Kirkuk University Journal- Scientific Studies Vol. 18, Iss. 2, p 39-46, 2023 doi:10.32894/kujss.2023.140184.1101

Effect of Nd:YAG Laser's Wavelength on the Optical Properties of Agarose Thin Films.

Ihsan Sedeeq Jalal[*1], Abdulsattar A. Aesa[2]

[*1]Department of Physics, College of Sciences, University of Kirkuk, Kirkuk, Iraq.
[2]Department of Physics, College of Education for Women, University of Kirkuk, Kirkuk, Iraq.
*Corresponding author : scph21m025@uokirkuk.edu.iq

Article Information

Article Type:
Research Article

Keywords:
Agarose thin films; Nd:YAG laser; Optical properties; Absorption coefficient; Extinction coefficient.

History:
Received: 10 May 2023
Accepted: 20 June 2023
Published: 30 June 2023

Citation: Ihsan Sedeeq Jalal, Abdulsattar A. Aesa Effect of Nd:YAG Laser's Wavelength on the Optical Properties of Agarose Thin Films., Kirkuk University Journal - Scientific Studies, 18(2), 39-46, 2023, https://doi.org/10.32894/kujss.2023.140184.1101

Abstract

The optical properties of agarose thin films, such as absorption, absorption coefficient, and extinction coefficient, are presented in this study. To obtain a 2% wt/v concentration of agarose, 0.2 mg of agarose was dissolved in 10 mL of water, and the mixture was then heated in the microwave for 30 second until boiling. In the current investigation, three types of water were used, including distilled water labeled as W1 (pH = 7.5 and TDS = 18 ppm), Zamzam water labeled as W2 (pH = 8 and TDS = 339 ppm), and so forth well water with the designation W3 (pH =8.6 and TDS = 1440 ppm). Total dissolving salts (TDS) and pH vary across the aforementioned types of water. The agarose thin film was irradiated using a (Nd:YAG) laser with three different wavelengths, including (532, 1064, and 1320) nm. Investigations into the impacts of changing the laser's wavelength on the optical characteristics of agarose thin films were conducted.

1. Introduction:

Agar is made up of agarose and agaropectin fractions, and it is harvested from some red algae together with its derivative agarose [1]. When dissolved in water, the neutral, linear polysaccharide known as agarose produces thermoreversible gels. A mixture of charged and sulfated non-gelling galactans makes up agaropectin. D-galactose, which is 1,3 linked, and 3,6-anhydro-L- galactose, which is 1,4 linked, make up the agarose chain. The ability of some types of biopolymers to form a gel structure in water is a characteristic shared by substances including agarose, carrageenan, and gelatin. These hydrogels have continued to be sought after by theoretical and experimental researchers due to their ability to undergo both thermal and volumetric phase changes as well as a significant degree of solvent absorption. One of the most widely utilized polysaccharides in molecular biology and biotechnology applications is agarose [2], [3]. Due to its ability to produce strong gels even at low agarose concentrations, it is also extensively used in the food, cosmetics, and medical industries [4], [5].

The complex process of gel formation in an aqueous solution of gel producing polysaccharides depends on the polysaccharide structure, the concentration of the polymer, the temperature, and some particular counterions. Biomacromolecules' thermoreversible sol-gel and gelation processes, which produce various supramolecular structures through intra- and intermolecular hydrogen bonding as well as electrostatic and hydrophobic interactions, are of great intrinsic interest [6], [7].

Agarose is essentially a neutral polymer that does not require any additions to cause gelation, in contrast to anionic carrageenans [8].Optical absorption measurements are frequently employed to examine disorders, flaws, and changes in state densities brought on by laser irradiation. The band structure of agarose thin films is significantly impacted by disorder and flaws [9]. The optical properties of an agarose thin film were explored in the current work under the influence of the Nd:YAG laser's wavelength.

