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MOLTEN REGOLITH ELECTROLYSIS: SYSTEM DESIGN AND VACUUM COMPONENT TESTING

Abstract

The Molten Regolith Electrolysis (MRE) process has been demonstrated to produce raw feedstock materials and oxygen at high yield from simulated lunar materials with NASA's ISRU project funding in the 2000's. Among current chemical processing techniques, MRE offers the only one-step process to produce oxygen and metals by direct electrochemical separation of molten metal oxides at opposite electrodes. Melting the regolith rather than involving chemical solvents (an approach used for the terrestrial production of aluminum) simplifies functional flow design, greatly reduces contamination of the produced oxygen and metals, lowers overall landed mass and frees the technology from dependence on consumable components that may not be readily available in space. These attributes and its higher yields of oxygen and metal per unit mass of regolith give MRE the edge over techniques requiring chemical compounds to react with mineral constituents. MRE is also the only existing technology producing molten metals in their raw form, and available for processing to become stock for additive manufacturing (3D printing) to enable fabrication and repair techniques for sustained operations on the lunar surface. Previous work on MRE reactors characterized their nominal operations at small scale and the electrochemical reactions on which they operate (Sibille, 2009) and showed consistent performance with regolith of compositions from any locations on the moon. Current development work is guided by systems engineering methodology with a focus on demonstrating the operation of an integrated reactor in a vacuum environment with a production capability of several tonnes of oxygen per year. Although simple in principle, the reactions occur at temperatures above the melting point of the regolith oxide mixture to enable ionic current between electrodes at low potentials. The containment and handling of molten metal alloys and corrosive oxide melts at such temperatures creates a problem for reactor material design both thermally and chemically. The cold-walled reactor design includes internal Joule-heating of the molten regolith, which is surrounded with granular regolith to protect the reactor inner walls. Multiphysics modeling and model-based system engineering are used to support the development of reactor sub-systems performing processing functions. Experimental test results of the core functions of a sub-scale reactor are presented that guide the scaling and design options for larger subsystem concepts. A review of experiments performed to propose potential solutions for critical operations such as cold-wall reactor start, regolith feed delivery, and molten material transfer will be presented.