Discrimination of Heavy Charged Particles Using Optically Stimulated Luminescence

Bret A. Yount[1,2], Eduardo G. Yukihara[1], and Stephen W. S. McKeever[1],

[1]*Arkansas-Oklahoma Center for Space and Planetary Sciences, Department of Physics, Oklahoma State University, Stillwater, OK.*

[2]*Arkansas State University, Department of Physics, Jonesboro, AR.*

Introduction

Astronauts are subjected to many different types of radiation, including helium nuclei and electrons, as well as gamma and X-rays. In an effort to keep track of the dose an astronaut receives, they wear dosimeters which can be read by different means. The newest method, termed Optically Stimulated Luminescence, entails using green light (532nm) from a Nd:YAG laser to stimulate the dosimeter material causing it to emit light of a different wavelength. By measuring the amount of light emitted, we can infer the dose received. The material we are using for OSL dosimetry is aluminum oxide, Al_2O_3. This material has many exceptional dosimetric properties, including a very high sensitivity to ionizing radiation, low background, low fading during storage in the dark, a relatively simple glow curve with a peak at ~177°C (450 K), a linear response over 6 orders of magnitude in dose, a simple emission band centered at 420 nm, and a relatively low effective atomic number (10.2) (Akselrod *et al.*, 1990; 1993). In this study, we will be investigating the potential of Al_2O_3 for discrimination of different types of radiation (alpha and beta in this study).

Background

Heavy charged particles (HCP) deposit energy in a different way than do beta particles or gamma and X-rays. Where non-HCP's deposit most of their energy uniformly across the material, HCP's deposit all of their energy along linear tracks following the path of the particle. This results in a possible low dose averaged over the entire material, but very high dose in small volumes along the particle track. The radiation is characterized by a parameter known as the Linear Energy Transfer (LET). This is a quantity representing how much energy is transferred per linear track. High LET radiation, such as helium nuclei, is more prone to cause radiobiological damage (Benton and Benton, 1999). By discriminating between how much dose was from HCP's, we can determine more accurately the health risk to an astronaut. This study is also applicable to airline pilots subjected to cosmic rays, since this is the main source of high LET radiation.

Al_2O_3 has the potential to allow discrimination between different types of radiation. Our problem is to develop a system that has a high sensitivity, and also a high resolution. We are using a Pulsed OSL system (POSL), which is described under Methodology, instead of a Continuous Wave OSL (CW-OSL) since the POSL system has much better sensitivity.

Objectives of this study are to:

- **To optimize the POSL system, to allow for maximum sensitivity and resolution, and**
- **To determine the minimum contribution of alpha, in a mixed (alpha and beta) system, that can be discriminated.**

Methodology

We are using a POSL system in which a Nd:YAG laser is Q-switched to deliver 300 ns short pulses at a frequency of 4 kilohertz, and a power of ~2.5 mW. The setup for the POSL system is shown below in Fig. 1. The emitted signal is measured between the pulses using a gated photon counting system, filtered appropriately to protect the detector and measure signal only. This timing process is shown more clearly in Fig. 2. As mentioned above, we are using the POSL system, as opposed to the CW-OSL system, since the POSL system has much better sensitivity. This is due to the fact that we measure the OSL signal when the laser is off, and therefore reduce the filtration and improve the signal–to–noise ratio. To give a representation of the sensitivity of the POSL system, a decay curve, resultant from ~2mGy of beta dose, is shown in Fig. 3. When gathering data, we place approximately 1143 V across the PMT (photomultiplier tube), and measure for 60 s. using an integration time of 0.1 s., giving a total of 600 data points, followed by a measurement of the background for that sample, which is later subtracted from the signal. Power is also measured against time, to ensure it is constant. To compare the resolution between the two systems, for each system we irradiate 6 samples with a known dose of alpha, measure the OSL, bleach the sample, irradiate it again with a similar dose of beta and then measure the beta OSL. The graph of these resulting curves, normalized, is shown in Fig. 4 and Fig. 5. Notice that the entire measurement period is not shown, since the remainder gives no information.

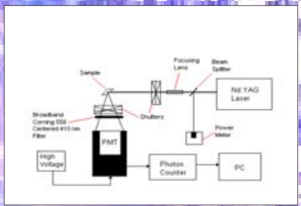

Fig. 1 POSL System Setup

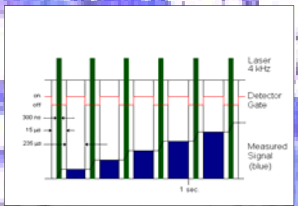

Fig. 2 POSL Timing Diagram

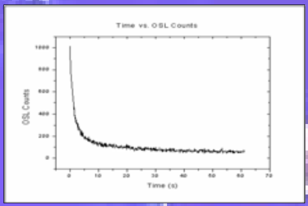

Fig. 3

Fig. 3: POSL decay curve from ~2 mGy of dose, showing resolution.

Fig. 4: α and β curves from the POSL System.

Fig. 5: α and β curves from the CW-OSL System.

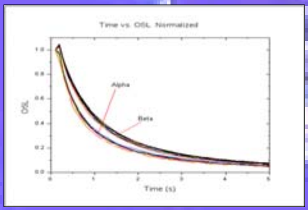

Fig. 4

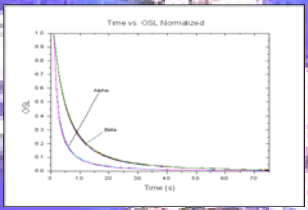

Fig. 5

Conclusion

Although this project is still in the beginning stage, we have already come to a few conclusions. The POSL system is much more sensitive that the CW-OSL system. However, the POSL system lacks the resolution required to distinguish between different types of radiation.

Further Research Plans

During the remainder of the summer, we plan to continue to optimize the POSL system and increase the resolution. We will begin by investigating the effect of power delivered to the sample by changing either the laser power, or the laser frequency.

We will also continue investigating the OSL decay curve shape from irradiations of alpha particles. Furthermore, we plan to correlate these decay shapes with the OSL decay curves from high doses of beta particles.

Finally, we will determine the minimum dosage of alpha particles necessary, in a mixed alpha and beta irradiation, to allow discrimination between the two.

References

Akselrod, M. S., Kortov, V.S., Kravetsky, D. J., Gotlib, V. I., 1990. Highly Sensitive Thermoluminescent Anion-Defect α-Al_2O_3:C Single Crystals Detectors. Radiat. Prot. Dosim. 33, 119-122.

Akselrod, M. S., Dortov, V. S., Gorelova, E. A., 1993. Preparation and Properties of α-Al_2O_3:C. Radiat. Prot. Dosim. 47, 159-164.

Benton, E. R., Benton, E. V. 1999. Space Radiation Dosimetry in Low-Earth Orbit and Beyond. Nucl. Instr. and Meth. In Phys. Res. 257.

Acknowledgements

I would like to thank Eduardo Yukihara for giving me the opportunity to learn as much from this summer experience as possible, and for being so helpful; Dr. Stephen McKeever for being a great supervisor and giving me the tools I need to keep up in his lab; Dr. Richard Marston for being the father figure this summer; the National Science Foundation for playing their role in this wonderful summer experience; and lastly, everyone involved with the Arkansas-Oklahoma Center for Space and Planetary Sciences and make it exciting as well as challenging.