2. Experimental Part:

The thin film was created using three distinct types of water. Agarose biopolymer (A6013-25G, Type I, low electroendoosmotic (EEO)) was bought from Sigma-Aldrich for the experimental component. To obtain a 2% wt/v concentration of agarose, 0.2 mg of agarose was dissolved in 10 mL of water, and the mixture was then heated in the microwave for 30 seconds until boiling. The specimen tube (75×25) mm containing the agarose solution was heated to 95 oC and swirled for 15 min. to completely dissolve it. To serve as a substrate, a microscope slide with dimensions of (25×75) mm from Thermo Scientific was cleaned and then sliced into (25×25) mm pieces. To achieve film thicknesses between 500 nm and 1 μm, the agarose films were spin coated on the cleaned glass using a spin coater at 500 rpm. After that, manufactured films were given five to dry in atmospheric pressure and room temperature. In the current investigation, three types of water were used, including distilled water labeled as W1 (pH = 7.5 and TDS = 18 ppm), Zamzam water labeled as W2 (pH = 8 and TDS = 339 ppm), and so forth well water with the designation W3 (pH =8.6 and TDS = 1440 ppm). Total dissolving salts (TDS) and pH vary across the aforementioned types of water.

A pH and TDS meter were used to measure the pH and TDS values.The agarose thin film was exposed to three different (Nd:YAG) laser wavelengths, including (532, 1064, and 1320) nm. One by one, the achievable agarose thin films were positioned, and a perpendicular Nd: YAG laser beam was directed over their surface. About 7 cm separated the surface of the specimen from the laser window. The laser's output average power was 60 W, and the dry laser technique was used to irradiate samples without using water spray. The exposed region of the samples served as the subject of all tests and characterizations. The Nd:YAG laser system ran at a repetition rate of 5 Hz, with pulse widths between 14 and 15 ns. The irradiated detector pieces were etched in a water bath with two types of chemical solutions of aqueous NaOH and KOH of different molarities (3, 5, 7, 9 and 11) N at a temperature $(70 \pm 1)^{o}$C for successive periods of time of (3 h). The diameters of the tracks for all selected times and molarities have been measured.

3. Results and Discussions:

For all investigations involving the attenuation of a beam of light after it passes through a generated thin films of agarose using various pH and TDS solutions, UV-Visible absorption, absorption coefficient, and extinction coefficient spectra provide vital information about the electronic and molecular states of the material. All methods are appropriate for thin film measurements both before and after irradiation using various Nd:YAG laser wavelengths, such as (532, 1064, and 1320) nm. They help to identify the species in the sample that are excited. Using three types of water were used, including distilled water labeled as W1 (pH = 7.5 and TDS = 18 ppm), Zamzam water labeled as W2 (pH = 8 and TDS = 339 ppm), and so forth well water with the designation W3 (pH =8.6 and TDS = 1440 ppm).

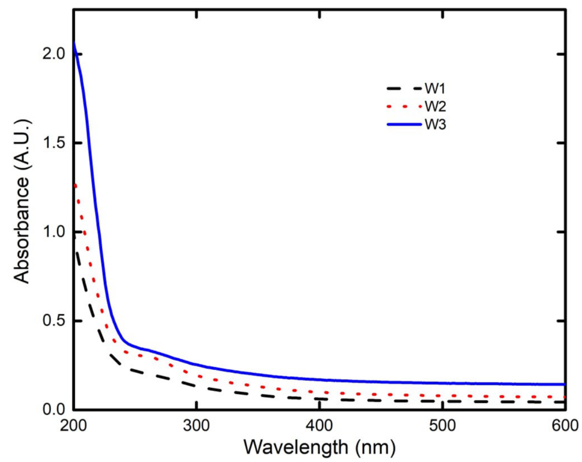

Figure 1. Absorption spectra of agarose thin films dissolved in different pH and TDS waters.

Figure 1 displays the absorption spectra of the agarose thin films prepared by dissolving the agarose powder in three types of waters: distill water (pH = 7.5 and TDS = 18 ppm) labeled as W1, Zamzam water (pH = 8 and TDS = 339 ppm) labeled as W2 well water (pH = 8.6 and TDS = 1440 ppm) labeled as W3. Figure 1 shows that the shape of the absorption spectrum does not change when the pH and TDS of the water are changed, and the intensity of the spectra is directly proportional to the number of the active molecules; here, the molecules denote the total dissolving salts in the specific type of sample.

