

Formation of Nanophase Iron in Lunar Soil Simulant for Use in ISRU Studies

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Abstract. For the prospective return of humans to the Moon and the extensive amount of premonitory studies necessary, large quantities of lunar soil simulants are required, for a myriad of purposes from construction/engineering purposes all the way to medical testing of its effects from ingestion by humans. And there is only a limited and precious quantity of lunar soil available on Earth (i.e., Apollo soils) – therefore, the immediate need for lunar soil simulants. Since the Apollo era, there have been several simulants; of these JSC-1 (Johnson Space Center) and MLS-1 (Minnesota Lunar Simulant) have been the most widely used. JSC-1 was produced from glassy volcanic tuff in order to approximate lunar soil geotechnical properties; whereas, MLS-1 approximates the chemistry of Apollo 11 high-Ti soil, 10084. Stocks of both simulants are depleted, but JSC-1 has recently gone back into production. The lunar soil simulant workshop, held at Marshall Space Flight Center in January 2005, identified the need to make new simulants for the special properties of lunar soil, such as nanophase iron (np-Fe⁰). Hill et al. (2005, this volume) showed the important role of microscale Fe⁰ in microwave processing of the lunar soil simulants JSC-1 and MLS-1.

Lunar soil is formed by space weathering of lunar rocks (e.g., micrometeorite impact, cosmic particle bombardment). Glass generated during micrometeorite impact cements rock and mineral fragments together to form aggregates called agglutinates, and also produces vapor that is deposited and coats soil grains. Taylor *et al.* (2001) showed that the relative amount of impact glass in lunar soil increases with decreasing grain size and is the most abundant component in lunar dust (<20 μm fraction). Notably, the magnetic susceptibility of lunar soil also increases with the decreasing grain size, as a function of the amount of nanophase-sized Fe⁰ in impact-melt generated glass. Keller *et al.* (1997, 1999) also discovered the presence of abundant np-Fe⁰ particles in the glass patinas coating most soil particles. Therefore, the correlation of glass content and magnetic susceptibility can be explained by the presence of the np-Fe⁰ particles in glass: small particles contain relatively more np-Fe⁰ as glass coatings because the surface area versus mass ratio of the grain size is so increased.

The magnetic properties of lunar soil are important in dust mitigation on the Moon (Taylor et al. 2005). Thus material simulating this property is important for testing mitigation methods using electromagnetic field. This np-Fe⁰ also produces a unique energy coupling to normal microwaves, such as present in kitchen microwave ovens. Effectively, a portion of lunar soil placed in a normal 2.45 GHz oven will melt at >1200 °C before your tea will boil at 100 °C, a startling and new discovery reported by Taylor and Meek (2004, 2005).

Several methods have been investigated in attempts to make nanophase-sized Fe⁰ dispersed within silicate glass; like in the lunar glass. We have been successful in synthesizing such a product and continue to improve on our recipe. We have performed extensive experimentation on this subject to date.

Ultimately it will probably be necessary to add this np-Fe⁰ bearing silicate glass to lunar soil stimulant, like JSC-1, to actually produce the desired magnetic and microwave coupling properties for use in appropriate ISRU experimentation.

ACKNOWLEDGMENTS

We thank Allan D. Patchen for his assistance in the lab. This work is partially supported by a contract for dust mitigation studies from NASA through the Colorado School of Mines.

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