



Study the Optical Properties of Polyvinyl Alcohol Thick Film Irradiated with Violet Laser

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دراسة الخواص البصرية لغشاء بولي فينيل الكحول المشع بالليزر البنفسجي

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ABSTRACT

Background:

The aims study of this work is the effect of violet laser beam irradiating on the optical properties of the Polyvinyl alcohol PVA before and after irradiation to a laser beam of different time 10, 20, 30 and 40 minute.

Materials and Methods:

The polymer powder PVA 0.008 mg was dissolved in 7 ml distilled water at temperature 40 °C and the thickness of the film was 3000 nm by using weight method to measure the thickness of the films. A semiconductor laser with a wavelength of 405 nm was used to irradiate the films.

Results:

The absorbance, transmittance and reflectance spectra of thick films before and after laser irradiation were plotted. The energy gap and optical constants were calculated.

Conclusions:

The irradiation with the violet laser causes a breakdown of the bonds, which causes a decrease in the absorbance and reflectance spectrum, while the energy gap increases.

Key words: PVA, Optical properties, Laser irradiating, Violet laser.

INTRODUCTION

Due to their numerous uses, polymeric materials have drawn the attention of experimental and technical experts. This is mostly because of their versatility as materials due to their small weight, high mechanical strength, and superb optical characteristics[1]. Poly(vinyl alcohol) (PVA) $[-CH_2CHOH-]_n$ is a polymer that has received much research owing to a number of intriguing physical features that are beneficial in a variety of technological applications, including biochemical and medicinal.[2][3]. PVA has dopant-dependent electrical and optical characteristics in addition to it has promising material with excellent charge storage, high dielectric strength. [4].

Laser is very important because it's coherent, monochromatic, brightness and directionality that allow them to be focused at a point and induce ionization, excitation, and scattering when passed through matter, which can be used to examine the properties of some materials[5].

This research studies the effect of irradiation with a violet laser at a wavelength of 405 nm on the optical properties of PVA film with different irradiation times.

When a laser beam contacts a surface (air/solid interaction), Beer Lambert's law applies to the beam because it is separated into three parts: reflected, transmitted, and absorbed[6]:

$$I = I_0 e^{-\alpha t} \dots \dots (1)$$

Where (α) is the absorption coefficient I_0 and I are the incident and the transmitted photon intensity respectively.

The optical properties give us an expounding about the interaction between the light and materials. The optical properties of materials are those that are discovered when the electromagnetic radiation hit the material[7].

The reflectance is calculated using the following relation[8]:

$$R + T + A = 1 \dots \dots (2)$$

Where A the absorption is given by the following equation[8]:

$$A = \log \frac{I_0}{I} \dots \dots (3)$$

As a consequence, the absorbance spectrum is used to calculate the absorption coefficient (α) of the solution using the following relationship. [9]:

$$\alpha = 2.303 \frac{A}{t} \dots \dots (4)$$

Based on information on the absorption coefficient, the tauc relation is used to determine whether a transition is direct or indirect[10]:

$$\alpha h\nu = B(h\nu - E_g)^r \dots \dots (5)$$

Where:

h : Planck's constant



ν : the frequency of photon

B: is the proportional constant

The value of r is $\frac{1}{2}$ and 2 for allowed and forbidden direct transition respectively. Whereas, it equals 2 for allowed transitions and 3 for forbidden indirect transition. E_g is represented the energy gap calculated using the following equation[11]:

$$E(\text{eV}) = h\nu = \frac{1240}{\lambda (\text{nm})} \dots \dots (6)$$

The relationship between the extinction coefficient (k) and the exponential decline of the light passing through the solution is explained by[12]:

$$k = \frac{\alpha\lambda}{4\pi} \dots \dots (7)$$

Where: λ : the wavelength of the incident light.

