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Alternative approach to fast neutron dosimetry

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Track recording plastic dielectrics are being used for personnel neutron dosimetry using chemical and electrochemical etching techniques. These detectors have certain limitations at both high and low neutron doses. An alternative approach based on variation of electrical resistivity with neutron fluence has been proposed.

Electrochemical-etching (ECE) techniques have been applied to fast neutron dosimetry by various workers[1-7] using both internal and external radiator methods. The obvious advantage of ECE over chemical-etching (CE) techniques is the possibility of amplifying the latent proton recoil tracks to voluminous discharge spots, thus making the detection simpler, faster and more reliable.

In most of neutron dosimetric applications, plastic dielectric poly allyl diglycol carbonate (PADC-trade name CR-39) has been extensively used because of its higher detection efficiency for recoil protons. In the present work, we have employed CR-39 (Pershore Mouldings Ltd., U.K.) and cellulose triacetate (CTA) plastic sheets for detection of proton recoil tracks without external radiator.

Track-etch methods employed for fast neutron dosimetry using CE and ECE are inherently tedious because of track overlap at high neutron doses and artifact backgrounds at relatively low doses. Fadel[8] suggested an alternative approach based on change in electrical properties of dielectrics caused by radiation damage using cellulose acetate as detector material. In the present study, an attempt has been made to investigate the variation of electrical resistivity of CTA caused by fast neutron irradiation.

Experimental details—In the present investigation CR-39 plastic foils of 12 mm dia and 250 μm thickness were irradiated under atmospheric pressure and at room temperature using collimated beams of fast neutrons available from Am-Be neutron source at Punjab Agricultural University, Ludhiana. CTA foils of thickness 115 μm were obtained after removing the emulsion from black and white photographic film manufactured by ORWO, East Germany (GDR). The chemical formula of monomer is $C_3H_4O_2$. The circular samples of 12 mm dia of this film were irradiated as in case of CR-39. Irradiation of CTA was also carried out with fast neutrons from ^{252}Cf source in our laboratory by stopping fission fragments with a thin piece of paper. The neutron fluence at the detector surface for normal incidence was varied from 1.5×10^5 to 3.15×10^6 n/cm^2.

Etching of samples—To find the optimum conditions for the revelation of neutron induced proton recoil tracks by ECE technique in CR-39, we have followed the procedure involving the following two steps:

(a) As a first step, CE of CR-39 foils was carried out using 6N NaOH at 70°C for various time intervals and thickness measurements were performed after every etching interval by using a micrometer. Due to this pre-etching, the background of alpha tracks produced by natural radioactivity of air, and other surface inhomogeneties were over-etched and appeared in track form of rounded tip unsuited to a subsequent ECE.

(b) As a second step, the same samples were etched using ECE keeping the irradiated side in touch with the same etch-media as used for pre-etching at the room temperature. Details of ECE technique are described elsewhere[9-10]. Since CTA foils are insensitive to alphas (responsible for background tracks) produced by natural radioactivity of environmental air, or dust, there is no need of pre-etching and direct ECE is performed after optimising the electrical parameters. Density of ECE tracks was determined using optical microscope at a magnification of 400x.

Measurement of resistivity—Irradiated foils of CR-39 and CTA were painted with silver paste on both sides to achieve good electrical contacts. The dc resistance of the samples was measured using million megohm-meter (Model RM 160 MK 111A) supplied by BPL, India. This instrument is capable of measuring the insulation resistance upto 400 million megohms and a current down to 1.0 picoampere with an accuracy of ±7 percent. The resistivity of plastic foils was calculated by using the relation, $\rho = R.A/d$, where d is the thickness, A the

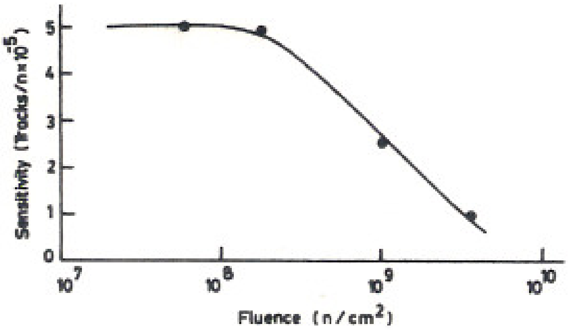

Fig. 1—Senitivity of CR-39 sheets as a function of fast neutron fluence using CE + ECE technique

effective area (which is equal to the cross-sectional area of the sample holder) and R the measured value of resistance of the irradiated sample.

Results and discussion—Al-Najjar *et al.*[11] reported that ECE response of a track etch detector is a function of track density. When the track density is too high the electrostatic repulsive forces between nearby tracks decrease the probability of the production of discharge spots during ECE. Therefore, the sensitivity of the detector will depend on the neutron fluence during irradiation. It is evident from Fig. 1 that the sensitivity of CR-39 for recording proton recoil tracks remains constant upto a fluence of about 10^8n/cm^2 and then there is an abrupt decrease with the further increase of neutron fluence. Our results are in agreement with those reported by Turek *et al.*[12].

An interesting trend of dc electrical resistivity variation with neutron dose has been observed in case of CTA (Fig. 2). At first, resistivity of the virgin sample is measured. It falls abruptly by 275 percent at a neutron fluence of 1.5×10^5 n/cm^2 and then shows a fluctuating trend upto 1.5×10^6 n/cm^2. It shows a linear dependence upto 2.25×10^6 n/cm^2. At higher neutron doses it rises slowly almost reaching a plateau value. However, CR-39 plastic did not exhibit observable change in the value of electrical resistivity on irradiation upto a neutron fluence of 5×10^6 n/cm^2.

It is evident that an alternative approach to fast neutron dosimetry is available without taking recourse to CE or ECE of tracks, if we choose a suitable dielectric material and the linear portion of

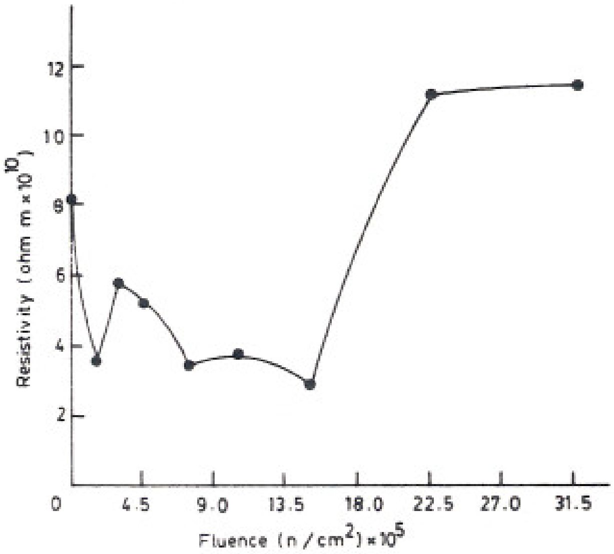

Fig. 2—The dc resistivity of CTA foil as a function of fast neutron fluence

the curve. We were able to measure a neutron dose as low as 0.35 mrem (Ref. 9). Further experiments are in progress to establish this new technique for personnel neutron dosimetry in high radiation risk area.

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