Charged particle range contraction in Solid State Nuclear Track Detectors

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The case for charge induced annealing and contraction of nuclear tracks in dielectric materials was first investigated (1), in glass (soda-lime) and a number of tektites, where samples primarily irradiated with Cf-252 fission fragments were exposed to varying doses of protons (10 MeV/nuc), either before fission fragment irradiation or after. It was shown that the dose threshold for the generation of a Coulomb field and/or a polarised medium by the incident protons was of the order of 6 X 10^{13} protons /cm^2. The reduction in the detection efficiency of the detectors was most effective when post-irradiated with protons, where the detection threshold was reduced by some 50% at a dose of 8 X 10^{15} P/cm^2 compared to those pre-irradiated with protons where the equivalent dose was 4 X 10^{17} P/cm^2. Isothermal and isochronal annealing of lunar chip number 62282,5 (feldspar), Brazil quartz, quartz glass (vitreosil), and soda-lime glass have yielded activation energies of annealing E_a, 4.74, 3.83, 0.85, and 0.62 electron volts respectively. The measurement for the axes parallel and perpendicular to the C-axis, were made in terms of track lengths and overall efficiency, being 10.7 $\pm$ 0.5 μm and 96% respectively for Cf-252 fission fragments (2).
In the same context a corresponding Arrhenius plot has yielded reaction rates for quartz as second order and for feldspar and vitreosil as third order, with the activation energies indicated for greater than 50% annealing.

For an investigation of the changes in critical energy loss $(dE/dx)_{critical}$ a number of crystals were exposed to heavy charged particles or fission fragments of various charges and energies. The effective values of (dE/dX) for tracks registered were then computed using the equations of Northcliffe and Schilling (3).

Material	$(dE/dX)_{critical}$ (MeV)/(mg/cm^2)
Mica	10.7-11.9
Quartz glass	15.1-17.8
" (terrestrial)	16.8-25.9
Feldspar (lunar)	17.9
Beryl	23.8-31.6

In the above cases, incident particles were (9.6 MeV/nuc) Fe and Kr ions or Cf-252 fission fragments. The indicated spread in the values of $(dE/dX)_{crit.}$ were generally due to variations in sample composition or crystal axes. Comparative results therefore, tentatively indicate that although thermal

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annealing prior to charged particle irradiation does not significantly alter the detection threshold in mineral crystals, pre-, or post-irradiation of track containing SSNTDs, by high doses of protons , that is greater than 10^{13} protons/cm^2 leads to the superficial erasure of tracks. Thus a reduction in the effective thereshold for charged particle registration is observed, leading to erroneous representation of particle ranges and hence charge assignment, if disregarded. This is however more significant for the lower energy 1-3 MeV protons, since a large fraction of the lunar breccia have thickness of 100-1000 µm, and thus particularly susceptible to charge induced annealing of nuclear tracks.

That the variations in the $(dE/dX)_{critical}$ and hence charge induced annealing is largely a function of crystal composition , was shown to be true by proton induced X-ray analysis of the lunar chip under invstigation, showing the abundance of the various trace elements, acting as polarizable charge carriers with different energies of activation for annealing.

Simulation experiments for 9.6 MeV/nuc. tracks of Fe and Kr ions, irradiated at 90 degrees to each other and at 30 degrees to the detector surface created a matrix of intersecting tracks acting as internal etching channels during the etching process, and therefore enabling fractional range measurements in the various detectors. The post irradiation of the detectors with 5 X 10^{16} P/cm^2 prior to etching in appropriate solutions, showed range contractions in the maximum etchable ranges. A corresponding reduction in the restricted energy loss or $(dE/dX)_{critical}$ was therefore confirmed. As such those tracks starting to register at the surface with no proton irradiation, were generally erased,(when irradiated with protons), in the top few microns and had contracted surface openings.

References:

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