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Beneficiation of Lunar Ilmenite

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Abstract

One of the most important commodities lacking in the moon is free oxygen which is required for life and used extensively for propellent. Free oxygen, however, can be obtained by liberating it from the oxides and silicates that form the lunar rocks and regolith. Ilmenite ($FeTiO_3$) is considered one of the leading candidates for production of oxygen because it can be reduced with a reasonable amount of energy and because it is an abundant mineral in the lunar regolith and many mare basalts.

In order to obtain oxygen from ilmenite, a method must be developed to beneficiate ilmenite from lunar material. Two possible techniques electrostatic or magnetic methods. Both methods have complications because lunar ilmenite completely lacks Fe^{3+}. We have tested magnetic methods on eucrite meteorites, which are a good chemical simulant for low Ti mare basalts. The ilmenite yields in the experiments where always very low and the eucrite had to be crushed to xxxx. These data suggest that magnetic separation of ilemnite from fine grain lunar basalts would not be cost effective. We are presently performing experiments with electrostatic separators and waiting for lunar regolith so that we do not have to depend on simulants.

Introduction

A fundamental question in the utilization of lunar material for manufacturing of chemicals is the degree to which the raw material: mostly anorthosite, basalt and regolith and their mineral components can be high-graded from bulk. Specifically, ilmenite is a mineral that is abundant in regolith and in high-titanium basalts and can theoretically be used for the production of oxygen. Various processes that involve the reduction of ilmenite to liberate oxygen are being investigated in the hope that oxygen can be manufactured on the moon. This is important because oxygen is required for life support and is an important propellent. Transporting oxygen from the earth to the moon in large quantities may make lunar bases cost-prohibitive.

The most realistic separation methods for ilmenite from regolith or rock that could be used in the moon are electromagnetic since gravity aided separation techniques would not work in the low gravity environment of the moon and liquid-based separation techniques would be very difficult to control. Electromagentic separation techniques have been used in terrestrial mines for many decades and in some cases can produce very high yields of clean separates. Producing charged particles on Earth or separating minerals with different $Fe2^{+}/Fe^{3}+$ by magnetic methods is quite different than trying to charge particles in vacuum or magnetically separate minerals with no Fe^{3+} as is the case for lunar material.

Because we do not have lunar material yet, simulants were used in magnetic separation experiments. Lunar ilmenite is almost stoichiometric and contains no ferric iron. Consequently teerestrial ilmenite cannot be used as simulant. Meteoritic analogs were examined and the best simulant was found to be eucrititic meteorites. Table 1 show the chemical composition of lunar ilmenite from high titanium basalts and eucritic ilmenite.

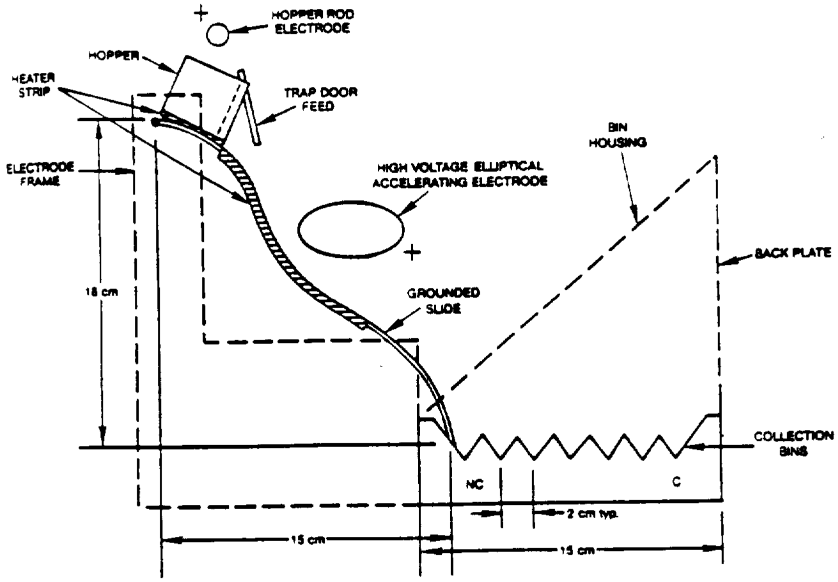
Table 1

	lunar mean	range (wt%)	eucritic mean	range
FeO	43.3	(35.2-47.7)	44.2	(42.8-45.0)
TiO_2	52.7	(49.9-55.5)	52.8	(52.5-53.0)
Al_2O_3	*	(0.1-0.3)	0.06	(0.03-0.11)
Cr_2O_3	0.64	(0.5-2.12)	0.09	(0.03-0.27)
MgO	2.23	(0.0-9.5)	1.05	(0.46-2.35)
MnO	0.42	(0.0-0.95)	0.88	(0.82-0.93)
CaO	*	(0.0-0.3)	0.10	(0.03-0.16)

Lunar data from a compilation of 133 ilmenites from hi-Ti basalts (Vaniman, et al., 1989), except for Al_2O_3 and CaO, which are for Apollo 11 ilmenites (Mason and Melson, 1970). Eucritic data are for 8 eucrites (Bunch and Keil, 1971)

Our attempts to beneficiate eucritic ilmenite were not very succesful. The best concentrate was only about 20% ilmenite. Our work generally agrees with the interpretations of Taylor and Oder (1990). It appears that electrostatic separation will be the best option for the beneficiation of lunar ilmenite. However, experiments by Agosto (1985) indicate that electrostatic separation of ilmenite from lunar soils is not very efficient because of the presence of agglutinates, which have an inherent heterogeneous behavior to electrostatic charging. It may be that rocks provide feedstock to soils. However, the use of rocks would require crushing to liberate the ilmenite. During our attempts to liberate ilmenite from the eucrite sample, the rock did not crush along grain boundaries; most of the ilmenite remained trapped in composite grains. In addition, a static cling problem was observed in which all the particles produced during crushing were covered with fine dust. The coating included FeS which would create problems during electrostatic beneficiation and reduction of the ilmenite.

Experiments with lunar regolith and rocks will be made in 1991 using an electrostatic separator based on Agosto's (1985) original design (Figure 1). The separator can be used under vacuum or inder Ar or N atmospheres. Electrostatic separations will be attempted on untreated lunare regoliths and crushed regolith and rocks under vacuum and inert gas atmospheres. In addition photoelectric charging will be attempted since this technique has been very succesfull on terrestrial samples (Fraas, 1976).



References

Agosto, W.N. (1985) Electrostatic concentration of lunar soils and minerals, in, Lunar Bases and Space Activities of the 21st Century, LPI p 453-464.

Fraas, F, (1976) Electrostatic separation with photoelectric charging,. U.S. Bureau of Mines Report 7610. U.S. Bureau of Mines, Minneapolis 13 p.

Taylor L.A. and Oder R.R. (1990) Magnetic beneficiation of Hi-Ti Mare soils. Concentration of ilmenite and other components. Lunar and Planetary Sciences XXI, Lunar and Planetary Institute