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RESEARCH PAPER

Investigation of the Impact of Radiation on the Optical Characteristics and Structure of PVA/PEG/CdS Nanocomposite

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ABSTRACT

Thin films of PVA/PEG and PVA/PEG/CdS nanocomposite liquid were prepared by spin coating that has a 132 nm thickness. The optical characteristics were examined., and the outcomes showed that the irradiation process led to an increase in the values of A and α decline in the values of T and Eg .The structural properties of XRD were studied and the results showed that the films prepared before and after irradiation were of the monoclinic type and that the irradiation process led to an rise in the G.S values and a decrease in the FWHM because the relationship between them is inverse. In addition, the Miller coefficients and the inter-crystalline plane distance were calculated. SEM was used to examine the produced thin film surfaces both before and after irradiation. The results showed that the irradiation process led to more homogeneity of the films, a reduction in crystalline defects on the film surfaces, and an increase in G.S. The XRD results and this outcome are in agreement.

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INTRODUCTION

Laser interaction with matter Laser is a unique type of light with amazing properties. "LASER" stands for "Light Amplification by Stimulated Emission of Radiation" [1]. Since its invention in 1960, lasers have proven to be of great value in industry, medicine, technology, and the military. Scientists have been inspired to study this topic because of its widespread application in society. Lasers are valuable because they are coherent, monochromatic, and have other features that allow them to focus on a point and induce toning, excitation, and scattering as they pass through matter, which can be used to examine the properties of certain materials]2,3 [.

A layer of material with a thickness ranging from nanometers to micrometers is called a thin-film coating. They have extremely intriguing attributes that are distinct from those of the bulk material they produce since their film properties depend on the quantity of interconnected criteria as well as the method employed to create thin-film [4,5].

Thin films have diverse applications in various sectors, including shielding, filters, color isolation, fire resistance, high-temperature superconductors, silicon sensors, anti-fog, memory sensors, electronic semiconductors, and optical coatings [6,7[.

Semiconductors and their physics have become one of the most important topics of solid-state physics in terms of applications as a result of its astonishing progress [8]. Semiconductors get

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their name from their moderate ability to conduct electricity. In fact, a typical semiconductor's conductivity can be changed by temperature to the extent that most of them appear to be insulators at low temperatures and metais at high ones. Impurities may also play a significant role. Whereas extrinsic semiconductors are doped with impurities, intrinsic semiconductors are devoid of significant impurities. The operation of microelectronic devices requires both of these features [9].

Nanostructures material is a modern material type, with a large variety of non-linear optics, with unique characteristics in specific sectors [10]. In areas such as electrical, magnetic, optical, and mechanical systems, nanomaterials have a technological application[11]. In recent years they have drawn tremendous attention and provide fascinating prospects in many structural applications [12].

A semiconductor of the II_VI group, cadmium sulfide (CdS) exhibits a direct bandgap of 2.4 eV at ambient temperature.[13].

The macromolecule is a polymer composed of several repeating subunits. Because of their many different properties, both natural and manufactured polymers are essential and ubiquitous in daily life. More familiar synthetic plastics like polystyrene coexist with natural biopolymers like proteins and DNA, which are essential to the structure and operation of life. A vast number of tiny molecules called monomers are polymerized to produce both natural and synthetic polymers. Their hardness and tendency to form glasses and semi-crystalline structures instead of crystals are among their remarkable physical traits [14].

In this research two polymers are used A common polymer in many different applications, especially in semiconductors, is polyvinyl alcohol (PVA). It is an important component in the creation of devices because of its special qualities and high visible light transmission. PVA has excellent tensile strength, storage capacity, electrical and optical qualities, it is semi-amorphous and resistant to oils and solvents. Commercial production involves hydrolyzing poly (vinyl acetate) [15,19].

The other polymer employed in this study is polyethylene glycol, which was originally reported to be manufactured in 1859, the first reports of polyethylene glycol manufacturing were made. Polyethylene glycols were the products that Charles Adolphe Wurtz and A. V. Lourenço separately isolated [20].

PEG is a polyether molecule that has numerous uses in anything from medicine to industrial manufacture. PEG is frequently referred to as polyethylene oxide (PEO) or polyoxyethylene (POE), depending on its molecular weight. [21].

