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Abstract

The technique of counting fission fragments tracks through the sparks produced in Makrofol foils has been developed in this laboratory to be used as routine. This kind of detectors is being exploited in recent years due to the number of applications they have in nuclear technology and in work connected with fission processes.

I - Introduction

The solid state track detectors are been used in recent years for a number of applications in nuclear technology as well as in pure research. Measurements of fission cross section and excitation functions, fission fragments angular distributions, neutron flux, absolute fission rate, geological dating of minerals, determination of $^{235}U/^{238}U$ fission ratios, estimation of uranium in sea water, etc are some of the uses of this type of detectors. These detectors are increasing in importance once they are powerful and inexpensive tools for fission work.

As we are involved with many experiments in which photofission fragments have to be measured[1,2] we dicided to study in detail the Makrofol method in order to establish it as a routine technique.

The technique developed here consists not only in using thin foils of Makrofol as detectors but also in counting the fission fragments traks electronically[3].

Fission fragments in general come in a high field of other radiation types, thus difficulting its detection. So it is very important to choose detectors which have sensibility only to fission fragments as the solid state track detectors like mica, glass, plastics[4], etc. This kind of detectors is largely used due to such properties as: a) low sensibility, needing a high energy dissipation of the incident radiation thus avoiding the detection of α,β,γ, or neutrons; b) high efficiency, about 100% for fission fragments.

When the fission fragments hit this kind of detectors they produce tracks that can be enlarged by a chemical etching. In the case of Makrofol foils this chemical etching is made by KOH which produces small holes that can be counted in a microscope. This is an exhausting work, mainly if a wide area has to be examined.

In order to avoid this incovenience the Makrofol can be used as a dielectric of a capacitor where a suitable voltage is applied. Discharges will be produced through the holes and each one of them can be counted by a scaler. This method is very quick and reproducible and is used in almost all the laboratories where fission fragments need to be counted[5].

II - Description of the Method

Fission fragments produce through their passage in materials such as mica and glass a radiation damage in the form of a track. These tracks are easily enlarged by a chemical etching, thus permiting their observation in an optical microscope. The same phenomenon happens when this radiation passes through Makrofol which is a plastic material in the form of thin foils (2 μm to 20 μm thickness) with a dielectric constant of ~ 2.9. After the chemical etching the Makrofol foils are placed as an insulator between two conducting plates where a high voltage is applied.

One of the conducting plates is an aluminized Mylar foil. When a discharge occurs through one of the holes the aluminium of the Mylar foil evaporates due to the local increase of temperature thus avoiding a new discharge at the same point. The capacitor is recharged until a voltage sufficiently high is achieved to produce a new spark through another hole. The process will be repeated till all the holes have been used. In fig. 1 we can see the electronic circuit employed to count automatically the sparks produced through the holes.

The spark pulses are counted in a scaler coupled to the capacitor and at the same time one gets at the Mylar a replica of the Makrofol pattern. The holes in the Mylar (fig. 2) can also be counted by visual method using a projector in an easy way.

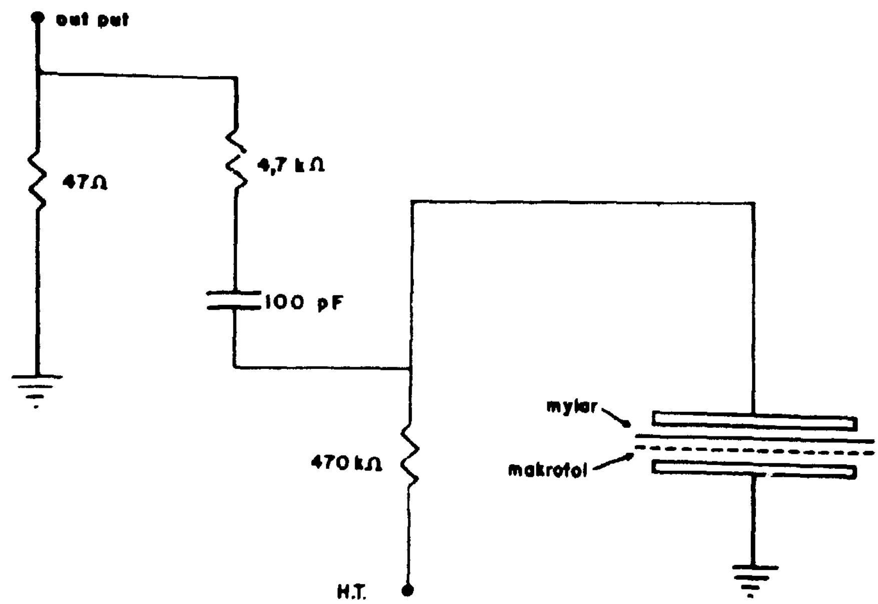

Fig. 1
Eletronic circuit employed for counting the sparks.

