Characterization of Nuclear Tracks in Centuria Film and LR-115 (polyester based) Solid State Nuclear Tracks Detectors (SSNTDs) with Various Radiations

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Abstract

The interaction between SSNTDs (Centuria film, LR-115) and different radiations (alpha, neutron and gamma) were studied in this work. For those purposes, neutron irradiation (irradiation time, one month) from Am(Be) source with flux 10^4 neutrons $cm^{-2}s^{-1}$, alpha irradiation (irradiation time, 1 hour) from Am-241 source with activity 12µCi, gamma irradiation (25 kGy, 50 kGy, 75 kGy, 100 kGy) from Co-60 source were exposed to SSNTDs (Centuria film, LR-115). After irradiation, the tracks formed were etched with alkaline solution 10% NaOH at 60°C for 1 hour. The etched tracks in irradiated SSNTDs (Centuria film, LR-115) were observed by using optical microscope. The changes of composition of gamma irradiated SSNTDs (Centuria film, LR-115) were studied by FT IR method. The shape and distribution of tracks appeared before and after gamma irradiated SSNTDs (Centuria film, LR-115) were studied by SEM method. It was found that the shape and distribution of tracks of irradiated detectors was different due to kinds of radiation and it was found that the greater the energy, the higher the track density on all detectors (Centuria film and LR-115).

Key words: SSNTDs, Centuria film, LR-115, neutron, alpha and gamma

Introduction

Solid State Nuclear Track Detectors (SSNTDs) are well known for the detection of ionizing radiation through track formation of heavy ionizing particles. The composition, processing, and applications of SSNTDs are sufficiently discussed by many researchers. SSNTDs, particularly CR-39 and LR-115, are used to measure the ^{222}Rn and its progeny. Radon (^{222}Rn) is a radioactive gas produced as a decay product of radium (^{226}Ra). The red LR-115 type II detector (from DOSIRAD) is based on cellulose nitrate and is a commonly used solid-state nuclear track detector (SSNTD). The LR-115 type II detector is a commercially available red cellulose nitrate detector with an active layer of 12 µm on a 100 µm clear polyester base (as declared by the manufacturer). Alpha particles emitted by ^{222}Rn and its progeny hit the detector and leave the latent tracks in it. Several different techniques of track revelation are known, e.g. grafting but, the chemical etching technique is the most frequently used in which tracks can be made visible under the optical microscope after chemical amplification via etching. The passage of heavily ionizing nuclear particles through most insulating solids creates narrow paths of intense damage on an atomic scale. These damaged tracks may be revealed and made visible in an ordinary optical microscope by treatment with a properly chosen chemical reagent that rapidly and preferentially attacks the damaged material. It less rapidly removes the surrounding undamaged matrix in such a manner to enlarge the etched holes that mark and characterize the sites of the original, individual, damaged regions. The technique of Solid State Nuclear Track Detector is simple, inexpensive, employs very little electronic, and is portable. Therefore it becomes a powerful scientific tool in all scientific fields.

Centuria film

DNP Photo Marketing Co., Ltd., a wholly owned subsidiary of Dai Nippon Printing Co. Ltd. (DNP) will, from late May, launch the "Centuria Film" series of color negative film for cameras using silver halide film**.**

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LR-115

These consist of thin films of a special cellulose nitrate, coloured deep red and coated on a 100 µm thick polyester base. Only one side of these films is sensitive. The thickness of the sensitive layer of "LR-115 type II" films is 12 µm. The red sensitive layer of the Type II stripping film (strippable) must be removed from the base while it is still wet at the conclusion of the washing stage.

The LR-115 Type II plastic track detector (Manufactured by Kodak Pathe, France) has been used in present study for measurement of radon, thoron and progeny. It has maximum sensitivity for alpha particles, fission fragments and ionizing particles. The film is mainly intended for the dosimetry of small quantities of ionizing particles (mainly alpha particle) or neutron. (Tse, K.C.C., *et al*, 2007)

Experimental

Solid state nuclear track detectors

Photographic film $(C_6H_{14}O_3)_n$ Centuria Color Plus was distributed by Dai Nippon Printing Co. Ltd. (DNP), New York, USA. The LR-115 $(C_6H_8O_9N_2)_n$ type II plastic track detector was procured from DOSIRAD, France.

