*21st International Cosmic Ray Conference*

# CONFERENCE PAPERS

## *Volume 6*
## *(SH Sessions)*

Edited by R.J. Protheroe

XXI ICRC
6-19 January
1990
Adelaide,
Australia

1990

Department of Physics and Mathematical Physics
The University of Adelaide, Australia

# TEMPERATURE EFFECTS ON CHARGED PARTICLE RANGES IN CR-39 PLASTIC DETECTORS

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Abstract

It is well known that the rate of energy loss of charged particles in plastic detectors depends on the mass, effective charge and velocity of the incident particle as well as the elemental composition of the stopper. This paper presents experimental results of one additional parameter: the temperature of the stopping medium. The study was carried out by irradiating CR-39 samples at temperatures in the interval of 103°K to 373°K with monoenergetic $\alpha$-particles. The experimental data is discussed in the light of the track formation theory which may accounts for this temperature effect. The implications of this effect is pointed out for Cosmic Ray registration.

Introduction. It has been known for some time that environmental factors affect the formation and stability of nuclear tracks (Fleischer et al,1975). In particular, Benton (1970) has emphasized the important role that plays the parameter temperature in the process of track formation in relation with environmental effects during the phases of thermal and chemical equilibrium. O'Sullivan and Thompson (1980) reported for the first time the temperature dependence on the sensitivity of plastic detectors at the time of track registration. Though it seems now well-established that finite temperature of SSNTD during particle irradiation affects the energy and charge spectrum of Cosmic Rays, it is not enough studied how does it affect them of precise manner. Also there are still questions as for example, whether these temperature effects may contribute to our understanding of track formation, since the effects are of opposite nature in plastics and crystals, whether these effects may be used for better identification of the ion parameters, whether the available materials are sensitive enough to draw profit of these effects, etc. In previous works, Pérez-Peraza et al,(1983, 1984) pointed out that the conventional formulations of energy losses of charged particles in their passage through solid media do not take into account the temperature of the traversed material. This misleading may have severe implications regarding calibrations and interpretations associated with nuclear track detection in SSNTD. Introducing the temperature parameter during particle energy deposition in the material, the theoretical evaluations of those authors on Total Energy Loss for plastic SSNTD in the range T 375°K, show the following features: (1) for a given particle energy, the range increases as T increases (2) at a fixed T, the effect mentioned in (1) is more important at low energies, with a tendency to disappear at high energies relatively to the formulation with no T-dependence (3) at a fixed T the effect in (1) is more important for light elements than for heavy ions, however at high temperatures the effect for heavy ions shifts to higher energies (4) at a fixed T and energy, the effect in (1) is less important as ions becomes more an more stripped of their electrons. It was suggested in those works that these effects may be employed to control sensitivity of SSNTD, and by using several stacks of detectors at different temperatures a best identification of particle parameters is expected. It was also suggested that concepts about Restricted Energy Loss and Track Registration of Latent Damage may be modified if the temperature is included in the formulations of energy loss. These results are of course, model dependent and strongly sensitive to the employed interatomic potentials. So, an adjustment of theory must be done within the frame of highly confident data. At this regard an important amount of experimental work has been done in the course of this decade: using α-particles in CR-39, in the domain T<375°K, Karamdoust (1989) and Kumar et al (1986) and O'Sullivan et al (1979) and Thompson et al (1981) with Ar and Fe ions have shown that the overall track etch rate decreases as T increases, in opposition to the tendency in mineral crystals (Durrani and James, 1987; James and Durrani, 1988). The importance of these experimental temperature effects are about the same order, but much more important than our theoretical predictions which remain quite moderate. Here we examine, by another experimental technique, the importance of the temperature effects during particle irradiation in CR-39 plastic detector.

