The Government of the Union of Myanmar
Ministry of Education

Department of Higher Education (Lower Myanmar)
and
Department of Higher Education (Upper Myanmar)

Universities Research Journal

Vol. 1, No. 3 December, 2008.

Universities Research Journal 2008
Vol. 1, No. 3

Prof. Dr. Than Win, Head of the Department of Physics, University of Myeik
Prof. Swe Swe Yi, Head of the Department of Physics, University of Monywa
rof. Dr Thet Thet, Head of the Department of Physics, Mandalay University of Distance Education
Prof . Dr. May Yee Thein, Head of Physics Department, University of Panglong
Prof. Dr. Soe Soe Nwe, Head of the Department of Physics, University of Lashio
Prof. Dr. Khin May Oo, Head of Department of Physics, Myinchan Degree College

Contents

Study on the Number of Alpha Tracks and Pore Diameters Based on Annealing Method

Mya Mya Win

Abstract

The present research work concerns the study of annealing effect in Solid State Nuclear Track Detectors, LR-115 type I and II. By using annealing method, diameters and number of alpha tracks of these detectors are measured using optical microscope (Nikon Eclipse 50i). Recording of the alpha tracks and their densities in LR-115 type I and II were carried out and alpha pore diameters were also measured. It is observed that the Poisson distribution (frequency distribution) for different values of pore diameters are similar to the Gaussian distribution.

Key words: LR-115 SSNTDs, Alpha tracks, Annealing effect

Introduction

SSNTDs can be divided into two categories: (i) Organic detectors and (ii) inorganic detectors. Plastics are included in organic detectors while all other detectors, such as glasses, minerals etc, fall under the second category. Plastics are found most sensitive among these detectors. SSNTDs have found a wide range of applications viz., nuclear physics, particle physics, dosimetry, geology, geochronology and exploration, medicine etc. One such application of technological significance lies in their use as Nuclear Track Filters (NTFs) (Kalsi, 2005).

The Structure of Red Cellulose Nitrate LR- 115 Type I and Type II

One of the most commonly used SSNTDs is the LR-115 detector. It consists of thin films of cellulose nitrate, red color coated on a 100 μm thick polyester base. Only one side of these films is sensitive in Fig (1.a & b). There are two types of LR-115. The thickness of the sensitive layer of type I film is about 6 μm that of type II film is about 10μm. In this research work LR 115 type I and II films were used. Applications of LR- 115 films are:

(i) Detection and dosimetry of thermal and epithermal neutrons.

(ii) Detection and dosimetry of fast neutrons.

(iii) Auto radiography of alpha radioactive objects (Price, 1978)

Professor and Head, Department of Physics, Hinthada University

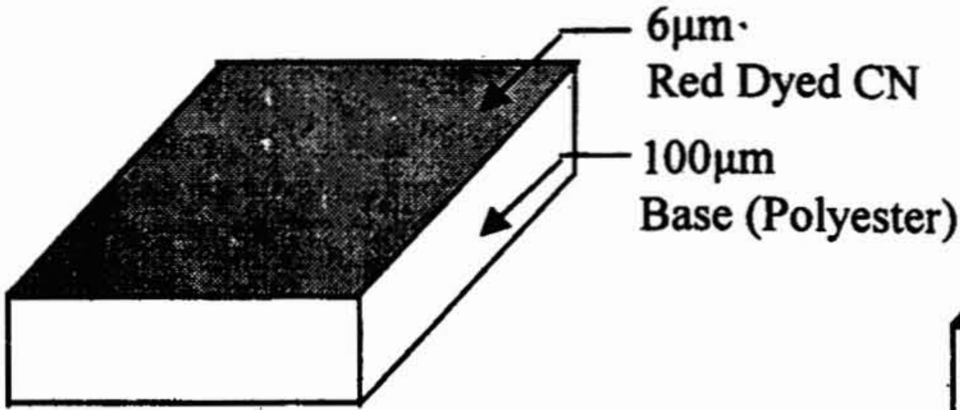

Figure 1(a). The structure of LR-115 Type I Cellulose Nitrate

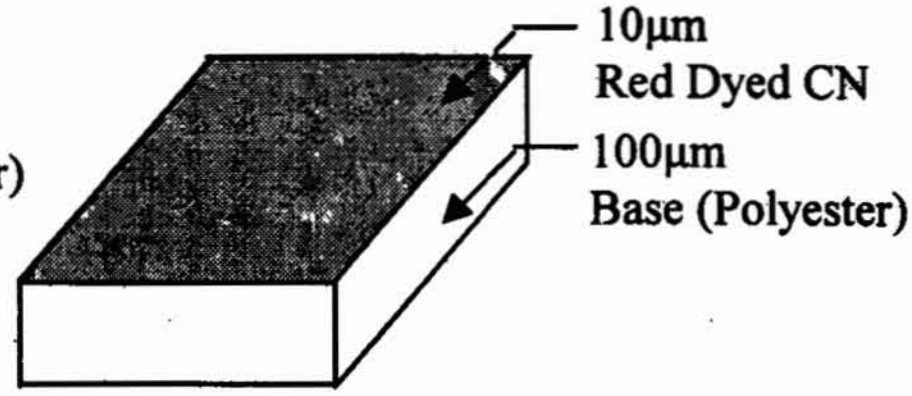

Figure 1(b). The structure of LR-115 Type II Cellulose Nitrate

Materials and Methods

The technique of SSNTDs is based upon the damage created in an insulating solid along the path of a heavily ionizing particle such as alpha particle or a fission fragment. The damage along the path, called a track, may become visible under an ordinary optical microscope after etching with suitable chemical. The visible tracks are counted either by direct observation by a human or with the help of automated instruments. The best means of observing the tracks is by etching the SSNTD material with a chemical that preferentially attacks the damaged material and enlarges the original track. It is believed that the damaged region is preferentially attacked because it is more active chemically than the surrounding undamaged region. This is a result of the free energy associated with the disorders created along the trajectory of the particle. After etching, the track is enlarged because the chemical attacks the surface of the SSNTD and the interior surface of the original track and creates a conical hole.

