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Hydrogenation effect on structural, electrical and optical properties of CdS thin films for solar cell

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ABSTRACT

Adsorption effects would be expected to be of considerable importance with thin films because of the changes in electron location accompanying adsorption. The effects of hydrogenation on structural, optical and electrical properties of the CdS thin films have been reported. GIXRD patterns shows that films have polycrystalline nature with a hexagonal structure. The optical band gap increased after hydrogenation of the film. The variation of conductivity of CdS films have been investigated depending upon the applied voltage at room temperature. The resistivity increased after hydrogenation of the films. Hydrogenated thin films can be used in solar cells because hydrogen plays an important role to modify the physical properties.

1. Introduction

CdS with a direct band gap is a suitable window material for heterojunction solar cell. There are two basic requirements for the window material: a. low electrical resistivity and b. high transmittance with optimum band gap [1]. However, a higher resistivity of as-deposited CdS films (of order of 10^{4-5} Ωm) puts a limitation on its use [2,3]. The efficiencies of solar cells prepared with sputtered CdS layer in pure argon are quite low (8–10%). The reduction of the efficiency is due to a very high reverse saturation current, caused by the presence of grain boundaries in the polycrystalline CdS. The grain boundaries are electrically active and able to canalize the reverse current reducing the device performances.

A commonly used method to reduce the resistivity of CdS films is to dope the impurity into CdS films. There are a number of reports on the properties of CdS polycrystalline films prepared by various techniques such as molecular beam epitaxy, thermal evaporation, spray pyrolysis, electrodeposition, chemical vapor deposition, pulsed-laser deposition and chemical bath deposition [4–9]. The changes in optical and electrical properties, as well as changes in material structure and morphology have been evidenced in the above-mentioned references. The advantage of using a thin film as a partner in a heterostructure for photovoltaic device structures is based on the fact that the films can be deposited directly on semiconductor substrates using easy and low-cost processes [10]. A heterojunction solar cell including InP as a substrate with cadmium sulphide (CdS), as a window material, utilizing both low sheet resistance and wide band gap of 2.42 eV is expected to be attractive [11].

Regardless on the deposition technique, the post deposited film's characterization and deposition processes optimization is still an open subject. A large number of studies are carried in order to produce CdS thin films with good optoelectronic properties suitable for photovoltaic applications. For this

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purpose several properties are required for the CdS thin films: (i) relatively high transparency and not too thick to avoid absorption in the buffer layer and favors the absorption in the Copper Indium Selenium (CIS) layer (ii), not too thin to avoid the short circuiting (iii) relatively large conductivity to reduce the electrical solar cells losses and higher photoconductivity to not alter the solar cell spectral response.

Hydrogen molecules are known to interact with materials via two ways: it is either physisorbed in molecular form or chemisorbed in atomic form [12]. It has been reported that a small amount of hydrogen in argon plasma induces an increase in the crystallite size of the as-deposited films. In addition, control of hydrogen partial pressure is expected to improve the carrier mobility by increasing the crystallinity of the film [13]. Hydrogen strongly affects the electronic properties of materials. Interstitial hydrogen is a fast diffuser. It can bind to native defect or other impurities, often eliminating their electrical activity – a phenomenon known as passivation. Hydrogen can induce electrically active defects. Research is going on yet to store the hydrogen and observe the properties affected by hydrogenation of thin films [14–16]. Electrical measurements such as current/voltage provide detailed information about the electronic effects of hydrogen. A “universal alignment” model successfully describes the electronic behavior of hydrogen in a wide range of materials and allows for prediction for materials in which the role of hydrogen is yet to be explored [17,18].

In the present work, we report the structural, optical and electrical properties of as grown and hydrogenated CdS thin film deposited on Indium Tin Oxide (ITO) substrate by electron gun evaporation technique. We investigated here only change in the basic properties of CdS thin film which is widely used in solar cells.

