جامعة الفيوم
Fayoum University
Faculty of Science

EFFECT OF LASER IRRADIATION ON THE PHYSICAL PROPERTIES OF SOME SOLID STATE NUCLEAR TRACK DETECTORS

BY

Adel Mohamed El-Sayed

A thesis submitted in partial fulfillment

of
The requirements for the degree of Master of Science

Department of Physics

Faculty of Science

FAYOUM UNIVERSITY

Supervisors

Prof.Dr. Mohamed Nabil Yasein
Dean of the Faculty of Science
Fayoum University

Prof. Dr. Samir Ahmed Nouh
Physics Department,
Faculty of Science,
Ain Shams University

Dr. Taha Abd El-Mageed Hanafy
Physics Department, Faculty of Science
Fayoum University

2008

Abstract

Makrofol-DE 1-1-CC Polycarbonate is a class of polymeric solid state nuclear track detectors, which have many applications in various radiation detection fields. In the present work, Makrofol samples were irradiated using different laser fluencies in the range of 0.47 –10.40 J/cm^2 of IR pulsed lasers. The structural modifications in the laser irradiated Makrofol samples have been studied as a function of fluence using different characterization techniques such as X-ray diffraction (XRD), intrinsic viscosity, Fourier transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), differential thermal analysis (DTA), refractive index, color difference studies, mechanical and electrical properties.

Structural property studies using XRD and FTIR were performed on the non irradiated and irradiated Makrofol samples. The intensities of the characteristic absorbtion bands were found to decrease predominantly with the increase of laser fluence in the ranges; 0.47-0.94 J/cm^2 and 7.07-10.40 J/cm^2 indicating that the degradation process is the dominant mechanism inside the investigated samples. An increase in the –OH groups was observed in the fluence range 0.47-0.94 J/cm^2 due to the degradation of C=O group and the –H abstraction from the polymer backbone to form hydroxyl groups. This degradation, which reported by FTIR, enhanced the degree of ordering in the degraded samples as revealed by XRD technique.

The effect of laser fluence and temperature on the intrinsic viscosity of the liquid Makrofol samples, as a measure of the mean molecular mass, was studied. The results indicate that the intrinsic viscosity depends largely on both the laser fluence and temperature. The intrinsic viscosity, thus the mean molecular mass, was found to decrease with the increase of the laser fluence in

the range 0.47-0.94 J/cm^2 due to the formation of shorter molecules as a result of degradation that causes both a random breaking of bonds and the formation of stable molecules with a lower molecular weights. Above 0.94 J/cm^2 and up to 7.07 J/cm^2, it increases. The intrinsic viscosity almost decreases linearly with temperature. This could be attributed to the fact that the temperature speeds up the decay of a number of organic materials via degradation mechanism and causes changes in the polymeric chain flexibility.

Thermal studies were carried out and the obtained TGA thermograms indicate that the Makrofol detector decomposes in one main weight loss stage. Using the TGA curves, both the onset temperature of decomposition and the activation energy of thermal decomposition were calculated. The results indicate that the laser irradiation of Makrofol samples in the fluence range 0.47-0.94 J/cm^2 causes an initial scission that reduces the thermal stability of the Makrofol samples. But the laser irradiation in the fluence range 0.94-7.07 J/cm^2 led to a more compact structure of Makrofol polymer, which resulted in an improvement in its thermal stability with an increase in the activation energy of thermal decomposition. On the other hand, using differential thermal analysis (DTA), the melting temperature of the polymer, T_m, was investigated to probe the crystalline domains of the polymer. At a fluence range 0.94-7.07 J/cm^2, the defect generated destroys the crystalline structure, thereby reducing the melting temperature.

Optical properties of Makrofol polycarbonate detector appeared to be connected to the chemical and structural modifications induced by laser irradiation. Refractive index measurements provided information about the structural properties of Makrofol samples. At the ranges of laser fluencies 0.47-0.94 J/cm^2 and 7.07-10.40 J/cm^2 the refractive index decreases as a random breaking of bonds takes place through the degradation process. At the fluence range 0.94-7.07 J/cm^2 the active sites or branching points created by scission lead to intermolecular cross-linking and allow the formation of covalent bonds between different chains, leading to an increase in refractive index and thus minimizes the anisotropic character of the polymer.

The transmission of the Makrofol samples in the wavelength range 380-780 nm, as well as any color changes, were studied. The Commission International de É Clair (CIE units x, y and z) methodology was used in this work for the description of colored samples. The variation of color intercepts (L^*, a^* and b^*) with laser fluence was studied. It could be seen that the color parameters were significantly changed after exposure to laser irradiation. The green ($-a^*$) and blue ($-b^*$) color components of the non irradiated sample were changed to red ($+a^*$) and yellow ($+b^*$) after exposure to lasers in the fluence range up to 10.40 J/cm^2. This is accompanied by an increase in the darkness of the samples ($-L^*$). The color difference (ΔE^*) between the non irradiated Makrofol sample and those irradiated with different fluencies was calculated.

The stress-strain curves for laser-irradiated Makrofol samples were investigated. Generally, the strain increased on increasing the stress due to the increase in the flexibility of the main chains in the Makrofol samples. These curves served to calculate several useful quantities including yield stress σ_y, fracture stress σ_f, fracture strain ε_f and the elastic modules. The results indicate that, at the fluence ranges 0.47-0.94 J/cm^2 and 7.07-10.40 J/cm^2, the standard chains and a great number of chain ends weaken and the material may become softer (chain scission). Also the decrease in elastic modules indicates that the sample has become more flexible, which simply results from the decrease in inter-atomic force constants.

The results of electrical properties of the samples indicate that the increase in electrical current upon irradiation, in the fluence range 0.47-0.94 J/cm^2, could be attributed to the increase in the number and mobility of charge carriers. These charge carriers are capable of conduction of the electric current. Higher laser fluencies, 0.94-7.07 J/cm^2 cause branching that reduces crystallinity and induces further lattice defects that may act as scattering centers and energy barriers for the flow of the electric current.

Finally, the results obtained from the different techniques used in the present work were found to be in a good agreement with each other and confirm that the Makrofol polycarbonate detector, which is a degradable material, can be cross-linked when irradiated at increased laser fluencies, where the active sites or branching points created by scission can lead to intermolecular cross-links.