Effect of 532 nm KTP Nd: Yag Laser on Poly Methyl Methacrylate Polymer Optical Properties

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Abstract

This research studied the effective of laser irradiation (532nm KTP Nd: YAG laser) on PMMA optical properties. The energy gap is disproportionate with the laser irradiation time. The optical properties such as absorbance, absorption and extinction coefficients and refractive index of pure and irradiated PMMA. The real and imaginary parts of dielectric constant is proportional with the laser irradiation time except the transmittance and the energy gap that decrease with laser irradiation time increasing.

Key Words: Optical Properties, PMMA Polymer, Laser Irradiation.

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Introduction

Various fields used polymers in normal life beginning from house to bio-medical devices [1]. Nanosecond and femtosecond excimer lasers are typically used for polymers treatment for the development of micro device and micro-machining of polymers especially with biodegradable ones. UV energy is capable to breakdown chemical bonds directly wanting temperature change to the nearby material [2,3]. Short pulses stimulate fast vaporization of the material. Calm and active change to UV radiation [4] suggestions a cost- active source for polymers photochemical ablation. Ablation of polymers different from that of metals. Most of polymers decay prior to evaporation. The ablation ratio is connected to the cracked bonds number in the chain of polymer [5, 6]. Size of the remains and monomers is larger than that of the polymer. Size burst is the force for dismissing of the material [7]. Growth of the polymer surface was detected under the ablation threshold in the laser irradiated areas [8].

Materials and Methods

PMMA (Poly Methyl Methacrylate) was dissolved in 30ml chloroform with stirring then casted in petri dish making a film. The film was put in 25cm^2 glass then washed with water and sonicated. The samples were put in oven at 50ºC for 2h. The films thickness are 0.03 to 0.07Cm. The absorption spectrum and transmittance were obtained for the wavelengths ranged from 190 - 890nm using UV/Vis absorbance at 25ºC. The samples were irradiated by green KTP Nd: YAG laser (CW) with 532nm wavelength and 20mW. The beam spot size was increased from 1.5mm to 20mm using beam expander.

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Samples irradiated for different time periods (10, 20 and 30minutes). The connection between the incident and transmittance intensity was calculated using beer lamberts law equations [4]. The energy gap was calculated from the Tuac Plot equation and the association between the refractive index and reflectivity was calculated using Fresnel equation [9]. The refractive index and extinction coefficient were stated as mentioned by [6].

The optical conductivity is associated with the refractive index and absorption coefficient through a relationship described by [4] and the finesse coefficient was calculated through the relationship equation mentioned by [4,10,11].

Results and Discussion

Fig. (1) displays the UV-Vis absorption spectra against wavelengths where the peak intensity is proportional with the radiation exposure time. There is no change in the peak position, this mean that the applied laser beam do not alter the chemical construction of the PMMA polymer but there is a physical change in polymer properties.

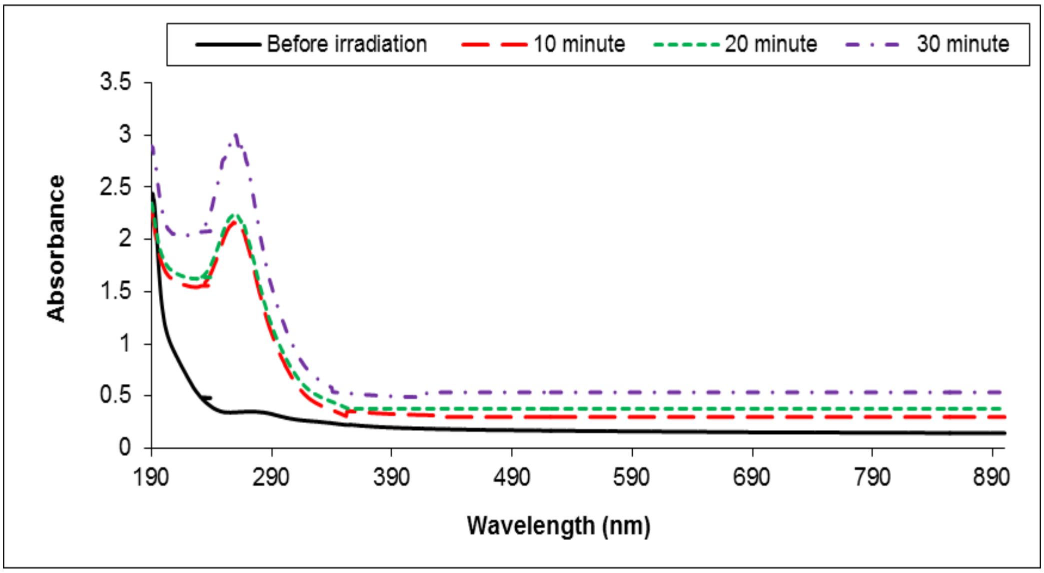

Fig. 1. UV-Vis absorption spectra of PMMA before and after Laser Irradiation

Fig. (2) Shows the polymer transmittance according to wavelength where it is reduced with laser irradiation increasing time.

