NON-IONIZING AND IONIZING DOSIMETRY IN A SPACE RADIATION ENVIRONMENT WITH GaAs and SiC LEDs

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ABSTRACT

This paper describes a dosimetry experiment that will be carried onboard the Russian MIR space station. The experiment will compare the ionizing and Non-Ionizing Energy Loss (NIEL) in semiconductors of the radiation encountered in space. The ionizing dose will be detected using ThermoLuminescent Dosimeter (TLD) whereas SiC and GaAs LEDs will be used to measure the non-ionizing component. The tray will be mounted on the outside of the station for a minimum period of 4 months. The goal of the experiment is to determine the feasibility of using SiC and GaAs LEDs as NIEL dosimeters in space.

INTRODUCTION

Devices fabricated with GaAs and other compound semiconductors are expected to play an increasingly important role in space electronics. Satellites in space are exposed to the radiation belts, solar flares, and cosmic radiation. In contrast to silicon devices, the radiation damage to GaAs devices is caused by displacement of atoms from their crystal lattice sites by incident energetic particles. Burke et al. (1), Summers et al. (2), and Barry et al. (3) have shown that atomic displacement damage is proportional to the NIEL of the radiation in the semiconductor. In order to assess the sensitivity of compound semiconductor devices to space radiation, it is of great interest to develop a practical NIEL dosimeter. A second objective of the mission is to investigate a possible method of discriminating between radiation damage due to electrons and heavy particles.

EXPERIMENT DESCRIPTION

The monitor package will be installed on an aluminum tray measuring 300 mm x 75 mm. Three different experiments will be fitted on the tray. The NIEL experiment will occupy 68 mm x 75 mm and consists of i) 20 GaAs LEDs; ii) 10 SiC LEDs; iii) 13 locations for TLD 700s of varying thickness; iv) 4 pieces of 10^{15} n−doped; and v) 4 pieces of 10^{16} n−doped GaAs wafer. Figure 1 shows a schematic diagram showing the relative position of the various TLD 700s ($B_1 - B_4$, $D_1 - D_3$, $F_1 - F_3$ and $I_1 - I_3$), the SiC LEDs ($A_1 - A_5$ and $J_1 - J_5$), the GaAs LEDs ($C_1 - C_5$, $E_1 - E_5$, $G_1 - G_5$, and $H_1 - H_5$) while positions X_1, X_3, X_5, and X_7 and X_2, X_4, X_6, and X_8 are the 10^{15} and 10^{16} n−doped GaAs wafers, respectively.

In order to probe different energy regions of the radiation field (i.e. different points on the dose depth curve), the package is divided in 4 compartments: #1 in which all the devices, TLDs, SiC and GaAs LEDs and GaAs wafers are directly exposed to the radiation field; #2 in which all devices are covered by protected 13μm thick Kapton sheet; #3 is covered by a 51 μm steel sheet under a protected 51 μm thick Kapton sheet; and #4 in which all devices are covered by a 3 mm thick Tantalum absorber, itself covered by two different thicknesses (13 and 51 μm) of virgin Kapton sheet.

PRE-FLIGHT QUALIFICATION TESTS

The lens and caps of the GaAs and SiC LEDs (which were manufactured by Telefunken and CREE Research, respectively) were removed in order to directly exposed the chips to the radiation environment and avoid any shielding due to these components. However, in order to stabilize the electrical characteristics and to protect them from Atomic Oxygen (AO), they were nitrided. Sample LEDs and TLDs were exposed to AO for 120 minutes (corresponding to approximately 3 months in low earth orbit) using a Large area Microwave Plasma (LMP) facility with an O_2-SF_6 mixture excited in the radio-frequency mode. The package will be exposed to temperature extremes in space; therefore, the sample LEDs and TLDs were subjected to repeated temperature cycling between liquid nitrogen and 115°C. The tests indicated that the samples suffered no apparent deterioration.

NIEL MONITORS

The use of LEDs as NIEL monitors was developed by Barry et al. (4) and their response over a wide energy range has been established (3). The NIEL is proportional to the change in the inverse of the minority carrier lifetime (5), which is deduced from the frequency response of the LED prior to and after exposure. However, due to the relatively short time the experiment will be in space, only a small dose is expected.