Interaction with neutron

SSNTD samples of Centuria film and LR-115 were cut into small pieces of 1 cm × 1 cm. The samples were irradiated with neutron from Am(Be) source with the flux 10^4 $ncm^{-2}s^{-1}$ at 3.5 cm distance from source target for one month at Nuclear Chemistry Laboratory, University of Yangon.

Interaction with alpha

SSNTD samples of Centuria film and LR-115 were cut into small pieces of 1 cm × 1 cm. The samples were irradiated with alpha from Am-241 source with 12µCi at 0.5 cm distance from source target for one hour at Nuclear Physics Laboratory, University of Yangon.

Interaction with gamma radiation

In this research, Centuria film and LR-115 were used as SSNTDs, and Co-60 was used for gamma source. Solid State Nuclear Track Detectors were cut into small pieces of 1 cm x 1 cm. These detectors were irradiated with 25 kGy, 50 kGy, 75 kGy and 100 kGy gamma radiation of Co-60 at the Department of Atomic Energy (DAE), Ministry of Education.

Preparation of etchants

To get 10% NaOH solution, 10 g of NaOH pellets (99% purity) were put into 100 mL measuring cylinder and distilled water was poured on to the NaOH pellets. Then, the solution was stirred with a glass rod until all NaOH pellets were dissolved. After that, the solution was poured into a glass beaker.

Chemical etching procedure

After the preparation of etchant, the etching procedure was done to examine the observable track parameters through the track densities. The effect of etching temperature was studied by treating the irradiated detectors at etchant temperature of 60°C. The beaker with 10% NaOH solution was heated on a water bath with temperature controller. When the temperature reached 60°C, the detector was chemically etched in 10% NaOH for 1 hour that preferentially dissolves the damage of track detector left in the path of the fission fragment. During etching, the temperature was kept constant with an accuracy of ± 1°C without stirring.

After etching, the detector was removed from etchant and washed under the running aqueous HCl (1N) for 15 mins and water until the surface of the detector become clear from etchant. Finally the detector was taken out and dried with filter paper. Then the other pieces of irradiated samples were etched in 10%NaOH solution at 60°C respectively as the same procedure.

Microscopic observation of track

Track visualization, track photographing, track counting and measuring the length of fission tracks in solid state detectors were performed by using the optical microscope. The light coming from the bottom of microscope to the detector was set to the brightest and all lens were cleaned using alcohol before capturing of images. The images 40x (400) were recorded in the JPEG format by a digital camera (OLYMPUS BX51) installed on the microscope at University' Research Centre, University of Yangon.

Results and Disscussion

The study of the interaction of Solid State Nuclear Track Detectors (Centuria film and LR-115) with neutron, alpha and gamma radiation was carried out. The characterization of nuclear tracks by neutron irradiation was found out that the formation of line and the whole tracks on Centuria film and LR-115. It can be seen in Figures 1(b) and Figure 2(b). These formations of tracks agreed well with the literature.

(a) non-irradiated

(b) irradiated

Figure 1 Photographs of centuria film with neutron from Am(Be) source (40x)

(a) non-irradiated

(b) irradiated

Figure 2 Photographs of LR-115 with neutron from Am(Be) source (40x)

The characterization of nuclear tracks by alpha irradiation was found to be the formation of line and the whole tracks on Centuria film and LR-115. It can be clearly seen in Figures 3(b) and Figure 4(b). These formations of tracks agreed well with the literature.

(a) non-irradiated

(b) irradiated

Figure 3 Photographs of centuria film with alpha from Am-241 source (40x)

(a) non-irradiated

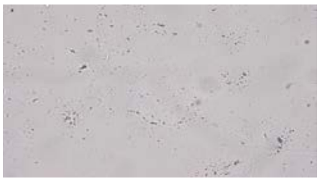
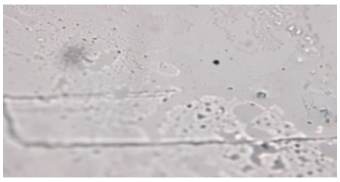
(b) irradiated

Figure 4 Photographs of LR-115 with alpha from Am-241 source (40x)

The characterization of nuclear tracks by different doses of gamma radiation (25 kGy, 50 kGy 75 kGy and 100 kGy) was found to be the formation of line and the whole tracks on Centuria film and LR-115. It can be clearly seen in Figures 5 and Figure 6. These formations of tracks agreed well with the literature. Therefore, it was found that as the gamma doses were increased the net track densities were increased. Calculated track densities are reported in Table 1 and Table 2.



