NEUTRON DOSIMETRY BY THE SPARK-REPLICA COUNTER WITH AND WITHOUT ETCHING

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1. INTRODUCTION

A combination of a fissile radiator and an insulating foil in which to record damage tracks represents a convenient fast neutron dosimeter. The spark-replica technique for the rapid counting of etched fission fragment holes in plastic films has removed the practical difficulties of determining low neutron doses (1). Since these neutron dosimeters provide either rad or rem response and are sensitive, simple and inexpensive, they are used in several laboratories throught the world. On the other hand, application to measuring neutron doses by these counters is possible only for track densities lower than 3000 tracks per square cm, which corresponds to a fast neutron dose of about 10 Rads when Th radiators are used. Other drawbacks arise when good reproducibility is desired, since troublesome etching conditions are required. Furthermore these dosimeters can not provide dose measurements at the time of the exposure and dose rate evaluations when the neutron flux is time dependent, since chemical etching is required before the track detection.

This paper describes a new spark-replica counter, which helps to overcome these difficulties and avoids chemical etching, by counting electrical breakdowns initiated by fission fragment in thin film capacitors. The property that makes thin film capacitors suited for detection is that fission fragments induce breakdowns at fields distinctly lower than those due to the application of field only (2).

2. THE DETECTOR AND THE EXPERIMENTAL PROCEDURES

The detecting element is a thin film capacitor with a few hundreds Angstroms dielectric film and at least one electrode with thickness less than about 1000 Å. In such devices, high electrical fields are obtained at low applied voltages so that breakdowns cause limited destruction. Each breakdown produces by evaporation a hole through the insulator and through the thin electrode thus avoiding the short-circuit (3).

Fig. 1 shows how simple the breakdown detection equipment is. A resistor larger than 10 KΩ is usually placed between the power source and the capacitor to prevent large destruction by propagating breakdowns (3). This resistor can be replaced by any Geiger-Müller-type quenching circuit, capable of fast removal of the voltage from the capacitor at the time of the breakdown.

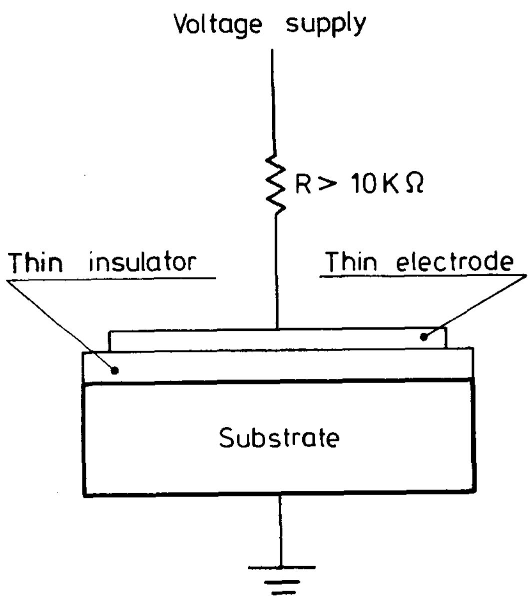

FIG. 1 Basic circuit for breakdown counting with a thin film capacitor

The electrical pulses produced by the breakdowns can be counted directly by a scaler and the evaporated spots can be observed by a reflection optical microscope. The thin film capacitors used here consisted of a degenerate p^+ silicon substrate with a thermally grown silicon dioxide film and a thin aluminum top electrode. The fission fragment irradiations were carried out by a thin planar ^{252}Cf source.

3. RESULTS

In a 380-Å-thick silicon dioxide capacitor with 150-Å-thick Al top electrode, breakdowns started occurring at applied fields above 8MV/cm. When the capacitor was irradiated with fission fragments, breakdowns occurred at relatively low electric fields. The fission fragment breakdown number versus the applied voltage, after a first steep rise, reached a plateau and it lied mostly in a range below the voltages for purely electric fields breakdowns.

At a plateau voltage of 29.5 volts the breakdown counting was equal, within statistics, to the number of the fission fragments crossing the SiO_2 film, as determined by counting damage tracks in a polycarbonate foil. At this applied voltage and up to 10^5 events per square cm of the capacitor area, there was a good proportionality between the breakdown counting and the number of fission fragments crossing the detector. The average diameter of the evaporated spots on the Al electrode was about 5 microns. With the increase of the number of breakdowns a decrease of the sample capacitance is registered, which indicates that the detector area decreased. When the breakdown counts were corrected by the capacitance losses this proportionality was extended up to millions of events per square cm of the detector area.

4. CONCLUSIONS

Apart from the detecting element, the thin film breakdown detector is similar to the spark-replica counter of etched-through tracks (1). With the track counter the breakdowns occur in the gas of etched holes in a few microns thick plastic film and each breakdown evaporates an aluminum spot with an average diameter larger than about 100 microns. In this case the fission fragment counting could be carried out only up to spot densities of a few thousands per square cm, which spot densities are two order of magnitude lower than those which can be detected with thin film capacitors.

For the thin film capacitors such those used here, non-shorting breakdowns cause collapse of the sample voltage within a microsecond to less 10-20 V (4). For samples between 300 and 3000 Å with breakdown voltages between 25 and 250 V, a pulse of at least a few volts is obtained at each breakdown. Such pulses do not require amplification and can be counted directly by a scaler. When compared with the track spark counter which require chemical etching before the detection, the thin film capacitors present fast time response.

A fissile radiator such a ^{238}U, ^{232}Th or ^{237}Np foil can be placed against the thin electrode for the detection of neutron-induced fission fragments. A simple neutron detector is thus obtained with the only requirements of a thin film capacitor, a power supply of a few tens of volts and a scaler. By modern miniaturization and processing techniques, these components could be packaged in a compact pocket-sized detecting system, which might be highly valuable for alarm neutron detection and dosimetry.

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