Study of the effect of annealing during and after deposition on (crystal growth and some physical properties) of zinc sulfide (ZnS) nanoparticles prepared by vacuum thermal evaporation method (PVD)

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Abstract

This research deals with the study of the effect of annealing during and after deposition on the optical and structural properties for zinc sulfide (ZnS) films prepared on Soda glass bases under pressure (10^(-5) torr) by vacuum thermal evaporation method. Then studying the crystal growth of thin films through the results have been obtained, where the optical properties were studied during deposition by taking temperatures ((50°C, 100°C, 150°C, 200°C) for an hour and after depositing annealing at temperatures (R.T, 250°C, 300°C, 350°C) using a spectrometer from Type (UV-Visible). It has been found during deposition that the transmittance increases oscillating correspondingly with the increase in the wavelength of the photon while it increases more oscillatory so that the transmittance eV (68,75,82,88) corresponding to the temperature (R .T,250°C, 300°C,350°C). The energy gap decreased from eV (3.7,3.65,3.63,3.6) corresponding to temperatures (200°C,150°C,100°C,50°C) to eV (3.44,3.45,3.47,3.48) corresponding to temperatures Temperature (350°C, 300°C, 250°C, R.T after annealing.

The absorption coefficient was calculated, and it was found that eV decreases (4.2,5.6,7,9) at temperatures (300°C, RT, 350°C, 250°C, and by calculating the refractive index after annealing, eV (12,8,4,2) becomes (300°C,R .T,350°C,250°C) By calculating the damping coefficient and the imaginary and real part of the optical constants, it was found that increasing the annealing temperature increases the pores in (ZnS) films, which results in a decrease in the refractive index and an increase in the damping factor. Structural parameters such as lattice modulus (a,b) were calculated. It was proved that the surface of (ZnS) films at room temperature and (250°C) random (Amporphous) transformed into polycrystalline at (300°C) with a hexagonal structure through the peaks of More severe and thus the crystallization increases at (350°C) with a distinct growth direction (101) and we obtained trends (102,103) and the grain size was calculated and the average grain size was nm(18.1) and it increased nm(19.1) to nm(20).) at a temperature of (300°C), then nm decreases (12.2,11.7), then increases nm (24.7), then decreases nm (22.2), then increases with increasing temperature. It is note the improvement of crystallization with the increase in the temperature of the heat treatment. We notice that when the crystal size increases, the dislocation intensity and the fine stress decrease with the increase in the annealing temperature. We have noticed from the AFM readings (atomic force) that the grain size nm(38.48,39.4,43.9,34.43) is greater than the grain size in the case of (XRD) due to this Because the first measures the size of the particles on the surface of the membrane, while the second measures the size of the particles (18.1,19.1,20,11.7,12.2,24.7,22.2) inside the membrane surface.

Key words:nanomaterials, energy gap, crystal growth, optical properties, refractive index, structural properties.

Introduction

The term thin films is used to describe a layer, or many layers (layers) of atoms of the material, the thickness of which does not exceed one micrometer, or several nanometers, and because they are thin and fragile (easy to break) they must be deposited on a solid material such as glass, silicon, or some salts, or polymers.

Work had begun in the field of preparing thin films in the middle of the nineteenth century. In the year 1852, Bunsen and Grove reached to prepare thin films using the chemical reaction technique as well as the glow discharge technique. Thin-film technology has gone through rapid stages of development as a result of its basic characteristics such as accuracy and size reduction. Over the years, scientists have developed techniques for preparing thin films until the technique of binary evaporation (joint) in a vacuum, which was discovered by the scientist Hogarth (Hogarth) in 1968.

Thin films have properties and characteristics that are not available in other materials’ structures. The fact that they are extremely small and have a large surface-to-volume ratio gave them a unique physical structure that sometimes matches the structure of a single crystal, and sometimes exceeds it at other times. Solid (Bulk), and the possibility of preparing most of the solid materials in the form of thin films is one of the important techniques for obtaining new characteristics of materials that are difficult to see and feel when they are in their natural mass form [1,2,3].

Theoretical part

Physical properties for Zinc Sulphide (ZnS) Compunds

Zinc sulfide is one of the metal sulfide compounds. It is similar in structure to lead sulfide and its chemical formula (ZnS) and is used as a primary mineral substrate for the extraction of zinc (Zn) and it is transparent or semi-transparent and yellow. Also, the properties of zinc sulfide (zinc) are always bivalent, and because it shows sensitivity towards magnetism, electricity and particulate radiation, and it has been widely used in electronics, and by mixing it with other elements, it is luminescent and exists in several forms where both types are positive-ion. The negative ion (Ion-Negative) is surrounded by four surfaces and its structure depends on the oxidation number and the electronic structure. Where the (ZnS) complex consists of two face-centered cubes (FCC) shifted from each other by a quarter of the cell, the first leads us to the (CCP) (Cubic Close-Packed Structure), and the second has a hexagonal symmetry called (HCP) (Hexagonal Close-Packed Structure The compound (ZnS) consists of the union of two elements of the periodic table (II-VI), one of the second group (II) which is (Zn), and the other of the sixth group (VI) which is (S) as in the figure (1-10).