Track Formation Models

Many models have been proposed to explain the mechanism of track formation. Several track formation models are (i) Direct atomic displacement model, (ii) Thermal spike model, (iii) Ion explosion spike model, (iv) Primary ionization model, (v) Restricted energy loss model, and (vi) Katz and Kobetich model.

Ion Explosion Spike Model

For inorganic solids like glasses and minerals, the ion explosion spike model has been advanced. This model was discovered by Fleischer and Price in 1965. This model suggests that a cylindrical region of positive charge particles due to ejection of electrons, and that the mutual repulsion of the remaining heavy positive ions results in atomic displacement in the crystal lattice (Fig. 2, 3 & 4). This process causes a cylindrical region of imperfections that is more easily attacked by an etching reagent than the surrounding undamaged material. The process ultimately leads to microscopically visible etch pits or tracks. According to this model, the burst of ionization along the path of a charged particle created an electrostatically unstable array of adjacent positive ions, which eject one another from their normal sites into interstitial positron. Attempts at applying the ion explosion spike mechanism to the formation of etchable tracks in the much more sensitive organic polymers have not been successful, mainly because such a model implies that the ionization produced by delta electron is irrelevant to track formation (Spohr, 1990).

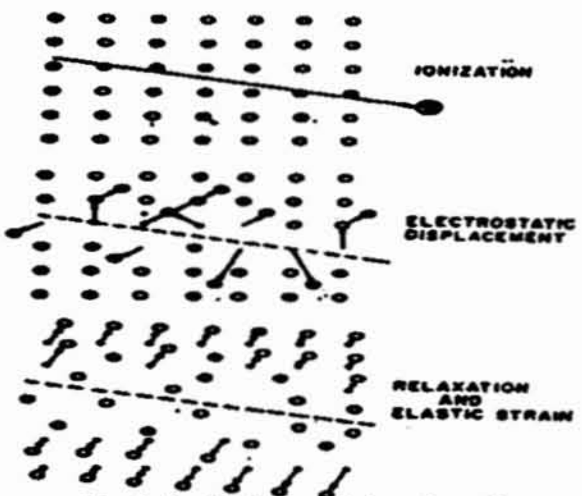

Figure 2. (a) Original ionization; (b) Electrostatic displacement (c) Relaxiation & Elastic strain

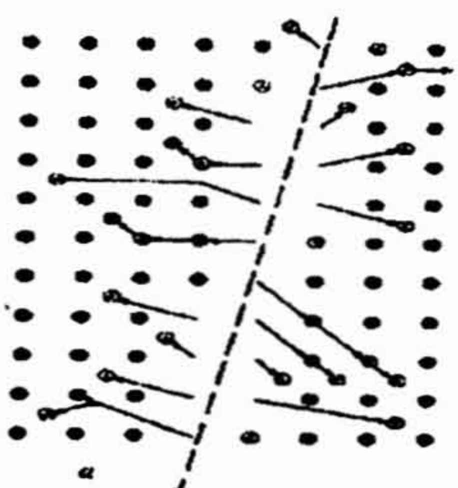

Figure 3. The mechanism of ion explosion spike model for track

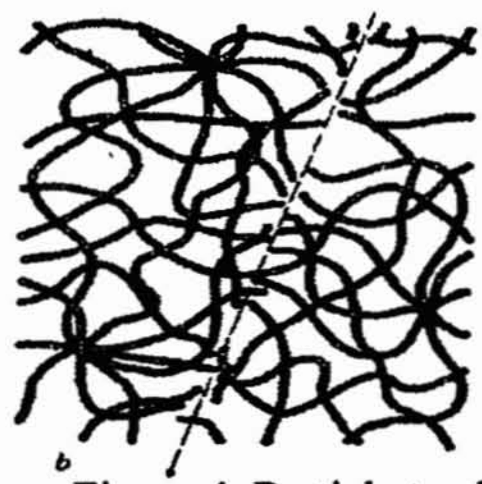

Figure 4. Particle track formation mechanism (radiochemical damage mechanism) in a polymer

Fundamental Shapes of Etched Tracks

Three types of tracks can be recorded on SSNTDs is shown in Fig. 5. (Singh, 1989) They are:

(1) Single-ion tracks

(2) Non-overlapping tracks

(3) Overlapping tracks

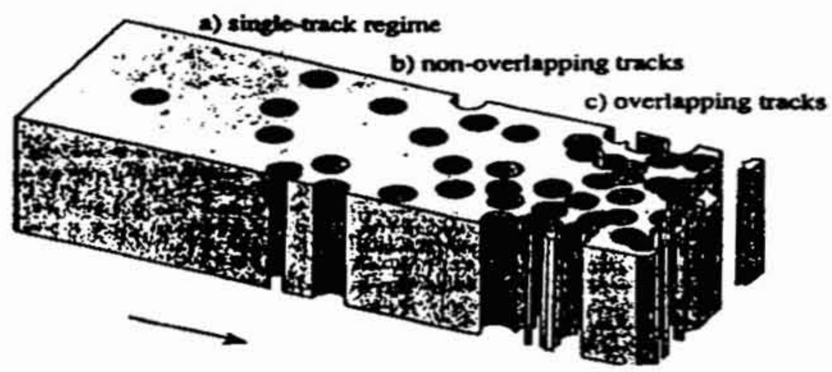

Figure 5. Three types of tracks

Application of SSNTDs

Solid State Nuclear Track Detectors have found many applications in various fields of physics and other branches of science. Apart from measurements of indoor radon and progeny concentrations, there are many other applications. (http:// www.2.i.j.s. 2002)

The Detection Area of the SSNTDs

Solid State Nuclear Track Detectors (SSNTDs) have found various applications in myriad of fields of science and technology from high energy particle physics to generation of nano / micro structures and nano - particles encompassing nano - technology in to their folds.

The following low cost experiments can be performed using solid state nuclear track detectors.

1. Alpha, fission fragments track recording
2. Nuclear statistics
3. Range and half-life measurements
4. Auto radiography techniques
5. Filtration characteristics (Chakarvarti, 2001)

Some interesting experiments for the students of botany and zoology have also been suggested.

Activation Processes in Track Annealing

The repair of the complicated atomic structure of a particle track is governed by a complicated series of atomic processes. In the simplest case, pieces of a solid containing tracks are heated at a series of temperature (T) and the time (t) for total fading at each temperature is determined. Since the result normally fits a Boltzmann's equation of the form $t = A \exp (E_{act}/kT)$, an energy of activation (E_{act}) for total fading can be determined. Partial removal is often the result of heating for times that are less than times for complete erasure. Useful environmental effect on particle tracks has been the annealing of tracks. Track fading can be caused by a high-temperature event of short duration (Fleischer, *et al.,* 1975).

Experimental Measurements

Etching and Annealing of LR-115 Detectors for Present Work

Chemical etching and annealing of particle tracks depend upon the nature of SSNTD and the types of tracks (fission track, alpha track).

In this work to enlarge the size of particle tracks in LR -115 detectors caused by alpha particle, 6.5N NaOH was used as etchant.

Before etching, some of pieces of LR-115 detectors were annealed with klain at URC (Universities' Research Centre) in different temperatures.

Again, the detectors were taken out from the etchant and washed and dried.

Measurement Conditions

Detector	:	SSNTDs LR-115 Type I and II Cellulose Nitrate
Source	:	^{241}Am
Irradiation time	:	1 second in 2π geometry.
Etchant	:	6.5N NaOH at 50°C, without stirring
Etching time	:	60 min, 90 min, 120 min
Annealing time	:	1 hr
Annealing temp:	:	60°C, 80°C, 90°C, 100°C, 110°C
Microscope	:	Nikon Eclipse 50i with Digital Camera (Fig.6)

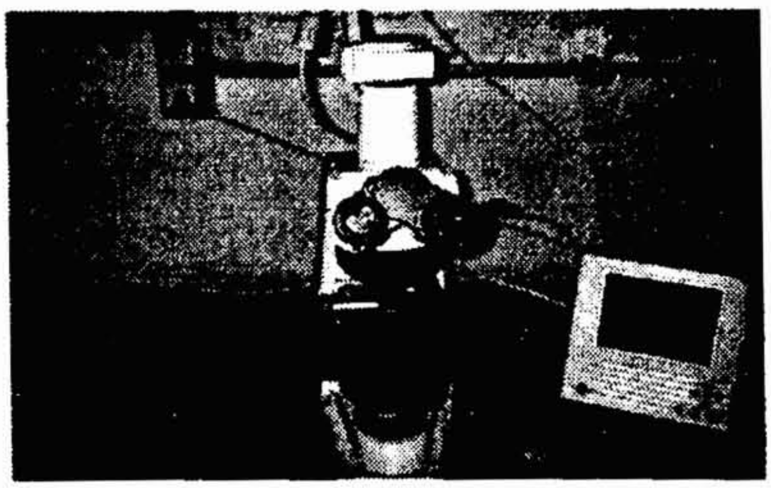

Figure 6. Nikon Eclipse 50i microscope, DS camera head D5-5M and camera control unit DS-L1

Track Counting and Measuring Diameters

Track counting and measuring were performed by using an optical microscope (100 x magnifications) attached with DS camera and camera control unit (Fig. 7 & 8). The track density was calculated from the following equation (Ng F.M.F., *et al.*, 2004).

$$\text{Track density} = \frac{no.of tracks}{microscopic view area}$$

It can be found that the number of track distribution is similar to Gaussian distribution. Detailed histogram figures for both LR-115 Type I and II are given in Fig.7 and 8.

Figure 7. Photomicrograph of alpha tracks in LR-115 Type I detectors (with annealing temperature 90°C, etching time 90min)

Figure 8. Photomicrograph of alpha tracks in LR-115 Type II detectors (with annealing temperature 90°C, etching time 90min)

Table 1. Data of number of tracks vs. pore diameter (without annealing temperature, etching time 90 min) for LR-115 Type I detector.

Sr.	Pore diameter (μm)	No. of tracks
1	-	-
2	0.50-0.75	26
3	0.75-1.00	28
4	1.00-1.25	47
5	1.25-1.50	124
6	1.50-1.75	157
7	1.75-2.00	232
8	2.00-2.25	120
9	2.25-2.50	94
10	2.50-2.75	49
11	2.75-3.00	-
12	3.00-above	-

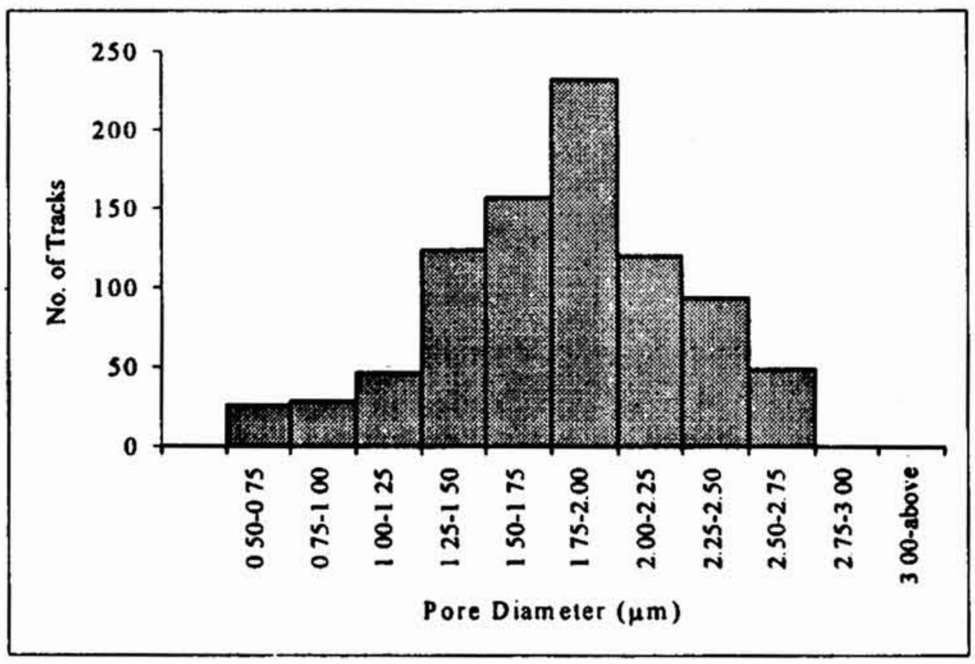

Figure 9. Histogram of the observed no. of tracks vs. pore diameter at LR-115 Type I (without annealing, etching time 90 min).

Table 2. Data of no. of tracks vs. pore diameter (without annealing temperature, etching time 90 min) for LR-115 Type II detector.

Sr.	Pore diameter (μm)	No. of tracks
1	0.5-1.0	-
2	1.0-1.5	67
3	1.5-2.0	145
4	2.0-2.5	350
5	2.5-3.0	444
6	3.0-3.5	682
7	3.5-4.0	343
8	4.0-4.5	255
9	4.5-5.0	190
10	5.0-5.5	149
11	5.5-6.0	121
12	6.0-6.5	90
13	6.5-7.0	48

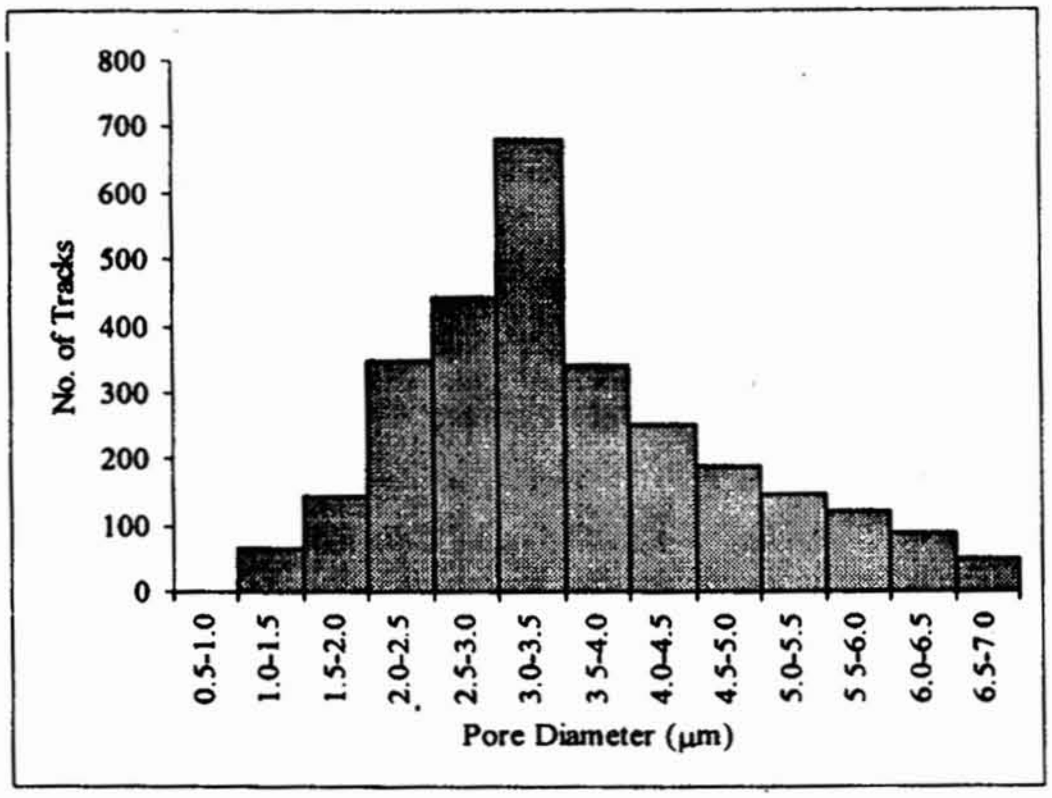

Figure 10. Histograms of the observed no. of tracks vs. pore diameter at LR- 115 Type II (without annealing, etching time 90 min)

Table 3. Data of no. of tracks vs. pore diameter (with annealing temperature 90°C, 60 min) for LR-115 Type I detector

Sr.	Pore diameter (μm)	No. of tracks
1	-	-
2	0.50-0.75	2
3	0.75-1.00	10
4	1.00-1.25	42
5	1.25-1.50	70
6	1.50-1.75	101
7	1.75-2.00	111
8	2.00-2.25	46
9	2.25-2.50	26
10	2.50-2.75	6
11	2.75-3.00	-
12	3.00-above	-

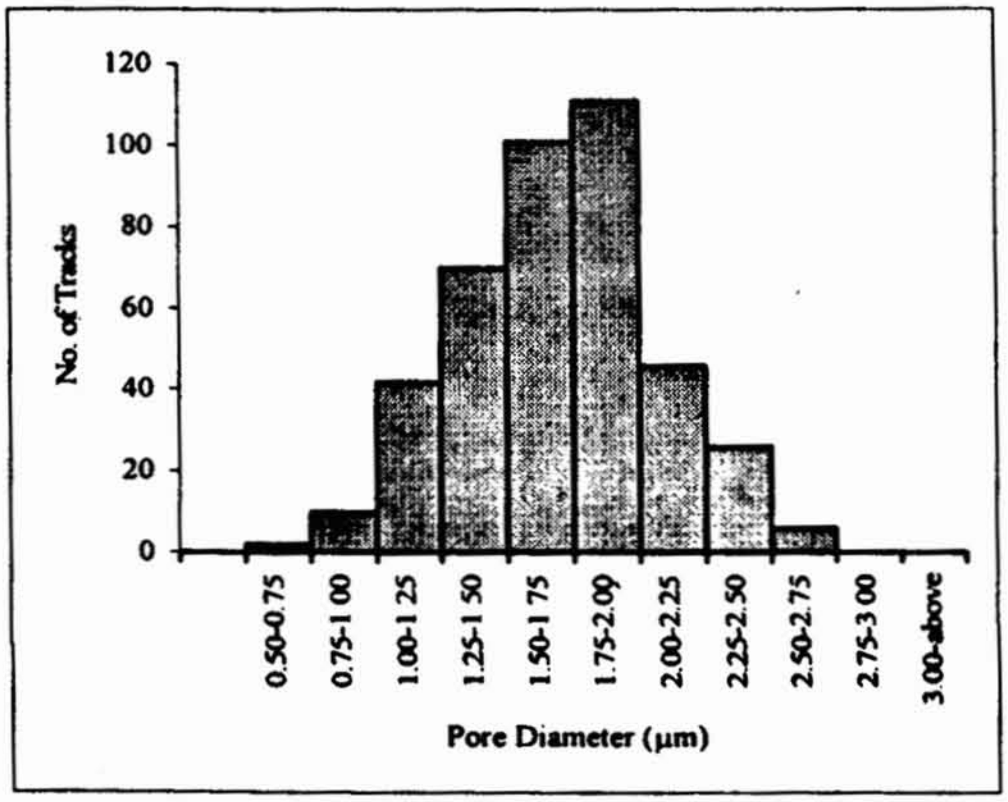

Figure 11. Histograms of the observed no. of tracks vs. pore diameter at LR-115 Type I (at annealing temperature 90°C, etching time 60 min)

Table 4. Data of no. of tracks vs. pore diameter (with an annealing temperature 90°C, 60 min) for LR- 115 Type II detector

Sr.	Pore diameter (μm)	No. of tracks
1	-	-
2	0.5-1.0	30
3	1.0-1.5	68
4	1.5-2.0	432
5	2.0-2.5	440
6	2.5-3.0	619
7	3.0-3.5	349
8	3.5-4.0	238
9	4.0-4.5	94

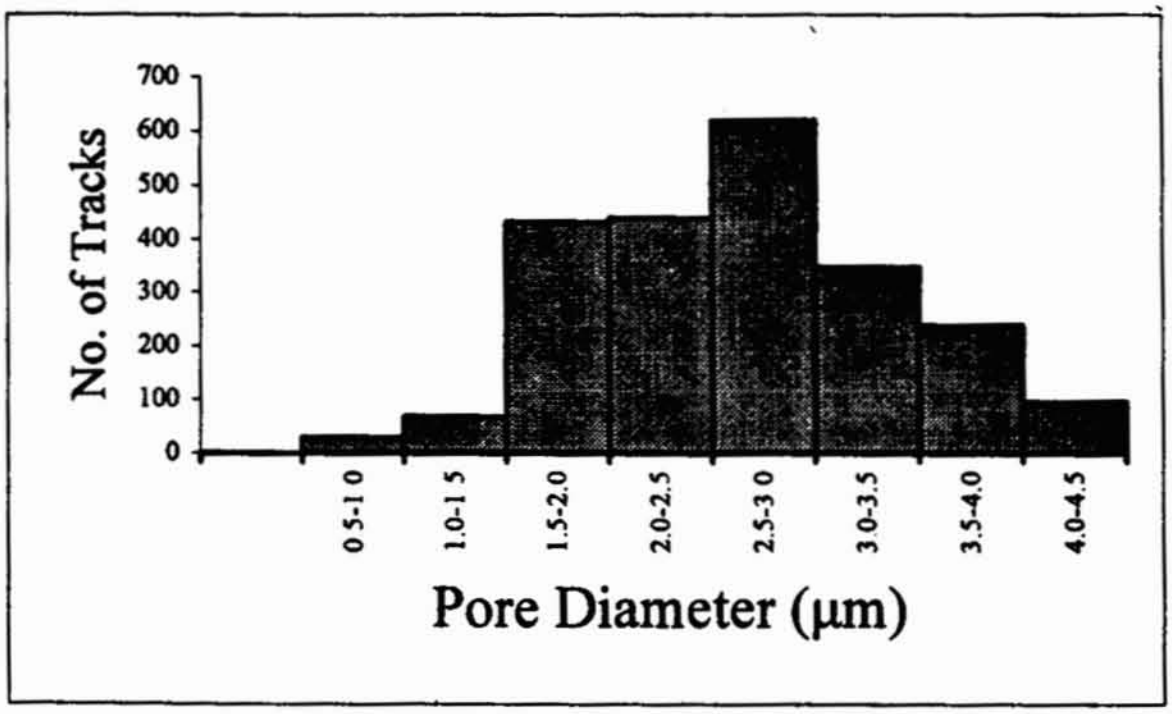

Figure 12. Histograms of the observed no. of tracks vs. pore diameter at LR- 115 Type II (at annealingtemperature 90°C, etching time 60 min)

Table 5. Data of no. of tracks vs. pore diameter (with an annealing temperature 90°C,120 min) for LR-115 Type I detector

Sr.	Pore diameter (μm)	No. of tracks
1	0-0.2	-
2	0.2-0.4	13
3	0.4-0.6	53
4	0.6-0.8	55
5	0.8-1.0	-
6	1.0-1.2	14
7	1.2-1.4	12
8	1.4-1.6	11
9	1.6-1.8	1
10	1.8-2.0	-

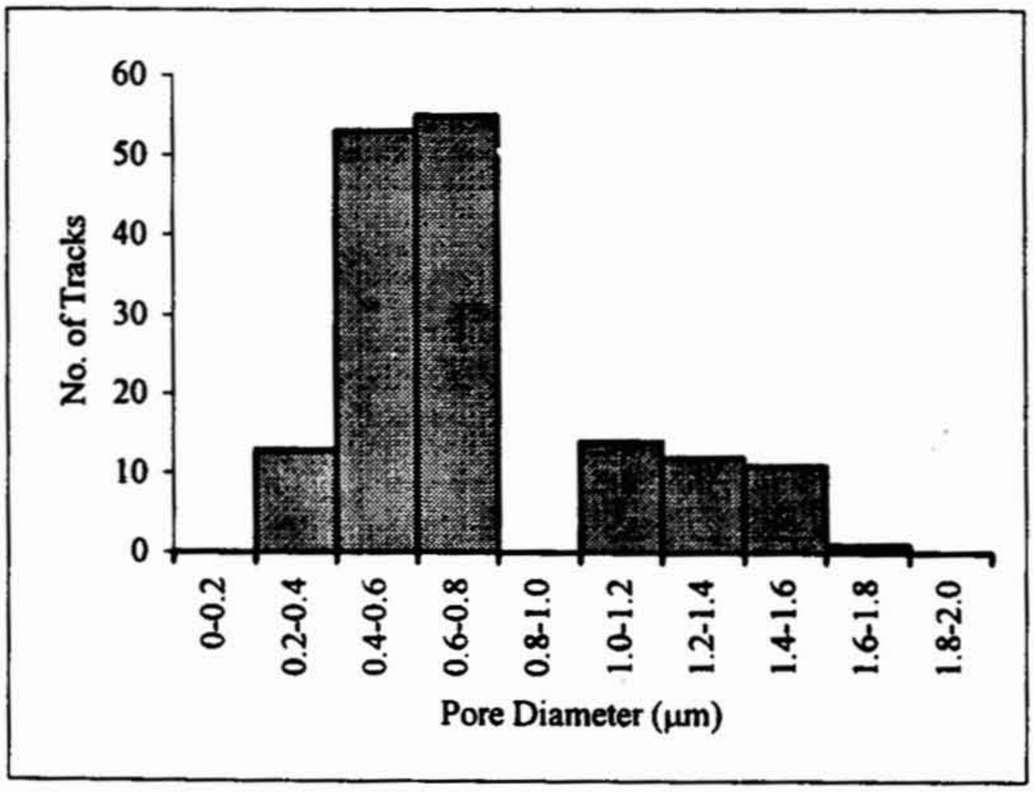

Figure 13. Histograms of the observed no. of tracks vs. pore diameter at LR- 115 Type I (at annealing temperature 90°C, etching time 120 min)

Table 6. Data of no. of tracks vs. pore diameter (with an annealing 90°C, 120 min) for LR -115 Type II detector

Sr.	Pore diameter (μm)	No. of tracks
1	0.5-1.0	-
2	1.0-1.5	-
3	1.5-2.0	274
4	2.0-2.5	757
5	2.5-3.0	1281
6	3.0-3.5	971
7	3.5-4.0	725
8	4.0-4.5	133
9	4.5-5.0	-

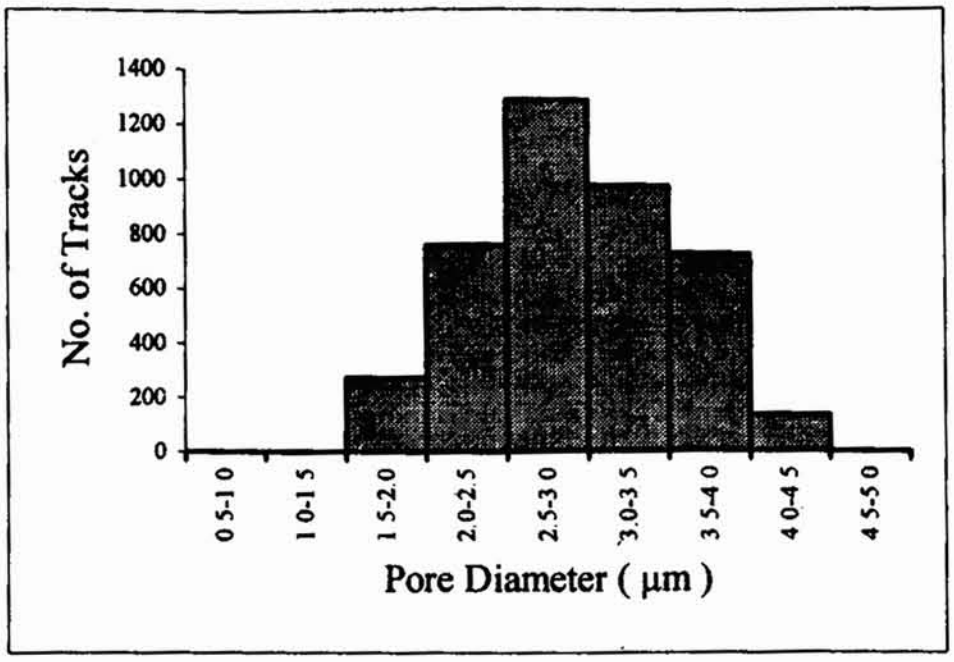

Figure 14. Histograms of the observed no. of tracks vs. pore diameter at LR- 115 Type II (at annealing temperature 90°C, etching time 120 min)

From the results, mentioned in Table 7 & 8 (Fig.15 &16), it was found that the values of track length of LR-115 type II at annealing temperature 90°C varied slightly although etching times were changed. The track length variation is very negligible. From this extent LR-115 type II is much more appropriate to be utilized.

Table 7. Comparison of track lengths for various annealing temperature in LR-115 SSNTD Type I

Sr.	Annealing temperature °C	Track length (μm)		
		Etching time 60 min	Etching time 90 min	Etching time 120 min
1	0	1.23± 0.13	2.57± 0.23	6.34± 0.72
2	60	0.98± 0.10	2.24± 0.22	5.04± 0.53
3	80	1.58± 0.13	2.83± 0.29	3.63± 0.35
4	90	1.65± 0.25	2.82± 0.28	3.79± 0.25
5	100	1.98± 0.18	2.80± 0.27	3.98± 0.04
6	110	-	0.15± 0.01	1.32± 0.00

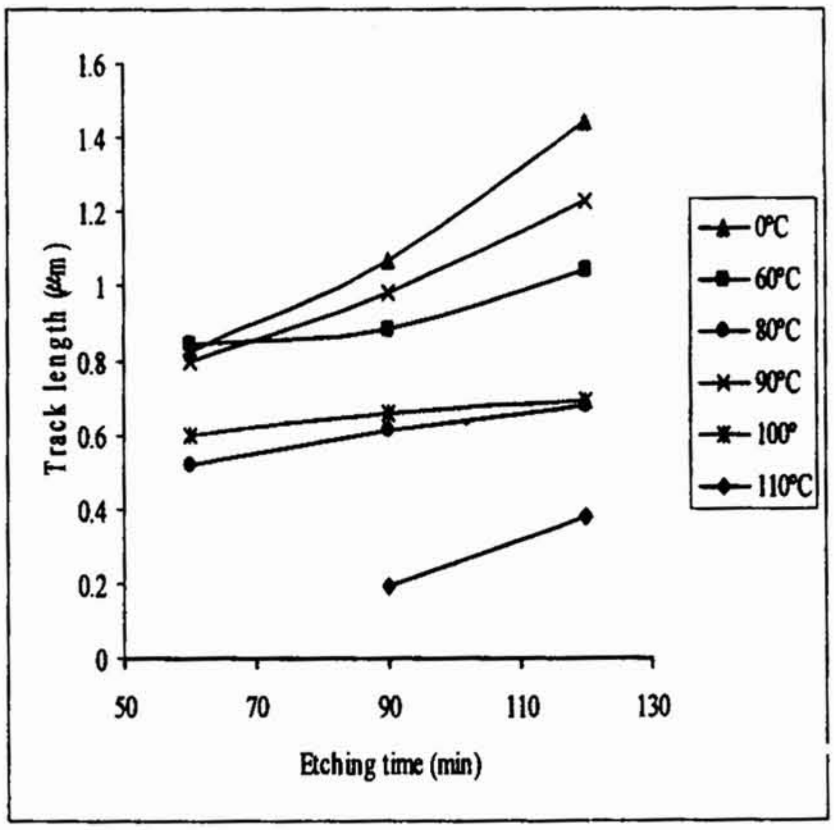

Figure 15. Comparison graph of track lengths for various annealing temperature in LR-115 SSNTD Type I

Table 8. Comparison of track lengths for various annealing temperature in LR-115 SSNTD Type II

Sr.	Annealing temperature °C	Track length (μm)		
		Etching time 60 min	Etching time 90 min	Etching time 120 min
1	0	0.82± 0.08	1.07± 0.10	1.44± 0.13
2	60	0.84± 0.10	0.88± 0.08	1.04± 0.11
3	80	0.52± 0.04	0.61± 0.06	0.68± 0.06
4	90	0.80± 0.09	0.98± 0.11	1.23± 0.11
5	100	0.60± 0.05	0.66± 0.06	0.69± 0.70
6	110	-	0.19± 0.02	0.38± 0.03

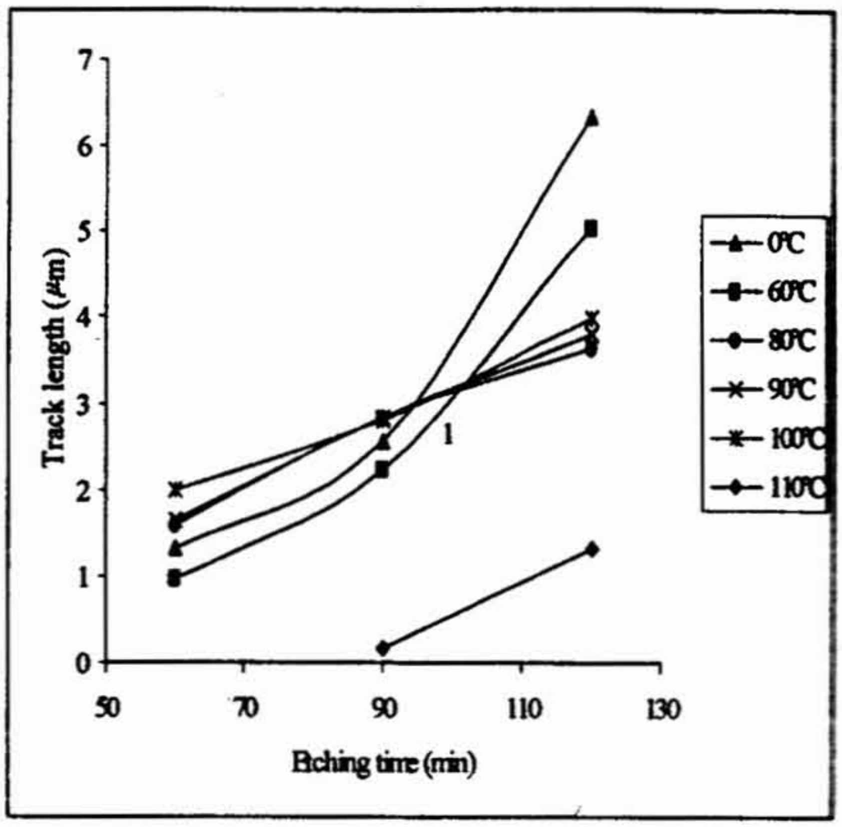

Figure 16. Comparison graph of track lengths for various annealing temperature in LR-115 SSNTD Type II

Results and Discussion

The normal distribution is the most important distribution for applications in measurements. The greater the number of trials, the better their representation by a Gaussian. The results of radiation measurements are in most cases, expressed as the number of counts recorded in a scalar by using annealing method. In either case, the emission of the particle is statistical in nature and follows the Poisson distribution. The number of counts involved is more than about 20, the Poisson approaches the Gaussian distribution. The individual results of such radiation measurements are treated as members of a normal distribution (Tables 1-8; Figs. 9-16).

Conclusion

According to the results, the annealing method is required for suitable annealing temperature because the alpha tracks were disappeared by using high temperature.LR-115 type II cellulose Nitrate film by using annealing method is merit over other methods for finding the alpha tracks. It is observed that the Poisson distribution (frequency distribution) for different values of pore diameters are similar to the Gaussian distribution. Therefore LR-115 type II was chosen for the study of radon concentration in any places.

Acknowledgements

I am greatly indebted to Professor Dr. Ko Ko Kyaw Soe, Head of Department of Physics, D. Engg. (Nagoya), University of Yangon, for his kind permission to carry out this work.

I am deeply grateful to my supervisor Dr. Than Win, PhD Engg. Tohoku, Associate Professor, Department of Physics, University of Yangon, for his valuable guidance, helpful advice and supervision of the present work.

References

Cartwright, B. G., Shirk, E. K., and Price, P. B., (1978). "Characteristics of LR-115", *Nucl. Instru. Methods*, ***153***: 457.

Chauhan, R. P., Kant, K., Mahesh, K. & Chakarvarti, S. K., (2001). *Indian Jour of Pure & Applied Physics*, ***39***: 491.

Fleischer, R. L., Price, P. B., and Walker, R. M., (1975). "Nuclear Tracks in Solids", (California: CUP)

Kalsi P C, Ramaswami, A. and Manchada, V. K., (2005). "Solid State Nuclear Track Detectors and Their Applications " (*http://www.barc.gov.in /Webpages / letter*)

Ng F M F et al., (2004). *Jour of Radiation Measurements* ***38***: 1.

Singh, P., (1989). "Solid State Nuclear Track Detector as Nuclear Track Filters", PhD Thesis. Unpublished, India

Spohr, R., (1990). "*Ion Tracks and Microtechnology*", (Braunschweig Vieweg). 2nd edition, Germany.

http://www.2.i.j.s.si/icjt/djs/20icnts/pprogram.html [International Conference on Nuclear Tracks in Solid 2002]