This study's main objective is to use the spin coating process to manufacture cadmium sulfide and add PVA and PEG polymers. Numerous goals were accomplished during the work period. The produced samples' optical and structural characteristics were then examined by UV- IR1800 spectrophotometer system , SEM, and XRD, and the results were compared to the samples' measurements following irradiation with a violet laser set to 60 microwatts of power for 15 minutes.

MATERIALS AND METHODS

The membrane (PVA/ PEG/ CdS) was first prepared by preparing PVA polymer liquid was prepared by placing a weight of 15 grams of PVA polymer powder in a 200 ml glass beaker and adding 100 ml of distilled water free of ions using a stirrer device to dissolve the polymer powder through continuous stirring using a magnetic needle and at a heating temperature of 50 degrees Celsius for half an hour. PVA polymer liquid was obtained after which the prepared liquid was left to settle and cool at the laboratory temperature.

After that PEG polymer liquid was prepared by placing a weight of 20 grams of PEG polymer powder in a 200 ml glass beaker and adding 100 ml of distilled water free of ions. A stirrer was used to dissolve the polymer powder through continuous stirring using a magnetic needle and a heating temperature of 50 degrees Celsius for half an hour. PEG polymer liquid was obtained, after which the prepared liquid was left to settle and cool at laboratory temperature.

The PEG/PVA polymer mixture was prepared by placing 50 ml of the prepared PVA polymer liquid in a 200 ml glass beaker and adding 50 ml of the prepared PEG polymer liquid to it. A stirrer was used and continuous stirring was carried out using a magnetic needle at a heating temperature of 50 degrees C for half an hour. A well-homogeneous polymer mixture was obtained. Cadmium sulfide or cadmium sulfide CdS was prepared by the following steps:

First: Cd liquid was prepared by dissolving 13.326 grams of cadmium salts in 100 ml of distilled water using a stirrer for the dissolution process at a temperature of 60 degrees for 20 minutes. Cd liquid was obtained.

The solution was left to settle and cool for two hours, after which filter paper was used to filter the prepared Cd liquid to avoid undissolved salts if they exist in the solution and cannot be seen.

Second: Sulifer(S) liquid was prepared by dissolving 3.806 grams of sulfur salts called thiourea in English using a stirrer and stirring continuously using a magnetic needle at a temperature of 50 C for half an hour. S liquid was obtained. 20% of the prepared cadmium sulfide liquid was added to 80% of the prepared polymer mixture PVA/PEG. The films were prepared by spin method with the following steps:

With a number of cycles of 2000 cycles for every 30 seconds. After cutting the glass slate into small pieces of 2.5 cm by 2.5 cm and cleaning them with ethanol and washing them with distilled water and drying them in air. The films PVA ,PEG ,PVA/PVA, PEG/PEG/CdS were prepared.

After the preparation process, the optical and structural properties of the prepared samples are measured, and then the samples are exposed to violet laser radiation with a power of 60 microwatts for 15 minutes. The optical and structural properties of the samples exposed to radiation are calculated and the results are compared to determine the effect of radiation on the samples.

RESULTS AND DISCUSSION

Study of optical properties

Many optical constants can be found by studying the absorbance spectrum for a wide range of wavelengths. Fig. 1 shows that the absorbance was measured using a UV-visible1800 device in the (300–1100) wavelength range as a function of wavelength and irradiation of the PVA/PEG/CdS film led to an increase in the absorbance value because the incident photon cannot excite the electron and transfer it from the valence band to the conduction band, as the incident photon's energy is lower than the semiconductor's energy gap value]22[.

