

**ELECTROLYSIS OF SIMULATED LUNAR MELTS;** Robert H. Lewis, David J. Lindstrom, and Larry A. Haskin, Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, Missouri 63130.

Molten silicate electrolysis has been proposed as a way to separate useful elements from lunar materials. Metal extraction processes used on Earth require reducing agents which are essentially unavailable on the lunar surface. Because electrolysis does not require imported reagents and can be powered by solar thermal and solar electric energy it is well suited to the lunar environment.

Earlier work demonstrated that Fe metal and O<sub>2</sub> gas can be produced by electrolysis of simulated mare basalt (1). Practical application of electrolysis requires further data on the electrical conductivities and conduction mechanisms of silicate melts. Electrolysis depends on ionic conduction, and energy transported by electronic conduction only serves to heat the melt.

In order to investigate the conduction mechanisms of these liquid semiconductors we measured the AC and DC electrical conductivities of Diopside (Mg Ca Si<sub>2</sub> O<sub>6</sub>) melts doped with FeO and TiO<sub>2</sub>. Sample charges suspended on Pt wire loop assemblies (2) were placed in a gas mixing furnace and exposed to a 10% CO-90% CO<sub>2</sub> atmosphere at 1550°C (log fO<sub>2</sub> = -5.27).

For AC measurements, the output of a Tektronix FG 504 function generator was directed through the charge and a reference resistor. The potentials across the charge and reference were measured by two digital voltmeters and the resistance of the charge calculated. The AC conductivity was then determined using the appropriate cell constant for our charge geometry (3). DC conductivity measurements were made using a PAR Model 170 electrochemistry system as a constant current source, and a digital voltmeter. An initial voltage peak occurred which decreased with time. After approximately twelve seconds the voltage had stabilized sufficiently to get a representative value. The results of these measurements are shown in Table 1.

The AC conductivity represents a combination of ionic and electronic conduction. The addition of TiO<sub>2</sub> produces little change in AC or DC conductivities. Similarly, adding one weight percent FeO has only a small effect on AC conductivity, in contrast to its large effect on the DC conductivity. Adding ten weight percent FeO increases both the AC and DC conductivities substantially.

The DC conductivity of a simulated mare basalt was also measured and found to be a function of the voltage across the charge (Fig. 1). Three regions can be identified in figure 1. At potentials below about 300mv the measured DC conductivity appears to be due to electronic conduction only. These low potentials are insufficient to electrolyze the ions present. At higher potentials, Fe is electrolyzed as is indicated by the increase in conductivity. The region above one volt is not yet well characterized but it may be that both Si and Fe are being electrolyzed. At one volt potential the conductivity is approximately 0.24 ohm<sup>-1</sup> cm<sup>-1</sup> and is due to both electronic and ionic conduction. At 140 mv the conductivity is 0.18 ohm<sup>-1</sup> cm<sup>-1</sup> and is due only to electronic conduction. Thus, in this example, the electronic component represents about 3/4 of the current and the ionic component should be approximately 1/4.

Electrolysis was performed under the same conditions on the mare basalt, ilmenite, and an equal mixture of the two. A constant current was passed through each charge for approximately 400 seconds and then the charge was quickly quenched. The portion of the cathode within the charge was removed by shattering the surrounding glass, then was treated with HF for a short time to remove any adhering glass, and weighed. The mass of Fe electrodeposited was determined to within about plus or minus one milligram. Typically, one to four milligrams were deposited.

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At about 900 mv, the mare basalt had an electrolytic efficiency of about 30%. This is similar to the predicted efficiency of 25% for mare basalt, based on our DC conductivity measurements. Ilmenite at the same potential was about 10% efficient, and the mixture of 50% mare basalt and 50% ilmenite had an efficiency of less than 5%.

For the mare basalt and the mare basalt-ilmenite mix, both silicates, the efficiency decreases with increasing Fe content. The electronic component of conduction within the melt increases with increasing Fe content, as it did with FeO doped diopside. The electrolysis efficiency of ilmenite, which is not a silicate, is moderate even though the FeO content is quite high.

These preliminary results have important implications for electrolytic processing on the moon. It appears that reasonable efficiencies may be expected from 'ores' such as mare basalt but that ores richer in FeO may be less attractive from an energy standpoint due to the larger electronic component of conduction. The conductivity and electrolytic efficiency of Apollo 15 mare basalt appear to be suitable for practical oxygen and iron production. This work was supported by NASA grant NAGW-179.

#### References

- (1) Lindstrom, D.J. and Haskin, L.A., (1979) 'Electrochemistry of Lunar Rocks', Fourth Princeton/AIAA Conference on Space Manufacturing Facilities
- (2) Waff, H.S., (1976) Rev. Sci. Instrum. 47, 877-879
- (3) Lindstrom, D.J., Lewis, R.H. and Haskin, L.A., (1984) Lunar and Planetary Science XV, 479-480

Table 1. Composition	Conductivity, 1/(ohm-cm)	
	AC, 10 kHz	DC
Diopside	0.65	0.0012
Diop + 1% TiO <sub>2</sub>	0.65	0.0017
Diop + 10%TiO <sub>2</sub>	0.73	0.0055
Diop + 1% FeO	0.67	0.015
Diop + 10% FeO	1.26	0.092
log fO <sub>2</sub> = -5.27      similar potentials		

Figure 1.

