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Effect of Thickness on the Structural Properties of Tellurium Film Prepared by Thermal Evaporation

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Abstract

In this research, tellurium (Te) film with thicknesses of 100-250 nm were deposited on ceramic substrates by thermal evaporation at 373 K. The thickness of the film was determined by Rutherford backscattering spectroscopy. The influence of the thickness on the structural, morphological and molecular bonds was characterized using XRD, scanning electron microscope, and Raman spectroscopy. The XRD results confirmed that increasing the thickness, increased the intensity of the peaks, indicating increased crystallinity. SEM images indicated that the density of the film and holes in the film decreased as thickness increased. The Raman spectrum revealed that the TeO_2 molecular bond formed on the surface only at room temperature up to 100 nm in thickness; as thickness increased, this bond was observed at 323 K.

1. Introduction

Tellurium is a p-type elemental semiconductor with a narrow band gap and an energy gap of 0/35 eV. It has interesting physical and chemical properties that make it suitable for use in photoconductor, thermoelectric, and piezoelectric devices [1]. It is also suitable for technological applications, such as shields in passive radiative cooling [2, 3], nonlinear optoelectronic [4] and gas sensors [5]. The structural and electrical properties of tellurium film has been investigated by several researchers [6]. In this work, Te film was prepared using the thermal evaporation method. The effect of Te film thickness on the structure, surface morphology, and molecular bond were studied and are presented here.

2. Materials and Methods

Te film of 100, 150, 200 and 250 nm in thickness were deposited on ceramic substrates by

thermal evaporation of tellurium in a tungsten crucible. During deposition, the substrate temperature was fixed at 373 K. The ceramic substrate was 2 cm × 2 cm and was cleaned ultrasonically in acetone and alcohol for 15 min each and blown dry using N_2 gas before being were introduced into the chamber. The vacuum chamber base pressure was 3×10^{-5} mbar and the working pressure was 1×10^{-4} mbar.

The thickness of the film was measured using Rutherford backscattering spectroscopy (RBS). The phase and crystalline structure of the film was determined by x-ray diffraction (XRD; Philips, pw 1800) using Cu K_α radiation (λ = 0.154). The surface morphology of the film was characterized by scanning electron microscopy (SEM, Philips, xl 300). The molecular bond was characterized using Raman spectroscopy. Raman spectra of the films were recorded in a back scattering geometry with a spectral resolution of < 3 cm^{-1} and the 785 nm line Ar^+ laser was used for excitation.

3. Results and Discussion

The RBS spectrum for sample C_4 are shown in Fig. 1. The thickness of the Te film determined by RBS analysis and is summarized in Table 1. During deposition, the ceramic substrate and the glass substrate were placed into the deposition chamber; the Si, O spectrum in the figure represents the glass substrate.

The XRD patterns of the Te film deposited on the ceramic substrate at different thicknesses are shown in Fig. 2. In all XRD patterns, the peaks at $2\theta = 20.70°$, $2\theta = 21.72°$ and $2\theta = 26.45°$ represent the ceramic substrate. The Te (101) and Te (201) peaks with hexagonal structures can be observed at 27.70° and 50.10°, respectively [6]. The film growth was polycrystalline and, as thickness increased, the intensity of the peaks increased, indicating that the crystallinity of the film increased; no peaks conforming to tellurium dioxide are seen in Fig. 2. The grain size was calculated using the Scherer equation; it was determined that grain size increased as thickness increased, as shown in Table 2.

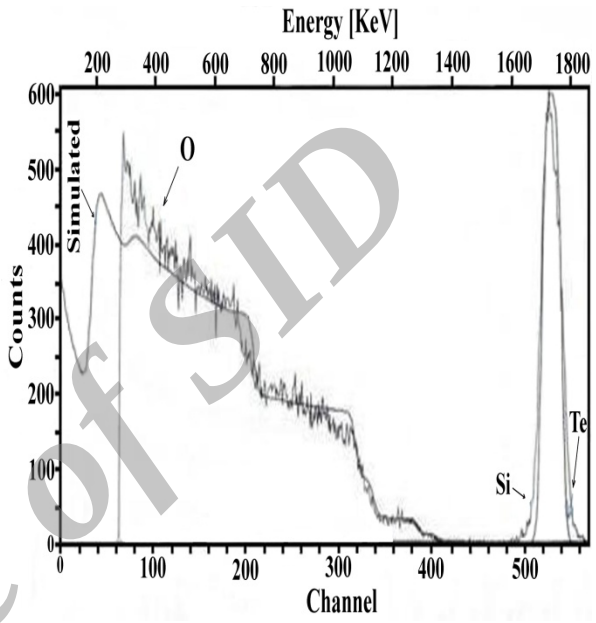

Fig. 1. Example of RBS spectrum for tellurium film.

Table 1. Thickness of Te films that measured by RBS analyses.

Samples	Thickness (nm)
C_1	100
C_2	150
C_3	200
C_4	250

The effect of thickness on the surface morphology of C_1, and C_4 samples are shown in Fig. 3. The SEM images reveal that, as thickness increased, the density of the film increased, it became more uniform, and the number of holes decreased.