From the figure we notice an increase in the absorbance value of the second sample exposed to laser radiation, as the heat generated will increase the secondary energy levels between the valence band and the conduction band. We notice that the maximum absorbance is in the short wavelength region, and we also notice that the absorbance

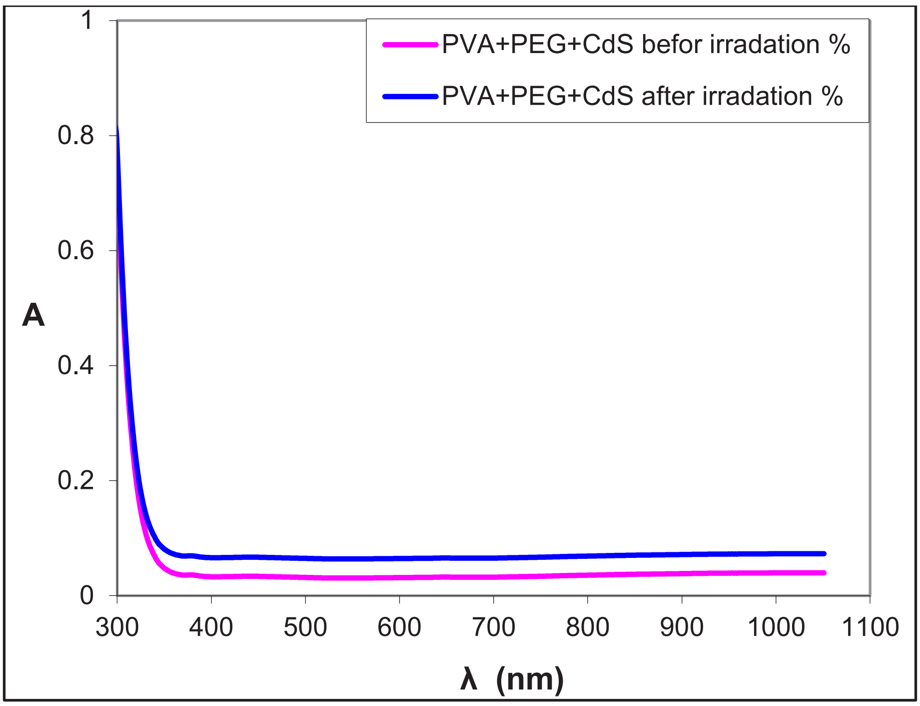

Fig. 1. shows the relationship between absorbance and wavelength of the sample before and after irradiation.

decreases slightly at long wavelengths. This means physically that the incident photon could not excite the electron and transfer it from the valence band to the conduction band because the energy of the incident photon is less than the energy gap value of the semiconductor, and therefore the absorbance decreases with increasing wavelength. We find that the absorbance value increases after exposure to radiation, as we notice that laser irradiation has a noticeable effect on the absorbance of the prepared films, as seen in Fig. 1.

T was calculated from the spectrum of A using the Eq. 1 [23]:

$$\mathrm{A} = \log\left(\frac{1}{\mathrm{T}}\right)$$

The transmittance spectrum is characterized by its opposite behavior to the absorbance spectrum. Fig. 2 shows that the transmittance was measured as a function of wavelength within the range 300-1100 and the results showed that the lowest transmittance value for the membrane before and after irradiation was at a wavelength of 300nm. We note that the irradiation process of the membrane PVA / PEG / CdS led to a decrease in the transmittance values, which is the opposite of the absorbance behavior.

It is clear from the figure that the permeability generally begins to appear at the wavelength that represents the dividing line between the membrane's absorbance and its permeability, or what is called the cut-off wavelength ($\lambda_{cut\ off}$). Then the permeability generally increases with the increase in the wavelength of the electromagnetic radiation falling on the membrane material, i.e. at wavelengths with low energies, the permeability spectrum of the membrane, as shown in Fig. 2, quickly begins to gradually decrease as a result of laser irradiation, and the subsequent development of local levels inside the prohibited energy gap between the conduction and valence bands, which results in a decrease in permeability and an increase in absorbance [25].

