DOSIMETERS FOR MEASURING NEUTRON DOSE EQUIVALENT: NEW APPROACHES

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ABSTRACT

Continued advancement in electronic dosimetry and recent success in developing new high-sensitivity thermoluminescent (TL) materials provide novel and exciting possibilities for developing improved neutron dosimeters.

INTRODUCTION

Development of electronic personnel dosimeters for photons is underway in several laboratories. These dosimeters, based on silicon detectors, are capable of covering a wide photon energy range (17 keV to 7.0 MeV). The possibility of expanding this concept and developing a multi-element personnel beta-gamma-neutron microelectronic dosimeter is discussed. The second part of this paper deals with recent improvements in neutron thermoluminescent dosimetry (TLD) including the new Harshaw albedo TLD and the potential application of high-sensitivity thermoluminescent materials to neutron dosimetry.

BETA-GAMMA-NEUTRON ELECTRONIC PERSONNEL DOSIMETRY

Electronic personnel dosimeters for photon and beta fields typically consist of two major components, one or more silicon diodes, and the signal processing circuit. Ionizing radiation interacting with the diode produces electron-hole pairs which are separated by the detector's internal electric field, resulting in charge pulses. These pulses are amplified, counted and stored for further processing and dose calculation. An electronic dosimeter using a pair of PIN silicon photodiodes has been developed recently at the National Radiation Protection Board in England. There are obvious advantages to electronic dosimetry: real time dose indication, use of off-the-shelf components, no need for a reader and the ability to transfer the dose information to a central computer using a modem. This concept might be expanded to enable dosimetry in photon-beta-neutron mixed fields by combining PIN photon-beta dosimeters with dynamic random access memories (DRAM), the latter acting as the neutron sensitive element. In a DRAM, binary information is stored as a charge on small cells (miniature capacitors). Neutron-induced heavy charged particles can cause a random error to appear by generating a sufficient concentration of electrons in the vicinity of the cell to change the amount of charge stored, causing a bit
flip (a change of "1" to "0"). Assuming that the W value in silicon is 3.6 eV, it can be shown\(^6\) that \(10^4-10^6\) electrons typically are needed to cause a bit flip, which corresponds to energy in the range of 360 keV-3.6 MeV. Considering the fact that typical cell dimensions are on the order of a few \(\mu\text{m}\), it is expected that the sensitivity to low LET radiation, including gamma, will be negligible.

Recent feasibility studies\(^5\) using \(\text{t}4\) K memory chips (Apple II microcomputer) have demonstrated that thermal neutron dose levels as low as 25 \(\mu\text{Sv}\) could be detected. A possible configuration of a multi-element personnel electronic dosimeter might consist of two photodiodes for photon-beta monitoring and two DRAM memory chips, one covered by polyethylene and the other by \(^6\text{LiF}\) for fast and thermal neutron monitoring respectively. However, before such a multi-element dosimeter can be considered for practical use, its response has to be characterized and dose calculation algorithms\(^6\) need to be developed. Furthermore, the effectiveness of the dosimeter-algorithm combination needs to be tested at dose levels and neutron energies and with radiation types typical of routine field use.

![Glow curves for LiF:Mg, Ti and Al\(_2\)O\(_3\):C for 5 MeV \(\alpha\)-particle irradiation. Note the high temperature peak of the Al\(_2\)O\(_3\):C glow curve.](image)

**FIGURE 1.** Glow curves for LiF:Mg, Ti and Al\(_2\)O\(_3\):C for 5 MeV \(\alpha\)-particle irradiation. Note the high temperature peak of the Al\(_2\)O\(_3\):C glow curve.

**IMPROVED NEUTRON THERMOLUMINESCENT DOSIMETRY**

Although both albedo and direct proton recoil TL neutron dosimeters are known to have serious limitations, their small size, wide dose range, and the availability of automatic commercial TLD readers make it worth investigating their full potential.
A new type of albedo multi-element TLD\textsuperscript{(5)} was recently developed. The dosimeter consists of four LiF:Mg,Ti paired TLD-600 and TLD-700 chips. One pair is filtered with plastic and the other with cadmium, to enable fast neutron discrimination in the presence of a thermal neutron field. The contribution to the TL signal of the incident photons and electrons, as well as the contribution of the cadmium capture gamma rays and the small contribution of the incident fast neutrons, are treated as noise and subtracted out, taking advantage of the symmetry of the dosimeter. This dosimeter has passed, by a large margin, all the neutron test categories of the Department of Energy Laboratory Accreditation Program (DOELAP).

The new high-sensitivity\textsuperscript{(6)} TL materials LiF:Cu,Mg,P and Al\textsubscript{2}O\textsubscript{3}:C, 25 and 60 times more sensitive than TLD-100 respectively, are both excellent candidates for improved proton recoil direct neutron dosimetry. To determine whether Al\textsubscript{2}O\textsubscript{3}:C could be the basis of the useful "direct" neutron dosimeter, we have recorded glow curves following 5 MeV α-particle irradiation. The results shown in Figure 1 demonstrate that for α-particle irradiation, Al\textsubscript{2}O\textsubscript{3}:C maintains its high sensitivity relative to LiF:Mg,Ti (TLD-700). By taking advantage of the high sensitivity of the new materials and reducing their thickness, it can be expected that their neutron-to-gamma response ratio can be improved, while remaining sufficient sensitivity to enable low dose dosimetry. However, both experimental and theoretical work is needed to investigate the fast neutron response of different combinations of high-sensitivity thin TLDs with hydrogen-containing radiators.

REFERENCES


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