(a) non-irradiated (b) 25 kGy of γ-irradiated (c) 50 kGy of γ- irradiated

(d) 75 kGy of γ-irradiated (e) 100 kGy of γ-irradiated

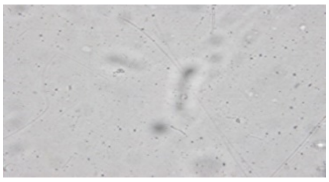
Figure 5 Photographs of centuria film detector

Table 1 Estimation of Nuclear Tracks on Centuria Film with Different Gamma Doses

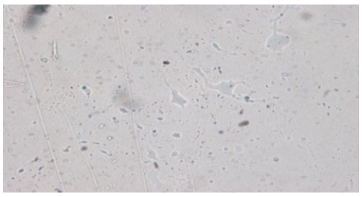
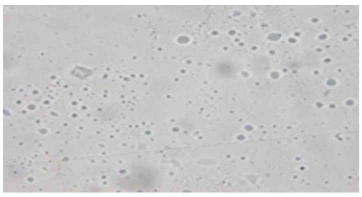
Gamma dose (kGy)	Net tracks density (tracks/cm^2)
25	$0.3055x10^4$
50	$0.4074x10^4$
75	$0.7638x10^4$
100	$1.1712x10^4$

Microscopic view area = $19.6375 \times 10^{-4} cm^2$ (40x)





(a) non-irradiated (b) 25 kGy of γ-irradiated (c) 50 kGy of γ-irradiated

(d) 75 kGy of γ-irradiated (e) 100 kGy of γ-irradiated

Figure 6 Photographs of LR-115 detector

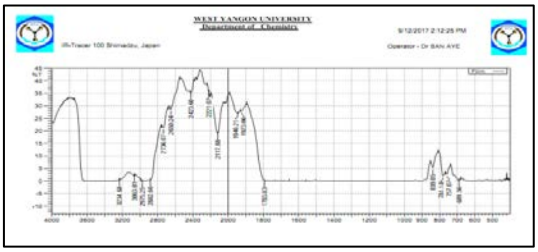
Table 2 Estimation of Nuclear Tracks on LR-115 with Different Gamma Doses

Gamma dose (kGy)	Net tracks density (tracks/cm^2)
25	$0.1528\text{x}10^4$
50	$0.4074\text{x}10^4$
75	$1.3749\text{x}10^4$
100	$1.7314\text{x}10^4$

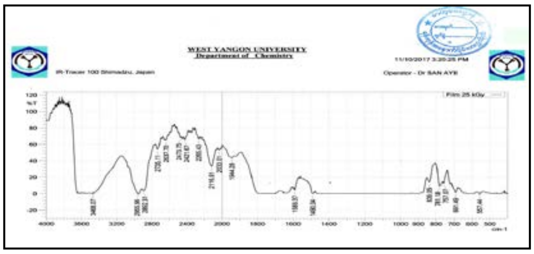
Microscopic view area = 19.6375×10^{-4}cm^2 (40x)