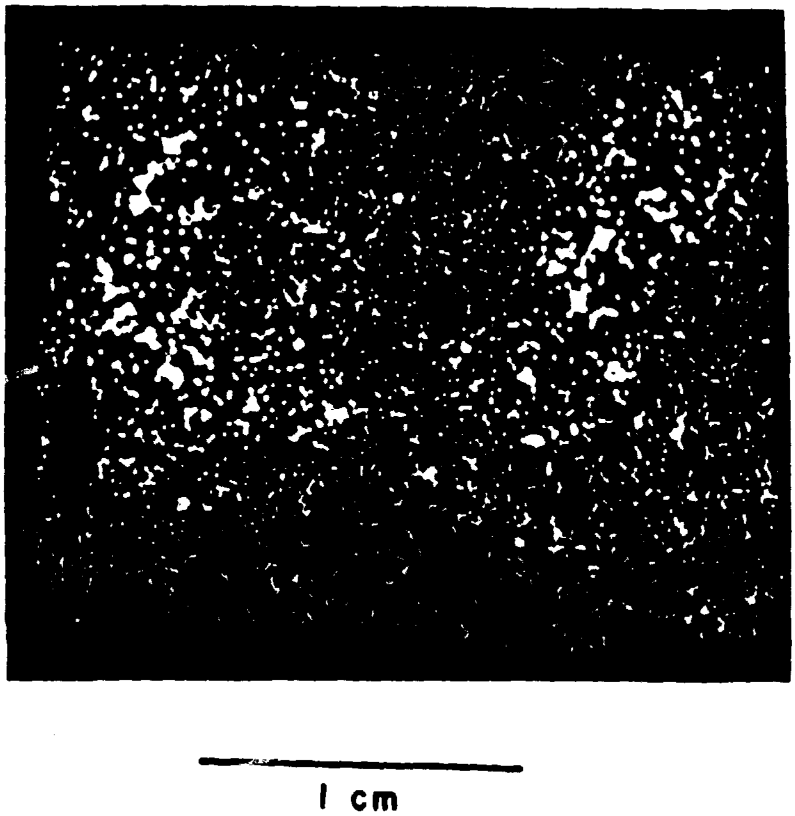

Fig. 2
Replica of the Makrofol holes at the Mylar.
The hole density is equal to $430/cm^2$.

III - Experimental Results

1 - Irradiation and chemical etching of the Makrofol foils

It was employed, as a source of fission fragments, a natural uranium radiator (about $2 mg/cm^2$ thickness) in an aluminium backing with an area of $4.2\ cm^2$. The fission was induced in uranium by the neutrons provenient from an Am-Be source of 2 Ci.

The Makrofol foils ($10\,\mu m$ thickness) were placed in direct contact with the uranium, thus getting the fragments in all the incident angles.

This experimental arrangement for irradiation has a reproducible geometry so the number of tracks in the Makrofol depends only on the irradiation time.

After being bombarded with the fission fragments the Makrofol foils were etched in KOH (35%) at 60°C temperature[3].

As the couting efficiency depends on the amount of etching, to reproduce the detection efficiency it is necessary to control the etching time and the temperature. This last one was maintained constant to within ± 0.5°C. With these experimental conditions the variation of counts as a function of the etching time was studied in order to choose the most convenient one Fig. 3 shows the results obtained. We observe a sensible increase in the number of counts as the etching time changes. This can be explained by the fact that the tracks in the Makrofol have an isotropic angular distribution as can be seen in fig. 4. When the etching time is short the sparks will occur only by the tracks of type a, and it is difficult to break the dielectric through tracks of type b. Increasing the etching time the tracks of type b will be deepened thus making it possible to break the dielectric. This variation of efficiency with the etching time does not occur for perpendicular incidence of the fission fragment as in the case of a colimated beam.

