Effect of the Dielectric Barrier Discharge Plasma on the Optical Properties of CDS Thin Film

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Abstract:

Cadmium sulphide CdS films with 200 nm have been prepared by thermal evaporation technique on glass substrate at substrate room temperature under vacuum of 10^{-5} mbar. In this paper, the effect of Dielectric Barrier Discharge plasma on the optical properties of the CdS film. The prepared films were exposed to different time intervals (0, 3, 5, 8) min. For every sample, the Absorption A, absorption coefficient α , energy gap Eg ,extinction coefficient K and dielectric constant ε were studied. It is found that the energy gap were decreased with exposure time, and absorption , Absorption coefficient, refractive index, extinction coefficient, dielectric constant increased with time of exposure to the plasma. Our study considers the first investigation of the effect of cold atmospheric plasma on the optical properties of CdS film.

Key words: Cadmium sulphide, Dielectric barrier discharge, Optical properties, Thermal evaporation.

Introduction:

Recently, many possible applications that regard with non thermal atmospheric-pressure plasma where it produced in tight tubes have been stated. One of these applications that must be mentioned is thin film sedimentation on the inner surface for tubes in addition to disinfecting and sterilization of tubular medical apparatus. Therefore, it became necessary for studying atmospheric-pressure plasma that produced in tight tubes(1).At present, interest in the development of sterilization methods and the use of new methods for biomedical tubes, which have made from thermosensitive material, has increased. There are many disadvantages of the conventional techniques of sterilization where some of them include exposure to high-temperature, for example, dry, and moist heat sterilization and steam autoclave (2). These disadvantages lead to degradation of sensitive materials thermally, moreover, there are other disadvantages of conventional techniques that are toxic to the environment such as ethylene oxide sterilization and gamma irradiation. The low-temperature plasmas, which used in sterilization of polymeric medical tubes was useful (3)where this method takes place at room temperature, olso, it is environmentally friendly. Exactly, the reactive area that formed in the discharge hole(O, O3, OH, NO,

NO2, etc.)at an atmospheric pressure largely take part in biological decontamination and biomaterial surface modifications (4).

Moreover, several of these species have a considerable curative effect. The dielectric barrier discharges (DBD) is considered one of the important high potentials in biomedical implementation(3). The dielectric barrier discharges plasma (DBD) can be defined as a no equilibrium highly collisional plasma, which produced at partly high gas pressure using a pulse that has high voltage (HV) where it is applied to a special system of electrodes. According to the structure of the gassy mixture, the volume of the applied voltage, the excitation frequency and/or duration of the voltage pulse, and the hole distance, different discharge modes of dielectric barrier discharges were noted. Filamentary and homogeneous discharge can be considered the main modes where it can be called diffuse mode. Furthermore, the homogeneous discharge can appear in two forms: the glow discharge and Townsend discharge. Generally, in glow mode, dielectric barrier discharges (DBD) in noble gasses are driven. The Townsend mode can be obtained in small gas hole and barriers with low dielectric constant (5) Because of the various applications in optoelectronic devices, thin films of CdS have been largely investigated. Especially, heterojunction solar cells with a tight band gap base and a wide band gap window for example CdS/CdTe and CdS/CuInSe solar cells (6).CdS thin film is a direct band gap that has (2.42 eV) metal

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chalcogenide II-VI semiconductor with refraction, which has a high index of (2.5) and n-type conductivity (7).CdS is the best visible light active semiconductor photo catalyst(8). One of the most important characteristics that leads to the great experimental interest in these materials is wide energy gap of CdS semiconductor (9). The different techniques such as chemical bath deposition (CBD), thermal evaporation, molecular beam epitaxy, and spray pyrolysis have been explored to deposition of CdS films (10,11).

This study investigates the effect of plasma on the optical properties of CdS films prepared by thermal evaporation and exposed to different plasma time periods (0.3,5,8).

