FABRICATION AND TESTING OF A JUMPING SPARK COUNTER FOR ALPHA PARTICLES

DISSERTATION
Submitted in partial fulfilment of the requirements for the award of the degree of
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IN
APPLIED PHYSICS

BY
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1995
CERTIFICATE

Certified that the results reported in this dissertation are from the original work carried out by Mr. Mohd. Mujahid under my supervision.

Prof. D.S. Srivastava
(Supervisor)
To,
My sister
ACKNOWLEDGEMENTS

I am very grateful to my supervisor Dr. D. S. Srivastava, Professor and Chairman, Department of Applied Physics, Z. H. College of Engg. & Tech., A.M.U. Aligarh, who has introduced me a realistic and solitary picture of Solid State Nuclear track Detectors (SSNTDs), a research field which has a fancy and sunny multi-disciplinary attractive outlook and potentials. Undoubtedly, at one stage it seemed that fabrication of jumping spark counter was going to be tough job, but by his continued guidance in-spite of his administrative work, today I got success and am able to present the whole effort in the form of this dissertation.

I got utmost co-operation from Mr. Padam Singh in the circuit design of the jumping spark counter and its testing, for which I am especially thankful to him.

The assistance which I received from Mr. Ameer Azam in the irradiation of the samples in standard radon chamber at BARC and also in the handling of Computer for giving this dissertation a final shape, had been very valuable. I am indeed highly indebted to him for all this help. Co-operation of Mr. N.P.S. Rana is also thankfully acknowledged.

(MOHAMMAD MUJAHID)
him in his SSNTD research laboratory.

This dissertation has been divided into three Chapters. Each chapter is followed by references giving also the titles of papers and arranged in alphabetical orders.

Chapter I describes the development, need and uses of jumping spark counters. This Chapter also contains brief details about the history of development of plastic track detectors, their threshold characteristics, suitable etching conditions etc..

Chapter II contains the designs of various kinds of spark counting devices and their working principles. The electronic circuits used by others for making their jumping spark counter are also included in this chapter. Moreover, the formation of through-etched holes by etching of a plastic detector is explained with the help of diagrams.

Chapter III is the last Chapter and contains what the author claims his original contribution. It describes the indigineously made jumping spark counter in all its details, including its actual dimensions and details about its various components. Actual data obtained during its testing are presented and described. It is found that this jumping spark counter gives a very flat plateau after two pre-sparking of the LR-115 Type II (strippable) plastic detector at 850 volt and its
spark counting efficiency relative to visual counting is very close to 100 %, for small value of track density (less than 3000 track cm$^{-2}$), at 650 volts. Final conclusions about its utility are also included in the end.
Chapter 3 Our Indigineously Made Jumping Spark Counter

3.1 Introduction

3.2 Constructional Details

3.3 Irradiation And Etching Of LR-115 Type II Strippable (Pelliculable) Plastic Detector

3.4 Counting Procedure

(1) Mounting Of The Detector Foil On The Grounded Flat Electrode

(2) Pre-sparking At Higher Voltage (typically at 850 V)

(3) Determination Of Plateau Characteristics And The Operating Voltage For The Jumping Spark Counter

3.5 Results And Discussion

3.6 Conclusion

References
Chapter I

Jumping Spark Counter
For Plastic Track Detectors
Becker & Johnson (1970). Somogyi et al., (1976) later developed another jumping spark counter for alpha particles in CA (cellulose acetate) and PC (polycarbonate) plastics. They described in great detail the theory of through-etched hole formation in thin plastic foils (Somogyi et al., 1976, 1977) and also the method of making thin plastic films of uniform thickness by fast bulk etching. In the following years Somogyi et al., (1978) used their jumping spark counter for counting alpha particle tracks in a special type of thin plastic detector (LR-115 Type II plastic) which became commercially available from Kodak-Pathe (France). Successively, a few firms have started making jumping spark counter on special orders.

The author of this dissertation has also fabricated successfully a jumping spark counter in his laboratory in the Applied Physics Department, AMU, Aligarh for its applications in counting the alpha-particle tracks in LR-115 Type II plastic detectors. It can be used for measurements of low level alpha activity due to radon and radon-daughters present in the ambient air or emitted as soil gas.

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* Now LR-115 detectors are marketed by DOSIRAD SARL (Mr.Jean ANDRU) villa parc Le rue Lech Walesa F-77185 Longnes, FRANCE.

** Viz.-MICROTEL SRL (Switzerland), DIGILIN (India). The address of the Indian firm is DIGILIN Electronics, 38-40 Wadiabander Road Mazagao, Bombay-40010.
Fig. 1.1(a) Longitudinal section of the particle track in a plastic detector, showing the breaking of molecular chains along the particle's trajectory and formation of chemically reactive species (black dots).

(b) Transverse section of the 'latent track' produced by a charged particle in an insulating solid, showing the inner 'track core zone' and the outer 'track halo' (after Ilic, 1989).
dielectric solid can be considered as a two-step process (Ilic, 1989).

(1) defect creation and
(2) defect relaxation

(1) The defect creation takes place in three time-dependent steps:

(i) The primary interaction of the ionizing particle with the atoms of the solid while it is in motion. This occurs in a very short time (for example $10^{-17}$ sec. for 1 MeV alpha particles).

(ii) The electronic collision cascade process that spreads out from the particle's trajectory, leaving behind a positively charged plasma zone. This process lasts for a time almost three orders of magnitude higher than the primary interaction (i.e., $10^{-14}$ sec.) and produces activated molecules outside the positive charged zone and

(iii) The atomic collision cascade occurring due to 'coulomb explosion' of the positively charged plasma. This process completes in about $10^{-12}$ sec.

(2) After the creation of defect, the defect relaxation takes place in the following two steps:

(i) In about $10^{-10}$ sec. all the atomic defects are aggregated within a depolymerized zone which may be called as 'track core' (see fig. 1.1 b) and

(ii) The molecular defects produced due to the secondary reaction of chemically activated species (like free
radicals) relax in a time scale of about 1 sec. forming a partly depolymerized zone 'track halo' (see fig. 1.1 b).

The longitudinal and transverse sections of a latent damage track are shown in fig. 1.1 (a) and 1.1 (b). The track core is less than 10 nm (100 Å) in diameter and corresponds to the atomic collision cascade. The molecular weight to the material in this zone is drastically reduced compared to the bulk material of the solid. The 'track halo' is an annular zone surrounding the 'track core' and has a diameter between 100-1000 nm (0.1 to 1.0 μm). It is formed due to the electronic collision cascade that makes the portion chemically more reactive.