The refractive index (n), which is also determined by the following formula, is the ratio of the speed of light in a vacuum to the speed of light in a material[13].

$$n = \sqrt{\frac{4R}{(1-R)^2} - K^2} + \frac{1+R}{1-R} \dots \dots (8)$$

The dielectric constants (real and imaginary) of the solution are evaluated using the following relations[14]:

$$\varepsilon_r = n^2 - k^2 \dots \dots (9)$$

$$\varepsilon_i = 2nk \dots \dots (10)$$

According to the following relationship, the optical conductivity (σ_{op}) directly depends on the refractive index (n), the speed of light (c), and the absorption coefficient (α)[15]:

$$\sigma_{op} = \frac{\alpha nc}{4\pi} \dots \dots (11)$$

MATERIALS AND METHODS

Sigma-Aldrich Company provided the polyvinyl alcohol (PVA) powder used in this research. A precise 0.008 mg of PVA with a molecular weight of 10,000 g/mol is weighed into 7 ml of distilled water and diluted at 90 °C. The mixture was then thoroughly agitated for about 10 minutes at room temperature with a magnetic stirrer until the PVA was entirely dissolved. The thickness of the film was in the range of 3000 nm by using gravimetric method.

The thick film is irradiated using a semiconductor violet laser of 405 nm wavelength and 80 mW laser power for four different times (10, 20, 30 and 40) min. By using UV-Vis spectrophotometer (Shimadzu, UV-1800 OA, JAPAN) optical properties was measured. The transmittance and the absorbance spectra are measured in the range of 190–1200 nm. Before and after laser irradiation, optical constants are determined. The Fourier transform infrared

(FTIR) spectrum is measured for PVA powder by FTIR spectrometer IR Affinity-1 (Shimadzu Company) Japanese made with range of 400- 4000 cm^{-1} , While the optical properties were calculated using a local Excel program.

RESULTS AND DISCUSSION

Figure 1 illustrates the FTIR Spectrum for PVA powder. Peaks in the spectrum appear to be connected to the carbonyl (-C-O) wagged vibration at 1263.42 cm^{-1} , the carbonyl (-C-H) wagged vibration at 1375.29 cm^{-1} , the carbonyl (-CH₂) wagged vibration at 1570.11 cm^{-1} , and the carbonyl (-C=O) group at 1722.49 cm^{-1} , suggesting that the PVA reaction is occurring[16].

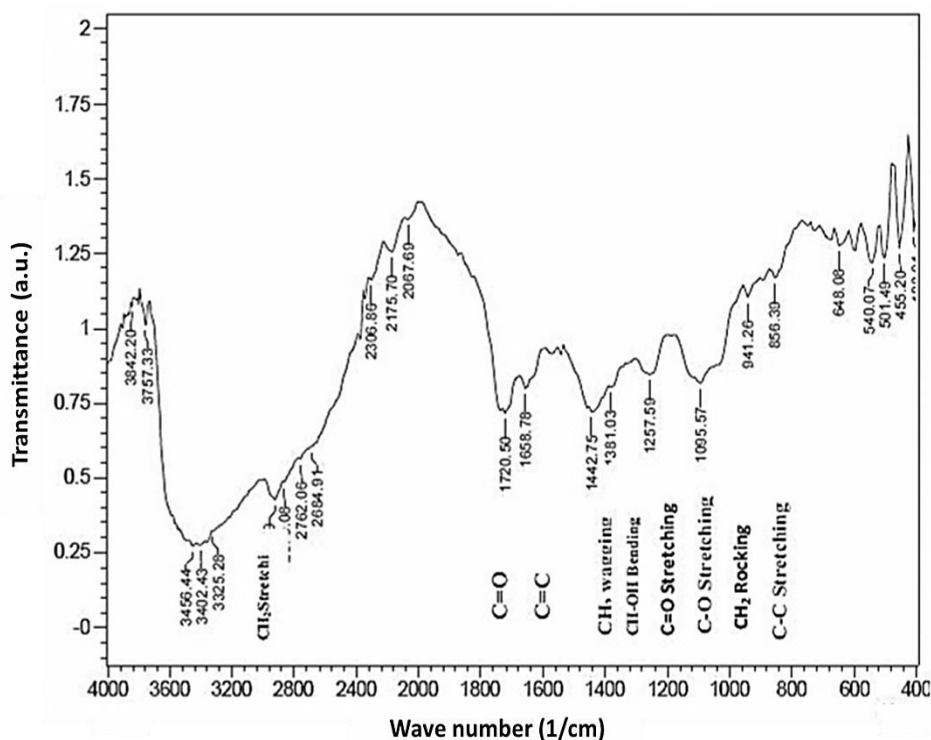


Figure 1: FTIR Spectrum for PVA powder.

