Effect of annealed temperature on some structural, optical and mechanical properties of selenium thin film

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Abstract

In this paper a thin films of selenium was prepare on substrates of n-Si by evaporation in a vacuum technique with thickness about 0.5µm. And then an annealing process was done on samples at two temperature (100 and 200) C ° in a vacuum furnace (10^{-3} torr).
Some structural, optical and mechanical properties of prepared thin films were measured. Results showed that the prepared film was the crystallization, optical transmittance and micro hardness of the prepared thin films increased significantly after annealing.

Key words
selenium, thin film, transmittance, annealing, XRD.

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تأثير درجة حرارة التلدين على بعض الخواص التركيبية, البصرية و الميكانيكية لأغشية السلينيوم الرقيقة

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الخلاصة

تم في هذا البحث تحضير أغشية رقيقة من السلينيوم على قواعد من السليكون نوع n- بتقنية التبخير في الفراغ وبسمك 0.5 µm, من ثم أجراء عملية التلدين الحراري على النماذج عند درجتين حرارة (100 و200) C° في فرن بالفراغ (10^{-3} torr). تم قياس بعض الخواص التركيبية والبصرية والميكانيكية للغشاء الرقيق.
أظهرت النتائج بأن الاغشيه المحضرة كانت متبلورة, و النفاذية البصرية و الصلادة للأغشية المحضرة ارتفعت بعد التبلور الذي تحسن بشكل ملحوظ بعد التلدين.

Introduction

Selenium is known as an essential element for life due to its great nutritional effect and many fascinating properties in biology ,chemistry and physical sciences: for example, protecting cells against the effects of free radicals that are produced during normal oxygen metabolism, reinforcing the normal functions of the immune system and thyroid gland, localizing malfunction in the pancreas, and the safe uses of selenium in agriculture and in the biosciences [1].

Amorphous (semiconducting) selenium is used for electro-static imaging, as well as for photovoltaic cells, in the visible region of the electromagnetic spectrum. The photoconductive properties determine how effective and fast responding the material will be; that is, the higher the mobility, the faster the response and the faster the material can be optically scanned. It is hoped that *a* study of the photoconductive properties will lead to more efficient materials. In addition, it would be of practical importance to develop materials sensitive over a wide region of wavelengths [2].Methods for fabrication of thin films in general and selenium particularly such as evaporation, electroplating spray pyrolysis etc. [3,4].

Fella *et al*. [5] study sodium assisted sintering of chalcogenides and its application to solution processed $Cu_2ZnSn(S,Se)_4$. Demonstrate thin film solar cells were improvement in grain growth in the presence of sodium. It enhances the surface chemisorption of selenium molecules and can promote the formation of liquid Na_2Se_x phases during reactive annealing of the precursor.

Lu et al. [6], fabrication of flexible thermoelectric Se thin film devices for ink jet printing by using thermo electric nanomaterials successfully serve power generation and cooling. Tan [7], study renewed interest in the electrical and optical properties of selenium films due to its use as an ultra-sensitive photoconductor in the newly developed flat panel x-ray image detector and high definition digital and video camera. This project has examined the optical properties of a range of Se films fabricated by conventional vacuum deposition technique. Cabral et al. [8], study Nano gravimetric study of lead under potential deposition of selenium thin films as a semiconductor alloy formation procedure, an electrochemical quartz crystal, microbalance Au electrode modified with a Se thin film was used to investigate the electrochemical behavior of lead atoms using under potential deposition (UPD) conditions. These findings offer a new strategy for alloy formation in semiconductor films using an effective tool to quantify the exact amount of the incorporated metal.

The goals of this paper are to fabrication selenium thin film by evaporation technique, and study some of structural, optical and mechanical properties, and the effect of annealing in a vacuum.

Experimental work

Practical includes:

a. Preparation of substrates:

The substrates that used is laboratory glass sheet slides with diminutions of in standard dimension as (5x2x0.2) cm and purity (99.99%), and clean by Distilled water and alcohol 99% and dying in air. n-Si (1*1* 0.2) mm was cleaned with Cp-4 solution(Nitric acid, hydrofluoric acid and acetic acid and ratios (3:2:3)) for (10) min.

b. Material:

Selenium pure powder (99.99%) was used to fabrication thin films.

c. Preparing thin film :