Materials and Methods:
Experimental Preparation of Thin Films

CdS films were deposited onto ultrasonically cleaned glass by thermal evaporation technique from high purity CdS powder supplied from Balzar compeiny. The film thickness 200 nm was measured by using weighting method and Michelson interferometry Using He-Ne laser (632.8 nm). The optical properties of CdS were studied in the wavelength range 400-1100 nm by using UV-Vis spectrophotometer UV-2610 plus. The output data of wavelength, transmittance, and absorptance are used in a computer program to deduce the optical energy band gap. and absorption coefficient, refractive index, extinction coefficient, dielectric constant.

DBD Plasma System.

DBD is composed of two parallel electrodes where one electrode is connected to the high voltage (AC) power supply and the other electrode is connected to the ground. One or two dielectric plates are located either on the powered electrode or on the both of the electrodes. The plasma reactor includes two electrical electrodes. They are cylindrical stainless steel electrodes enclosed by Teflon for insulation. The flat surface of each electrode with a diameter of (4.5cm) is fixed by concentric form on moving gradual stand, as shown in(Fig.1a), The flat surface of the upper electrode is covered by a sheet of Pyrex with thickness of (1.2 mm) as an electrical insulator. To study the characteristics of the plasma system, the upper flat surface electrode is made in two sizes, the larger size electrode has a 4.5 cm diameter and the smaller size electrode is 2.5 cm in diameter.

The filamentary discharge occurs at atmospheric pressure in air or other gases when high voltage of sinusoidal waveform or short period, pulses is exercised between two electrodes, with at least one electrode being dielectric(12) The

insulator precludereinforcement of current between the electrodes, creating electricallysafe plasma without substantial gas heating. This process allows direct treatment of living tissue, (Fig.1b), and biological systems without thermal disadvantage observed in more conventional thermal plasma (13, 14).
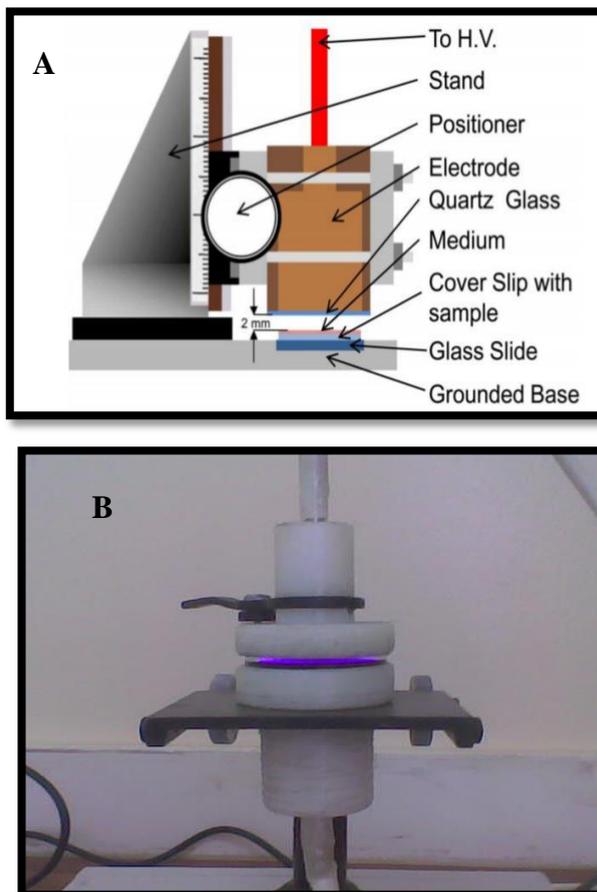

Figure 1. (a): Schematcdigram of DBD system Schematc digram of DBD system, (b):photograph image of DBD system

