OASIS: Organics Analyzer for Sampling Icy Surfaces

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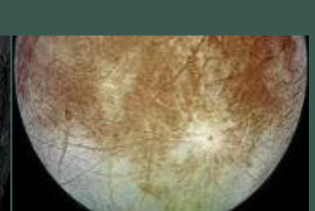
Instrument Features:

- *In situ* liquid chromatography-mass spectrometry, targeting the organic composition of icy surface materials
- Front-end LC separation of prebiotic organics, such as amino acids and nucleobases
- Mass spectrometer provides mass identification of eluting species

Targeted Future Mission Opportunities:

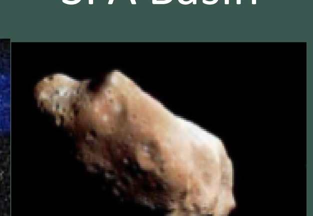

Enceladus


Europa


Ganymede


SPA Basin


Comets


Icy Asteroids

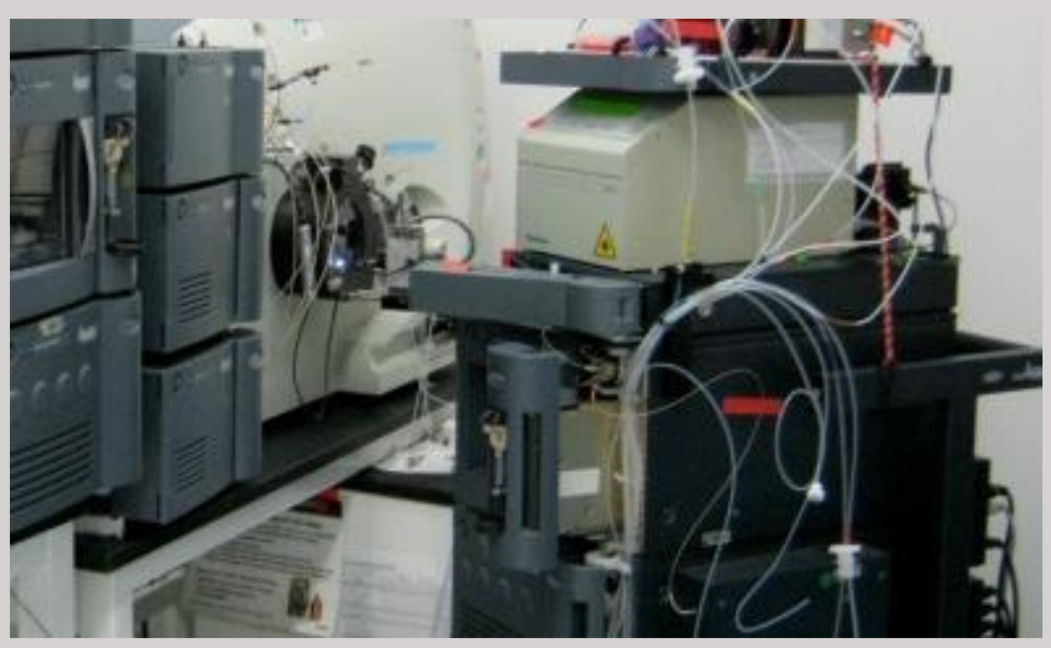
Acknowledgements:

- Paul Mahaffy
- Inge Loes ten Kate
- Steven Feng
- Todd King
- Vincent Holmes
- Greg Hidrobo
- Marvin Noreiga
- GSFC Instrument Design Lab
- Astrobiology Science and Technology for Instrument Development (ASTID) Program
- GSFC Internal Research and Development Program

Abstract:

