

MICA: Microfluidic Icy-World Chemistry Analyzer

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Introduction: MICA will use electrochemical sensors to quantitatively measure key chemical properties of European surface materials. The measurements will help evaluate habitability (SDT mission Goal 2) and provide sample context to other instruments in the search for evidence of potential biosignatures (SDT mission Goal 1). Although Europa's subsurface ocean is estimated to be tens of kilometers below the surface, determining its nature can be accomplished by analyzing materials that have been brought to the surface by either ice shell activity or ejection by plumes. Water-rock interactions necessary for habitability can only be discerned by analyzing dissolved salts in ionic form. The relative and absolute abundances of such ions as Na⁺, K⁺, Mg²⁺, Ca²⁺, Cl⁻, SO₄²⁻, and CO₃²⁻ can provide information on the depth and duration of water-rock interactions and the probable geologies and geochemistries involved. Enhanced levels of trace species such as Li⁺ and Zn²⁺, as well as transition metals with multiple oxidation states (e.g. Fe, Mn, Cu, Co) can be indicative of hydrothermal activity as well as constrain potential metabolic pathways of putative organisms.

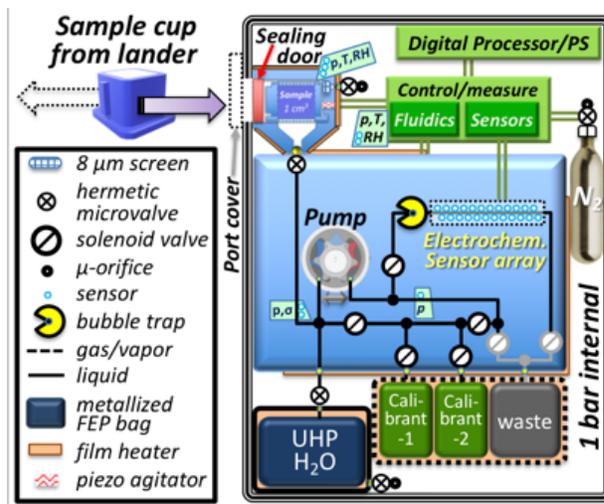
Wet Chemistry Lab Heritage:

Electrochemical sensors are an ideal means to determine habitability on/in an icy world because they excel at detecting ionic species in solution. MICA is a microfluidic implementation of the Wet Chemistry Laboratory (WCL) flown on the Phoenix Mars mission, which, using a chemical survey approach, measured high levels of perchlorate (ClO₄⁻) in the Martian surface materials [Hecht et al., 2009]. This discovery profoundly impacted the understanding of the Martian surface environment, leading to recognition that the Viking GC-MS search for organics resulted in a false negative, a misinterpretation that adversely impacted Mars science for nearly 40 years [Navarro-Gonzalez et al., 2010]. For Europa exploration, the environmental-survey approach provides fundamental chemical science return (e.g., energy and redox gradients, geochemistry, ocean chemistry, and habitability) and critical environmental context likely to be needed to properly interpret and validate the results returned from other payload instruments.

Current technology status: After the successful operation of WCL on Mars there have been a number of ASTID-, PIDDP-, and COLDTech-funded projects to improve sensor capabilities, develop microfluidic

implementations, and prepare of Ocean World mission scenarios. This work has led to a number of developments [Oberlin et al., 2017], including: 1. Production of Ag/AgCl reference electrodes that are stable for use during flight missions. 2. Cyclic voltammetry methods for the specific detection of SO₄²⁻ and NO₃⁻. 3. Adaptation of hydrogel-based ion-sensitive electrodes (ISEs) for use in microfluidic arrays. 4. The development of solid-contact ISEs for use during flight missions. 5. The identification of suitable ISE ionophores for detection of phosphate and carbonate. 6. Radiation testing of ISE ionophores. 7. The development of microfluidic infrastructure based on successful SmallSAT payloads. The combination of all this work has led to a mature microfluidic electrochemical sensing instrument well poised for interrogating the inorganic components in Europa's ice.

Planned MICA architecture: The figure below outlines the proposed MICA architecture funded through a recent ICEE-2 selection, which at a high level combine the electrochemical measurement capabilities of WCL with the small satellite microfluidic capabilities developed at NASA Ames over the previous ~10 years. The specific challenges of Europa including temperature, pressure, and radiation environment have guided the proposed design and will continue to be accounted for throughout the development.



References:

- Hecht M.H. et al. (2009) *Science*, 325, 64–67.
 Navarro-Gonzalez, R., et al. (2010) *J. Geophys. Res.* 115, E12010.
 Oberlin, E.A., et al. (2017) *Astrobiology Science Conference*, Abs# 3251.