As for the absorption coefficient, we notice from the results in Fig. 3 that the absorption coefficient changes as a function of the wavelength of the PVA/PEG/CdS membrane for a range of wavelengths from nm (300-1100). After that, the membrane was exposed to irradiation with a violet laser for a time of (15 minutes) with a power of (60 μw). The absorption coefficient of the PVA/PEG/CdS membranes increases for the sample from ($0.1112 cm^{-1}$) to ($0.1720 cm^{-1}$). By increasing the laser energy as a result of the increase in the crystal size, which leads to an increase in the

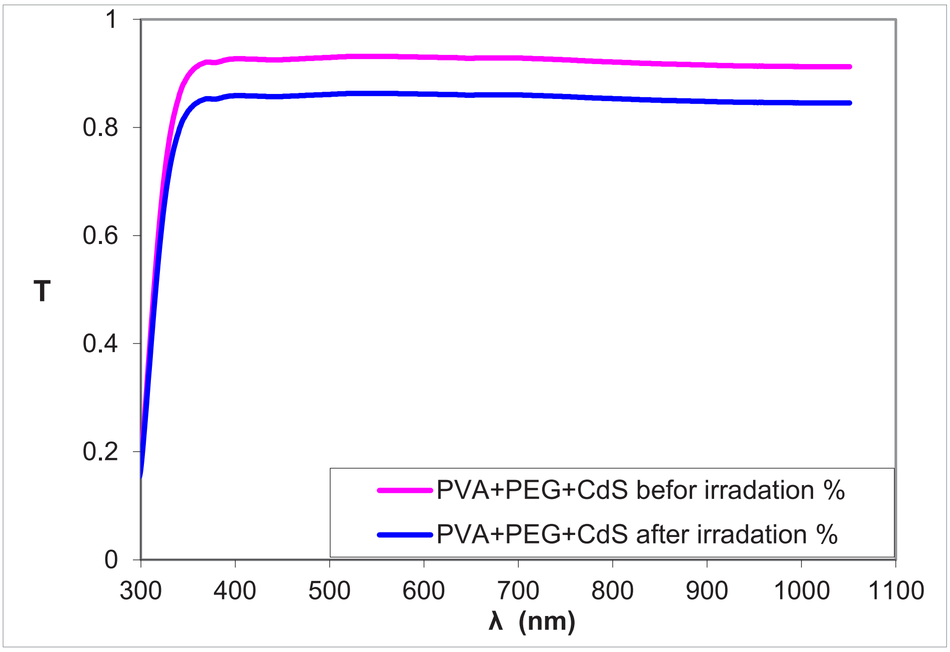

Fig. 2. shows the relationship between transmittance and wavelength of the sample before and after irradiation.

absorbance, as the maximum photon absorbance is in the ultraviolet region at approximately (320 nm). Therefore, the maximum photon energy is in this region because it contains a low range of wavelengths, so the absorption coefficient will increase.

One of the most crucial optical constants in semiconductor physics is the optical energy gap, which may be calculated. The value of this constant determines whether semiconductors are used in optical and electrical applications. The basis for the dependence of the energy gap value on the crystal structure of the material and the value of (Eg) is determined by knowing the values of both the absorption coefficient and the photon energy. Fig. 4 shows the values of the allowed energy gap for the film before and after irradiation of PVA / PEG / CdS . It is clear to us that the energy gap decreases and the reason for the decrease in its value in the second sample is the result of bombarding it with a violet laser beam for a time of (15 minutes) with a power of (60 µW). Thus, the semiconductor material approaches the conductive material and the decrease in the energy gap indicates an increase in the absorbance and absorption coefficient of the film, where the value of the energy gap for the first sample is (3.8 eV) and (3.7 eV) for the second sample.

X-ray diffraction test results

X-ray diffraction technology was used to study the crystal structure of the film before and after irradiation with a violet laser of (60µW) for 15 minutes using an X-ray machine. The grain size, crystal system, Miller coefficients, and interplane distances were calculated using the X-pert software. In Fig. 5 shows the results of X-ray diffraction measurements for the prepared thin films PVA/PEG/CdS.

The results of the diagnosis by X-ray diffraction showed that all the prepared thin films had a polycrystalline structure, and that the prepared thin film cadmium sulfide had a cubic structure and this result was also found rouguly in [26-28].