Results and Discussion:
Absorption

Figure 3 shows the spectrum of absorption 'A' of the CdS film exposed to the plasma for different times intervals (0, 3, 5, 8) min as a function of wavelength. From Fig 3, it can be shown that the absorption at a given wavelength increases with increasing exposure time.
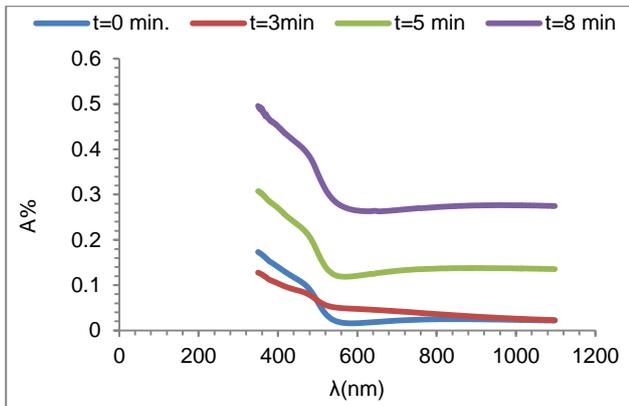
Figure 3. The spectrum of absorption A as a function of wavelength of the CdS film exposed to the plasma for different time's intervals (0,3, 5,8) min.

Absorption Coefficient

The absorption coefficient is calculated using the following Lambert formula (15):

$$\alpha = 2.303 A/t \ldots\ldots\ldots 1$$

Where α is the absorption coefficient, A is the absorption and t is thickness of the film.
Figure 4 shows the absorption coefficient as a function of photon energy of the in the region of the spectrum (400-1100) nm CdS film exposed to the Argon plasma for different times intervals (0,3, 5,8) min. It was noted from the figure that the absorption coefficient decreases with increasing photon energy, also at a given photon energy the absorption coefficient increases with increasing exposure time, except for t=3 min.
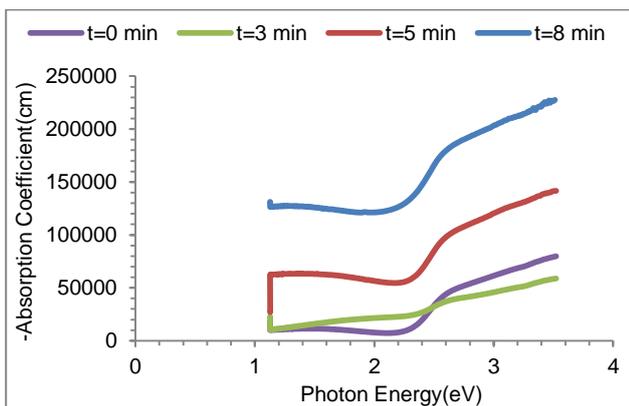

Figure 4. The absorption coefficient as a function of photon energy of the CdS film exposed to the plasma for different times (0, 3, 5, 8) min.

Energy gap

The coefficient of absorption is given according to the Tauc 's relation as follows (16):

$$\alpha h\upsilon = B(h\upsilon - Eg)^m \ldots\ldots\ldots 2$$

Where B is a constant, its value varies depending on the transitions, Egis the energy gap, hυ is the photon energy, m is a constant which has value 1/2 for direct allowed transmittance for semiconductors (16). By plotting $(\alpha h\upsilon)^2$ against photon energy hυ, when extending the straight part of the resulting curve to cut the hυ axis at point $(\alpha h\upsilon)^2=0$, the intersection point represents the energy gap Eg.

Figure 5 shows the relationship between $(\alpha h\upsilon)^2$ as a function of photon energy for CdS films exposed for plasma for different times intervals (0, 3, 5, 8)min. the energy gap for each curve was calculated were (2.4 ,2.3, 2.28, 2.2) eV respectively. It is found that the energy gap decreased with exposure time.

Extinction Coefficient
The Extinction Coefficient of the prepared films is calculated by the following relation (17):

$$\lambda K = \frac{\alpha \lambda}{4\pi} \ldots\ldots\ldots\ldots 3$$

Where as:λ:the wavelength for incident photon.

