Wearable Radiation Sensors

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14. ABSTRACT

The Nu-Trek team is proposing to develop the µGmRH, a low Size, Weight, Power, and Cost (SWaP/C) radiation-hardened gamma dosimetry module which will replace dosimeters based on Geiger-Müller (G-M) tubes in radiation detectors (RADIACs). A RADIAC using the µGmRH solution will be smaller, lighter, and have longer battery life than one using G-M tubes. The µGmRH has two key components: A cadmium zinc telluride (CZT) detector and a custom readout integrated circuit (IC), the µDetRH IC. The µDetRH IC replaces a number of discrete component with a single IC resulting in the large SWaP/C savings. In Phase I the Nu-Trek Team developed a baseline design for the µDetRH, with particular attention paid to radiation hardness and meeting SWaP/C requirements. In Phase II the design of the µDetRH will be completed and fabricated. Phase II will culminate with the integration and testing of the µGmRH, delivering modules that will be available for evaluation by potential end users. To meet the Army's productization requirements, Nu-Trek has teamed with a major supplier of CZT. The µGmRH is expected to meet topic requirements.

15. SUBJECT TERMS

gamma dosimeter, RADIAC, CZT, G-M tube, rad hard, low SWaP/C, µGm, µGmRH

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SUMMARY REPORT

Key Army objectives for the JDS-S are 1/2 the volume, 1/3 the weight, and 3X the battery life (or 1/3 the power) of the RADIACs currently in use, UDR-13&14**.** The objective of this program is to replace the Geiger-Müller (G-M) tube, one of 3 detectors used in UDRs 13&14, with the with a lower size, weight, and power, and cost (SWaP/C) detector of higher performance. Price target is < $100/unit in very high volume. Other key requirements include gamma dose rate between $6x10^{-8}$ and 10 Gy/hour, Gamma energy between 20 keV and 6 MeV, accuracy of +/- 15%, and operating temperature of -50 to 55 ^{0}C.

To this end, the Nu-Trek Team is developing the µGmRH, a G-M tube replacement based on the solid-state Cadmium Zinc Telluride (CZT) crystal. Other key components of the µGmRH are a rad hard readout integrated circuit (µGmRH-IC), and a compensator that enables conversion of the µGmRH counts into dose. This program is a collaboration between Nu-Trek, a company with core competencies in the design of detector readout integrated circuits (ICs) that are rad-hard-by-design (RHBD), and a CZT supplier.

Key Phase I activities included: (1) Modeling and simulation using the Los Alamos Monte Carlo code MCNP and other custom spreadsheets, architectural design of the µGmRH and µGmRH-IC, and assessing the CZT vulnerability to displacement damage by exposing them to neutrons at the White Sands Missile Range (WSMR) Fast Burst Reactor (FBR).

Central to the use of a G-M tube to measure dose rate is the ability to convert the count rate into dose using a single conversion factor. This is critical as the G-M tube does not have any knowledge of the incident spectrum and is accomplished with a compensator that “flattens” the response of the G-M tube. It is typically in the form of a cylindrical tube that goes around the Gm tube and has one or more slots. A key Phase I task was to demonstrate that this is possible with CZT and to develop a number of baseline designs, that will be finalized in Phase II.

Using MCNP 6.2, various configurations of CZT, and compensators were evaluated to determine if the count rate from a detector could be related to the dose rate. A thin tungsten compensator with a small hole performed the best. Additional computations will be performed in Phase II to finalize the compensator design so that the accuracy requirements will be met.

Another key question that was addressed with MCNP 6.2 was conversion of the dose rate requirement of 10 Gy/hour into counts. This is important because the µGmRH has to have adequate sensitivity at the low dose rates and not saturate at the high dose rates. Simulations performed for various sizes of CZT crystals, with and without compensators, were used to guide the design.

Displacement damage tests were performed at the WSMR FBR. Twenty-five CZT detectors were used. Exposure levels were between 10^{9} and 10^{12} n/cm^{2} (0.26 – 262 Sv). While there is a degradation of the mobility-lifetime ($\mu\tau$) product as a function of neutron flux, the CZT crystals continued to operate adequately for the G-M tube replacement application at promising neutron fluence levels.

As discussed earlier, the µGmRH includes a CZT crystal, compensator, and rad hard readout integrated circuit (µGmRH-IC). In Phase the design of all the components were optimized with an emphasis on minimizing SWaP/C while meeting all the performance requirements. This has resulted in a streamlined design that is easy to manufacture and assemble.

Phase II work will focus on finalizing the design, fabrication and assembly of all components as well as substantial modeling and testing to demonstrate that the functional, SWaP/C, and radiation hardness specs have been met. Issues identified will be addressed and re-verified.