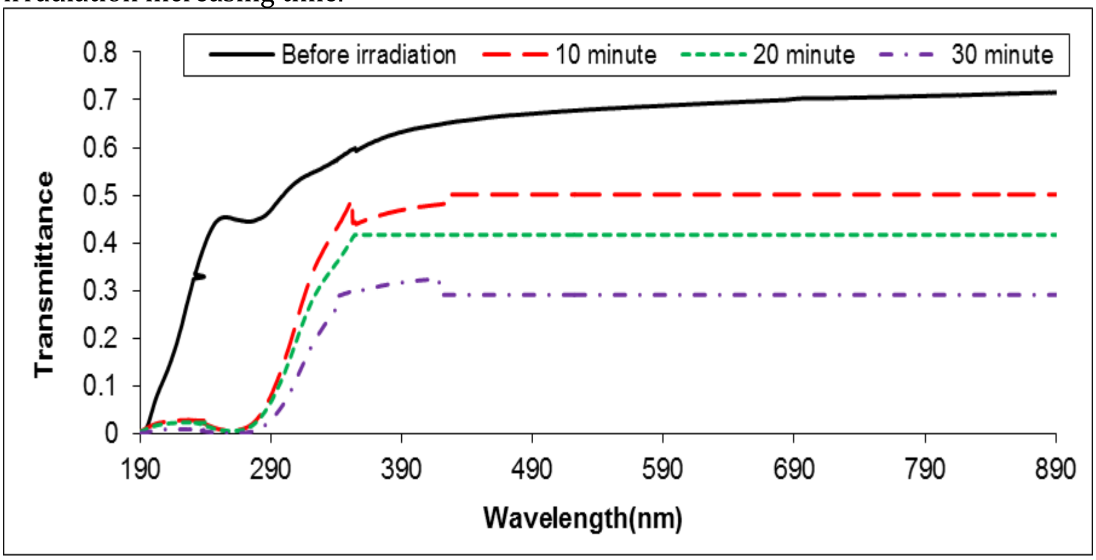

Fig. 2. PMMA transmittance according to laser irradiation wave length

Fig. (3) displays the absorption coefficient (α) against the energy of photon, it shows that absorption is moderately lesser at low energy, so the electron transition probability is low due to not enough incident photon energy to transfer the electron from the valence to conduction band
At high energies, the absorption process is greater which indicates that there is a high probability of electrons moving to the conduction range so the falling photon energy is higher than energy gap [10]. The laser irradiation time is proportional with the absorption coefficient.

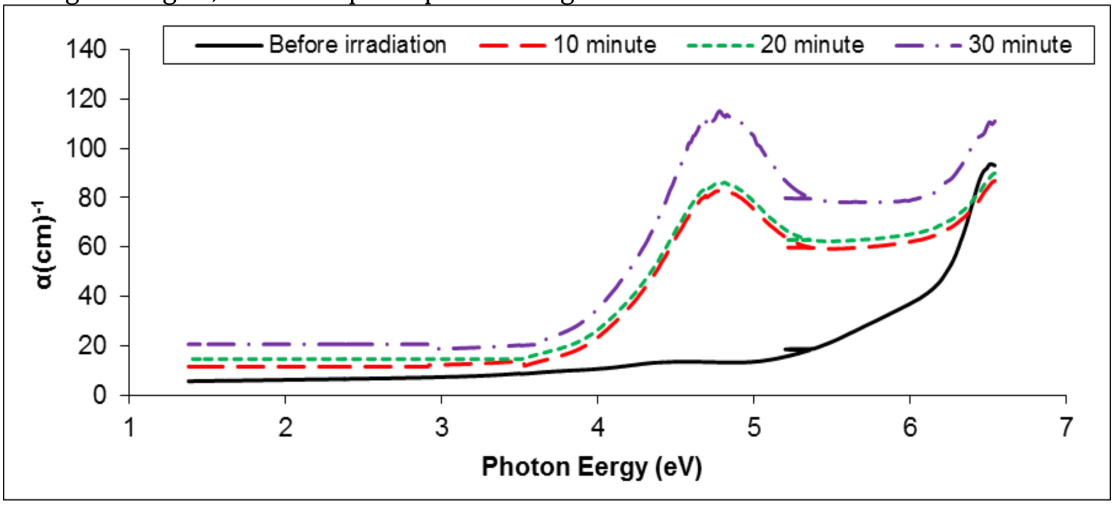

Fig. 3. The PMMA absorption coefficient according to laser irradiation time

Fig. (4), The energy gap can be found using tauc plot equation. When the straight portion of the graph of $(\alpha h\upsilon)^{1/2}$ against energy photon (hυ) is extrapolated to (α = 0) the intercept gives the indirect allowed transition.