The interfacial distance(d_{hkl}) between the atomic levels of all thin films prepared from X-ray diffraction points and Bragg angles(2Θ) was calculated. Where it was found that the values of

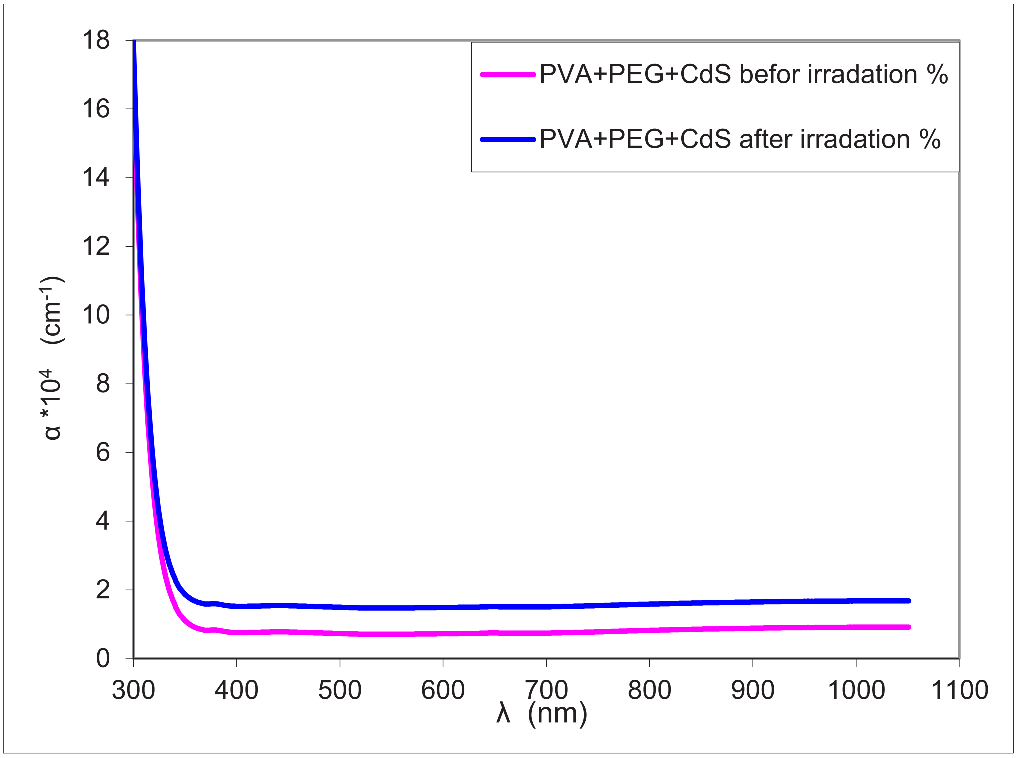

Fig. 3. shows the relationship between the absorption coefficient and the wavelength of the sample before and after irradiation.

the distance between the atomic levels obtained are very close to their theoretical values and this result agree with rouguly agree with [29,30].

Through the values of the distance between the atomic levels and the Miller coefficients, the lattice constants (a,b and c) were calculated for the levels that represent the Miller coefficients for a cadmium sulfide compound with a cubic type structure. Where it was found that the values of the obtained lattice constants are completely identical to their theoretical values and this result agree with rouguly agree with [31-33].

The full width half maximum (FWHM) was calculated from the X-ray spectrum of the PVA/PEG/CdS film before and after irradiation. It was found that after irradiating the film with a violet laser of 60 microwatts for 15 minutes, this led to a decrease in the FWHM values.

The reason is that there is an increase in the average particle size values, because the inverse relationship between the full width half maximum and grain size. This result agree with rouguly agree with [34,35].

The average grain size (G.S) of the prepared thin film was calculated by substituting the values obtained from the XRD results using the Debye-Scherrer equation based on the full width half maximum values [36].

The crystallite size was measured using the Debye-Scherrer equation [34] which is given by:

$$D = \frac{k\lambda}{\beta\cos\theta}$$

Where (D) is the crystallite size, (β) is the full width at half maximum of a diffraction line located at an angle (θ) while (λ) is the X-ray diffraction wavelength of Cu Kα radiation (0.1514 nm and ķ are a Scherrer constant (0.94)), which depends on the peak width, the crystallite size distribution, and the crystallite shape.

The result showed that after the film irradiation process, the average grain size values increased. This result was also found approximately in [37, 38, 39].This is due to the fusion of particles and this result was also found rouguly in [37,40].

