Experimental results of newly developed techniques for volatile extractions using lunar simulant and oxides

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Abstract: A soil heating reactor system was developed to analyze gas release from lunar regolith simulants and to evaluate Molten Regolith Electrolysis (MRE) under simulated lunar conditions. The system operates under vacuum and can reach temperatures up to 1,500 °C. During controlled heating to 1,000 °C over 50 minutes, released gases were continuously measured using residual gas analyzers. Results show that water vapor and oxygen peaked near 200 °C, indicating desorption of adsorbed volatiles, while CO_2 increased steadily up to about 600 °C due to decomposition of carbonates or organic materials. A slight increase in oxygen release above 800 °C suggests thermal decomposition of mineral phases. These findings provide insight into volatile extraction and oxygen production from lunar regolith.

The soil heating reactor system consists of a vacuum chamber, a turbo pump, a rotary pump, an electrically heated crucible that can be moved outside the chamber, control hardware, and a water cooling system. The vacuum chamber is equipped with internal illumination, a shutterable viewing window, and two RGA (Residual Gas Analyzer) systems manufactured in Korea and Germany (Pfeiffer Vacuum). The water cooling system cools the exterior of the vacuum chamber, enabling operation at temperatures of up to 1,500 °C.

Temperatures above 1,500 °C can be used to extract metals and oxygen from lunar regolith. This heating chamber was designed to test Molten Regolith Electrolysis (MRE) under lunar environmental conditions. The heating program was set to continuously increase the temperature to 1,000 °C over a period of 50 minutes. During heating, the extracted gases were continuously measured to evaluate which volatile substances were released at specific temperatures.

Around 200 °C, the release of water vapor and oxygen reached its peak. This suggests that moisture and oxygen adsorbed or weakly bound to the regolith simulant were actively desorbed or decomposed at that temperature. Afterward, the release began to decrease and returned to background levels at 650–700 °C. This indicates that most of the volatile oxygen and water vapor had been removed (reduced) within this temperature range. After 800 °C, the amount of oxygen released showed a slight increase again. This may suggest that some of the mineral components within the lunar soil simulant began to undergo thermal decomposition at high temperatures, resulting in the release of oxygen.

The amount of carbon dioxide (CO_2) extracted up to 600 °C increased steadily with temperature. This indicates that carbonate minerals or organic materials gradually decomposed within this temperature range, releasing CO_2. After 600 °C, the CO_2 release remained nearly constant. This suggests that most CO_2 precursors had already decomposed by 600 °C, or that the decomposition rate of the remaining precursors had become very slow. The regolith simulant mainly released moisture and oxygen at relatively low temperatures (~200 °C), which appears to originate from adsorbed volatile substances. Carbon dioxide was continuously released up to a relatively higher temperature (~600 °C). At temperatures above 800 °C, the re-release of oxygen due to thermal decomposition of the minerals themselves was observed.

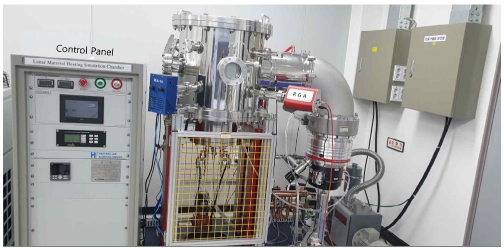

Figure 1. A soil heating reactor sytem at KIGAM

Figure 2. Photos of the soil heating reactor in use (L) and the design (R)

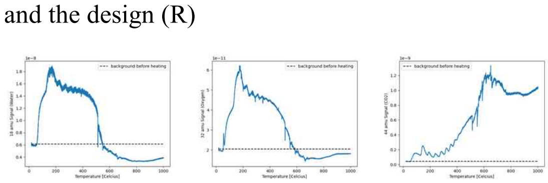

Figure 3. Temperature vs gas release for H_2O, CO_2, and O_2

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