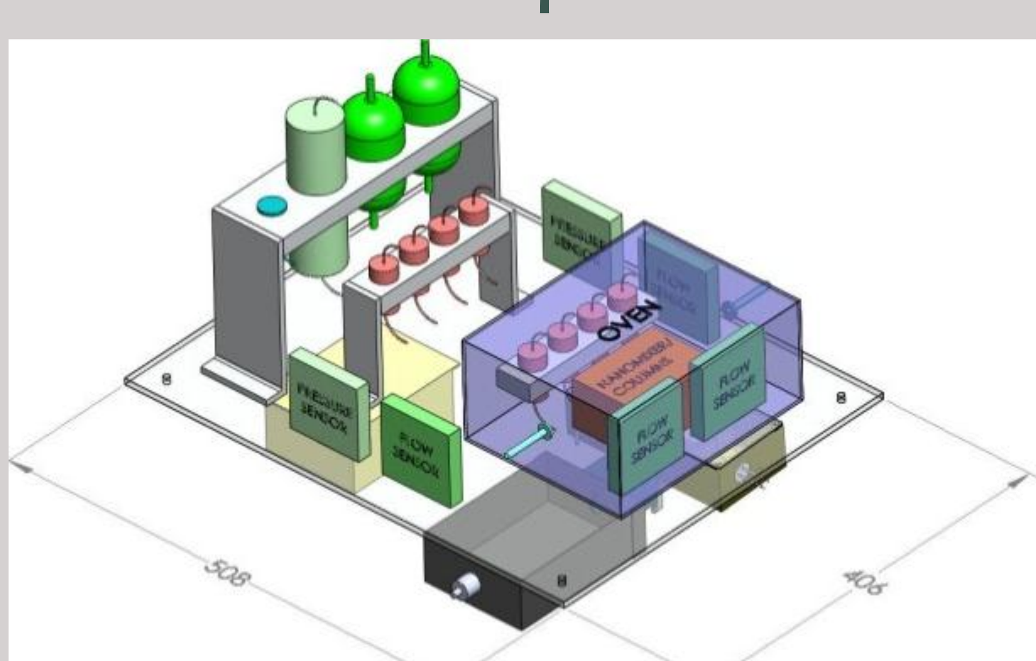
Liquid chromatography mass spectrometry (LC-MS) is a well established laboratory technique for detecting and analyzing organic molecules. This approach has been especially fruitful in the analysis of nucleobases, amino acids, and measuring enantiomeric ratios. We are developing OASIS, Organics Analyzer for Sampling Icy Surfaces, for in situ analysis on future landed missions to astrochemically important icy bodies, such as asteroids, comets, and icy moons. The OASIS design employs a microfabricated, on-chip analytical column to chromatographically separate liquid analytes using known LC stationary phase chemistries. The elution products are then interfaced through electrospray ionization (ESI) and analyzed by a time-of-flight mass spectrometer (TOF-MS). A particular advantage of this design is its suitability for microgravity environments, such as for a primitive small body.

Background:



Liquid chromatography-mass spectrometry has been a valuable tool used by the GSFC Astrobiology Analytical Laboratory in the analysis of amino acids, nucleobases, and other prebiotic organics in meteoritic and returned cometary materials [1-3]. These analytical techniques are compatible with miniaturization techniques that will use microfabricated LC and ESI components, interfaced to a time-of-flight mass spectrometer leveraged from the VAPoR instrument development [5-7].

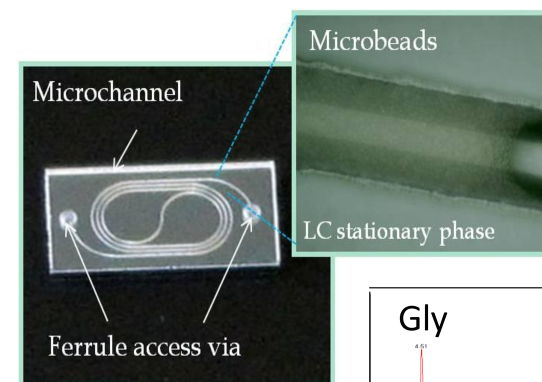
Breadboard Development:



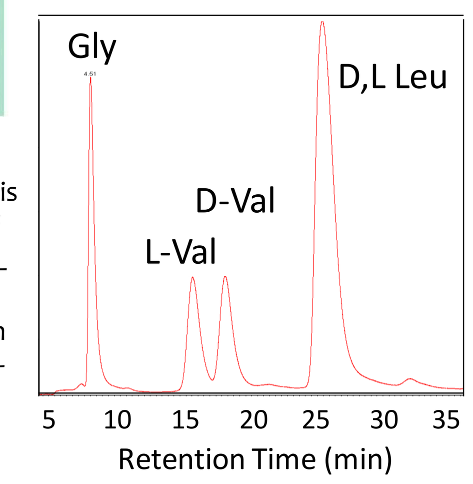
Our current goal is to demonstrate an integrated instrument breadboard using components that are flight qualifiable or have a path to qualification. The critical components of OASIS – the on-chip LC column, the electrospray ionization nozzle, and the TOF-MS – will be integrated and tested under high vacuum as part of this effort.