Experimental Procedure. Several pieces of CR-39 plastic detectors 2 x 2 $cm^2$ 250 μm thick were irradiated under vaccum with α-particles from a $^{241}Am$ source in a versatile irradiation chamber (Balcázar et al, 1982). The detectors were kept at a controlled constant temperature during irradiation. Low temperature irradiations were achieved by placing the plastic detector in contact to a cold finger through which liquid air was put in. Figure 1 shows the temperature dependence with time, measured by a thermocouple device in contact with the plastic detector. A hot-plate holder is used to increase detector temperature by means of a soldering iron with variable power supply.

A wide range of high detector temperatures can be obtained by adjusting the output voltage in the power supply. Figure 2 shows the variation of temperature with time. In the low temperature region, a maximum variation of 3% was observed, whereas for temperatures above room temperature the variation was around 2%. One temperature at 103°K in the low temperature region and several from 290°K up to 351°K in the high temperature region were selected for irradiation. Eight detectors were irradiated, one at a time, with the 5.48 MeV α-particles for each temperature, being the angle of incidence 90° with respect to the detector surface. All detector thicknesses were recorded and then etched in 25% NaOH at 70°C. Steps of one hundred minutes were selected to reveal α-tracks in the plastics, after each step, one sample for each set of irradiation temperature was taken out the etching bath and their final thickness recorded. Detectors were cut through the irradiated area, their edges polished; then, cleaned by a ultrasonic bath in a weak solution of NaOH at room temperature for one minute; after that, cleaned in destilled water. Track length measurements were made at the irradiated side-edge of the detectors, allowing in this way to size the track cone length within a precision of ± .4 μm. Track diameters were also measured.

Results and Discussion. The track etching rate, deduced from the slopes of track cone lengths as a function of etching time, shows a slight increase with irradiation temperature from 103°K up to room temperature; then, if irradiation temperature increases a steep reduction in track etching rate is observed which even leads to a total erase of the track at temperature higher than 328°K. The bulk etching, however, remains constant for all irradiation temperatures as is deduced from thickness measurements. The etchable range is affected by the temperature during irradiation as can be clearly observed in Figure 3. Such reduction is not attributable to the annealing effect commonly known, because ten minutes heatting either before or after irradiation is proved not to produce a measurable track annealing. No appreciable variation in track diameter is obtained as can be seen in Figure 4.

As possible and still not well understood explanation of this temperature effect in the etchable range, during detector irradiation, could be given in terms of the latent track formation. In fact, ten minutes heatting is such a short time to produce annealing effects on a stable latent damage trail in a plastic detector; but is a huge time for the several mechanisms involved, from the time the $\alpha$-particle pass through the detector, up to the damage trail becomes stable. The primary interaction occurs in about $10^{-17}$ s; then, an electronic collision cascade leaves a positively charged plasma around particle trajectory lasting for $10^{-14}$ s; formation of highly-reactive free-radicals take place between $10^{-12}$ and $10^{-9}$ s. Chemical equilibrium begins to take place after $10^{-8}$ s. We believe that in the case of polymers, the temperature applied to the detector during irradiation, increase movility of free radical and acts as a catalyzer for recombining some molecules. The new molecular species formed do not react with the etchant, increasing the registration threshold value; thus producing a new worth-to-study instantaneous annealing effect.

Plastizer and additives used during polimerization may greatly influence this effect and could be the reason of differences in the results from several laboratories. Workers are gradually becoming aware the important mis-interpretation may be taking place in Cosmic Rays experiments, fission-track thermometry, dating terrestrial rocks and meteorites, thermoluminiscence and so on. For instance, Cosmic Ray bombardment of meteorites took place at $T<150^{\circ}K$, whereas calibrations are usually done at room temperature. In fact, according to James and Durrani (1988), an underestimation of the charge of Cosmic Rays deduced from meteorite crystals may lead to 2-6 e in the case of Br ions.

