National Aeronautics and Space Administration

High temperature Batch Reactor for fabrication of Lunar Simulants.

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Program: Topical RTD

Project Objective:

- **Our primary objective** is to the are development of new simulant suitable for lunar science and the geo-technical investigations
- These new simulants will enable crucial first step towards understanding the geologic history, origin, and processes that were and/or are active on lunar surfaces.
- Present simulants do not adequately represent the presence of this glass fraction because it is very difficult to recreate, especially in the quantities needed for adequate testing of flight hardware.

FY21/22 Results:

- This Year 1 effort emphasizes development of lunar high temperature reactor system. The assembly and initial functional testing results of JPL's lunar simulant reactor is highlighted in **Figure 1**. The lunar simulant reaction was successfully testing for materials production as indicated by sample holder thermal profile and temperature vamp rate requirements of about 2 hours at a minimum of 1100°C. We also provided a dedicated facility to house the reactor station in the **197-101 lab** where it can be managed and operated safely on the near-term. Several processing conditions of our lunar simulant variants are summarized in **Table 1**.
- **Figure 2** highlights the lunar simulant chemical compositional analysis comparisons. We employed several lunar simulants for morphological and chemical comparisons to those produced at JPL, including JSC-1 for benchmarking the chemical analysis. In addition, a fine-grained lunar simulant was infused with SiO_2 materials to assess the structural and chemical microscopy and XRD characterization (top of Figure 2); this result did not result in any amorphous response with SiO_2 which strongly suggests simulants much require sintering process to achieve chemical correctness.
- **Figure 3** demonstrates the chemical adsorption of water on an γ-Fe2O3 nanoparticle (NP) with dangling bonds at room temperature (298.15 K) using the atomistic reactive force field molecular dynamics (ReaxFF MD) simulations.

Benefits to NASA and JPL (or significance of results):

- **Mission relevance:** NASA already has several proposed missions to the moon, and our work will fulfill an important need of detailed characterization of lunar regolith compositions and physical properties critical to many applied areas in lunar science, ISRU, space engineering, and all future science missions involving surface or near surface contact. In addition, the validation of future rover concepts and operations will rely on a comprehensive determination of the strength and deformation behavior of soil-like lunar materials within its many localized environments.
- **Significance:** At the same time, protection of moving parts against fine-grained regolith (dust) is a major challenge for hardware on the lunar surface. Such factors involving detailed understanding the mechanical and physical properties of the regolith are part of geo-technical interrogation critically needed for future lunar missions, and will also be fulfilled as part of our proposed work.

Figure 1: Operational Lunar Simulant Reactor

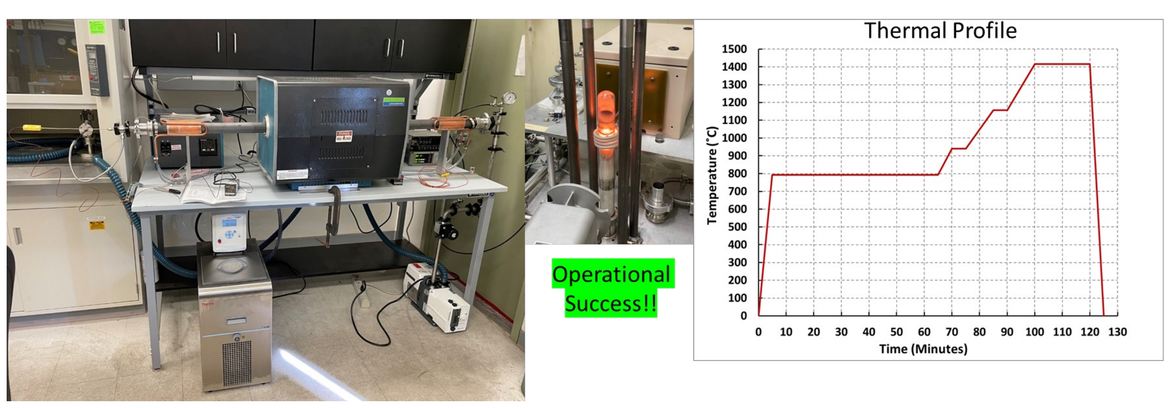


Table 1: Summary of Three Lunar Stimulant Variants and Their Processing Conditions.