Using thermal vacuum evaporation system type EDWARDS with Mo- boat. Fig.1, deposition rate was 2 nm/sec at 10^{-3} torr. The distance from the substrate to evaporation source about (12 cm), the coating thickness accurately by eqs(1 and 2) [9], and it was 0.5±0.01 µm:

$$T= (1-R^2) *e^{-\alpha t} \quad (1)$$

and

$$R= (n-1)^2 /(n+1)^2 \quad (2)$$

where

T: Optical transmittance

n : Refractive index

α: Absorption coefficient

t: coat thickness

d. Annealing process:

At vacuum furnace type (IVOCLAR), Fig.2, the samples were annealed for 30 min in 100 and 200C°, in addition to as deposited sample basically.

e. Testing

1- X-ray diffraction with diffractometer type CuKα (λ = 1.5406 Å). This test is carried out in Advanced Materials Research Center at the Technology and Science Ministry, the scanning speed was 3%. . To determine the (a- lattice constant) from X-ray spectrum were using the following formulas were used for hexagonal crystal system [10] which is a relationship between the d-spacing and lattice constants:

$$1/d^2 = (4/3)\,[(h^2+hk+k^2)/a^2] + l^2/c^2 \qquad (3)$$

where h, k, and l, are known as the Miller indices (hkl) and are used to identify each lattice plane.

Fig. 1: Evaporation system.

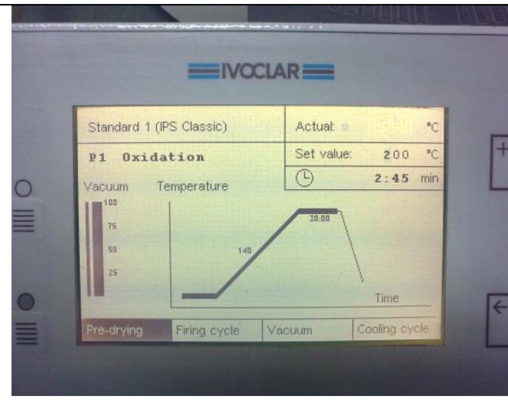


Fig. 2: Furnace screen.

2- The optical microscopic test of the prepared film using a microscope type (permable) 100X can be used to characterize information on the structural morphology of the film. The test was carrying out in Nanotechnology and Advanced Materials Research Center / the University of Technology.

3- The prepared film were examined by using Scanning Electron Microscope (SEM) type (S-4160 Hitachi, Japan) at university of Tehran/Iran.

4- UV- VIB test by using spectrophotometer (CECIL7200) from (500-700 nm).

5- Measuring Hardness: Microhardness was measured using a device of the type (microscope universal research) Load amount (5gm) for 5sec was calculated hardness of Eq. (4):

$$M.H.V = \frac{1854.4\ P}{t^2} \qquad (4)$$

where **:**

M.H.V: Vickers microhardness

P: load

t :diameter trace generated

Results and discussion

Fig. 3 shows diffraction patterns of XRD results chart for Se films as-deposited and after annealing at different temperature . The (JCPDS) database was used to evaluate the XRD response, card (No. 27-0601), and the data of the figures were listed in Table 1.

It was evident after this procedure that the diffraction peaks of the film are a combined response of Se. The structure of Se is hexagonal polycrystalline and the lattice constant is listed in Table 2.

Without annealing crystallization does not occur, by annealing crystallization arise. With increased annealing temperature lattice constants approaching towards so the standard values as shows in Table 2 and in particular the values of lattice constant c. It can be notice that the increase of annealing temperature increased the degree of crystallization [7,11], as can see from Fig. 3, average grain size was estimated using the

Scherrer's formula[12], and it was 0.05 nm for film annealed at 100C° and (0.151)nm for film annealed at 200C° .

$$g = (0.94\, \lambda) / [\Delta_{(2\theta)} \cos\theta] \qquad (5)$$

where :

λ: is the x-ray wavelength (Å).

$\Delta_{(2\theta)}$: FWHM (radian).

θ : Bragg diffraction angle of the XRD peak (degree).

