UCRL--92652

DE86 001561

PERSONNEL NEUTRON DOSIMETRY USING HOT, LOW-FREQUENCY ELECTROCHEMICAL ETCHING

Dale E. Hankins
Steven G. Homann
Joane M. Davis

This paper was prepared for submittal to
13th International Conference on Solid-
State Nuclear Track Detectors
Rome, Italy
September 23-27, 1985

September 19, 1985

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RESTRICTIONS OF THIS DOCUMENT ARE INDICATED BY THE FOLLOWING

PERSONNEL NEUTRON DOSIMETRY USING HOT, LOW-FREQUENCY ELECTROCHEMICAL ETCHING*

Dale E. Hankins, Steven G. Homann, and Joane M. Davis

Hazards Control Dept., Lawrence Livermore National Laboratory, Livermore, California 94550
U.S.A.

ABSTRACT

We have developed an electrochemical-etch procedure for the processing of large numbers of CR-39 dosimeters. Specially designed Homann-Type chambers can etch up to 24 CR-39 chips, or foils, at one time. In our two-step procedure, the second step, called blow-up, increases the tracks' size and makes them relatively uniform. The energy response is fairly flat from ~ 150 keV to 4.5 MeV, but drops by about a factor of three in the 13-16 MeV range. The sensitivity of the dosimetry system is 6 tracks/mrem with a background of 8 mrem, giving a lower limit of sensitivity of approximately 10 mrem for the dosimeter (when three foils are used). Because greater numbers of CR-39 foils can be accommodated at any one time, our procedure is quite efficient for operations with large numbers of dosimeters to be processed.

KEY WORDS

CR-39, electrochemical etching, track detectors, track size, neutron energy response, Homann-Type etch chamber

INTRODUCTION

We have developed a CR-39 dosimeter and etch procedure suitable for operations whose personnel numbers require many CR-39 dosimeters to be processed. The combination of dosimeter and procedure enables one full-time technician to etch and evaluate 2,000 foils per month. Etch chambers were designed to reliably handle large numbers of CR-39 chips, or foils. To improve the energy dependence, we adopted the hot (60°C), low-frequency (60 Hz) etch procedure recommended by Tommasino (1983). We etch the foils in two stages to improve the track quality and the precision of the track counting. The two-stage etch procedure also reduces the background counts caused by imperfections, scratches, or dirt on the foils. This dosimeter and procedure have been used at Lawrence Livermore National Laboratory for over six months and have proven to be very reliable.

ETCH CHAMBERS

We designed Homann-Type etch chambers to handle 8 or 24 CR-39 foils simultaneously. The Lucite chambers have one liquid and one aluminum-foil electrode. The modified chambers are convenient to handle, and several chambers can be processed at the same time with a single power supply. These chambers were designed to be used in a 60°C oven. Drawings of these chambers are available from the authors.

ETCHING PROCEDURE

Table 1 shows the etching parameters. The etch chambers are placed overnight in an oven maintained at 60°C. The following morning, 60 °C KOH is added to the chambers, which starts the first etch step. The power supply is manufactured by Homann-Bell (1985), and is

* This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-Eng-48.

programmed using a HP-41CX calculator to provide selected voltages, frequencies, and times. The second step, which we call blow-up, is very important because it increases the size of the tracks which exist at the end of the first etch step, making them much larger and reasonably uniform in size. This greatly improves the precision that can be attained with the Biotran colony reader because the tracks are large as compared to imperfections, dirt, scratches, etc., often present on the CR-39 foils. The background from the foils is reduced by using a higher track-size threshold on the reader, which allows us to discriminate against most of these small imperfections. The precision of the Biotran results are usually within $\pm 1\%$ for repeated readings of the same foil.

NEUTRON ENERGY RESPONSE

Using low-frequency etching at elevated temperatures changes the energy dependence obtained from CR-39 foils. Figure 1 shows the energy response we determined by using neutrons from the Battelle Northwest Laboratory accelerator. This energy dependence is relatively flat from 150 keV to about 4.5 MeV, but drops by a factor of three in the 13-16 MeV range. Using our etching technique, the CR-39 does not respond to thermal neutrons or to neutrons having energies up to about 80 keV. We are presently repeating this energy-response curve using monoenergetic neutrons generated by the Los Alamos National Laboratory's accelerator in order to confirm the accuracy of the curve shown in Fig. 1.

The results from ^{252}Cf neutrons with various moderators are shown in Table 2. We found essentially the same number of tracks per unit dose independent of the moderator, except for the large D_2O spheres. These spheres produce thermal and low-energy neutrons that are not detected by CR-39, and the dosimeter readings will be slightly low. For comparison, these large D_2O moderators cause an albedo dosimeter to over-respond by a factor of ~ 10 if the dosimeter is calibrated using a bare ^{252}Cf source.