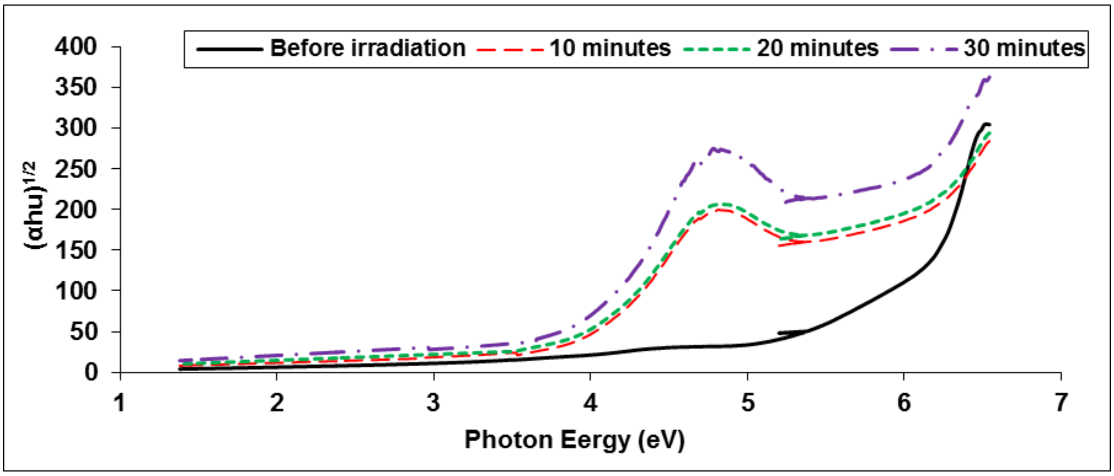

Fig. 4. $(\alpha hu)^{1/2}$ as a photon energy (hv) function before and after Laser Irradiation

From Fig. (4), the energy gap decreases with laser irradiation time increasing. This indicates additional levels within the energy gap that simplify the electron crossing from the valence of local levels to conduction level [7]. The refractive index decreases with laser irradiation time increasing for wavelength range 190nm to 275nm while the refractive index is proportional with laser irradiation time for wavelength range 275nm to 375nm because the longest wavelength transmission is high (Fig. 5).

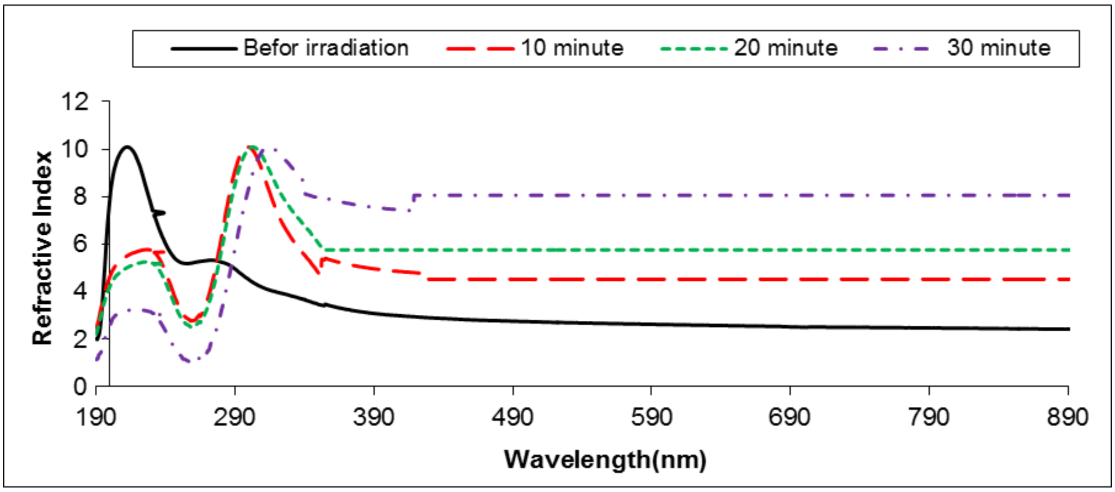

Fig. 5. Change the refractive index of PMMA against wavelength before and after Irradiation by Laser beam.

Fig. (6A) shows the alteration of the extinction coefficient of the PMMA against of wavelengths function. It is proportional with the irradiation time. At the longest wavelengths, the extinction coefficient is high.