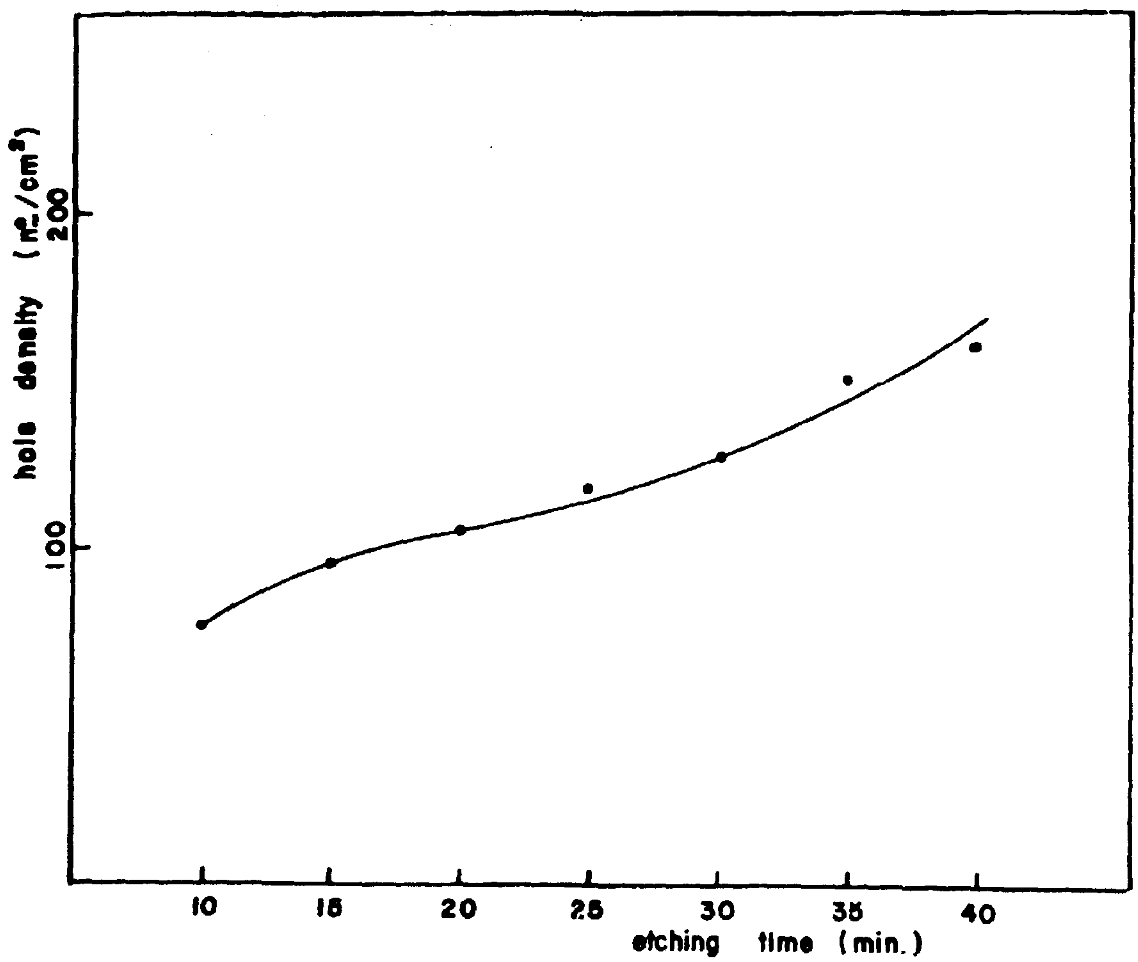

Fig. 3
Variation of the number of holes with the etching time, (KOH 35%, 60°C).
These points were obtained with a constant
irradiation time of 4 hours.

