TITLE: ELECTROSTATIC SURFACE STRUCTURES OF COAL AND MINERAL PARTICLES

GRANT NO.: DE-PS22-96PC96202 **DATE:** April 1998

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ABSTRACT

OBJECTIVE: Electrostatic beneficiation of dry coal has received significant attention in the last two decades. In this process the coal is ground and then charged by triboelectrification (friction charging). Coal and minerals receive opposite polarities of charge and can then be separated in an electric field. The aim of our studies is to develop a comprehensive physical and chemical model for electrostatic charging of coal carbon and mineral particles. Properties of the fundamental constituents of coal are analyzed in relation to bulk coal powders processed with a laboratory scale electrostatic separator. Characterization techniques employed include: quantitative sulfur analyses, single particle charge and mass measurements, petrographic analyses, ultraviolet photoelectron spectroscopy, and diffuse reflectance infrared spectroscopy (DRIFT). In addition the effects of conditioning agents and oxidation on beneficiation are studied.

WORK PERFORMED: Two instruments will be described which we have developed to aid us in understanding the charging properties of different subclasses of coal. These are an Ultraviolet Photoelectron Spectrometer (UPS) for measurement of effective work function of insulator and semiconductor surfaces in air and a video image analyzer for measurement of charge and size spectra of coal powders. Also discussed will be recent Diffuse Reflectance Infrared Spectroscopy (DRIFT) measurements, the affects of several surface conditioning agents on electrostatic beneficiation, and the use of two stage separation for improving overall beneficiation.

The UPS instrument will be used to provide electron work function data for individual macerals and minerals in a coal matrix. The work function data will then be related to triboelectric charging. In the method, originally developed by Kirhata the surface of a test sample is bombarded by monochromatic ultraviolet light. At atmospheric pressure the photo-ejected electrons will generally attach to air molecules forming negative ions. The ions are attracted by an applied electric field into a detector where they are accelerated to sufficient energy that they stimulate electric discharges in the air inside the detector. The rate at which these discharges occur is proportional to the rate at which photoelectrons are generated at the sample surface. From a plot of the discharge rate as a function of photon energy the minimum energy needed to remove an electron can be determined.

In the video image analyzer airborne particles are illuminated by laser light and subjected to a sinusoidal electric field while a video camera and frame grabber capture images of the trajectories of the particles. Analysis of the particle tracks allows the size and charge of the particles to be determined. A maximum count rate of about 50 particles per second has been achieved with a bread board demonstration instrument. A prototype instrument is now under construction.

A significant fraction of the coal carbons go to the refuse fraction of the beneficiated coal powders. Petrographic studies show more liptinite and inertinite particles (relative to the number of vitrinite particles) in the refuse than in the clean fraction. The increases are by 66% and 35% for the liptinite and vitrinite, respectively. Recent DRIFT measurements have confirmed these results. The IR bands centered at 1608 cm^{-1} and 1457 cm^{-1} are due to aromatic ring modes and aliphatic bending (deformation) modes, respectively. The ratio of the intensity of the 1608 cm^{-1} band to the intensity of the 1457 cm^{-1} band is consistently greater for the refuse fraction of the beneficiated coal than for the clean fraction. This means that the refuse contains a slightly greater aromatic content (i.e. inertinite) than the clean coal. Inertinite often has plant cell remnant cavities containing minerals and it is therefore reasonable to assume that the presence of minerals will dominate the charging preference of such a particle to be negative. The greater quantity of liptinite in the refuse may also be due to entrained minerals, which charge negatively. This is reasonable since minerals are generally concentrated in trimacerite layers in coal seams and both inertinite and liptinite are found in greater concentrations in trimacerite. Therefore, the efficiency of mineral and carbon separation may dependent significantly on how finely the feed coal has been ground.

