IS CR39 WORTH THE EFFORT?

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INTRODUCTION

CR39 proton sensitive track detectors were greeted by the radiation protection community at the end of the last decade as a major breakthrough for personnel neutron dosimetry. A number of laboratories eagerly began research on application of CR39 to their dosimetry needs. However, in the last two or three years the enthusiasm has subsided, and many health physicists have stopped working with the material. The number of participants using CR39 in the Oak Ridge National Laboratory Personnel Intercomparison Studies dropped from six in 1985 to three in 1986 [1,2]. On a national level, the Federal Republic of Germany with researchers active in CR39 research recently adopted an albedo system as their national standard [3]. In contrast, the United States Department of Energy (DOE) is supporting development of a CR39 based combination dosimeter to meet Department wide dosimetry needs [4]. The English National Radiological Protection Board (NRPB) now features the use of CR39 in the NRPB PADC(CR39) [5]. There has obviously been a range of experiences with CR39 in the dosimetry community. Why has this been the case, and what is the proper role for CR39 in personnel neutron dosimetry?

DISCUSSION

First, it is essential to understand that the simple term "CR39" does not specify the dosimeter any more than saying "neutron dosimeter." There are a large number of variables involved in using and processing CR39 track detectors, and three of the primary performance characteristics of CR39 based dosimeters (sensitivity, neutron energy response, and background) are highly dependent on the specific values of these variables. The basic detector processing can be done by using either chemical or electrochemical etching (CE or ECE). Although initially performed at room temperature (LTECE) [6,7], ECE can now be done at elevated temperatures (≥50°C, ETECE) [8,9], with the result being a dose equivalent response that is much flatter in the range from 0.1 to 5 MeV. Figure 1 illustrates generic differences in energy response between CE, LTECE and ETECE using typical processing conditions. Even within a particular etching class (ETECE for example), the energy response depends a great deal on the particular parameters used (Fig. 2).

CR39 background and neutron sensitivity depend on the source of track detector material, age, and the full range of processing conditions--etchant type and concentration, etch time, temperature, pre-etch conditions parameters, post-etch parameters, frequency, field strength, and detector thickness. The effect of these conditions can sometimes be profound. In a recent EURADOS-CENDOS intercomparison program, 11 national laboratories submitted CR39 dosimeters for irradiation using 6 monoenergetic sources plus ^{252}Cf [10]. Three laboratories used CE, three used LTECE, four used ETECE and one used two sets of dosimeters--one with CE and the other with ETECE. The background and neutron sensitivity ranges shown in Table 1 clearly reflect the effect of the particular processing protocol on detector performance.

TABLE 1

Backgrounds and Cf Fission Neutron Sensitivities for Participants in the Joint European/USA/Canadian Irradiation Program [10]

Processing Technique Used	Number of Participants	Background Range mSv	^{252}Cf Sensitivity Range $cm^{-2} \bullet mSv^{-1}$
CE	4	0.16 - 1.89	297 - 969
LTECE	3	0.19 - 0.64	43 - 160
ETECE	5	0.05 - 3.03	424 - 721

In addition to the problem of parameter dependent dosimeter response, CR39 development has been inhibited by the lack of high quality, dosimetry-grade material capable of providing truly reproducible results. Issues of manufacturer differences and batch-to-batch variations in surface quality, background and sensitivity are well known. These problems are understandable, however, considering that initially the sources of CR39 were plastics companies that use the material for optical applications which do not require the quality control necessary for dosimetry. It should be remembered that significant materials' problems also plagued dosimetrists during the development of TLD.

A final problem that caused a number of users to become skeptical of CR39 performance was the poor performance exhibited by key commercial suppliers of dosimetry services. Users of these services often found that the results provided by the services were anomolous and inconsistent. In intercomparisons, data provided by these services may not have been of acceptable quality. Unfortunately, for whatever reason--poor quality material, poor quality control, lack of appreciation for the details of the application, etc.--these experiences gave CR39 a bad image, but were not representative of the true potential of CR39 dosimetry. This potential is illustrated by the quality of results obtained in the European/USA/Canadian Joint Irradiation Program.

Although a number of users have experienced problems with the development and use of CR39, a lot of progress has been made. Improved detector material capable of providing good quality results is gradually becoming available, although the material quality problems are by no means solved. Processing techniques necessary to obtain reproducible results have been identified. Even though different protocols yield different dosimeter characteristics, careful adherence to a given procedure will produce satisfactory results [10]. Commercial suppliers are beginning to take advantage of the experience of national laboratories through technology transfer programs.

