FAST NEUTRON DOSIMETRY WITH CR-39 PLASTICS PLATE

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ABSTRACT

CR-39 detectors were irradiated with fast neutrons and etched in several alkaline solutions. An automatic image analyzer was used to obtain the density and size distribution of etch-pits. When etching conditions were kept at 30% KOH, 60℃ and 8h, the sensitivity was found to be 3.1×10^{-4}, 4.2×10^{-4} and 2.0×10^{-4} for neutron energies of about 1MeV, several MeV and 14MeV, respectively. The size of etch-pits increased with neutron energy. The etching time could be reduced to less than one tenth as a result of a rising from 60 ℃ to 90℃. After due consideration of background counts, a dose of 0.2mSv could be measured with this system.

INTRODUCTION

Many types of CR-39 detectors are used for personal neutron dosimetry. Chemical and electrochemical etching are performed to enlarge latent tracks caused by nuclear reactions to etch-pits. There are several methods to count the etch-pits. A lot of conditions are proposed for the etching and the counting. The energy response of the detectors depends on the combination of these conditions intensely.[1, 2] It is important to know the energy response under adapted etching and counting conditions for accurate dosimetry.

There is a demand for shorter etching time of CR-39 detectors. Several hours or more prolonged etching time is too long to adapt for practical measurement. Generally, high temperature promotes the etching, though it has a tendency to roughen the detector surface. It is set as a goal in this study to reduce the etching time to one hour or less without enhancement in surface roughness. In this study, sensitivity is measured for three energy regions of fast neutrons under our conventional and present etching conditions.

EXPERIMENTAL METHODS

The composition of the CR-39 plates used in the present study was 97% of allyl diglycol carbonate and 3% of diisopropyl peroxy dicarbonate. The transparent plate with a thickness of 1.6mm was sandwiched with polyethylene sheets with a thickness of 0.1mm to form a detector. The detectors were irradiated with about 1MeV neutrons from a fast neutron source reactor, several MeV neutrons from an Am-Be source or 14MeV neutrons from a Cockcroft-Walton type accelerator. Irradiated neutron fluences were estimated by an activation method.

After irradiation, the CR-39 plates were separated from the polyethylene sheets, and were etched in aqueous solutions of 30 wt% of KOH or NaOH at 60-90 ℃ for 0.4-20h. The solution was agitated by magnetic-driven vanes during etching. After etching, the plates were immediately washed clean in flowing water and dried under clean ventilation. In order to determine the amount of bulk etching, plate thicknesses were measured before and after etching by micrometer callipers.

Etch-pits and the state of the surfaces were observed using an optical microscope. The etch-pits were counted with an automatic image analyzer having an optical microscope, TV-camera and computer. The distributions of etch-pit diameters were measured with this analyzer. The number of etch-pits on an unirradiated and etched plate was subtracted from that of an irradiated and similarly etched plate.

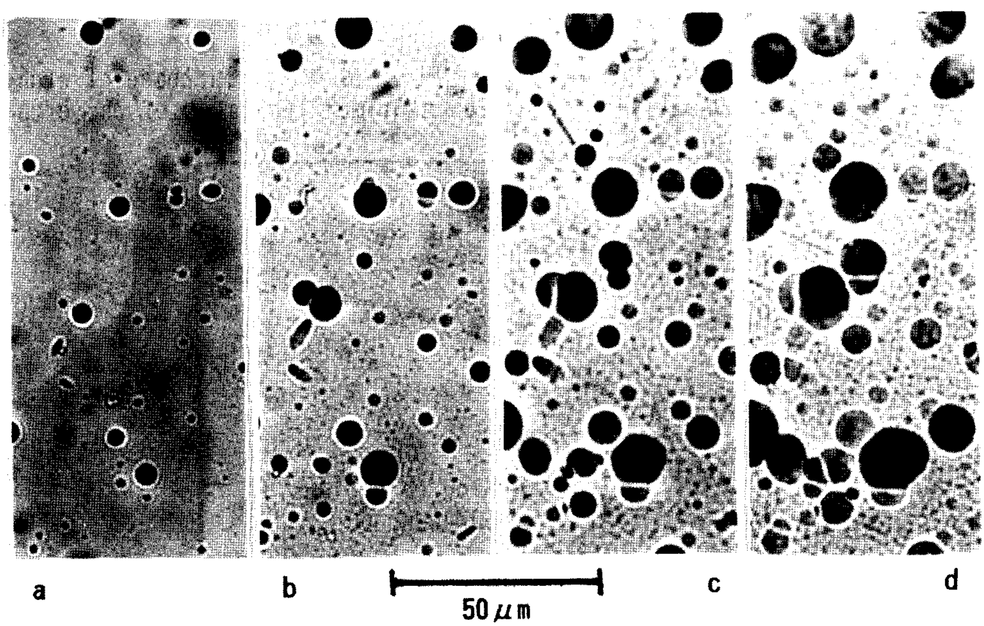

Fig. 1 Growth of etch-pits on a CR-39 plate irradiated with fission neutrons. Etching conditions : 30% KOH, 60℃. Etching time : a 4h, b 8h, c 12h, d 16h.