All the results obtained from the X-ray diffraction measurement of the prepared thin film and when compared with the values in the

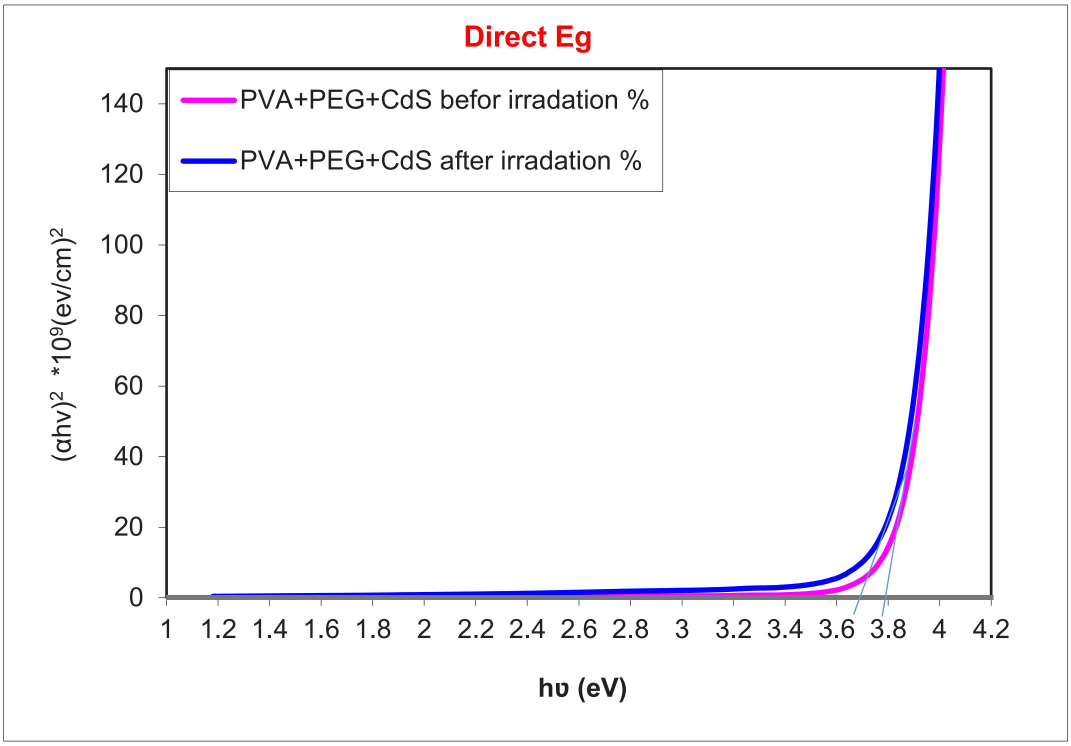

Fig. 4. shows the relationship between the energy gap and the photon energy of the sample before and after irradiation.