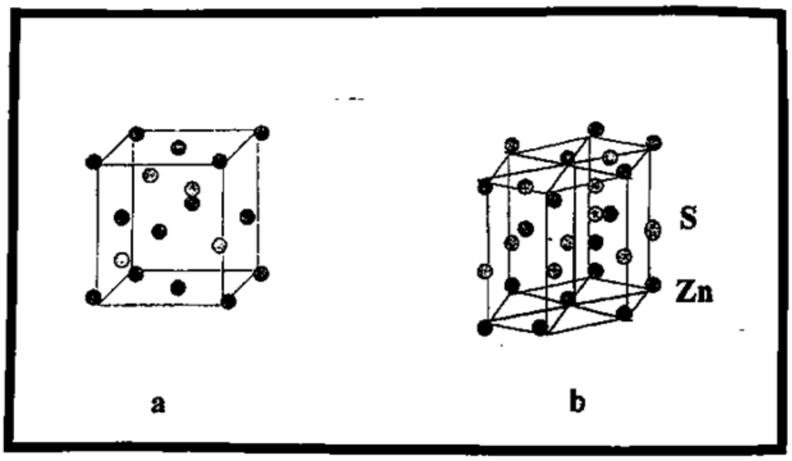


Figure (1-1): Crystal structure of the compound (ZnS)

a- Crystal structure of zinc substrates (Zinc Blend)
b- Crystal structure of a hexagonal

Zinc sulfide (ZnS) is a crystalline powder that is insoluble in water. It has a molar mass of gm/mol (97.475), a standard enthalpy of kj/mol (4.6), a density of gm/cm3 (4.090), and a melting point of about °C (1185).Zinc sulfide (ZnS) is an attractive material for LEDs, lasers, and flat-beams because it has excellent luminescence that can be obtained in almost all visible range with suitable inlays and has a wide energy gap. It is used in industry and widely used in the manufacture of dyes, waxes and white glass. It is opaque, and it is mainly used in the manufacture of television screens by nanotechnology and in the formation of elastomers, and it is used in lighting and glowing watch faces, and it is also a fungicide, so it is used in the manufacture of medical ointments for this [4], and Table (1-1) shows some The physical properties of the compound.

Properties	ZnS	
Group	II-VI	
Crystal Structure	b = Hexagonal Wurtzite	A = Cubic Zinc Blend
Lattice Constant	For cubic a=5.41 A°	For wurtztite a=3.82 A°
GapEnergy	Eg = 3.53Ev	
Color	Yellowish Broun to Black	
Density	3.9 , 4.2 g/cm3	

Atoms move across the grain boundary as well as inside crystals in both directions. The movement of atoms across the wall of the grain boundary is balanced, meaning that the number of atoms that cross the wall in one direction is equal to the number of atoms that cross it in the opposite direction. When the wall is curved, there are two regions around the arch, one of them is concave, and the other is convex. As for the concave region, it is more compact with atoms than the convex region. Therefore, the number of atoms in the concave region is more than the neighboring atoms, and therefore its energy is less than that of the atom in the convex region, and therefore the movement of atoms across the grain boundaries is not equal.

Where the process of moving atoms across the granular boundaries in this way results, i.e, the boundary itself moves towards the center of the curvature, and the driving force is for this transition, which is to reduce the area of the granular boundaries and the energy of the atoms in the crystal structure as a whole, and as a result the boundaries shrink towards curvature center.

Since the small grains have areas of high convexity relative to the large grains, so the large grains will expand at the expense of the fading of the small grains and this process is called granular growth. After the membrane material in the melting pot reaches its melting temperature, its vapor atoms begin to volatilize in all directions inside the evaporation chamber. The sedimentation rate is little) or due to the difference in the thermal expansion coefficient for each of the atoms of the precipitated material and the atoms of the base material (and on this basis the appropriate bases are selected for sedimentation) and the other due to the high temperature of the base and thus the base is a source of evaporation and thus the holes are created, according to which the density of the membrane is less From the density of the material from which it is prepared [5,6].

All crystalline materials, both metallic and non-metallic, are subject to this granular growth characteristic. As the temperature increases, the granular growth increases, as the diffusive transfer of atoms is exponentially proportional to the absolute temperature. Therefore, we find that the increase in the granular growth rateis greater in the dimensions that the granules reach at the higher temperature. As for decreasing the temperature after the granules grow, it reduces the granule growth rate, but it never reverses the process.

The growth of the nuclei is in three dimensions with the dominance of growth in the surface dimensions (i.e. parallel to the base of sedimentation) due to the nature of the surface diffusion of atoms. Granular (Grain Growth) to the stage of the active granule, which is then ready to coalesce with its peers of similar size granules with a behavior similar to the behavior of the connection between two drops forming that connected membrane, and this is in the event that the granules are similar in terms of their atomic orientations, i.e. the formation of a crystallized membrane (Single Crystal), but if these grains are different in terms of their atomic orientations, the so-called grain boundaries will arise, which is the characteristic of polycrystalline materials on the one hand, and a kind of surface defects on the other hand [7,8].

Practical part

The films were prepared for (ZnS) by the method of vacuum evaporation using the (Edwards E306A) device. The samples were prepared in several stages, the most important of which is cleaning the slides with an alcoholic solution. After that, it is keen to place the samples directly on the electric heater for a period of not less than half an hour before the evaporation process until the temperature reaches Required after completing the evaporation and we have taken the temperatures (50°C,100°C,150°C,200°C).

Then the annealing process (heat treatment by electric furnace) with temperatures (RT,250°C,300°C,350°C) to obtain outstanding crystal growth using X-ray diffraction (XRD) technology and AFM (atomic force device). The method is guaranteed to obtain films with a possible number of stress centers, reduces the process of collision or scattering between the atoms of the material, is easy to prepare, and does not produce ionizing radiation. The bases are fixed in the upper part of the bell, then the system is emptied of air until the pressure reaches (torr 〖10〗 ^(-5)) at different temperatures (200°C,150°C,100°C,50°C) and then the models are annealed using an electric furnace It has been annealed in different degrees (RT,250°C,300°C,350.°C).

Results and discussion

Optical properties measurements results

The study of the optical properties of the films is of great importance in finding the optical constants through which it is possible to identify the amount of the optical energy gap value according to the specific preparation conditions (pressure, temperature, thickness of the film, ... etc.), as well as we can know the other constants of absorption and transmittance and their coefficients As well as the damping coefficient and the real and imaginary dielectric coefficients, and we used in our research this optical spectrometer (UV-VIS Spectrophotometer-1800, UK), which records the absorbance as a function of the wavelength within the range (1000-300) nm.