Figure 6 shows the graph of extinction coefficient as a function of wavelength for CdS films exposed for non-thermal plasma for different times (0, 3, 5, 8)min , It was showed that when the wavelength was fixed, the Extinction coefficient increased with an increase in the exposure time of the plasma.
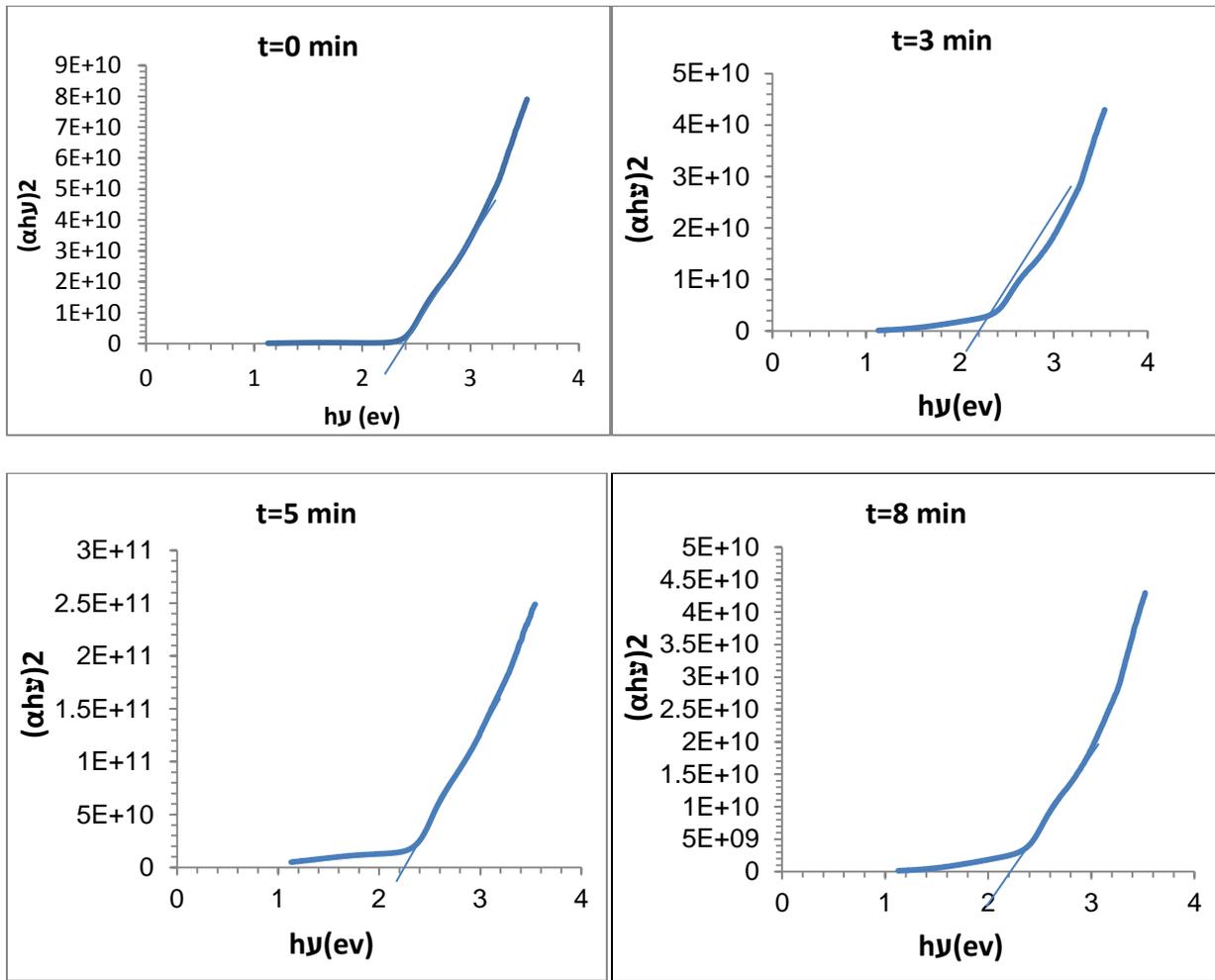
Figure 5. The Energy gap as a function of photon energy of the CdS film exposed to the plasma for different times interval (0, 3, 5, 8) min.
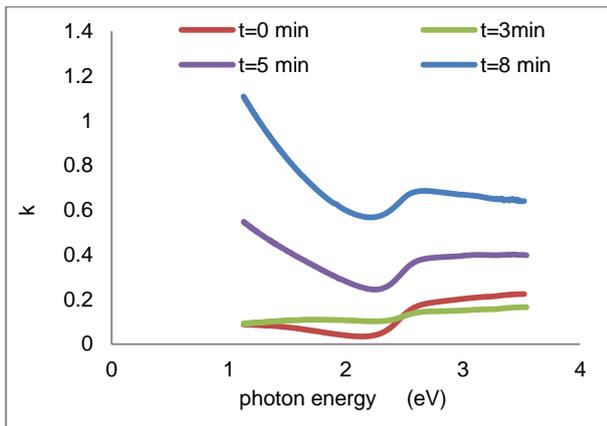

