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ABSTRACT

This paper reports the photon and neutron responses of four types of optical absorption dosimeters used at SLAC. The neutron responses are about 50% of their photon responses when expressed as tissue dose responses.

INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is a high energy physics research facility. It has a capability to deliver high energy (up to 50 GeV) and high power (up to 600 kW) electron beam to experimental areas. During an operation, photon and neutron radiation can reach inside shielding barriers as high as 1000 Gy (Si)/hr and 1×10^8 n/cm^2/s (1 MeV, Si) due to beam losses. This may result in large accumulated doses to the beamline components and nearby electronic devices. To study the pattern of beam losses and protect electronic devices, a high-level dosimetry system has been used at SLAC. Four types of optical absorption dosimeters are used to cover different radiation ranges (Optichromic FWT70-40M, Optichromic FWT70-83M, Radiochromic FWT60-1P, Red Perspex 2423). This paper reports the photon and neutron responses of these dosimeters.

MATERIALS AND METHODS

Optichromic FWT70-40M, FWT70-83M and Radiochromic FWT60-1P dosimeters were provided by Far West Technology Inc. Optichromic FWT70-40M and FWT70-83M are filled with a liquid radiochromic dye solution, encapsulated within a long plastic tube. Their sizes are 0.5 cm in diameter and 5 cm in length. Radiochromic film is composed of radiochromic dye intermixed with nylon film in 0.005 cm thick. It is sealed in an aluminum laminate pouch (0.01 cm thick) for protection from humidity and light during exposure. Red Perspex 2423 dosimeters were cut from plastic plates. Their sizes are 1.5 cm $\times$ 1.5 cm $\times$ 0.32 cm. Red Perspex 2423 is composed of polymethylmethacrylate (PMMA) along with a red dye mixture.

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After these dosimeters are exposed to the high radiation dose fields, some undergo a change in color. The change of the color can be measured by its change in optical density and is related to the absorbed radiation(1). The Optichromic (FWT-98), Radiochromic (FWT-91) Readers made by Far West Technology, Inc. are used to measure the optical density for optichromic and radiochromic dosimeters, respectively. Optichromic dosimeters are measured at 3 different wavelengths of 600, 656 and 680 nm. Radiochromic dosimeters are measured at the wavelength of 500 nm. Red perspex dosimeters are read by the Macbeth Quantalog Densitometer (TD-102), made by Kollmorgen Corp.

The first step was to study the photon responses of these dosimeters. The photon calibration source was a ^{60}Co irradiation device (GammaCell 220) at Lockheed Martin Missiles & Space. The dose rate of the source was 0.15 Gy (Si)/s (± 5 %) during the exposure. The integrated absorbed dose varied from 10 to 30,000 Gy (Si) as the exposure time changed. One package was exposed at one dose point. Each package had sixteen dosimeters, ie. four dosimeters per one type of dosimeter. All packages were covered with a 0.1-mm thick aluminum foil as build-up materials.

The second step was to study the neutron responses of these dosimeters. Sandia Pulse Reactor Facility at Sandia National Laboratories was used as the neutron calibration source. As the exposure locations and the reactor power changed, the neutron fluence varied from 1×10^{10} to 2×10^{15} n/cm^2 (1 MeV, Si), which was measured with ^{32}S dosimeters. The ratio of the neutron fluence to the photon dose is 3×10^{11} n/cm^2 (1 MeV, Si) per 1 Gy (Si). One package (as described above) was exposed at one neutron fluence point. Sandia Pulse Reactor Facility(2) reported the neutron fluence and photon dose (measured by CaF_2 TLDs) for each package.

In the calculations of the neutron response, the following formulas were used:

Change in optical density (neutron contribution) = total change in optical density - change in optical density (photon contribution) (1)

Change in optical density (photon contribution) = photon dose (provided by Sandia) × photon response (measured in Lockheed) (2)

TLDs obtained from Sandia National Laboratories were used to check the photon dose output from the ^{60}Co irradiation device (GammaCell 220) at Lockheed Martin Missiles & Space(3). The TLD read-out from Sandia agreed with the photon dose output from the ^{60}Co irradiation source at Lockheed within ± 10 %.

RESULTS

The standard deviations of change in optical density in four dosimeters of the same package were all less than ± 10 %. Photon and neutron responses were produced for each type of dosimeter. They are shown in Figures 1–8. If both photon and neutron response are expressed as change in optical density per ICRU tissue dose, the neutron responses of four types of dosimeters are all about 50 % of their photon responses.