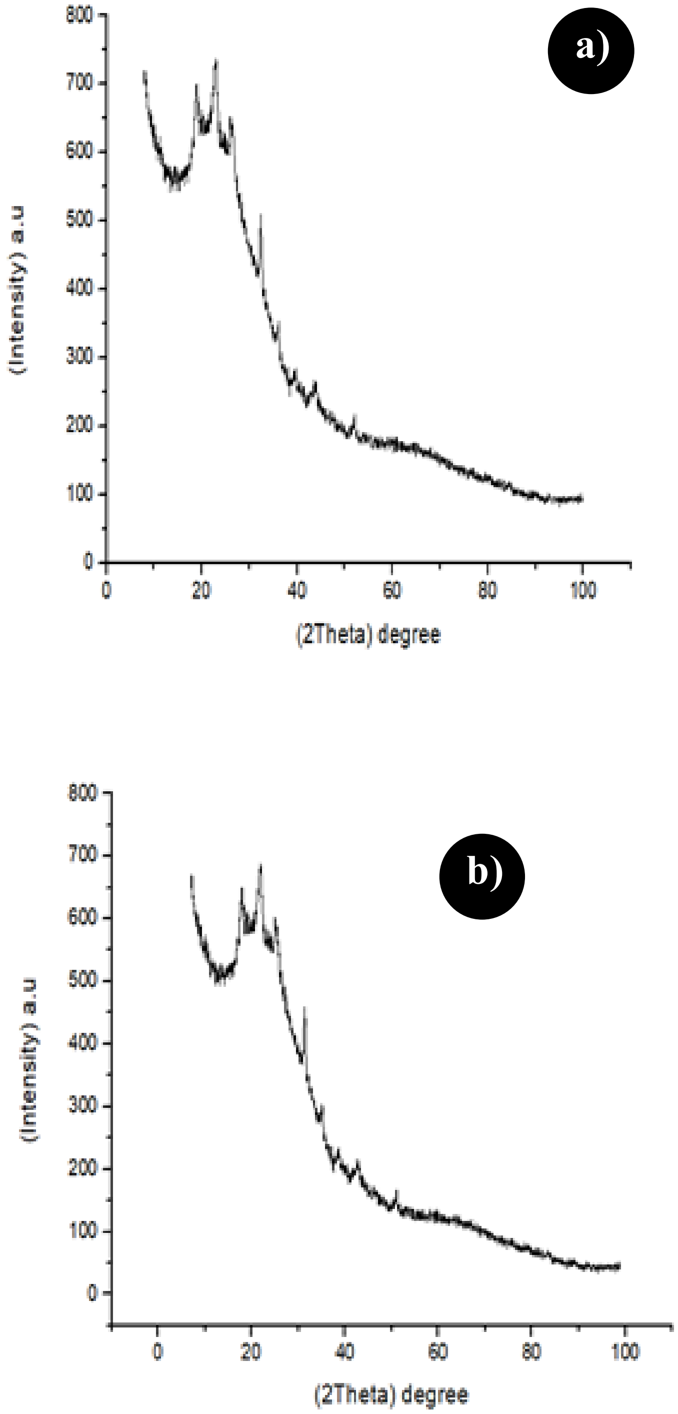

Fig. 5. shows the X-ray diffraction measurement of the sample before and after irradiation.