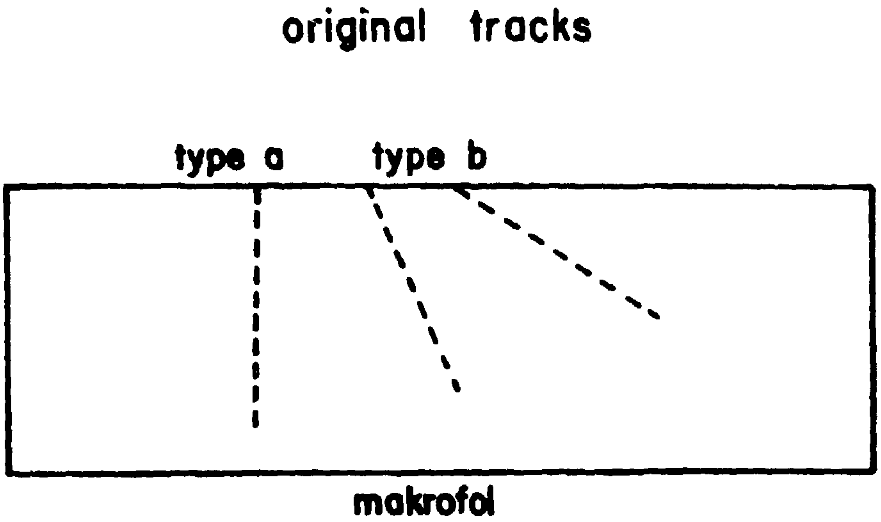

Fig. 4
Form of the tracks produced at the Makrofol for isotropic incident fission fragments before the chemical etching.

For the irradiation conditions employed this means an isotropic incidence, we have chosen the etching time of 20 minutes. If a reproducibility of 1% is desired, the etching time can not have variations greater than 2.5%. Using 20 minutes for the etching time, the background due to defects on the Makrofol foils was verified to be of the order of 1/10 cm^2. If the etching time increases, the detection efficiency will be higher but the background will also increase in a rapid way as can be seen in fig. 5.

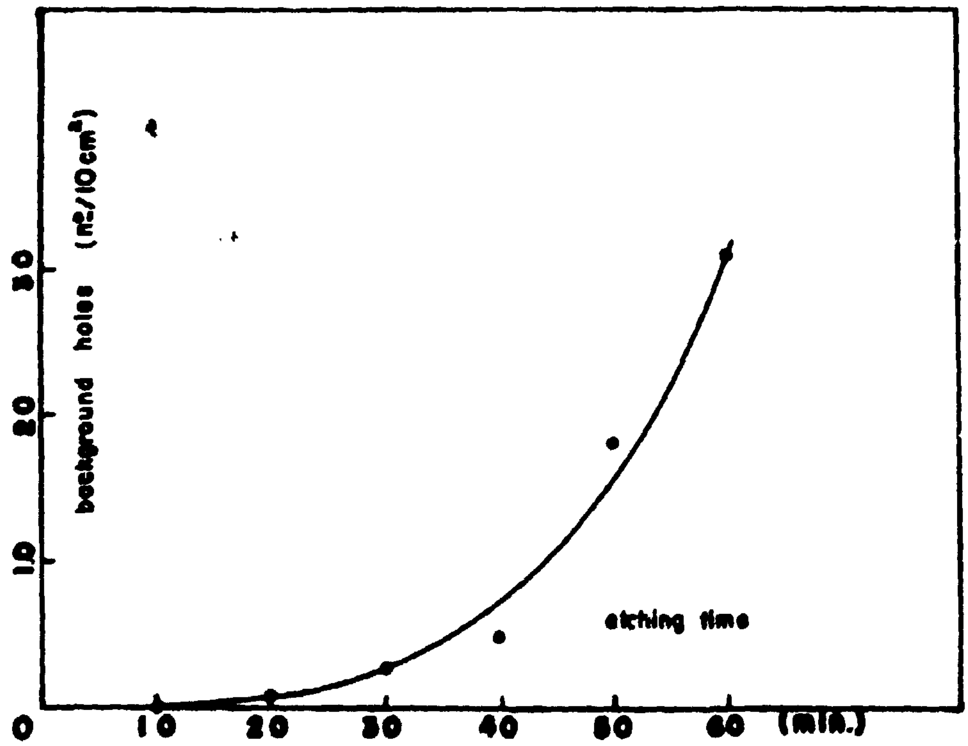

Fig. 5
Variation of the background with the etching time (KOH 35%, 60°C) for a Makrofol foil with thickness equal to 10 μm.

2 - Counting the sparks

After being chemically etched the Makrofol is placed in the spark chamber that can be seen in fig. 6. Care has to be taken in order to get a perfect contact between the Makrofol and the conducting plates. The lacking of this care will produce counting losses.