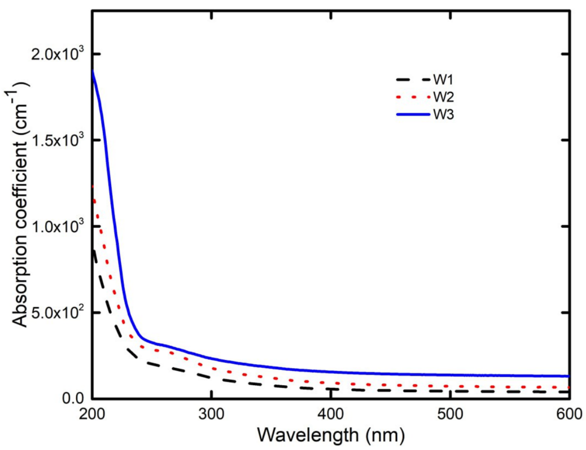

Figure 2. Absorption coefficient spectra of agarose thin films dissolved in different pH and TDS waters.

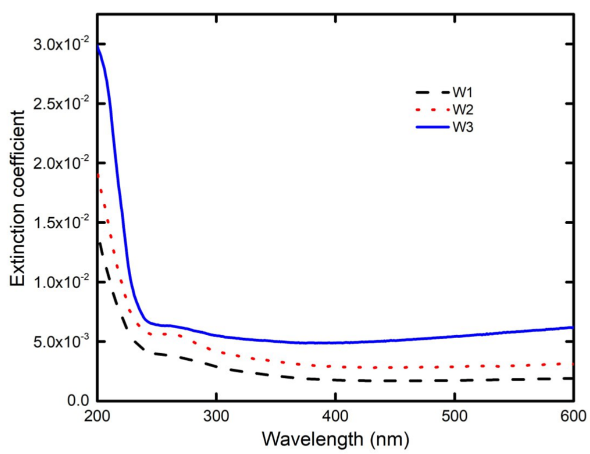

Figure 3. Extinction coefficients of agarose thin films dissolved in different pH and TDS waters.

It was not possible to compare the absorption intensity quantitatively because of the nature of the gel and sample preparation. Figure 2 shows the absorption coefficient spectra of the agarose thin films prepared by dissolving the agarose powder in three types of waters labeled as W1, W2, and W3.

All films exhibit greater absorption (or shift) on the shorter wavelength (or higher energy) side; this behavior is explained by an increase in defect states, which in turn causes an increase in the absorption coefficient. Figure 3 displays the extinction coefficients of the agarose thin films prepared by dissolving the agarose powder in three types of waters labeled as W1, W2, and W3. Figure 3 shows that for the thin films under investigation, the extinction coefficient increases as photon energy rises. While the extinction coefficient rises with decreasing pH values of the various types of water, this may decrease the likelihood of a direct transition occurring. This is related to the formation phase, the growth of thin film

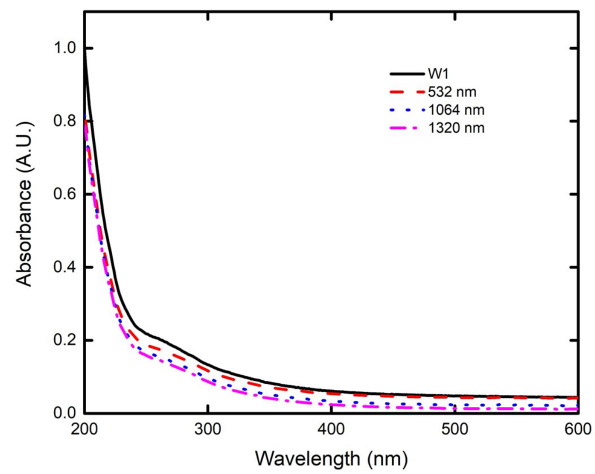

Figure 4. Absorption spectra of the agarose thin films prepared using W1 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

grain size and density, and the effect of light scattering on its high surface roughness. Figure 4 shows the absorption spectra of the agarose thin films prepared by dissolving the agarose powder in type W1 of water as: distill water (pH = 7.5 and TDS = 18 ppm) irradiated by three different wavelengths of Nd:YAG laser as: (532, 1064, and 1320) nm respectively.

