Study the Effect of Irradiation by Co_2 Laser on Dielectric Constant in PbS Thin Films

Mohammed Sh. Marie
Dept of Physics , College of Science , Tikrit University , Tikrit , Iraq
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Abstract:
Lead sulfide (PbS) thin films were prepared by thermal vacuum evaporation on a glass substrate from powder (PbS). The films were deposited on the substrate maintained at room temperature. We annelid the samples at **250** °C by using oven under vacuum for one hour after that we irradiation the samples by using Co_2 laser with power **1** watt at time **3** second and the distance between the samples and laser source was **100** cm.
Absorption spectrum was calculated by using FTIR measurement in range (**400-4000**)cm^{-1}. and from the Absorption spectra we calculated the dielectric constant with two parts (real and imaginary) before and after irradiation.

Introduction
Lead sulfide (PbS) is important members of the semiconductors compound [**1**]. Lead sulfide (PbS) were grown by various physical deposition technique such as conventional vacuum evaporation of the compound, flash evaporation and chemical methods [**2**]. The films obtained by these methods were essentially polycrystalline [**3**].
Lead sulfide PbS is one of such materials whose band energy, (E) lies in the visible solar energy spectrum and could be increased to higher energy by change in compositions and reducing film thickness or grain [**4**]. We study in this work the preparation and characterization of thermal evaporated thin PbS films on glass substrates.

Theoretical part:
In recent years there has been increasing interest in the size-dependent electrical and optical properties of semiconductors [**5**]. In nanocrystallites, the electrons confined in a narrow potential well exhibit extraordinary characteristics in the optical and electrical properties [**6**].
When the width of such confining potential is very small,. i.e. of the order of few hundred angstroms, quantum size effect arises [**7**]. During the last few years, the research on the growth of nanoparticle PbS films has increased, for its technological applications in photoresistance, diode lasers, decorative coatings, and optoelectronic devices [**8-9**]. Many researchers have reported properties of thermal vacuum evaporation deposited PbS thin films.

PbS Compound
PbS Compound is semiconductor and known with in IV-VI. it has a good features of photoconductive in range in IR radiation (**800-5000**)nm at room temperature it is used widely in fabrication the solar cells that is used in military and civilian applications[**10**]
To know a crystal structure for materials and lattice constant we can distinguish more futures of crystal, for example volume, density of atoms. PbS compound consist of to groups IV-VI, it is crystalline compound which has the same structure of (NaCl) as shown in figure bellow , so PbS has a cubic lattice (Fcc) and lattice constant is a= **5.94**A° [**11**]
PbS Compound is a polar semiconductor it has a mixture chemical bound, it owns (Ionic-valance) bounds.

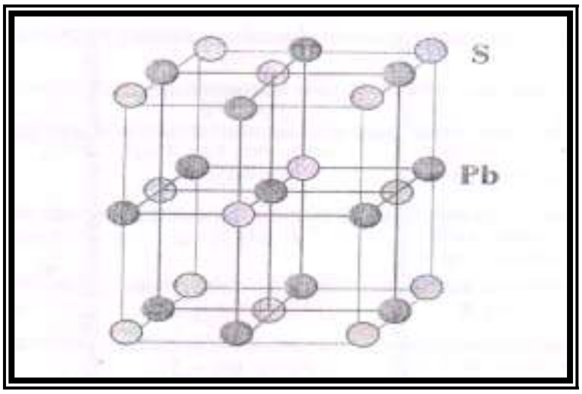

Figure (1) the structure of PbS compound [11]

Dielectric Constant:
Refractive index for materials happen duo to the change for light velocity in space and in the materials which consider complex quantum and give by relation

$N=n_\circ+iK_\circ$……………………(**1**)

Where: N is complex refractive index
$n_\circ$ is the real part of complex refractive index
$K_\circ$ is extinction coefficient which represents the imaginary part of complex refractive index and the imaginary part of complex refractive index refers to missing in energy because the reaction between the light and material charge this reaction led to polarize for material charge and the polarize consider the complex dielectric constant to material and give in relation [**12**]

$\varepsilon\varepsilon_\circ = \varepsilon_1 + i\varepsilon_2$ …………………(**2**)

where: ε is complex dielectric constant
$\varepsilon_\circ$ is free space permittivity constant and equal to **1**
ε_1 is the real part of dielectric constant
ε_2 is the imaginary part of dielectric constant.
The relation between dielectric constant and the refractive index is

$\varepsilon = N^2$ …………………….... (**3**)

$(\varepsilon_1 + i\varepsilon_2) = (n_\circ+iK_\circ)^2$ ………….(**4**)

And from the equation (4) we can conclude the following:

$\varepsilon_1 = (n_\circ^2 - K_\circ^2)$ ………..………..(**5**) (real part of dielectric constant)

$\varepsilon_2 = 2\ n_\circ * K_\circ$ ………………(**6**) (imaginary part of dielectric constant)[**13**].

