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The electrical, optical properties of CdTe polycrystalline thin films deposited under Ar–O_2 mixture atmosphere by close-spaced sublimation

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Abstract

In order to further decrease the fabrication cost, a technology of close-spaced sublimation under Ar–O_2 mixture atmosphere has been studied. A deposition method of CdTe thin films on smooth glass substrates has been developed. The structural characteristics of CdTe films, which are deposited on glass substrate and CdS/SnO_2:F/glass substrate, have been compared. The effects of oxygen partial pressure on the structure and characteristics have been investigated and the preferred orientation was quantificationally studied, which shows that there are the same structures of CdTe thin films on both kinds of substrates, if these films are deposited in an appropriate close-spaced sublimation process. Then the optical and electrical properties of CdTe films on glass substrates are studied, and the effects of post-treatment on the properties are observed. These results have been used to prepare CdS/CdTe/ZnTe:Cu solar cells.

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1. Introduction

The fabrication and the properties of CdTe layer are the most important things to the performance of the CdTe thin film solar cells although there are four function layers in the devices. To date, about ten methods of fabricating CdTe thin films have been developed [1–3], but the highest efficiency records of small-area CdTe solar cells have been demonstrated only by close-spaced sublimation (CSS) [4–6]. In these papers, CdTe thin films were deposited under He–O_2 mixture atmosphere. In order to decrease the cost of CdTe thin film solar cells, it makes sense to develop the CSS process using cheap Ar–O_2 mixture atmosphere as the substitute of expensive He–O_2 mixture atmosphere. Therefore, we wish to study the structure, as well as optical and electrical properties of the CdTe thin films by CSS under Ar–O_2 mixture atmosphere. However, we have noted that the reports about electrical and optical properties of CdTe polycrystalline thin films have been rarely found. We can understand that it is impossible to study the properties of the CdTe films deposited on SnO_2 or CdS layers by electrodeposition or by CSS, and also understand that it is difficult to obtain high-quality CdTe films on glass substrates by CSS because the density of CdTe crystal nuclei is very low on the smooth glass surface in current CSS process.

In our CSS process, it takes enough time to form the CdTe crystal nuclei before growing films [7]. Therefore, the continuous and dense CdTe polycrystalline films have been obtained on glass substrates. The structural properties and the preferred orientation are nearly the same for both kinds of the samples on glass and CdS/SnO_2:F/glass. Then the electrical and optical properties of CdTe films deposited on the glass under different oxygen partial pressure have been studied. The effects of post-treatment on the properties have

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been investigated. The changes in dark conductivity and activation energy of dark conductivity with the annealing temperatures have been discussed.

Based on the studies, CdTe solar cells with the structure SnO_2:F/n-CdS/p-CdTe/p-ZnTe/P^+-ZnTe:Cu/Au without anti-reflection layer have been fabricated. And the 0.5 cm^2 solar cell with the filling factor of 70.3% and the efficiency of 13.38% has been achieved.

2. Experiments

CdTe thin films were deposited by CSS under an Ar–O_2 mixture atmosphere. The oxygen partial pressure was varied from 0 to 15%, and the total pressure was 2 kPa. Soda-lime glass and the CdS/SnO_2:F/soda-lime glass were used as substrates respectively. The samples were prepared at two conditions: the first, the substrate temperature was 500 °C and the source temperature 620 °C; the second, the substrate temperature was 620 °C and the source temperature 680 °C. The thickness of CdTe thin films was 8–12 μm. The time and rate of deposition were 4 min and about 2–3 μm/min, respectively. CdS thin films were fabricated by chemical bath deposition, and ZnTe and ZnTe:Cu thin films were deposited by co-evaporation. The details of preparation processes were published in a previous paper [8].

