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Characterization of cadmium telluride thin films fabricated by two-source evaporation technique and Ag doping by ion exchange process

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Abstract

Cadmium telluride (CdTe) thin films were deposited onto scratch free transparent glass substrates by two-source evaporation technique, using Cd and Te as two different evaporants. In the next step films were heated under vacuum at 400 °C for 1 h and dipped in $AgNO_3$–H_2O solution at room temperature. These films were again heated under vacuum for 1 h at 400 °C to obtain maximum Ag diffusion. The samples were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM), electrically i.e. DC electrical resistivity by van der Pauw method at room temperature, dark conductivity, activation energy analysis as a function of temperature by two-probe method under vacuum and optically by Lambda 900 UV/VIS/NIR spectrophotometer. The EDX results showed an increase of Ag content in the samples by increasing immersion time of the CdTe films in the solution.
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1. Introduction

CdTe shows unique properties making it important and very suitable for several applications. Its band gap is just in the middle of the solar spectrum, which makes it an ideal material for photovoltaic conversion. Its high average atomic number of 50 and good transport properties with its low absorption coefficient allows high performance electro-optic modulators and photorefractive devices.

The electrical and optical properties of semiconductors are essentially determined by the presence of donor and acceptor atoms. The group I elements Ag and Cu are known as substitutional acceptors in CdTe. Ag as group I element acts as an acceptor dopant in II–VI semiconductors [1] but the hole concentration achieved by doping with Ag or Cu is much lower than the corresponding concentration of group I atoms. In addition, both elements are reported to be incorporated as interstitial donors and the mobility of interstitial Cu or Ag atoms is known to be very high [2–4]. The influence of the respective lattice site on the diffusion of Ag or Cu in CdTe was discussed by Wolf et al. [5]. Ag and Cu diffused into CdTe exhibit unusual shapes of their concentration profiles [6]. The CdTe is an ideal material for several applications like photovoltaic cells and nuclear detectors. It can exhibit both n- and p-types of conductivity, which makes diode and field effect transistors technology possible [7]. Hard X-ray and gamma ray detectors for imaging have been demonstrated from CdTe [8]. CdTe has a direct band gap of 1.5 eV at room temperature, which is optimum for single junction solar cell

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efficiency [9]. Wu et al. [10] have reported on a CdTe/CdS solar cell with an efficiency of 16.5%. Because of its low sublimation temperature, CdTe polycrystalline films can be prepared by several techniques [11–13].

The purpose of this work was to study the properties of Ag doped CdTe polycrystalline thin films grown on glass substrates at 400 °C temperature. We have analyzed the dependence of the lattice parameters, energy band gap and the CdTe electrical resistivity on the Ag content in the range of 0.01–12 wt.%. It was found that Ag provokes the reorientation of the planes in the films observed in the X-ray diffraction measurements.

2. Experimental

Cadmium granulated and Tellurium powder (⩾99.998% pure) were used as two-source materials inside Edwards E306A vacuum coating unit. The materials were loaded into two cylindrical graphite boats, with a hole of ~2 mm diameter on the top to act as point sources and tightly wrapped around by tungsten wire. The boats were heated indirectly by passing current through the Cd and Te heaters, respectively. The temperature controllers with K-type thermo-couples were used to maintain the evaporation temperatures of Cd and Te within ±1 °C. Scratch free glass substrates of visibly good surface finish of area 5 cm × 5 cm were cleaned for 3 h, in pure IPA bath by ultrasonic cleaner. Substrate was placed over the stainless steel substrate holder, while the infrared heater was used to heat the substrate fixed at a distance of about 15 cm from the source materials, a third K-type thermocouple was placed over the substrate for temperature control. The chamber was then evacuated to $\sim 10^{-6}$ mbar with the help of rotary and diffusion pumps. The vacuum during the film deposition was around 1×10^{-5} mbar. The thickness of the film and the deposition rate were measured with the help of a film thickness monitor. The thickness of the film was around 0.55 μm. Substrate was kept at 400 °C temperature

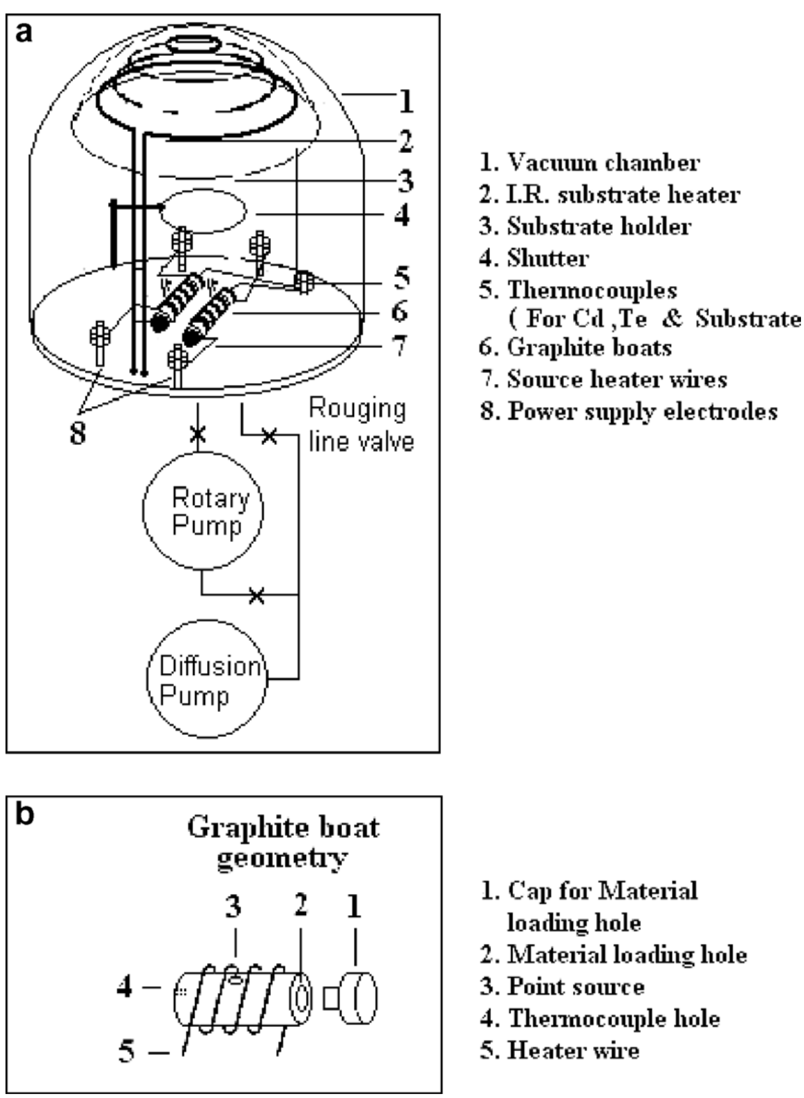

Fig. 1. Two-source evaporation unit fabricated at thermal physics laboratory.

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