Experimental Part
PbS thin films were prepared by thermal vacuum evaporation on to glass substrate from powder PbS. The powder was prepared by the ingot samples which prepared from the pure elements (lead and sulfide). The films were deposited on the substrate maintained at room

temperature. The deposition chamber was evacuated to a residual air pressure of $\mathbf{10^{-6}}$ Torr to all deposition experiments. We used balzer type system to prepare the samples.

Molybdenum (Mo) boats was used in evaporation progress, the distance between Molybdenum boat and substrate was **16**cm. Polycrystalline PbS thin films were annelid at **250** $^{\circ}$C under vacuum by using oven for one hour The thickness of the films was 400 nm, and was measured using the Fizaue multiple beam interference fringes method. In this search the samples irradiated by Co_2 laser with **1** watt power for **3** second, the distance between the laser and the samples was **100**cm.

Absorption spectra was calculated by using FTIR measurement in range (**400-4000**)cm^{-1}. and from the Absorption spectra we calculated the dielectric constant with two parts (real and imaginary by using the equations (**5,6**) in series.

Result and discussion:

Dielectric constant:

Real part of dielectric constant is calculated by the use of equation (**5**) as a function to wave length (µm) in a figure (**2**) we note that real part of dielectric constant at room temperature is gradually increased by increasing the wave length till the high value of real part of dielectric constant is (**6.976**), after that it will gradually decrease as wave length increases. We conclude that PbS films has ability to polarize in the wave length (**3.125**) µm.

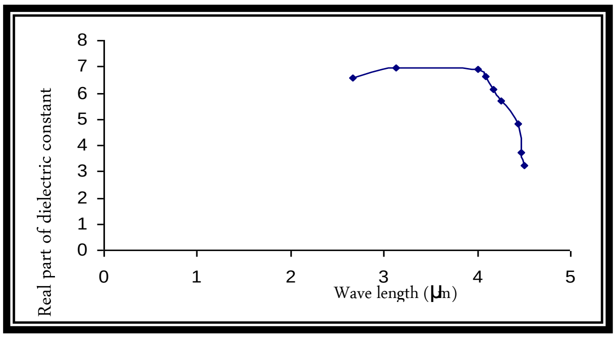

Figure (2) real part of dielectric constant as a function to wave length in (µm) at room temperature before irradiation with Co2 laser

In figure (**3**) which refer to real part of dielectric constant as a function to wave length (µm) at room temperature after irradiation by $\mathbf{Co_2}$ laser from the figure we note the maximum value it is **6.842** at the wave length **3.921**µm. We conclude the polarize ability of PbS thin films after irradiation by laser was shifting toward the high value of wave length, and the value of real part of dielectric constant was decrease sharply till it will arrive to minimum value of dielectric constant and it is value decrease after irradiation by Co2 laser.

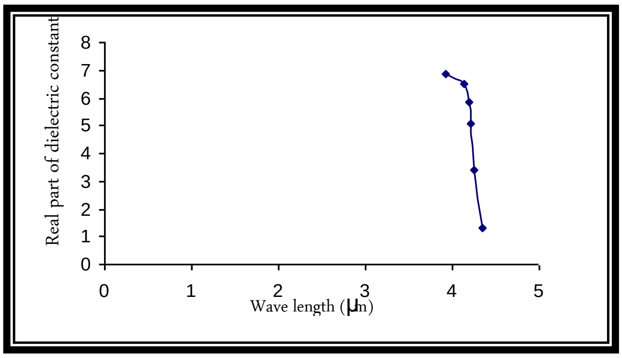

Figure (3) real part of dielectric constant as a function to a wave length in (µm) at room temperature after irradiation by Co_2 laser.

Figure (**4**) shows the real part of dielectric constant annealing at **250** C$^{\circ}$ before irradiation by Co_2 laser from the figure we see the real part of dielectric constant has nearly equal values in range of wave length between (**2.75-4.29**) µm and the maximum value it is **6.957** at the wave length **4.29** µm after this wave length the values of dielectric constant was decreased gradually.