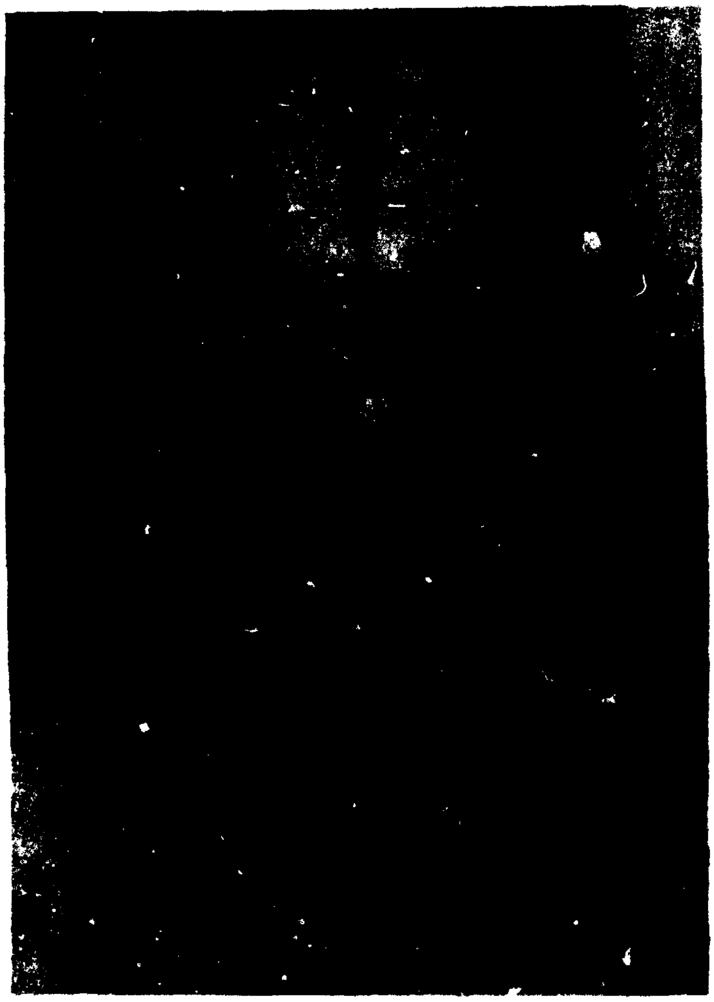

Fig. 6

Spark chamber view.

In a first step a high voltage (~ 1300 V) is applied in order to break completely the dielectric through the original holes. Then using a new aluminized Mylar foil and a lower voltage (~700 V) the counting of the sparks is made in a scaler.

The electronic circuit employed in the chamber makes it possible to get an output signal that has $\frac{1}{100}$ of the applied voltage, thus allowing one to count the sparks in a scaler without adding more electronic equipment. Fig. 7 shows the pulse height distribution at the output when the voltage applied is 700 V.

