National Aeronautics and Space Administration

Developing an Electrochemistry-Based Geochemical Framework for Organic Systems

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Program: Topical RTD

Project Objective:

Our aim now is to develop an *electrochemistry-based geochemical characterization framework for organic-containing systems*.

•**Objective 1** is to develop technologies for an integrated experimental test station capable performing in-situ EIS measurements over a wide range of environmental conditions and material phases (i.e., liquid, solid, mixtures of both) as shown in Figure 1.

•**Objective 2** is to test the electrochemical signatures measured in mineral-rich and organic-rich soils (e.g. Martian subsurface analogs) for a variety of organic species and reactive mineral components.

•**Objective 3** is to test the electrochemical signatures measured in more ice-rich soils or and organic-rich ices (e.g. Mars permafrost, or Ocean World surfaces) for a variety of organic species and inorganic solutes.

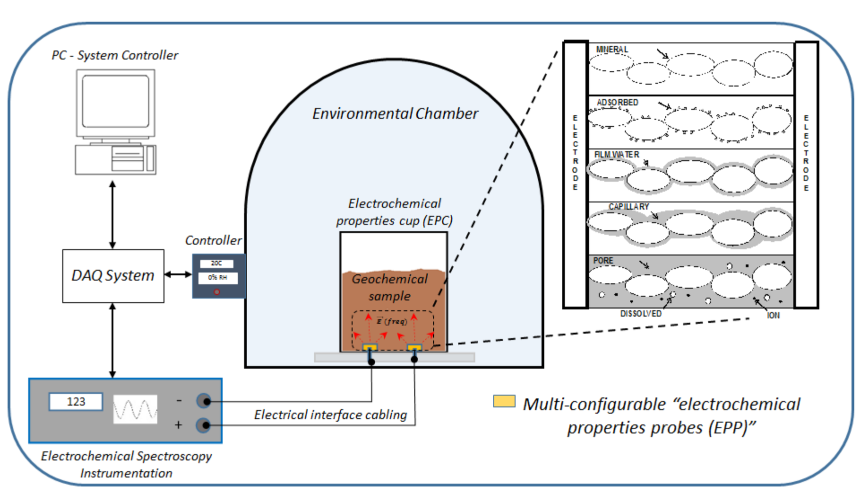


Figure 1: Proposed technology development of integrated electrochemistry system capable of multi-phase geochemical characterization.

FY18/19 Results:

•All milestones for technology development was successfully achieved on the integrated electrochemical system for multi-phase geochemical characterization.
- Automation drivers enable in-situ continuous measurements at various relative humidity and temperature profiles.
- Electrochemical sample cells of 2-4 electrode configurations with probes made from stainless steel, gold, etc.
- Integrated vacuum chamber the drill actuators enables subsurface EIS measurements under various planetary environments (i.e., Mars, moon, etc.)

•Measurement on planetary soil analogues (i.e., MMS-2) confirm sensitivity to water content down to very low levels (<<1.0 wt%) on pure DI water only.
- Note: Water containing organics or other ionic species should significantly improve sensitivity.