OASIS is estimated to be a 5 kg-class instrument with power requirements of only 3 W. These instrument resource estimates were compiled with the input of the GSFC Integrated Design Lab, a group of accomplished, seasoned discipline engineers with extensive experience in flight instrumentation.

Breadboard Components:



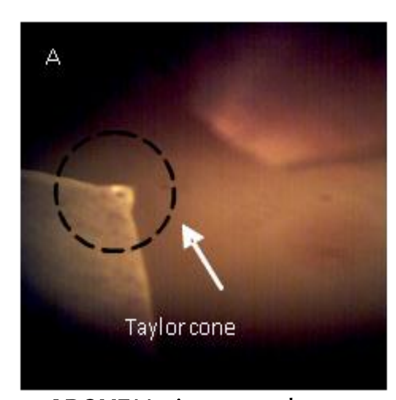
LEFT Amino acid standards were analyzed in an on-chip column: 80 mm long x 75 µm dia., 5 µm phenylhexyl resin.

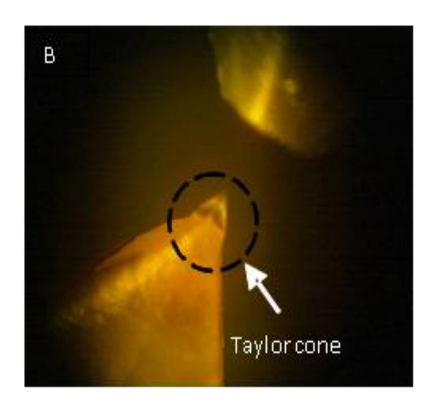


RIGHT A chromatogram is shown for a mixture of glycine, leucine, and D,L valine standards. OPA/NAC derviatization was used for this proof-of-concept.

On-Chip High-Performance Liquid Chromatography

Our approach to on-chip LC analytical column fabrication focuses on overcoming two challenges: (1) sustaining the high delivery pressures (> 5000 psi) needed for LC analysis and (2) maintaining organic cleanliness for high sensitivity and low background contamination. The chip itself is formed out of etched wafers of silicon and glass that mate together to form a round cross-section channel. The stationary phase microbeads are then introduced into the channel by a pressurized slurry packing method. Once dried, the beads are held together and to the channel walls via van der Waals forces forming a packed stationary phase that is robust to backpressure. Stationary phase chemistry can be readily tailored to a wide variety of targeted analytes.

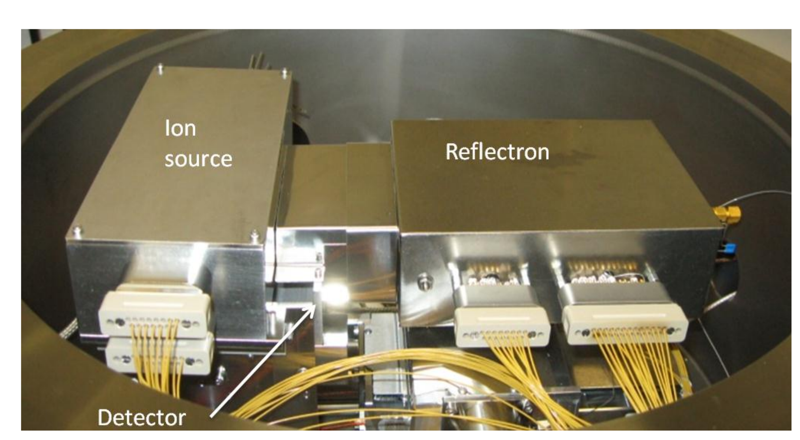




ABOVE Various nozzle geometries have been demonstrated to produce electrospray ionization when interfaced to a commercial MS atmospheric pressure inlet.