Although, the basic mechanisms of formation of defects in the inorganic and organic solids are different (Srivastava, 1971) the end results are the same i.e., the physical and chemical properties of the damaged region surrounding the trajectory of the charged particle in the dielectric solid become much different from that of the bulk material. This makes the latent damage tracks chemically more etchable whereby they can be enlarged to be finally visible under optical microscope when their size becomes several time more than the wavelength of visible light and they start diffracting the incident light.
1.3 BRIEF HISTORY OF DISCOVERY OF NUCLEAR TRACKS IN SOLIDS:

Historically, D.A. Young (1958) of AERE Harwell was the first to show that fission fragments produced in a uranium oxide film irradiated with thermal neutrons, on entering a crystal of LiF placed 1 mm away from the uranium foil, created latent tracks which could be etched in a chemical reagent (HF+CH₃COOH saturated with FeF₃) and enlarged to be visible under optical microscope as 'etch pits'. A year later, Silk and Barnes (1959) also of AERE Harwell, unaware of the work of Young, showed that the fission fragments produced 'latent damage tracks' in mica, which could be observed by transmission electron microscope (TEM) without etching.

A more systematic and sustained research in this field which later came to be known as 'nuclear trackology' was started by a trio of scientists R.L. Fleischer, P.B. Price and R.M. Walker in the early sixties (Price and Walker 1962 a, b; Fleischer et al., 1975), then working at General Electric Co. Schenectady, Newyork (USA). They showed that all dielectric solids like minerals (muscovite mica, apatite, sphere, zircon etc.), glasses (soda lime glass, phosphate glass etc.) and plastics (like cellulose nitrate, cellulose acetate, polycarbonates
etc.) are capable of registering the latent tracks of heavy charged particles passing through them and these tracks can be chemically etched to microscopically visible sizes (Price and Walker 1962 b, Fleischer and Price 1963 a, b; Fleischer et al., 1964). These dielectric solids are now known by the apt name of Solid State Nuclear Track Detectors, SSNTDs (Bhagwat, 1993). Suitable etching conditions for fission fragments and alpha particles in various SSNTDs can be found in many scientific literatures (Srivastava, 1971; Fleischer et al., 1975; Durrani and Bull, 1987).

1.4 VARIOUS KINDS OF AVAILABLE PLASTIC TRACK DETECTORS:

Among the various inorganic solids (minerals, glasses) and the organic solids (polymers or plastics) that serve as SSNTDs, the plastics are more sensitive to ionizing particles. Among the plastics themselves, a great variation of sensitivity from plastic to plastic has been found. The most sensitive plastic detectors are SR-90 and SR-86 developed by Fujii et al., (1988, 1993). It can record tracks of protons of \( E < 13 \text{ MeV} \). Then comes CR-39 plastic detector, first reported by Cartwright et al., (1978). It can register the tracks of \( E < 1 \text{ MeV} \) protons and 30 MeV a-particles. After that we have cellulose nitrate plastic which are available by various trade names viz., LR-115, CN-8015 or CN-85,
Daicell CN, Nixon Baldwin CN etc., in order of their decreasing sensitivity. Then comes the cellulose acetobutyrate plastic (CAB). Lesser sensitive plastics are polycarbonate plastics (Lexan, Makrofol-E etc.) and the least sensitive plastic detector is polyethylene terephthalate plastic (viz. Cronar and Melinex).

Each dielectric solid registers track only, if the incident ion produced in it, a primary ionization along its trajectory at a rate greater than a certain critical value—the characteristic of the material (Fleischer et al., 1967). Hence any given materials records etchable tracks of energy known as the upper threshold \( E_{\text{max}} \) or \( E_{\text{crit}} \). For some particles and materials, there may exist a minimum threshold energy \( E_{\text{min}} \) also. The tracks are registrable only if the energy of the particle is below \( E_{\text{max}} \) (or \( E_{\text{crit}} \)) and above \( E_{\text{min}} \). For lighter particles in more sensitive plastics \( E_{\text{min}} \) generally approaches zero. Thus the plastic track detectors are threshold type of nuclear detectors. The detection threshold of some plastics and other dielectric solids are shown in fig. 1.2, where the horizontal dotted lines mark the minimum material damage (in terms of primary ionization rate) for giving etchable tracks in various solids (after Fleischer et al., 1967).

Some important plastic detectors in order of their increasing sensitivity are given in Table-1.1
Fig. 1.2 Threshold characteristics of various SSNTDs according to the critical \((dJ/dx)\) criterion of Fleischer et al. in (1967).
<table>
<thead>
<tr>
<th>Plastic (in order of increasing sensitivity)</th>
<th>Atomic composition</th>
<th>Trade Name</th>
<th>Lightest detectable positive ion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene terephthalate</td>
<td>$^{19}$C$^{16}$H$^7$O$_7$</td>
<td>Melinex, Cronar, Mylar, Terphane, Hotaphan, Lavasan,</td>
<td>$^{16}$O$^+$ (E&lt;16 MeV)</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>$^{16}$C$^{14}$H$^4$O$_3$</td>
<td>Lexan, Makrofol, Kimfol, Merlon</td>
<td>$^2$He$^+$ (E&lt;0.3 MeV)</td>
</tr>
<tr>
<td>Cellulose acetobutyrate</td>
<td>$^{12}$C$^{16}$H$^6$O$_7$</td>
<td>CAB</td>
<td>$^2$He$^+$ (1.0 MeV)</td>
</tr>
<tr>
<td>Cellulose triacetate</td>
<td>$^{12}$C$^{16}$H$^6$O$_6$</td>
<td>Cellit-T, Trifol-T, Kodacel TA-401</td>
<td>$^1$H$^+$ (E=0.75 MeV), $^1$H$^2$ (E&lt;0.2 MeV), $^2$He$^+$ (E&lt;3 MeV)</td>
</tr>
<tr>
<td>Cellulose nitrate</td>
<td>$^{6}$C$^8$H$^9$O$_9$N$_2$</td>
<td>Nixon Baldwin CN Daicell, Kodak's CA-8015 or CN 85, LR-115</td>
<td>$^1$H$^+$ (E&lt;0.5 MeV), $^2$He$^+$ (E&lt;4 MeV)</td>
</tr>
<tr>
<td>Allyl diglycol carbonate</td>
<td>$^{12}$C$^{15}$H$^7$O$_7$</td>
<td>CR-39, MA-ND, TASTRAK</td>
<td>$^1$H$^+$ (E&lt;13 MeV)</td>
</tr>
<tr>
<td>Allyl diglycol carbonate containing sulphonate linkages</td>
<td>SR-86 SR-90</td>
<td>$\alpha$-particle of energy 0-60 MeV</td>
<td>$^1$H$^+$ (E&lt;13 MeV)</td>
</tr>
</tbody>
</table>
1.5 ETCHING OF LATENT TRACKS IN PLASTIC DETECTORS:

The charged particle tracks in plastic detectors are mostly revealed by selective chemical etching. For this purpose, the plastic detector containing the 'latent tracks' is immersed in a suitable etching solution for a particular duration of time. The solution is maintained at a fixed temperature for reproducibility of results. Initially, suitable etching conditions were found only by trial and error but now sufficient number of etching data are available for various detectors in scientific literature for guidance (Fleischer et al., 1975; Durrani and Bull, 1987). However, still one must first try the etching conditions for his own detectors and find the standard etching condition suitable for his own work.

