Tribocharging Lunar Soil for Electrostatic Beneficiation

2006 Center Director's Discretionary Fund Project

In Situ Resource Utilization (ISRU) Oxygen Production

Future human lunar habitation requires using *in situ* materials for both structural components and oxygen production. Lunar bases must be constructed from thermal- and radiation-shielding materials that will provide significant protection from the harmful cosmic energy which normally bombards the lunar surface. In addition, shipping oxygen from Earth is weight-prohibitive, and therefore investigating the production of breathable oxygen from oxidized mineral components is a major ongoing NASA research initiative. Lunar regolith may meet the needs for both structural protection and oxygen production. Already a number of oxygen production technologies are being tested, and full-scale bricks made of lunar stimulant have been sintered. The beneficiation, or separation, of lunar minerals into a refined industrial feedstock could make production processes more efficient, requiring less energy to operate and maintain and producing higher-performance end products.

The method of electrostatic beneficiation used in this research charges mineral powders (lunar simulant) by contact with materials of a different composition. The simulant acquires either a positive or negative charge depending upon its composition relative to the charging material. The charged particles can then undergo electrostatic separation in an electric field based upon their charge-to-mass ratio *(Q/M)*. Characteristics such as bulk, surface composition, and particle size influence the ability of the material to garner a charge and separate under the influence of the electric field. The lunar regolith grains and the lunar environment are ideal for triboelectrification and electrostatic separation because the lack of moisture prevents the grains from sticking together and the lower gravitational pull permits longer contact times during charging and increased particle separation.

After successful beneficiation experiments had shown proof-of-concept with JSC-1 lunar simulant, an application to use lunar regolith was accepted by the lunar curator at Johnson Space Center. All the beneficiation experiments performed with JSC-1 lunar simulant were then repeated with Apollo 14163 lunar soil samples.

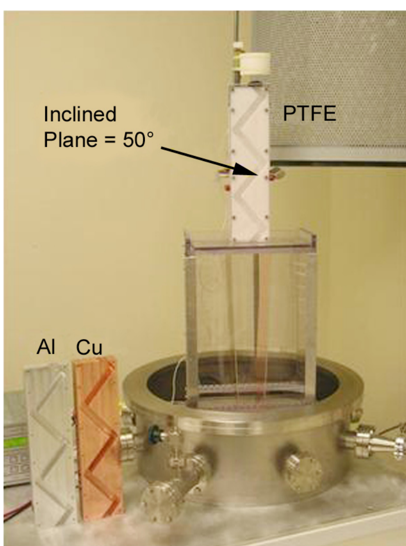

Figure 1. Inclined-plane charger and charge seperator experimental setup.

Three inclined-plane tribochargers were constructed of copper, aluminum, and polytetrafluoroethylene (PTFE). These materials were selected because they offer different charging capabilities, and consequently separate the soil differently. The inclined-plane charger (Figure 1) was made from a block of material with a zigzag pathway (at an optimum angle of 50° as determined by friction studies performed prior to construction) cut the length of the block from top to bottom. Simulant was fed directly from the inclined-plane charger into an electrostatic separator between two charged plates (one positive and one negative) and collected as separate fractions.

X-ray photoelectron spectroscopy (XPS) was performed for the purpose of characterizing chemical composition before and after beneficiation. The XPS data (see the table) shows a change in the chemical composition of a number of elements in each of the beneficiated fractions.

Mean relative percentage change in elemental concentration compared with starting sample for Apollo 14163 lunar regolith, using aluminum charger (particle size = 50 to 75 μm).

Sample	Na	Fe	O	Ti	Ca	C	Si	Al
Positive plate	23	15	8	70	–*	–20	8	–*
Negative plate	7	–8	–10	–20	–7	7	–*	–*
Unseparated	–*	31	16	210	21	–44	15	17

** Relative changes are within error.*

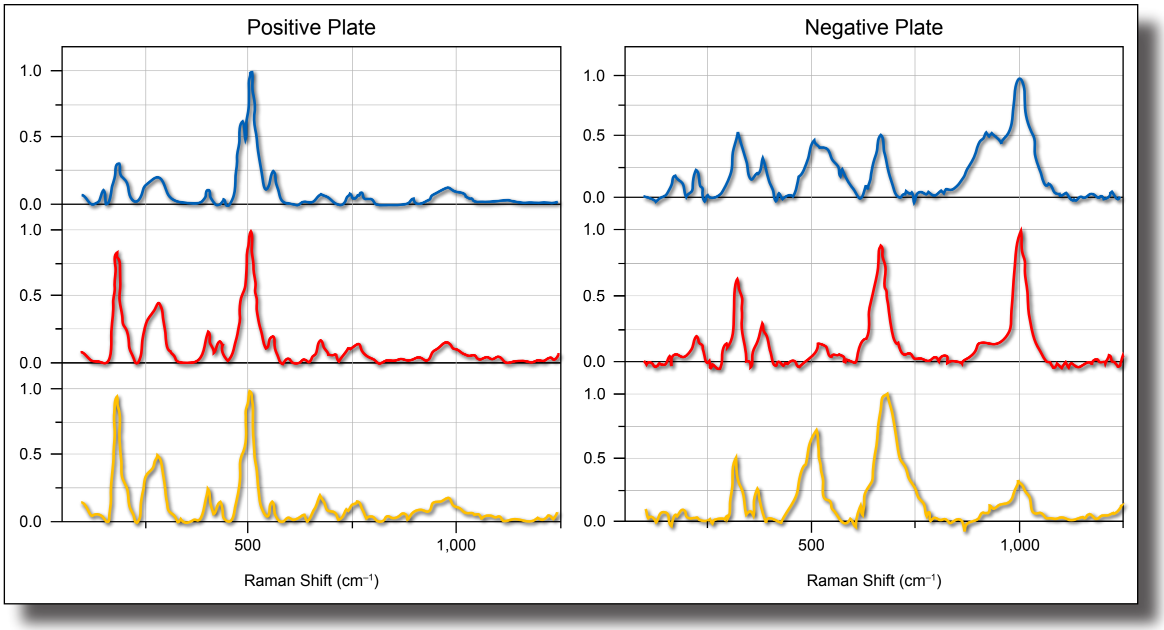

Figure 2. Raman spectra of beneficiated Apollo 14 samples, using an aluminum tribocharger.

Raman spectroscopy was performed for the purpose of characterizing the mineralogy of the samples before and after beneficiation. The Raman data (Figure 2) shows the difference in spectra between the different beneficiated fractions that result from the different mineral compositions. The positive plate is composed mostly of plagioclase. A few extra minerals are present, but their corresponding peaks are of low intensity. The negative plate is a mixture of solid solution α $Fe_2O_3/FeTiO_3$ (226 cm^{-1}), Pseudobrookite – $FeTiO_5$ (323 cm^{-1}), plagioclase, ilmenite ($FeTiO_3$), and pyroxene (997, 1,000 cm^{-1}).

The newly designed tribocharging setup successfully charged and separated JSC-1 lunar simulant and Apollo 14 lunar soil. It also provided preliminary data indicating enrichment of iron- and titanium-rich minerals in a vacuum. This technique may prove to be a viable tool for specific mineral enrichment of regolith prior to oxygen production processing or other structural-material processing. Future work will focus on optimizing the length of the tribocharger and the charge separator, as well as possible integration into the *In Situ* Resource Utilization project's engineering breadboard unit.

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