The Thermoelectric Properties of Vacuum Evaporated $In_{0.8}Se_{0.2}$ alloy Thin Film Nanostructure

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Abstract

$In_{0.8}Se_{0.2}$ thin films were prepared on glass substrate by vacuum evaporation technique at a pressure of 10^{-5} torr. The crystallinity of the thin film has been analyzed by X-ray diffraction, which show the formation of hexagonal system, Scanning Electron and Atomic Force microscopy examination indicates that the grain size have nearly spherical shape with diameters range from 100nm to 600nm. The thermoelectric properties of the films were determined over the thickness of 200nm Thermoelectric properties show a negative sign exhibiting n- type semiconducting nature of films. The electrical conductivity and Seebeck coefficient were measured from room temperature up to about 423 K, the Seebeck coefficient increases with increasing temperature and the electrical conductivity decreases with increasing the temperature of the sample the power factor coefficient increases with increasing temperature.

Keywords: Vacuum evaporation technique, electrical conductivity, Seebeck coefficient, $In_{0.8}Se_{0.2}$ thin films.

Introduction

In Se is a III–VI semiconducting layered compound whose physical properties make it attractive for application of electronic device, solar energy and heat energy conversion to electrical energy.

Thermoelectricity is based on the Peltier-Seebeck effect, which is the direct conversion between thermal and electrical energy, and can be used for heating and cooling applications [1,2]. High performance thermoelectric materials require a high Seebeck coefficient, large electrical conductivity and low thermal conductivity.

The Seebeck coefficient, S, was calculated from the following formula: $S = \Delta V/\Delta T$, (1) [3] where ΔV is the thermoelectric potential and ΔT is the temperature difference.

The molecular beam epitaxy, chemical vapor deposition, chemical bath deposition, evaporation technique, and electrochemical atomic layer epitaxy, PLD, are some of the methods used for the growth of III–VI materials like InSe [4–14].

In this work, we optimize the evaporation $In_{0.8}Se_{0.2}$ thin film on glass substrate and investigate the thermoelectric properties of the films studies including, electrical conductivity, Seebeck coefficient and power factor.

Experimental

In $_{0.8}Se_{0.2}$ bulk alloy (99.99% purity prepared by Bridgman method) was evaporated from a resistive heated molybdenum boat onto cleaned glass substrates held at room temperature .The pressure inside the chamber was lower than 10^{-5} Torr. The thickness of films 200nm was measured by using gravimetric method, the crystalline structure of the films is analyzed using X-ray diffractometer (XRD-6000 Shimadzu). For the present AFM (model AA3000 angstrom advanced.inc) and SEM (tescan ll vega) investigation were employed to study the roughness and the grain size ,an electrometer (FLUK) was used for seebeck coefficient and electrical conductivity measurement in the temperature range of 300-423 K. The film temperature was monitored during the measurement by the electrical resistance and thermocouple instrument, the cold edge of the film is set at 273k.

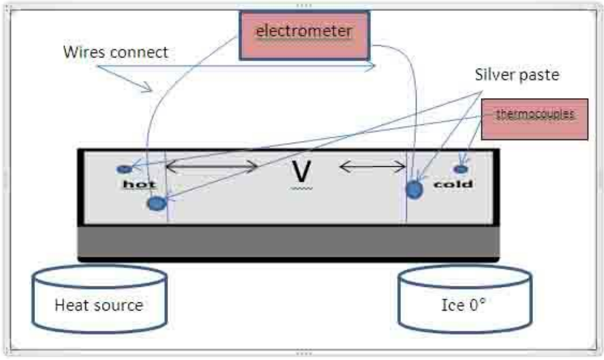

Fig.(1) Show the setup of the measurement configuration for the seebeck coefficient and electrical conductivity.

Results and Discussion

1. Structure Characteristics

Structural characteristics of the films Fig.(2) shows the XRD patterns of $In_{0.8}Se_{0.2}$ film grown on substrate at room temperature. The film exhibit a diffraction pattern typical for a polycrystalline structure [7]. The strong diffraction peak at 2θ□=32.94° corresponds to diffraction from the (101) planes while the other peaks at 2θ□□=27.90°, 36.34° and 38.5 are the result of diffraction from the (201) (002) and (110) planes, respectively. According to XRD results, the $In_{0.8}Se_{0.2}$ film is polycrystalline (hexagonal system) [7,8] (ASTM Diff. File No. 71-0250).