1-Absorbance and Optical Absorption

It is considered one of the important and highly effective studies in the field of semiconductor and membrane physics, and that the fall of electromagnetic rays with an energy of (hv) is greater than the value of the energy gap and strongly of (I_°) on the material whose thickness (t) will absorb part of it to run out of its intensity (I_T), this enables us to find the relationship by which the absorption spectrum (∝) is calculated according to equation [9,10]:

$$\mathbf{I_T = I_\circ e^{(-\propto t)}} \quad \ldots\ldots\ldots\ldots\ldots \mathbf{(2-8)}$$

Absorption spectrum (A) was drawn for the range of wavelengths (300-1000 nm) for all films prepared using a (Visible-UV) spectrometer. The direction of propagation of this wave within the semiconductor material), and it is defined as the percentage that decreases from the radiation energy falling on the material relative to the distance it traveled in the direction of the propagation of this wave within the semiconductor material, and the calculation of this ratio depends on the energy of the incident rays (hv) and on the optical properties For the semiconducting material as the amount of energy gap width of the semiconducting material and the type of electronic transition that occurs between the valence band and the conduction band [11], and to calculate the absorption coefficient we start by calculating the photon energy of the incident rays from equation [12]:

$$\mathbf{E = hv} \ldots\ldots\ldots\ldots\ldots (\mathbf{2-9})$$

As for the amount of this energy (T) being transmitted through the semiconductor material, which will reflect some of it (R), the transmittance portion is given according to the equation:

$$\mathbf{T = (1-R)^2} \boldsymbol{e^{-at}} \ldots\ldots\ldots\ldots\ldots (\mathbf{2-10})$$

To calculate how much material (A) absorbs these rays, the equation is based:

$$\mathbf{T} = \boldsymbol{e^{-2.303A}} \ \ldots\ldots\ldots\ldots\ldots (\mathbf{2-11})$$

Substituting the value of (T) from equation (2-11) into equation (2-10) then get equation [12]:

$$\boldsymbol{e^{-2.303\mathrm{A}}} = \mathbf{(1-R)^2} \boldsymbol{e^{-at}} \ldots\ldots\ldots\ldots\ldots (\mathbf{2-12})$$

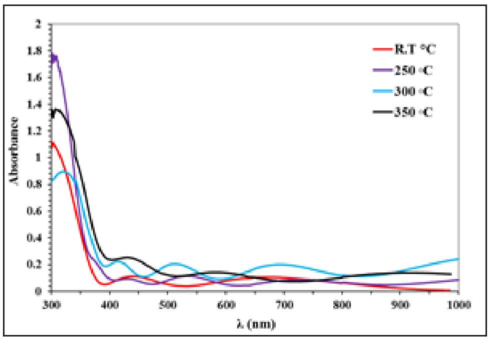
In the event that the amount of what is absorbed by the substance and the amount of what is permeated from it is approximately one, that is, the amount of what the substance reflects approaches zero, then equation (2-12) will turn into the equation: :

$$\boldsymbol{e^{-2.303\mathrm{A}}} = \boldsymbol{e^{-at}} \ldots\ldots\ldots\ldots\ldots (\mathbf{2-13})$$

Where we found from the calculations that the absorbance of the films decreases during deposition and at temperatures (100 °C, 50 °C, 150 °C, 200 °C) for all films so that it decreases with the wavelength due to the low energies of the previous photons and their inability to raise electrons from the valence bundle to the conduction bundle. We explain Physically, this is that the incident photon could not irritate the electron and transfer it from the valence band to the conduction band, as the E_r<E_(Silice(ZnS)): As for after annealing, we notice that the absorbance is less than it was before annealing. The absorption coefficient also decreases with increasing wavelength before annealing (during deposition) (4,4.2,6,7) at temperatures (50 °C, 100 °C, 150 °C, 200 °C) and after annealing (after deposition) the absorption coefficient fluctuates with the length The wavelength (4.2,5.6,6.8.9) temperature (RT,250 °C,300 °C,350 °C) and its value creeps in the direction of low energies towards long wavelengths, so the absorption edge is sharp upwards.

From it we can find the value of the absorption spectrum (a) from equation (2-14) and apply it as shown in the figures:

$$\boldsymbol{a} = \mathbf{2.303\ (A/t)} \ \ldots\ldots\ldots\ldots\ldots (\mathbf{2-14})$$



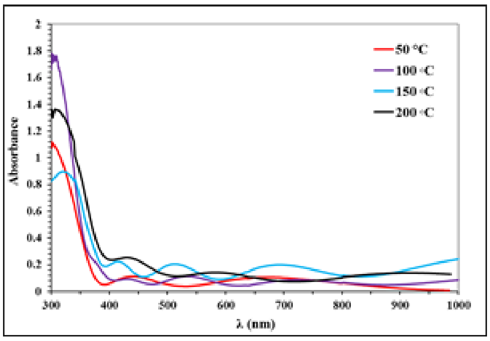
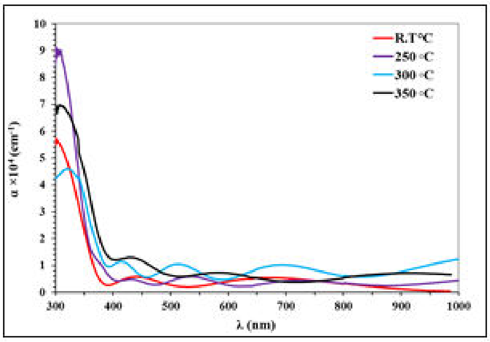


Figure (1-2): Before annealing (during deposition) Figure (1-3): After annealing (after deposition)



