Nanospray Ionization for Coupling Capillary Electrophoresis with Mass Spectrometry for In Situ Titan Exploration. F. Greer[1], A. Fisher[2], T. Corso[3], J. MacAskill[2], and P. A. Willis[2] [1]NASA Jet Propulsion Laboratory/California Institute of Technology (4800 Oak Grove Drive, Pasadena, CA 91109 Frank.Greer@jpl.nasa.gov), [2]NASA Jet Propulsion Laboratory/California Institute of Technology. (4800 Oak Grove Drive, Pasadena, CA 91109), [3]CorDiscovery, Inc. Ithaca, NY.

Introduction: The objective of this research effort is to develop the technology and operational protocols necessary to build and test a flight-sized brassboard composite instrument comprised of a microCE system, a nanoelectrospray ionization source, and a mass spectrometer, capable of performing integrated end-to-end chemical analyses on samples that are of paramount interest in astrobiology (see Fig. 1). More specifically, this integrated Lab-on-a-Chip instrument, when paired with an appropriate means of sample preparation, will enable *in situ* detection and analysis of target compounds on Mars or the moons of the Outer Solar System. Targets of interest include biotic or prebiotic organic compounds such as amino acids, polycyclic aromatic hydrocarbons, carboxylic acids and small aromatic compounds and inorganic compounds such as SO_4, NO_2, etc. of which the isotopic ratio of S, O, and N can carry geological and volcanological and possible metabolic information.

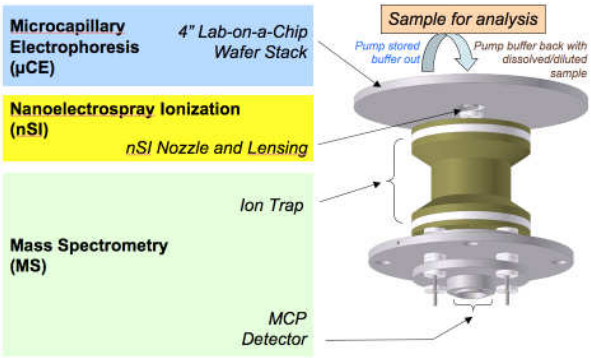

Figure 1. Nanoelectrospray Ionization (nSI) enables the real-time coupling of two extremely powerful analytical techniques: Microcapillary Electrophoresis (μCE) and Mass Spectrometry (MS). The lab-on-a-chip system performs sample handling using integrated pumps capable of distributing stored buffer solutions to and from the instrument. Samples for analysis (wet or dry) are mixed with buffer solution in order to prepare them for analysis by the instrument.

Hybrid systems that interface CE to MS were first demonstrated in 1987, and are commonly employed in the biochemical industry today[1,2]. The most common systems are concerned with structural analysis of extremely large biopolymers, typically proteins weighing hundreds of thousands of mass units. The most common method for ionizing the biomolecules is via conventional, high-flow electrospray ionization (ESI).[3,4] Due to the extremely large size of these molecules and resulting complex fragmentation patterns, extensive time-averaging must be performed, often using tandem mass-spectrometric approaches, to unambiguously determine protein structure.[5] In these systems, a given apparatus will be operated continuously for up to 24 hours at flow rates as high as 1 mL/minute (corresponding to 1.4 liters of buffer sprayed), then disassembled, cleaned, and reassembled for use the following day.[6]

In comparison to the state-of-the art, there are a few key differences between a hybrid system optimized for astrobiology investigations and the industrial systems optimized for biochemical and pharmaceutical applications. Firstly, the target molecules of interest are much smaller, below 1000 AMU, making identification of mass spectra simpler and requiring less time for analyses. Secondly, the number of samples required for analysis in an *in situ* astrobiological mission is extremely small in comparison to the high-throughput (effectively continuous) analysis requirements of the modern pharmacecutical industry. For example, the Urey instrument payload aboard the ExoMars Mission includes a total volume of just 75 mL of buffer for all operations associated with microcapillary electrophoresis planned during the mission. For such small liquid analysis volumes, mass spectrometer cleaning will never be required during the duration of an entire *in situ* mission.

Technology/Protocol Development: As this highly coupled instrument requires integration of three separate components, the first step in this research effort is to validate the performance of each of the individual components to find a common set of operating conditions for optimal integrated performance. First, the fabrication technology necessary for producing the microcapillary electrophersis chip

shown in Fig. 2 using a fluorinated membrane (Fluorocur™) to prevent valve stiction under the environmental conditions required for Martian and Outer Solar System Exploration was developed and tested at JPL.

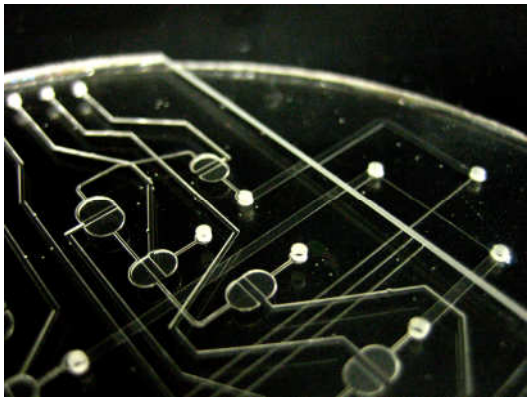

Figure 2. Microfludic Lab-on-a-Chip device fabricated at JPL using a flexible Fluorocur™ membrane for valve actuation and pumping. Devices like those pictured shown above underwent successful environmental testing including over one million valve actuations and 30 temperature cycles from -50 to +50°C.

Microcapillary electrophoresis measurements were subsequently performed to validate the separation efficiency of this type of chip for a representative set of amino acids (see Fig. 3).

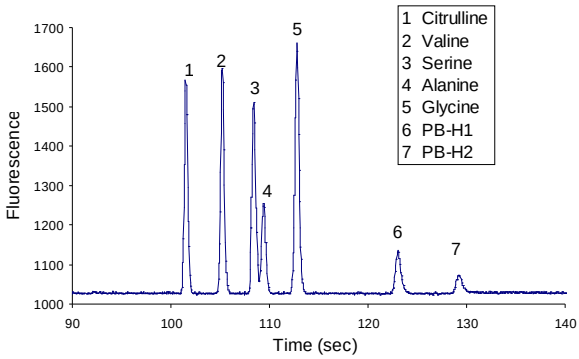

Figure 3. Data produced from JPL's µCE apparatus (in an analysis of a 20 nM concentration amino acid mixture labeled with Pacific Blue dye.

Lastly, a commerical, automated chemical workstation coupling liquid chromatography to a mass spectrometer via nanospray ionization was used to analyze a similar mixture of amino acids (see Fig. 4).

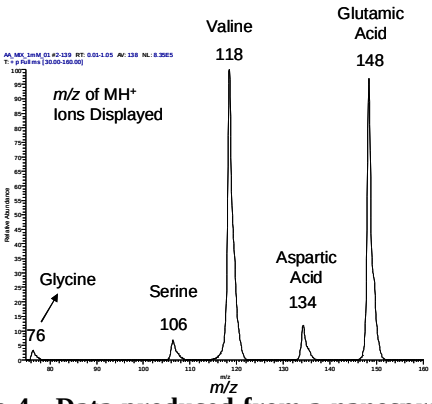

Figure 4. Data produced from a nanospray ionization chip spraying into a mass spectrometer for a mixture of five amino acids.

This paper will present this work in greater detail, and describe the status of our efforts to integrate these component technologies together.

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References:

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