DIELECTRIC CONSTANT MEASUREMENTS ON LUNAR SOILS AND TERRESTRIAL MINERALS

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Introduction: The return to the Moon has ignited the need to characterize the lunar regolith using *in situ* methods. An examination of the lunar regolith samples collected by the Apollo astronauts indicates that only a few minerals (silicates and oxides) need be considered for *in situ* resource utilization (ISRU). This simplifies the measurement requirements and allows a detailed analysis using simple methods. Characterizing the physical properties of the rocks and soils is difficult because of many complex parameters such as soil temperature, mineral type, grain size, porosity, and soil conductivity. In this presentation, we will show that the dielectric constant measurement can provide simple detection for oxides such as TiO_2, FeO, and water. Their presence is manifest by an unusually large imaginary permittivity.

Impedance Spectrometer: The dielectric constant, ε, is expresses as the product of the permittivity of free space, ε_0, times the relative permittivity, ε_r. The permittivity is further described as $\varepsilon_r = \varepsilon' - i\varepsilon''$ where ε' is the real permittivity and ε" is the imaginary permittivity [1]. Fig. 1 shows that the real permittivity, ε' can be used to determine the density of lunar soils [2] and terrestrial minerals [3]. The simple relationship shown in the figure holds for silicates and oxides with a few exceptions such as titanates which have high permittivities. The graph in Fig. 2 demonstrates a direct correlation between the amount of $\%TiO_2$ + %FeO in the lunar soil. At a measured ε', the amount of $\%TiO_2$ + %FeO is determined from ε". Other minerals or water can also cause ε" to be abnormally large. The deviation of the ε" versus ε' above the $\%TiO_2$ + %FeO = 0 line signals the detection of a mineral in the regolith that needs further identification by, for example, Raman or XRD. The data [2] in Fig. 2 was fitted using a multivariate least squares method; the equation is at the top of the graph.

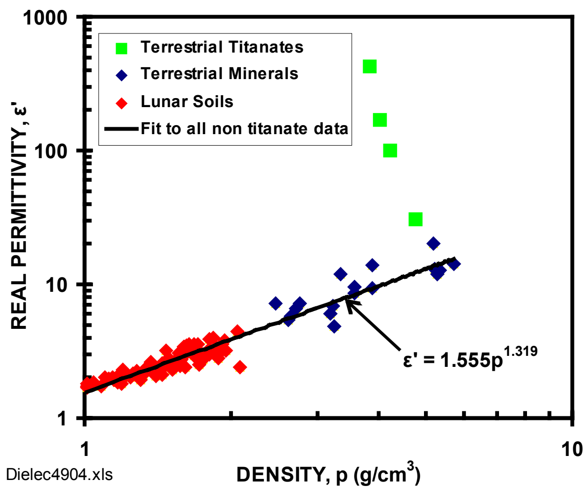

Figure 1. Relationship between real permittivity and density of lunar soils [2] and terrestrial minerals [3].

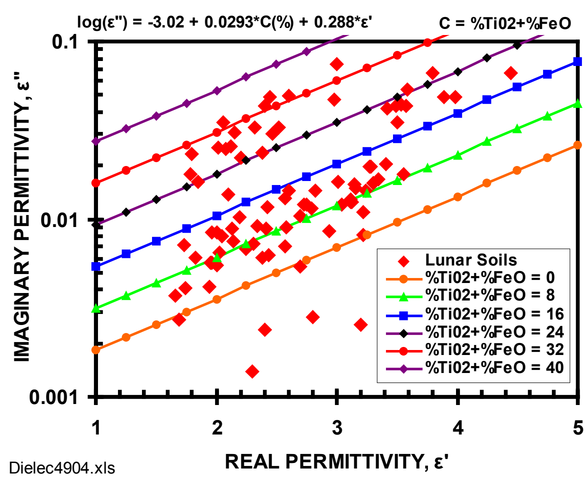

Figure 2. ε" versus ε' for various percentages of TiO_2 and FeO for lunar soils obtained from Apollo missions [2].

Conclusion: Prospecting for minerals on the surface of the Moon calls for developing rapid survey techniques. We propose using impedance spectroscopy that provides dielectric constant measurements, electrostatic measurements that provide data for signature analysis techniques, and magnetic properties measurements. All of these measurements are rapid and the sensors are small and so can be incorporated into the wheel of a roving vehicle allowing real-time *in situ* measurements while the vehicle is in motion.

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References: [1] Anderson, J. C. Anderson, *Dielectrics*, Reinhold Publishing Corp. (New York, 1964).
[2] Heiken, G., D. Vaniman, and B. M. French, *Lunar Sourcebook*, Cambridge University Press (New York, 1991).
[3] R. S. Carmichael, *Practical Handbook of Physical Properties of Rocks and Minerals*, CRC Press (Boca Raton, Florida, 1990).