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Effectiveness of Nuclear Track Detectors irradiation by Laser on Recording Concentration and Track Diameter of Alpha Particles Emitted from Radon

The effects of laser irradiation on the registration properties of nuclear solid state track detectors were examined. Two different kinds of lasers were used, along with three detectors. The findings demonstrated that the quantity of radon gas-produced tracks increased with irradiation time, peaking at 8 minutes increasing about 25%, suggesting that bonds in the detector broke and free radicals were created. The recording of tracks was then varied by the detector solidification due to recombination between the free radicals and other molecules, finally falling to a value near the initial value. In addition suggesting that laser power matters more than wavelength.

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1. Introduction

The domains of application for nuclear track detectors have grown and increased due to their affordability, accuracy, and ability to preserve antiques. They are also simple to operate and do not require a power source. In uranium exploration, radiation protection in nuclear power plants, optical applications, and radiation protection dosimetry, the CR-39 detector is utilized as a simple charged particle monitor [1-4]. One of the most significant uses for them is radon gas concentration measurement to estimate the ensuing pollution to the environment [5]. Radiation is divided into two sorts based on its impact on matter: ionizing radiation and non-ionizing radiation. Ionizing radiation includes cosmic rays and x-rays, whereas non-ionizing radiation includes ultraviolet light, radiant heat, radio waves, and microwaves. Non-ionizing radiation has a longer wavelength, which results in a lower frequency and energy. Ionizing radiation has a shorter wavelength, a higher frequency, and a higher energy. Both non-ionizing and ionizing radiation can harm organisms and affect the natural environment [6]. Several research have lately investigated the impact of the laser on the polymeric detector to investigate the sensitivity increase [7-9]. The laser's interaction with polymeric detectors is influenced by factors such as wavelengths, pulse duration, pulse repetition rate, power density, energy density of the coherent beam, and ambient conditions, which are broadly classified as thermal and non-thermal [10]. Low-ionizing laser radiation can cause the polymer molecules in plastic track detectors to either cut or cross-link, which would speed up the etching process overall [11]. One of the organic reagents, CR-39 is a polymeric substance composed of small repeating units called monomers that are bonded together. Asra defeated her O-H, the CN-85 and LR-115 detectors utilizing cellulosic reagents. Due to the fact that the polymeric reagent is made up of tiny units that are joined by some that have an O-H covalent link that is easily broken when exposed to radiation, small polymeric chains with ends are produced [12]. Unlike other active chemicals, free radicals can interact with one another. These molecules become irritated and ionized due to the effect of radiation on the polymer. This stored effect, which breaks the links between them and damages the polymer material without dissipating under normal circumstances, is called the latent effect. Ionizing radiation-damaged areas are more able to interact with alkaline solutions, like sodium hydroxide, than intact areas. Consequently, the irradiated areas are swiftly penetrated by the chemical solution, leading to an increasing effect. When examined under a microscope, the latent effect of ionizing radiation may be observed, and its depth and diameter increase with scraping time [13]. Radiation either dissolves the polymer into free radicals or free radicals and ions, or causes dissolution, which includes reactions that break the chemical bonds between atoms in the polymer's main chains, resulting in a loss of structural strength, ductility, or flexibility, and a decrease in molecular weight [14-16]. A higher percentage of chemical processes and products involve free radicals. The polymers that emerge from these reactions might have tangled, branching, or linear forms. Alternately, harden it. If the free radicals are able to travel and restore fusion with other roots or with the main chain, this will lead to entanglement. The molecular chains are linked to one another by cross-linking, creating a complex network structure at the end, and this entwining increases the molecular weight, strength, and hardness of the reagent. When the polycarbonate surface was exposed to a laser, this resulted in both hardening and softening at power. The stability of the polymer is determined by the strength of the interatomic connection, and laser free ions have a comparatively limited lifetime [17-20].

The objective of the current investigation is to ascertain how laser radiation affects the detector's capacity to record alpha particle traces released by radon gas, as well as the diameter of those traces. Nuclear track solid state detectors, which can record tracks (damage places) and its width using ImageJ software after acquiring images from an optical microscope, were utilized to acquire results and information helpful in explaining some of the events that occur in polymers when exposed to laser.

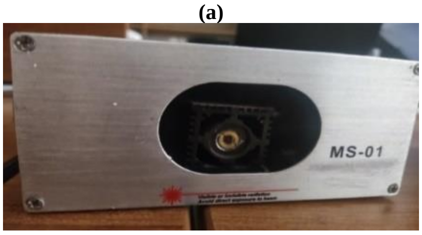
2. Experimental Part

The nuclear track detector was exposed to a laser before being placed in a plastic container "Can technique" used as a dosimeter to measure the number of alpha particle tracks emitted from radon gas, in order to study the effect of lasers on the number and diameters of tracks resulting from radon gas exposure ImageJ software was used. The detectors CR-39, CN-85, and LR-115 were used, and the exposure lasers were:

1- (He-Ne) laser beam, is a type of gas laser, that irradiates with powers (5 mW) for (5 min), the distance between the source and the detectors is (0, 4, 8, 12, and 16 cm) and the wavelength is 632.8 nm as in Fig. (1a).