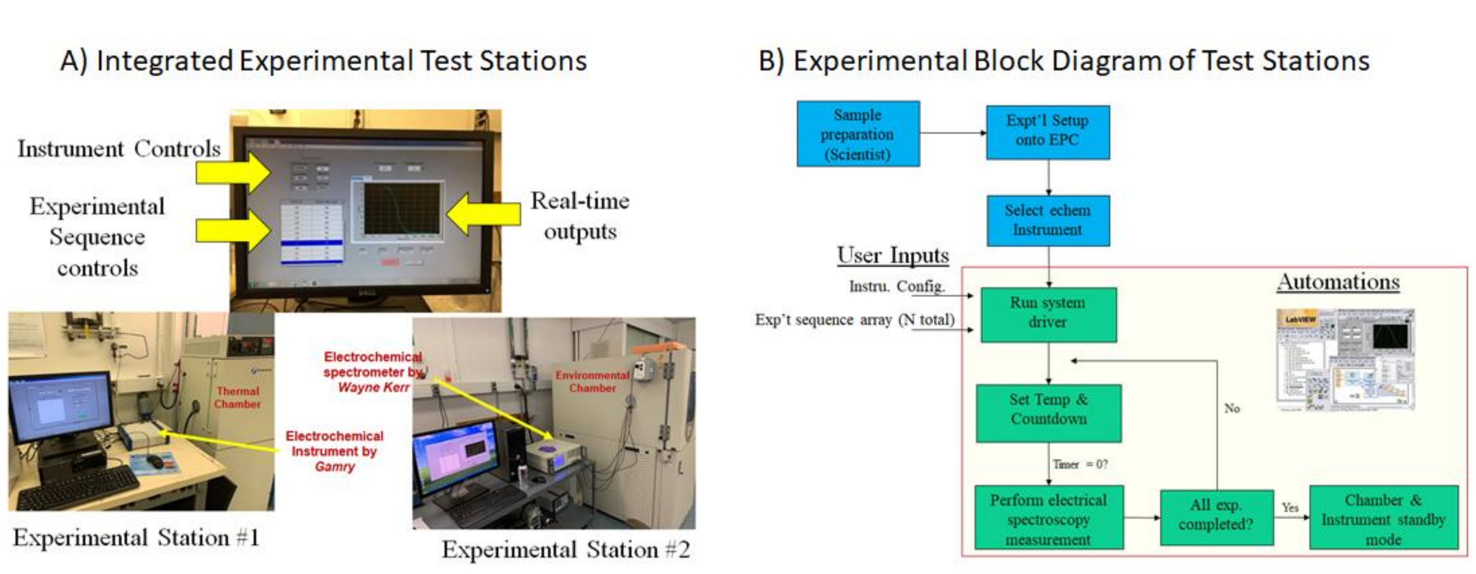
○Measurements on ice show detection of thermally activated relaxation time-constant unique to different organic materials.

•In liquid chemical systems, we employed gold (Au) electrodes to measure adsorption rate of difference amino acids.
- Capacitive profile shows amino acid such as Cysteine can absorb more readily onto Au surfaces.
- Atomistic simulations substantiated EIS measurement results confirming chemi-adsorption does occur with Cysteine but not Glycine.

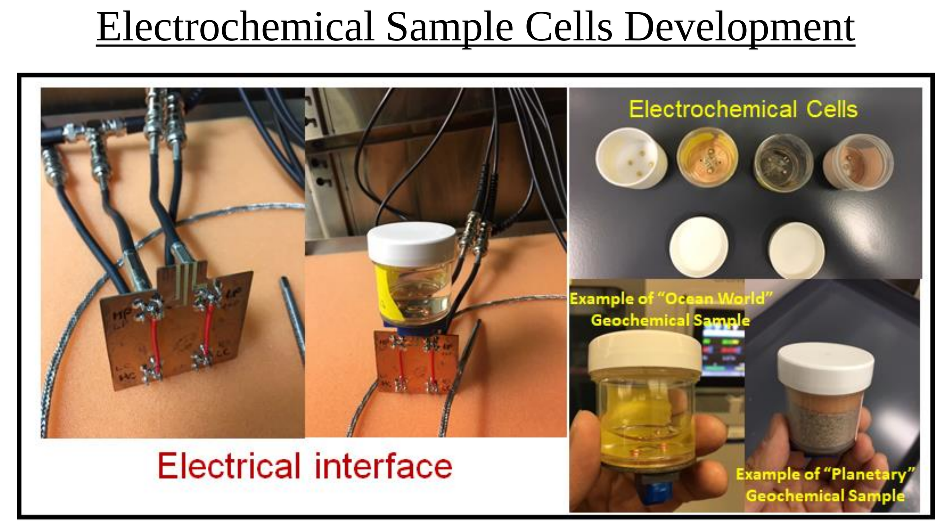
Benefits to NASA and JPL (or significance of results):

Electrical spectroscopy is a cost-effective yet highly robust technique for *in-situ* geochemical interrogation in planetary or ocean/icy worlds. Instrumentation is low power capable (<5W), highly sensitive (ppb), non-destructive, and scalable to many deployment platforms such as rovers, landers, and subsurface penetrators. In terms of science, electrical spectra (or Bode plot) provide many important electrical properties (including conductivity & dielectric constants) which are specific to the material makeup. Theoretical models (i.e., atomistic simulations or equivalent circuit models) provide predictive capabilities and behavior emanating from the molecular level (emphasis in Year 2 effort).