	JPL-Stock-01	JPL-LF1Silica-01	JPL-WS-01
Mixture	Stock materials purchased from Sigma-Aldrich	50/50 wt.% LF1 sample/stock SiO_2 powder	50/50 wt.% slag/fly ash
Sample weight (g)	~2.5	~2.5	~2.5
Production time (mins)	128	125	51
Equipment	RF reactor	RF reactor	RF reactor
Sintering temperature (°C)	1450	1450	1450
Powder particle size (microns)	>100	>100	~0.1*

*powder particle size can be manipulated by ball-milling time

Figure 2: Compositional comparison of lunar simulant JPL-1 to JSC-1

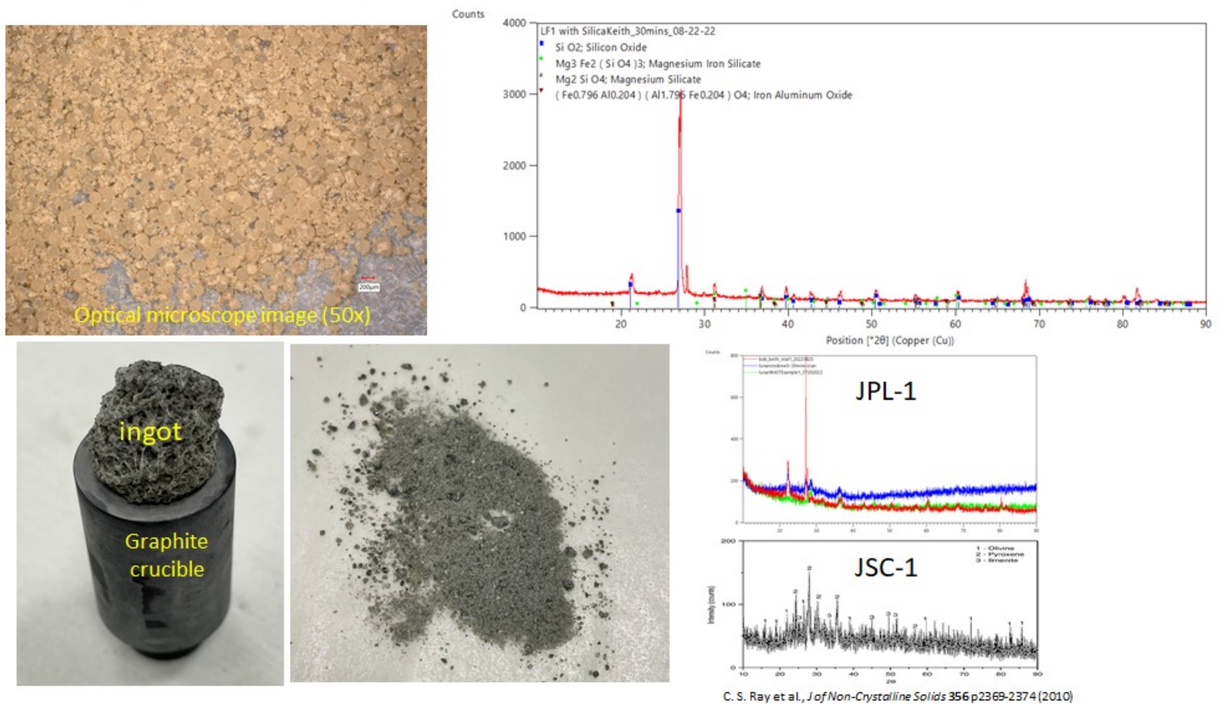
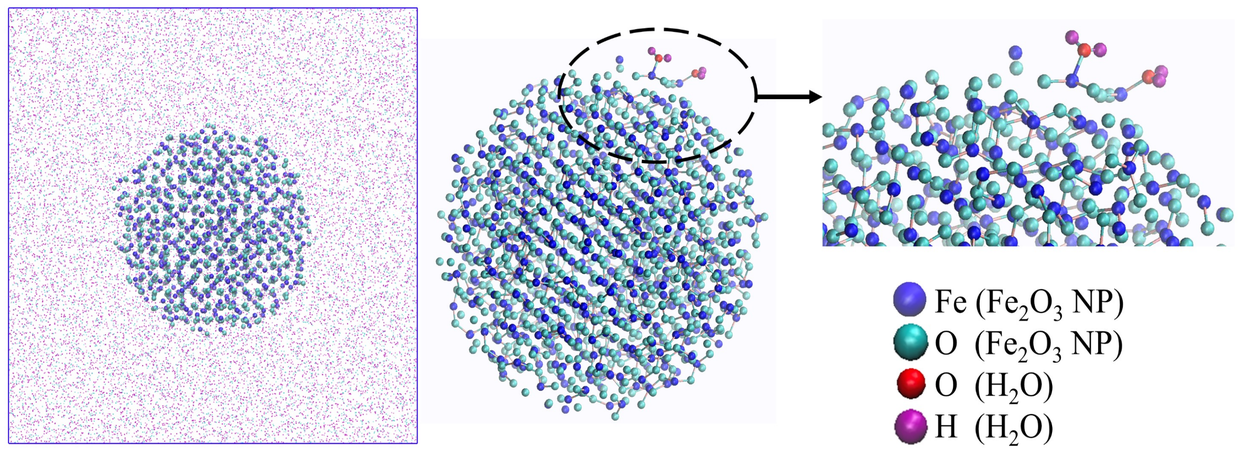


Figure 3. Atomistic ReaxFF MD simulations of the γ-Fe2O3 NP (3.2 nm) in water at 298.15 K.



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Poster No: