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Morphological and elemental analysis of spray pyrolysis deposited CdS thin films for CdS/Cu_2S solar cell heterostructure

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Abstract: In this paper, room temperature deposition of CdS thin film on antimony doped tin oxide (ATO) substrate through spray pyrolysis technique. The size of thin film is estimated through field-emission scanning electron microscope (FESEM) FESEM and TEM (Quanta 200 and HITACHI SU8010) have been used to analyze surface morphology and particle size. The AFM(NT-MDT,INTEGRASpectra) was employed to analyze the topography and roughness of CdS thin film. The elemental analysis of the film was done by EDS spectra. The thickness of CdS film is also measured by AFM technique.

Keywords: Spray pyrolysis, CdS, FESEM, TEM, AFM, EDS etc.

I. INTRODUCTION

In the last few decades much more effort has been put into the development of thin films. Mostly, thin film research is concentrated around II-VI group semiconductors junction thin films. One of the most promising thin films are Cu_2S/CdS due to the high percentage of conversion of solar energy into electrical energy more than 10%.

To synthesis of different morphologies of CdS based heterostructure such as nano-flakes, triangular, nanospheres, nanorods, flake like shape, up to date various physical and chemical routes are used for the synthesized of CdS or CdS based heterostructures such as magnetron sputtering, thermal evaporation, electron-beam, sol-gel, co-precipitation, chemical bath deposition, spray pyrolysis, etc. On other hand various solution (sol gel, spin coating and all inorganic solution) [1-3] processed thin film heterojunction are used at low temperature for various potential applications, interesting observation the irradiated (200 ◦C) dielectric exhibited the highest number of traps on the same energy level (at 0 eV) [1], the processing temperature dependent tunable electronic band structure for the solution processed dielectric with tuning the electron affinity is applicable to other dielectrics which are useful to obtain improved performance from electro-optical devices[4], on other hand a highly sensitive controllable trap detection method is used to detect shallow and deep level electronic traps in dielectrics. The method is simple, independent of substrate material and captures the trap energy signature in dielectrics; this can assist in material selection during technology development [5], also advantage of solution-processed thin film for fabrication of device is to control the contact resistance due to dimension modification [6]The excellent observation was reported at low temperature below 200 °C solution processed tunable flash memory device without tunneling and blocking layer [7]. Among all mentioned techniques, spray-pyrolysis process is successfully applied to synthesize a thin film. It has several advantages over other processes, like high purity of synthesized films, regular shape of particles, a better control of stoichiometry and chemical regularity in coupled oxide, and continuous working. Also, this technique makes the experimental process relatively simple.

II. EXPERIMENTAL DETAILS

The CdS thin films were prepared onto antimony doped tin-oxide (ATO) substrate by cost affecting spray pyrolysis and dip coating. First the CdS film was deposited at temperature of 320°C. Prior to CdS thin films deposition, the tin oxide and antimony doped tin oxide films on glass substrate were prepared by spray pyrolysis in which an aqueous solution of stannic chloride mixed with alcohol was sprayed over heated clean glass substrate for the undoped tin oxide films. The sprayed droplets undergo an endothermic reaction on the surface of the substrate. The heat of the substrate initiates the chemical reaction, by providing the necessary thermal energy for decomposition of reacting materials into its constituents and recombination of these constituents form desired oxide films. The other volatile products formed during this process escape out. The reaction involved is given as:

$$SnCl_4 + 2H_2O \rightarrow SnO_2 + 4HCl$$

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However, the reaction does not proceed towards completion, thus forming oxygen deficient SnO_2 films. The alcohol acts as a reducing agent and deeds as carrier solution and dispersive medium. A transparent layer of antimony doped tin oxide (ATO) which acts as the bottom electrode to the CdS layer, was achieved by adding antimony chloride ($SbCl_2$) dissolved in concentrated hydrochloric acid. This procedure was repeated for different concentrations of antimony chloride. The deposition was carried out at 320°C. Thus, we obtained conducting glass. To deposit a film of CdS onto ATO substrate, the solution of cadmium chloride ($CdCl_2$) and thiourea (NH_2CSNH_2) was spread over ATO at 320°C. The reaction involved was given as:

$$CdCl_2 + NH_2CSNH_2 + 2H_2O \rightarrow CdS + 2NH_4Cl + CO_2$$

$$NH_4Cl \rightarrow NH_3 + HCl$$

The volatile products formed during this process escape out to the ambient atmosphere. Now the films were annealed for 10 minutes in vacuum to decrease the resistivity of the alloy films by removal of acceptor like oxygen levels.

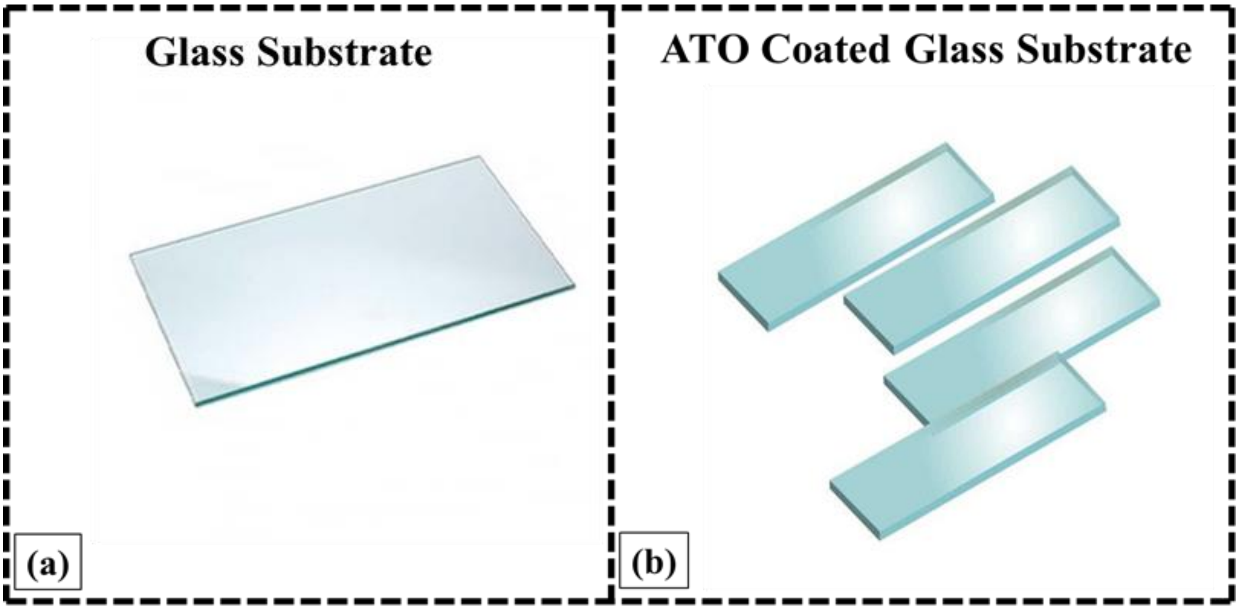

Fig.1 Different substrate used to deposition of thin films

4.3 Morphological and elemental analysis of CdS thin film:

The FESEM is a suitable technique for analysis of surface morphology and estimation of average particle size of film. Fig.2 (a) shows the FESEM images of CdS film. The FESEM images show mainly a block with nearly spherical, uniform size but irregular surface morphology distributed over the entire surface. Moreover, it is clear from the FESEM images of doped CdS film that the particles are aggregated in a peculiar way. Here the increment in particle size can be evidenced with the naked eye. The average particle sizes estimated using the FESEM image are found to be in the range of 80 nm. The TEM image for CdS thin film is shown in Fig.2 (b). The average sizes estimated using the TEM image are found to be in the range of 22 nm.