It has been noted that as the wavelength changes from (532 to 1320 nm), the absorbance reduces at the region of fundamental absorption. The spectral behavior of these films demonstrates that the irradiated thin films' absorption edge changes to shorter wavelengths (higher energy). The incoming photons in this region have enough energy to excite electrons from the valence band to the conduction band, reducing the transmittance by being absorbed by the material. The agarose thin films' absorption coefficient spectra are displayed in Figure 5 after the agarose powder was dissolved in type W1 distill water with a pH of 7.5 and a TDS of 18 ppm. The water was then exposed to Nd:YAG laser radiation.

Figure 5 shows the absorption coefficient spectra of the agarose thin films prepared by dissolving the agarose powder in type W1 of water as: distill water; (pH = 7.5 and TDS = 18 ppm) irradiated by Nd:YAG laser.

It is obvious that exposure to Nd:YAG radiation causes a significant change in the optical absorption spectrum's structure around the absorption edge. The values of the absorption coefficient near the band edge, as determined by an optical absorption curve, exhibit an exponential dependence on photon energy and follow Urbach's formula [10].

$$\alpha(E) = \alpha_o \exp(\frac{E - E_1}{E_o}) \quad (1)$$

where α_o and E_1 and are fitting parameters with dimen-

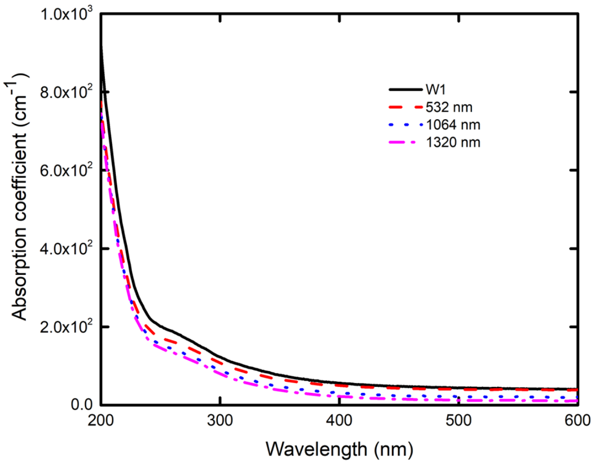

Figure 5. Absorption coefficient spectra of the agarose thin films prepared using W1 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

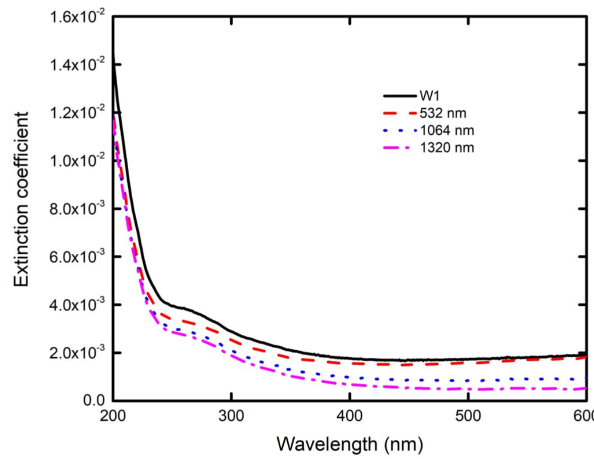

Figure 6. Extinction coefficient spectra of the agarose thin films prepared using W1 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

sions of inverse length and energy, respectively, and E_o is the Urbach Energy.

Figure 6 shows the extinction coefficient spectra of the agarose thin films prepared by dissolving the agarose powder in type W1 of water as: distill water; (pH = 7.5 and TDS = 18 ppm) irradiated by Nd:YAG laser.

The behavior of the excitation coefficient is similar to that of the absorption coefficient. Figure 6 shows that for W1 agarose thin films, the extinction coefficient will decreases as the laser wavelength increases. The extinction coefficient generally declined noticeably with increasing wavelength until it reached its virtually constant values at 400 nm for all films until 600 nm, as can be seen from these data.

Figure 7 shows the absorption spectra of the agarose thin films prepared by dissolving the agarose powder in type W2 of water as Zamzam water (pH = 8 and TDS = 339 ppm) irradiated by Nd:YAG laser.