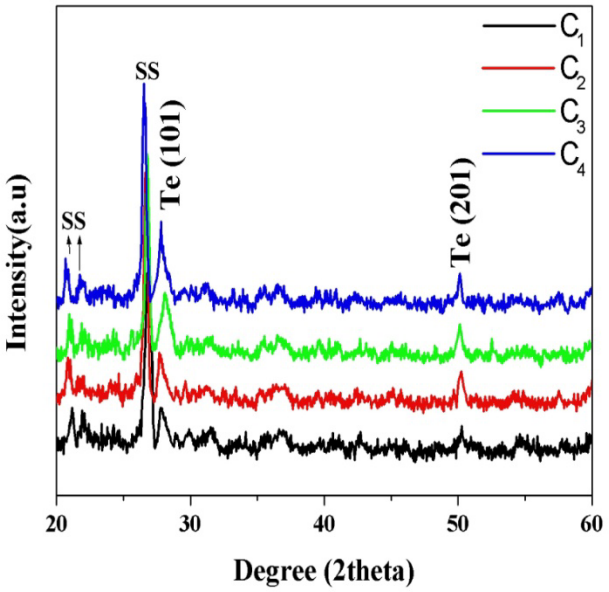

Fig. 2. XRD patterns of tellurium films with different thicknesses.

Table 2. Grain size of tellurium films with different thicknesses.

Samples	Grain Size (nm)
C_1	120
C_2	165
C_3	180
C_4	205

The Raman spectrum of the samples are shown in Fig. 4. It was found that, at room temperature, peaks formed at 115, 138 and 260 cm^{-1} that correspond to tellurium [2]. For sample C_1, in addition to the three peaks mentioned above, there was a peak at 460 cm^{-} that represents the TeO_2 molecular bond [7]. As thickness increased, this peak was observed at 323 K. By comparing the intensities of the peaks corresponding to Te and TeO_2, it can be seen that the ratio of TeO_2 in the film was very small and indicates that TeO_2 formed on the surface only. A TeO_2 peak was not observed in the XRD pattern because this peak is amorphous in structure.

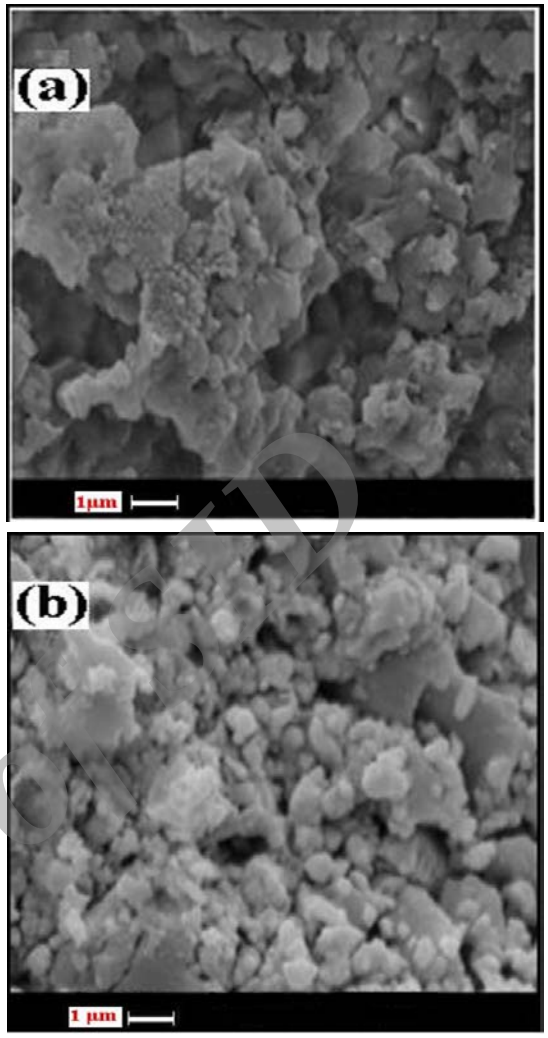

Fig. 3. Electron microscope images for samples with different thickness: (a) sample C_1 and (b) sample C_4.

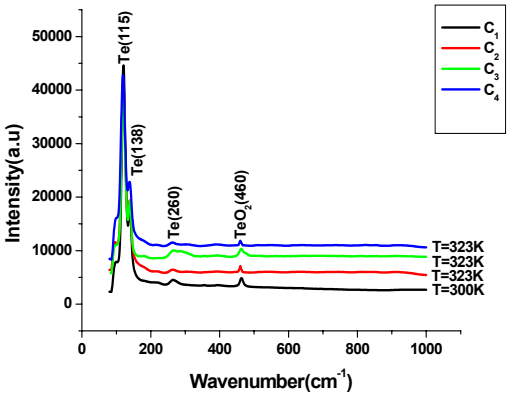

Fig. 4. Raman spectra for all samples with different thicknesses.

4. Conclusion

Tellurium films deposited on ceramics by thermal evaporation show an improvement in crystallinity and morphology. As the thickness increased, grain size and film density increased. The Raman spectra exhibited a very small TeO_2 peak, indicating that it formed on the surface only.

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