Optical Properties of Tellurium Thin Film Prepared by Chemical Spray Pyrolysis Method

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ألخلاصة:

تم فى هذا البحث تحضير غشاء التلريوم الرقيق بطريقة الرش الكيميائي الحرارى وترسيبه على قواعد زجاجيه رقيقه. بينت نتائج حيود الأشعة السينية ان الغشاء المحضر ذات تركيب متعدد البلورات (Polycrystalline). وقد أظهر الغشاء المحضر قمما للتلريوم ذات تركيب سداسي(Hexagonal structure).
أظهرت نتائج تحليلات التركيب الدقيق باعتماد المجهر الضوئي العاكس أن الغشاء المحضر ذات تجانس وأنتظام عاليين.
شملت الخصائص البصريه قياس النفاذية والأمتصاصية الطيفية وحساب معامل الخمود ومعامل الامتصاص وفجوة الطاقة البصرية. بينت النتائج ان فجوة الطاقة البصرية للغشاء المحضر تقدر ب(0.5 ev) ويمتلك الغشاء المحضر معامل امتصاص عال يصل إلى 10^4 cm^{-1}.

Abstract:

In this work, Tellurium thin film has been prepared by chemical spray pyrolysis deposition on glass substrates. X-ray diffraction spectrum have shown that the prepared film has polycrystalline structure and peaks for Tellurium hexagonal structure. Also, the microstructure analysis using optical microscope illustrated the contrast of topography of this thin film which showed highest homogeneity and regularity. The obtained results of this work are in good agreement with the standard X-ray published data [1]. Optical properties involved measurement of transmittance, absorptance, and calculation of extinction coefficient in addition to calculation of the absorption coefficient and energy band gap. Optical measurements results showed that optical band gap of prepared thin film is (0.5) ev with absorption coefficient of 10^4 cm^{-1}.

1- Introduction

Polycrystalline thin films of Tellurium have received considerable attention during recent years because of their potential applications in IR detectors, surface sensitive devices, thermoelectric devices, and thin film transistors[2][3] because of its suitable band gap (0.37 ev) [4]. Recently researches have shown that Tellurium films may be used for detection of harmful gases at room temperature such as NO_2, CO, NH_3, and H_2S [5]. Many published works have studied the physical properties of Tellurium in view of its possible application as selective surface devices among them[4]. Optical absorption coefficient measurements are necessary for the determination of band structure of semiconductor and the spectral response of selective surface. Various researches have characterized Tellurium films prepared by evaporation method [6][7]. Chemical spray deposition is a low cost and convenient method has recently been utilized to prepare thin polycrystalline films of a wide variety of compound semiconductors by a number of investigators among them [8][9]. In the present work, a Tellurium thin film is prepared by utilizing chemical spray pyrolysis method at substrate temperature of 225 ± 10 ^oC, The structure and optical properties of the prepared thin film is measured and the main conclusions of using this method are highlighted.

2- Experimental Details

The spray pyrolysis technique consists of spraying a solution containing a soluble salt of Tellurium onto a heated substrate. For Tellurium thin film preparation, A Tellurium dioxide TeO_2 with molecular weight of 159.6 gm/mol is dissolved in Hydrochloric acid (HCl) with concentration of 37%. The acid was added and mixed with 0.199 gm from TeO_2 in order to prepare solution with 0.05 M after that a distillation water was added to obtain solution of Tellurium salt according to the following chemical reaction equation[10]:

$$TeO_2 + 4\,HCl = TeCl_4 + 2H_2O$$

This solution was sprayed onto a heated Borosilicate glass substrate with dimensions of 20 mm x 26 mm and thickness of 0.4 mm. The reason for using small thickness in our work is to prevent producing a big difference between the temperature of the upper and lower surfaces of the glass and providing a uniform temperature.

A series of experiments were conducted in order to measure X-ray diffraction and determine the crystalline structure of the prepared thin film using X-ray diffraction instrument with the specifications of Source Cu-Kα and wavelength of 1.54050 A^o. The spacing of the planes, d_{hkl} , is calculated using Bragg's law [11]:

$$\sin\theta = \lambda / 2d_{hkl} \quad \ldots\ldots\ldots\ldots (1)$$

Where, θ is the diffraction angle (in degree), λ is the wavelength of X-rays (in Angstrom), d_{hkl} is the interplanar spacing (in Angstrom). The interplanar spacing d_{hkl} is calculated and the results were compared with the standard ASTM X-ray powder file data.

The optical properties of the prepared thin film including the spectrum of the transmission and absorption are measured using (UV-VIS-NIR Double Beam Spectrometer) in the spectral region 300-2400 nm. Using the data obtained form the measurements, the absorption coefficient (α) is calculated using the following formula [9][12]:

$$\alpha = 2.303 * (A/D) \quad \ldots\ldots\ldots(2)$$

Where A is the absorptance and D is the thickness of the thin film. The extinction coefficient (k) is calculated using the following formula [3] [13]:

$$k = \alpha\lambda/4\pi \quad ....(3)$$

Where λ is the wavelength. The energy band gap of the prepared thin film was calculated by plotting $(\alpha h\nu)^2$ versus $(h\nu)$.

