23rd IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Strategies & Architectures as the Framework for Future Building Blocks in Space Exploration and Development (1)

Author: Dr. Deddy Nababan
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

ZERO WASTE IRON PRODUCTION PROCESS ON MARS

Abstract

Structural metals, particularly iron, production is crucial for supporting the infrastructure construction of potential habitation on Mars as part of further space exploration. Considering the accessibility of CO2 in the atmosphere as a potential carbon source, previous studies have suggested carbothermic reduction as a feasible method to extract iron from Mars' regolith. Therefore, investigating the reduction behavior and mechanism of the regolith is important. This work presents a study of the carbothermic reduction of simulated Mars regolith (MGS-1) starting from the characterization of the simulant, selected carbothermic experimental work, and assessment of the slag utilization.

Several characterization techniques were conducted including XRF, Quantitative XRD, SEM-EDX, EPMA, Particle Size Analysis, and TGA-EGA. It was found that the MGS-1 simulant has similar mineralogical properties to the soil in the Gale Crater on Mars. The dominant minerals contained in the regolith included plagioclase (41.54 wt.

The thermodynamic assessment using FactSage 8.2 of the reaction between oxides in the simulant with various carbon additions was carried out as the reference for the experimental work. It predicted the conversion of all Fe from 100g regolith into a liquid Fe (alloy) when reacted with 6g carbon at 1150 under the pressure of 7 mbar, the typical Mars ambient pressure. The system was transformed into a fully molten (slag and liquid alloy) system starting at 1400.

Selected experimental works were conducted at 1000 to 1450 under controlled pressures of 4 to 10 mbar, the typical Mars pressures. It was found that the iron in magnetite and hematite phases would be reduced first to form pure metallic iron at low temperatures (1000-1070C). As the reduction temperature was increased (1100-1450C), the iron (with a certain amount of silicon and other metals) in olivine and pyroxene minerals would be reduced to form an iron silicon alloy. Aligned with the simulation results, the experiment at 1400C transformed the sample into a smelting stage producing liquid metal and slag. This study was then expanded to assess the potential use of the slag which contained a high amount of SiO2, Al2O3, MgO, and CaO for other applications, e.g. cement additive, brick, glass, etc. This closed-loop process would provide a zero-waste process of iron production on Mars.