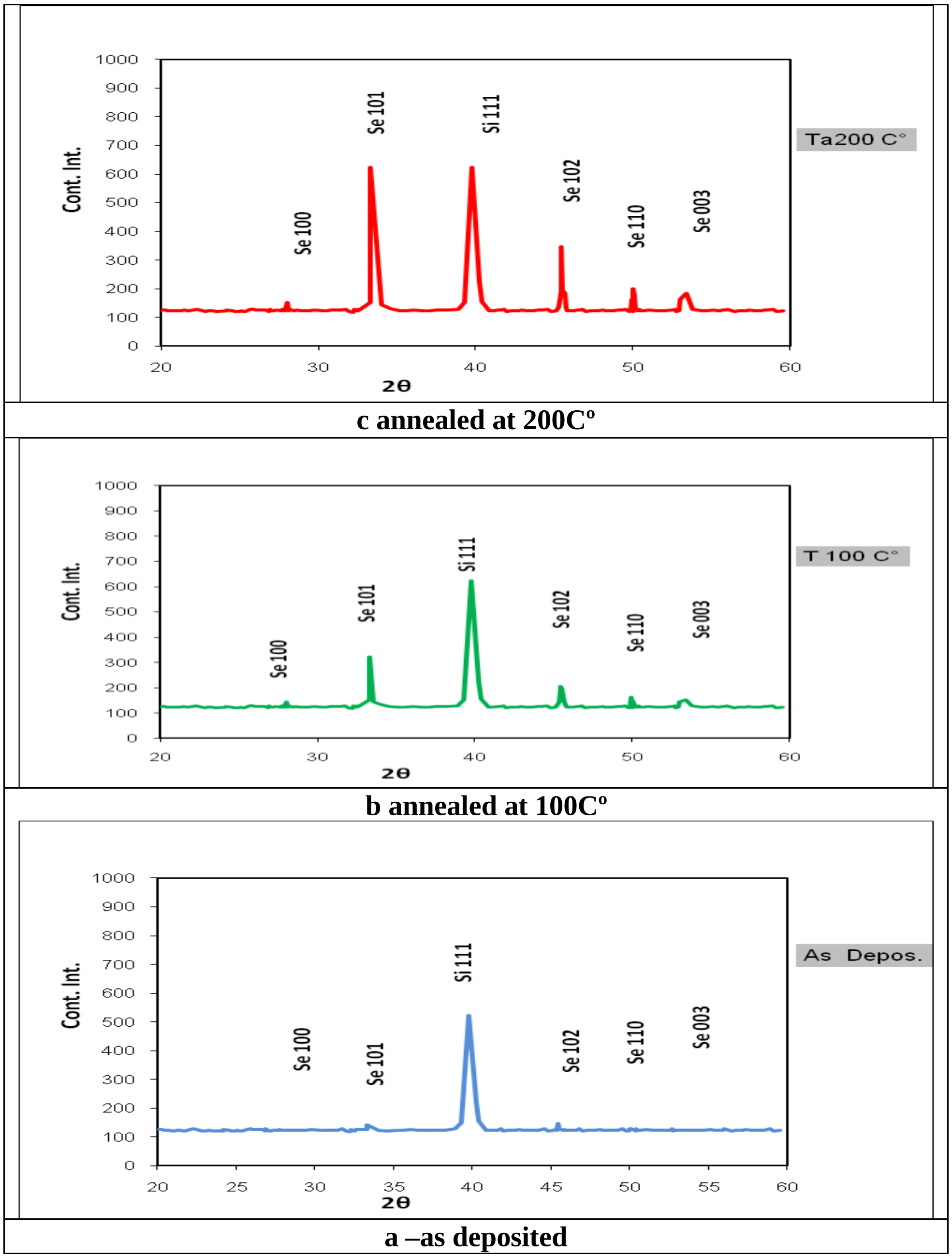


Fig. 3: XRD of selenium thin film at different annealing temperature.

Table 1: XRD data selenium thin film as depositedand annealed at different temperature.

No. **27-0601**		***T C°***					
2θ_{ASTM}	***I_{ASTM} %***	**R.T**		**100**		***200***	
		2θ_m	***I_m %***	***2θ_m***	***I_m %***	***2θ_m***	***I_m %***
28.036	10	--	--	28.032	3.4	28.034	7
33.330	100	33.30	5%	33.318	100	33.325	100
45.473	50	45.42	4%	45.429	26	45.429	45.1
50.019	30	--	--	50.009	8.9	50.013	23.7
53.411	30	--	--	53.366	5.7	53.369	20.2

Table 2: Lattice constant of Se thin film.

