Electrical Responses of Grain Surfaces Measured by Spectral Induced Polarization and Atomic Force Microscopy

University- Led Research

N. Hao, R. Chen, D. Dean, S. Moysey (PI) – *Clemson U.;*
D. Ntarlagiannis, K. Keating-*Rutgers-Newark U.*

Quantitatively describing the spectral induced polarization (SIP) response (a.k.a complex conductivity) of the subsurface is a problem that spans nanometer to meter length scales. We are combining surface-sensitive, micron-scale polarization and atomic force microscope (AFM) techniques with column scale SIP observations to bridge these scales. Recently we have been evaluating whether complex conductivity measurements of grain surfaces can be obtained using AFM. Initial AFM calibration measurements were performed on glass slides with different geometries to confirm that complex surface conductivity values could be achieved. After accounting for geometry, we found consistent patterns in the real conductivity change with frequency for different slide geometries and a very strong capacitive response; the order of the magnitude for the low frequency real conductivity was 10^{-11} S/m which is comparable with the theoretical values for glass (10^{-11} to 10^{-15}S/m). We then performed SIP experiments and AFM measurements using glass beads under four different experimental conditions: (1) unaltered, (2) etched with hydrofluoric acid, (3) calcite coated, and (4) iron oxide coated. The calcite coated beads showed a decrease in real conductivity of 10% compared to the plain beads for the SIP measurements and a decrease of approximately two orders of magnitude for the AFM measurements. This observation is consistent with the fact that surface charge maps obtained with the AFM also showed a decrease in surface charge density for the calcite coated beads. In contrast, both the etched and iron coated beads showed an increase in real conductivity relative to the plain beads, though the magnitude of increase was inconsistent between the SIP and AFM measurements. The iron oxide coated and etched beads increased in real conductivity by 34% and 12%, respectively, for the SIP measurements. For the AFM measurements the real conductivity of the iron coated beads doubled, whereas it increased by approximately an order of magnitude for the etched beads. The difference between the SIP and AFM response could be an indication that even though the etching created a larger impact on individual grain surfaces, the iron oxides bridge grains to create a continuous conductive surface pathway through the porous medium. The SIP measurements showed that the peak response of the imaginary conductivity shifted from approximately 0.03Hz for the plain beads to approximately 0.1Hz for the etched beads and 0.5Hz for calcite coated beads without a significant change in magnitude between any of these samples. In contrast, the imaginary conductivity of the iron oxide coated beads exhibited a shift in peak response to 0.05Hz, but doubled in magnitude relative to the other treated beads. Consistent phase measurements for the beads have not yet been obtained using the AFM.