Studies on effect of irradiated SSNTDs by FT IR

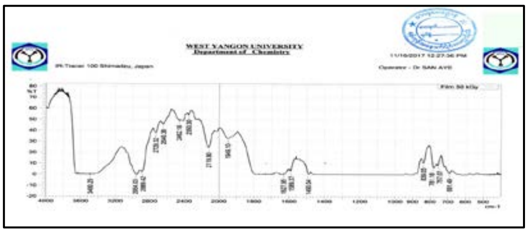
The changes of composition of non-irradiated and irradiated Centuria film and LR-115 SSNTDs were study FT IR. In this work a comparison between the effect of gamma radiation (25 kGy, 50kGy, 75kGy and 100 kGy) on the sensitivity of Centuria film and LR-115 detectors by using the FT IR spectrometer. FT IR spectrum of non-irradiated film detector is represented in Figure 7(a) and Figures 7(b), (c) and (d) are reported of gamma irradiated (25 kGy, 50kGy, 75kGy and 100 kGy) Centuria film. Figure 8 (a) shows the FT IR spectrum of non-irradiated LR-115 and Figures 8(b), (c) and (d) are presented of gamma irradiated (25 kGy, 50kGy, 75kGy and 100 kGy) LR-115. FT IR spectroscopy has been found to be an important technique to understand the changes in molecular bands after irradiation. The changes have been estimated from the relative increase or decrease in the intensity of the typical bands associated to the functional group present in the detectors. The position of absorption bands (cm^{-1}) and % transmittance value of non-irradiated and irradiated detector (Centuria film and LR-115) with different gamma are shown in Table 3 and Table 4 respectively. It was found that the wave number of functional groups in all irradiated detectors are slightly shifted by gamma radiation but there is no change in their functional groups. These solid state nuclear track detectors consist of C, H and O groups which are highly infrared active. Therefore, it can be seen the distinct characteristic peaks for functional group related with C, H and O elements. The FTIR spectra shows an overall reduction in transmittance values of highest gamma dose take place. Therefore, irradiation leads to appearance and disappearance of bands due to the decreasing transmittance value. The observations suggested that the potentiality of SSNTDs (Centuria film and LR-115) can be used as dosimeters.



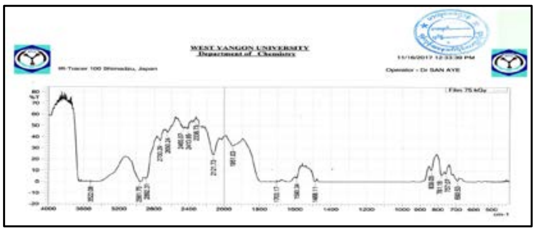
(a) non-irradiated Centuria film



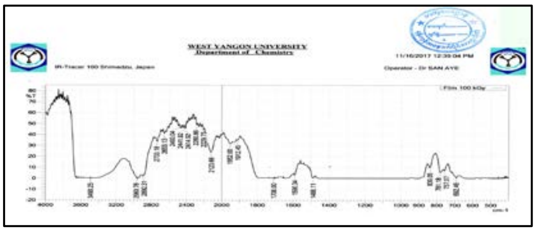
(b) irradiated with gamma 25 kGy



(c) irradiated with gamma 50 kGy



(d) irradiated with gamma 75 kGy

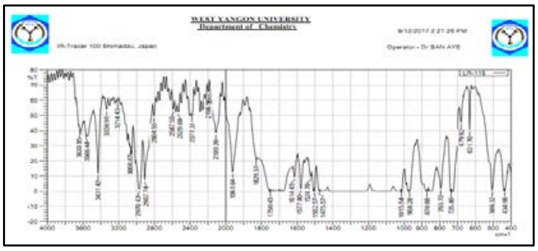


(e) irradiated with gamma 100 kGy

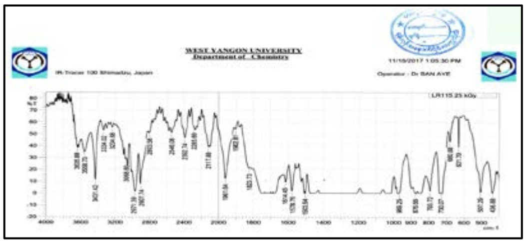
Figure 7 FT IR spectra of centuria film detector before and after irradiated with gamma and etching in 10% NaOH at 60°C for 1 hour

Table 3 FT IR Data for Centuria Film Irradiated with Gamma Doses

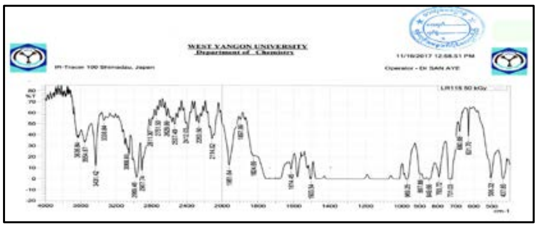
Wave number (cm^{-1})					**Transmittance (%)**				
Centuria Film	**Gamma dose (kGy)**				**Centuria Film**	**Gamma dose (kGy)**			
	25	**50**	**75**	**100**		**25**	**50**	**75**	**100**
3063	2955	2954	2961	2960	3	0	0	0	0
2736	2735	2729	2730	2733	21	52	38	36	34
2423	2421	2421	2413	2414	36	64	49	46	44
2117	2116	2119	2121	2123	19	32	24	24	22
839	839	839	839	839	5	5	5	5	5



