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Comparative studies of the properties of CdS films deposited on different substrates by R.F. sputtering

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Abstract

CdS films have been prepared on polycarbonate, polyethylene terephthalate, and Corning 7059 substrates by R.F. magnetron sputtering technique at room temperature. A comparison of the properties of the films deposited on polymer and glass substrates was performed. In addition, the influence of the sputter power on the structural and optical properties of these films was evaluated. The XRD measurements revealed that CdS films were polycrystalline and retained the mixed structure of hexagonal wurtzite and cubic phase, regardless of substrate types. As the sputter power was increased from 75 to 150 W, the structure of CdS films was converted from the mixed of hexagonal and cubic phase to hexagonal phase. The morphology of CdS films is found to be continuous and dense. Also, the grain of CdS films is larger with increasing the sputter power. The average transmittance exceeded 80% in the visible spectrum for all films and decreases slightly with the sputter power.

Keywords: Cadmium sulphide; Sputtering; Solar cells; Polymer; Optical properties; Structural properties

1. Introduction

Cadmium sulfide (CdS) has been the most widely used and most successful window layer for thin film solar cell application. Both CdTe and Cu(In,Ga)Se_2 thin film solar cells have utilized CdS films prepared by the chemical bath deposition (CBD) to demonstrate efficiencies in excess of 16.4% and 19.2%, respectively [1,2]. The CBD process is simple and very attractive for small area research devices. However, it must be considered that CBD is not fast and gives a liquid waste that needs to be recycled. Other deposition technologies such as closed space sublimation (CSS), sputtering, and MOCVD have also been utilized for CdTe thin films solar cells. The use of a plasma-based method such as magnetron sputtering can have significant advantages including the use of low energy particle bombardment to achieve lower growth temperatures and the use of excited state species to improve the doping control during growth [3].

CdS films deposited on polymer substrates, such as polycarbonate (PC) and polyethylene terephthalate (PET), have many merits compared with those deposited on glass substrates; they are light weight, of small volume and can make the obtained devices foldable, easy to carry. Development of thin film solar cells onto polymer substrates is interesting for many applications that require flexible and light weight sources of power [4]. Recently, efficient polycrystalline solar cells based on Cu(In, Ga)Se_2 and CdTe have been developed onto polyimide substrate [5–9].

In this work, we give a comparative study on the structural and optical properties for CdS films deposited on glass and polymer substrate, such as PC and PET substrate, by magnetron sputtering at room temperature. In addition, the effect of sputter power on the structural and optical properties of CdS films was investigated.

2. Experimental

The substrates used in this work were 7059 glass, PC, and PET film (100 μm). Before depositing the CdS thin films, the substrates were ultrasonically cleaned in a detergent bath, and dried in nitrogen. The CdS thin films were deposited by R.F. magnetron sputtering system from a commercially available, sintered ceramic CdS target with 99.999% purity of 3 in. in diameter. The separation between target and substrate was

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about 4.5 cm. The sputtering gas Ar was controlled by a mass flow controller and the sputter pressure was fixed to 1.0 Pa. After the chamber was evacuated to a base pressure below 6.6×10^{-4} Pa, presputtering of 10 min was carried out at an argon gas pressure of 1.0 Pa in order to clean the target surface. The R.F. sputter power was varied from 50 to 150 W. All the films were deposited at room temperature and the thickness is about 600 nm.

The film thickness was measured with the surface profile. X-ray diffraction (XRD) was used to study the crystallinity and crystal orientation of the films. The composition analysis of CdS films were carried out by X-ray photoemission spectroscopy (XPS). The surface morphologies of the films were observed by field-emission scanning electron microscope (FE-SEM). The optical transmittance of the films was measured by the UV–Visible spectrophotometer.

3. Results and discussion

The prepared films at optimum conditions on PC or PET substrates were physically stable and had good adhesion to the substrates. No cracking or peel-off of the films was observed after deposition. The color of the CdS film was transparently yellowish.

Fig. 1 shows the dependence of the growth rate of CdS films on the sputter power. It is observed a clear increase on growth rate as the sputter power increases. This increase indicates that the number of atoms sputtered from the target is proportional to the R.F. power. For higher sputtering power, the sputtered species get a higher energy that contributes to the film growth. These high energy particles have high surface mobility and therefore a higher growing process at the surface takes place.

