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Effect of annealing on the structural properties of thermal evaporated $CdIn_2Te_4$/CdS thin film solar cells

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ABSTRACT

In this study, a thermal evaporation technique and the effect of annealing on the structural properties of $CdIn_2Te_4$/CdS thin film solar cells were investigated. Thin film solar cells were deposited onto an indium tin oxide (ITO)-coated glass substrate using a thermal evaporation technique. The nitrogen atmosphere was 400 °C for 1 h of annealing. X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive X-ray (EDAX) analysis were performed on the solar cells. XRD analysis revealed two peaks ($2\theta = 27.2^\circ$ and 33.6°). We observed increased peak severity but identical peak position in the annealed films. The X-ray diffraction patterns of the annealed and as-deposited solar cells' preferred orientations in nature have been detected as (200) and (202), respectively. Crystallite size (D), interplanar distance (d), and lattice constant (a) values were calculated for the thin film solar cells using the XRD data. When examining the EDAX analysis and element placement, we detected only $CdIn_2Te_4$ in the absorber layer and only CdS atoms in the window layer, but no impurity atoms in the structure. We also observed an increase in surface roughness of the annealed films in SEM images. The I–V characteristics show that the current is increased for annealed thin films solar cells.

1. Introduction

Thin film solar cells have attracted attention in recent years due to their potential to lower costs and increase energy conversion efficiency. Thin film solar cells have been found to be lower in efficiency than silicon solar cells, but these films have been chosen for their low production costs [1]. According to studies reported in the literature, the efficiency rates of thin film solar cells; cadmium tellurium (CdTe), copper indium gallium selenide (CIGS), and amorphous silicon (a-Si) are 18.3%, 20%, and 12.3%, respectively [2]. Researchers have extensively studied II–VI compounds for applications in the optoelectronic and photovoltaic industry [3–6]. CdTe, one of the most studied compounds in this family, is suitable for use in the production of solar cells because it has a solar energy conversion bandwidth of 1.5 eV [7–12]. These compounds generally crystallize in the form of cubic or hexagonal systems, and they have a defective chalcopyrite structure [13–15]. The most appropriate structure for CdTe thin film solar cells is produced by matching n-type CdS and p-type CdTe [16]. II-III_2-VI_4 compounds, such as $CdIn_2Te_4$ compounds and II–VI compounds, have received great attention in recent years [17,18]. In the last decade, the emphasis has been on the development of low-cost deposition techniques [19]. The thermal evaporation technique for

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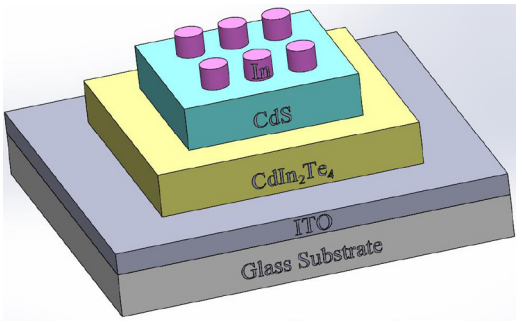

Fig. 1. Schematic diagram of $CdIn_2Te_4$/CdS solar cells on ITO-coated glass substrate [16,32].

depositing CdInTe [18] and CdS thin films is one of the most widely used because it is very simple due to having relatively few control parameters [20].

CdInTe and CdTe films are very sensitive, so various preparation techniques are used to prepare them, including thermal evaporation [21,22], electro deposition [23], the molecular beam epitaxial technique [24], closed-space sublimation [25–27], closed-space vapor transport [28,29], magnetron sputtering [30], and chemical deposition [31]. The properties of CdInTe films have been investigated in many studies [11,15,17,18,29], but more information is needed. In this study, for the first time, solar cells were manufactured by depositing $CdIn_2Te_4$ and CdS on an ITO-coated glass substrate using the thermal evaporation technique. The effects of annealing on the structural characteristics of these solar cells were examined. The results are presented in graphs and tables.

2. Experimental details

2.1. Materials and methods

2.1.1. Depositing $CdIn_2Te_4$

$CdIn_2Te_4$ polycrystalline was deposited on an ITO-coated substrate at a pressure of 5×10^{-5} Torr with a thermal evaporation system. During the deposition process, the substrate was rotated at a constant speed so that the deposition parameters were consistent and homogenous. The evaporation rate of the material was maintained at approximately 15–25 Å/s. When 1 μm (10 kÅ) of closed cutting thickness was reached, the storage process was terminated.

2.1.2. Annealing process

$CdIn_2Te_4$ deposited substrates [16] were annealed for 1 h in a PROTHERM brand horizontal furnace, which was heated up to 400 °C and maintained in a nitrogen atmosphere.

2.1.3. Depositing CdS

After the glass/ITO/$CdIn_2Te_4$ structure was formed, annealed and as-deposited samples were placed in the thermal evaporation system holder to store polycrystalline CdS, which has a window layer. After the CdS was placed into the tungsten crucible in the form of a powder of 99.999% purity, the system was closed. The process of rotating the substrate holder and vacuuming the system began, and the vacuum process continued until the inner pressure of the vacuum circle reached 5×10^{-5} Torr. The deposition process then continued until the cutting thickness reached 1 μm (10 kÅ). The evaporation rate of the material was maintained at approximately 10–15 Å/s during the process.

2.1.4. Contact process

After the glass/ITO/$CdIn_2Te_4$ structure was formed, annealed and as-deposited samples were placed in the thermal evaporation system holder for the contacting process. Solid In was placed into the tungsten crucible, and the contacting process started when the inner pressure of the vacuum circle reached 5×10^{-5} Torr. The deposition process was stopped by closing the cutter after reading a 0.5 μm (5 kÅ) coating thickness value from the monitor. The schematic structure of the prepared solar cells is given in Fig. 1.

2.2. Physical characterization and electrochemical measurements

18 mm × 18 mm × 2 mm ITO-coated glass was used as the substrate material. 12 mm × 12 mm $CdIn_2Te_4$ and 8 mm × 8 mm CdS were obtained as active areas in the solar cells. The surface morphology and composition of the films was obtained through scanning electron microscopy (SEM) and energy dispersive X-ray (EDAX) analysis with a QUANTA (FEG-250) model.