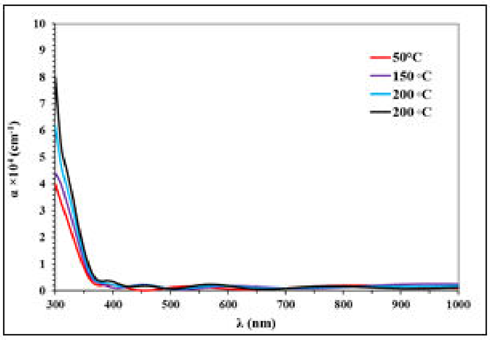


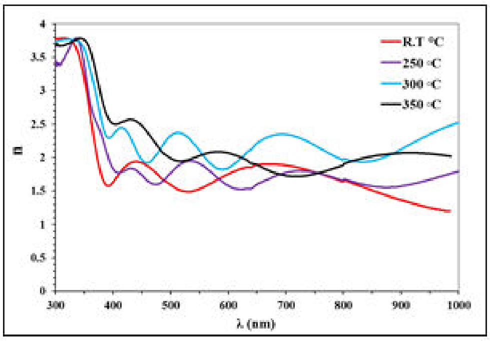
Figure (1-4): Before annealing (during deposition) Figure (1-5): After annealing (after deposition)

1- Refractive Index (n_0)

The ratio between the speed of light in a vacuum to its speed in any other material medium is termed by the refractive index that can be found depending on the knowledge of the value of the inertia constant (K) and the value of the reflectance value of the film (R), so it is according to equation [13]:

$$n_\circ = [\, \{(1+R)/(1-R)\}^{\wedge}2 - (k^2+1)]^{1/2} + \{(1+R)/(1-R)\} \;\ldots\ldots\ldots (2-16$$

The refractive index during deposition (3.5,3.4,2.8,2.2) corresponding to temperatures (50°C,100°C,150°C,200°C) and post-deposition annealing (12,8,4,2) became oscillatory with temperatures (300°C). (RT,350°C,250.°C).



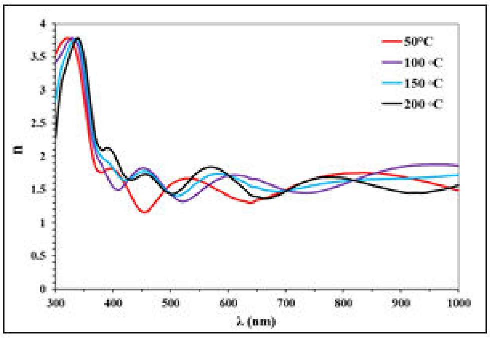
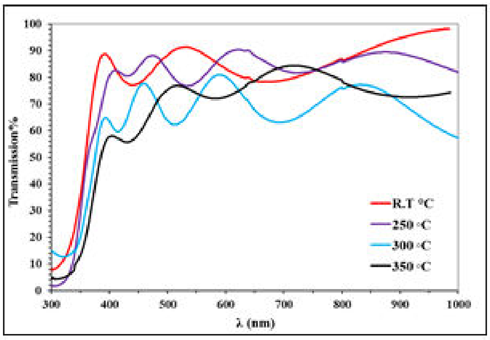


Figure (1-6): Before annealing (during deposition) Figure (1-7): After annealing (after deposition)

1- Transmission (T)

The transmittance represents the amount of radiation energy falling on the membrane after the radiation falls on it
It can be found from equation [13]:
$\mathbf{T = 10^{-A}}$ …………… $\mathbf{(2-17)}$



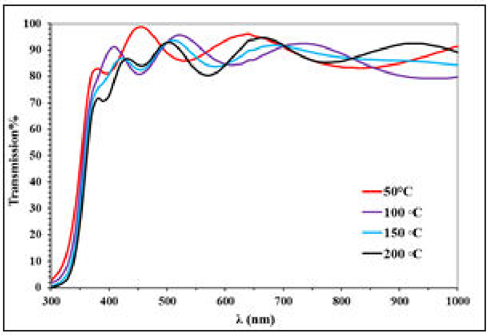


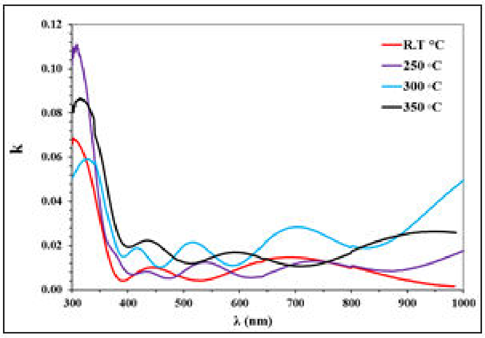
Figure (1-8): Before annealing (during deposition) **Figure (1-9): After annealing (after deposition)**

Before annealing, the transmittance was (86,85,90,82) corresponding to the temperatures (200 °C, 150 °C, 100 °C, 50.(°C

1- Extinction Coefficient (K)

It is defined as the amount of energy absorbed by the electrons of the valence beam when the electromagnetic rays fall on the material, that is, the amount of energy that these electrons extinguish from the incident rays or the amount of attenuation in the energy of the incident rays, and it depends on the amount of wavelength of the incident rays and on the value of the absorption coefficient (a) for each material It is calculated from the relationship [13]

$\mathbf{K = \boldsymbol{a\lambda} / 4\boldsymbol{\pi}}$ …………… $\mathbf{(2-19)}$



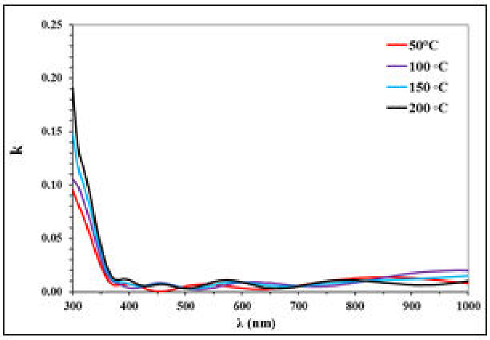


Figure (1-10): Before (sedimentation) annealing (during sedimentation) **Figure (1-11): After annealing (after**

From the observation of Figures (1-10) and (1-11), the damping coefficient of the film will decrease uniformly to (0.8,0.11,0.15,0.18) corresponding to the temperatures (50 °C,100 °C,150 °C,200 °C) so that we notice that it decreases With an increase in the temperature and wavelength of the photon. As for after annealing, we notice that it is less volatile so that (0.8,0.5,0.11,0.07) corresponding to temperatures (350°C,300°C,250°C,R.T).

