The New Personnel Neutron Dosimetry System at the PAUL SCHERRER INSTITUTE

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INTRODUCTION

The characteristics of CR-39 detectors have been investigated intensively during the last years in many laboratories. The enlargement of tracks by electrochemical etching made counting easier but, on the other hand, complicated the etching process. For routine application of CR-39 in neutron personal dosimetry neither etching nor reading should be complicated or time consuming.
Recently NE-Technology (formerly: Vinten) introduced an automatic reader for chemically etched CR-39 detectors. Along with this reader a new CR-39 Material, PN3, was made available. This system would allow for a routine application of CR-39.
The characteristics of PN3 detectors and possible batch constructions were investigated.

EXPERIMENTAL CONDITIONS

Detector material

The CR-39 material which we used was PN3 from NE-Technology, England. The detectors were 1,5 mm thick and 20 mm x 25 mm in size. All detectors were cut and coded by the supplier.

Etching conditions

The detectors were chemically etched using a two-step technic. This etching procedure is the standard procedure recommended by the manufacture [1]. During the first step, the pre-etch step, the detectors were immersed in a 60% methanol and 40% 6.25 N NaOH solution at 70°C for one hour. Under these conditions the bulk etching velocity is equal to the track etch velocity and therefore the surface of the detector is polished without etching the tracks in this surface layer [1]. About 30 µm of each detector surface is removed by this step.
During the second step the detectors are immersed in 6.25 N NaOH solution at 70°C for six hours.

Counting system

Since the automatic reader of NE Technology was available as a prototype instrument only, most detectors were counted with the Quantimet 920 in connection with an optical microscope under the magnification of 32×. For each detector 200 fields of view with the field size of 250 µm × 250 µm each were analysed. The total analysed area was 1/8 cm^2. Tracks with a diameter smaller than 2,7 µm were discriminated.

ENERGY RESPONSE

Response to thermal neutrons

For thermal neutron irradiation a polyethylen moderated Am-Be source was used. For the detection of thermal neutrons the Li-6(n,α)H-3 reaction was applied. The resulting α-particles have an energy of 2,04 MeV which corresponds to a range of about 10 µm in CR-39 [2]. Because of this short range, the α-particles do not penetrate the pre-etch layer and are therefore not detectable. The tritium particles of the same reaction have an energy of 2,74 MeV what results in a range of about 60 µm in CR-39 [3]. Therefore the H-3 particles are detectable.
For the irradiation with thermal neutrons we placed TLD-700 (LiF) on the detector surface. The response was found to be about 100 times as high as for bare Cf.

Response to Cf-252 and Am-Be neutron fields

Since over a wide range of neutron energies the elastic scattering on protons is the dominating reaction for the poduction of detectable particles, a radiator with a high hydrogen content is used to increase the response of the detector. As mentioned above, a 30 µm layer is removed during the pre-etch step. Since this thickness corresponds to the range of about 1,2 MeV protons [2], this pre-etch layer serves as an effective radiator for neutrons with energies below about 1,2 MeV. If the neutron energy exceeds this value the response can be increased by an external radiator.
To test this effect, the detector was divided in two different fields. One field was covered by 3 mm of polyethylen. The second had to be covered by a material with a low overall cross section for neutrons. For this purpose aluminium was chosen. Figure 1 shows the radiator stack that was applied during the irradiations. This stack was irradiated with bare Cf and Am-Be neutrons. The frontside of the detector, this is the side that is analysed later by track counting, faced the source. The stack was mounted on a 15 cm thick 30 cm × 30 cm plexiglass slab phantom. Table 1 shows the results of this experiment.
The ratio of the responses of the aluminium covered detector field to the polyethylen covered detector field for the Am-Be irradiaton is lower compared to the Cf

irradiation. This shows that this ratio can serve as a rough figure for spectrometric information.
If the main dose contribution derives from neutrons with energies up to 1,2 MeV this ratio should be close to 1. If the percentage of higher energy neutrons increases, the ratio decreases.

Table 1: Response for Various Neutron Energies

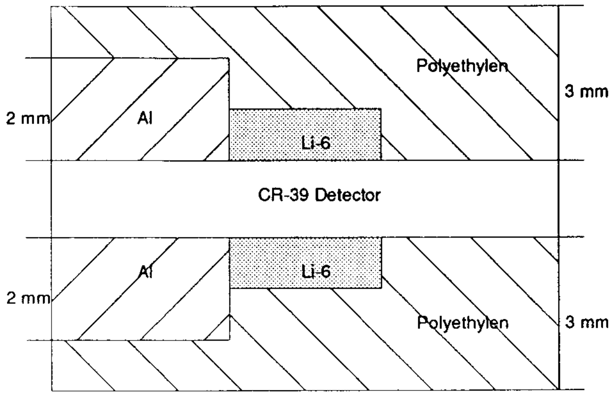
Neutron field	Radiator	Response ± SD [Tracks * cm^{-2} * mSv^{-1}]
Thermal	Li-6 (TLD-100)	31500 ± 7040
Bare Cf	3 mm polyethylen	250 ± 61
Bare Cf	2 mm Al	164 ± 46
Am-Be	3 mm polyethylen	295 ± 57
Am-Be	2 mm Al	117 ± 32
50 MeV	air	165 ± 20
50 MeV	3 cm plexiglass	179 ± 45
70 MeV	air	160 ± 23
70 MeV	3 cm plexiglass	167 ± 25

In order to look at the effect of the wearing direction of the dosemeter, we turned the radiator stack by 180° towards the phantom. Now the front side of the detector faced the phantom. As expected, both fields showed a similar response, since in this case the 1,5 mm thick detector serves as a radiator. The overall response (210 ± 31 tracks * cm^{-2} * mSv^{-1}) decreased because the relative hydrogen content of CR-39 (48.6 %) is lower than that for polyethylen (66.6 %).
In order to be able to receive some spectrometric information from the comparision of the two fields, the dosemeter should be worn in the proper direction.

Response to 5o MeV and 70 MeV Neutrons

Different CR-39 materials, including PN3 were irradiated with 50 MeV and 70 MeV neutrons at the Paul Scherrer Institute. For a more detailed describtion of the experiment and the results see ref. [4]. For the irradiation one detector was placed in front of a 3 cm plexiglass slab and a stack of 5 detectors was fixed behind the slab. The results show that the plexiglass had practically no influence on the response of the detectors. The results are also shown in Table 1. In general the sensitivity is about 2/3 of that for bare Cf.

Fig. 1: Detector stack



APPLICATION IN ROUTINE DOSIMETRY

For routine application a first reading could be restricted to the fields covered by polyethylen and Li-6. The reading of the field behind aluminium is thought to be applied for detectors only which show a dose above a certain investigation level.
The feasibility of the system is being investigated in an extended field test in accelerator and reactor environments.

REFERENCES

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