Lunar Dust and Lunar Dust Simulant Activation and Monitoring

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During the Apollo missions, many undesirable situations were encountered that must be mitigated prior to returning humans to the moon. Lunar dust (that part of the lunar regolith that is less than 20 µm in diameter) produced several problems with astronaut suits and helmets as well as with spacecraft mechanical seals and equipment, and could conceivably harm astronauts on future missions. Although efforts were made to exclude lunar dust from the cabin of the lunar module, a significant amount of material nonetheless found its way inside. During ascent of the lunar module from the lunar surface to rendezvous with the command module, major portions of the contaminating soil and dust began to float, irritating the astronauts' eyes even as they inhaled this particulate matter into their lungs. As our goal is to understand what properties might make lunar dust hazardous, we are studying methods to understand its dangerous chemical properties.

Lunar dust is likely in an "activated" state, particularly due to the 1/6g and the lack of significant atmosphere on the moon. The purpose of our research is to understand the reactive properties of active lunar dust. Lunar dust is probably the product of various sources, including pulverization by micrometeorite impacts, exposure to unmitigated ultraviolet (UV) radiation, and bombardment by galactic/cosmic and solar-wind particles. These activation methods may produce free radicals on the surface of the dust particles. Free radicals have long been monitored using electron paramagnetic resonance (EPR), but EPR technology is extremely costly and the instrumentation is bulky, making it unsuitable for use on the lunar surface. To overcome these limitations, we developed a novel fluorescent technique that is based on the conversion of nonfluorescent terephthalate to fluorescent 2-hydroxyterephthalate on exposure to hydroxyl radicals.

These hydroxyl radicals are produced when free radical species are exposed to aqueous solution. The response of this assay to hydroxyl radical concentration is linear, as can be seen in figure 1. The fluorescent product was synthesized using a method from the literature and purified until the fluorescence intensity was maximized. Using the spectra obtained from this product allows for the determination of hydroxyl radical concentration in a particular solution.

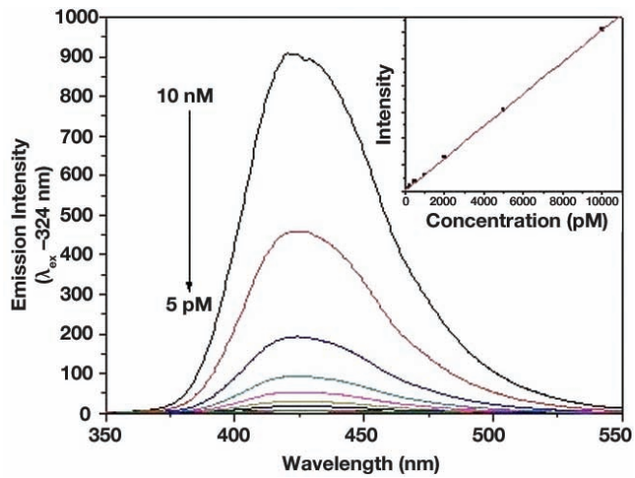

Fig. 1. *Fluorescence of synthetic z-hydroxyterephthalate.*

We used a mortar and pestle to hand-grind samples of quartz (Min-U-Sil 15), lunar dust simulant (JSC-1A-vf), and lunar soil that was returned by Apollo 16 (62241) to provide an initial activated mimic of conditions that will be found on the lunar surface. Quartz, which produces hydroxyl radicals after grinding, acted as a positive control. As expected, samples that were not activated (i.e., not hand-ground) did not produce a significant amount of radicals. Hand-grinding the different materials under identical conditions, however, leads to quite different emission intensities. As illustrated in figure 2, the level of activity increases in the following order: quartz < lunar dust simulant < lunar dust. Based on the calibration curve shown in figure 2, we can see that ground lunar dust produces two to three times the amount of hydroxyl radicals as lunar dust simulant and more than 10 times that of quartz under ambient conditions.

This work demonstrates a method of activating quartz, lunar dust simulant, and lunar soil and monitoring the various levels of activation. These results provide evidence of the need for further studies on these materials prior to returning humans to the lunar surface. We are also determining the mechanisms behind the activation of these materials (by grinding and UV exposure) as well as the time required to return activated samples to their passivated

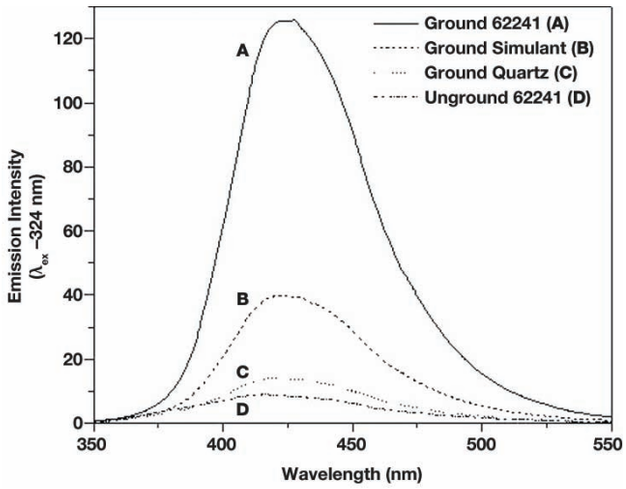

Fig. 2. *Emission spectra comparing ground and unground soil.*

state. These activation methods on lunar dust simulant and lunar dust in aqueous solution may have toxic effects on cellular systems. These studies will provide important information on the nature of lunar dust that will allow mitigation measures to be developed, ensuring the safety of astronauts and mechanical systems in lunar habitats.

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