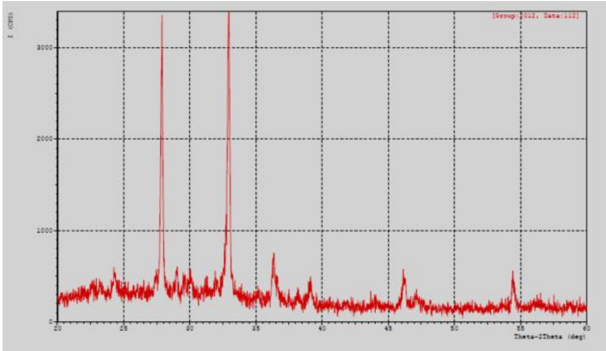

*Fig.(2) Show X-ray diffraction patterns for **$In_{0.8}Se_{0.2}$**thin films.*

The grain structure and surface roughness of the polycrystalline $In_{0.8}Se_{0.2}$ films determined by using AFM and SEM are shown in Fig. (3) For the $In_{0.8}Se_{0.2}$ films.

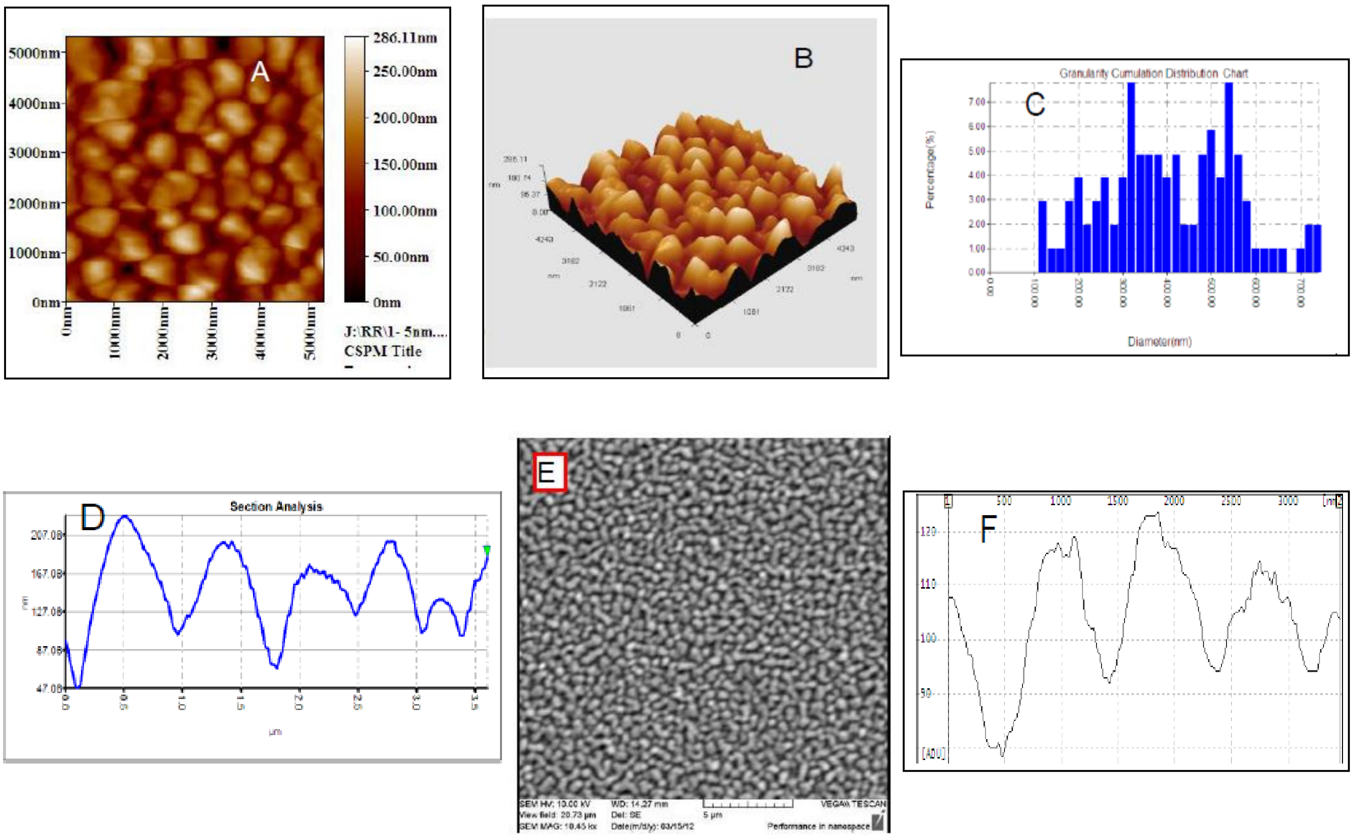

Fig.(3) Show images of $In_{0.8}Se_{0.}$thin films deposited on glass substrate (A) AFM image (B) 3D AFM image (C) grain size distribution (D) section analysis of AFM image (E) SEM image (F) section analysis of SEM image.

The deposited film show crystalline nature with small grains, the Fig.(3 A) and (3 D) image in Fig.(3 B) describe shape of grains with image area size(5µmX5µm) the figure shows that the grains have nearly spherical shape and the maximum height at 286nm. Fig.(3 C) shows the Particle size distributions of grain size, the image was analyzed by imager programs(ver.4.7). The grain size have diameters range from 100nm to 600nm. Fig.(3 E) show that SEM image is very Similar to the AFM image Fig.