Astrobionibbler: Microfluidic Subcritical Water Extraction of Organics on Mars

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Introduction: Searching for trace levels of organic molecules on Mars or other rocky bodies presents a formidable challenge for robotic instrumentation. Many organic molecules of specific interest, including potential biomarkers such as amino acids, are not ideally suited for identification via gas chromatography and mass spectrometry (GC/MS) the current robotic state of the art. Wet chemical methods such as liquid chromatography (LC) and capillary electrophoresis (CE) are typically used for analysis on Earth, and because of this automated microfluidic versions of LC and CE capable of separation and sensitive detection of a broad variety of organic molecules are already demonstrated or under development [1, 2].

However, there is a current lack of a small sample extraction and concentration instrument which can deliver the appropriate liquid extracts to the analytical microfluidic devices. The Astrobionibbler instrument (ABN) [3, 4], meets these needs and can be conceptually broken into three functional sections: 1. Sample acceptance and slurry preparation 2. Extraction of organics from the soil via subcritical water extraction (SCWE) performed on chip. 3. Extract filtration and concentration via a laminar flow diffusion interface (H-Cell).

Background: An ideal organic extraction method will efficiently extract a wide range of organic molecules from solid matrices without degradation. The development of SCWE for this purpose is based on the fact that the dielectric constant of water changes dramatically with temperature making it a polar solvent at room temperature but becoming increasing nonpolar with increasing temperature, especially above 100°C [5]. Both amino acids and polycyclic aromatic hydrocarbons have been extracted from Atacama soils using SCWE [5, 6].

Instrument Design and Preliminary Results: First prototypes of each of the three functional portions of ABN have been developed and tested.

1. Sample acceptance and slurry preparation: Small prototype sample cups designed to accept solid powder samples and water to create homogenously mixed slurries via sonication with piezoelectric actuators. Using a peristaltic pump it was possible to reproducibly move slurries up to 20% weight from the sample cups to another device.

2. Microfluidic SCWE extraction chip: A significant challenge in creating a SCWE instrument is withstanding the pressures and temperatures required during extraction. A bonded glass chip has the inherent strength, but creating pressurized seals at the interfaces that are easily automatable is non-trivial. The ABN prototype extraction chip overcomes this by using ice plugs in the microfluidic channels as a sealing mechanism while ultrasonication is used to locally heat a SCWE extraction chamber defined on the chip.

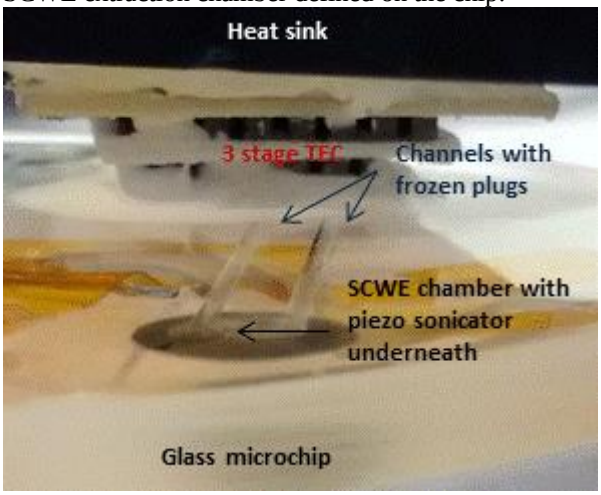

Figure 1 Image of SCWE extraction microchip

Frozen plugs can be maintained and the chamber heated to ≥ 150°C with both pure water and slurry solutions. Preliminary tests of SCWE extractions are ongoing.

3. Filtration and concentration using an H-Cell: Prototype microfluidic devices for testing diffusion transport of amino acids in H-Cells have been built. Preliminary data demonstrating the development of the LFDI under laminar flow conditions has been demonstrated and tests of the desired flow conditions to allow optimal diffusion have begun.

References:

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