Optical Energy Gap for Direct Allowed Transitions

The optical energy gap is defined as the lowest energy required to transfer an electron from the top of the valence band to the bottom of the conduction band. The value of the optical energy gap for the permissible direct transfers was calculated through the following equation [14]:

$$\mathbf{a(h\upsilon) = A'(h\upsilon - E_g)^r \ldots\ldots\ldots\ldots\ldots (2-19)}$$

Where:

A′: base modulus , r : proportionality constant , E_g: energy gap , a : absorption coefficient

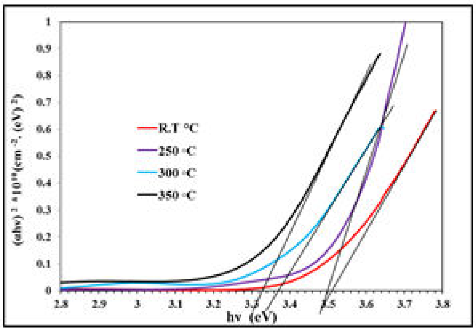


Figure (1-12): Before annealing (during deposition)

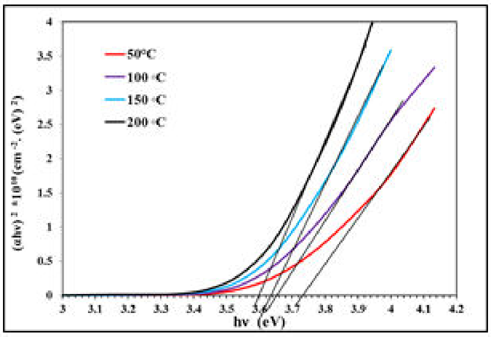


Figure (1-13): After annealing (after deposition)

Figures (1-12) and (1-13) show during deposition and after annealing, where the energy gap was large (3.52,3.54,3.55,3.6) eV corresponding to the temperatures (350°C,300°C,250°C,200°C,) respectively. After annealing, it decreased to eV (3.32,3.34,3.35,3.4) corresponding to the temperatures (200°C,250°C,300°C,350°C), respectively.

4-(ϵ)Dielectric Constant

The fall of electromagnetic rays on the material leads to the interaction of these rays with the charges of the material falling on it, which polarizes and absorbs a measure of the incident energy, which is usually called the dielectric constant of the material (ϵ), which is given by the relationship [14]:

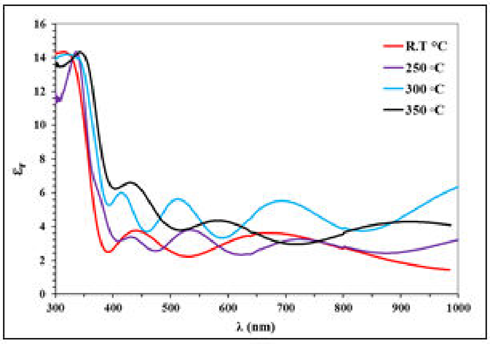
$$\boldsymbol{\epsilon = \epsilon_r - \epsilon_i \ldots\ldots\ldots\ldots\ldots (2-20)}$$

Where (ϵ_r) is the real part of the dielectric constant, and (ϵ_i) is the imaginary part of the dielectric constant.

A- (ϵ_r) Real part of dielectric constant

The real part of the dielectric constant (ϵ_r), which expresses the polarization of the medium regardless of the value of the energy lost as a result of light falling on it, is related to the value of the refractive index (n_o) and the damping coefficient (K) according to the following equation:

$$\epsilon_r = n_o^2 - K^2 \ldots\ldots\ldots\ldots\ldots (2-21)$$



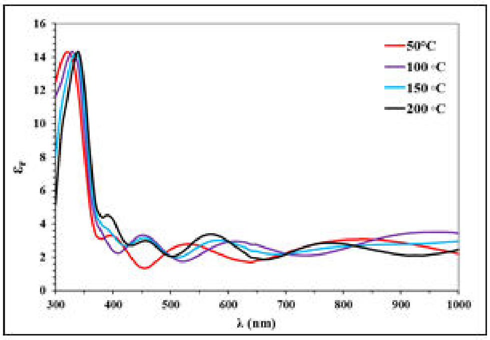


Figure: (1-14) Before annealing (during deposition) Figure: (1-15) After annealing (after deposition)

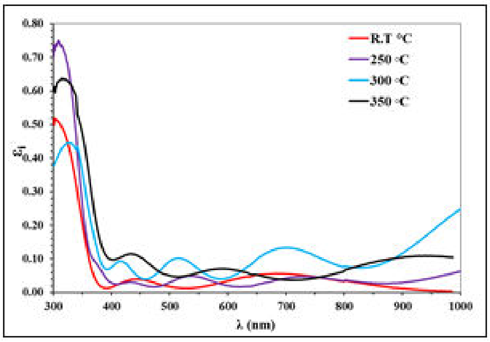
We notice in Figures (1-14) and (1-15) that ϵ_r has decreased uniformly (13,12,8,6) corresponding to (200°C,250°C,300°C,350°C), but after annealing, ϵ_r is oscillating from the beginning (14.2,11.8,13.8,14) corresponding to temperatures (200°C,250°C,300°C,350°C) oscillating with the increase in the wavelength of the photon.

