SILICON, ALUMINUM AND OXYGEN FROM LUNAR ORE

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Abstract

A process scheme to produce silicon, aluminum and oxygen from lunar anorthite is presented. In a dry-extraction process, silicon will be obtained by reduction of the ore with aluminum metal, subsequently aluminum and oxygen by molten salt electrolysis. Conceptual and experimental work is progressing at EMEC Consultants with the support of NASA's SBIR program.

Lunar Resources to Produce Silicon, Aluminum and Oxygen

Considering the high transportation cost from the earth's surface into space, it appears attractive to exploit lunar resources to produce silicon, aluminum and oxygen. Attractive ore resources contain high amounts of anorthite, $CaAl_2Si_2O_8$, from which the elemental constituents (19.4 wt% Al, 20.2 % Si, 14.4 % Ca, 46.0 % O_2) are to be extracted.

Except for the calcium, all components constitute very desirable products. Silicon and aluminum can be used for structural materials, silicon for solar cells and glass (if reconverted to the oxide), oxygen for life sustaining environments. Reduced metallic components and oxygen, furthermore, may be employed as fuels for space transportation.

Dry-Extraction Process

EMEC Consultants has suggested a dry-extraction process to produce silicon, aluminum and oxygen from lunar anorthite. The process scheme, represented in Figure 1, is comprised of three major process steps. First, silicon is obtained by reducing the silicon dioxide content of the ore with aluminum metal. The thereby produced aluminum oxide, together with the original content of the ore, is electrolyzed in the second major process step, to yield aluminum metal and oxygen. In a further step, the calcium component of anorthite is removed from the system to avoid its accumulation.

In addition to the above major process steps, a preliminary step to treat the ore, mainly to remove iron-rich components, may be included. Some additional intermediate process steps were also found to be necessary. To electrolyze calcium, for instance, the aluminum has to be removed completely from the electrolyte, and it is advisable to accomplish this in a special electrolysis step, or by reduction with calcium metal.

The process is tailored to the constraints introduced by the extraterrestrial environment: lack of water and carbon prohibit their employment as solvents and reactants, respectively. In the detailed conception, the reduced gravity and the presence of vacuum have to be considered, having particular impact on heat and mass transfer.

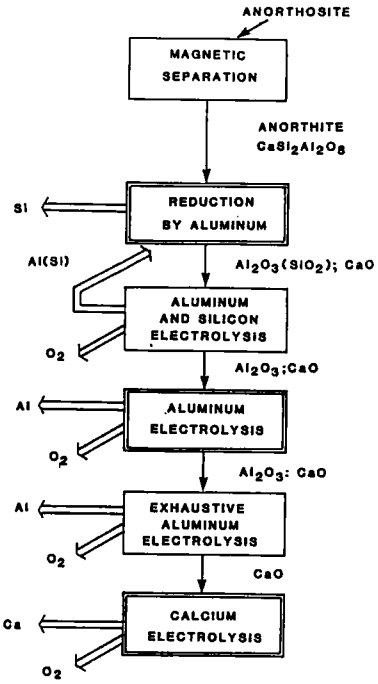

Figure 1. Process Scheme to Extract Silicon, Aluminum and Oxygen from Lunar Ore

Ongoing R & D

In a NASA SBIR Phase I contract, NAS 9-17575, EMEC Consultants investigated the feasibility of the first major process step, producing silicon metal. Silicon dioxide or Wyoming anorthosite were added to cryolitic melt and reduced by metallic aluminum. Recovering the reduced silicon from a resulting hypereutectic Si-Al melt appears most promising.

NASA awarded a Phase II contract to EMEC Consultants. A conceptual effort shall produce a flowsheet of the process and a conceptual design of an installation to produce 5000 t of aluminum, 5000 t of silicon and 10000 t of oxygen annually. The reduction of silicon by aluminum shall be investigated further, along with the elimination of calcium from the process, possibly the most difficult of the major process steps.

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