Electrospray Ionization Interface

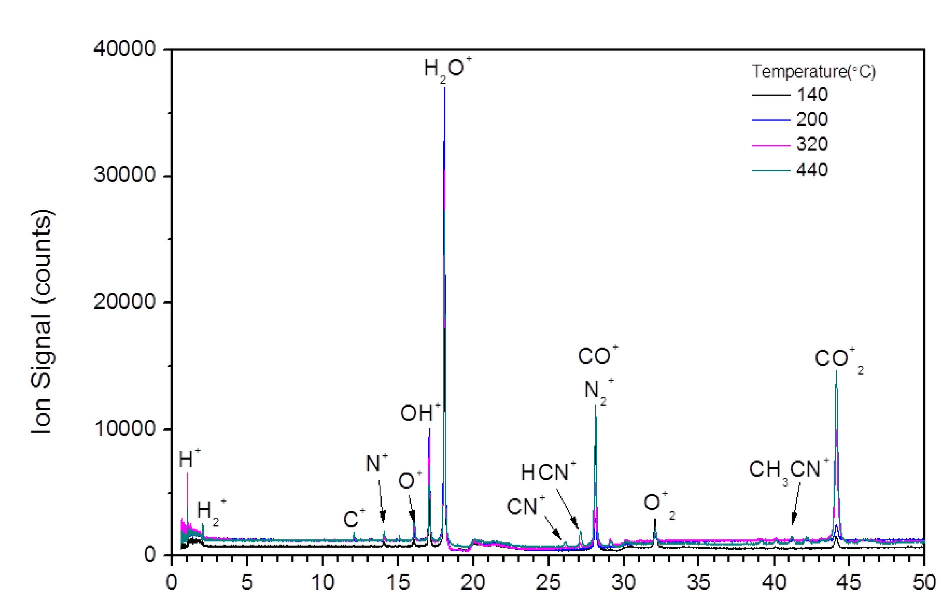
Our electrospray ionization nozzle is microfabricated to produce a spray from the edge of a bonded chip [4]. The component-level demonstration is shown to be tolerant to nozzle taper. Two different ESI nozzles are shown in A and B, where a Taylor cone is clearly visible in each case. We are currently addressing the challenge of interfacing this ambient-pressure device to the vacuum inlet of a time-of-flight mass spectrometer. Our design employs a combination of differential pumping and a curtain gas to enable this ion interface.

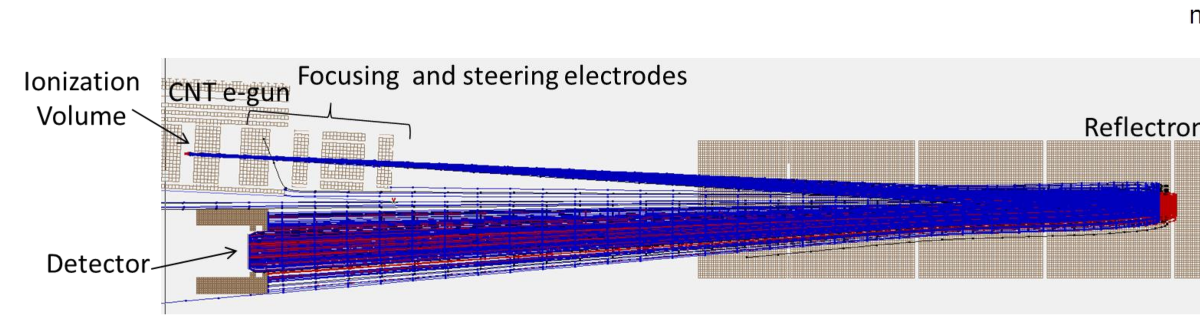


Time-of-Flight Mass Spectrometer

The mass analyzer employed on OASIS is derived from the TOF-MS developed as part of the VAPoR (Volatile Analysis by Pyrolysis of Regolith) instrument [5,6]. The performance of this TOF-MS has been optimized using an electron impact ionization source for analysis of pyrolysis products from regolith or crushed rock samples.

Representative mass spectra taken during a pyrolysis study of JSC Mars 1A are shown at various oven temperatures. The evolution of water vapor (m/z 18) is maximum at T =200 C, whereas CO_2 and several organic fragments are seen to evolve at higher temperatures. These data show calculated mass resolution exceeding $m/\Delta m = 200$. These electron ionization spectra were obtained with the use of a large-area (2 mm x 40 mm emitting area) carbon nanotube field emission electron gun [7].





LEFT We use SIMION charged particle software to guide design and optimization of the instrument.

References:

[1] Glavin D.P. *et al.* (2006) *Meteorit. Planet. Sci. 41,* 889-902. [2] Elsila J. E. *et al.* (2009) *Meteorit. Planet. Sci.* **44**, 1323-1330. [3] Callahan M. P. *et al.*, (2011) *PNAS* **108**, 13995-13998. [4] Yue G.E. *et al.*, (2005) *Lab Chip* **5**, 619-627. [5] King *et al.* (2008) *Proc. SPIE* **6959**, 6959E., [6] Getty *et al.* (2010) *Int. J. Mass Spec.* **295**, 124-132. [7] Getty *et al.* (2009) *Proc. SPIE* **7318**, 731816.