To analyze the morphological, homogeneity and distribution of particles size of deposited thin films, AFM was used, 2-D tapping mode imaging process was carried out using the WiTec software. Fig.2 (c) shows the 2-dimensional morphological image (scans ($3 \times 3\ \mu m^2$) of CdS film. The AFM images show that the thin film is made with a large number of spherical nanoparticles and are distributed all over the surface. The estimated values of surface profile parameters such as average surface roughness (Ra) and root mean square roughness (Rq) are 19 nm and 43 nm respectively.

The recorded energy dispersive spectroscopy (EDS) spectra of CdS film is shown in Fig.2 (d) . EDS reports spectra confirmed the composition of cadmium (Cd) and sulfur(S) in the CdS film. The strong peaks of Cd and S are present in the expected range and there are not any other peaks observed, which confirm the purity of the synthesized of CdS samples.

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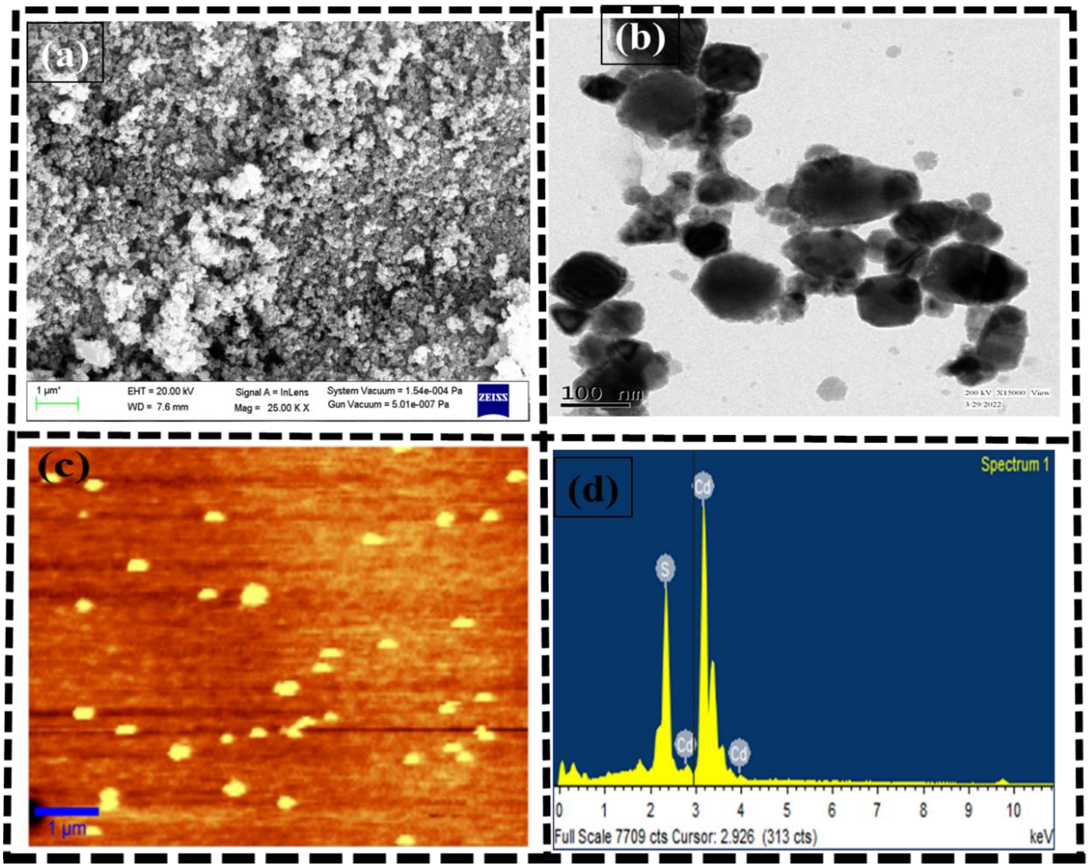

Fig. 2 (a) FESEM, (b) TEM, (c) AFM and (d) EDS spectra of CdS thin film

4.2 Measurement of thickness of CdS thin film by AFM techniques

The thickness obtained for CdS film using Gwydion software is as shown in Fig 4.2. The parameter "h" in the profile graph gives the thickness of the CdS thin films. Thin Films thickness estimated by direct step height measurement by using AFM were 44.5 nm.