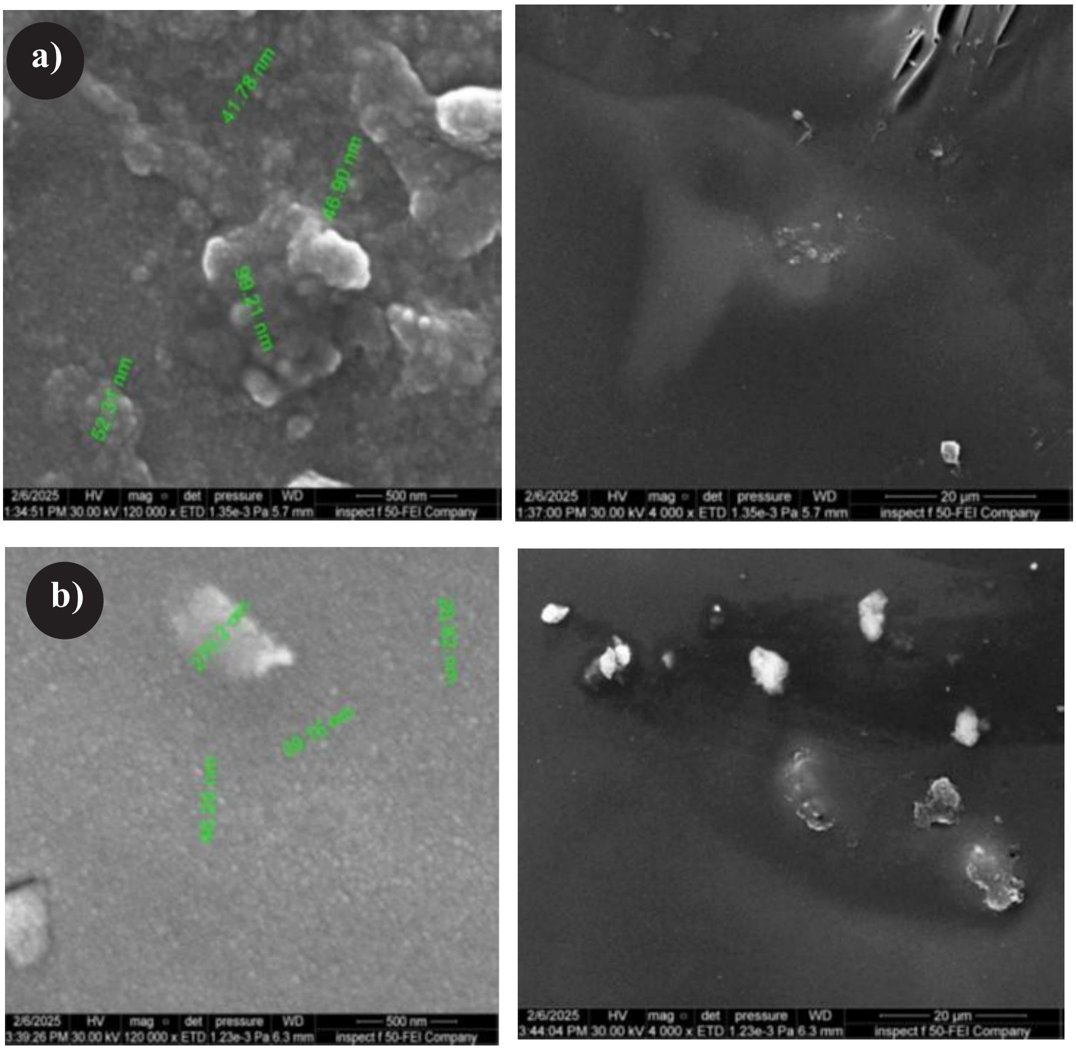

Fig. 6. shows a scanning electron microscope image of the sample before irradiation; and shows a scanning electron microscope image of the sample after irradiation b.

card numbered (00-049-2035), of the American Standard Specification for Testing Materials (ASM), it was found that the results are somewhat identical.

Scanning electron microscope (SEM)

The prepared PVA/PEG/CdS films were measured before and after irradiation using SEM to study the surface morphology and grain size. In Fig. 6a, and b the results showed that the prepared films were relatively homogeneous, although there were some holes in the films. This was due to the viscous liquid used to prepare the polymers, which causes holes to form during the spin-coating process.

The results also showed a difference in the color of the prepared membranes, which is an expected outcome due to the difference in the chemical materials used in their preparation, which are polymers and cadmium sulfide.

SEM measurements showed that the irradiation process and the addition of cadmium sulfide to the prepared polymeric mixture led to an increase in grain size. This is because when the polymeric mixture is exposed to a laser, high energy is transferred to the material, resulting in local heating that increases the mobility of the polymer molecules and facilitates their interactions, resulting in the merging of small grains into the formation of larger grains.

Laser irradiation led to molecular rearrangement and the formation of new chemical bonds, which promoted grain growth. Heating also reduced the viscosity of the polymer, allowing the grains to move more freely and aggregate together. This result is consistent with the X-ray diffraction measurements, which showed an increase in grain size after irradiation of the prepared film]41,42[.

The results indicate that the laser irradiation process, with the addition of cadmium sulfide, leads to a reduction in pinholes in the prepared films due to improved crystal structure and reduced defects through chemical and electronic interactions. Enhanced structural stability and photocatalytic reactions play an important role in reducing pinholes in the films]43,46[.

CONCLUSION

After the conducted study and discussion of the results, we were able to conclude that the PVA/ PEG /CdS membrane can be successfully prepared using the spin coating technique.The prepared sample also proved to have a monoclinic structure and that the grain size of the second sample exposed to laser irradiation increased, which demonstrates the effect of radiation on the increase in grain size. This was reinforced by the X-ray energy dispersion test and the results of the scanning electron microscope. The results also showed that the process of adding CdS compound to the polymer mixture and the irradiation process led to a reduction in holes. The results of the optical properties showed that the absorbance value increased after the irradiation process with a violet laser with a power of (60) microwatts and a time of 15 minutes. In contrast, the energy gap value decreased, as its value for the first sample before irradiation was 3.7 microvolts and after irradiation it became 3.8 microvolts. The transmittance of the membrane is within the range (1100-300), as the transmittance of the first sample is less than the transmittance of the second.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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