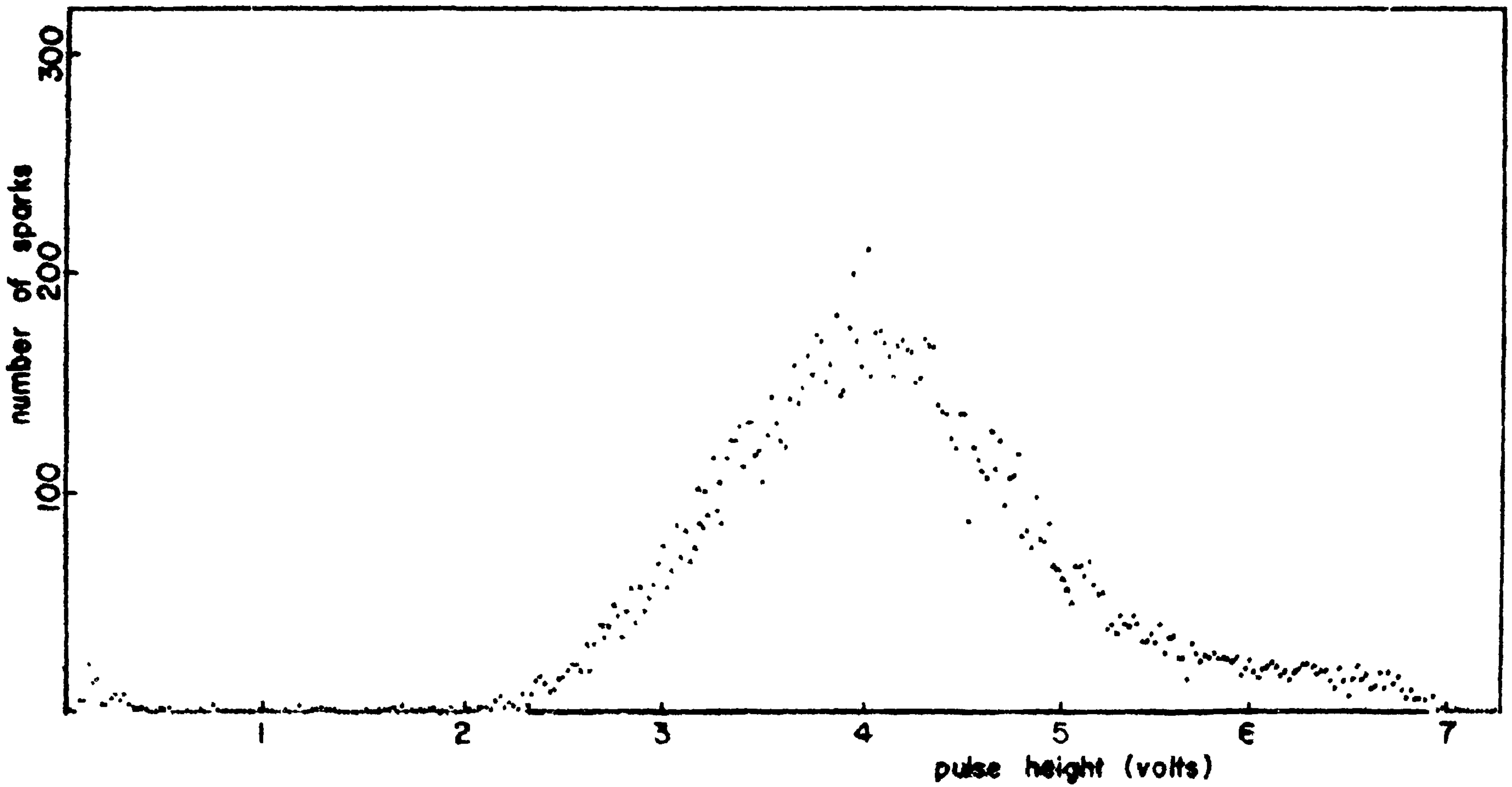

Fig. 7

Pulse height distribution at the spark chamber output with an applied voltage equal to 700 V.

The initial voltage to be applied can be anywhere between 1000 and 1500 Volts. The variation of efficiency with the initial voltage is seen in fig. 8. In the present paper the initial voltage chosen is 1300 Volts. For the counts reaching the scaler the voltage is between 500 and 850 Volts and the changing in efficiency with voltage can be seen in fig. 9. In the present paper we have chosen the value of 700 Volts.

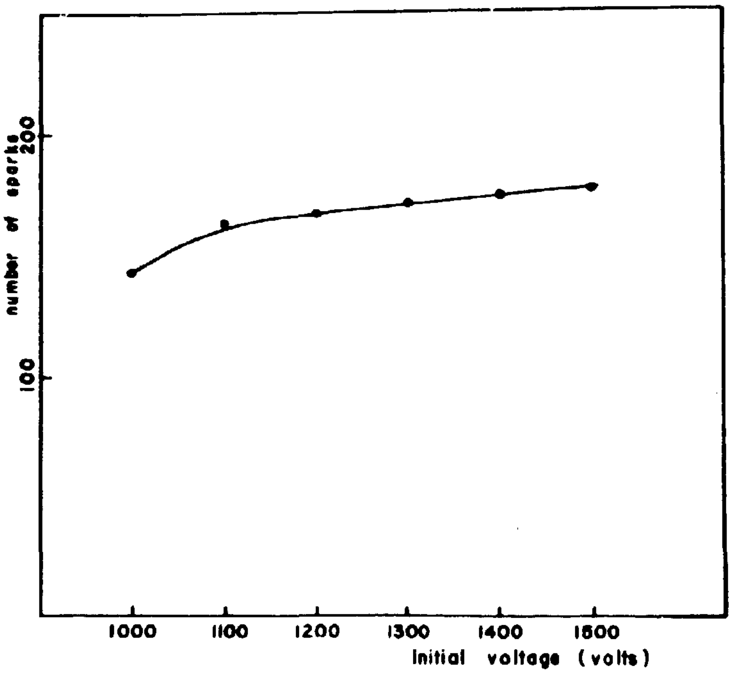

Fig. 8

Variation of the number of holes with the initial applied voltage.
The applied voltage used for counting the sparks was equal to 700 V.