The thin agarose films had a low absorption and were transparent. Following the laser irradiations, the films' absorption increased significantly. Agarose crystallization and a change in the films' surface roughness were said to be the causes. The photo-absorption of the films decreased thereafter in the visible region when the laser's wavelength was raised from (532 to 1320) nm.

Figure 8 shows the absorption coefficient spectra of the agarose thin films prepared by dissolving the agarose powder in type W2 of water as: Zamzam water (pH = 8 and TDS = 339 ppm) irradiated by three different wavelengths of Nd: YAG laser as (532, 1064, and 1320) nm respectively.

The absorption coefficient of each agarose thin film varies. Films with higher values are more easily able to absorb incident photons. According to this, they cause electrons to transition from the valence band to the conduction band. At this wavelength (from 200 to 300 nm), the greater numbers reflect strong photon absorption, while the smaller values represent weak photon absorption. A lack of energy in the substance prevents an electron from moving from one level to the next, as seen by the sharp point on the absorption coefficient chart. The absorbance and the absorption coefficient function similarly. It is clear that when laser energy rises, the absorption coefficient will rise as well. This might be caused by variations in the film thickness [11].

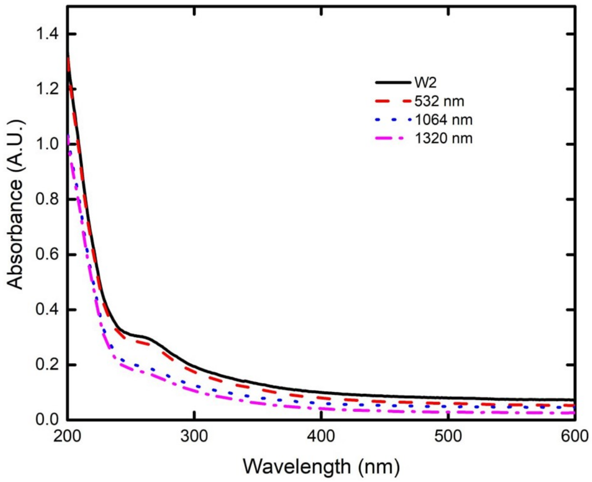

Figure 7. Absorption spectra of the agarose thin films prepared using W2 irradiated by wavelengths of Nd:YAG laser as (532, 1064 and 1320)nm respectively.

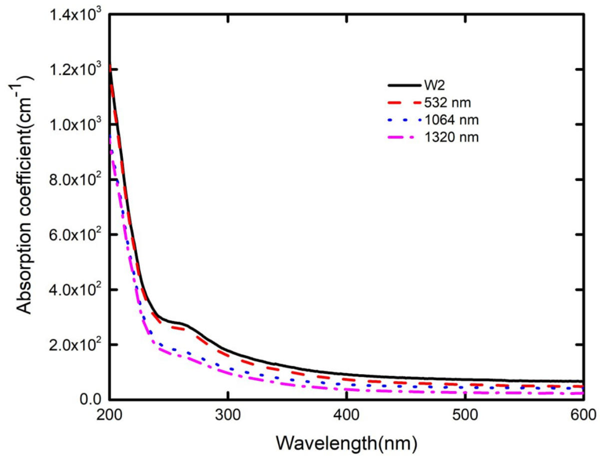

Figure 8. Absorption coefficient spectra of the agarose thin films prepared using W2 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

Figure 9 shows the extinction spectra of the agarose thin films prepared by dissolving the agarose powder in type W2 of water as Zamzam water; (pH = 8 and TDS = 339 ppm) irradiated Nd:YAG laser.

From Figure 9, it can be noted decreasing in the extinction coefficient (K) with increasing wavelength before and after irradiation with Nd:YAG laser and this behavior is identical to the absorption coefficient (α) behavior according to equation (2) [12]:

$$K = \frac{\lambda\alpha}{4\pi} \tag{2}$$

The extinction coefficient, which represents the amount of absorption loss experienced during electromagnetic wave propagation through the material. Figure10 shows the absorption spectra of the agarose thin films prepared by dissolving the agarose powder in type W3 of water as: well water; (pH = 8.6 and TDS = 1440 ppm) irradiated by Nd:YAG laser.

