets deposited on the wall of the container and surface of the substrate. CBD method has been used successfully to deposit binary and ternary semiconductors. The parameters like temperature, pH value, concentration of ions, the nature of the substrate, nature of the complexing agents and salts used control the deposition process.CBD technique is very simple and low cost. In CBD method, thin films are deposited on the substrate from aqueous solution either by passing a current or by chemical reaction under appropriate conditions. CBD yields stable, adherent, uniform and thin films with good reproducibility by a relatively simple process. The growth of thin films strongly depends on growth conditions, such as duration of deposition, composition and temperature of the solution and topographical and chemical nature of the substrate.

II. EXPERIMENTAL METHOD

Thin glass slides were used as substrates for deposition of CdS. The glass slides were cleaned by boiling for 1-2 hours in solution of Chromium trioxide. The boiled substrates were washed using double distilled water and finally cleaned with acetone and then dried. The materials used for deposition were $CdSO_4$ as a source of Cd^{+2} ions, Thiourea as a source of S^{-2} ions, TEA as complexing agent and liquid Ammonia to maintain p^H of reaction mixture at 10.5. A complexing agent is usually employed to control the reaction at suitable rate to obtain the desired thin film growth [4, 5, 6, 9].10 ml of 1M CdSO4 solution was prepared in double distilled water. Then 10 ml of 1M Thiourea solution was prepared in double distilled water. 10ml of 1M CdSO4solution and 10 ml of 1M Thiourea solution were mixed together by constant stirring forming a reaction mixture. 2.4 ml Triethylamine (TEA) solution was added drop by drop with constant stirring. Then 18 ml Ammonia solution was added drop by drop to the reaction mixtureto maintain pH at 10.5. The temperature of

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the reaction mixture was maintained uniform and constant by means of paraffin oil bath. The glass substrates were mounted on the substrate holder and then immersed in the reaction mixture, which was stirred at arateof 70 rpm by a rotator for a deposition time of 90 mins as shown in Fig.1.Then after 90 mins thin, uniform and adherent yellowish Orange colored deposition was obtained on the glass substrates as shown in Fig.2.

Fig.2.CdS deposited thin films.

Weight of the deposited Cadmium sulphide substrate per unit area (mg/cm^2) was measured by digital weight balance with a least count of ~ 0.1mg/cm^2. The internal structure of the Cadmium sulphide thin films was studied by using X-ray diffraction patterns carried out by X-ray diffractometer (XRD) (Rigaku D/max 2550Vb+18 kw with CuKα 1=1.54056Å) in the range of diffraction angle 2θ from 20^o–80^o.

III. RESULTS AND DISCUSSIONS

A. Chemical Reaction

$[Cd(NH3)_4]_2$+ Cd^{+2} + $4NH_3$
(dissociation of complex to free Cd^{+2} ions) ---- (1)

$(NH_2)_2CS$ + 2OH- S^{-2}+ CN_2H_2 + $2H_2O$
(formation of sulphide ions) ----------(2)
Cd^{+2} + S^{-2} - CdS
(CdS fromation by ionic reaction) ---------- (3)
The simple cluster (hydroxide) mechanism:
nCd^{+2} + 2nOH $[Cd(OH)_2]n$
(formation of a Cd(OH)2 cluster) ---------- (4)
$[Cd(OH)_2]n$ + nS^{-2}nCdS + 2nOH
(exchange reaction) ---------- (5)The complex decomposition ion - by - ion mechanism:
$(NH_2)_2CS$ + Cd^{+2} $[(NH_2)_2CS-Cd]^{+2}$-------- (6)
$[(NH_2)2CS-Cd]^2$+ + 2OH- CdS + CN2H_2 + $2H_2O$
---------- (7)
The complex decomposition cluster mechanism:
$[Cd(OH)_2]n$ + $(NH_2)2CS$ $[Cd(OH)_2](n-1)(OH)_2Cd$------S-----$C(NH_2)_2$ ---------- (8)
$[Cd(OH)_2](n-1)(OH)_2Cd$----S---$C(NH_2)_2[Cd(OH)_2](n-1)$ + CdS + CN2H_2 + $2H_2$-----(9)