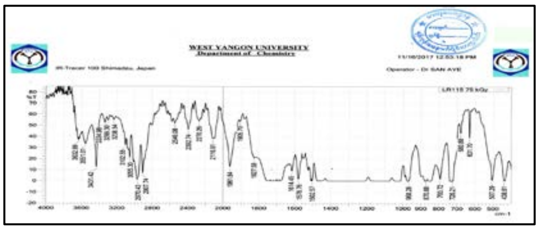
(a) non-irradiated LR-115 film



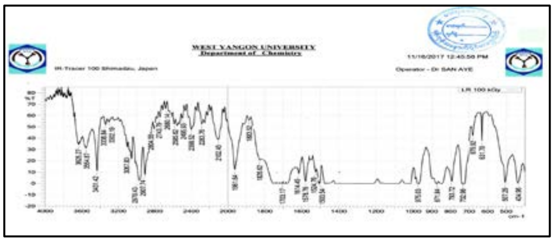
(b) irradiated with gamma 25 kGy



(c) irradiated with gamma 50 kGy



(d) irradiated with gamma 75 kGy



(e) irradiated with gamma 100 kGy

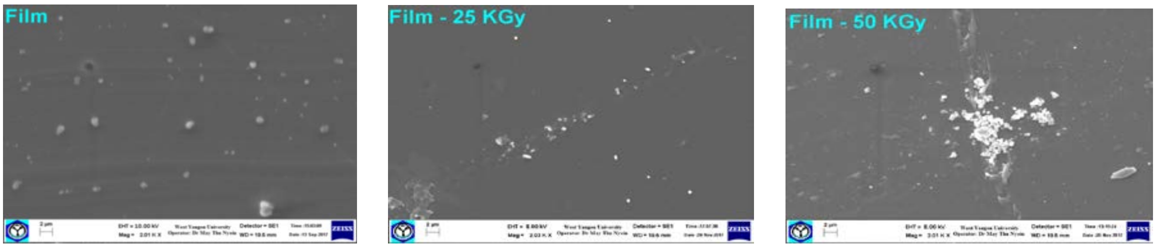
Figure 8 FT IR spectra of LR-115 film detector before and after irradiated with gamma and etching in 10% NaOH at 60°C for 1 hour

Table 4 FT IR Data for Irradiated LR-115 with Different Gamma Doses

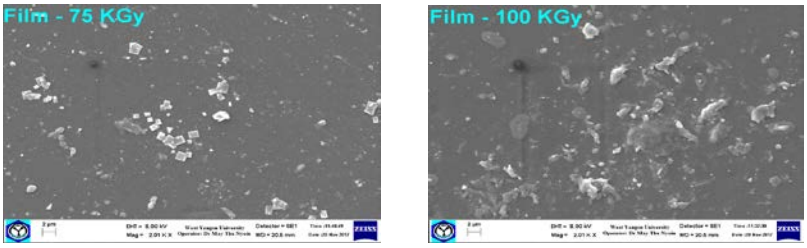
Wave number (cm^{-1})					Transmittance (%)				
LR-115	Gamma dose (kGy)				LR-115	Gamma dose (kGy)			
	25	50	75	100		25	50	75	100
3431	3431	3431	3431	3431	12	12	12	12	12
2970	2971	2969	2970	2970	1	1	1	1	1
1961	1961	1961	1961	1961	11	11	11	11	11
1577	1578	1577	1578	1578	1	1	1	1	1
793	793	793	793	793	1	1	1	1	1

