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Effect of neutron irradiation on dosimetric properties of TLD-600H (^{6}LiF:Mg,Cu,P)

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ABSTRACT

Ideally, dosimeters should measure the dose without their dosimetric properties being affected by the radiation type being measured. Industry-wide occupational radiation workers that can be potentially exposed to neutron radiation fields are routinely monitored by thermoluminescent (TLD) dosimeters. The neutron dose measured by these devices is obtained from the interaction products of thermal (slow) neutrons and ^{6}Li. The number of alpha particle and $^3H^-$ ions (tritium) released in the (n, ^{6}Li) reaction is proportional to the dose received by the dosimeter. It is a common practice to evaluate the neutron dose indirectly from these products. In this work we present for the first time direct evidence that the neutron exposure to LiF:Mg,Cu,P (TLD-600H) can have deleterious effects on the dosimetric properties of one of the most commonly utilized dosimeters in the world. The interstitial non-negligible tritium dose contribution to the dosimeter is a result of the beta decay of the tritium nuclei interstitially present in the material. If not accounted for the effect of this self irradiation can directly affect the measured occupational dose to workers. In order to estimate the significance of these effects, tritium dose buildup was measured in the TLD-600H irradiated to different neutron doses from a reactor and a ^{252}Cf source and then calculated in terms of a daily dose buildup rate. The effect of the self irradiation on these dosimeters resulting from tritium decay was extensively studied. The TLD dosimeters that were exposed to neutron doses show a significant dose buildup even after they have been annealed, i.e. even after the signal produced by the incident neutron dose is completely erased from the lower energy trap states of the dosimeter. The other discovered effect of neutron irradiation on TLD-600H is a significant loss in the detection sensitivity (up to 15%).

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1. Introduction

Neutron albedo dosimetry of most passive dosimeters is based on following nuclear reaction

$$^6\mathrm{Li} + {}^1n \rightarrow {}^3\mathrm{H}^-(2.73\ \mathrm{MeV}) + {}^4\alpha^+(2.05\ \mathrm{MeV}) \quad (1)$$

The neutron dose-response results from the α particles and tritium ions released as a result of the reaction (1). However there is a possible second contribution to the total neutron dose from the dosimeter readout, which is neglected in common practice. That is, the contribution from the self irradiation of the dosimeter material resulting from the radioactive decay of the tritium atoms that were created in the neutron–lithium interaction. Tritium atoms created in the dosimeter material are in a radioactive state and decay with a half-life of 12.33 years by ejecting a beta particle with an average energy of 5.7 keV and an associated antineutrino. The radioactive tritium atoms created in the dosimeter then act as an internal source of beta particle radiation. A conservatively negative consequence of the self irradiation is the over-estimation of the neutron dose reported to the individual worker.

While the effect has been studied in other TLD materials, no peer reviewed study of this effect has been demonstrated for ^{6}LiF:Mg,Cu,P (such as the Harshaw model 8840/41 dosimeter[1]) dosimeter (Burgkhardt and Piesch 1982 (a,b). It was estimated in

[1] Certain commercial equipment, manufacturers, instruments, or materials are identified in this paper in order to specify the experimental procedure adequately. Such identification is for informational purposes only and is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the manufacturer, materials or equipment are necessarily the best available for the purpose 1.

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