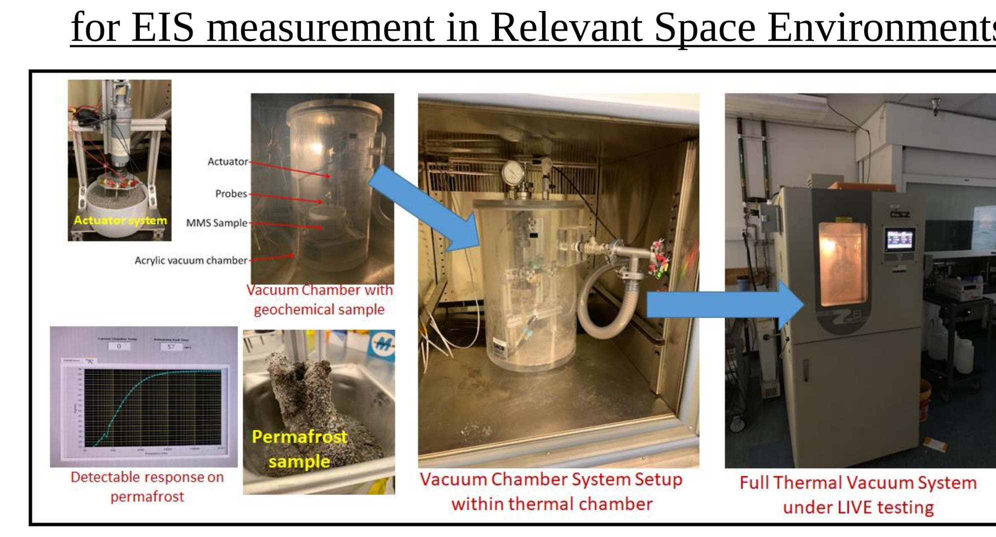
NEW In-situ Geochemical Electrochemistry Sensor Lab – FY18 &19



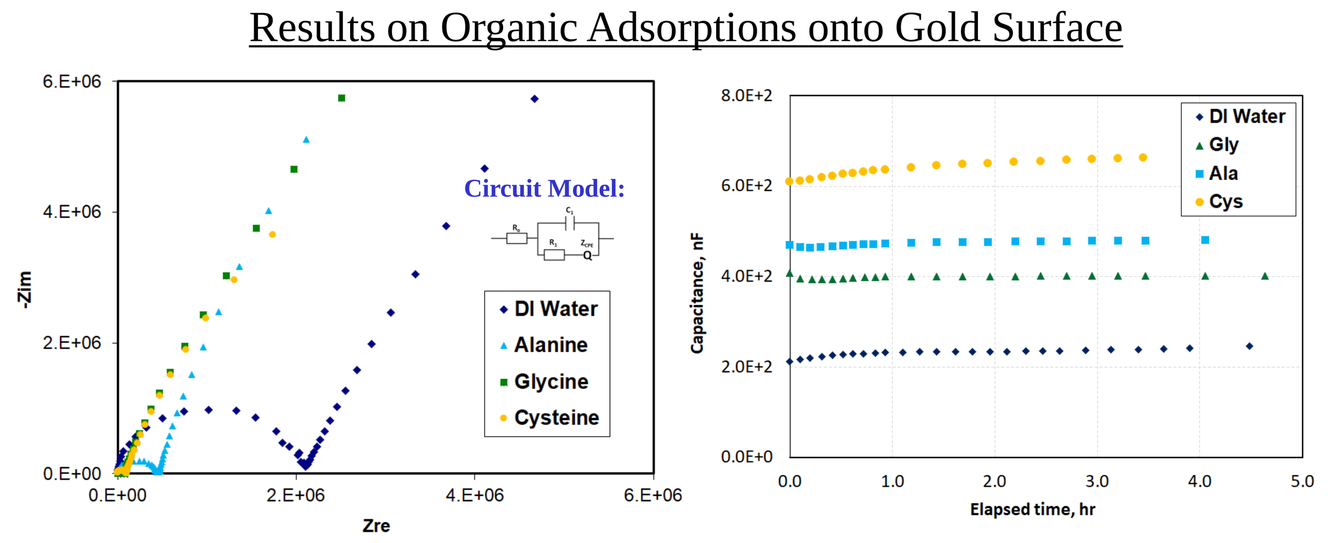
Electrochemical Sample Cells Development



