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S and Te inter-diffusion in CdTe/CdS hetero junction

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Abstract

Effects of post formation thermal annealing of the CdTe–CdS device on the inter-diffusion of S and Te at the junction in a substrate configuration device have been studied by Auger electron spectroscopy. While the migration of S and Te atoms increases with annealing temperature, the extent of S diffusion is always higher than the diffusion of Te atoms. Inter-diffusion of S and Te causes the formation of $CdTe_{1-x}S_x$ ternary compound at the CdTe–CdS interface.

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1. Introduction

CdTe based photovoltaic devices are highly interesting due to the availability of a variety of CdTe film fabrication techniques such as electrodeposition, sputtering, physical vapor deposition and close spaced sublimation (CSS) [1–5]. A good number of reports and reviews are available on the characterization of both CdTe films [6–13] and CdTe/CdS devices [14–20]. Post fabrication annealing of the CdTe–CdS hetero-structures is a very common practice and critical to improve their photovoltaic performance in fabrication of solar cells. For solar cell fabrication, generally, the CdTe/CdS hetero-structures are annealed in $CdCl_2$ atmosphere in between 350 and 450 °C [21–23], which promotes the recrystallization, grain growth, diffusion of sulfur (S) and tellurium (Te), enhanced p-type conductivity of the CdTe and passivation of defects present at the interface [24,25]. However, the diffusion process depends on the annealing temperature, annealing time, distribution of grains and defect density of the material. The quantification of S and Te inter-diffusion between CdTe and CdS during the post deposition treatment is important in optimizing the annealing process and understanding the devices operation.

The Te diffusion in to the CdS layer produces $CdS_{1-y}Te_y$ ternary compound, with a band gap less than that of the CdS, increasing the light absorption in the window layer thereby diminishing the J_{sc} of the device [24]. In analogous way the diffusion of S in to CdTe forms the compound $CdTe_{1-x}S_x$. The effect of the formation of this compound in the performance of the device is not clear, however, a correlation between spectral response at the absorption edge of CdS and the intermixing of CdTe and CdS has been reported [26]. The intermixing of CdTe and CdS results in a decrease in band gap of CdTe which can lower the V_{oc}, but the reduction in lattice mismatch and interface states reduces the J_o and consequently a higher V_{oc} is obtained [22]. The effect of the inter-diffusion on device performance depends on the composition of the alloy formed during annealing. It was reported that for longer annealing durations, the S concentration in CdTe increases and reaches the solubility limit of S in CdTe [24].

In this paper we report on the study of inter-diffusion of S and Te across the CdTe/CdS interface using Auger electron spectroscopy (AES) technique. CdTe/CdS devices in the substrate configuration is ideal for the AES depth profile study since the junction is easily accessible than that

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in the glass based superstrate configuration. The AES depth profile study of a substrate configuration CdTe/CdS device is discussed and the results are presented.

2. Experimental

The CdTe/CdS hetero junctions were prepared on stainless steel (SS) substrates (Goodfellow AISI 302) using the following procedure: CdTe film of approximately 8 μm thickness was deposited onto the substrate by CSS. The substrate and source temperatures were 570 and 670 °C, respectively [5,27]. The CdTe films were treated with a saturated solution of $CdCl_2$ in methanol, dried in air and annealed at 400 °C for 5 min in air. The CdTe/CdS junctions were developed by depositing approximately 0.2 μm CdS layer onto the CdTe substrates from a chemical bath containing 0.033 M cadmium acetate, 1 M-ammonium acetate, 28–30% ammonium hydroxide and 0.067 M thiourea. The deposition time was about 35 min. The bath was maintained at a constant temperature of 90 °C and continuously stirred during the deposition to ensure homogeneous distribution of the chemicals [28]. Finally the CdTe/CdS junctions were treated with a saturated solution of $CdCl_2$ in methanol and annealed for 20 min in air at different temperatures in the range 350−450 °C.

The cross-sectional composition profiles of the samples were obtained by Auger technique using a JAMP-7800 (JEOL) equipment, with a base pressure of 2×10^{-9} Torr. The parameters of the primary electron beam were: 3 keV of energy and 0.2 μA of current. The samples were inclined at 55° with respect to the normal of the surface. The AES depth profiles were obtained with a Ar^+ beam of 3 keV of energy and 20 mA of current. The atomic concentration of the elements is given by the following relationship [29]:

$$C_k = \frac{I_k/S_k}{\sum_i I_i/S_i}, \quad (1)$$

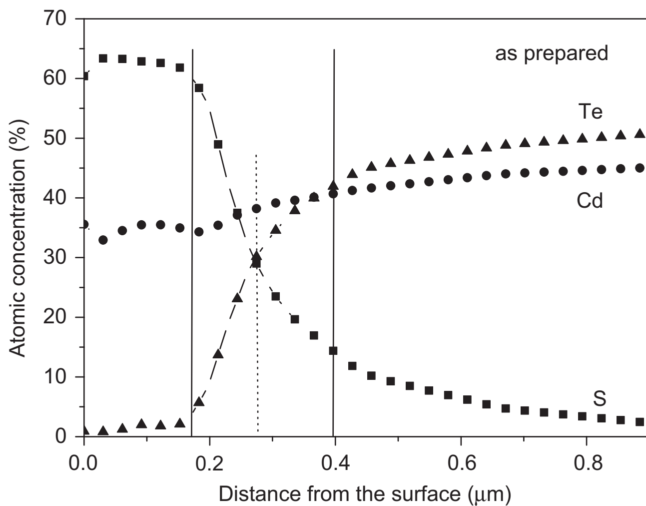

Fig. 1. Auger depth profile of the as prepared CdTe–CdS device.

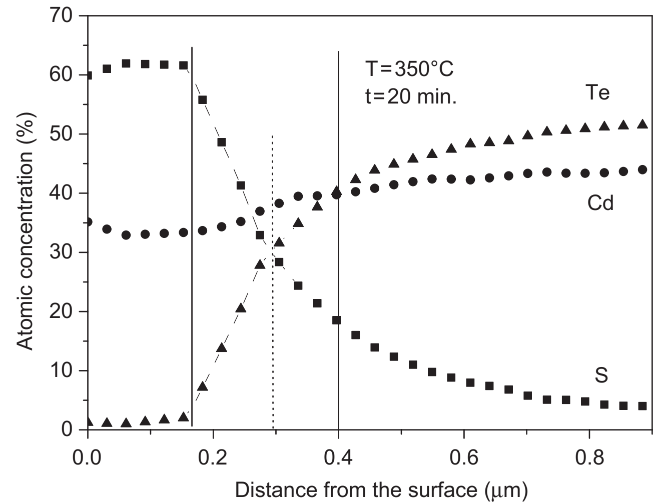

Fig. 2. Auger depth profile of the CdTe–CdS device annealed in dry air at 350 °C for 20 min.

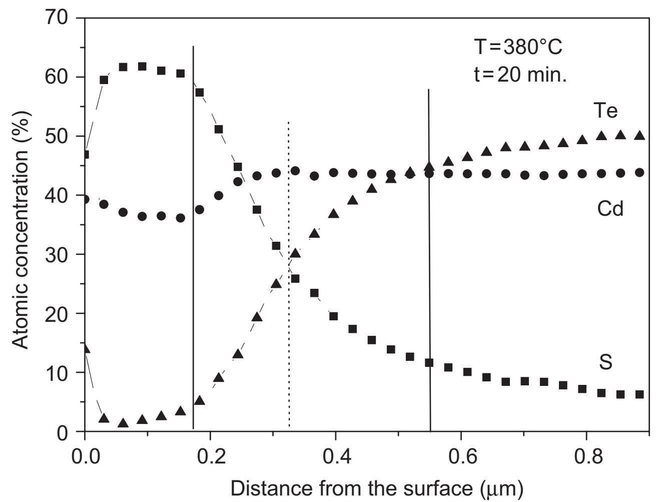

Fig. 3. Auger depth profile of the CdTe–CdS device annealed in dry air at 380 °C for 20 min.

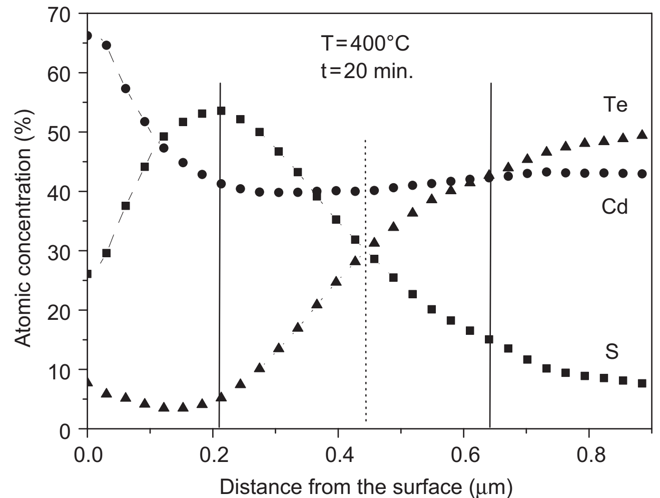

Fig. 4. Auger depth profile of the CdTe–CdS device annealed in dry air at 400 °C for 20 min.

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