

RADIATION RESISTANCE OF A SILICONE POLYMER GREASE BASED REGOLITH COLLECTOR FOR THE HERA NEAR-EARTH ASTEROID SAMPLE RETURN MISSION. E. M. Venechuk^{1,3}, M. A.

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Introduction: The goal of the HERA mission is to collect regolith from a near-Earth asteroid. After launch, HERA will approach a pre-determined asteroid, match its orbit, descend to the surface, touch for a few seconds, and ascend. The touch-and-go impregnable pad (TGIP) that contacts the surface passively collects regolith by embedding it in silicone polymer grease. After collection, the pad and regolith are contained in the spacecraft and returned to Earth for removal from the grease and subsequent analysis.

The collector must survive the six years of the mission in a hostile space environment. One major factor to be considered is radiation from both galactic and solar sources. Although it is difficult to simulate space irradiation in the laboratory, using a radiation capable of ionizing and breaking bonds, which have typical energies of only 0.25 eV, provides an effective reproduction. In terms of the absorbed dose rate, predicted galactic dose rates between Earth and Mars are ~14 cGy/year [1] and up to 2 Gy/day for solar doses [2]. Knowing the dose rates of our space environment-simulation sources, we can express the administered dose in our experiments in terms of dose expected on the mission.

Methods: The first of our radiation sources were two ⁹⁰Sr sealed sources that produced beta particles with a maximum energy of 564 keV, simulating solar radiation. In order to obtain higher energies, we used a linear accelerator located at the Northwest Arkansas Radiation Therapy Institute that produced a focused beam of 6 MeV electrons, simulating galactic radiation. Radiation levels up to 8 times greater than expected on the mission in terms of beta radiation and 50 times greater than expected on the mission in terms of the accelerator were administered to the substrate. Small, cylindrical, lipped aluminum pans, 2.2 cm in diameter and 0.51 cm in height, held the collection substrate during exposure and the times were calculated to obtain the desired total absorbed dose. The pans contained ~3 g of substrate with an area 0.63 cm². An approximately equal number of control samples were also prepared. Triplicate samples were run at each dose in the case of the beta cell irradiations, but single samples were run in the accelerator. This is reflected in the uncertainties reported for the experiments in Figure 2.

After irradiation, samples were weighed, placed in a holder that would take a total of eight sample pans,

and then pressed into a simulated regolith, consisting of 210-300 µm sand particles in a dish atop an electronic scale. The force applied, measured by the scale, varied between 10 and 17.5 lbs depending on the thickness of the sand. After collection, the samples were reweighed and the mass of sand collected was determined. The efficiency of the irradiated substrate samples in collecting samples of mock regolith was compared with that of non-irradiated substrate.

Results: No difference beyond experimental uncertainty was observed, physically or quantitatively. Our results are shown in Figures 1 and 2. The control samples and the triplicates, where available, have been averaged. The error bars represent one standard deviation on the mean.

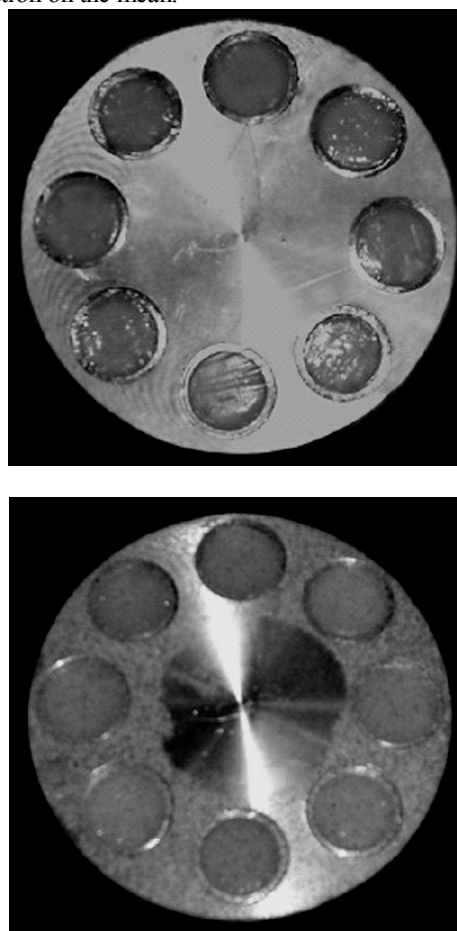


Figure 1. The TGIP collector head before (top) and after (bottom) collection. Control and irradiated samples are alternated. Notice no physical differences.