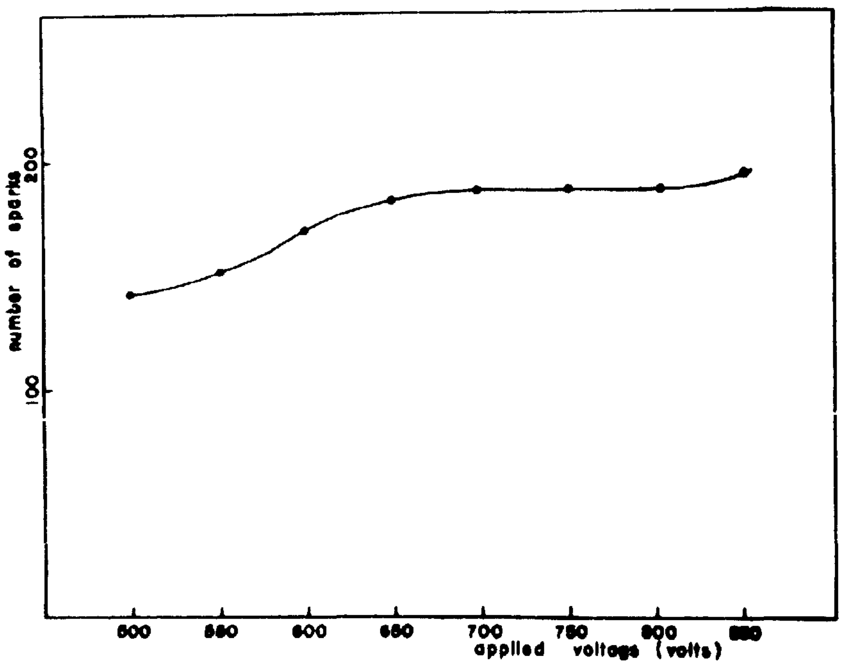

Fig. 9

Variation of the number of holes with the applied voltage used for counting the sparks.
The initial applied voltage was equal to 1300 V.

With these experimental conditions we verified the performance of this detection technique when the incident density of tracks in the Makrofol changes. Fig. 10 shows the results obtained, the tracks density being proportional to the irradiation time. For densities above 1100 holes/cm^2 the counts obtained are lower than the expected ones. This loss is due to the overlapping of holes in the Mylar. This will limit the intensity of the source to be measured. This upperlimit is a function of the capacitance employed and can be increased if this capacitance is reduced. This reduction is related to the area of the Mylar used. In the present work the capacitance was ~ 0.003 μF.