Two-stage separation has been applied and has demonstrated improved electrostatic beneficiation of coal. Results closer to DOE targets for pyritic sulfur and ash reduction and energy recovery have been achieved. In one experiment, 85.5% energy recovery was achieved while the ash content was reduced from 8% to 3.5%. Pyritic sulfur was not measured directly. However, it could be inferred from the total sulfur measurements that the pyritic sulfur was reduced by no more than about 50%. The two-stage separator could also be used to reduce ash to less than 2% and pyritic sulfur by significantly more, but with only 50% energy recovery. The two-stage separator appears to warrant further investigation.

The affect of conditioning agents on coal beneficiation was investigated. Coal powders were exposed to SO_2, Acetone, and NH_3 prior to beneficiation. Total sulfur and ash were measured. Ammonia was found to be a significant detriment to beneficiation, reducing the energy recovery on the clean plate and increasing the ash content of the clean component as well. Acetone gave slight improvement in beneficiation. Sulfur dioxide did not significantly affect energy recovery or ash removal but caused an increase in the sulfur content of both the clean and refuse portions due to absorption of the gas into the coal.

The effect of size classification of the coal powder prior to beneficiation was examined. Particles were classified into size ranges of 45-75 mm, 75-106 mm, 106-150 mm, and 150-300 mm and then passed through the triboelectric charger and electrostatic separator. Ash and total sulfur measurements were made on the separated fractions for each size range. No significant differences in beneficiation were observed, though energy recovery was higher for the more finely ground particles.

PLANS FOR THE COMING YEAR:

1. Complete UPS instrument and measure effective work functions for different subclasses of coal from different mines.
2. Complete construction of the video image analyzer for size and charge spectrum studies of coal and mineral particles charged by triboelectrification.
3. Apply newly developed high-voltage electrometers to separator studies to provide real time monitoring of the charge separation process.
4. Perform additional investigations on two-stages of separation.

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ARTICLES AND PRESENTATIONS

M.K. Mazumder, K.B. Tennal, and D.A. Lindquist, "Electrostatic Beneficiation of Coal," Proceedings of the Tenth Annual Coal Preparation, Utilization and Environmental Control Contractors Conference, July 18-21, 1994.

"Electrostatic Beneficiation of Coal" Presented at the Fall Meeting of the Materials Research Society, Boston, MA, November 28 - December 2, 1994.

D.A. Lindquist, M.K. Mazumder, K.B. Tennal, M.H. McKendree, M.G. Kleve, and S. Scruggs, "Electrostatic Beneficiation of Coal", in Advances in Porous Materials, Edited by S. Komarneni, D. Smith, and J. Beck, *Proc. Mater. Res. Soc., Vol. 371*, 459-463, (1995).

M.K. Mazumder, K.B. Tennal, and D.A. Lindquist, "Triboelectric Separation of Coal from Mineral Impurities," Electrostatic Society of America 1995 Annual Meeting Proceedings, Laplacian Press, Morgan Hill, CA, p. 59-70, 1995.

K.B. Tennal, M.K. Mazumder, D.A. Lindquist, J. Zhang, and F. Tendeku, "Triboelectric Separation of Granular Materials," Conference Record of the 1997 IEEE Industry Applications Society 32nd Annual Meeting, New Orleans, LA, Vol. 3, pp. 1724-1729, October 5-9, 1997.

N.R. Mason, M.K. Mazumder, D. Lindquist, "Diffuse Reflectance Spectroscopy and Surface Agents on Electrostatically Separated Coal," presented at the 215th American Chemical Society National Meeting, Dallas, TX, March 29 - April 2 1998.

SUPPORTED AND PARTICIPATING STUDENTS (1997-1998)

Graduate Students

Jian Zheng – Completed M.S. degree in Applied Science - summer 1997
Adam Brown – M.S. student in Applied Science
Gan Kok Hwee – M.S. student in Applied Science

Undergraduate Students

Story Robbins – summer 1997 ORISE participant
Nathan Mason -- summer 1997 ORISE participant

High School Student

Ross Brown -- Little Rock Central High School
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