Figure 10, which depicts this phenomenon, showed that each film showed an increase in photo-absorption as the laser wavelength decreased. It was caused by a change in the surface roughness of the films exposed to a higher laser wavelength. As a result of the films' surface's reduced light scattering, photoabsorption was increased.

Figure 11 shows the absorption coefficient spectra of the agarose thin films prepared by dissolving the agarose powder in type W3 of water as: well water; (pH = 8.6 and TDS = 1440 ppm) irradiated by three different wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively. From Figure 11, can note that the value of the absorption coefficient decrease with increasing wavelength before and after irradiation with an Nd:YAG laser this increase in the absorption coefficient is due to increase in the absorption (A) according to equation (3) [13]:

$$\alpha = \frac{2.303\,A}{d} \tag{3}$$

where (d) is the thickness of the agarose thin film. The absorbance decreases with the wavelength; therefore, the absorption coefficient decreases with the wavelength. Figure 12 shows the extinction spectra of the agarose thin films prepared by dissolving the agarose power in type W3 of water as well water; (pH = 8.6 and TDS = 1440 ppm) irradiated by three different wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

It is discovered that the behavior of the curves is the same for each wavelength and that the extinction coefficient decreases as the Nd:YAG wavelength increases.

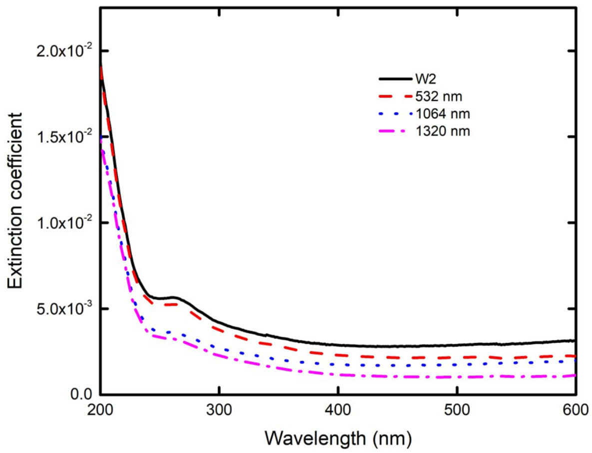

Figure 9. Extinction coefficient spectra of the agarose thin films prepared using W2 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

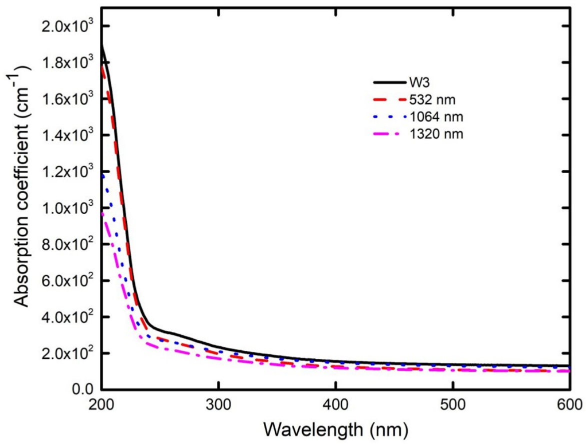

Figure 11. Absorption coefficient spectra of the agarose thin films prepared using W3 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

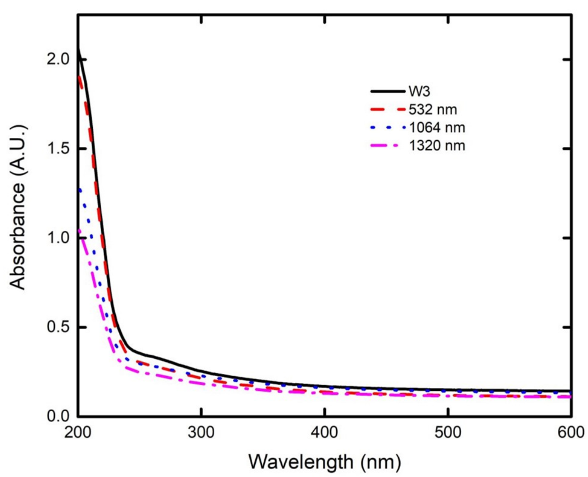

Figure 10. Absorption spectra of the agarose thin films prepared using W3 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

