**Multiphysics modeling for dimensional analysis of a self-heated Molten Regolith Electrolysis reactor for oxygen and metals production on the moon and Mars**

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The technology of direct electrolysis of molten lunar regolith to produce oxygen and molten metal alloys has progressed greatly in the last few years The development of long-lasting inert anodes and cathode designs as well as techniques for the removal of molten products from the reactor has been demonstrated The containment of chemically aggressive oxide and metal melts is very difficult at the operating temperatures ca 1600°C Containing the molten oxides in a regolith shell can solve this technical issue and can be achieved by designing a self-heating reactor in which the electrolytic currents generate enough Joule heat to create a molten bath

In a first phase, a thermal analysis model was built to study the formation of a melt of lunar basaltic regolith irradiated by a focused solar beam This mode of heating was selected because it relies on radiative heat transfer, which is the dominant mode of transfer of energy in melts at 1600°C Knowing and setting the Gaussian-type heat flux from the concentrated solar beam and the phase and temperature dependent thermal properties, the model predicts the dimensions and temperature profile of the melt A validation of the model is presented in this paper through the experimental formation of a spherical cap melt realized by others The Orbitec/PSI experimental setup uses an 3 6-cm-diameter concentrated solar beam to create a hemispheric melt in a bed of lunar regolith simulant contained in a large pot Upon cooling, the dimensions of the vitrified melt are measured to validate the thermal model

In a second phase, the model is augmented by multiphysics components to compute the passage of electrical currents between electrodes inserted in the molten regolith The current through the melt generates Joule heating due to the high resistivity of the medium and this energy is transferred into the melt by conduction, convection and primarily by radiation
The model faces challenges in two major areas, the change of phase as temperature increases, and the dominance of radiative heat flux as heat transfer mechanism within the melt The change of phase concerns the regolith itself which is present in states ranging from a fine grain regolith with low thermal conductivity and low density to a vitrified melt with much higher thermal conductivity, and higher density As the regolith is heated, it starts to soften around 1300°C The melt is very viscous and evolving gas bubbles out in thick, lava-like fashion By 1600°C the regolith is completely melted and the viscosity is low The second challenge resides in the proper modeling of the radiative heat flux requiring the addition of the computing-demanding radiative-heat-transfer function to the general heat transfer equation The model includes temperature-dependent properties (density, thermal conductivity, heat capacity, and viscosity, and absorption coefficients) and solves the radiative heat flux equation assuming gray (fine grains) and semi-transparent (melt) media and using an absorption coefficient spectral found in the literature for terrestrial minerals similar in composition to those of lunar regolith simulant