The shape and size of etched track at a particular time depends upon the angle of incidence of the particle, its atomic number, energy and also on the etching parameters viz. the etching solution, its concentration, its temperature and etching time. The tracks are revealed by chemical etching only if the entrance angle measured for the plastic detector surface is more than a certain minimum angle, called the 'critical angle'. For normal incidence, the etched track cross-section on the detector surface is circular whose diameter under particular etching condition is determined by the ratio of two etch rates known as the
track etch rate, $V_T$ and the bulk etch rate, $V_0$. The length of the etched track depends upon the range of incident particle in the plastic detector. For oblique incidence the track section is elliptical. Little defocusing of the microscope can also show the conical shape of the track in the depth of the detector (fig. 1.3). The 'critical angle' $\Theta_c$ is given by

$$\Theta_c = \sin^{-1} \left( \frac{V_0}{V_T} \right)$$

Detailed track growing equations have been developed by many workers and can be found in scientific literature viz. Somogyi and Szalay (1973), Somogyi and Paul (1973), Fleischer et al., (1975), Ali and Durrani (1977), Durrani and Bull (1987).

The plastic detectors are generally etched in concentrated solution of NaOH or KOH maintained at higher than room temperature by means of an ultrathermostat or a constant temperature bath. Some typical etching conditions for important plastic detectors are summarized in Table 1.2. Stirring of etching solution during etching gives more reproducible results. Very good account of track etching and processing of detectors can be found in the publications of Somogyi (1977) and Monnin (1980).

After etching, the detector has to be thoroughly washed in flowing water to remove the etch product layer and the sticking etchant. Finally, the etched and the washed detector is dried under an infra red lamp or a
Fig. 1.3 Conical shape of the track in the depth of the detector (after W. Enge, 1980).
<table>
<thead>
<tr>
<th>Plastic detectors</th>
<th>Etching solution and temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Melinex</td>
<td>6N, NaOH at 60 °C for one hour for fission fragments</td>
</tr>
<tr>
<td>2. Makrofol-E</td>
<td>15% KOH at 50 °C for two hours for fission fragments</td>
</tr>
<tr>
<td></td>
<td>PEW Solution (15g KOH + 40g C(_2)H(_5)OH +45g H(_2)O) at 70 °C for 30 minutes for (\alpha)-particles</td>
</tr>
<tr>
<td>3. Lexan</td>
<td>6N, NaOH at 60°C for one hour for fission fragments</td>
</tr>
<tr>
<td>4. Cellit-T</td>
<td>20% (6N) NaOH at 70 °C for 15 min. to 2 hours for (\alpha)-particles</td>
</tr>
<tr>
<td></td>
<td>OR 100 cm(^3) 20 &amp; KOH +4.5g KMnO(_4) at 50 °C for one hour for (\alpha)-particles</td>
</tr>
<tr>
<td>5. CN</td>
<td>20% (6N) NaOH at 50 °C for 15 min. to 2 hours for (\alpha)-particles</td>
</tr>
<tr>
<td>6. CN-8015</td>
<td>4N, NaOH at 50 °C for 30 min. for (\alpha)-particles</td>
</tr>
<tr>
<td>7. LR-115 Type II</td>
<td>2.5N, NaOH at 60 °C for 1-2 hours for (\alpha)-particles</td>
</tr>
<tr>
<td>8. CR-39</td>
<td>6N, NaOH at 70 °C for 6-12 hours for all particles</td>
</tr>
<tr>
<td>9. SR-86 and SR-90</td>
<td>6N, NaOH at 70 °C for 6-12 hours for all particles</td>
</tr>
</tbody>
</table>
hot air blower before observation by an optical microscope at magnification of x100-400 or more.

A new technique for quickly increasing the track diameters to very large sizes has also been reported in the literature (Tommasino et al., 1982). It is known as the Electro Chemical Etching (ECE). Since we are not concerned with this kind of etching in our work hence the details of ECE are not described here. Recent development about ECE can however be found in the paper of Sohrabi (1995).

1.6 ABOUT THE PRESENT WORK:

This dissertation describes the constructional details of a jumping spark counter fabricated by the author in his SSNTD laboratory in the Department of Applied Physics, AMU, Aligarh. It is working nicely and is giving a good plateau characteristic for counting the alpha particle tracks. The details of fabrications and its testing are given in chapter III. It is found that this particular spark counter gives almost 100 % relative efficiency for counting through-etched holes in LR-115 Type II detector after two pre-spark at about 800 volts. If the pre-sparking is done three times, then multiple sparks pass through the same hole and the counted number given by this spark counter is found to be much larger than that obtained by visual counting in an optical microscope.
REFERENCES


Cross W.G. and Tommasino L. (1968), "Electrical detection of fission fragment tracks for fast neutron dosimetry". Health Physics 15, 196.


Somogyi G. and Szalay S.A. (1973), "Track diameter
kinetics in dielectric track detectors", Nucl. Instrum. Meth., 109, 211.


Somogyi G. (1977), Processing of plastic track detector". Nucl. Track Detection, 1, 3.


Chapter 2

Principle, Construction and Applications of Jumping Spark Counter
2.1 INTRODUCTION:

In the earlier jumping spark counter designed by Cross and Tommasino (1968) for counting the fission fragment tracks in a thin plastic detector (≈10 μm) used for fissionographic experiments, the high voltage electrode was in the form of a knife edge which could be moved parallel to itself on a thin etched plastic detector having nearly through-etched fission track holes and placed on a flat brass electrode which was earthed (fig 2.1). A similar spark counter was also made by Lark (1969) who made a spark scanning device for counting fission fragment tracks in polycarbonate plastic (Makrofol). In fact he used the frame of a scanning microscope for the purpose by screwing a flat metallic plate on its horizontal stage and replacing the optical focusing system by means of a holder having a flat blade or thick knife edge parallel to the stage. Thus only the stage and frame of the optical microscope were used without the microscope tube or lenses. The z-motion screw was used to control the spark gap between the blade and the flat earthed plate. The flat plate served both to hold the detector foil and also to move it past the spark top or blade. The circuit used by Lark
Fig. 2.1 Schematic diagram of jumping spark scanning device of Cross and Tommasino (1968).
is shown in fig 2.2. In this case the potential difference and the distance between the two electrodes is adjusted so that the portion of intact plastic foil does not allow the spark to pass through and the spark passes only when there is perforated hole in the plastic foil. Moreover, the power dissipation by the spark should be limited so that excessive damage of the plastic foil does not take place. This is accomplished by using a 200 pf capacitor in parallel to the electrodes and charging both through a 50 Ω resistance. Typically, the spark gap was between 50-150 μm and the potential difference between the two electrodes was 1500-2000 volt.

When multiple sparking through each hole takes place, the size of the etched holes is increased from \( \approx 1 \) μm to \( \approx 20 \) μm in diameter. The increase in diameter of the holes due to spark passing through them was found to depend on the material of the electrodes. For example, with copper electrodes the diameter was increased to \( \approx 100 \) μm (or 0.1 mm) and also a dark deposit was formed around the periphery of the enlarged hole. These enlarged holes with dark rims could be easily seen by naked eye when the foil was held against good illumination. Even xerox copies of enlarged holes could be made. Alternatively, the foil may be mounted in a photographic slide and the image of holes could be
Detector foil (8-10 µm)

Fig. 2.2 The Spark counting device of Lark (1969).
projected on a screen for visual counting. This device is very useful for counting large sheets of plastic detectors having very low track density (100 cm$^{-2}$), such as in the study of cosmic rays. In such a case the blade could be 1 cm wide and scanning could be done at a speed of 10 cm$^2$ per minute.

This spark scanning device was used in the studies involving counting of few fission events per cm$^2$ such as in the measurement of spontaneous fission decay of several heavy elements and angular distribution measurements in fission reaction of very low cross-sections. It was used by Lark at Niels Bohr Institute, University of Copenhagen, Denmark, in the studies of isomeric states which decay by spontaneous fission.

In a later design of their jumping spark counter, Cross and Tommasino (1970) replaced the moving knife edge type H.V. electrode by a flat aluminized Mylar surface which is a thin polycarbonate plastic sheet (~20 μm thick) with one of its surfaces coated with a thin layer (10-12 μm thick) of aluminium. This 'aluminized Mylar' is placed above the etched plastic track detector and is in electrical contact with the high voltage terminal of a dc power supply.

Thus, a jumping spark counter essentially consists of two electrodes (forming a capacitor) between which is placed a thin plastic track detector having through-
etched holes. The two electrodes are connected to a variable high voltage dc power supply giving voltage between 0-2000 volt. Generally, the lower plate of this capacitor is made of thick brass plate (fig. 2.3) which is earthed and the upper plate is provided by the thin 'aluminized Mylar'. During actual working, first the etched plastic detector is placed on the flat earthed electrode and the 'aluminized Mylar' is placed on it with its aluminium coated surface in intimate contact with the detector and extending to larger distance where it is in electrical contact with the high voltage electrode (fig. 3.1, given in chapter III). A heavy weight is placed on the upper surface of the Mylar extending between the two electrodes so as to ensure intimate electrical contact by pressure.

This design forms the basis of all the successive spark counters fabricated in various laboratories (Viz. Johnson et al., 1970; Becker and Johnson, 1974; Lupica, 1975; Somogyi et al., 1976; Somogyi et al., 1978 and Wilson, 1982). However, different workers have used different sizes and shapes of the two electrodes (spark plates of the counter) and also the values of elements of electronic circuitry.

2.2 ELECTRONIC CIRCUITRY OF A JUMPING SPARK COUNTER:

The circuit elements of a typical jumping spark counter described by Wilson (1982) are shown in fig.
Fig. 2.3 Schematic diagram of jumping spark scanning device of Cross and Tommasino (1972).
2.4. The high voltage electrode was an outer thick annular brass cylinder and the earthed electrode was a coaxial inner solid brass cylinder with the intervening space filled by non-conducting Nylon plastic block. The upper ends of the two electrodes were made flat and polished while the lower ends could be connected to a high voltage dc power supply through base pins or studs.

2.3 WORKING OF THE JUMPING SPARK COUNTER:

When a high voltage is applied between the two electrodes of the jumping spark counter through the resistance $R_1$ and a parallel capacitor $C_1$, by closing the key $K_1$ and $K_2$, the electric field between the aluminized Mylar and the earthed electrode goes on increasing as the capacitor $C_1$ gets charged. The potential across the capacitor $C_1$ rises to approach the voltage of the EHT. Before it reaches the maximum voltage (RC Circuit) a spark passes between 'aluminized Mylar' and the earthed electrode due to the break down of the trapped air in the through-etched hole. The capacitor $C_1$ thus discharges through the resistance $R_3$, thus a momentary current flows through $R_3$ producing a voltage pulse across it. The resulting voltage pulse is shaped by the time constant of $R_4C_3$ and is recorded unamplified by a scaler counter. The zener diode $Z$ prevents oscillation in the system. The capacitor $C_1$ is
Fig. 2.4 The Spark counter and electronic circuit after Wilson (1982).
again charged and time taken to recharge it depends on
the resistance $R_i$ (2MΩ). This resistance also limits the
current drawn from the high voltage dc power supply (or
EHT).

The energy in this spark is sufficient to vapourize
the part of aluminium that is opposite to the track-hole
through which the spark has passed. Hence, the spark is
automatically quenched and the charging cycle starts
again until another spark passes through another hole in
the plastic detector and so on. When the key $K_1$ is
opened and $K_2$ is closed, there is no charge on the
capacitor.

2.4 CIRCUITS USED BY OTHERS:

The spark counter and the electronic circuit used
by Somogyi (1976) is reproduced in fig. 2.5 Durrani has
171) which is also reproduced here (fig 2.6).

2.5 THROUGH-ETCHED HOLE FORMATION IN A PLASTIC TRACK
DETECTOR:

As explained in chapter I, a charged particle
entering a plastic, leaves trails of material damage
along its trajectory. If the damage is more than a
certain critical value (corresponding to the horizontal
lines in fig. 1.2), preferential track etching starts
because then $V_T$ becomes greater than $V_0$. The condition
Fig. 2.5 The Spark counter and electronic circuit after Somogyi et al., 1976.
Fig 2.6 The Spark counter and electronic circuit after Durrani (1987).
$V_T > V_0$ remains satisfied practically over the whole residual range (in fact till the energy reduces to the lower threshold. Thus, the etchable length is equal to the residual range of the charged particle of energy $E_{\text{crit}}$ in that plastic for all practical purposes (taking lower threshold to be zero). In case a charged particle passes through the entire thickness of the plastic foil, the track etching will start from both the surfaces (fig. 2.7a). The track etch rate $V_T$ from the stopping end is more than that at the entering end in the case of alpha particle (fig. 2.7a). A reverse trend is observed in the case of fission fragments due to their varying effective charge. Fig. 2.7b and 2.7c show through-etched hole formation in a plastic track detector when both the cones touch each other. Using the above concept and knowing the variation of $V_T/V_0 = V$ with energy (or range) for a given charged particle in a particular plastic detector, it is possible to calculate the residual foil thickness when the through etched track hole will just be formed in that plastic for particles of various energy entering the detector at different angles. Some typical cases of through-etched track formation are shown in the fig. 2.8 (after Somogyi 1976). When calculations for through-etched track holes are actually performed it is found that the residual thickness of the plastic foil just when the through-etched holes are
(a) The track etching from both the surface.
(b) & (c) Through-etched hole formation in a plastic track detector when both the cones touch each other (after W. Enge, 1980).
Fig. 2.8 Schematic diagram of the through-etched track formation in a plastic foil (The meaning of the notations are given in the text of Somogyi et al., 1976).
developed along the particle's trajectory, is a sensitive function of irradiation angle and the particle's energy (Somogyi et al., 1976). The most advantageous situation is found for the case of normal incidence of the particle in a thin plastic foil whose initial thickness is equal to the range of the particle.

2.6 USEFULNESS OF THE LR-115 TYPE STRIPPABLE PLASTIC DETECTOR FOR USE WITH SPARK COUNTER:

For the use of spark counter, the plastic detector foils must develop through-etched or nearly through-etched holes, during etching. For this, it is better to have the initial thickness of the plastic detector foil equal to or slightly less than the range of the particle. For fission fragments, the range in plastic detector is \( \approx 18-20 \, \mu m \) and for alpha particles of energy equal to \( E_{\text{crit}} \), (say 3 MeV, in most plastic), the range is about 12 \( \mu m \). Therefore, for counting fission fragment tracks, plastic foil of thickness 10-15 \( \mu m \) can be used but for counting of alpha particles, the plastic foil must be of much smaller thickness (about 8-10 \( \mu m \)).

Commercially, 15 \( \mu m \) thick Makrofol-G plastic and 25 \( \mu m \) thick Cellit-T plastics are available. Their thickness can be further reduced to the desired level by pre-irradiation etching. Most suitable solution for fast bulk etching of the Polycarbonate plastic is the PEW solution of Somogyi et al., which contains 15g KOH + 40g
C₂H₅OH + 45g H₂O at 70°C while for the cellulose acetate plastic (Cellit-T) the best solution is 100 cm³ of 20% KOH + 4.5g KMnO₄ at 70°C. For reducing the thickness of the commercially available thin foils to the desired level, it is necessary to mount the detector foil in specially designed plexiglass frame and it has to be rotated in the solution to avoid the formation of wrinkles etc. and to give smooth thin film of uniform thickness. Moreover, the KOH + KMnO₄ solution used for Cellit-T plastic deposits a layer of MnO₂ on the surface of the plastic which must be removed by dipping it in 10% HCl solution. The pre-irradiation etching, however, has a problem also that it enlarges the background tracks in old alpha sensitive plastics.

Fortunately Kodak Pathe (France) have developed a special plastic known as LR-115 which can provide suitable thin films of cellulose nitrate plastic sensitive to alpha particles. This plastic has been developed especially for nuclear track detection applications. The LR-115 plastic consists of a 100 μm thick colourless non-etchable, transparent polyester base, over which a thin film of red-dyed cellulose nitrate plastic is deposited. In the LR-115 Type II plastic the thickness of this sensitive layer of CN film is about 12-13 μm while in the LR-115 Type I plastic this thickness is about 6 μm. Specially made strippable
or pelliculable LR-115 Type II plastic is also available in which the sensitive CN layer can be removed by dipping it in warm water and cleaving it carefully.

The LR-115 Type II (strippable) plastic is very suitable for making through-etched track holes with low energy alpha particles and for use with a jumping spark counter for counting them. The most suitable etching condition for LR-115 Type II plastic is 2.5N NaOH, at 60°C. The etching time may vary 60 to 120 minutes. Best results with strippable plastic are obtained for 90 minutes etching.

Our experience shows that a 2 hours etching of LR-115 Type II plastic under the above condition reduces the 13 μm thick sensitive CN layer to a residual thickness of 5 μm. Under this condition the through-etched holes are made in it by alpha particles having an energy between 1.9 and 4.2 MeV. Thus, there exists an 'energy-window' of 1.9-4.2 MeV for getting through-etched holes for the detection of alpha particles with LR-115 Type II detector. When observed in a binocular research microscope, these through-etched holes are seen as bright circular shining spots against red background and can be easily counted even at a magnification of x100. A green filter further improves the contrast and facilities the through-etched hole counting.

The LR-115 Type II plastic has been found to be
most suitable for measuring radon and radon-progeny concentration in human environment. However, the radon study requires the counting of a very large number of irradiated foils at many different locations simultaneously. The number of detectors may be several hundreds and it may require long sittings with the optical microscopes causing strains to the scientist's eyes and backache etc. It is here that the jumping spark counter comes as an aid. The strippable (pelliculable) LR-115 Type II track detectors have to be employed while using the jumping spark counters.

As will be seen in chapter III, the jumping spark counter gives a very flat plateau for track counting and the operating voltage typically is 650 volt or so. For consistent result of track counting by a spark counter it is found necessary to do a few pre-sparkings at higher voltage (≈ 850 V), before actual counting at the operating voltage (of 650 V). This pre-sparking opens the partially closed through-etched holes, widens them a little and also punctures the nearly through-etched track holes whose ends lie 0.2-0.5 μm close to the lower etched surface of the detector. More than one pre-sparking may be necessary for the reproducibility of results during actual counting by the spark counter.
REFERENCES


Cross W.G and Tommasino L. (1968), "Electrical detection of fission fragment tracks for fast neutron dosimetry". Health Physics, 15, 196.


Chapter 3

Our Indigineously Made
Jumping Spark
Counter
3.1 INTRODUCTION:

The need of a jumping spark counter has been increasingly felt in our laboratory for using it in quick determination of the track densities in a large number of LR-115 Type II plastic track detectors. It is required for the on-going project on Radon Studies with Plastic Detectors. The author of the present dissertation took up the job of making such a jumping spark counter and succeeded in doing so. The constructional details of this jumping spark counter along with actual data obtained during the testing of its characteristics will be given in this chapter in sequence.

3.2 CONSTRUCTIONAL DETAILS:

The entire system which makes the complete jumping spark counter consists of the following four parts:

1. The electrode structure for sparking
2. High voltage dc power supply (300-3000 volts)
3. The electronic circuit for pulse shaping, and
4. The scaler & counting system.

The dimensional details of the electrode structure used in our jumping spark counter are shown in fig. 3.1 along with the values of circuit elements actually employed by us for making the charging and the pulse shaping circuits.
Fig. 3.1 The dimensional details of the jumping spark counter.
The two electrodes were made up of brass and fitted in the fine cylindrical holes drilled 2.0 cm apart through the entire thickness of a 2.0 cm thick block of plexiglass having cylindrical base and a step of 1.0 cm as shown. The diameter of the upper surface of the block on which the electrodes are seen was 4.99 cm while that of the lower surface was 8.04 cm. The grounded electrode was in the form of a thick flat polished brass disc coated with nickel and having a stem which was screwed at the lower surface of the block. A connecting lead was soldered to the screw itself. The diameter of this flat disc-type electrode was exactly 11.283 mm so that its area was exactly 1 cm². Its thickness side was embedded in the plexiglass block such that its top surface was coplanar with the upper surface of the plexiglass block. The high voltage electrode was a spring-loaded-type electrode but not so thick. It has a central metal cylindrical piece of diameter 3.5 mm loaded with spring and protruding out of the electrode surface by 1 mm. It gets pressed on loading the aluminized Mylar with the heavy cylindrical weight. The loading weight was in the form of an annular brass cylinder of outer diameter 8.02 cm, inner diameter 3.74 cm, a height 3.95 cm and a weight of 1.5 kg. At the lower end of this load, the diameter of the central opening was 5.02 cm and a thin transparent sheet of plexiglass of thickness 1.5 mm was
fitted at 0.97 cm above the base of this weight. It served as a window to make the sparks visible and also for pressing the 'aluminized Mylar' tightly on the high voltage electrode and the plastic detector placed on the grounded electrode. Since, the nearest distance between the edges of the two circular electrodes was 8 mm and one of them was embedded in the plexiglass block, no direct sparks could pass between them. The electrode system is shown in the photograph given in fig. 3.2.

The high voltage dc power supply used by us was APPLAB 7341 N. It is capable of giving continuously varying but constant high voltage between 300 to 3000 volts with a maximum current rating of 50 mA.

The electronic circuit design employed by us was basically the same as given by Wilson (1982) and Durrani (1987). The circuit elements whose values are shown in figs. 2.4 and 2.6, were connected using a Sun-Mica board in the form of wooden chassis with studs and pin bases fixed on it for making connections to the dc power supply at one end and an electronic scaler and pulse counter on the other. The scaler and pulse counter used was from the part of a Radiation Counting System RCS 4027 A available in our Department and manufactured by Electronic Corporation of India Ltd. (ECIL), Hyderabad, for use with G.M. counter experiments. Its EHT and 'paralysis time' switches were kept at "off"
Fig. 3.2 The actual photograph of the electrode system of our indigineously made Jumping Spark Counter.
position and the function was set at "Manual". The output of the jumping spark counter was connected to "input" terminals at the back of the Radiation Counting System through a BNC cable.

3.3 IRRADIATION AND ETCHING OF LR-115 TYPE II STRIPPABLE (PELLICULABLE) PLASTIC DETECTOR:

For testing of this jumping spark counter, the strippable LR-115 Type II plastic sheet was cut into several pieces of size 2 cm x 2 cm and irradiated with alpha particles. Two different irradiations with alpha particles were made. (i) By the alpha particles emitted from radon and its daughters present in the Standard Irradiation Chambers available in the Air Monitoring Division of BARC, Bombay described by Srivastava et al., (1995) and (ii) By the alpha particles from an $^{241}$Am planchet type source available in our laboratory.

For irradiation with alpha particles coming from radon and its progeny, the plastic detector was mounted on a card and suspended inside the radon chamber for a definite time, care being taken to see that there was nothing to obstruct the view of the detector in front of it in a hemisphere of radius 9.5 cm. This kind of irradiation produced a small value of alpha track density in the detector depending upon the radon concentration in chamber.

For testing the jumping spark counter also in the
higher track density region, the LR-115 Type II (strippable) plastic pieces were irradiated with alpha-particles entering the detector surface at right angles for different times (0, 5, 15 and 60 min.) held at distance of 1.6 cm from a planchet type $^{241}$Am alpha source. In this geometry, the energy of alpha particles at the point of entry into the detector was $\leq 3$ MeV, depending upon the angle of entrance. Irradiation for four different times gave four different track densities.

The etching of these detectors was carried out for 90 minutes in 2.5N NaOH solution kept in a conical flask and maintained at a temperature of 60°C with the help of a constant temperature water bath provided with contact thermometers which could keep the temperature constant within $\pm 0.1^\circ$C. After etching, the detectors were washed with flowing water for half an hour and the remaining sensitive red CN layer was detached from the non-etchable polyester base by cleaving it out carefully in hot water. Great care is necessary in this step otherwise the foil gets torn off and spoiled. In the case of irradiation with $^{241}$Am source two set of four detectors were irradiated. Out of these, one set was etched for 90 min. and the other set for 120 min. in 2.5 N NaOH solution at 60°C to study the dependence of the efficiency of the counter on the etching time.
3.4 COUNTING PROCEDURE:

The counting procedure using the jumping spark counter involved the following steps:

(1) Mounting of the detector foil on the grounded flat electrode: The peeled off thin layer of the LR-115 plastic detector was carefully placed on the flat polished grounded electrode and smoothened with the help of a finger wrapped with tissue paper so that there remained no wrinkles on its surface. The a piece of 'aluminized Mylar' cut to 4 cm x 2 cm size, was placed over the detector in such a manner that its aluminium coated surface was in contact with the detector and covered it completely and also that it extended to touch the high voltage electrode (with its switch in the "off" position). After that, the heavy cylindrical brass loading weight was fitted on the electrodes so that its plexiglass window plate pressed the 'aluminized Mylar' on the detector and also the central protruding part of the high voltage electrode. The 'aluminized Mylar' film used by us had 25 um thick layer of aluminium deposited on a polyester base film (Mylar) having a thickness of 10 μm.

*Aluminized Mylar was supplied by Nayan Trade Corporation 99/103 Loharchawl, Govindniwas, IIInd floor Bombay-40002.
(2) Pre-sparking at higher voltage (typically at 850 V):
First the high voltage dc power supply was set at 850 volts and the switches K₁ and K₂ were kept "ON". This started the charging of the capacitor C₁ and the parallel capacitor formed between the aluminium layer of the Mylar and the grounded electrode with a time constant of about R₄C₃ (≈18 ns). After about a second, the switch K₂ is switched "Off" and the "Start" switch of scalar is switched "ON". Since the electric field in the pores of the through-etched track holes becomes sufficiently large to break down the insulation of air, a spark passes between the aluminium and the grounded electrode. This generates a large ionization current which passes through the load resistance R₃ (220 kΩ) due to the discharge of capacitor C₁. Thus a voltage pulse of short duration is developed across the load resistance R₃. This pulse is shaped by the time constant R₄C₃ and is passed on the scaler for counting. The spark through a hole is automatically quenched due to the evaporation of the aluminium at the site opposite to the hole. The spark then passes through another hole and so on. The counter goes on giving readings till all the holes have been counted. The number of counts obtained during pre-sparking is not the true counts as multiple sparking takes place, through the same hole over and over again. It is clearly seen through the plexiglass plate window.
In the beginning, the spark passes through the completely clear etched holes. This happens even at smaller voltages beyond 450 or so. But at high voltages (850 or so) spark passes and 'punctures' those etched tracks also whose ends are very near (within 0.5 \( \mu \)m) to the lower surface of the detector which is in contact with the grounded electrode. This kind of pre-sparking at higher voltage is necessary to get a plateau for track counting.

In the case of our Jumping spark counter it was found that two time pre-sparking at 850 volts is sufficient and necessary. It gave very reproducible results and a counting efficiency of 100% vis-a-vis the track countings performed visually by means of an optical research microscope at a magnification of X100.

The relative track counting efficiency of the jumping spark counter is defined as:

\[
\eta = \frac{\text{No. of tracks counted by the spark counter}}{\text{No. of through-holes counted by optical microscope}}
\]

\[
\eta = \frac{N_s}{N_m}
\]

(3) Determination of plateau characteristic and the operating voltage for the jumping spark counter: After the pre-sparking, the 'aluminized Mylar' piece was replaced by a fresh one and the same detector was counted at different voltages starting from 350 volts to
1000 volts in steps of 50 volts. For each counting, a fresh aluminized Mylar piece has to be used. The number of counts (which in our case was also the track density due to 1 cm² area of the grounded electrode), was plotted as a function of applied voltage. A flat plateau curve was observed. The midpoint of the plateau was chosen as operating voltage. At this voltage three countings were performed for each detector and the mean number of counts ($N_s$) was determined. The aluminized Mylar provided us with a replica of the track holes counted and it could also be used in a slide for projection. The track holes in the counted plastic foil were then observed under a microscope at a magnification of x 100 to find the average number of tracks ($N_m$) per cm². Again the second pre-sparking was done for the same detector foil at 850 volt and the counting at different voltages was repeated as above. In the same manner, three pre-sparkings were performed for one detector and each time similar counting experiments were performed and calculations of efficiency were made from equation 3.1.

The operating voltage of 650 volts was employed for spark counting of the pre-sparked detector foils. For the case of plastics irradiated with $^{241}$Am the, plateau observed earlier were accepted and the first two pre-sparkings were performed at 850 volt for each etched
detector. Then each one of them were three times spark counted at 650 volt and mean value was used to calculate the relative efficiency compared to the microscopic observation of through-etched holes using equation 3.1.

3.5 RESULTS AND DISCUSSION:

The observed data of jumping spark counter in two different LR-115 Type II (strippable) detector foils coded as P-0 and P-19 are shown in Table 3.1 and 3.2 respectively. P-19 was the plastic irradiated in the radon chamber at BARC, while P-0 was the control sample for background tracks. These data are displayed by means of personal computer which is given in fig. 3.3 and 3.4, showing number of counts as a function of applied voltage. The HPG (software) was used to draw best fit plateau curves (continuous lines) for the displayed data points. Table 3.3 shows the variation of relative track counting efficiency calculated from equation 3.1.

It is clear from Table 3.3 that just after two pre-sparking carried out at 850 volts in our case, the efficiency of the spark counter relative to visual counting becomes 100%. After three pre-sparking the relative efficiency of the spark counter becomes almost 180-186%, which is ridiculous. This apparent increase in efficiency beyond 100% is due to the fact that multiple sparks pass through the same hole after three pre-sparking. Visual observation through the plexiglass
TABLE 3.1

Observed data showing the number of spark counts of the through etched holes made by background alphas in a LR-115 Type II (strippable) plastic foil, as a function of applied voltage after three different pre-sparkings at 850 volts for the case of detector coded as P-0.

<table>
<thead>
<tr>
<th>Applied voltage (volts)</th>
<th>No. of spark counts observed after</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I pre-sparking</td>
<td>II pre-sparking</td>
<td>III pre-sparking</td>
</tr>
<tr>
<td>350</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>450</td>
<td>7</td>
<td>7</td>
<td>63</td>
</tr>
<tr>
<td>500</td>
<td>15</td>
<td>13</td>
<td>64</td>
</tr>
<tr>
<td>550</td>
<td>23</td>
<td>30</td>
<td>65</td>
</tr>
<tr>
<td>600</td>
<td>23</td>
<td>31</td>
<td>67</td>
</tr>
<tr>
<td>650</td>
<td>27</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>700</td>
<td>27</td>
<td>33</td>
<td>66</td>
</tr>
<tr>
<td>750</td>
<td>27</td>
<td>34</td>
<td>67</td>
</tr>
<tr>
<td>800</td>
<td>27</td>
<td>36</td>
<td>70</td>
</tr>
<tr>
<td>850</td>
<td>34</td>
<td>37</td>
<td>74</td>
</tr>
<tr>
<td>900</td>
<td>78</td>
<td>129</td>
<td>187</td>
</tr>
<tr>
<td>950</td>
<td>78</td>
<td>179</td>
<td>197</td>
</tr>
<tr>
<td>1000</td>
<td>138</td>
<td>220</td>
<td>243</td>
</tr>
</tbody>
</table>
TABLE 3.2

Observed data showing the number of spark counts of the through-etched holes made by radon alphas in a LR-115 Type II (strippable) plastic foils, as a function of applied voltage after three different pre-sparkings at 850 volts for the case of detector coded as P-19.