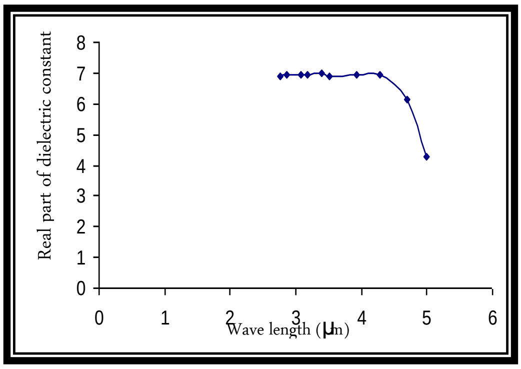

Figure (4) the real part of dielectric constant as a function to wave length with annealing at 250 C$^{\circ}$ before irradiation by Co_2 laser.

Figure (**5**) shows the relation between the real part of dielectric constant as a function to the wave length (µm) after irradiation by Co_2 laser we note the real part of dielectric constant increase gradually till it arrive to maximum value is **6.899** at the wave length **4.166** (µm) that is mean the PbS thin films can be a polarize at this wave length and after the wave length **4.166** (µm) dielectric constant will decrease sharply. Also we can note the effect of irradiation by Co_2 laser led to decrease the real part of dielectric constant from **6.957** at wave length **4.29** (µm) before irradiation by laser to **6.899** at wave length **4.166** (µm) after irradiation by laser.

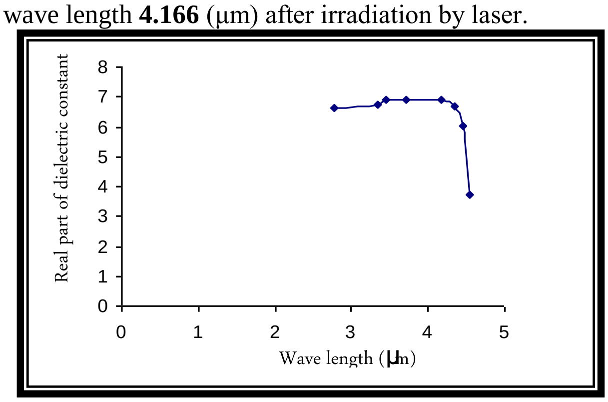

Figure (5) the real part of dielectric constant as a function to wave length with annealing at 250 C$^{\circ}$ after irradiation by Co_2 laser.

Imaginary part of dielectric constant is calculated by the use of equation (**6**) as a function to wave length (μm), figure (**6**) refers to imaginary part of dielectric constant at room temperature before irradiation by Co_2 laser from the figure below we note it has the minimum value at the wave length **2.666** (μm) after that it increased by increases the wave length and the maximum value is **0.246** at the wave length **4.444** (μm). The imaginary part of dielectric constant depended at extinction coefficient and this is clear from the equation (**6**). The imaginary part of dielectric constant represents the thin films ability upon insulating and missing in incident radiation's density upon the films.

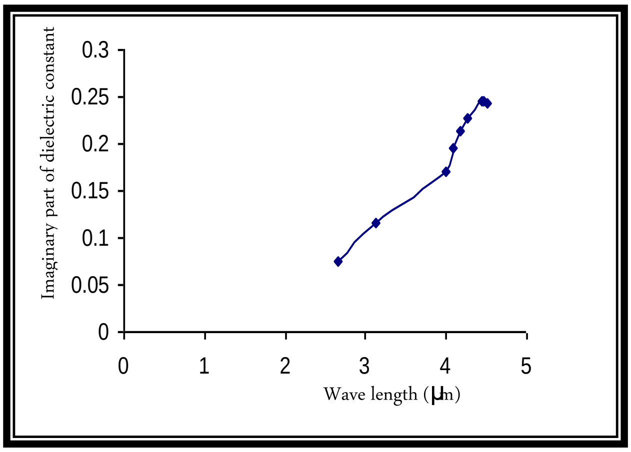

Figure (6) imaginary part of dielectric constant as a function to wave length (μm) at room temperature before irradiation by Co_2 laser.

Figure (**7**) imaginary part of dielectric constant at room temperature after irradiation by laser. It has the maximum value is **0.232** at the wave length **4.21** (μm), we conclude the irradiation by laser led to decrease the value of imaginary part of dielectric constant and also cause to decrease the PbS thin films ability to insulating and missing in incident radiation's density upon the films. And also we note the dielectric constant begin decreasing with increasing the wave length.

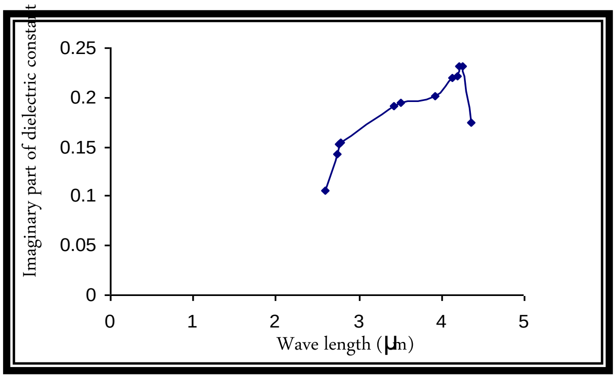

Figure (7) imaginary part of dielectric constant as a function to wave length (μm) at room temperature after irradiation by Co_2 laser.