B. Structural Analysis

The graph of Intensity against 2θ illustrates the recorded XRD diffractogram of CdS thin film, of thickness 484 nm deposited at substrate temperature of 56^0 C. The diffraction pattern clearly shows that CdS thin film is polycrystalline with mixed phases of hexagonal & cubic crystals structures. The diffraction details are presented in a tabular form in Table.1.

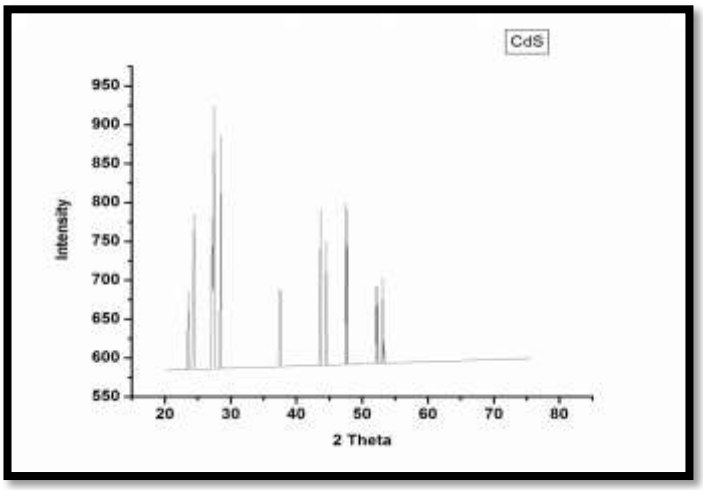

Fig.3.XRD pattern of Cobalt sulphide thin film

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	2θ Obs. Deg.	2θ Std. Deg.	d (^{0}A) obs.	d (^{0}A) std.	I/I_{ma} Obs.	I/I_{ma} Std.	Phase CdS	Phase β-CdS
	24.5	24.363	1.68	1.68	780	10	------	222
	27	26.336	2.603	2.414	125	10	104	-----
	28.193	28.193	4.528	4.528	880	999	101	-----
	44	43.048	3.536	3.533	790	414	------	220
	48	48.117	1.007	1.007	800	406	103	-----
	52	52.076	1.754	1.751	695	35	-----	311

Table.1.Structural parameters of CdS thin films

Fig.3 shows XRD pattern of CdS thin film of 484 nm deposited at 56^{0}C temperature. The observed d values are in close agreement with the standard data.The diffraction pattern clearly reveals that deposited CdS thin film is polycrystalline and a mixture of cubic and hexagonal crystal structures. The observed and standard data well matches with PDF# 020454 (222) planes, PDF#020544 (104) planes, PDF#892944 (101) planes, PDF#750581 (220)planes, PDF#800006 (103) planes, PDF#751546 (311) planes respectively.

.The average crystallite size was calculated from (101) planes using Scherrer's relation as,

$$D = \frac{k\lambda}{\beta cos\theta}$$

Where, D is the average crystallite size, β is full width at half maximum of the diffraction line,θ is diffraction angle, and λ is the wavelength of the X-ray radiation. The size of the crystallite was estimated to be 45 nm. Nanocrystalline thin films are of significant interest for a large variety of electronic and optoelectronic devices [7, 8].

IV. CONCLUSION

Cadmium sulphide thin films were deposited by Chemical bath deposition technique. The thickness of the deposited thin film was 484 nm. XRD analysis shows that the films are polycrystalline with mixed phases of hexagonal & cubic structures. Chemicalbath deposition technique was suitable for the preparation of Cadmium sulphide thin film. The deposited Cadmium sulphide thin film was yellowish Orangein colour and hexagonal in crystal structure.

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