A- ϵ_i (Imaginary part of dielectric con)

The imaginary part of the dielectric constant represents a measure of the absorption of the radiation energy falling from the atoms of the material, and it is also related to the value of the refractive index, and the value of the damping coefficient according to equation [14]:

The imaginary part of the dielectric constant (ϵ_i) represents the imaginary part of the dielectric con-

$$\epsilon_i = 2n_o K \ldots\ldots\ldots\ldots\ldots (2-22)$$



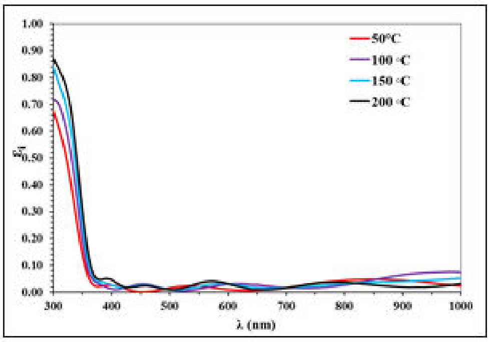


Figure (1-16) Before annealing (during deposition) Figure (1-17) After annealing (after deposition)

It has been noted in Figures (1-16) and (1-17) that ϵ_i during deposition decreases uniformly (0.68,0.72,0.85,0.88) corresponding to (200°C,250°C,300°C,350°C), while after annealing, ϵ_i Swinging decreases from the beginning (0.52,0.75,0.38,0.60) corresponding to the temperature (200°C,250°C,300°C,350°C) oscillating with the increase in the wavelength of the photon.

Structural Properties

The structural properties of films are studied by several techniques, and X-ray diffraction (XRD) is one of the most reliable methods that were adopted in this research, so we will explain it in some detail [15]:

1- X-ray diffraction (XRD)

X-rays (Ray-X) are electromagnetic waves that result from the collision of high-energy accelerated electrons with a target material with a large atomic weight. Because of the radiation transmittance of the material (λ≤2d_hkl), and therefore it can be used in crystal diffraction technology [16].The use of X-ray diffraction is one of the effective and common techniques for studying the crystal structure of thin films, which provides us with a lot of information about the unit cell. It uses an X-ray detector that records the intensity as a function of angle change. As the single-wavelength X-rays fall from the source (T) on the sample to be examined (S) at an angle of (θ), which represents the angle of incidence of the X-rays measured in degrees (deg), and is reflected at an angle of twice the angle of incidence to be recorded on the detector (C), then Changing the angle of incidence time after time to record the readings starting from the value of the angle zero up to the angle (160°) degrees according to the need for this range.

This technology provides us with information about the locations of the characteristic peaks that represent the dominant crystal growth direction within the crystal lattice, and we found that it is equal to (101) and then (102,103) and the middle width of the greatest intensity level by which it is possible to obtain information about the grain boundaries and thus know the growth in the grain size of the test sample.

A- Surface Space (d_{hk1})

The device that was explained represents the mechanism by which the scientist (W.Bragg) was able to put his well-known law represented by the following equation (2-3), and it is the same law that enables us to calculate the value of the interface space (d_{hk1}) from equation [17]:

$$n\lambda = 2d_{hk1}Sin\theta \ldots\ldots\ldots\ldots\ldots (2-3)$$

Where (n) represents the diffraction order, (θ) represents the angle of incidence of the X-rays at wavelength (λ), and hk1 is the Miller index.

B- Grain Size (67uG.S)

The information provided by the obtained diffraction pattern, from which we can find the rate at which the crystals grew inside the crystal lattice, it can be found the rate of the grain size according to Scherer's Formula, where we can find the exposure amount for the characteristic peaks (β) depending on the amount of Half Width The peak (FWHM) (Full Width at Half Maximum) is measured in radial units (rad), so the particle size is measured in (nm) according to equation [18,19]:

$$\mathbf{G.S} = (0.94\,\lambda)\backslash\, \beta_{FWHM}\,.cos\theta \ldots\ldots\ldots\ldots\ldots (2-4)$$

(β_{FWHM}) is the width of the curve at the mid-peak (FWHM), and (θ) the Brake angle.

And we found that the granular dimension nm(18.1,19.1,20,12.2,11.7,24.7,22.2,28.2,13.6,13.7) at temperatures (250°C,300°C,350°C)

C- δ (Dislocation Density)

This term is applied to the number of lines in which the dislocation appears within the crystal structure of the material within the unit area measured in (m^^{2}), which is an indicator of the quality of the crystal structure, and we can find it from the relationship [20]:

$$\delta = 1\,/\,(\mathbf{G.S})^2 \ldots\ldots\ldots\ldots\ldots (2-5)$$

It was found that the dislocation density $line/m^2 \times 10^{15}$)3.5,2.76,2.5 at temperature (250°C) and $line/m^2 \times 10^{15}$) 6.69,7.29,1.64,2.04 and (300°C)and(a $line/m^2 \times 10^{15}$) 1.26,5.43,5.32 temperature (350°C).

D- N_o (Crystals layers number)

It is the number of grains within a unit of volume measured in (m^3), which we can find by the relationship [21]:

$$N_o = t / (G.S)^3 \;\ldots\ldots\ldots\ldots\ldots (2-6)$$

Where (t) represents the thickness of the membrane, measured in (cm).

A-

B- Lattice constant (a)

We can find the lattice constant (a) from Figure (2-7) by deriving it from Brack's law, and deduce the relationship [20]: $a = d_{hk1}(h^2 + k^2 + l^2)^{1/2} \;\ldots\ldots\ldots\ldots\ldots (2-7)$

As shown in the following tables and figures.