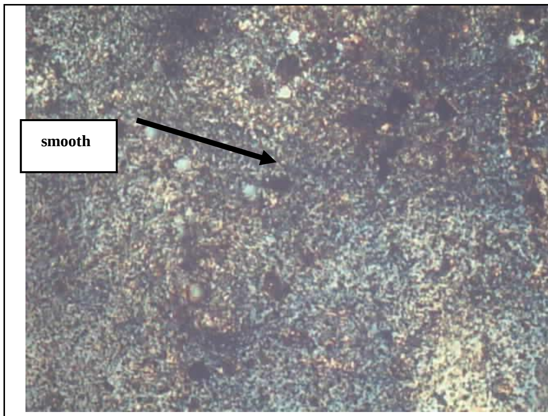
Lattice con. _{ASTM}	***T C°***		
	R.T	**100**	***200***
a (3.642)	--	3.150	*3.156*
c (5.147)	---	5.115	*5.145*

Fig. 4 minutes for the surface structure of the building turned out fine in general roughness increases with annealing ,there is no evidence of a columnar microstructure from evaporation[13,14]. This agrees with SEM results as it can seem in Fig. 5.

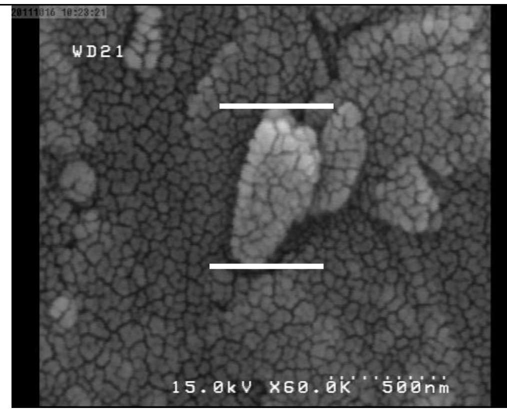
Fig. 6 shows the relationship between optical transmittance and wavelength within the visible (near IR; 550-1200 nm) range for samples prepared at different annealing temperature. It is clear from a figure that there are two regions, the first region at wavelengths that are less than 580nm full absorption. The second region is the area that appears after 580 nm and displays my visual transmittance and be clearly linked with annealing.

In fact appears a clear positive effect in transmittance, This wavelength asymptotic length he received researcher Tan [7], increasing in annealing increases as a result of crystallization by the effect of annealing[15,16].

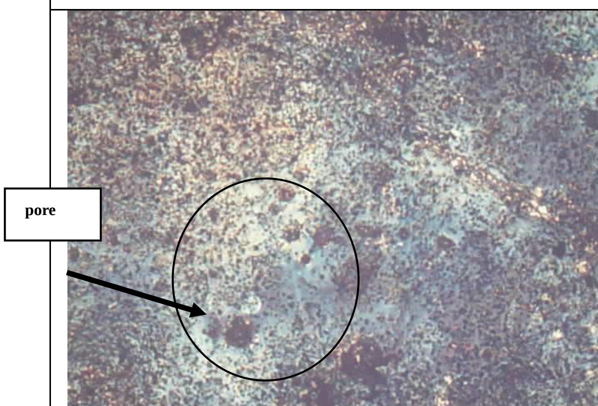
Fig. 7 shows the relationship between Se thin film micro hardness and annealing temperature, also these increased the crystallization and related with increasing the alignment ,integration and adhesion of films with the substrate, this agree with [17,18,19].



