Measuring Laser Beam Transmission through Exposed/Etched CN-85 Detectors

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Abstract
Cellulose Nitrate (CN-85) plastic detectors, with a thickness of 100 µm, were exposed to radiation by alpha particles. Then, the irradiated detectors were etched and treated with radiation by using He-Ne laser source. The influence of laser irradiation on the physical characterization of CN-85 track detectors has been investigated through track radii. In this study, the tracks’ number and track radii were calculated. The results showed that the track radii of laser-etched CN-85 detectors were reduced with increasing the etching time. Further, the track radii were changed due to the effects of alpha particles on the CN-85 detectors. This method is found to be a relatively inexpensive, easy, and effective tool for measuring the radiation dose.

Keywords: CN-85; alpha particles; laser beam; NTD; etching time.

1. Introduction
Solid-state nuclear track detectors (SSNTDs) have been thoroughly scrutinized in various science and technology applications due to their unique characteristics (1-3). SSNTDs are used according to the fact that the material is ionized when a heavy charged particle is passed through it (4). Ionizing particles are acted on the detectors and formed latent tracks due to radiation damage (5). The excellent benefits of SSNTDs are low reactivity to electrons and photons and powerful sensitivity to ions in wide energy range (6). The detection, of charged particles method by SSNTDs, is employed in high-temperature plasma (7), medicine (8), geology (9), biology (10), and nuclear physics (11), etc. SSNTDs are made from special polymers and applied as biological filters, sensors, and dosimeters (12-14). Irradiation of polymeric materials is usually utilized as a conventional method to enhance its physical and chemical properties (12, 15). Cellulose Nitrate (CN-85/ C₆H₈O₈N₂) is one of the
various types of SSNTDs, which is widely used to detect alpha particles rather than radon gas and Uranium (16). The optical density (D) measurement, of CR-39 and CN-85 detectors throughout a laser beam, is reported earlier in literature (17). The electromagnetic radiation affected the detectors’ materials due to the changes in the CN-85 structure (18). Most of these changes relied on some factors such as exposure condition, etching process, and radiations' types (19). Al-Saad & Abbas (20) examined the influence of He-Ne laser beam transmission on the etched CR-39 and CN-85 detectors which was irradiated with alpha particles or neutrons. Further, Mahmood et al. (21) examined the CN-85 track registration efficiency through the critical angle of etching, etching time, and low-energy protons. Their results showed that the track diameter was enlarged with increasing the protons’ energy. However, etching efficiencies were decreased with increasing the protons’ energy.

Jassim (16) measured the optical density of irradiated CR-39 and CN-85 plastic detectors. The irradiation process was achieved by using high does α-particles. Results showed that the optical density peak for the CR-39 occurred at the etching time beyond that required for the CN-85. The impact of laser light on the etching parameter, optical, and photoluminescence characteristics of CR-39 and CN-85 detectors were studied by Zaki et al. (22). When the energy of 5.44 MeV alpha particles was exposed, the optical band gap energy for both detectors was reduced with increasing laser energy density. Qindeel et al. (23) inspected the influence of Q-switched pulsed Nd:YAG laser on the characteristics of the irradiated CN-85 polymer detector.

It was found that the evaluated optical band gap energy for the high dose is more prominent than the low dose. As a result, material hardening is developed due to the cross-linking influence of the CN-85 detector with the increasing band gap energy. Zaki (12) investigated the He–Ne laser influence on the CN-85 detectors via different irradiation
fluences. It was found that optical band gap energy at the high does declined from 3.6 to 2.6 eV, for original and irradiated samples, respectively.

There is a relative paucity of scientific literature, specifically concerning the laser effect on the irradiated polymer detectors. Therefore, this paper aims to examine the influence of the transmitted laser light on track radius and etching time of the alpha irradiated CN-85 detectors.