(T)°C	a	c
300	3.3085	6.6169
350	3.3093	6.6187

Table (1-18): The lattice constant with temperature

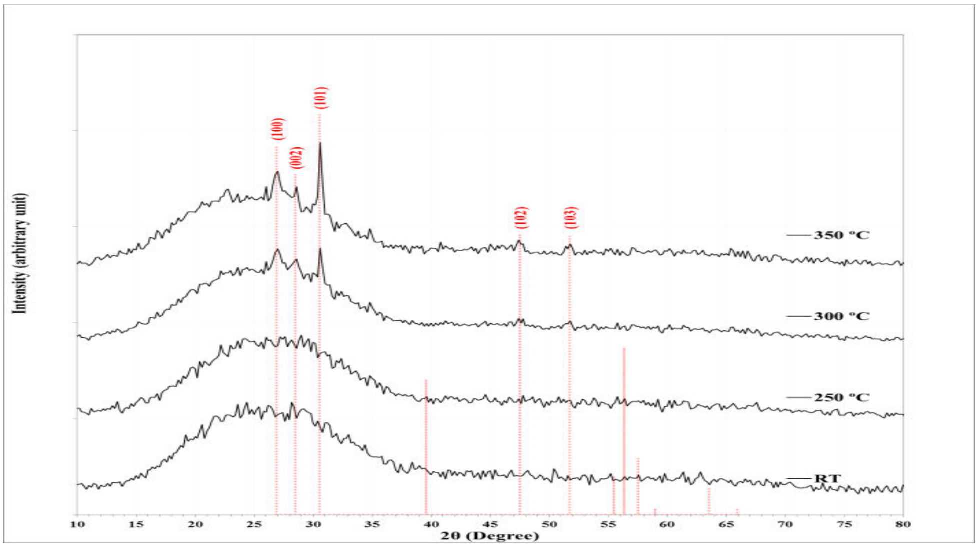


Figure 1-2: X-ray diffraction pattern of (ZnS) compound

Table (1-3): Card for (ZnS) Compound

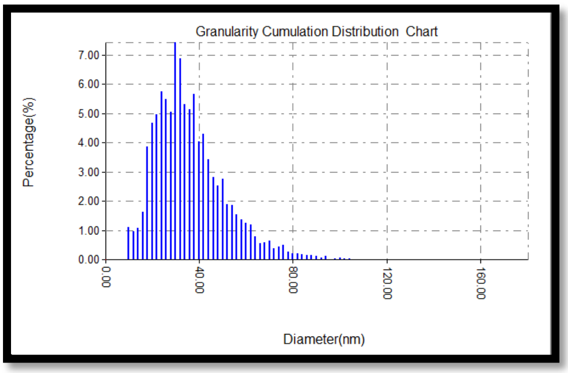
(T (°C	(.Deg)θ 2	FWHM (.Deg)	$_{hkl}$d Exp.(Å)	C.S (nm)	td.(Å$_{hkl}$d)	hkl	10^{15}×δ (^{2}line/m)	ε
RT	**Amorphous**							
250	**Amorphous**							
300	26.9271	0.4510	3.3085	18.1	3.3106	(100)	3.05	0.0019
	28.4969	0.4300	3.1297	19.1	3.1304	(002)	2.75	0.0018
	30.6134	0.4120	2.9180	20.0	2.9266	(101)	2.50	0.0017
	47.5371	0.7100	1.9112	12.2	1.9114	(102)	6.69	0.0028
	51.7470	0.7540	1.7652	11.7	1.7654	(103)	7.29	0.0030

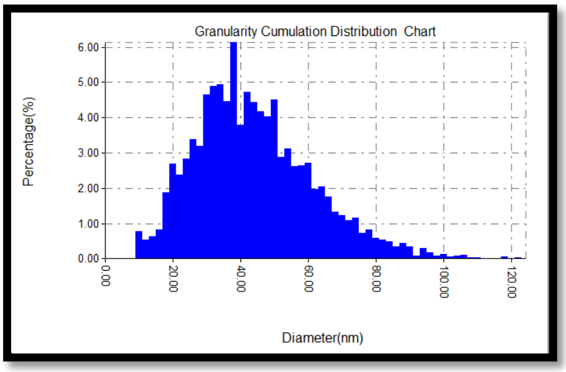
350	26.9200	0.3310	3.3093	24.7	3.3106	(100)	1.64	0.0014
	28.4940	0.3699	3.1300	22.2	3.1304	(002)	2.04	0.0016
	30.6050	0.2920	2.9187	28.2	2.9266	(101)	1.26	0.0012
	47.5330	0.6398	1.9114	13.6	1.9114	(102)	5.43	0.0026
	51.7430	0.6440	1.7653	13.7	1.7654	(103)	5.32	0.0025

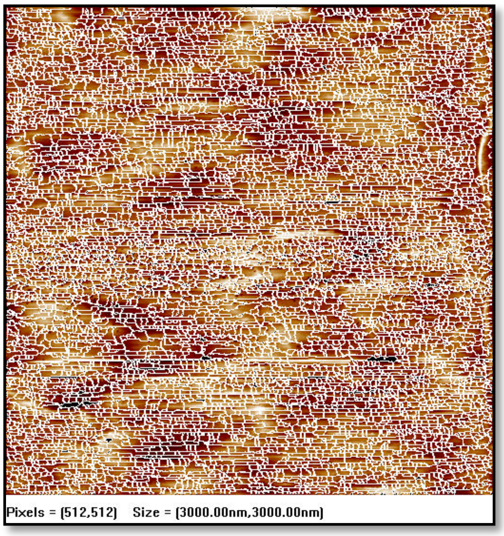
Atomic Force Microscope

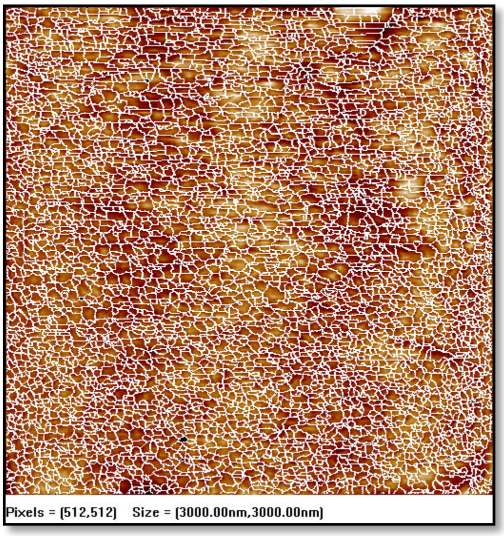
Atomic force microscopy is used to study the surface topography and surface crystal structure of precipitated films, and through it it can calculate the grain size, surface roughness average, and root mean square.

