FAST NEUTRON DOSIMETRY USING CR-39 PLASTIC

H. Tawara, M. Miyajima, S. Sasaki and K. Hozumi
Radiation and Safety Control Center
National laboratory for High Energy Physics
Oho1-1, Tukuba-shi, Ibaraki-ken, 305, Japan

Abstract

Methods of measuring low level fast neutron dose have been developed using CR-39 solid state nuclear track detector. The measured density of etch-pits of recoil protons as a function of neutron dose shows excellent linearity down to 10 μSv. The sensitivity is 1.34 etch-pits/cm^2·μSv in a scanning etch-pits with a sharp tips under an optical microscope with eyes. In the case of an automatic scanning, the sensitivity is 0.64 etch-pits/cm^2·μSv.

Introduction

CR-39 plastic is highly sensitive martial for the detection of tracks of recoil protons produced by fast neutrons. Furthermore the aging and fading effects of CR-39 are small at room temperature for several months. It has pointed out that an accumulated neutron dose of 10μSv (=1mrem) or less is measurable with CR-39 detector[1,2]. Because of these remarkable properties as a solid state nuclear track detector, CR-39 plastic has recently being developed for neutron detection, neutron dosimetry and personal monitoring of neutron doses. We have developed new methods of measuring low level neutron dose (≤100μSv). In this paper, we will describe the outline of the methods for fast neutron dosimetry using CR-39 plastic : one is a direct observation of proton etch-pits under an optical microscope with eyes[3], another is a counting method using an automatic scanning system[4].

Experimental

CR-39 plastic sheets supplied by Sola Optical Japan, Co. are used in this experiments. The thickness of the sheets is 1.6 to 1.7 mm. The stacks of 3 to 10 layers of CR-39 sheets were irradiated at various distances from an Am-Be neutron source. The dose at etch location was measured by a rem-counter of the Anderson type (Studsvic). Each sheet was etched in about 6.8N NaOH solution at 70°C for 6 to 24 h after irradiation .

In the case of the direct observation of etch-pits under an optical microscope with eyes, background tracks, which are produced by alpha particles from airborne alpha-emitters deposited on the surface of the plastic, are not completely distinguishable from that of recoil protons. We attempted a deep etching of CR-39 plastic in order to eliminate an incorrect counting of tracks. If a depth of removed layer in etching is equal to the range of alpha particle with the energy of around 5 MeV, the residual etch-pits due to alpha particle show round tips. On the other hand, many tracks of protons which are recoiled by fast neutrons inside plastic sheets are observed as etch-pits with sharp tips after such a deep etching. Although some etch-pits of recoil protons may have round tips as etch-pits of alpha-particles, the number of etch-pits with sharp tips does not change, because the number of etch-pits of recoil proton with sharp tips lost by deep etching is compensated by newly formed etch-pits of proton recoiled inside CR-39 plastic in succession. The tips of etch-pits are easily observable under an optical microscope by changing its focus point. Therefore, the etch-pits of recoil protons can be easily distinguished from the background etch-pits of alpha-particles. In the scanning of etch-pits under optical microscope with eyes, however, there may be a distinctive feature that their efficiency tends to be influenced by individual variation of observers.

An automatic scanning has been tested in order to eliminate differences in scanning efficiency from person to person in the above-mentioned human scanning method. The automatic scanning system is composed of a auto-focused optical microscope with a video camera, a X-Y stage, an image processor and a personal computer. In this arrangement, features of etch-pits, labelings, areas, perimeters and diameters, are automatically analyzed. Etch-pits are counted as binarised images which are fixed according to a threshold with a selected grey level. In this case, etch pits of alpha-particle is easily discriminated because they identified by measurement of area and diameter for their big size. Binarised pictures of streaks and adhered matters on a surface of CR-39, however, may becomes backgrounds.

Results and Discussion

The depth dependence in the counted number of etch-pits of recoil protons is displayed in fig.1. The front surface of each sheet was scanned. The densities of etch-pits were almost constant except for the first layer in both scanning methods.