EXPERIMENTAL RESULTS AND DISCUSSION

Figures 1(a-d) reveal the transition in shape and number of etch-pits on a plate irradiated with about 1MeV neutrons. They represent the photographs of the same area of the plate at successive stages of etching, to show how individual etch-pits generate, grow and then disappear with progress of etching. It will be noted that in the course of etching, new etch-pits are continually making their appearance. The etch-pits grow in size with etching time, become easily detectable and remain so during a certain period. Beyond the certain limits of etching time, however the etch-pits begin to lose their shape, which makes it difficult to avoid counting loss.

The automatic image analyzer is able to adjust the lower limit of etch-pit diameter and of contrast between etch-pit's black and surface's white. The lower limit of the diameter was set for 2 μm. That of the contrast was adjusted to be able to discriminate the etch-pits from the surface roughness. The number of countable etch-pits increased rapidly with etching time in the first stage of etching. However, in the prolonged etching time, the increasing rate became slow because the appearance of the etch-pits had to compensate for the disappearance. From these observations, it was found that 8-12 hours were suitable for etching time when 30% solution of KOH or NaOH was used at 60℃.

With respect to 14MeV neutrons, Fig.2 shows an increase of etch-pit density and sensitivity with etching time. The ratio of the etch-

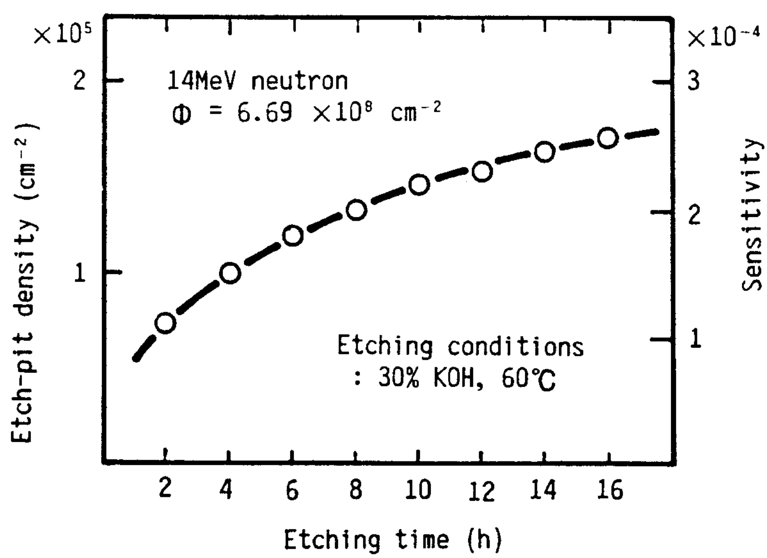

Fig.2 Increase of etch-pit density and sensitivity with etching time

pit density to the neutron fluence is termed sensitivity. In the case of about 1MeV and several MeV, similar relationships were obtained. When etching conditions were kept constant, the sensitivity was the highest for several MeV, middle for about 1MeV and the lowest for 14MeV. For example, when the condition was kept 30%KOH, 60℃ and 8h, the sensitivities were found to be 3.1×10^{-4}, 4.2×10^{-4} and 2.0×10^{-4} for neutron energies of about 1MeV, several MeV and 14MeV, respectively. When etching conditions were kept constant, the average of etch-pit diameter increased with neutron energy.

From the experimental results, the following formulas (1) and (2) were obtained as relationships of bulk etching rate V(μm/h) and temperature T(K) of etching solution for KOH and NaOH.

$$V = 3.17 \times 10^{13} \exp(-1.13 \times 10^{4} / T) \quad (1)$$
$$V = 3.11 \times 10^{13} \exp(-1.12 \times 10^{4} / T) \quad (2)$$

Activation energies are calculated to be 0.89 and 0.88 eV for KOH and NaOH from the formulas (1) and (2). These values agree with the value derived before.[3] The bulk etching rate at 90 ℃ is twelve times as fast as that at 60℃. The increasing rates of the sensitivity and the etch-pit diameter are approximately proportional to the bulk etching rate. The etching time could actually be reduced to less than one tenth as a result of a rising from 60℃ to 90℃. This increase did not change the energy response and did not enhance in surface roughness. After due consideration of background counts, it was found that a dose of 0.2mSv can be measured with this detection system. At the present time, we adopt 30% KOH, 90 ℃ and 1h as ordinary etching conditions for fast neutron dosimetry.

REFERENCES

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