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Effect on optical properties of annealing temperatures on thin films CdS/Cu_2S/ ATO glass substrate for solar device

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Abstract: In this research paper the effect of annealing temperatures on thin films CdS /Cu_2S/ATO glass substrate is studied. The room temp. deposited films are annealed at 100°C-400°C and are optically anayzed by UV-Visible spectrophotometer to study transmission spectra and band gap. The estimated values of optical band gap of Cu_2S/CdS films are 2.75eV, 2.73eV, 2.70eV, 2.66eV for annealing temperature of 100ºC, 200ºC,300ºC and 400ºC respectively.

Keywords: CdS, Cu_2S, ATO, UV-Visible spectrophotometer etc.

1. INTRODUCTION

Transition metal chalcogenides are getting attraction day by day due to their exotic physical-chemical properties. Such properties make it suitable for numerous potential applications, such as optical sensors, solar cells, photodiodes, catalysts, light-emitting diodes, microelectronic devices, etc. [1]. The copper sulfide (Cu_xS) exhibits five different phases, including anilite (Cux =1.75S), digenite (Cux =1.8S), djurleite (Cux =1.95S), chalcocite ($Cu_x =_2S$), and covellite (CuS) [2]. Among all these phases, the Cu2S has demonstrated astounding characteristics, which make it suitable for large-scale optoelectronics applications. Cu_2S shows p-type semiconducting behavior with an indirect band gap of 1.2eV and a high absorption coefficient over 10^4 cm^{-1} [3]. Moreover, Cu_2S thin film shows an important role in various applications including a photodiode, sensors, lithium-ion batteries, LED, and heterojunction diode in the form of Cu_2S/X, where X = CdS, ZnS, ZnO, n-Si, etc. [4–6]. Similarly, the cadmium sulfide (CdS) is an n-type semiconductor of binary group II-VI, a combination of cadmium (Cd) from group II and sulfide (S) from group VI [7], and has a bandgap around 2.4eV at room temperature [8]. CdS exhibit outstanding behaviors for various optoelectronic applications such as photoconductive, photodiode, electroluminescent, photo luminescent, solar cell device, etc. [8].
In recent years, various researchers have tried to synthesize several thin film-based heterojunction devices in order to enhance the diode performance. One among them is heterostructures of Cu_2S (p-type) and CdS (n-type) in the form of Cu_2S/CdS thin film heterojunction [9,10]. The Cu_2S/CdS thin film-based device showed significant improvements

In this work, Cu_2S/CdS thin film are deposited using the spray pyrolysis and dip coating technique on ATO glass substrate. The films deposited are than anneaied at100°C-400° C in order to study the effect of annealing temp. on the transmission spectra. Also effect of annealing temp. Is studied on bandgap.

2. EXPERIMENTAL DETAILS

The Cu_2S/CdS thin film are deposited onto ATO coated glass substrate through spray pyrolysis and dip coating technique. Before deposition of Cu_2S/CdS thin film, the ATO thin film was deposited onto a glass substrate through spray pyrolysis. Further, the CdS layer was deposited through spray pyrolysis technique using a mixture of cadmium chloride ($CdCl_2$) solution and thiourea [$CS(NH_2)_2$] on ATO substrate at 320 ˚C. On other hand, the Cu_2S thin film was produced through dip coating technique by dipping the previously obtained alloy films in a heated solution of $CuCl_2$. The Cu_2S/CdS thin films were inserted into a vacuum chamber for vacuum heat treatment at a vacuum of 10^{-5} torr. The films are annealed in vacuum of 10-5 torr at 100 ˚C, 200 ˚C, 300 ˚C and 400˚C.

3. RESULT AND DISCUSSION

Optical characterization of Cu_2S/CdS films

Transmission spectra of Cu_2S/CdS thin films with different temperature from 100ºC-400ºC are shown in Fig. 1. The samples exhibit nearly 85% transparency in the wavelength interval of 400–700 nm. Transmission spectra of thin films show an increasing behavior till the wavelength of 760 nm and the highest T value of above 90% for 100ºC sample. When

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Cu_2S/CdS thin films are annealed with 400°C, the T decreases and reaches below 70% over 530 nm, which indicates as temperature increases the transparency get decreases. However, the band edge study of Cu_2S/CdS thin films displays a sharp fall at the wavelength of almost 400 nm, as temperature increases the wavelength shifted towards longer wavelength, absorption edges of films are related to the size decrease of nano particles due to the quantum confinement (QC) effect, indicating a decrease in the band gap.