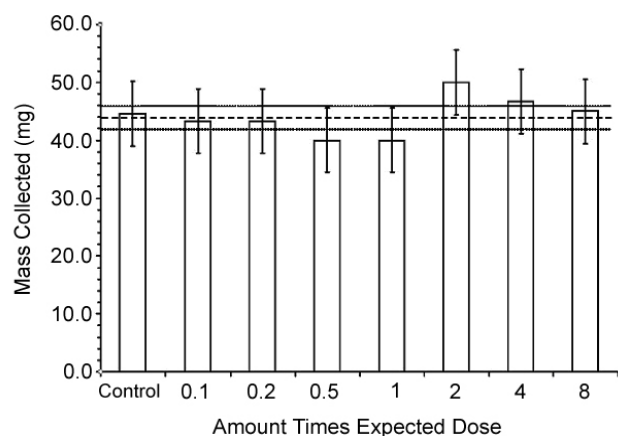


Figure 1A. Mass collected by samples receiving ^{90}Sr β particle radiation.

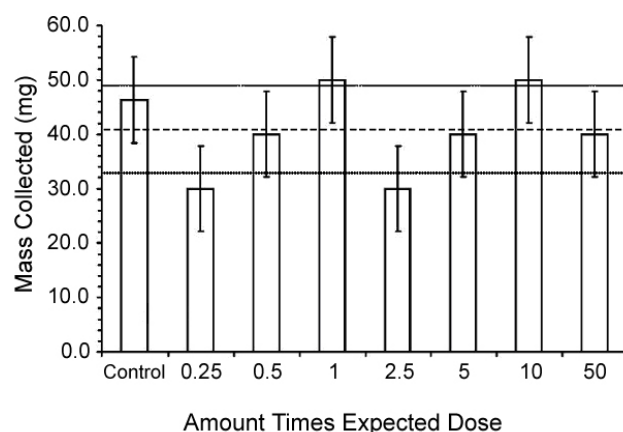


Figure 1B. Mass collected by samples receiving 6 MeV electrons.

Figures 1A and 1B show the amounts of sand collected by each pad after irradiation by ^{90}Sr β particles (1A) and 6 MeV electrons (1B) compared with control samples. Data for the control samples and triplicate samples have been averaged. The dashed line is the average of all samples and the dotted line represents $\pm 1\sigma$ from the average. Within the experimental uncertainties, neither irradiation by 564 keV β particles or irradiation by 6 MeV electrons cause a change in the ability of the collector substrate to collect samples of the simulated regolith, even though the dose of β particles was up to 8 times that expected for a near-Earth asteroid sample return mission and the dose of 6 MeV electrons was up to 50 times that expected for such a mission. The experimental uncertainties in our experiments reflect variations in the force applied to the pad that, in turn, reflect regolith thickness, and packing.

Dose is expressed in terms of the dose expected for a six-year mission to a near-Earth asteroid. For example, a dose of 2 simulates a radiation exposure twice as long or twice as intense as expected for the mission.

Discussion: The TGIP collector is reliant upon the physical properties of the collection substrate, and any change in these properties, due to the space environment or otherwise, could jeopardize the mission. If space radiation causes a decrease in viscosity or an increase in penetrability, as thickness of grease is traditionally measured, collection ability could be compromised. Predicted alteration mechanisms were primarily degradation of the polymer or hardening, due to increased cross-linking of the polymer. In these experiments, we found that the properties of the collection substrate were unchanged, suggesting that neither degradation nor hardening of the polymer occurred. The stability of the compound is of interest and likely is due to the strong Si-Si bond (453 kJ/mol), although other factors may be involved such as the material's ability to repair broken bonds and to dissipate energy by other means.

The extent to which our irradiations simulate irradiation in space is obviously of concern. Previously we argued that since the energies of the radiation sources we used were orders of magnitude greater than typical bond energies this was a reasonable test. Further tests could be performed using larger accelerators, and protons and ^4He atoms, but given the present results we doubt it is necessary. Further tests should be performed combining the effects of radiation with temperature and low pressures. Based upon these results, however, the silicone grease is well-suited to resist the expected radiation of the space environment.

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References [1] IAA (1998) The International Exploration of Mars - 4th Cosmic Study of the IAA. Compiled by the International Academy of Astronautics (IAA), Committee on International Space Plans and Policies, Subcommittee on the International Exploration of Mars. Paris, France. (See http://www.iaa.net.org/p_papers/mars.html). [2] Petrov V.M. (1994) *Adv. Space Res.*, 14, 10397-10408.