Development of a Cold-Walled Molten Regolith Electrolysis Reactor for Lunar Oxygen Production

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On the lunar surface, production of commodities to support human presence, such as water, food and oxygen, and sustain the growth of a permanent outpost will likely require the use of local resources. The moon is covered almost entirely with fragmented oxide minerals known as regolith hundreds of meter thick. As a resource, it is rich in oxygen (> 42 wt.%) bound in a solid state with a variety of metals. The molten regolith electrolysis (MRE) reactor is a promising technology for the production of gaseous oxygen from the lunar regolith in a simple, single-step reaction that requires minimal consumable materials, produces oxygen and metals with high electrical efficiency and high yields from any regolith composition. This process involves melting regolith to ~1600°C then electrolyzing the molten pool to separate metal and oxygen ions that are then collected as liquid metal and gaseous oxygen at the respective electrodes. Lab-scale demonstrations of the MRE technology have previously relied on external heating sources to bring the entirety of the reactor up to the operating temperature which creates corrosive interfaces between the molten regolith and the containment material in the reactor, limiting the overall lifespan of a reactor [1]. The Gaseous Lunar Oxygen from Regolith Electrolysis (GaLORE) project is focused on the development of a “cold-walled” or “Joule-heated” reactor design in which an internal heating source is used to selectively melt a pool of regolith between the electrodes of the reactor, leaving a shell of solidified regolith between the molten pool and the containment vessel of the reactor. This next generation reactor concept has been under development as molten oxide electrolysis (MOE) by MIT and Boston Metal for the production of iron from pure ores for terrestrial application [2]. The GaLORE project in engaged in early development of the technology for use with varying lunar regolith compositions in the lunar environment.

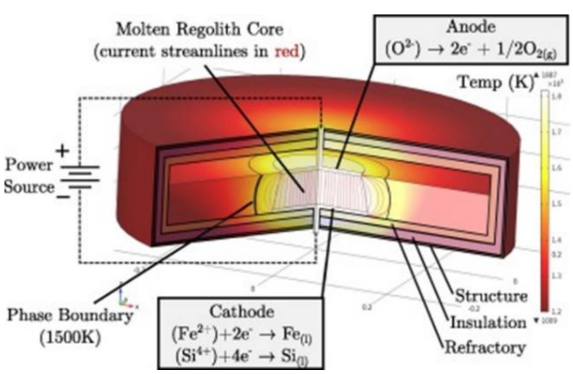

Figure 1. Illustration of a multiphysics simulated cold-walled MRE reactor with calculated regolith temperature. The reactor width is based on a requirement to keep the inner walls of the reactor below regolith melting point [3]

Thermal modelling of a proposed cold-walled reactor design were used as a scaffold to develop parameters for a feasible reactor shape and size as well as target energy consumption [3]. The current development effort for the cold-walled reactor design will be presented as a trade study of the most promising techniques for melting regolith within the constraints imposed by the lunar environment. Heater devices are designed to accommodate limited electrical power availability on the moon, a wide range of regolith compositions that may be seen on the moon, limited metals available for replacing consumed parts, and the low thermal conductivity of granular regolith in vacuum. Heater devices will be down-selected based on performance measurements within the above operational constraints, and selected devices will be integrated into a reactor with electrodes to begin producing oxygen.

[1] Sibille, L., Sadoway, D.R., Sirk, A., Tripathy, P., Melendez, O., Standish, E., Dominguez, J. A., Stefanescu, D.M., Curreri, P.A., Poizeau, S., 2009. “Recent Advances in Scale-up Development of Molten Regolith Electrolysis for Oxygen Production in support of a Lunar Base.” AIAA 2009-659, 47th AIAA Aerospace Sciences Meeting, 5 - 8 January 2009, Orlando, FL.

[2] Boston Metal, https://www.boston-metal.com/moe-technology/#moe-process

[3] Schreiner, S.S., Sibille, L., Dominguez, J.A., Hoffman, J.A., 2016. "A parametric sizing model for Molten Regolith Electrolysis reactors to produce oxygen on the Moon." Advances in Space Research 57.,7, 1585-1603.