2. Experimental details

2.1. *Sample preparation*

Thin films of CdS have been prepared by electron gun evaporation method using vacuum coating unit (HIND HIGH VACUUM system modal No. 12A4D) at a pressure of 10^{-5} torr on well-cleaned ITO substrate. Compound cadmium sulfide (99.99% purity) in powder form was purchased from Alfa Aesar, USA used for the present study; first pallets were prepared of CdS powder for electron beam evaporation at University of Rajasthan, Jaipur. The substrate were boiled with detergent, soaked in chromic acid, cleaned in isopropyl alcohol, rinsed in distilled water and dried after that loaded it in the vacuum chamber. Electron gun evaporation technique was used to deposit thin film of CdS (200 nm) on ITO substrate. The thickness of the thin film was measured by the quartz crystal monitor. The base pressure of the chamber was 1×10^{-6} torr and the process pressure was maintained at 4×10^{-5} torr.

2.2. *Hydrogenation & characterization of the CdS thin films*

Hydrogenation of CdS thin films has been performed by keeping these in hydrogenation cell, where hydrogen gas was introduced at 5 bar pressures for 1 h at a constant temperature 125 °C. The structural characterization of the films was performed by Grazing Incidence X-ray Diffractometer (GIXRD) using CuKα (λ = 1.5406 Å) radiation. The optical absorption spectra of the thin films of CdS were recorded over the wavelength range 250–900 nm using an USB 2000 Spectrophotometer. In this spectrophotometer, absorption spectra are obtained directly through the computer using OOIBase32 software. These measurements were done in the above-mentioned wavelength range at room temperature. The light source is a deuterium and tungsten halogen lamp. Light falling on the sample is normal to the surface of film. From the absorption spectra, the optical band gap of CdS system was determined. Conductivity values of all the films are calculated using two probe method. The electrodes are placed at the surface of the film and conductive wires were attached to the electrodes by means of silver paste. Current-voltage measurements have been performed in the voltage range (−1 to 1 V) voltage range at room temperature by using a Keithely Electrometer.

3. Results and discussion

3.1. *Structural properties*

The crystalline structure of as grown and hydrogenated CdS thin films deposited onto ITO were confirmed by GIXRD using CuKα (λ = 1.5406 Å) radiation at University of Rajasthan, Jaipur. These measurements were carried out in the 2θ range of 20° to 70°. Fig. 1 shows the diffraction pattern of both thin films indicating polycrystalline nature of films with a hexagonal structure (JCPDS card no 006-314 and 041-1049). The seven peaks corresponds to the (100), (002), (101), (110), (103), (112) and (203) lattice planes, respectively [1]. The additional peak in as grown sample was observed which may be due to the partial oxidation of the sample and has been eliminated after hydrogenation. It is cleared from the GIXRD data that strong texturing occurs in (002) plane in both cases and this peak is broadened and increase in intensity with slight shift in position (2θ) after the hydrogenation. It may be due to interaction of hydrogen with cadmium sulfide.

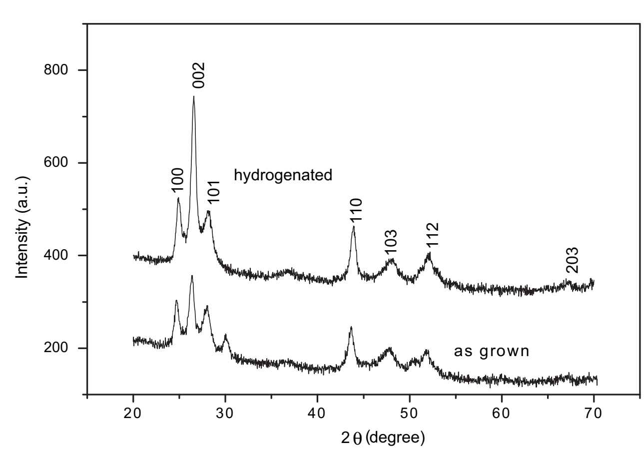

Fig. 1 – GIXRD pattern for as grown and hydrogenated CdS thin film on ITO substrate.