The UV-Visible absorption spectrum (A) for pure PVA thick film before and after irradiation at times (0, 10, 20, 30, and 40) minutes. The pure PVA thick film had an absorption peak in the ultraviolet region at (350nm). while, at longer wavelengths no absorption peaks are observed. As a result of laser irradiation, the absorbance peaks show a red shift to the visible wavelengths region, and the absorption decreases with increasing irradiation due to the breaking of intermolecular bonds as shown in Figure (2) absorption spectrum as a function of wavelength and as a function of irradiating time.

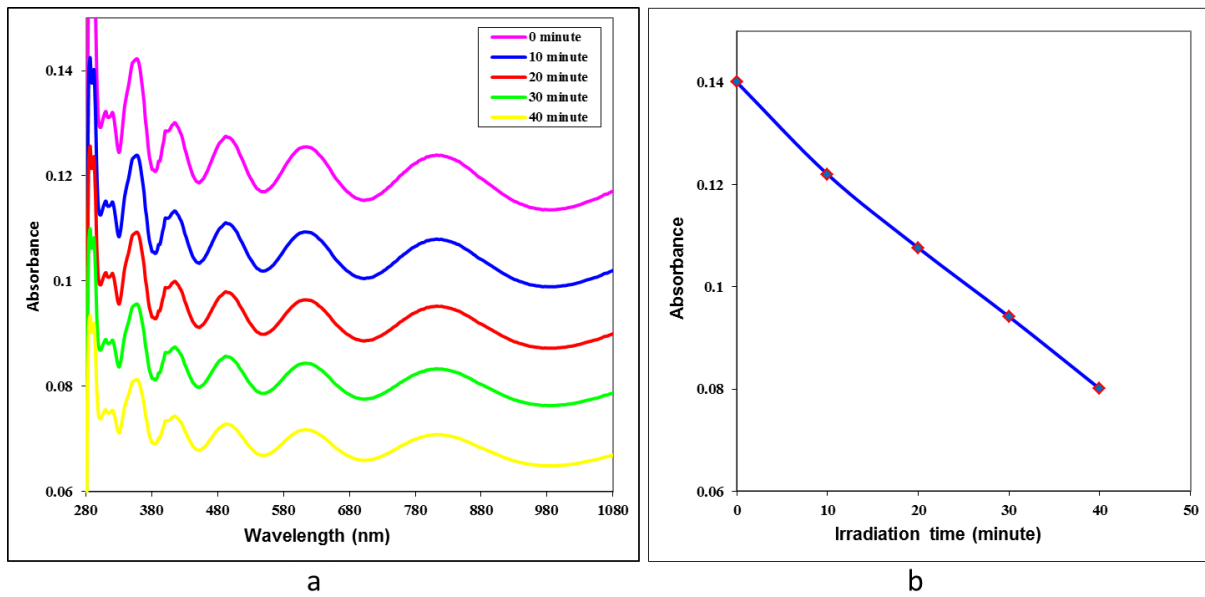


Figure 2 (a) The PVA absorbance spectra for different laser exposure times (0, 10, 20 , 30 and 40) mins. (b) The absorbance as a function of irradiating time at 350 nm wavelength.

Figure (3) transmission spectrum as a function of wavelength and as a function of irradiating time depicts the transmission spectrum (T) of a PVA thick film before and after violet laser irradiation. This spectrum exhibited reversed absorption characteristics. The minimum transmission was occurred at (350) nm, The transmittance decreases with increasing irradiation time due to the breaking of intermolecular bonds.

