Development and Testing of a Sample Cup for Laser-Based Instruments

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Introduction: Future planetary surface missions seek to capture surface and subsurface samples and deliver them to in-situ instruments for analysis. We report on an effort to develop a sample cup for self-metered pneumatic transfer of surface material for presentation to laser-based instruments.

Background: Sampling systems that pneumatically convey material from a planetary surface to an instrument on a lander must extract the suspended sample from the gas stream and deliver it to the instrument. We have developed a sample cup that collects a variety of samples from a flow of suspended solids and delivers the sample to a Laser Desorption Mass Spectrometer (LDMS) for analysis, bridging pneumatic transfer and laser-based instrumentation and extending their application to planetary exploration.

Design: The design of the sample cup combines two separate functions: collection of pneumatically transported sample, and presentation of the collected sample to the instrument for analysis [1-4].

Sample collection. The extraction of sample from the pneumatics is accomplished by the tilted mesh deflector plate at the mouth of the cup. The perforations in the deflector plate allow the gas to flow past while suspended particles deflect into the cup. A second mesh plate creates a labyrinth-style entrance and prevents recirculation of collected particles out of the sample cup and back into the flow.

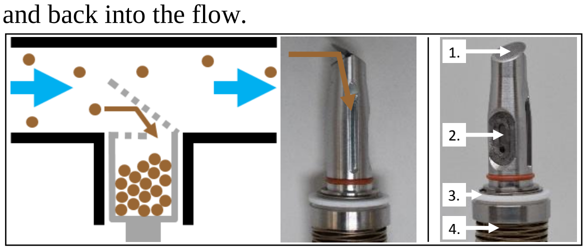

FIG. 1: (LEFT) COLLECTION. (RIGHT) DEFLECTOR PLATE (1.), LASER WINDOW (2.), KNIFE EDGE SEAL (3.), AND BELLOWS (4.).

The deflection plate extends only part-way into the conveying tube to allow excess sample to flow past the cup and enable the sample cup to self-meter: once the cup is full, any further ingested sample can be transported through the system with minimal disruption and clogging risk.

Sample presentation and analysis. Compatibility with the LDMS instrument requires that the sample cup presents a flat sample surface for analysis and seals to the instrument chamber. The sample cup uses a fine electroformed nickel mesh (3um thick, 11um holes) window to contain the sample in the cup while allowing the laser to desorb and ionize the sample through the mesh. The liberated ions then permeate through the window and are ingested into the mass spectrometer. The vertical orientation of the cup takes advantage of the collection method to ensure that sample is pressed against the window and the surface analyzed is as flat as the particles allow. A spring-energized titanium bellows and knife-edge seal allows the sample cup to be repositioned inside the instrument chamber without breaking hermetic seal, enabling multiple scans of the sample for improved analytical precision.

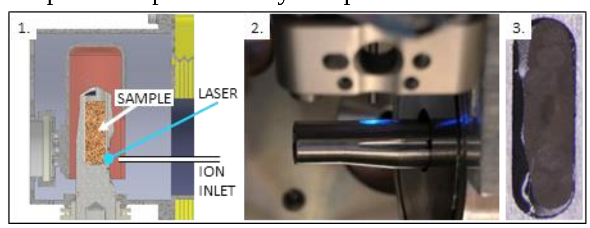

FIG. 2: SAMPLE CUP IN INSTRUMENT (1.), TESTING AT GSFC (2.), COLLECTED SAND THROUGH LASER WINDOW (3.).

Testing: The development of the sample cup has been guided by the goal of material and gravity agnostic sample collection. Collection has been tested in both room temperature air and in Titan atmosphere (N_2 gas, 96°K) with various Ocean-World simulants of ranging densities, particle sizes, and cohesiveness. These tests have shown that certain cup designs offer superior performance for even the most challenging of materials, and that this method of collection minimizes cross-contamination between samples.

Successful LDMS analysis of sample through an electroformed mesh window has been performed at Earth ambient temperature conditions. This testing demonstrated sensitivity to 1ppmw coronene (at S/B ~5). The preliminary testing of the laser-through-mesh concept during the development of the sample cup revealed an inversely proportional relationship between signal intensity and mesh open area (ratio of total screen area which is open space).

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References: [1] Lorenz R. et al (2018) 15th Interplanetary Probe Workshop. [2] Sparta J. et al. (2018) 15th Interplanetary Probe Workshop. [3] Zacny K. et al (2018) 42nd COSPAR Scientific Assembly. [4] Zacny K. et al (2019) IEEE Aerospace Conference.