Figure 6. the extinction coefficient as a function of wavelength of the CdS film exposed to the plasma for different times (0, 3, 5, 8) min.

Dielectric Constant

The values of the dielectric constant are complex values that depend on a real εr and imaginary part εi, as follows(18,19):

$$\varepsilon = \varepsilon_r - i\varepsilon_i \ldots\ldots..4$$
$$\text{where } \varepsilon_r = n^2 - K^2$$
$$\varepsilon_i = 2nK \ldots\ldots.5$$

Figure 7 shows the real and imaginary part, as a function of wavelength for CdS films exposed for non-thermal plasma for different times (0, 3, 5, 8) min.

It is observed from the real and imaginary curves that the peaks of the curve creep towards the long wavelengths by increasing the exposure time. Also, it is observed that for given value of the of the wavelength the value of real and imaginary increases with increasing the exposure time.
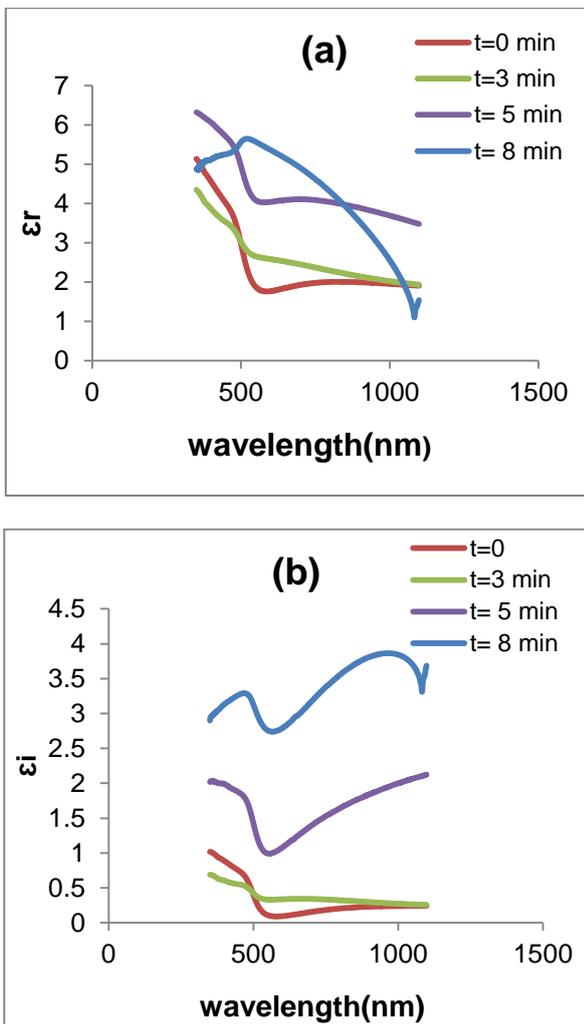
Figure 8. The refractive index as a function of wavelength of the CdS film exposed to the plasma for different times (0, 3, 5, 8) min