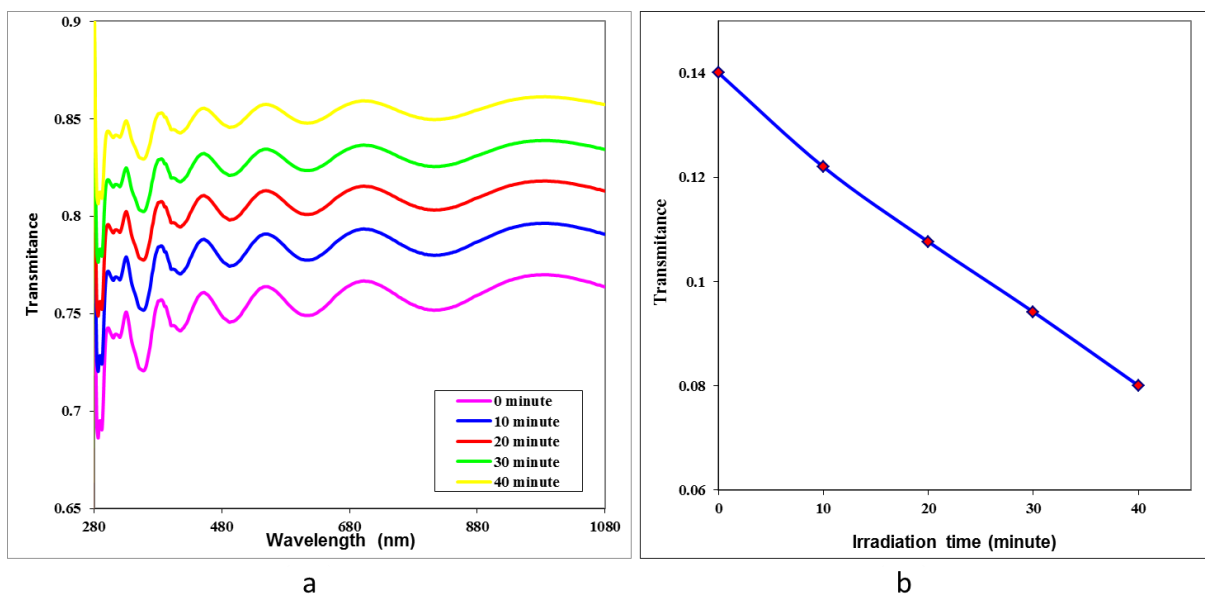


Figure 3 (a) The PVA transmission spectra for different laser exposure times (0, 10, 20 , 30 and 40) mins. (b) The transmittance as a function of irradiating time at 350 nm wavelength.

Also the reflectance spectrum for the thick film is shown in Figure (4) reflectance spectrum as a function of wavelength and as a function of irradiating time. The behavior of the transmittance spectrum is clear opposite to the reflectance. The high peak appears at a wavelength of (350) nm and disappears at higher wavelengths. The reflectivity increases with the increase in laser irradiation time.

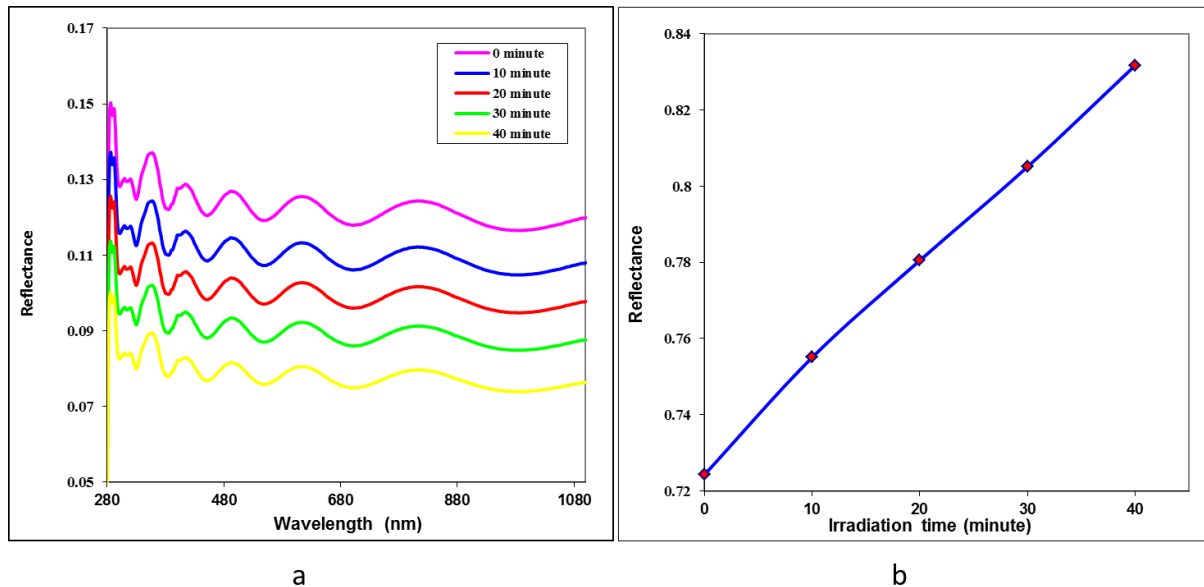


Figure 4 (a) The PVA reflectance spectrum for different laser exposure times (0, 10, 20 , 30 and 40) mins. (b) The reflectance as a function of irradiating time at 350 nm wavelength.