<table>
<thead>
<tr>
<th>Applied voltage (volts)</th>
<th>No. of spark counts observed after</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I pre-sparking</td>
<td>II pre-sparking</td>
<td>III pre-sparking</td>
<td></td>
</tr>
<tr>
<td>350</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>450</td>
<td>7</td>
<td>7</td>
<td>63</td>
<td></td>
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<tr>
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<td></td>
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<td>650</td>
<td>27</td>
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<tr>
<td>700</td>
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<td>67</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>27</td>
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<td>70</td>
<td></td>
</tr>
<tr>
<td>850</td>
<td>34</td>
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<td>74</td>
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<tr>
<td>900</td>
<td>78</td>
<td>129</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>950</td>
<td>78</td>
<td>179</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>138</td>
<td>220</td>
<td>243</td>
<td></td>
</tr>
</tbody>
</table>
PLATEAU CURVE FOR SPARK COUNTER
(DETECTOR CODE P-O)

Fig. 3.3
PLATEAU CURVE FOR SPARK COUNTER
(DETECTOR CODE P-19)

No. of Counts

350 400 450 500 550 600 650 700 750 800 850 900 950 1000

Applied Voltage

Fig. 3.4
### TABLE 3.3

Comparison of number of spark counts and visual microscopic counts after \( \text{MC} \) pre-sparking at 850 volts in the case of the two LR-115 Type II (strippable) foils

<table>
<thead>
<tr>
<th>Detector code</th>
<th>Pre-sparking number</th>
<th>Average no. of counts given by spark counter at operating voltage of 650 volts ((N_s))</th>
<th>Average no. of etched holes counted by microscope in area of (1\text{cm}^2) ((N_m))</th>
<th>Spark counting efficiency relative to visual counting (n = N_s/N_m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-0</td>
<td>I</td>
<td>27</td>
<td>32</td>
<td>84.3 %</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>36</td>
<td>36</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>67</td>
<td>36</td>
<td>186 %</td>
</tr>
<tr>
<td>P-19</td>
<td>I</td>
<td>63</td>
<td>74</td>
<td>85 %</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>85</td>
<td>85</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>153</td>
<td>85</td>
<td>180 %</td>
</tr>
</tbody>
</table>
window confirms this contention.

The plateau curves obtained for the two detector foils after two pre-sparking are separately shown in fig. 3.5 and 3.6. Obviously in both the cases, the operating voltage of 650 volt should be acceptable. The length of plateau is 300 volts extending from 550 to 850 volts at lower track density and from 500 volts to 800 volts at higher track density. The slopes* of the two plateau are 0.069 % per volt for lower track density and 0.028 % per volt for the higher track density. The slope thus becomes smaller and smaller with increase of track density but operating voltage remains the same.

Accepting the operating voltage of 650 volt for our spark counter, the through-etched holes were counted in the case of still higher track densities by this spark counter as well as by the binocular research microscope in the two sets of foils which were irradiated with the $^{241}$Am alphas. One of these 4 foils was not irradiated at all and hence it gives the background track density in the LR-115 Type II (strippable) plastic imported by us two years ago. Table 3.4 shows the number of counts in the case of two sets of four plastics each irradiated with different fluence of alpha particles and etched for

*Slope of the plateau is obtained by the expression
\[ \text{Slope} = \frac{(N_2-N_1)}{(N_1+N_2)/2} \times 100 \]

\[ \frac{(V_2-V_1)}{(V_2-V_1)} \]
PLATEAU CURVE FOR SPARK COUNTER
(DETECTOR CODE P-O)

No. of Counts

Applied Voltage

Fig. 3.5

II Pre-sparking
PLATEAU CURVE FOR SPARK COUNTER
(DETECTOR CODE P-19)

Fig. 3.6
TABLE 3.4
Spark counting efficiency relative to visual microscopic counts in LR-115 Type II (strippable) foils irradiated with different fluence of alpha particles from \(^{241}\text{Am}\) source

<table>
<thead>
<tr>
<th>Detector code</th>
<th>Etching time</th>
<th>Average number obtained by counting thrice with</th>
<th>Spark Counter efficiency relative to visual counting ((n = N_s/N_m))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spark counter ((N_s))</td>
<td>microscope ((N_m))</td>
</tr>
<tr>
<td>T-0</td>
<td>90 min.</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>T-5</td>
<td>90 min.</td>
<td>2630</td>
<td>2532</td>
</tr>
<tr>
<td>T-15</td>
<td>90 min.</td>
<td>6725</td>
<td>5853</td>
</tr>
<tr>
<td>T-60</td>
<td>90 min.</td>
<td>9926</td>
<td>8754</td>
</tr>
<tr>
<td>T'-0</td>
<td>120 min.</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>T'-5</td>
<td>120 min.</td>
<td>3981</td>
<td>3921</td>
</tr>
<tr>
<td>T'-15</td>
<td>120 min.</td>
<td>8775</td>
<td>8574</td>
</tr>
<tr>
<td>T'-60</td>
<td>120 min.</td>
<td>10847</td>
<td>10037</td>
</tr>
</tbody>
</table>
90 minutes and 2 hours respectively. After 90 minutes etching, the residual thickness of LR-115 plastic was 7 \( \mu m \), while after 2 hours etching it was \( \approx 5 \mu m \). It is seen that in both the sets the relative efficiency is very close to 100 \%, is obtained upto a track density of \( \approx 3000 \) tracks \( cm^{-2} \). Above this value multiple sparking through the same hole results into higher results by 8-13 \%.

Before concluding it is important to mention the effect of changing the polarities on the two electrodes of the jumping spark counter. It was found that when the thick electrode on which the detector foil is mounted, was connected to the -ve terminal (or earthed) then, even at high track density the track holes in the plastic and those developed in the 'aluminized Mylar' replica had one-to-one correspondence. But in the reverse case i.e., when the electrode on which the detector is mounted was connected to the +ve terminal and the other electrode was earth, then several holes developed in the 'aluminized Mylar' replica touche each other and make a bigger hole. Thus the correct counting of tracks by observing the replica under a microscope or by a projector is not possible.

3.6 CONCLUSION:

The jumping spark counter fabricated by the author counts the alpha particle tracks in LR-115 Type II
(strippable) plastic track detector with 100 % relative efficiency compared to the visual observation, only after two pre-sparking at 850 volt. The operating voltage for this jumping spark counter is 650 volt and the slope of the plateau is negligible at higher track density but little bit more at lower track density. However, the slope is always much less than those obtained in the case of typical G.M. counters. This spark counter is capable of giving 100 % relative counting efficiency up to track densities of ≈ 3000 track cm⁻² for alpha particles. Better results are obtained when the etching is carried out for 90 minutes.

This jumping spark counter will be very useful in low level alpha counting experiments especially the measurement of radon and radon progeny using LR-115 Type II track detectors and also in angular distribution measurements in the case of low cross-section α-emitting nuclear reaction like (p,α) and (d,α) etc., at low irradiation energies.
REFERENCES