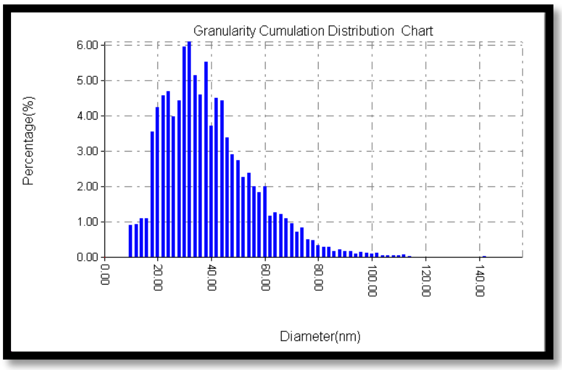
We performed (AFM) assays on the pure ZnS membrane as shown in the figures, which shows the distribution of the grains on the surface of the membrane, where we found that the grain size increased with increasing temperature, and it was noted that the membrane material is arranged in the form of stacked and superimposed circles, that is, the material is crystalline, and it can be observed by (Video Camera) if combined with an electron microscope to image the situation and a magnification power ranging from (10-5000) times, the crystal structure of ZnS material is diagnosed to obtain a clear visualization of the cube (Cubic) of the materials, and these examinations are very important along with X-ray examinations (X- ray) because it provides important information on the physical and structural properties and how to crystallize a wide range of materials.

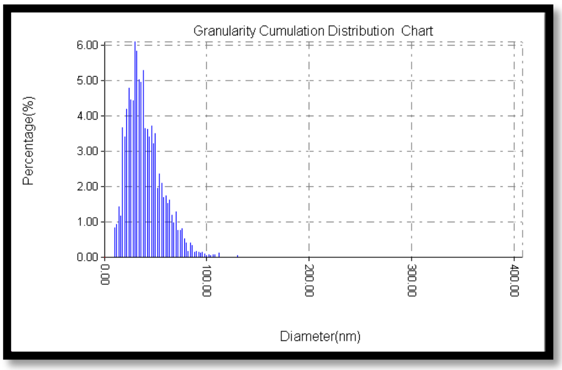


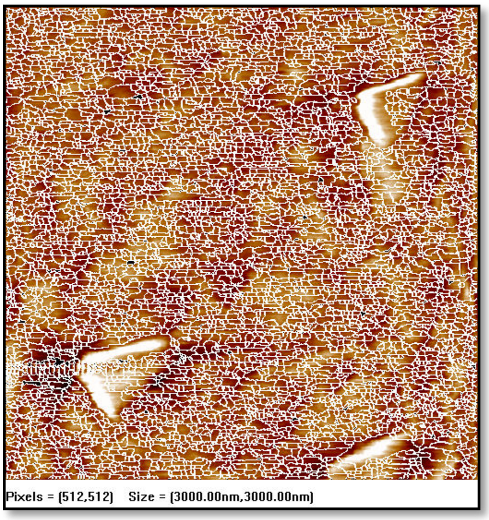


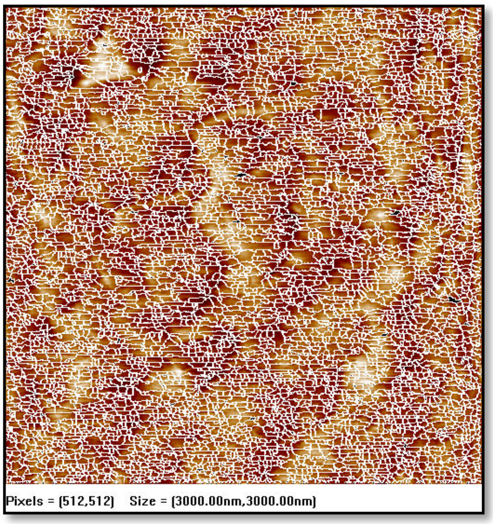












Conclusions:

1. The results of the structural examination showed that the film of ZnS material is random at room temperature and 250 °C and turns into polycrystalline at 300 °C and crystallization increases to become hexagonal structure at 350 °C and is more stable.

2. The results of the research showed that (ZnS) films have a gap of (3.6) eV, and upon annealing it becomes (3.4) eV.

3. The results showed that the absorption coefficient during deposition cm^(-1) 〖10〗 ^4×8,6.2,4.5,4)) at the corresponding temperatures (50°C,100°C,150°C,200°C) and after annealing cm^(-1) 〖10〗 ^4× (9,7,5.6,4.2) at temperatures (250°C,350°C,RT,300°C) and the refractive index before annealing (during deposition) (3.5,3.4,2.8,2.2) corresponding to the temperatures (50°C,100°C,150°C,200°C) and after annealing (during deposition) (12,8,4,2) became oscillating with the temperatures (300°C, RT, 350°C, 250°C) i.e. is not regular.

4. The transmittance increases and fluctuates in contrast with the decrease of the absorption coefficient, which leads to the absorption edge being sharp with the increase of the wavelength. However, after annealing, it increases oscillating until it reaches the greatest amount (90).

5. Noticed that there are (ZnS) film deformations as the annealing temperature increases until the crystal structure becomes more stable at 350°C.

6. Absorption decreases and permeability increases.

7. The crystal size increases with increasing temperature and the crystal size of the atomic force (35.43,43.09,39.04,38.48) is greater than the crystal size of X-rays nm(18.1,19.1,20,11.7,12.2,24.7,22.2)

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