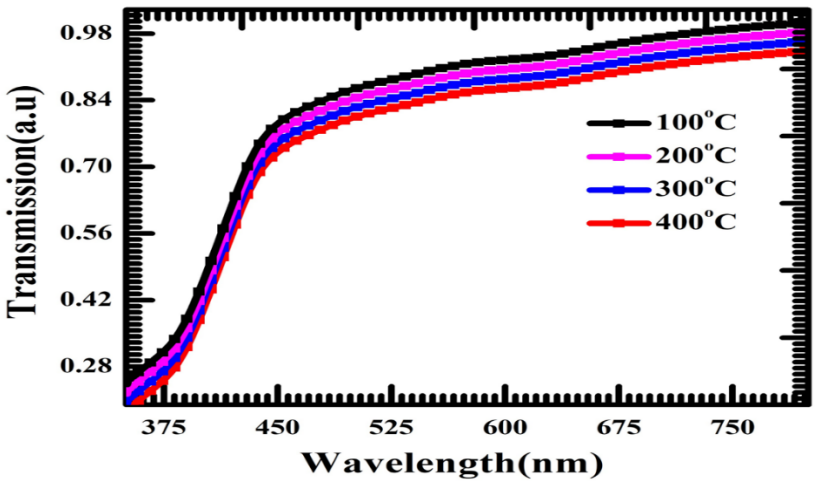

Fig.1.Transmission spectra of Cu_2S/CdS thin film with different annealing temperatures.

The band gap of Cu_2S/CdS films for each transmission curve are found from the variation of absorption coefficient (α) depending on the photon energy (hv), through Tauc plot, which is expressed as:

$$\alpha(hv) = \frac{M(h\nu - E_g)^n}{h\nu}$$

Here M is transition probability and n are exponent taking values of either 1/2 for direct transition or 2 for indirect transition. Fig. 2. shows the absorption coefficient variation $(\alpha hv)^2$ as a function of photon energy (hv) at various temperatures. The estimated values of optical band gap of Cu_2S/CdS films are 2.75eV, 2.73eV, 2.70eV, 2.66eV for annealing temperature of 100°C, 200°C,300°C and 400°C respectively. As temperature increases the band gap decreases, which is in good agreement with previous reported work on CdS thin films. This decrement in optical band gap is explained through the following aspects. (a) Annealing at 400°C, the carriers i.e electrons excite from the top of the valence band (VB) through energy gained by temperature, into the conduction band (CB), so band gap become narrow. (b) The band gap may be varying due to edge shifting in optical absorption spectra and varying carrier concentration of films, might be justified using the Burstein–Moss (BM) concept. (c) The band gap decreases because crystal size increases due to confinement effect.

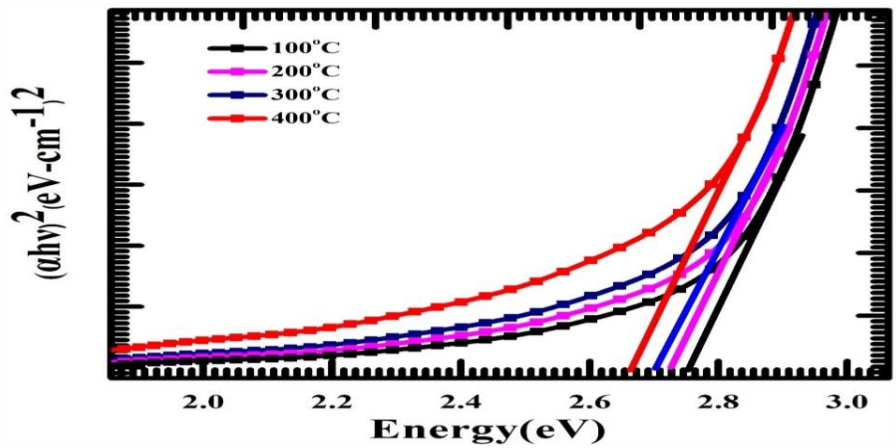

Fig.2. band gap of Cu_2S/CdS thin film with different annealing temperatures

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CONCLUSION

It is observed that annealing temp' significantly affects the transmission percentage and bandgap of CdS/Cu2S thin films. Both transmission and bandgap decrease with annealing temp. The estimated values of optical band gap of Cu_2S/CdS films are 2.75eV, 2.73eV, 2.70eV, 2.66eV for annealing temperature of 100ºC, 200ºC,300ºC and 400ºC respectively.

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