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RESEARCH ARTICLE

MEASUREMENT OF THE THICKNESS OF THE REMOVED ACTIVE-LAYER OF CELLULOSE NITRATE CN-85(LR-115, TYPE II) SOLID STATE NUCLEAR TRACK DETECTOR

***Khan, M. S. A.**

Department of Physics, Gandhi Faiz-e-Aam College, Shahjahanpur-(U.P.)-242001
Affiliated to M.J.P. Rohilkhand University, Bareilly (U.P.), India

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Corresponding author:* **Khan, M. S. A.

ABSTRACT

The measurements of the thickness of the removed active layer of a cellulose nitrate-85 (LR-115, type II) detector have been carried out by using surface profilometry method through Fourier transform infrared (FTIR) system with the spectroscopic wave number at 1598 cm^{-1} corresponding to the O–NO_2 bond of a CN-85 (LR-115, Type II) SSNTD. Due to chemical reaction between the etching solution (etchant) and the detector material, some molecules of the detector are removed. The final effect is the removal of the material from the detector surface. During etching, the material is removed layer by layer and the thickness of the detector becomes smaller and smaller. It was found that the bulk etch rate or removed active layer of CN-85 (LR-115, Type II) detector could not controlled by temperature easily during chemical etching and is significantly affected by the presence and amount of stirring. Therefore actual layer monitoring of the active layer thickness is necessary when using CN-85 (LR-115, Type II) solid state nuclear track detector (SSNTD). For the standard etching condition of CN-85 (2.5 N aqueous solution of NaOH kept at 60 ^{0}C temperature) detectors, the bulk etched rate under magnetic stirring and no stirring condition was found respectively 6.61± 0.33 μm h^{-1} and 3.59 ± 0.12 μm h^{-1}. Also there is some variation have been found in the initial thickness of the active layer in CN-85 (LR-115, type II) detector of 12 μm.

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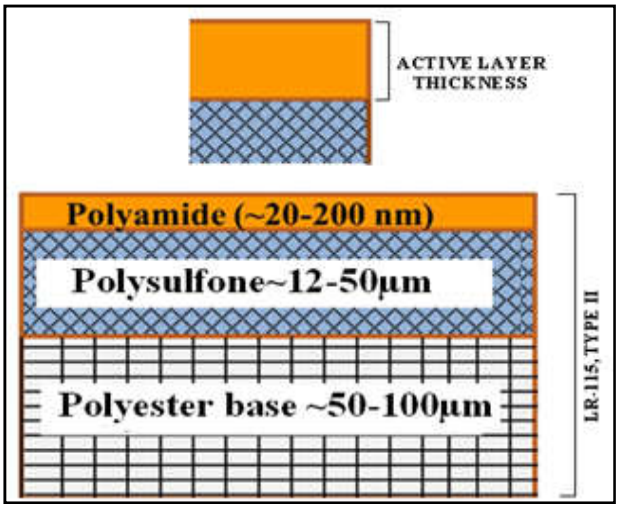
INTRODUCTION

Radon is present in trace amounts almost everywhere on the earth, being distributed in the soil, the groundwater and in the lower atmosphere. Radioactive radon can migrate from soils and rocks and accumulate in surrounding enclosed areas such as homes and underground mines. It is important that sources of radon as well as radon infiltration mechanisms be understood before making attempts to control the indoor radon. Recent epidemiological evidence suggests that inhalation of radon decay products in domestic environments could be a cause of lung cancer (ICRP, 1993; UNSCEAR, 1993; Lubin *et al.* 1995; NRC, 1999; WHO, 2007, 2008). It gives rise to considerable awareness of the ^{222}Rn problem. Various methods are available for the measurement of radon (^{222}Rn) concentrations by using the solid state nuclear track detector (SSNTD), LR115.The alpha particles emitted by radon and its progeny strike the detector leaving a track within the film called latent track. The tracks produced in the detector film can made visible by using etching process called chemical etching.CN-85(LR-115, type II) plastic detector is considered more suitable and more advantageous than other commonly used solid state nuclear track detector as CR-39. Due to chemical reaction between the etching solution (etchant) and the detector material, some molecules of the detector are removed. The final effect is the removal of the material from the detector surface. During etching, the material is removed layer by layer and the thickness of the detector becomes smaller and smaller. Yip *et al.,* (2003a) showed that for the CN-85 (LR-115, Type II) detector, the bulk etch rate or removed active layer could not controlled by temperature easily during chemical etching and is significantly affected by the presence and amount of stirring(Yasuda et. al, 1998). Therefore actual layer monitoring of the active layer thickness is necessary when using CN-85 (LR-115, Type II) solid state nuclear track detector (SSNTD). Various methods have been used to measure the thickness of the removed active layer of the detector CN-85 (LR-115, Type II). Nikezic *et al.* (1997 & 2002) proposed a new method to measure the thickness of the removed active layer called surface profilometry method. The same method was also used by us. But there is some draw back with this method because it is a destructive method and can be used only after the completion of etching. Yip et al. (2003b) proposed a non-destructive method to measure the active layer thickness of LR 115 SSNTD. This method was based on the absorption of fluorescence x-ray photons by the active layer. But there is a some risk also with this method because the x-ray radiation affects the track and bulk etching velocities. In the present work the thickness of the removed active layer of CN-85 (LR-115, Type II) SSNTD was measured by IR absorption method (Barillon *et al.,* 2002).

