TRACK ETCH TECHNIQUES AND APPLICATIONS

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Introduction

Almost all insulating solids, including natural minerals, glasses and plastics, record tracks of nuclear charged particles. Silk and Barnes (1959) were the first to detet induced fission tracks in mica with an electron microscope. The tracks are visible because the diffraction contrast has been locally altered by the production of damaged, strained regions around the paths of bombarding fission fragments. The radiation damage trails are 50-100 A in diameter and can be enlarged by chemical etching for optical microscopy of tracks. Fleischer, Price and Walker (1975) made extensive investigations of track recording characteristics of various minerals, dieletrics, insulators, meterorites and moon rocks. Track etch techniques have become popular due to their simplicity, cheapness and application in diverse fields, viz. nuclear physics, geology, cosmic rays, space physics, radiation biology, metallurgy and exploration geophysics.

Nature of Tracks

The basic radiation damage mechanism which produces the latent image of tracks in solids has been attributed to either “displacement spike” or “thermal spike”. One of the most striking characteristics of track-registering materials is the correlation with their electrical conductivity. Insulators and certain semiconducting glasses may register tracks; metals and the better semi-conductors like Si or Ge, do not. Ion explosion spike model explains the track formation in solids and dependence on conductivity. There is possibility of track formation in all those materials having resistivity more than 2000 ohm-cm. The fundamental idea is that a continuous, cylindrical region of damage may be created by the violent coulombic repulsion of the positive ions remaining after the scattering away of electrons by an energetic, massively charged particle. The proposed mechanism is shown in fig. 1.

The response of any substance to charged particles is determined by a single parameter, the critical rate of energy loss for track formation, $(dE/dx)_c$. Knowing the value of $(dE/dx)_c$, we can predict which particles will register tracks, and at what energies. Fortunately different substances have widely different values of $(dE/dx)_c$ thereby making it possible to choose detectors which will differentiate between particles of different mass. Table 1 summarizes the values of $(dE/dx)_c$ for various solids. Theoretical curves for critical energy loss are given in fig. 2

Tracks can be distinguished from dislocations in the solids on the basis of following criteria:

(i) They form line defects
(ii) They are straight and randomly oriented
(iii) They are of limited length (5-20 μm)
(iv) They can be caused to disappear by suitable heating.

The shape and size of the tracks in a solid depends upon various factors:

(i) Nature of the material.
(ii) Nature of the Particle.
(iii) Etching conditions.
(iv) Crystal plane.
(v) Irradiation geometry.

3. Etching of tracks

The technique for revelation of latent tracks in solids is known as etching. It is more of an art than a technique. It serves to develop and fix charged particle tracks for observation in the optical microscope and hence increases the usefulness of this method of particle detection. There are various versions of this technique.

(a) Chemical etching.
(b) Electrochemical etching
(c) Polymer grafting
(d) Sensitization and decoration.

(a) The chemical etching effect was first discovered in synthetic flour-phlogopite mica by Price and Walker (1962). Optimum etching conditions have been given in Table 2 for various solids. The radiation damage trails are more susceptible to chemical reaction compared to bulk material because of the large free energy associated with disordered structure of the damaged region. The chemical reagent dissolves the inside material around the trails and the width of hollow channel becomes comparable to the wavelength of light scattered. The shave of the track depends on the ration (V_T/V_G). The etched track p[attern will be conical in shape with cone angle, if (V_T/V_G) 1. For etched tracks to appear, the angle of inclination of charged particle with the surface of the detector must be greater than the critical value of the cone angle at which the tracks just appear (fig. 3a). The critical angle O_c is given by the relation:

$\mathrm{Sin}\theta_c = V_G/V_T$

In case of mica, $V_T \gg V_G$ and almost all the tracks appear on etching but in case of sodalime glass the value of θ_C is nearly 35^0.

The incubation time before the channels start enlarging is probably the time it takes to remove the reaction products from the cores of damaged regions and to supply fresh etchant to the sides of the channels. These steps involve diffusion, and it is clear they should to temperature dependent.

Etching rate of a solid depends upon the following three factors:

(i) Concentration of chemical reagent
(ii) Temperature
(iii) Time of etching

There is no simple mathematical relation to define etching rate but is varies linearly with time. Removal of etch product layer and ultrasonic stirring enhances the etching rate. Etching curves for glass are shown in fig. 3b.

(b) Tommasino proposed an elegant method for amplification of nuclear tracks in plastics known as electrochemical etching. At the beginning of the etching, the reagent rapidly diffuses in the preexisting fine channels resulting from the passage of heavy charged particles, producing conducting paths, which penetrate the insulating foil. If an A.C. coltage is applied through the dielectric itself during the etching, currents can be produced in these conductive paths, thus increasing their etching rate. Treeing phenomenon is produced at the damage sites by electrochemical etch technique using the arrangement shown in fig. 4. Electrochemical etching rate depends upon the following factors:

(i) Electric field strength
(ii) Etching time
(iii) Etching temperature
(iv) Frequency of applied field

© Monnin and Blanford (1973) devised a new method of track revelation in polymers which differs from chemical etching. The basic idea for this kind of new detection technique was to graft copolymer chains in the vicinity of the ion path in a polymer and then to dye it, making the track visible. The grafting technique consists of the following steps:

(i) Creation of active species
(ii) Diffusion of monomers and copolymerization ‘
(iii) Washing