Studies on effect of irradiated detectors by SEM

In this research work, SEM was used to investigate the traces shape and distribution on various SSNTDs such as mica, film and LR-115. These detectors were exposed to different does of gamma radiation (25 kGy, 50 kGy, 75 kGy and 100 kGy) from Co-60 gamma source. The representative SEM micrographs of non-irradiated detectors are shown in Figures 9 (a) and Figure 10 (a) respectively. Gamma irradiated SEM photomicrographs of Centuria film detectors are reported in Figures 9 (b), (c), (d) and (e). Figures 10 (b), (c), (d) and (e) are the gamma irradiated LR-115 of SEM photomicrographs. It was found that all of these gamma exposed detectors were different from non-irradiated detectors. The surface morphology of irradiated detectors was changed into the different surface texture. By comparing the SEM images recorded by SSNTDs with those previously reported by optical microscope, SEM images seem to be of a better quality. Therefore, SEM was recommended as one of the most appropriate technique for Solid State Nuclear Track Detectors research field.

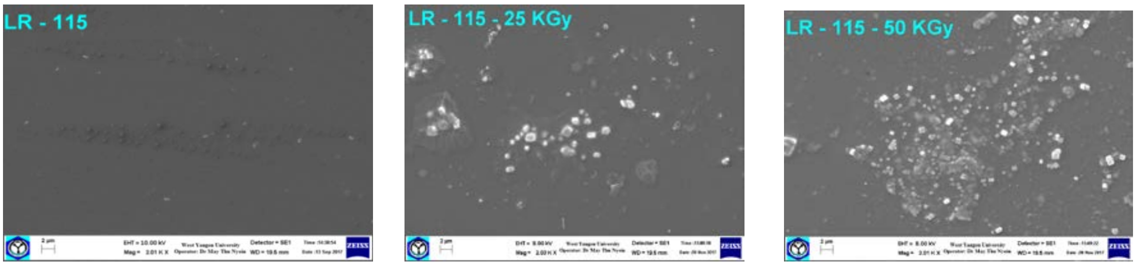


(a) before irradiation (b) irradiated with 25kGy (c) irradiated with 50kGy

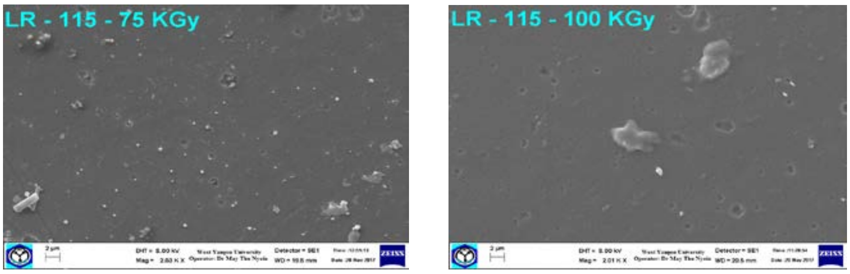


(d) irradiated with 75kGy (e) irradiated with 100kGy

Figure 9 SEM micrographs of centuria film detector before and irradiated with different gamma doses and etching in 10% NaOH at 60°C for 1 hour



(a) before irradiation **(b)** irradiated with 25kGy **(c)** irradiated with 50kGy



(d) irradiated with 75kGy **(e)** irradiated with 100kGy

Figure 10 SEM micrographs of LR-115 detector before irradiation and irradiated with different gamma doses and etching in 10% NaOH at 60°C for 1 hour

Conclusion

The present work deals with study of the Solid State Nuclear Track Detectors (Centuria film and LR-115) irradiated with neutron, alpha and gamma. The different nuclear tracks were found by different kinds of radiation (neutron, alpha and gamma). It was found that the nuclear track density was increased by increasing gamma doses. FTIR method indicated the changes of composition of SSNTDs before and after irradiation. The wave number of functional groups in all irradiated detectors are slightly shifted by gamma radiation but there is no change in their functional groups. Irradiation leads to appearance and disappearance of bands due to the decreasing transmittance value. SEM analysis was done to study the shape and distribution of tracks appeared after irradiation. From this analysis, it was clearly found that the surface morphology of irradiated detectors had changed into different surface texture. By comparing the SEM images were recorded by SSNTDs with those previously reported by optical microscope, SEM images seen to be of a better quality. Therefore, SEM was recommended as one of the most appropriate technique for SSNTDs.

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