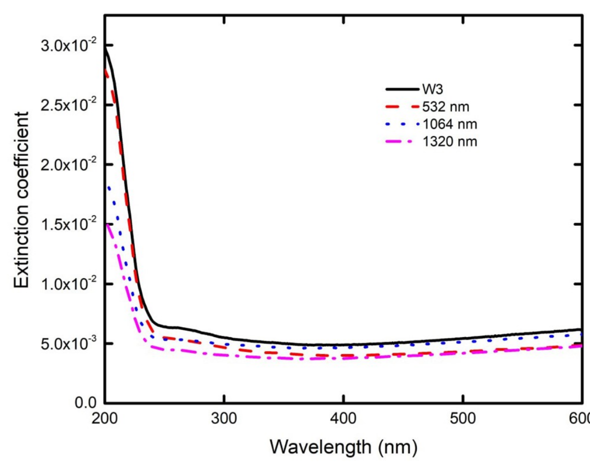

Figure 12. Extinction coefficient spectra of the agarose thin films prepared using W3 irradiated by wavelengths of Nd:YAG laser as: (532, 1064 and 1320)nm respectively.

4. Conclusions:

The goal of this study is to assess how the wavelength of Nd:YAG laser irradiation affects the optical characteristics of agarose thin films that have been successfully prepared by dissolving agarose powder in three types of waters that vary in their pH and TDS values. The Nd:YAG laser's wavelengths, which affect all optical properties including absorption spectra, extinction coefficients, and absorption coefficients, have an impact on these thin coatings. According to the findings, these three optical characteristics are getting better as Nd:YAG wavelengths go from 532nm to 1320nm, respectively.

Funding: None.

Data Availability Statement: All of the data supporting the findings of the presented study are available from corresponding author on request.

Declarations:

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: The manuscript has not been published or submitted to another journal, nor is it under review.

References

[1] Fu X. Duan D. Zhang, Y. and et al. Preparation and characterization of agar, agarose, and agaropectin from the red alga ahnfeltia plicata. *Journal of Oceanology and Limnology*, 37:pages815–824, 2019, doi:10.1007/s00343-019-8129-6.

[2] An D. Xiao Q. Chen F. Q. Zhang Y. H. Weng H. F. Xiao A. F. Zhang, C. Convenient agarose preparation with hydrogen peroxide and desulfation process analysis. *Marine Drugs*, 19(6), 2021, doi:10.3390/md19060297.

[3] Donald W. Renn. Agar and agarose: indispensable partners in biotechnology. *Industrial & Engineering Chemistry Product Research and Development*, 23(1):17–21, 1984doi:10.1021/i300013a004.

[4] Meena R. Kumar A. Singh, T. Influence of external and internal conditions of detector sample treatment on the particle registration sensitivity of solid state nuclear track detectors of type cr-39. *Radiation measurements*, 47(7):518–529, 2012, doi:10.1016/j.radmeas.2012.05.002.

[5] Jun-Ying Xiong Janaky Narayanan and Xiang-Yang Liu. Determination of agarose gel pore size: Absorbance measurements vis a vis other techniques. *Journal of Physics: Conference Series*, 28(1):83, 2006, doi:10.1088/1742-6596/28/1/017.

[6] Olga N. Makshakova and andYuriy F. Zuev. Measurement of radon exhalation rate and annual effective dose from marine sediments, ras tanura, saudi arabia, using cr-39 detectors. *Gels*, 8:287, 2022, doi=10.3390/gels8050287.

[7] Nicolas Fatin-Rouge, Antoine Milon, Jacques Buffle, Richard Goulet, and Andre Tessier. Diffusion and partitioning of solutes in agarose hydrogels: The relative influence of electrostatic and specific interactions. *Journal of Physical Chemistry B*, 107, 2003, doi:10.1021/jp0303164.

[8] Alistair M. Stephen and Glyn O. Phillips. *Food Polysaccharides and Their Applications*. Boca Raton, 2^{nd} edition, 2006, doi:10.1201/9781420015164.