(3 A) the scale is 5µm the two SEM AFM image have same characterization nearly spherical shape, Fig.(3 D) for AFM image and Fig.(3 F) for SEM image ensured above discussion the two profile section for two images is very similar.

2. Electrical conductivity and Seebeck coefficient and power factor

The variations in electrical conductivity , Seebeck coefficient and power factor with temperature in the range from 300 to 423 K for $In_{0.8}Se_{0.2}$thin film were presented in Figs. (4, 5, 6) respectively. Fig. (4) shows that Seebeck coefficient increases with temperature, attains a maximum value around 423 K. Further study is required to understand the relationship between the Seebeck coefficient and the temperature.

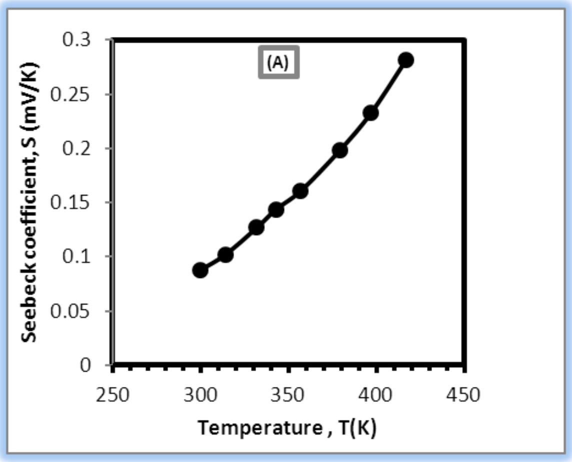

Fig. (4) Variation of seebeck coefficient with the temperature for $In_{0.8}Se_{0.2}$ thin films.

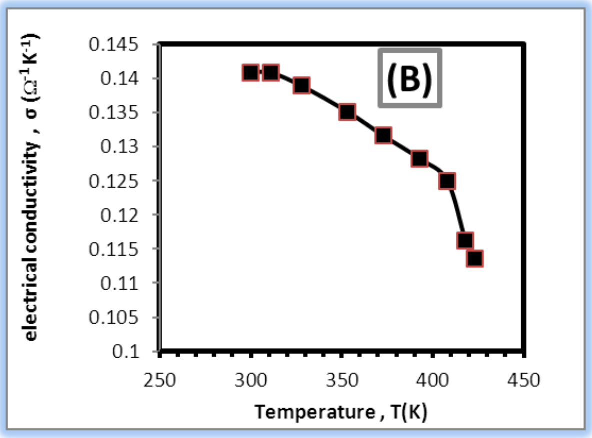

Fig. (5) Variation of electrical conductivity with the temperature for $In_{0.8}Se_{0.2}$ thin films.