Figure (8) the relation between the imaginary parts of dielectric constant at **250** C° as a function to wave length (μm) before irradiation by laser from the figure we note it is increasing gradually with increase the wave length and the maximum value is **0.242** at the wave length **4.366** (μm).

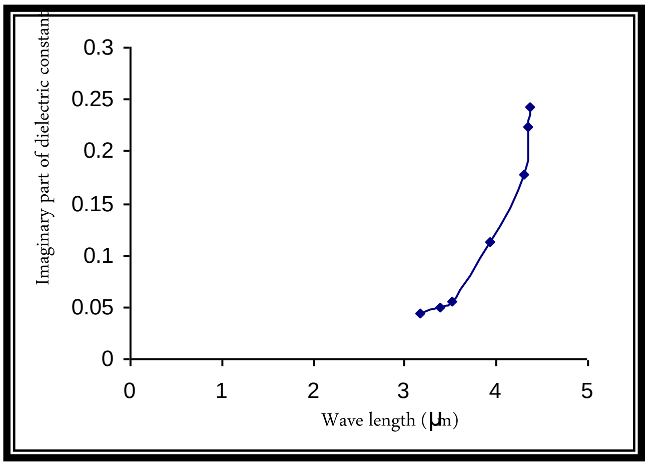

Figure (8) imaginary part of dielectric constant as a function to wave length (μm) at 250 C° before irradiation by Co_2 laser.

Figure (**9**) show the imaginary part of dielectric constant at **250** C° after irradiation by Co_2 laser we note the curve is increase gradually with increase the wave length until arrive to the maximum value it is **0.249** at the wave length **4.545** (μm) we can conclude that the effect of irradiation by Co_2 laser led to small increase in the value of imaginary part of dielectric constant

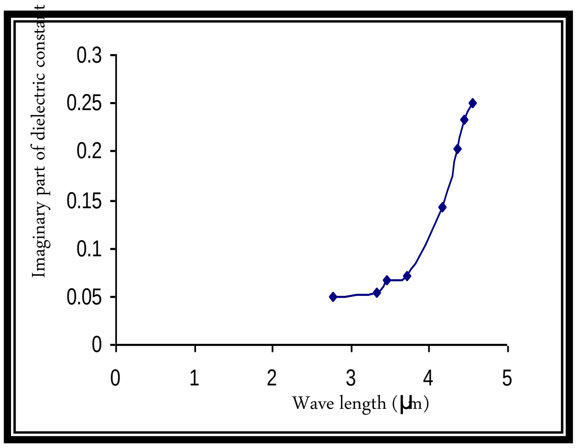

Figure (9) imaginary part of dielectric constant as a function to wave length (μm) at 250 C° after irradiation by Co_2 laser

Conclusion:

1. Irradiation by Co2 laser led to decrease in real part of dielectric constant at room temperature.
2. Irradiation by Co2 laser led to shifting in wave length from **3.125** μm to **3.921** μm at room temperature.
3. after annealing in **250** C° the irradiation by laser led also to decrease the maximum value of real part of dielectric constant.
4. The effect of irradiation by laser led to small increase in the value of imaginary part of dielectric constant at 250 C°.

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دراسة تاثير التشعيع بليزر ثاني اوكسيد الكربون عل ثابت العزل الكهربائي لغشاء كبريتيد الرصاص

محمد شياع مرعي

قسم الفيزياء ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

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الملخص

تم في هذا البحث دراسة خواص اغشية كبريتيد الرصاص المحضرة بطريقة التبخير الحراري الفراغي والمرسبة عل قواعد زجاجية بدرجة حرارة الغرفة ومن ثم تم تلدين الاغشية المحضرة باستخدام فرن مفرغ من الهواء لمدة ساعة واحدة وبدرجة حرارة $250^{\circ}C$ وبعدها تم تشعيع العينات باستخدام ليزر ثاني اوكسيد الكربون بقدرة 1 WATT ولمدة ٣ ثواني وكانت المسافة بين العينات المشععة وجهاز الليزر هي ١٠٠سم. تم حساب طيف الامتصاص باستخدام جهاز الاشعة تحت الحمراء وبمدى موجي من $(400\text{-}4000)cm^{-1}$ ومن طيف الامتصاص تم حساب ثابت العزل الكهربائي بجزئيه الحقيقي والخيالي قبل وبعد التشعيع.