Conclusion:

This work, studied the effect of plasma produced at normal atmospheric pressure on the optical properties of CdS prepared by thermal evaporation technique. Dielectric Barrier Discharge plasma laboratory manufactured for this purpose was used. after exposing prepared films to the plasma at different time's intervals (0, 3, 5, 8) min. The effects of the plasma on the absorption A, absorption coefficient α, Energy gap Eg, extinction coefficient K, refractive index and dielectric constant (ε) were calculated. It was found that the Energy gap Eg decreases with increasing the time of exposure while absorption A, absorption coefficient α, extinction coefficient K , refractive index n and the real and imaginary part of the Dielectric constant increases with increasing the time of exposure, The results show that the DBD techniques enhance some of the optical properties of CdS.

Conflicts of Interest: None.

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Figure 7. The Dielectric constant (ε) (real part (a) and imaginary part (b))as a function of wavelength of the CdS film exposed to the plasma for different times (0, 3, 5, 8) min.

Refractive Index

The refractive index is defined as the ratio between the velocity of light in the vacuum and its velocity within the material, It was calculated by using eq 6 (20):

$$n=\left(\frac{4R}{(R-1)^2}-k^2\right)^{1/2}-\frac{(R+1)}{(R-1)}......6$$

Figure 8 shows the graph of refractive index as a function of wavelength for CdS films exposed for non-thermal plasma for different times (0,3,5,8)min , It was shown that when the wavelength was fixed, it was found that for alow exposure time (less that 5 min) the refractive index decreased with increasing wavelength up to 500 nm and then it began increasing with wavelength . but when the exposure time increased (greater 5 min), the curve behaved in a seemingly different.
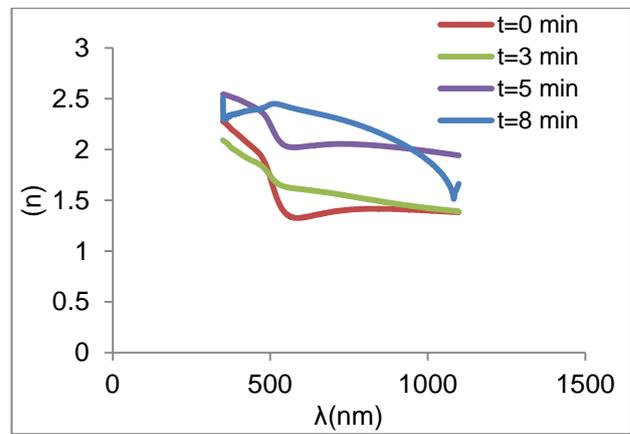
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تاثير بلازما حاجز العزل الكهربائي على الخواص البصرية لاغشية كبريتيد الكادميومCdS

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الخــلاصــة:

في بحثنا هذا تم دراسة تاثير بلازما حاجز العزل الكهربائي على الخواص البصرية لاغشية كبريتيد الكادميومCdS المحضرة بطريقة التبخير الحراري. عرضت الاغشية المحضرة لفترات زمنية مختلفة للبلازما (0، 3، 5، 8) دقيقة . درس في كل تعريض تاثير البلازما على كل الامتصاصية A ومعامل الامتصاص α وفجوة الطاقة ومعامل الخمود K وثابت العزل ε ومعامل الانكسار n. ظهر من خلال النتائج ان فجوة الطاقة تقل بزيادة زمن التعريض للبلازما بينما تزداد قيم كل من الامتصاصية ومعامل الامتصاص ومعامل الخمود وثابت العزل ومعامل الانكسار مع زيادة زمن التعريض للبلازما.واظهرت النتائج تحسين لبعض الخصائص البصرية لاغشية CdS .

الكلمات المفتاحية: كبريتيد الكادميوم، التفريغ بحاجز العزل الكهربائي، الخواص البصرية، التبخير الحراري.