The X-ray diffraction (XRD) patterns were measured using a Y-4Q X-ray diffractometer manufactured by Dandong Fangyuan Instrument LLC, China, using Cu Kα radiation. The scanning velocity is 0.03°/s. The transmission spectrum was measured using a spectrophotometer (Lambda 900, Perkin Elmer) and a 150 mm integrating sphere was used in order to obtain accurate diffusion transmission because of the rough surface of the CdTe film deposited by CSS. The film thickness was measured by stylus surface profilometry (Alpha-step 500, Tencor Instruments) with a lateral resolution of 1.00 μm and a vertical resolution of 2.5 nm, respectively. The performance of the solar cells was measured using a home-made solar cell tester with the solar spectrum simulator of long arc Xenon lamp in the conditions of AM 1.5 and 100 mW/cm^2 at the temperature of 25 °C. A few solar cell samples were tested in Tianjin Institute of Power Sources, China. The dark conductivity was tested in the 15 °C to 200 °C temperature range.

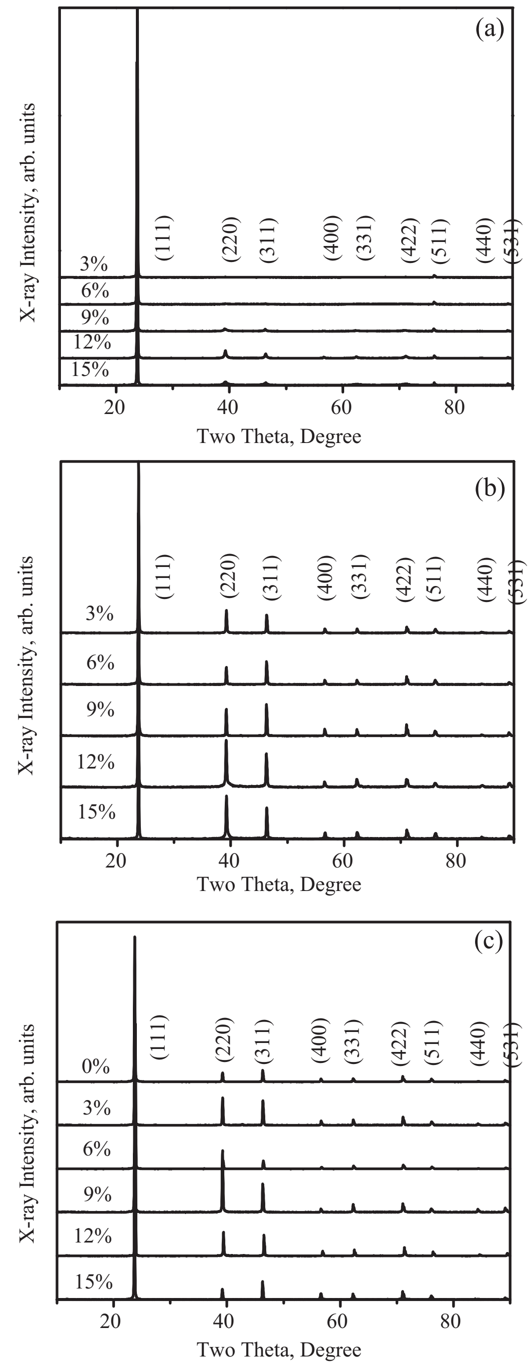

Fig. 1. XRD patterns of CdTe polycrystalline films deposited in different oxygen partial pressure. On the glass substrate at the substrate temperature of 500 °C (a) and 580 °C (b);(c) on the CdS substrate at the substrate temperature of 580 °C.

3. Results and discussion

3.1. The structures of CdTe films

Fig. 1 shows XRD patterns of three kinds of samples as a function of oxygen partial pressure which deposited (a) on the glass substrate at the temperature of 580 °C, and on the CdS/SnO_2:F/glass substrate at (b) 580 °C and (c) 500 °C. The oxygen partial pressure during each deposition is labeled on the top of each curve in Fig. 1. It can be seen that XRD patterns are nearly the same for two kinds of substrates in the same substrate temperature. In order to clearly understand the preferred orientation of the samples, the texture factor C_i of each XRD pattern was calculated according to the formula

$$C_i = \frac{I_i/I_{0i}}{\left(1/N\sum_{i=1}^{N}(I_i/I_{0i})\right)} \quad (1)$$