The result shows that the magnitude of S for $In_{0.8}Se_{0.2}$sample at room temperature (300 K) is about 0.88 mV/K, The increase in the Seebeck coefficient arises due to the quantum confinement of electrons induced by nanostructures and is necessary for the enhancement of the thermoelectric efficiency compared with Bi2Se0.3Te2.7 bulk materials is -102 µV/K[3].

In thermoelectric power measurements, the open circuit thermovoltage generated by the sample, when a temperature gradient is applied across a length of the sample, was measured using a digital microvoltmeter. The temperature difference between the two ends of the samples causes the transport of carriers from the hot to cold end, thus creating an electric field, which gives rise to thermovoltage across the ends. The thermovoltage generated is directly proportional to temperature gradient maintained across the ends of the sample. From the sign of the potentiometer terminal connected at the cold end, one can deduce the sign of predominant charge carries. In the case of In2Se3 thin film, the negative terminal was connected to the cold end, therefore, the film shows n-type conductivity [15].

The electrical conductivity decreased with increasing temperature shown in Fig.(5), exhibiting the behavior of metals. The power factor increased with increasing the temperature shown in Fig.(6). The maximum value of the power factor is 1.2×10^{-5} $Wm^{-1}K^{-2}$ at 423 K, and the room temperature value is 1.8×10^{-6} $Wm^{-1}K^{-2}$, which is comparable to the room temperature power factor value of about 7 ×10^{-5} $Wm^{-1}K^{-2}$ of Bi_2Se_3 [16].

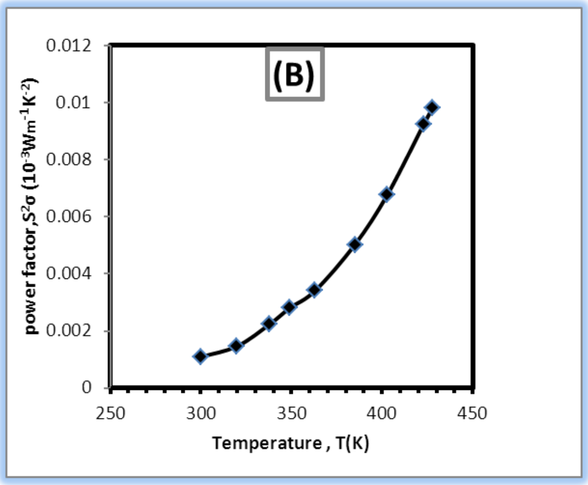

Fig. (6) Variation of power factor with the temperature for $In_{0.8}Se_{0.2}$thin films.

Conclusion

We synthesized In $In_{0.8}Se_{0.2}$thin films (approximately 200 nm in thickness), which showed spherical and regular morphologies, and smooth surfaces, by AFM, SEM. the grain size have diameters range from 100nm to 600nm. The $In_{0.8}Se_{0.2}$films are polycrystalline (hexagonal system). The electrical conductivity decreased with increasing substrate temperature, the Seebeck coefficient In0.8Se0.2 thin films sintered at various temperatures increased with increasing tempareture. The $In_{0.8}Se_{0.2}$thin films at 423°C showed the highest power factor 1.2 × 10^{-5} Wm-1K^{-2}

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الخلاصة

تم تحضير غشاء رقيق من مادة $In_{0.8}Se_{0.2}$ على قواعد زجاجية بطريقة التبخير الحراري تحت ضغط 10^{-5} تور . جرى تحليل ودراسة خاصية التبلور للغشاء الرقيق بأستخدام جهاز حيود الاشعة السينية ووجد ان الغشاء سداسي التبلور وجرى ايضا دراسة سطح الغشاء بجهاز المجهر الالكتروني الماسح ومجهر القوى الذرية ووجد ان الحجم الحبيبي كروي الشكل تقريبا بأقطار حوالي من ١٠٠ نانومتر الى ٦٠٠ نانومتر تم قياس سمك الغشاء ووجد سمكه ٢٠٠ نانومتر وتم دراسة الخواص الكهروحرارية ووجد ان الغشاء من النوع n-type والخواص الكهربائية ومعامل سيبك كدالة لدرجة الحرارة في درجة حرارة الغرفة الى حوالى ٤٢٣ كلفن ووجد ان معامل سيبك يزداد مع زيادة درجة الحرارة اما التوصيلية فقد قلت مع زيادة الحرارة اما معامل القدرة فقد ازداد مع زيادة الحرارة .