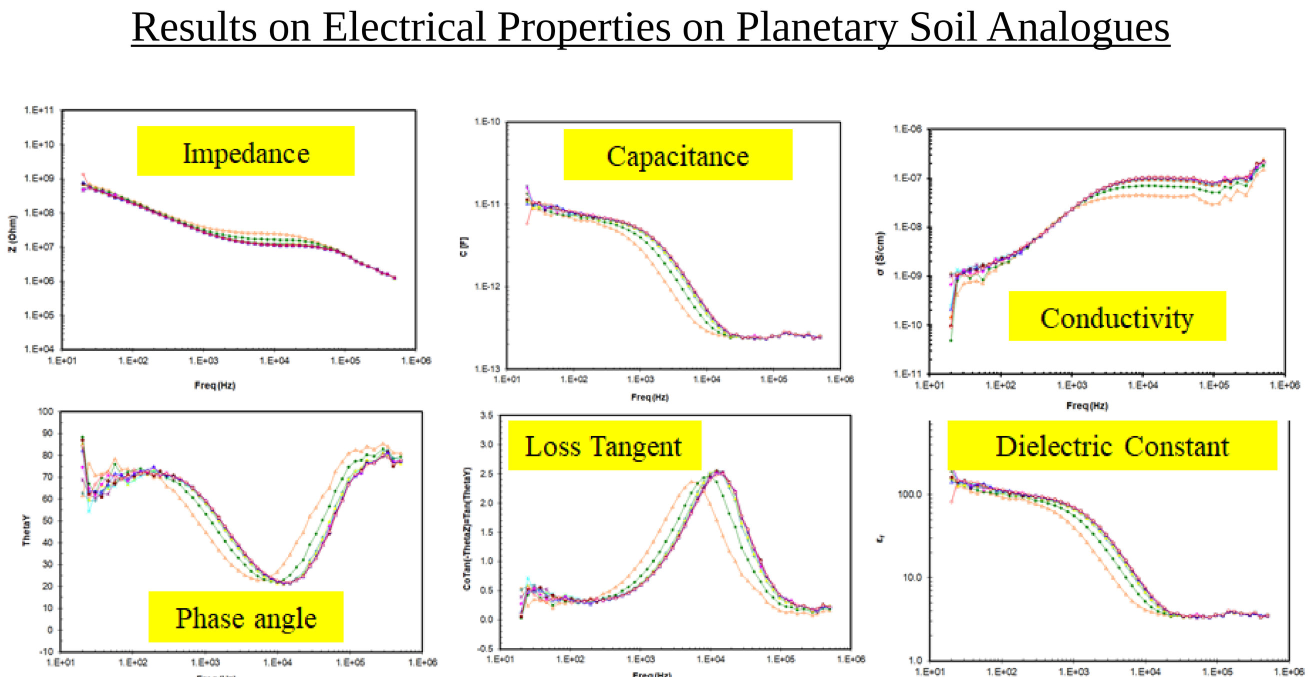
Thermal Vacuum System with Integrated Motor Controls for EIS measurement in Relevant Space Environments



