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Combustion and Resultant Structures of Lunar Regolith Based Microthermite Powders

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ABSTRACT

For sustainable development of lunar infrastructure, in-situ resource utilization must be prioritized to reduce the requirement for Earth derived materials on the Moon. Oxygen rich lunar regolith minerals have the potential to serve several engineering applications including energy production via their exothermic redox reaction with metal fuels and construction via the thermite reaction products. It has been shown in the past that metal fuel and regolith simulant oxidizing particles must be micro and nano sized to ensure reliable reaction. In this work, we present an in-situ lunar thermite material for energy harvesting and additive manufacturing (AM) and construction on the Moon. The thermite material consisted of micro-magnesium and micro-aluminum as metal fuels and nanoscale lunar regolith simulant as an oxidizer. The loading of metal fuels was kept constant at 30%, varying between 10-20% magnesium and 10-20% aluminum with 70% simulant by mass. The original size of the regolith oxidizing particles was tens of microns, but reduced to hundreds of nanometers via ball milling, which is expected to function in reduced gravity conditions due to the magnetically driven shear forces that break down the regolith particles. The combustion and physical properties of the material were experimentally evaluated to demonstrate its applicability as a dual use material for lunar energy harvesting and construction. Propagation rate, energy release, onset temperature, and ignition delay quantify the combustion capabilities of the material. The mass loss and volume change during combustion, and the resultant compressive strength quantify the mechanical and material properties of the regolith-based thermite material. The high reactivity of magnesium enabled reliable self-propagation of the reaction front. However, excess magnesium created weak, porous products due to its low vaporization temperature under vacuum conditions. Aluminum was found to be less reactive and was not capable of reliably allowing a thermite reaction to self-propagate without the addition of magnesium, but enabled greater mechanical strength of the products due to its lack of vaporization. Strong relations were found between the thermal reactivity of the thermite materials, and the mechanical properties of the products. The reaction products were evaluated via scanning electron microscopy and energy dispersive spectroscopy to demonstrate the microstructure of the post combustion material. After appropriate pre-processing it was found that the use of both metals in regolith-based thermite can provide both reaction reliability and improved physical characteristics after combustion demonstrating potential as an in-situ material for lunar infrastructure development.