[9] Ying Yang, Tian Chen, Dequn Pan, Jing Gao, Congtan Zhu, Feiyu Lin, Conghua Zhou, Qidong Tai, Si Xiao, Yongbo Yuan, Qilin Dai, Yibo Han, Haipeng Xie, and Xueyi Guo. Mapbi3/agarose photoactive composite for highly stable unencapsulated perovskite solar cells in humid environment. *Nano Energy*, 67:104246, 11 2019,doi:10.1016/j.nanoen.2019.104246.

[10] Franz Urbach. The long-wavelength edge of photographic sensitivity and of the electronic absorption of solids. *Physical Review*, 92:1324–1324, 1953, doi:10.1103/PhysRev.92.1324.

[11] J. Huang, X.and Ding. The structure, magnetic and transport properties of fe3o4 thin films on different substrates by pulsed laser deposition. *Journal of the Korean Physical Society*, 62:2228–2232, 2013, doi:10.3938/jkps.62.2228.

[12] Sabri Mohammed, Kadhim Aadim, and Maad Ameen. Effect of annealing on some properties of zn2sno4 thin films prepared by pld technique. *Kirkuk University Journal-Scientific Studies*, 13(4):96–112, 2018, doi:10.32894/kujss.2018.13.4.8.

[13] Rafea Abdullah Munef, Ali Ismail Salih and, and Hassan Jalal Akbar. The annealing effect on the some optical properties of (cu2znsns4) thin films. *Kirkuk University Journal-Scientific Studies*, 12(1):30–42, 2017, doi:10.32894/kujss.2017.124849.

تأثير الاطوال الموجية لليزر $Nd:YAG$ على الخصائص البصرية للاغشية الرقيقة للاكاروز

احسان صديق جلال [1*] ، عبدالستاراحمد عيسى [2]

[1] قسم الفيزياء، كلية العلوم، جامعة كركوك، كركوك، العراق

[2] قسم الفيزياء، كلية ألتربية للبنات، جامعة كركوك، كركوك، العراق

* الباحث المسؤول: $scph21m025$@*uokirkuk.edu.iq*

الخلاصة

تم في هذا البحث تحديد الخواص البصرية لأغشية الاكاروز الرقيقة مثل الامتصاصية ومعامل الامتصاص ومعامل الخمود. للحصول على تركيز 2% وزن من الاكاروز، تم إذابة 0.2 مغم من الاكاروز في 10 مل من الماء ، ثم تم تسخين الخليط في الميكروويف لمدة 30 ثانية حتى الغليان. تم استخدام ثلاثة أنواع من الماء ، بما في ذلك الماء المقطر والذي رمزنا له بالرمز $W1$ (الرقم الهيدروجيني = 7.5 و TDS = 18 جزء في المليون) ، ماء زمزم ذو الرمز $W2$ (الرقم الهيدروجيني = 8 و TDS = 339 جزء في المليون) ، ومياه الآبار ذو الرمز $W3$ (الرقم الهيدروجيني = 8.6 و TDS = 1440 جزء من المليون(تختلف الأملاح الذائبة الكلية (TDS) ودرجة الحموضة عبر أنواع المياه المذكورة أعلاه. تم تشعيع غشاء الاكاروز الرقيق باستخدام ليزر ($Nd:YAG$) بثلاثة أطوال موجية مختلفة وعلى النحو التالي: (532,1064,1320) نانومتر. ان اختلاف الاطوال الموجية لليزر المستخدم قد اثر على جميع الخواص البصرية للاغشية الرقيقة المحضرة في هذا البحث.

الكلمات الدالة : الاغشية الرقيقة للاكاروز ، ليزرالندميوم : ياك ،الخصائص البصرية، معامل الامتصاص ،معامل الخمود

التمويل: لايوجد.

بيان توفر البيانات: جميع البيانات الداعمة لنتائج الدراسة المقدمة يمكن طلبها من المؤلف المسؤول.

اقرارات:

تضارب المصالح: يقر المؤلفون أنه ليس لديهم تضارب في المصالح.

الموافقة الأخلاقية: لم يتم نشر المخطوطة أو تقديمها لمجلة أخرى، كما أنها ليست قيد المراجعة.