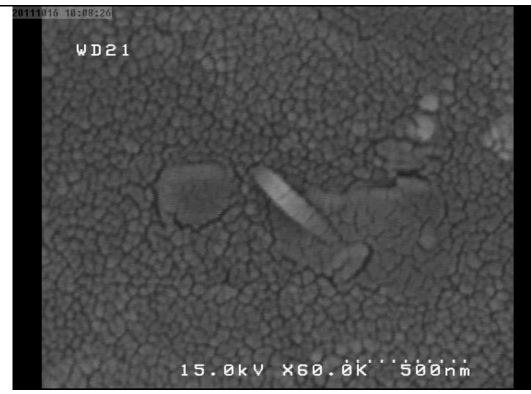
c annealed at 200C°



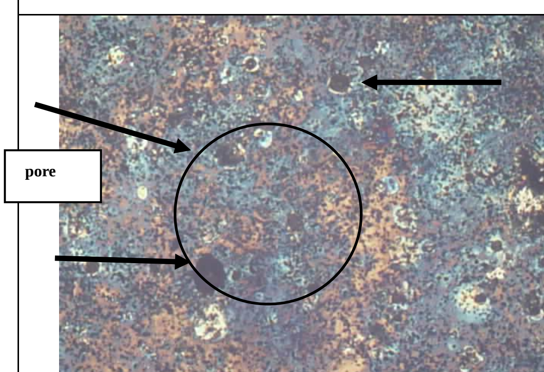
c annealed at 200C°



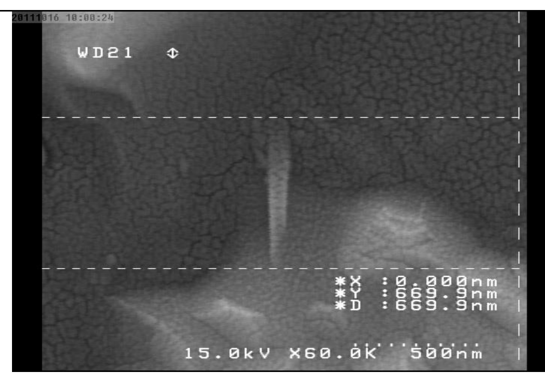
b annealed at 100C°



b annealed at 100C°



a as deposited



a as deposited

Fig. 4: Optical microscopy results of Se thin film X100.

Fig. 5: SEM results of Se thin film.

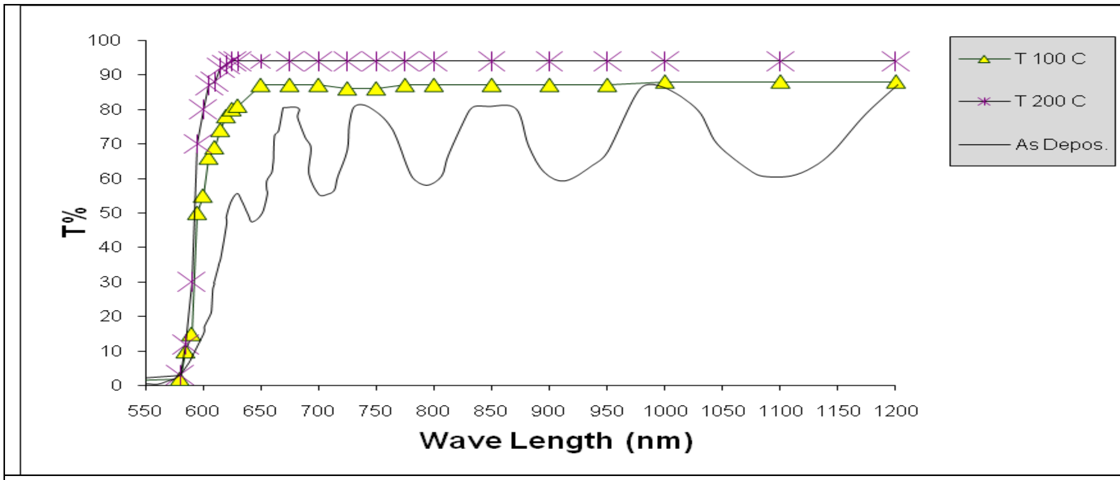


Fig. 6: Transmittance spectrum of Se thin film un annealed and annealing different temperature.

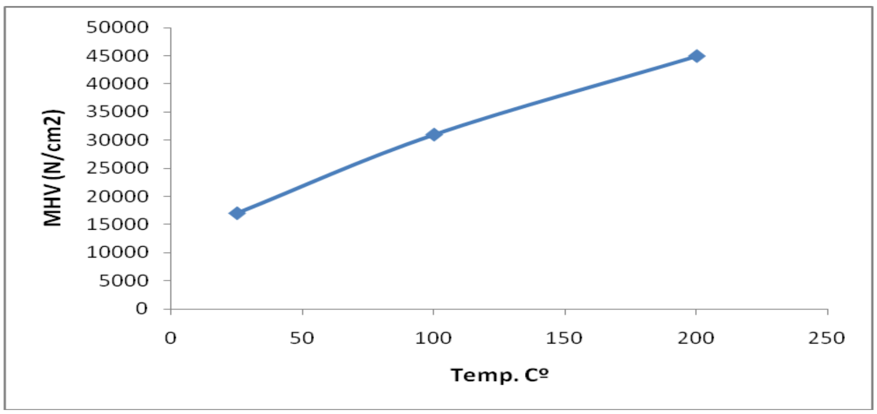


Fig. 7: MHV variation with annealing temperature of Se thin film.

Conclusions

1- Thin film of selenium transform from an amorphous structure to crystalline after annealing.

2- At the wavelengths least (580 nm) thin films have 0% transmittance and with annealing the transmittance will be increased heavily and settles.

3- Increasing the transmittance of thin film due to increase the regularity of the lattice.

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