The following figure (5) shows the optical conductivity as a function of wavelength and as a function of irradiating time. The peak of optical conductivity spectra also a bear in (350) nm. It decreases when increase in irradiating times because of the decrease in absorbance, which leads to a decrease in the absorption coefficient α , the relationship between σ and α is a direct relationship as explained by equation (11).

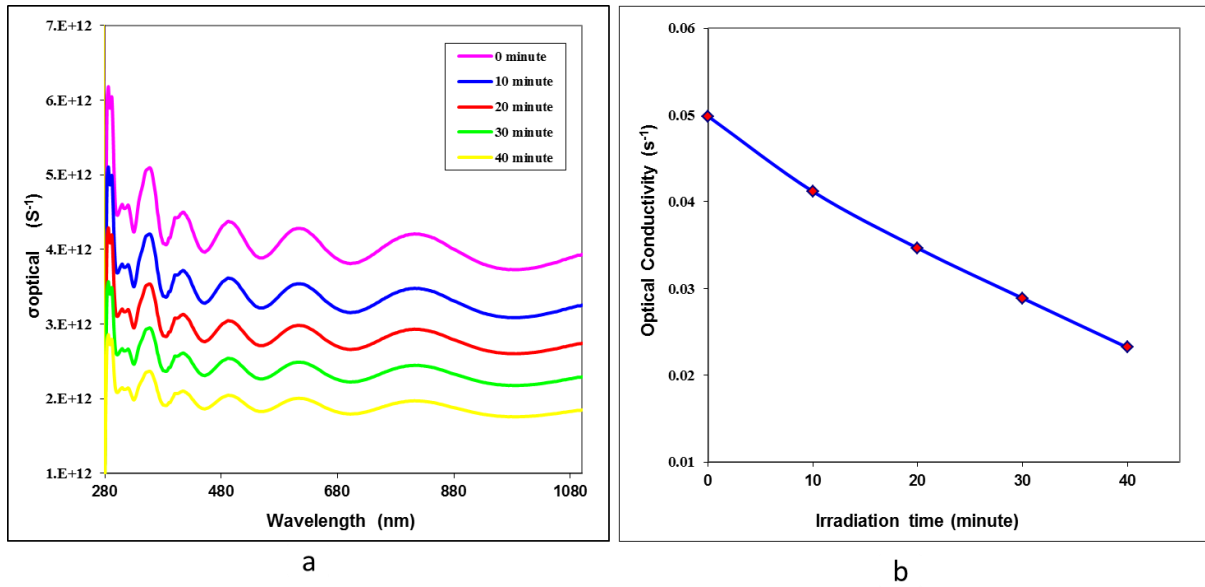


Figure 5 (a) The PVA optical conductivity spectrum for different laser exposure times (0, 10, 20 , 30 and 40) mins. (b) The optical conductivity as a function of irradiating time at 350 nm wavelength.

The energy gap was calculated by using the Tauc equation as illustrates in Figure(6). $(\alpha h\nu)^2$ is represented as a function of photon energy for various irradiating times. When violet laser irradiation was increases the direct energy gap increases consecutively. This is attributed to the fact that decreasing the absorption coefficient. This is critical in photovoltaic applications.