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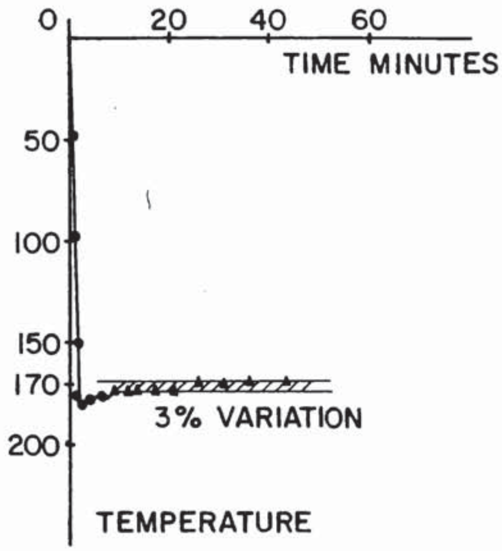


Figure 1
Temperature variation of CR39 detector with time measured by a thermocouple device in contact with detector surface. Detectors are cooled down by placing them on a cold finger through which air liquid is put in.

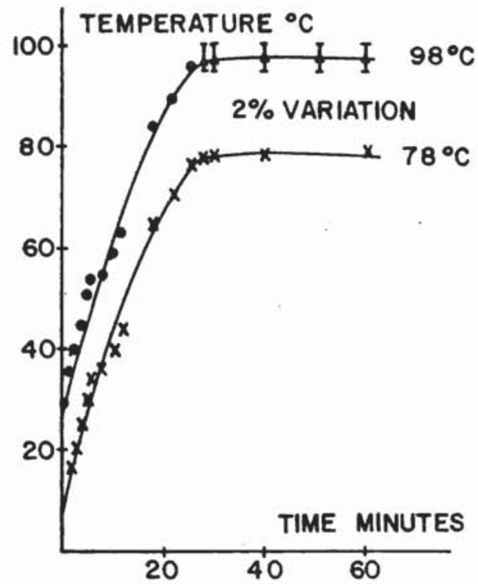


Figure 2
A hot-plate holder is used to increase detector temperature by means of a soldering iron with a variable power supply. The temperature variation is around 2%.

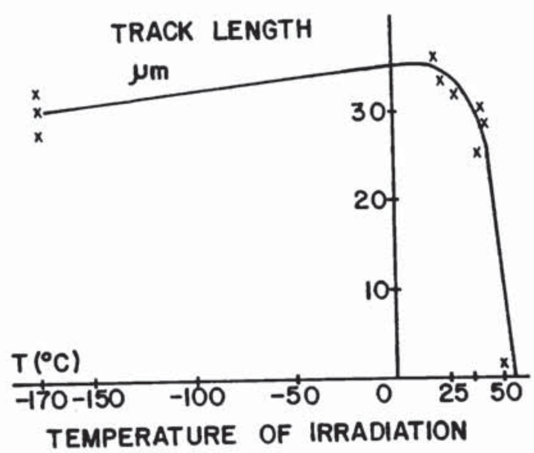


Figure 3
A reduction in the etchable track is observed as temperature of the irradiated detector increases. Such reduction is not attributable to the annealing effect commonly known but a new worth-to-study instanteneous annealing.

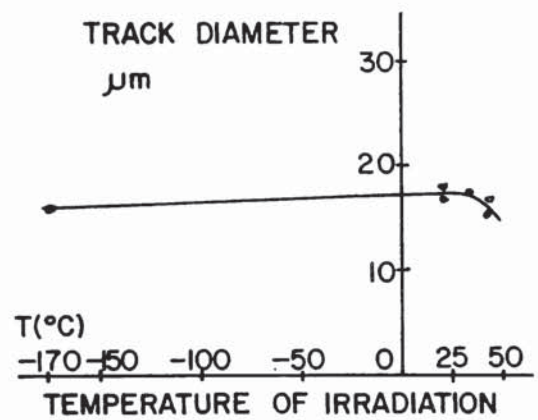


Figure 4
Not appreciable variation in track diameter with temperature is measured.