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OF CR-39 POLYMER
FOR REACTOR AND DOSIMETRY APPLICATIONS

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NEUTRON RESPONSE CHARACTERISTICS OF
CR-39 POLYMER FOR REACTOR AND DOSIMETRY APPLICATIONS

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ABSTRACT

A desensitized etching technique has been developed which has resulted in an excellent differential energy response for alpha particles in the energy range 3-14 MeV. This response complements the previously reported differential proton and integral alpha energy responses obtained with different etching techniques.

Proton recoil track yields and diameter distributions have been measured for CR-39 polymer solid state track recorders which were exposed to monoenergetic neutron sources in the energy range 0.57-15.1 MeV using various thicknesses and types of proton radiator materials.

KEYWORDS

CR-39 Solid State Track Recorders; neutron, proton, and alpha particle spectrometry; reactor dosimetry; neutron dosimetry.

INTRODUCTION

CR-39 polymer¹ is an extremely promising material for use as a solid state track recorder (SSTR) in high energy neutron dosimetry. Its unprecedented wide energy response for protons, variable response characteristics, resistance to radiation damage, and high optical quality make it ideal for this purpose. Because of these unique characteristics, applications of CR-39 polymer in Magnetic Fusion Energy, Light Water Reactor, and Fast Breeder Reactor Environments are currently being developed. The results of collaborative HEDL-USF work with CR-39 polymer SSTRs have been reported in several publications (Benton and co-workers, 1980; Ruddy and co-workers, 1980; Gold, and co-workers, 1980). More recent work has concentrated on an exploration of the following two areas:

¹CR-39 is a registered trademark of PPG Industries, Pittsburgh, PA.

1. Alpha spectrometry using a desensitized etch technique.
2. Optimization of the radiator type and thickness for in-situ neutron induced proton recoil spectrometry using CR-39 polymer.

ALPHA SPECTROMETRY

In previous publications (Benton and co-workers, 1980; Ruddy and co-workers, 1980) we have reported the results of calibrations of track diameter vs. energy for CR-39 polymer and shown the excellent potential of this material as a proton spectrometer in the energy range from 0.2-18 MeV. Under the same etch conditions, CR-39 polymer track diameters were relatively insensitive to changes in alpha particle energy in the energy range from 3.2-6.1 MeV. This integral response to alpha particles can be an advantage for certain dosimetry applications, as we have already pointed out (Ruddy and co-workers, 1980). However, it has been shown (Symogi and Hunyadi, 1980) that when etched under less sensitive chemical conditions, proton tracks are not revealed in CR-39 polymer, and the alpha particle energy response becomes differential. This type of response would be advantageous for applications based on the use of radiators which emit alpha particles under neutron irradiation, such as ^6Li and ^{10}B . Radiators composed of such isotopes could then also provide useful neutron spectral information. Alpha spectrometry with CR-39 polymer could be used to perform neutron spectrometry through (n,α) reactions on these and other isotopes.

Experiments have been initiated² to determine the alpha particle response characteristics of CR-39 polymer under a variety of etching conditions designed to be less chemically sensitive than the conditions used for our previously reported (Benton and co-workers, 1980) integral response. After extensive experimentation, a set of etching conditions was derived that resulted in the alpha track diameter vs. energy response shown in Fig. 1. An excellent differential energy response has been obtained for normally incident alpha particle track diameters in the energy range from 3 to 14 MeV. The use of these desensitized etching conditions would presumably also result in a considerable decrease in the registration efficiency for protons, allowing (n,α) spectrometry to be carried out with a greatly reduced background of (n,p) tracks. The etch consisted of three steps at 70° C: 1 hour in 7.5 N NaOH; 3 hours in PEW_{10} (15gKOH, 10 g ethanol, 75 g water); 1 hour in 7.5 NaOH. Experiments are in progress to further refine etching conditions for alpha particle spectrometry.

(n,p) SPECTROMETRY

In order to use the calibration curves for proton or alpha particle track diameter vs. energy directly for (n,p) or (n,α) spectrometry, one would have to design a measurement that employs carefully controlled experimental geometry to insure that tracks from the proton or alpha particle radiator impinge on the CR-39 polymer SSTR at normal or near normal incidence. Neutron dosimetry is simplified considerably if one can interpret measurements where the SSTR and proton radiator are in direct contact. Analyses of track diameter distributions (Ruddy and co-workers, 1980) have shown that valuable neutron spectral information might be obtained from such measurements. Indeed, neutron irradiations of CR-39 polymer SSTR in surface contact with thick polyethylene radiators from monoenergetic neutron sources of 0.57, 2.1, 5.3, and 15.1 MeV resulted in track diameter distributions that had peaks corresponding to proton energies close to the incident neutron energy. In order to

²This work was performed jointly under USF Bureau of Mines Contract # JO 188003.

Fig. 1. Track diameter vs. total energy for normally incident alpha particle tracks on CR-39 polymer. Isotopic exposures were performed with ^{148}Gd (3.18 MeV), ^{241}Am (5.49 MeV), ^{244}Cm (5.81 MeV), and ^{252}Cf (6.12 MeV). Accelerator exposures were carried out at Frankfurt using 6, 10, and 14 MeV alpha particles.

quantitatively interpret these track diameter distributions, further neutron irradiations of CR-39 polymer have been carried out using various thicknesses and types of proton radiator material. Au, Ni, Polyethylene, CR-39 and air have been used as the radiator material resulting in the proton recoil track yields shown in Table 1. The relatively high yield of proton recoils in the case of the air radiator is somewhat surprising and apparently results from (n,p) reactions on nitrogen. The high value at 14.1 MeV may be due to the interaction of room return neutrons with nitrogen. The relatively low yields for Au and Ni reflect the low (n,p) cross sections for Au and isotopes of Ni.

TABLE 1 TRACK DENSITIES OBTAINED FOR VARIOUS RADIATOR FOILS

Radiator	Sensitivity (tracks/cm ² /mRem)			
	Neutron Energy/0.57 MeV	2.1 MeV	5.3 MeV	14.1 MeV
750 μm polyethylene	---	15.60	20.41	8.34
1500 μm polyethylene	12.97	14.11	20.89	9.26
2250 μm polyethylene	13.18	14.11	21.84	12.32
3000 μm polyethylene	13.44	14.28	22.08	---
4500 μm polyethylene	---	---	---	13.27
1060 μm CR-39	---	---	---	4.48
2120 μm CR-39	---	---	---	7.13
3180 μm CR-39	---	---	---	6.87
750 μm Nickel	12.50	4.77	2.17	2.04
500 μm Au	---	---	---	1.48
Air	11.24	3.44	2.46	11.7

The track diameter distribution obtained for a thick polyethylene radiator at 14 MeV is shown in Fig. 2. Track diameter distributions for this and all of the radiator combinations listed above for 14 MeV neutrons resulted in a peak at a diameter of approximately 3.5 μm , corresponding to a proton energy approximately equal to the 14 MeV maximum proton recoil energy. The intensity of this peak reflects the track yields in Table 1. Further experiments are in progress to develop etching conditions for optimum interpretation of these diameter distributions and to investigate the diameter distributions for various radiators at other energies.

Fig. 2. Diameter distribution of proton recoil tracks produced by 14 MeV neutron bombardment of CR-39 polymer and a 2250 μm polyethylene proton radiator.

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