Experimental technique

The alpha sensitive plastic track detector CN-85(LR-115, Type II) manufactured by Kodak Pathe, France, has been used in present investigation for integrated measurement of active layer thickness. It is a 12 µm thick film red dyed cellulose nitrate emulsion coated on inert polyester base of 100 µm thickness and has maximum sensitivity for alpha particles, fission fragments and ionizing particles with high enough LET. The upper threshold energy in CN-85(LR-115, type II) which produces the tracks as through holes, is 4.8 MeV (Abu-Jarad *et al.,* 1980). The film can be used to record the tracks of protons with energy 100 KeV. However, it is insensitive to X or γ-rays, photons, electrons and high-energy protons. For fast neutrons, it has low detection efficiency (10.5 track/neutron) (Khan, 1975). The detection efficiency of alpha particles for the detector at normal incidence is about 50% for energies between 1.5 MeV and 4.8 MeV (Damkjaer, 1986; Nakahara *et al.,* 1980; Ramola *et al.,* 1996). A total of twelve pieces of size 2.5cm×2.5cm of CN-85(LR-115, type II) SSNTD was used for the experiment. A view of CN-85(LR-115, type II) detector with active layer is shown in the Figure 1.



Before etching, a small portion of the red cellulose nitrate layer was first removed by a blade or razor to expose the colorless polyester base (Gruhn *et al.,* 1974). After that the removed SSNTDs were carried out in an aqueous solution of sodium hydroxide (NaOH) in concentration of molarity 2.5N for etching in an etching bath at a temperature of 60^0C. The molarity of the etchant and temperature of etching are important parameters of the etching conditions. Also the etching time varies according to the etching conditions (Enge *et al.,* 1974). After the completion of etching periods, the detectors was removed and then washed with distilled water and drying few minutes in air. After drying a few minutes in the air, the detectors with active layer were carried out in a laboratory for scanning. The scanning was done by FTIR spectroscopy system with the spectroscopic wave number at 1598cm^{-1} corresponding to O-NO_2 bond of a CN-85 (LR-115, Type II) SSNTD. The scanned diameter of the removed active layer detector film was found 0.9cm or radius 0.45cm (Somogyi *et al.,* 1973). Therefore the scanned area of the removed active layer detector film. Therefore the scanned area of the removed active layer detector film was 0.64cm^2(Area= πr^2=3.14×0.45×0.45=0.64cm^2). The wave number 1598cm^{-1} is most sensitive to the thickness of the removed active layer. A spectrum showing the variation of the IR transmittance in percentage with the wave number at 1598cm^{-1} would be generated by the FTIR spectroscopy system after scanning. After the completion of FTIR measurements, the thickness of the removed active layer was revealed by surface profilometry measurements. A profilometer is a measuring instrument used to measure a surface profile, in order to quantify its roughness, surface texture, surface waviness, surface step height, deposited thin film thickness, and so on by means of contacting and scanning a sharp stylus with a very small measurements force less than mN. The measuring system is based on a laser interferometric transducer. A computer-controlled stylus passes slowly across a surface of the detector film during measurements. The data are processed by the computer to generate an output graph showing the profile of the scanned surface.