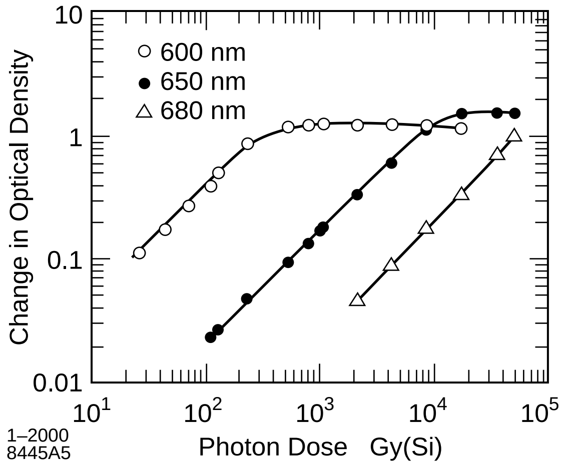

Fig. 1 Photon response of Optichromic dosimeter FWT-40M

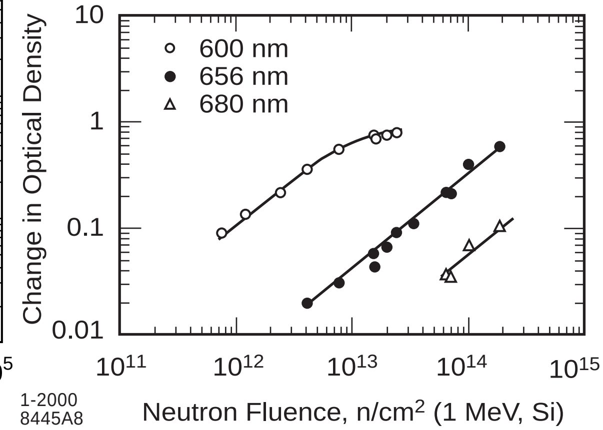

Fig. 2 Neutron response of Optichromic dosimeter FWT-40M

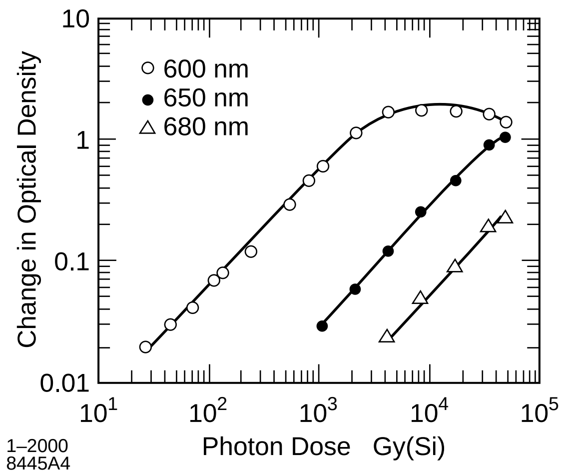

Fig. 3 Photon response of Optichromic dosimeter FWT-83M

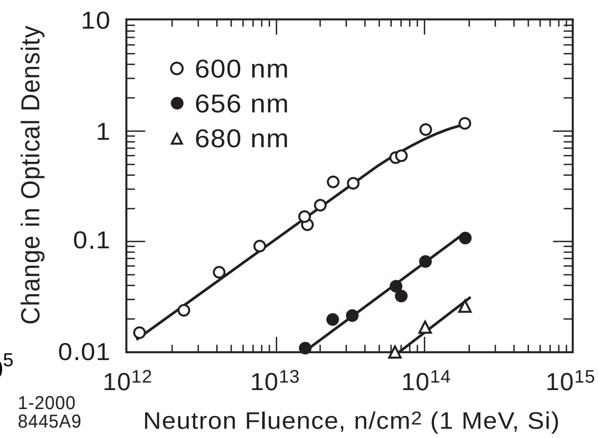

Fig. 4 Neutron response of Optichromic dosimeter FWT-83M

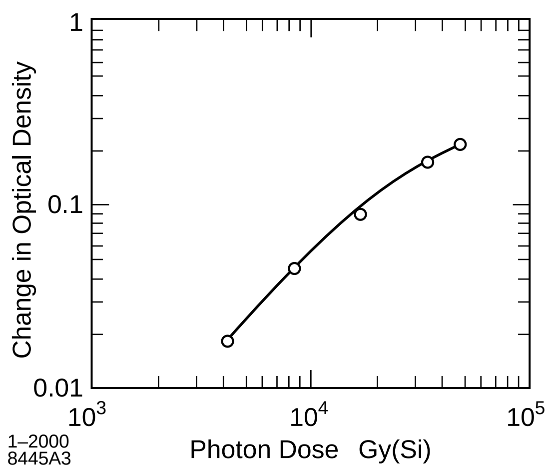

Fig. 5 Photon response of Radiochromic

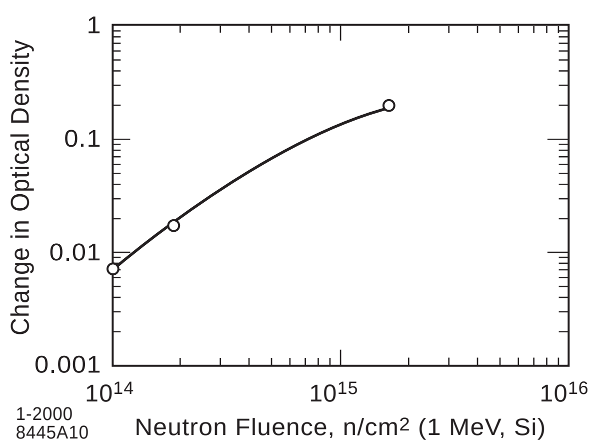

Fig. 6 Neutron response of Radiochromic

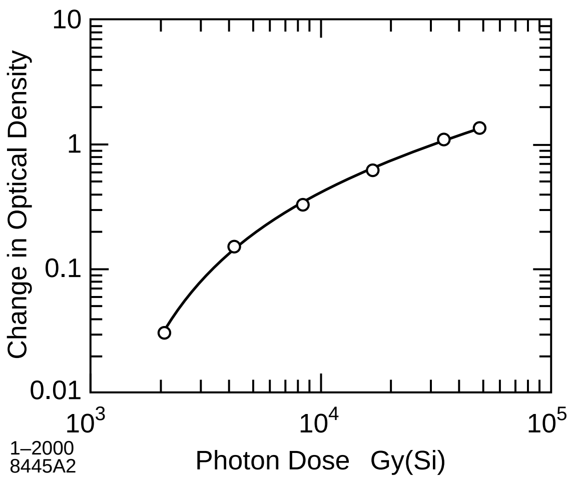

Fig. 7 Photon response of Red Perspex

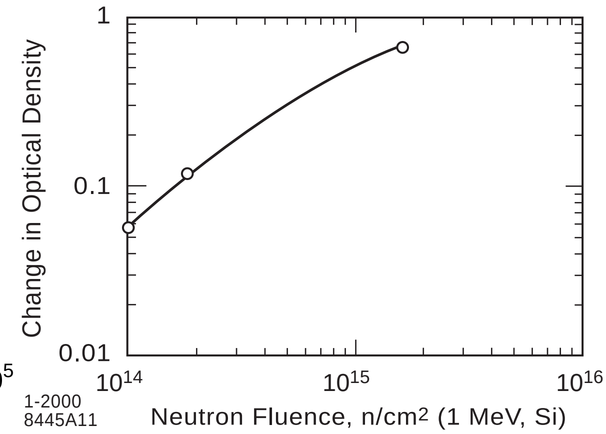

Fig. 8 Neutron response of Red Perspex

Combination of these dosimeters can be used to measure the photon dose from 20 to 30,000 Gy (Si) and the neutron fluence from 7×10^{11} to 2×10^{15} n/cm^2 (1 MeV, Si) as listed in Table 1.

Table 1 Photon Response and Neutron Response Range

Dosimeter	Wavelength (nm) or Filter	Photon Range Gy (Si)	Neutron Range n/cm^2 (1 MeV, Si)
Optichromic FWT70-40 M	600 656 680	20 – 250 100 – 10,000 2,000 – 30,000	7×10^{11} - 1×10^{13} 4×10^{12} - 2×10^{14} 6×10^{13} - 2×10^{14}
Optichromic FWT70-83 M	600 656 680	20 – 2,000 1000 – 30,000 3,000 – 30,000	1×10^{12} - 1×10^{14} 2×10^{13} - 2×10^{14} 6×10^{13} - 2×10^{14}
Radiochromic FWT60-1P	510	4,000 – 30,000	1×10^{14} - 2×10^{15}
Red Perspex	Gold	2000 – 30,000	1×10^{14} - 2×10^{15}

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