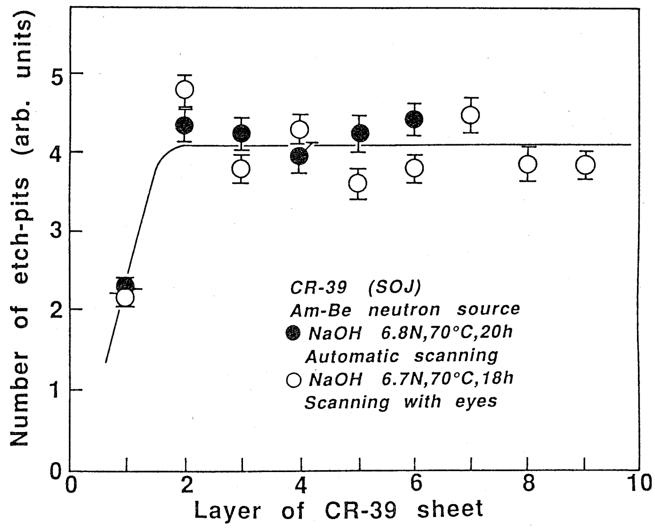

Fig.1 Depth dependence of the number of etch-pits per cm^2 for neutrons from an Am-Be source.

Fig. 2 shows the counted number of etch-pits due to recoil protons as a function of neutron dose. The results of scanning with eyes after etching 24 h show that the density of etch-pits is proportional to neutron dose. The sensitivity in the scanning with eyes, 1.34±0.37 etch-pits/cm^2·μSv, was obtained in the fast neutron dose lower than 100 μSv. In the automatic scanning, it seems that the densities of etch-pits are biased by the background, which is close to 24 ± 9 μSv/cm^2, and the sensitivity was 0.64 ± 0.08 etch-pits/cm^2·μSv. One reason for the low sensitivity in the automatic scanning is thought that pictures of small proton etch-pits which were recognized with visual inspection vanished in the binarised process of pictures. Another reason is that thresholds of parameters in the analysis of binarised pictures set somewhat highly in order to eliminate counting false pictures due to streaks and adhered matters on the surface and to count only true tracks.

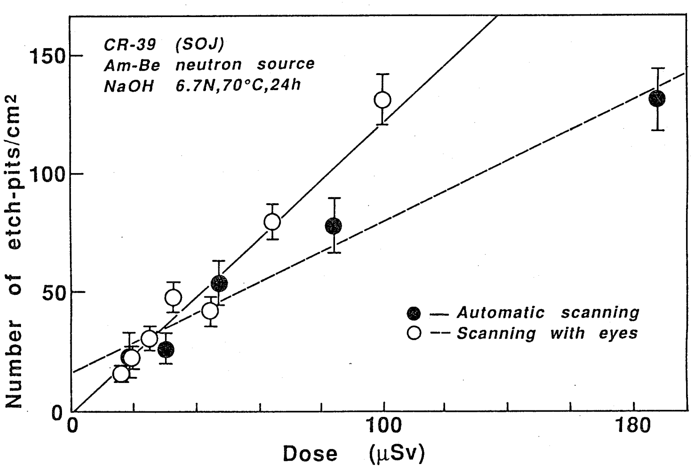

Fig.2 Density of etch-pits against neutron dose

It is necessary to examine the sensitivity at various threshold levels in the binarised process and to search suitable parameters for feature analysis and their thresholds for counting.

Conclusion

For neutron dosimetry using CR-39 detector, there are many points which must be clarified, for example , etching condition, the quality of CR-39 plastic itself, and etc. Radiator material of recoil protons is the CR-39 plastic itself in this experiments. However, it is advisable to use of hydrogenous front radiator which increase the sensitivity. The development of the automatic scanning technique is important for personal monitoring of neutron dose. At present, automatic scanning method for neutron dosimetry attempted by us is still at an experimental stage. Further experiments are in progress.

References

1. T. W. Turner, D. L. Henshaw and A. P. Fews, Nuclear Tracks and Radiation Measurements, **8** (1984) 341.
2. A. P. Fews, T. Portwood, D. L. Henshaw, T. W. Turner and A. Worley, Fifth symposium on Neutron Dosimetry Proceedings, (1985) 479.
3. H. Tawara, H. Takahashi, I. Watanabe, T. Doke, Y. Kang and M. Miyajima, Nucl. Instr. Meth., **B24** (1987) 369.
4. H.Tawara, M. Miyajima, S. Sasaki, K. Hozumi, Ionizing Radiation, **16**, 1 (1989) 82 (in Japanese).