EFFECT OF VARIOUS ETCHING PARAMETERS

We also determined which etching parameters are important in this procedure. We found that small changes in frequency and high voltage have little effect on the track density. The oven temperature and etching time are important, however, and must be carefully controlled. Figure 2 shows that at 60°C the effect of temperature variations on track density is about 8% for each degree centigrade. Figure 3 shows that the track density is approximately linear with etching time for etch times less than five hours.

Track density is affected by variations in the foil thickness, and a correction must be applied. Table 3 shows the foil-thickness correction factors we determined. Track density is also affected by KOH normality, but if 6.5N is used, small changes (± 0.25) have little or no effect on the results.

If the time of the first etch step is changed from five hours, a change must also be made in the second stage, or blow-up. For example, if the first step is reduced to two hours, the blow-up must be increased to ~ 50 minutes. We use a 15-minute post-etch that makes the tracks rounder, and therefore less ragged. This has no effect on the evaluation of the track density; however, at 30 minutes, the track quality begins to change, and therefore, the foils should be removed from the etch chamber within 25 minutes following the completion of the etch cycle.

PERFORMANCE OF THE DOSIMETER SYSTEM

Figure 4 shows that, for a 5-hour etch, the system is linear up to 1.5 rem and can be corrected for doses up to 10 rem. The linearity is a function of the number of tracks/cm² on the foil and can be extended to higher doses by reducing the etch time or changing some of the other etching parameters to produce less tracks.

We performed a 7-month fading study that indicated little fading had occurred (Fig. 5). A 6-month environmental study has indicated that about 18% fading does occur if the foils are kept at higher temperatures (40°C). Dosimeters that are changed only at 6-month intervals can be considered with little correction required for fading.

Our present CR-39 dosimeters and etching procedure result in a sensitivity of ~ 6 tracks/mrem. This gives us a lower limit of approximately 10 mrem for the dosimeter system (when 3 foils are used). The precision of foils exposed to 700 mrem has a standard deviation of 5%, and for background, it is around 30%.

The directional dependence of CR-39 is poor (Fig. 6). We attempted to improve this directional dependence by bending or arching the foils. The results, also shown in Fig. 6, indicate too slight an improvement in directional dependence to justify the use of bent foils.

REFERENCES

- Homann-Bell (1985). CR1200B Programmable, Electrochemical Track-Etch Power Supply, 39831 San Moreno Court, Fremont, California 94539
- Tommasino L., Zapporoli, G., Spiezio P., Griffith R.V., and Espinosa G. (1984). In: Proc. of the 12th International Conf. SSNTD and Nuclear Tracks and Radiation Measurements, Vol. 8, No. 1-4, pp.335-339.

Table 1. Electrochemical etching parameters.

Etch	Normality of KOH	6.5
	High voltage	3000 V
	Frequency	60 Hz
	Temperature	60°C
	Etch time	5 hr
Blow-up	High voltage	2700 V
	Frequency	2 kHz
	Temperature	60°C
	Time	~ 30 min

Table 2. Spectrum dependence of CR-39 for moderated ^{252}Cf neutrons.

^{252}Cf Moderator	Percent deviation in track density/unit D.E.	
	For neutron energies >0.1 MeV	For all neutron energies
None	0	0
2 cm poly	+9.5	+8.4
5 cm	+5.0	+1.5
10 cm	-5.7	-5.1
25 cm H_2O	-4.7	-6.7
5 cm D_2O	+4.1	+7.8
10 cm	+0.5	-5.3
15 cm	-0.1	-14.1
25 cm	-2.6	-31.9
20 cm Al	-3.6	+2.1

Table 3. Correction factor for foil thickness variations (foil thickness is in mils)

Foil thickness	Divide track density by	Foil thickness	Divide track density by
17	1.21	25	1.00
18	1.18	26	0.971
19	1.15	27	0.942
20	1.13	28	0.904
21	1.10	29	0.861
22	1.07	30	0.817
23	1.05	31	0.771
24	1.02	32	0.725

Fig. 1. Energy dependence of CR-39 using hot, 60-Hz electrochemical etching.

Fig. 2. Track density as a function of oven temperature.

Fig. 3. Track density as a function of etching times.

Fig. 4. Linearity of the CR-39 foils exposed to a bare ^{252}Cf source.

Fig. 5. Results of a long-term study of CR-39 foil fading after exposure to ^{252}Cf (error bars are 1σ).

Fig. 6. Directional dependence of the CR-39 foils when exposed flat and curved to a bare ^{252}Cf source.