3- Experimental Results

To get a better insight into the nature of the prepared film, X-ray diffraction study was made to determine its structure and to identify the components and phases. The X-ray diffraction pattern of sprayed Te is shown in figure 1. It is clear from the figure, the spectrum of Te exhibits sharp peaks at 2θ equal to 23^o, 27.5^o,38.1^o,40.4^o,47^o,49.6^o,56.9^o which correspond to diffraction from (100), (101), (102), (110), (200), (201), and (202) planes of the hexagonal Te phase respectively [3]. Both peaks highest and peaks position are in good agreement with ASTM X-ray powder file data for hexagonal Te (4,0554)[1]. Also, figure 1 shows that the film was polycrystalline in nature and only one phase was indicated in the film.

The topographical properties of the film was investigated by optical reflection (Leitz-Metallux3) with magnification factor of 200 and shown in figure 2. The process of deposition of Te showed that the film is silver colored. Experimental results obtained here, however, suggest that Tellurium film was homogenous. From the results of experiments measurements, the optical properties of the prepared thin film were investigated and graphs are plotted for this purpose. Figure 3 shows plot of transmission (in percent) versus wavelength in the region of 300 nm-2400 nm. As shown in the figure, the transmission of the prepared thin film increases with increasing the wavelength and the maximum value of the transmission appears at far infrared. This is because of reduction of the extinction coefficient with increasing the wavelength, which in turn reduces the value of the absorption coefficient due to electrons transform from the equivalent band to conduction band, which is called band to band transmission as a result of basic absorption.

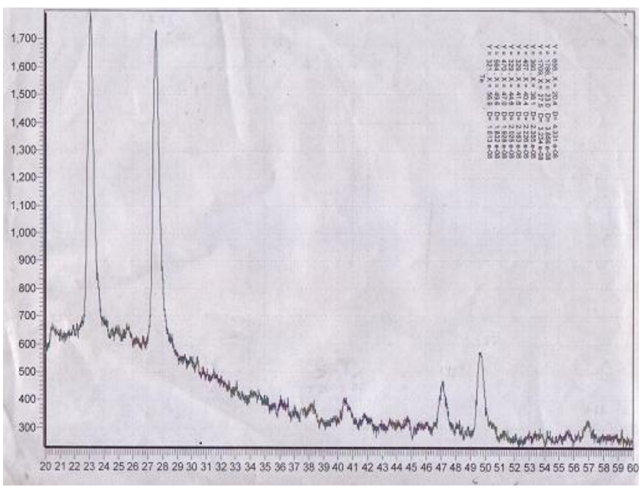

Fig 1: X-Ray diffraction of the prepared thin film

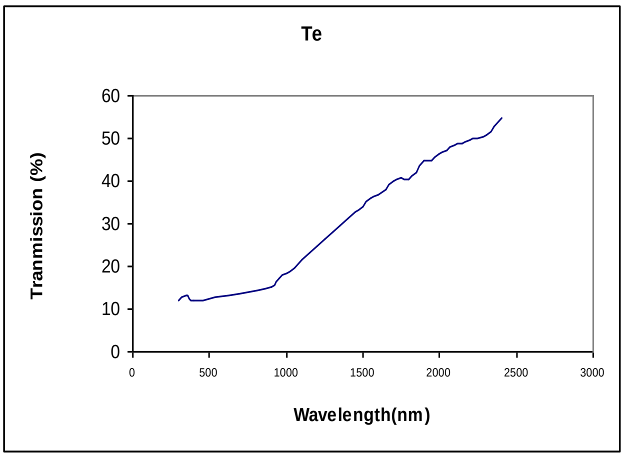

Fig. 3: Variation of Transmission coefficient vs photon energy

Figure 4. shows plot of calculated values of absorption coefficient α from formula (2) versus photon energy in the given range of the wavelength. As shown in the figure, the prepared thin film has high absorption coefficient at high photon energy which is related to the short wavelength (300 nm) and decreases as photon energy decreases (with wavelength increases).and remains approximately constant for wavelength greater than (2400). This is because of high transparency of thin film at these wavelengths. Researches have shown that the spectral absorption and absorption coefficients depend on the chemical and crystalline structure of thin film so as the high values of absorption coefficient for the prepared film ($>10^4$ cm^{-1}) means the high possibility of obtaining direct electron transfer [13]. Figure 5 shows the variation of extinction coefficient with photon energy. It is clear that the figure shows the similarity between the variation of extinction coefficient and absorption with photon energy. This is due to that the value of extinction coefficient is calculated from the absorption coefficient according to relation (3). Therefore, the values of extinction coefficient are high at high energy of photons and take low values at low energy of photons.