Fig. 2 shows the XRD pattern of the CdS thin films deposited at a sputter power of 50–150 W. Polycrystalline hexagonal and cubic CdS of random orientation are known to show many strong X-ray diffraction peaks. The diffraction spectra were obtained by scanning 2θ in the range of 20–80°. It can be seen that the film deposited at 50 W has a mixed cubic and hexagonal structure of CdS. The very small difference between the position of the peak (1 1 1), (1 1 0) of the cubic structure and the peak (0 0 2), (2 2 0) of the more stable hexagonal structure makes difficult to elucidate the crystalline structure of the sample [10–12]. The film exhibits two strong peaks at $2\theta=38.28°$ and 44.56°, which are associated with the hexagonal (1 0 2) plane and the mixture of hexagonal (1 1 0) and cubic (2 2 0) planes, and two weak peat at $2\theta=64.9°$ and 77.9°, which are associated with the cubic (4 0 0) and the hexagonal (2 0 4) planes. When the sputter power increases to 75 W, the peak at $2\theta=26.58°$, which is associated with the mixture of hexagonal (0 0 2) and cubic (1 1 1) planes, appeared. The H(0 0 2)/C(1 1 1) reflection is the most intense for the films deposited at 75 W, while the H(1 0 2) and H(1 1 0)/C(2 2 0) planes were grown preferentially for the one deposited at 50 W. This means that the change in preferential plane growth of the wurtzite and/or cubic phase happened in films deposited from 50 to 75 W. As the sputter power increases

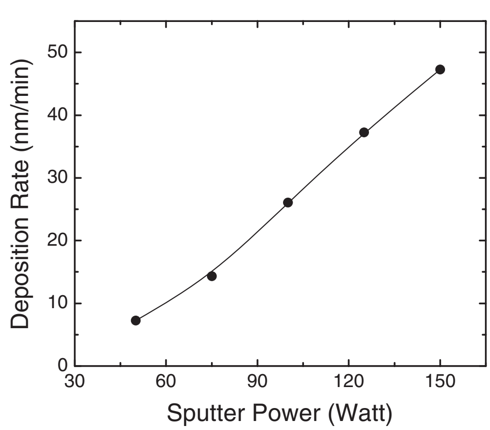

Fig. 1. Dependence of the growth rate on the sputtering power for CdS films deposited on glass substrate.

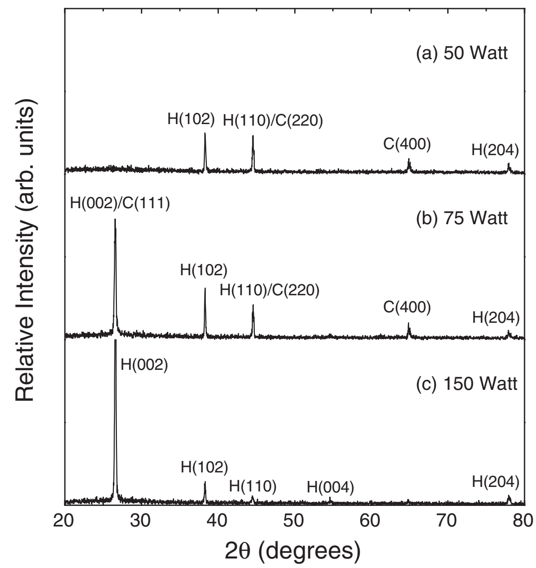

Fig. 2. XRD patterns of CdS films deposited at different sputter powers. The substrate type is the glass and the film thickness is about 600 nm.

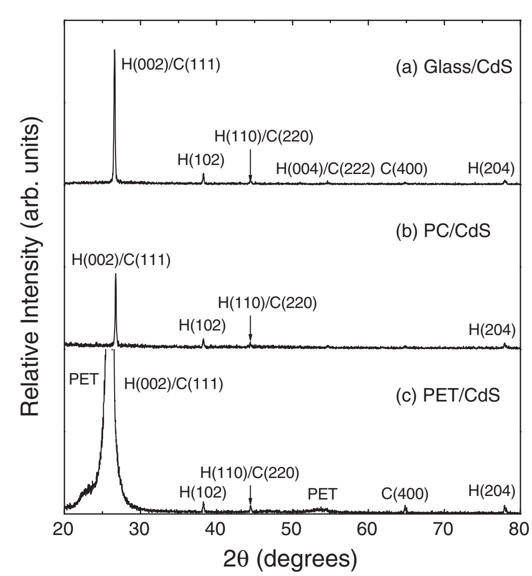

Fig. 3. XRD patterns of CdS films deposited on various substrate types. The sputter power is 150 W.