FAST NEUTRON SENSITIVITY OF POLYMER DOSEMETERS

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Abstract

The responses of polymer thermocurrent dosimeters to fission spectrum and 14 MeV neutrons were measured. The dosimeters are in the form of disks 1 cm diam by 0.5 mm thick. Relative to Cobalt 60 gamma responses, teflon® PTFE Dosimeters show a 6% response to 14 MeV neutrons and a 5% response to fission neutrons on a tissue rad basis. Polymethylpentene dosimeters show a 49% response to 14 MeV neutrons and a 40% response to fission neutrons on a tissue rad basis when provided with adequate recoil proton buildup. The sensitivity of these dosimeters is limited to neutron doses greater than 10 rads by spurious background currents.

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Thermocurrent dosimetry (TCD) with polymer materials has several potential advantages.^{1,2} First, the signal measured is a current or a charge. These are more easily and reliably measured than the light signals one is required to measure with thermoluminescence techniques. Polymers also offer the potential for constructing very nearly tissue equivalent dosimeters. Additionally, polymer TCDs are easy to fabricate, inexpensive and likely to be insensitive to light.

Dosimeters of teflon PTFE and polymethylpentene PMP were selected as the best combination for mixed neutron and gamma-ray fields. PTFE is the perfluorinated analogue of polyethylene and thus has no recoil proton dose. Sheets 0.7 mm thick were peeled from a large cylinder. Disks 1.2 cm diameter were cut from the sheet. The PMP is a branched hydrocarbon polymer of the (C_6H_{12}) form. Sheets 0.7 mm thick of PMP were compression moulded from beads and disks 1.2 cm diameter were cut from them. All the dosimeters were slowly cooled from the temperature appropriate to maximize their crystallinity.³

Graphite electrodes were found to be the most successful. These were applied as colloidal graphite in methanol. Evaporated carbon electrodes applied by the standard method for carbon coating electron microscope specimens were also tried. These worked well if the thickness was adequate to give a surface resistance much less than 100 k Ω per square. Guard ring structures were not needed. The high voltage electrode covered the entire back surface of the disk. The sensing electrode has an area of 0.7 cm² leaving a space about 1.2 mm wide around the edge.

A Block diagram of the reader is shown in Fig. 1.

The TC curves for polymers show an initial negative current due to their decrease in capacitance with increasing temperature. This decrease comes partially from the thermal expansion and partially from the change in susceptibility. The magnitude of this negative current depends on the heating rate but the charge transferred only depends on the temperature difference. At higher temperatures the leakage conductivity increases and the current becomes positive. The radiation induced conductivity gives a positive contribution to the current. Monitoring the collected charge is the most convenient method of readout. The heating profile is shown in Fig. 2 and representative TC thermograms are shown in Figs. 3 and 4. The TC signal measured is the integrated charge collected after 60 seconds.

To provide proper buildup during irradiation the dosimeters of PTFE and PMP were placed in holders of lucite acrylic or teflon about 3 mm thick. For neutrons, lucite provides recoil proton buildup approximately equivalent to tissue. The teflon provides electronic buildup for gamma-rays but no recoil protons.

Fast neutrons with essentially a fission energy spectrum are available at the #4 beam port of the UW nuclear reactor. The dosimetry of this facility was done previously.⁴ The dose rate is 130 tissue rads/hr of neutrons plus 17 rads/hr of gamma-rays. Irradiations of 50, 100, 200, 350 and 500 rads were given to dosimeters in both lucite and teflon holders. After readout, the dosimeters were calibrated with x-ray exposures comparable with their neutron doses. The x-ray doses were converted equivalent ⁶⁰Co tissue rads. The neutron responses exhibit the same non-linearity as the gamma-ray responses. The ratios of the neutron responses to the gamma-ray responses on a tissue equivalent rad basis are given in Table 1.

Neutrons of about 14.7 MeV were obtained from a neutron generator using the D-T reaction. Dosimetry of this beam was activation of sulfur, ³²S(n,p)³²P and fluorine ¹⁹F(n,2n)¹⁸F. Using a scintillator (NE213) with pulse shape discrimination, the gamma contamination is considered to be about 5% of the neutron dose in the exposure configuration used. Target to dosimeter distance was 15 cm. Doses of 8 and 66 rads tissue (1.5×10^8 n/cm²=1 rad tissue) were used.

The 8 rad dose proved to small for accurate readings. The ratios of the neutron responses to the gamma responses on a tissue rad basis are given in Table 1.

TABLE 1

Neutron Response/Gamma Ray Response (tissue rads)

<u>Neutrons</u>	<u>Acrylic Holder</u>		<u>Teflon Holder</u>	
	PHP	PTFE	PHP	PTFE
Fission	40 %	4.1%		4.7%
14 MeV	48.5%	16%	15%	6%

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Figure 1 Block Diagram of the Reader

The high voltage contact is heated from below by the projection lamp. The thermocouple provides feedback for the controller. The dosimeter resets on the heated high voltage contact. A weighted contact connects the sensing electrode to the electrometer. Either current or charge collected is measured. The high voltage, 300 volts, is switched on before the heating begins and off before cooling.

Figure 2 Heating Profile

The heating profile is a fast linear heating to about 130°C followed by a slow rise to about 170°C maximum. The dosimeter temperature stays within about 10°C of this profile. The arrows shows the time and temperature at which the charge integration is measured. The high voltage is turned off before the cooling begins.

Figure 3 PTFE Thermograms

- A. No Dose
- B. 100 m rad

Figure 4 PMP Thermograms

- A. No Dose
- B. 10 rad

Figure 1 Block Diagram of the Reader

Figure 2 Heating Profile

Figure 3 PTFE Thermograms

Figure 4 PHP Thermograms