The real dielectric constant (ε_1) and imaginary (ε_2) of PMMA have been calculated. Fig. (6B) and (6C) explain the constants variation according to wavelength. It shows that (ε_1) is greater than the (ε_2), because they depend on n and k values. The (ε_1 and ε_2) are proportional to the laser irradiation time.

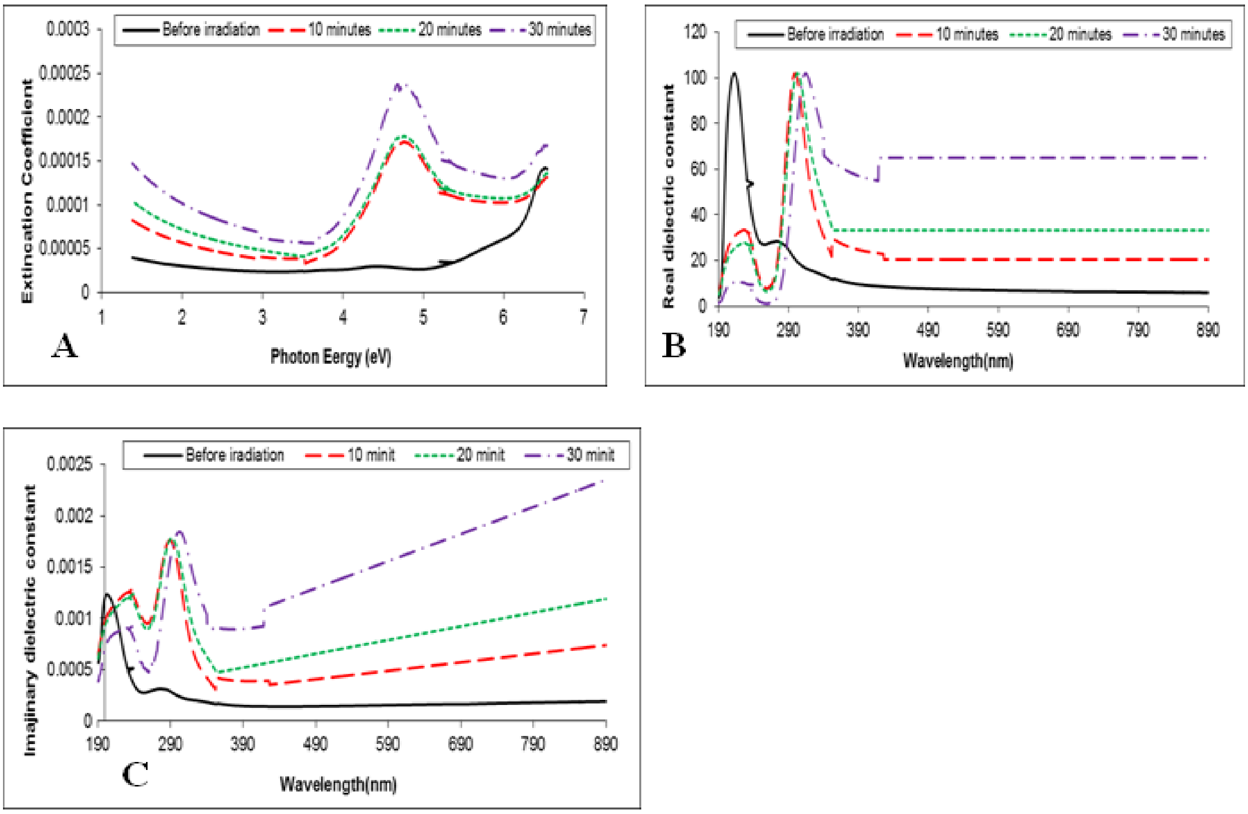

Fig. 6. A: Change the extinction coefficient of PMMA against wavelengths before and after Irradiation by Laser. B: The real dielectric constant of PMMA against wavelength before and after Irradiation by Laser. C: Change the imaginary dielectric constant of PMMA against wavelength before and after Irradiation by Laser.

Conclusion

Absorbance, extension and absorption coefficient and refraction index are proportional with the laser irradiation time whereas the transmittance is disproportionate with the laser irradiation time.

The irradiation of a polymer with a laser (λ=532nm) leads to reduce the Insulation property of the polymer and thus leads to its transformation into Polymer conductive because of its wide applications in the industry. The energy gap is disproportionate with the laser irradiation time. The dielectric constant (real and imaginary) part is proportional with the laser irradiation time.

Ethical Clearance

The Research is approved by environmental and health and higher education and scientific research ministries in Iraq

Conflict of Interest

The authors declare that they have no conflict of interest.

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