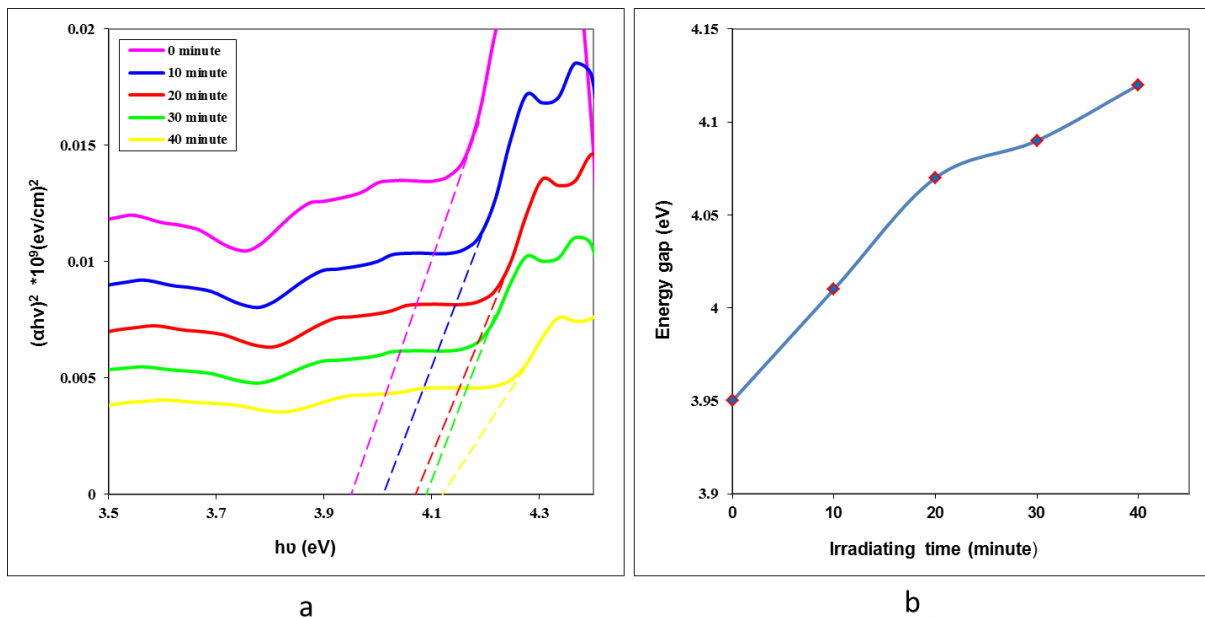


Figure 6 (a) The PVA energy gap $(\alpha h\nu)^2$ for different laser exposure times (0, 10, 20 , 30 and 40) mins. (b) The optical conductivity as a function of irradiating time at 350 nm wavelength.



The optical constant for example absorption coefficient, refractive index, extinction coefficient, dielectric constants). Refractive index depend on reflectivity . Whereas extinction coefficient proportional to absorbance and affected by radiation, they are listed in a table(1).

Table: show the optical constant of thick film PVA at (350) nm:

Time (mins.)	$\alpha * 10^4$ (cm^{-1})	k	n	ϵ_{real}	ϵ_{imag}	$\sigma_{op} * 10^{14} (s^{-1})$	$E_g (eV)$
0	0.107	0.0029	1.941	3.768	0.011	0.049	3.95
10	0.093	0.0025	1.840	3.388	0.009	0.041	4.01
20	0.082	0.0022	1.755	3.082	0.008	0.034	4.07
30	0.072	0.0020	1.672	2.796	0.006	0.028	4.09
40	0.061	0.0017	1.580	2.499	0.005	0.023	4.12
At $\lambda = 350$ nm							

CONCLUSION

PVA thick film is prepared by dissolving 0.008 mg of powder in distilled water at temperature 90 C. The effect of changing Irradiating before and after on the optical properties of the thick film is showed that the absorbance spectra decrease with increasing time radiation, and similarly for the transmittance spectra for laser irradiation times 0, 10, 20, 30 and 40 min. Also, the energy gaps increased with increasing laser irradiation. Optical parameters such as absorption coefficient, extinction coefficients, refractive index and dielectric were decreased with increasing laser irradiation.



Conflict of interests

There are non-conflicts of interest.

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الخلاصة

مقدمة:

يهدف العمل إلى دراسة تأثير إشعاع الليزر البنفسجي على الخواص البصرية لبولي فينيل الكحول PVA قبل وبعد التشعيع بالليزر بأزمان مختلفة 10 و 20 و 30 و 40 دقيقة.

طريقة العمل:

تمت إذابة مسحوق بوليمر البولي فينيل 0.008 مليغرام في 7 مل ماء مقطر عند درجة حرارة 40 درجة مئوية وكان سمك الفيلم 3000 نانومتر باستخدام الطريقة الوزنية لقياس سمك الغشاء.

الاستنتاجات:

رسمت أطراف الامتصاصية و النفاذية و الانعكاسية للأغشية السميكة قبل و بعد التشعيع بالليزر. و حسبت فجوة الطاقة و الثوابت البصرية. يؤدي التشعيع بالليزر البنفسجي إلى تكسير الروابط ، مما يؤدي إلى انخفاض طيف الامتصاصية والانعكاسية ، بينما تزداد فجوة الطاقة.

الكلمات المفتاحية: بولي فينيل الكحول، الخواص البصرية، التشعيع بالليزر، الليزر البنفسجي.