STUDIES ON THE CHARACTERISTICS OF NUCLEAR TRACK SPARK COUNTING

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1. INTRODUCTION

The fission track counting method using polycarbonate sheet is known to be very effective for neutron monitoring. The detection unit consists of a track detector foil placed in contact with a thin layer of fissile material. When the unit is irradiated with neutrons, fission fragments from the fissile material layer produce scars or tracks on the detector foil. The detector foil is then etched by suitable chemical treatment to enlarge the tracks to etch-pits, which are visible under an ordinary optical microscope. However visual track counting is a tedious and time-consuming job. Automatic spark counting of etched track on the surface of the foil was initiated by Cross W. G. and Tommasino L., and is applied for neutron monitoring of some nuclear institutes or plants (1)-(4). We have investigated spark counting characteristics of above system using polycarbonate detector foils of different thickness and aluminized polyester sheets of different aluminium thickness for an electrode.

2. FISSILE TARGET PREPARATION

Thin layer of natural uranium and thorium as fissile targets for neutron detection were prepared by electroplating on stainless steel plates of 33 mm diameter (electrodeposited area of 24 mm diameter). As the fissile target for fast neutron monitoring ^{232}Th, ^{238}U, ^{237}Np etc. may be used. Since the price of ^{237}Np is high, and natural uranium contains a small amount of fissile nuclide ^{235}U, thorium is suitable. Uranium and thorium electroplatings (10-1000 μg) were carried out using ammonium oxalate solution as electrolyte and ethanol at electric current density of 300 mA for uranium and 100 mA for thorium per 4.5 cm^2, respectively, in a water bath at 80°C for 3 hours. And then the target discs were rinsed sufficiently. Electroplating efficiencies of uranium (500 μg) and thorium (500 μg) were about 90% and 70%, respectively at optimum electric current density.

3. SPARK COUNTING

Five kinds of detector foils were used for comparison, namely, Makrofol KG 5 μm, 10 μm and 20 μm thick made by Bayer company in West Germany, Panlite 18 μm thick made by Teijin company in Japan, and Lumirror 6 μm thick made by Toray company in Japan. Makrofol KG and Panlite foils were polycarbonate and Lumirror was polyester. The foil was first placed in contact with a fissile target described above. This unit was exposed to neutrons in the UTR-B reactor (1 watt) operated at Kinki University, Osaka, Japan. The maximum thermal neutron flux in the center of the graphite in routine operation at 1 watt was about 1.2×10^7 n/cm^2.sec. The fast neutron flux was about one tenth of thermal neutron flux. However, the thermal neutron flux in the upper part of the graphite, where samples were irradiated, was about

5 x 10^5 n/cm^2.sec. A gold foil was irradiated with each detector foil in the reactor in order to compare and ascertain the thermal neutron flux. For the detection of fast neutron, thorium electroplated disc was used instead of uranium and calcium metaphosphate was irradiated with the unit for comparison.

After irradiation the detector foil was separated from the fissile material and immersed in a 30% KOH solution at 60°C for 20 minutes for etching. After drying, the etched detector foil was placed between the two electrodes for spark counting. One of the electrode is a copper disc of 26 mm diameter and the other is an aluminized polycarbonate sheet with the aluminized side facing the etched detector foil. The thickness of aluminium layer on the sheet is 98 Å. To punch the unperforated etch-pits on the foil, a punching voltage of about 1000 volts for Makrofol KG 10 μm thick is applied between the two electrodes. Sparks arise through the etch-pits of the detector foil. Each spark evaporates aluminium and produces a hole in the aluminized sheet, covering an area much larger than the size of the hole on the detector foil. This aluminium evaporation prevents multiple sparking through the same hole of the detector foil. As the rate of sparks during punching is too high to count with an ordinary scaler, the etched and punched detector foil is again placed on another new aluminized sheet and the sparks are counted with an ordinary scaler at a lower counting voltage.

4. LINEARITY

The relation between spark count and number of fissions was approximately linear until spark counts of 700 per 4.5 cm^2 as shown in Fig.1. Deviation from the linear line above 700 counts may be ascribed to the resolution of scaler used.

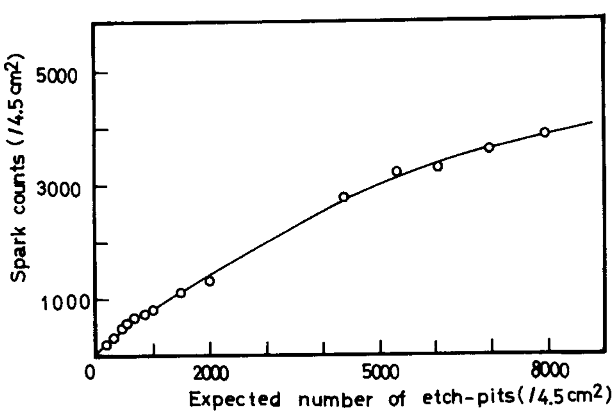

Fig.1 Relation between expected number of etch-pits and spark counts.

5. COMPARISON OF DETECTOR FOILS

Spark efficiencies were examined for five detector foils of different thickness as shown in Table 1. Optimum punching and counting voltages increased as the thickness of detector foils increased. It was found that spark efficiencies decreased abruptly after the foil thickness exceed 10 μm.

Foil	Thickness (μm)	Punching voltage (V)	Counting voltage (V)	Spark efficiency (No.of etch-pits: 1000~2000) (%)
Makrofol KG	5	800	500	100
Lumirror	6	700	500	74
Makrofol KG	10	1000	550	77
Panlite	18	1300	800	28
Makrofol KG	20	1300	800	8.4

Table1 Comparison of detector foils.

6. COMPARISON OF ALUMINIZED SHEETS

Aluminium hole sizes and spark efficiencies for Makrofol KG of 10 μm thick were examined for aluminized sheets of different aluminium thickness (27.3 - 287 Å). Aluminium hole diameter decreases from 196 μm (for sheets of 27.3 Å) to 146 μm (for sheet of 237 Å) as the aluminium thickness increases. Spark efficiencies slightly increase several percent as the aluminium thickness increases (Fig.2).

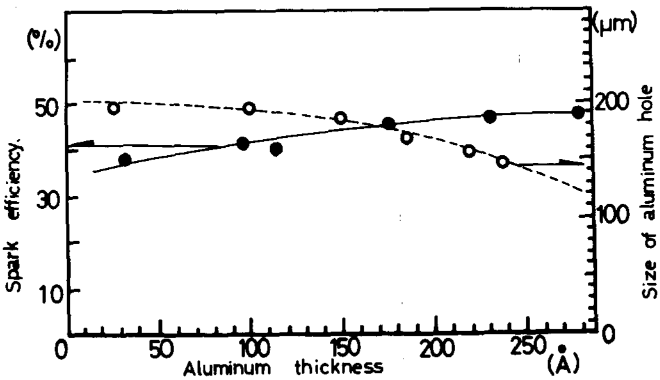

Fig.2 Relation between aluminum thickness of electrode and spark efficiency and size of aluminum hole.

7. CONCLUSION

As spark efficiency increases as detector foil thickness decrease, it seems that the thinnest Makrofol KG of 5 μm thick is the best. But this is so delicate for handling that Makrofol KG of 10 μm thick is considered to be suitable. Lumirror of 6 μm thick is stronger than Makrofol KG of 5 μm thick and can be used instead.

As for aluminized sheets, increase of spark efficiency is slight as the thickness of aluminium layer on the sheet increases. So any aluminized sheets are considered to be suitable, since aluminium thickness of sheets does not largely influence upon sparking characteristics.

8. REFERENCES

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