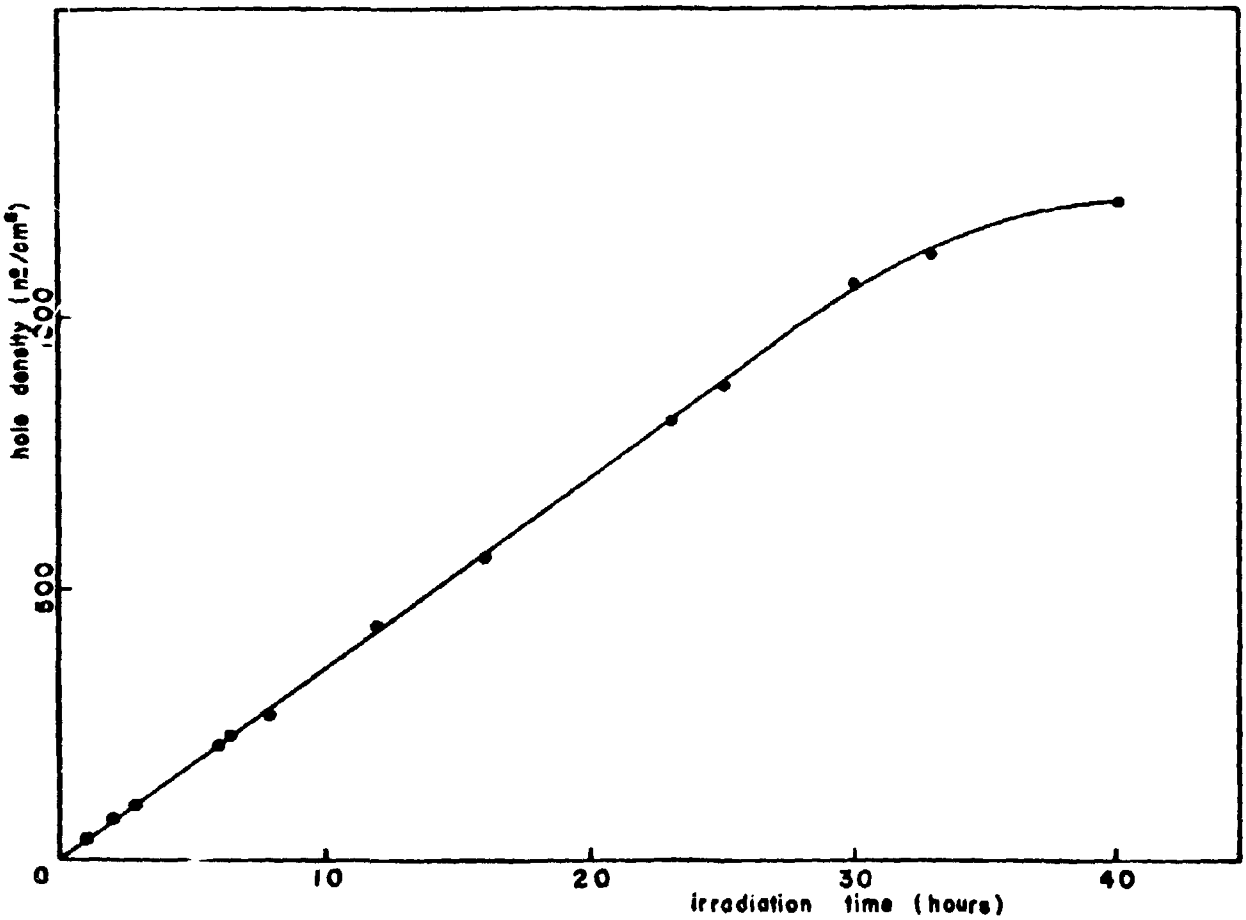

Fig. 10
Variation of the number of sparks counted by the scaler with the irradiation time.
(KOH 35%, 60°C, etching time equal to 20 min.).

3 - Overall detection efficiency

In order to calibrate the Makrofol efficiency when it is employed with the present technique, a comparison of number of tracks with the ones of a calibrated mica[6] was made.

For the experimental geometric conditions used, this means the isotropic source of fragments and the Makrofol in direct contact with the source, the efficiency is 37%.

IV - Conclusion

The detection technique described in this paper overcomes the main difficulty presented by the solid state track detectors[4] used for fission fragments. This difficulty is the long time required for track counting.

The spark method for counting fission tracks uses very simple equipment and permits one to make in seconds the counts which would take hours in a microscope, thus making their use practical in many experiments, mainly the ones in which the $^{235}U/^{238}U$ fission ratio has to be determined[7].

The reproducibility found with our experimental arrangement is about 3% and this is sufficiently accurate for the experiments in which we intend to use the Makrofol foils.

The upper limit of tracks density is 1100 tracks/cm^2. Above this density we get the overlapping of holes. This limit can be increased changing the area of the capacitor where the sparks occur to a lower value.

The low limit is the background counting that in our case was of the order of 1 track/10 cm^2.

Acknowledgements

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RESUMO

A técnica de contagem de traços de fragmentos de fissão através de descargas produzidas em folhas de Makrofol foi desenvolvida neste laboratório para ser usada como rotina. Este tipo de detector está sendo muito explorado recentemente devido ao grande número de suas aplicações em tecnologia nuclear e em trabalhos ligados ao processo de fissão.

RÉSUMÉ

La technique de comptage des traces de fragments de fission à travers des décharges dans les feuilles de Makrofol a été dévelopés dans ce laboratoire, pour des uses routinières. Ce type de detecteur a été bien exploré actuellement à cause de son grand numéro d'applications dans la tecnologie nucleaire et dans les traveaux rapportés à le process de fission.

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