In order to maximize the precision for the small NIEL dose anticipated, a set of 25 GaAs LEDs (from 200) and 15 SiC LEDs (from 100) were selected for optimum repeatability and minimum standard deviation of their measured lifetime. The temperature sensitivity has been carefully measured and a correction factor is applied to the data by the software. A group of these LEDs are being stored as "standard" for checking any drift in the lifetime measuring equipment.

For low energy particles, a significant correction to the measured NIEL, due to the energy loss in the surface layer of the LED, is required. Thus the thicknesses of the epitaxial layers were determined from the threshold in the variation of the change in the minority carrier lifetime with proton energy (5).

The epitaxial top layer of the GaAs LEDs was measured to be 30 ± 2 microns. Using TRIM-92 code, the energy loss of a proton as it travels through the epitaxial layer, steel, Kapton, and Tantalum is estimated. With this information, the sensitivity of each compartment is determined: > 1.9 ± 0.1 MeV for Compartment #1; > 2.2 ± 0.1 MeV for Compartment #2; > 4.9 ± 0.2 MeV for Compartment #3; > 53 MeV for Compartment #4. Thus LEDs in Compartment #4 will be used as "background" monitors and compared to the series of LEDs kept in the laboratory.

GaAs WAFERS

The damage (the Gallium vacancy V_{ga} and Silicon at the Arsenic site Si_{As}) due to room temperature irradiation with 0.6 to 200 MeV protons anneals out to a large part at 550°C, while that due to 7 MeV electrons anneals to a much less extent (6). The purpose of the n-doped GaAs wafers is to investigate the use of this phenomenon to differentiate between electron and proton components in the space radiation.

CONCLUSION

Dosimeters for measuring the total and the NIEL of radiation in space has been shipped to the Ukrainian Space Agency and will be installed on the MIR space station for a minimum period of 4 months probably in early 1996. The post-flight analysis of the data will be carried out as soon as the tray is returned to the ground. A dose depth curve for the NIEL will be obtained from the analysis.

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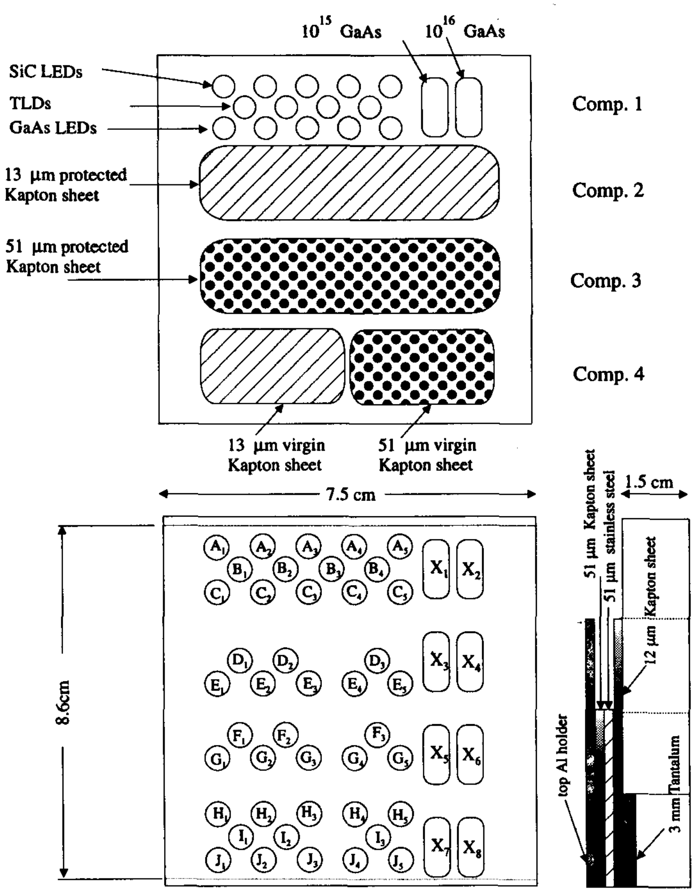

Figure 1 Schematic diagram of the NIEL experiment showing the four compartments of GaAs LEDs and wafers, SiC LEDs, and TLDs