RESULTS AND DISCUSSION

The thickness of the removed active-layer for CN-85 (LR-115, type II) detectors measured by surface profilometry and the corresponding IR transmittance are given in the table 1.

Table 1. Observed values of removed active layer thickness and corresponding FTIR transmittance

FTIR Transmittance (%)	Thickness of the removed active layer (µm)
5.35	10.05
6.00	9.29
6.50	8.74
7.85	7.43
8.15	7.16
9.00	6.46
10.00	5.73
11.15	4.98
12.00	4.49
12.75	4.12
13.87	3.58

There is an anti-correlation have been found between the two variables. If x is the Infrared transmittance in percentage and y is the thickness of the removed active layer measured by surface proflometry in micrometer (µm), then the exponential decay relationship between the two variables x and y is given as

$$y = A \exp(-Bx)$$

Where A and B are the two parameters. By best fitting the above exponential decay relationship to the experimental data, we have A=19.2±0.4 and B=0.121±0.004 with R^2=0.9874, where the value of R^2 was given by relation as

$$R^2 = (A-B) / (A+B)$$

The variation between the thickness of the removed active-layer for CN-85 (LR-115, type II) detectors and the corresponding IR transmittance is shown in Figure 2. The above exponential relationship for a large value of R^2 and the narrow 95% confidence band demonstrate that the thickness of the removed active layer for CN-85 (LR-115, type II) detectors can be satisfactorily reflected by the IR transmittance. The above observed fit to be valid only for the thickness of the active layer between the ranges from 5.6 µm to 11.3 µm. For the beast or standard etching conditions of a CN-85 (LR-115, type II) detectors (2.5 N aqueous solution of NaOH kept at 60 ^{0}C), the bulk etch rate was found to be 6.61± 0.33 µm h^{-1} under magnetic stirring where as 3.59 ± 0.12 µm h^{-1} (Ho et. al. 2002.2003; Yip *et al.* (2003a) under no stirring conditions.

Although, there is some variations have been found in the active layer thickness as compared to the initial thickness of the active layer in CN-85 (LR-115, type II) detector of 12 µm. A graph representing the relationship between the thicknesses of the removed active-layer for CN-85 (LR-115, type II) detectors measured by surface profilometry and the corresponding FTIR transmittance in percentage at the wave number 1598 cm^{-1} is shown in the figure 2. The graph shows the best fitting of the exponential decay curve represented by y = A exp (−Bx) with the parameters A and B.

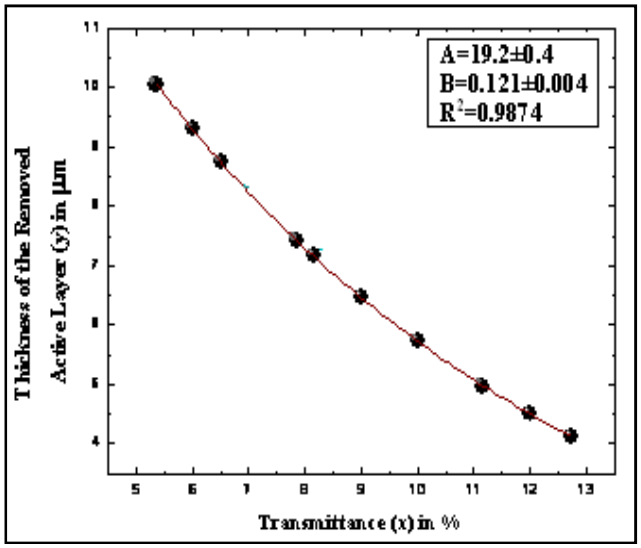


Figure 2. Variation of removed active layer thickness with transmittance

Conclusion

Surface profilometry method has been used to measure the thickness of the removed active layer of the CN-85 (LR-115, type II) detectors. The active layer thickness for the CN-85 detectors and the corresponding FTIR transmittance are given in the table 1.For the standard etching condition of CN-85 (2.5 N aqueous solution of NaOH kept at 60 ^{0}C temperature) detectors, the bulk etched rate under magnetic stirring and no stirring condition was found respectively 6.61± 0.33 µm h^{-1} and 3.59 ± 0.12 µm h^{-1}. It was also found that the initial thickness of the active layer might not be exactly the same but its thickness may also be varies.

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