An advantage to CR39 is that the track formation properties of CR39 can be used to provide valuable information about the neutron field. For example, the etching parameter dependent variability in detector response can be used to perform simple spectrometry [11]. In fact, recent work suggests that electrochemical etch pit size distributions can be used to characterize neutron spectra for more accurate calibration factor assignment [12].

CLOSING REMARKS

The development problems associated with implementation of CR39 dosimetry have been magnified by the small numbers needed for neutron dosimetry compared with the large number of people monitored world-wide for photons. The cost/benefit ratio for development of CR39 is relatively high. At the same time, development has been slow because the financial support available for research is low. However, in spite of its deficiencies, CR39 is the best fast neutron detector currently available at a reasonable cost for routine personnel dosimetry. Yes, CR39 is worth the effort.

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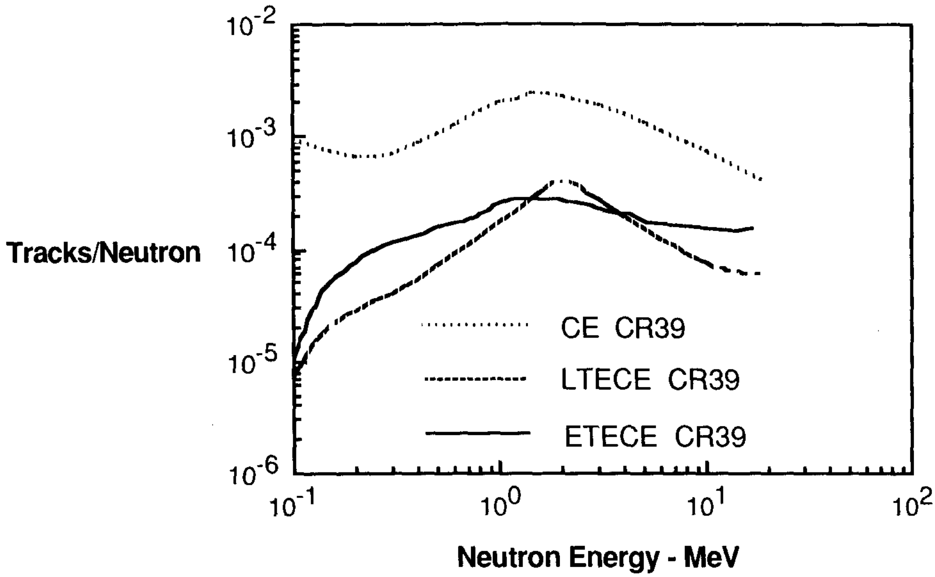
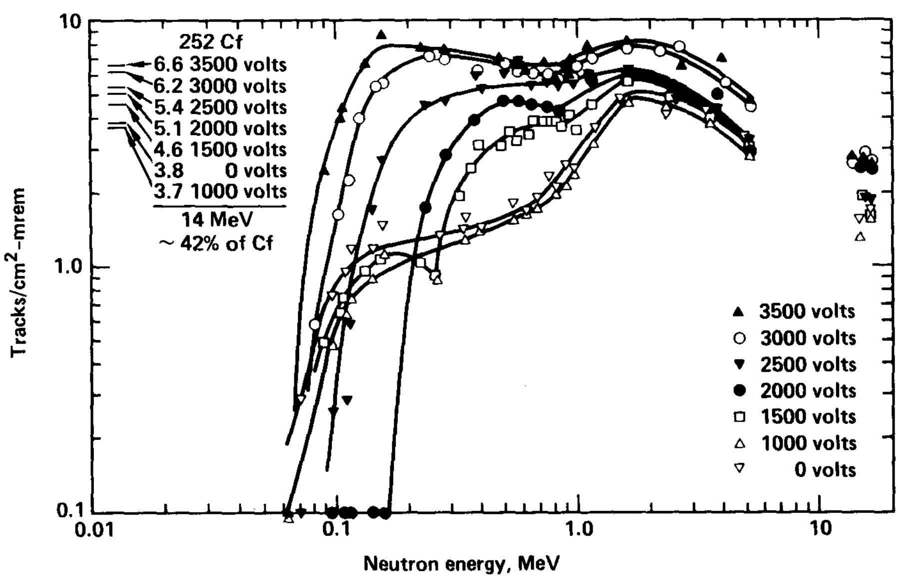


1. Comparison of typical CR39 neutron energy responses using chemical etching (CE), room temperature electrochemical etching (LTECE), and elevated temperature (60°C) electrochemical etching (ETECE).



2. Illustration of the voltage dependent ETECE CR39 neutron energy response for a 5 hour, 60 Hz etch, using a fixed 3000 volt, 2 kHz ECE post etch (approximately 30 minutes).