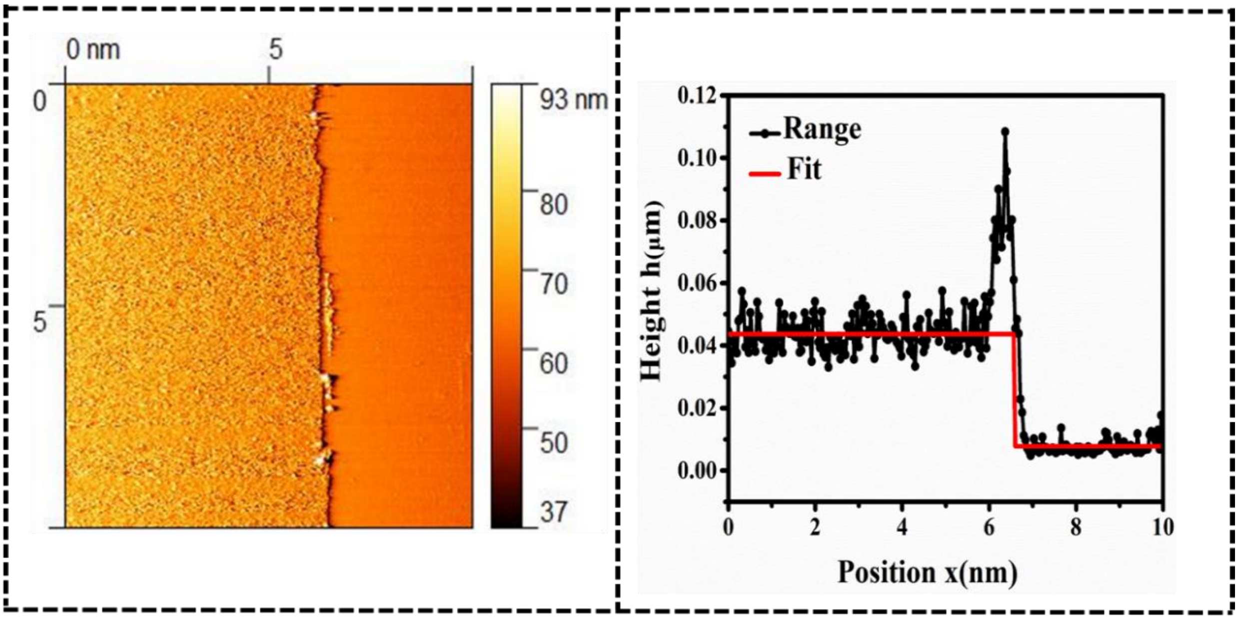

Fig. 3: Thickness measurement of CdS thin film by AFM techniques

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III. CONCLUSIONS

In summary, CdS thin films were prepared on ATO/glass substrate using spray pyrolysis methods. The films were characterized for their morphological and topographical studies. The EDS specra shows the presence of Cd and S presence. The average particle sizes estimated using the FESEM image are found to be in the range of 80 nm . The average sizes estimated using the TEM image are found to be in the range of 22 nm. The estimated values of surface profile parameters such as average surface roughness (Ra) and root mean square roughness (Rq) are 19 nm and 43 nm respectively using AFM technique. Thin Films thickness estimated by direct step height measurement by using AFM is 44.5 nm. Thus, the obtained results show that CdS films are beneficial to develop large-area, low cost and high-quality photovoltaic devices for advanced future technology.

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