2. Experimental set up and measurement

Pristine CN-85 detectors (100 µm thickness), purchased from Kodak France, were used in the current study. First, the detectors were irradiated by alpha particles for 5 min. The process was achieved with the aid of $^{241}\text{Am}$ with an activity of 1µCurie and $t_{1/2}$ of 457 years for periods. Second, the irradiated CN-85 detectors were etched at a temperature of 50 °C. The etching procedure is carried out at a time ranging from 30 to 60 minutes. Sodium hydroxide liquid (NaOH) is prepared with a concentration of 6.25M and applied as an etching solvent. Third, the He-Ne laser system (Germany/optectra Gmbht) with power 1mW is employed to observe the laser beam influence on the irradiated detectors. The detail of the experimental setup is shown in Figure 1. The track detector was placed next to the laser source at a distance of 8 cm. Moreover, transmitted laser light from the irradiated CN-85 detectors, which was scattered by the etched nuclear tracks, was collected by a photodiode detector (Sanwa Electric Instrument GI Ltd). It was set after the irradiated CN-85 detectors at a distance of 10 cm. The laser beam is implemented at a time ranging from 3 to 15 minutes.
3. The Results and Discussion

The relationship between the number of tracks and etching time for both irradiated and laser CN-85 detectors is illustrated in Figure 2. It can be seen from the graph that the number of tracks for all samples decreases gradually with increasing the etching time. Furthermore, it indicates that the irradiated CN-85 detector has the lowest number of tracks compared to the laser one. These results are in good agreement with those obtained by Hussain (24). The detected decrement in the number of tracks could be attributed to the chemical cross-linking that occurred in this area. As a result, the track size is reduced.

Figure 3 represents the number of tracks (NT) for the irradiated-etched CN-85 detectors as a function of applied laser time. As it is illustrated by the graph, the etching is gradually intensified by increasing the time until time of 12 minutes. After that, the number of tracks decreases with increasing the applied laser time.
Figure 2: Number of tracks as a function of etching time.

Figure 3: The number of tracks as a function of applied laser time for CN-85 detectors.
The effect of etching time on the radii of tracks is shown in Figure 4. From the graph, the tracks' radii decrease with increasing the etching time. Besides, the radii of tracks for the irradiated CN-85 detector are larger than the laser detectors at a time ranging from 55 to 60 min. Table 1 presents the experimental data of the radii track and etching time. This finding might be explained by the fact that the chemical cross-linking is developed. The development is obtained due to the irradiation process on the CN-85 detectors (25). Figure 5 shows the images of the track alpha particles under the optical microscope (USA/ Kenα vision type 1003) at different laser time.

Figure 4: The radius of track via etching time.
Table 1: Radii of track and laser etched CN-85 detectors with different etching time.

| Etching time (min) | Irradiation | 3 min | 6 min | 9 min | 12 min | 15 min |
|--------------------|-------------|-------|-------|-------|--------|--------|
| 30                 | 20.262      | 35.24 | 28.658| 25.098| 21.36  | 13.528 |
| 35                 | 19.758      | 16.198| 19.758| 22.606| 16.732 | 11.214 |
| 40                 | 14.418      | 16.02 | 16.376| 16.198| 13.172 | 10.68  |
| 45                 | 13.35       | 11.748| 14.24 | 10.68 | 11.57  | 10.146 |
| 50                 | 11.57       | 11.57 | 11.392| 10.50 | 10.59  | 9.79   |
| 55                 | 10.68       | 9.256 | 9.078 | 10.057| 9.54   | 9.256  |
| 60                 | 10.324      | 9.078 | 8.567 | 9.79  | 8.722  | 8.544  |

Figure 5: The CN-85 tracks under the microscope.

4. Conclusions

In this study, the effect of transmitted laser light on the irradiated CN-85 detectors was investigated. The irradiation process for the detectors was performed by using alpha particles. The physical characterization of CN-85 plastic detectors has been examined through track radii. The results showed that track radii of the detectors were reduced with increasing the etching time. Moreover, it became the lowest compared with the rest samples by applying
laser light for a time of 15 min. It can be concluded that CN-85 detectors served as perfect candidates for revealing of alpha particles. In addition, the method is considered very simple, cheap, fast, and it is useful in radiation dose measurements.

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