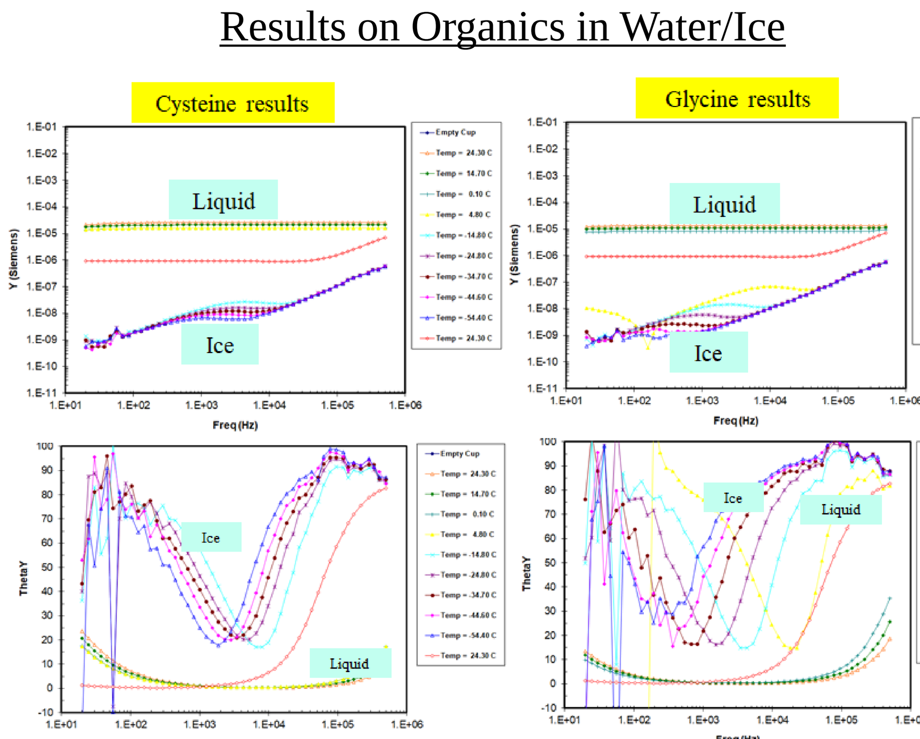
Results on Organic Adsorptions onto Gold Surface



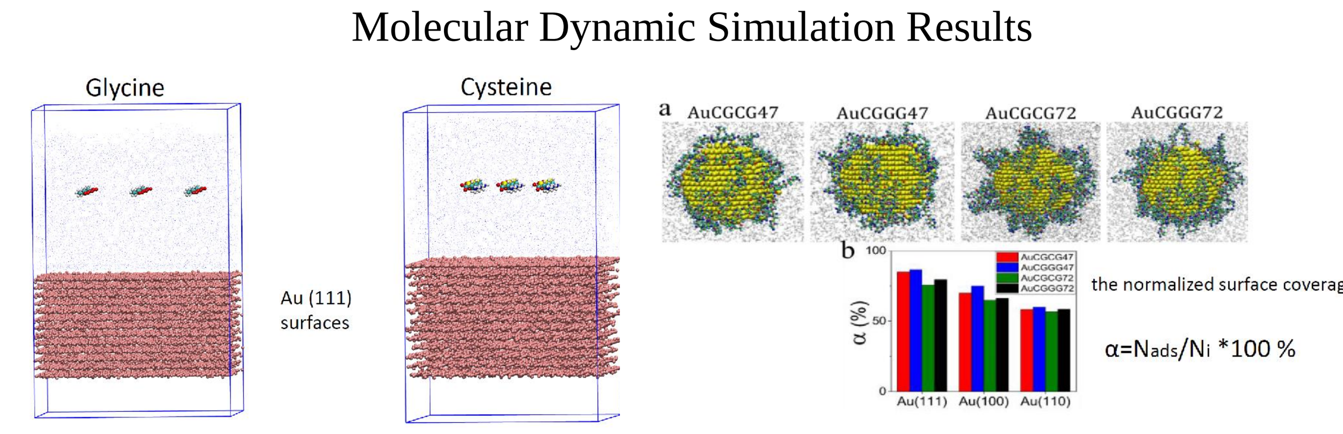
Results on Electrical Properties on Planetary Soil Analogues



Results on Organics in Water/Ice



Molecular Dynamic Simulation Results



Conclusions:
- EIS can be performed on material phases such as liquids, solids, and heterogeneous mixtures.
- Electrical spectra can provide information on many important electrical properties including relaxation and polarization.

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Publications:

- Md Symon Jahan Sajib, Wilson Jean-Baptiste, Keith Chin, Tao Wei, "*Interfacial behavior of Amino Acid Residues on Gold Surfaces Studied with Electrical Spectroscopy and Atomistic ReaxFF Simulations*," American Chemical Society (ACS) Conference Presentation, San Diego, CA, August, 2019.

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