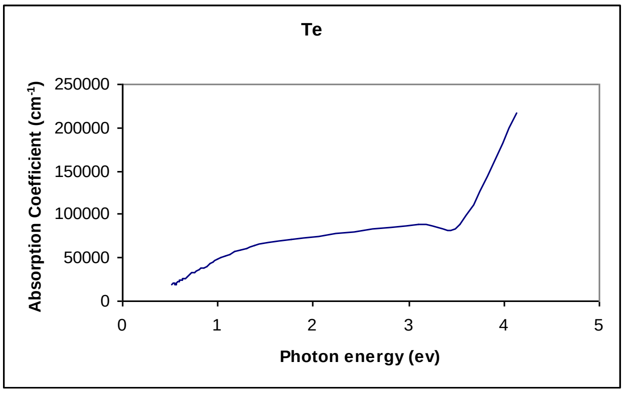

Fig. 4: Variation of absorption coefficient vs photon energy

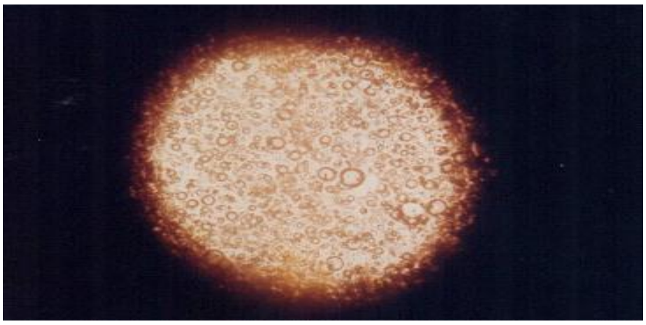

Fig 2: The topographical surface of the prepared thin film

In order to calculate the direct energy band gap of the prepared film, we plotted the values of $(\alpha h\nu)^2$ versus photon energy ($h\nu$) as shown in figure 6. It is clear from the figure a linear variation at the short wavelengths (high photon energy), this indicates obtaining a direct energy band gap. By plotting extra straight line as indicated in the figure, the energy band gap for the prepared thin film is found to be 0.5 ev. As compared to the published data [4], the variation in the value of energy band gap appears due to the procedure used to grow thin film and the circumstances at which the film is prepared.

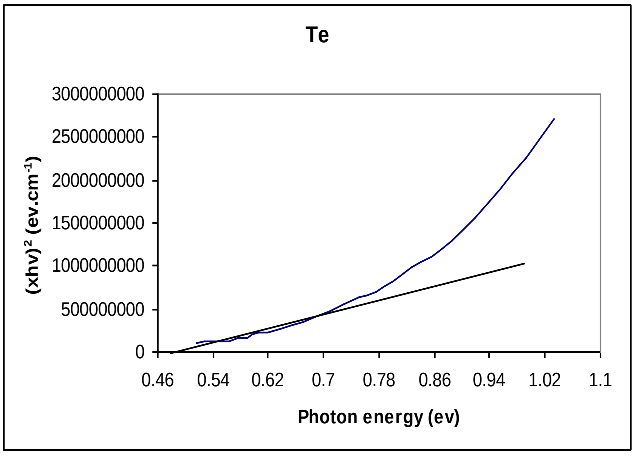

Fig. 6: Variation of $(\alpha h\nu)^2$ vs photon energy

4- Conclusions

In this work, Tellurium thin film was prepared by using chemical spray pyrolysis. With the aid of the X-Ray diffraction we observed that the prepared film has polycrystalline structure with peaks for Tellurium with hexagonal structure.

The experimental results have shown that the absorption spectrum is high in the region of 300 nm-2400 nm which covers the visible and infrared region with direct band gap energy of 0.5 ev and absorption coefficient $\alpha > 10^4$ cm^{-1}. These properties give possibility to use the prepared film in manufacturing near IR detectors and selective surface devices. Also, such film may have application in solar energy collector because of high absorptivity of sun light. In conclusion, spray pyrolysis of Tellurium appears to be a promising approach for forming the base material for photovoltaic devices.

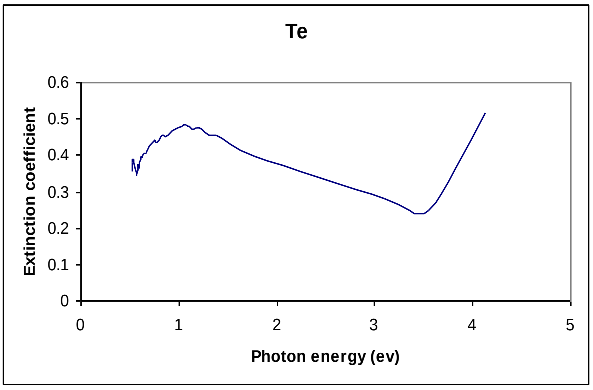

Fig. 5: Variation of extinction coefficient vs photon energy

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