2- A laser diode beam that emits (250 mW) of light (5 min). The wavelength of 405 nm and the distance between the source and the detectors are (0, 4, 8, 12, and 16 cm) as in Fig. (1b).

(a)



(b)

Fig. (1) The laser sources used in this work (a) He-Ne laser, and (b) Diode laser

To measure the number of tracks and their diameter, passive type detectors using the "Can technique" were used with detector film as alpha track detectors. Each detector piece was 1cm^2, fixed in the top of a sealed can and identified by a number or code, a hole on the bottom cover of 1.5 cm diameter covered with 2.5 x 1.5 cm^2 of sponge piece with a thickness of 1cm to prevent impurities, as shown in Fig. (2). Dosimeters were placed 50 cm away from the walls, windows, and sunlight, at a height of 2.00-2.25 m. For 60 days, dosimeters were placed in a room. After 60 days, the detectors were removed and etched at normality 6.25 N of NaOH in a water bath at heat 70°C tracks revealed. The detectors were then washed and dried, and the number of tracks was counted using ImageJ software, as well as the track diameter. The ImageJ software then calculates the average area of the tracks.

$$A = \pi r^2 \quad (1)$$

The mean radius can be calculated from the area by the relation

$$r = \sqrt{(A/\pi)} \quad (2)$$

Then the diameter calculated by the equation.

$$d = 2r \quad (3)$$

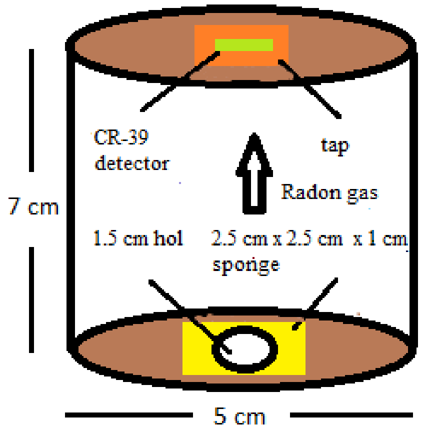


Fig. (2) Radon monitor technique "Dosimeter"

3. Results and Discussion

The obtained results from detectors of measured tracks number of alpha particles emitted from radon gas are listed in table (1). The calculated track diameters are listed in table (2).

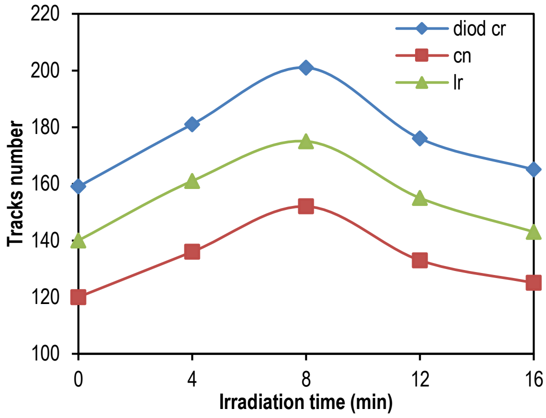
Table (1) Track numbers from the three types of detectors for both lasers used in this work

Irradiation time (min)	Laser Diode			He-Ne Laser		
	CR-39 Tr.c m^{-2}	CN-85 Tr.c m^{-2}	LR-115 Tr.c m^{-2}	CR-39 Tr.c m^{-2}	CN-85 Tr.c m^{-2}	LR-115 Tr.c m^{-2}
0	159	120	140	159	120	140
4	181	136	161	174	134	156
8	201	152	175	193	150	169
12	176	133	155	168	131	151
16	165	125	143	161	123	141

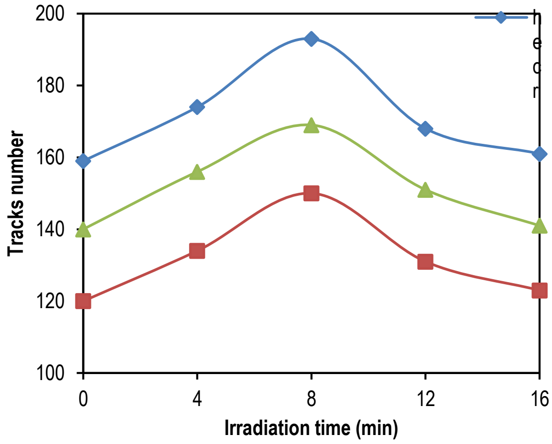
Table (2) Track diameters from the three types of detectors for both lasers used in this work

Irradiation time (min)	Laser Diode			He-Ne Laser		
	CR-39 μm	CN-85 μm	LR-115 μm	CR-39 μm	CN-85 μm	LR-115 μm
0	28.10	27.18	27.64	28.10	27.18	27.64
4	32.32	31.72	29.86	31.31	31.72	29.43
8	35.69	34.23	33.85	35.15	33.85	33.48
12	31.52	31.52	32.51	30.90	29.86	32.12
16	29.86	29.86	28.99	29.64	28.55	28.32

The outcomes are shown in table (1). It shows that as the laser irradiation time increases for both types of lasers, the number of tracks increases for all detectors up to the maximum value of the number of tracks at the 8-minute mark. After that, the number of tracks starts to decrease as the laser irradiation time increases until it reaches its lowest value at the 16-minute mark, which is almost equal to the number of original tracks without irradiation. This result implies that weakly ionizing laser radiation applied to the plastic path detectors may enhance polymer cross-linking, resulting in the breaking and conversion of long chain molecules into shorter ones. As radon outperforms O-H because it is composed of tiny, tightly spaced repeating units known as monomers, which are easily damaged by radiation. Different active compounds known as free radicals can interact with other molecules or with each other. Crosslinking is produced when the irradiation time is extended, allowing free radicals to reunite with the main chain or additional radicals. Ultimately, as the irradiation period rose, the number of traces and their diameter decreased as a result of the polycarbonate surface being exposed to the laser, which also induced particle and free radical re-adhesion and surface particle interlocking and hardening. The radiation that hits the polymer irritates and ionizes it. This causes the bonds between them to break and the chemical bonds between the atoms in the polymer's major chains to break. The polymer then disintegrates into free radicals and loses its structural strength and flexibility, as well as reducing its weight. Ions and roots The final products of these transformations are polymers with linear, branching, or cross-linked structures because free radicals participate in a larger proportion of chemical processes. This explains why the number of traces and their diameter grow with irradiation time. Crosslinking is produced by letting free radicals roam around and recombine with other radicals or the main chain over an extended period of irradiation. The resulting intricate network structure reinforces, hardens, and raises the molecular weight of the detector. The number of traces and the diameter of the traces decreased as the irradiation time increased, the number of traces produced by radon gas at room temperature for the detectors, when the polycarbonate surface was exposed to the laser because the surface particles interlocked and hardened as well as the particles and free radicals re-adhered to each other. The number of traces increased during laser diode irradiation for CR-39, reaching a maximum value of 201 traces at an 8-minute irradiation time, or a 26.41 percent increase. This indicates the maximum amount of bond disintegration and free radical formation that was possible. Following this, the number of traces started to decrease, approaching the beginning of the irradiation due to recombination between the free radicals and the remaining molecules. This led to an increase in detector solidification and a decrease in trace recording.



(a)



(b)

Fig. (3) Number of tracks comparison of the detector response among the three detector types for laser irradiation (a. Diode laser, b. He-Ne laser)

As there will be no more rise in the quantity of traces, radiation should be stopped. In contrast, the CN-85 detector showed a 26.66% increase, while the LR-115 showed a 25% increase. He-Ne laser irradiation resulted in increases of 21.38% for CR-39, 25 percentage for CN-85, and 20.71% for the LR-115 detector. The response to a laser diode is higher than that of a He-Ne laser for all detectors. The radon gas in the detectors produced a track diameter of 28.10 μm without laser irradiation. The track diameter rose with increasing irradiation duration, peaking at 35.69 μm during an 8 min irradiation time, or a 27.01% increase. Whereas the rise was 25.93% for the CN-85 detector and 22.46% for the LR-115 detector. There was a 25.08% rise for CR-39, a 24.54% increase for CN-85, and a 21.12% increase for an LR-115 detector when exposed to He-Ne laser radiation. The correlation between the two lasers' effects on the detectors is as follows: for the CR-39 detector, the laser diode's irradiation has an effect 5.03% greater than that of the He-Ne laser; for the CN-85 detector, the effect is 1.66 percent greater than that of the He-Ne laser; and for the LR-115 detector, the effect is 4.29% greater than that of the He-Ne laser. According to these findings, the CR-39 detector responds more quickly than the LR-115 detector, and both detectors are significantly bigger than the CN-85 for the laser kinds that were utilized. There is a difference of 42 tracks between the minimum and maximum number of track registrations of the CR-39 detector between the two lasers on the detectors (Fig. 3a: laser diode), which is more than the 35 tracks of the LR-115 detector and the 32 tracks of the CN-85 detector. As with CR-39 being higher than LR-115 and both being higher than CR-85 detector, the comparison for (Fig. 3b: He-Ne laser) displays the same difference.

4. Conclusion

The detectors exposed to the laser led to an increase in track density and track diameter. When it comes to track registration, diameter, and types of employed lasers, the CR-39 and LR-115 detectors perform better than the CN-85. Additionally, both detectors are substantially larger. The response of all detectors to the laser diode (power 250 mW, wavelength 405 nm) is larger than the response to the He-Ne laser (power 5 mW, wavelength 632.8 nm), suggesting that the laser power has a greater effect on the detector response than the wavelength.

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