Laser TOF-MS Instrumentation for Planetary Missions

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Comprehensive chemical analyses of asteroids, comets, and other solid planetary bodies are key to fundamental progress in planetary science. Compositional data are a powerful way to understand how these bodies formed, as well as to track their evolution into diverse present conditions. On future planetary missions, we need to analyze both organics and their inorganic host phases and isotopic properties, preferably species-by-species and on a fine spatial scale. The challenge is to achieve these capabilities with instrumentation limited in weight and complexity.

We are developing laser desorption mass spectrometry (LDMS) based methods and instrumentation for combined inorganic and non-volatile organic chemical analysis for in situ planetary missions. Such an approach is considered complementary to the analysis of thermally evolved gas from a bulk sample, which would preferentially detect more volatile compounds. LDMS desorbs/ionizes atoms and molecules, point-by-point, from an unprepared sample. The ions are detected in a miniature time-of-flight mass spectrometer (TOF-MS). At high laser intensity, molecules are dissociated, permitting a basic geochemical assay of the elemental and isotopic composition, correlated to a microscopic image of the sample. At lower laser intensity, a range of organics and their fragments are detected up to a few thousand Da. If desired, higher masses could be analyzed with some additional experimental complexity. Detection of organics at the 50 – 100 micron laser spot scales allows association with sample mineral phases. Carefully tuned ion optics permit the correlation of molecular fragmentation as it varies with laser fluence.

Our newest prototype has been designed at “flight scale” and mounts to various in-house sample manipulation systems which allow us to establish the requirements and scientific benefits of micro-analysis. These must be evaluated for quantitative elemental and isotopic ratios as well as sensitivity to organics; both are needed on astrobiology missions such as to Mars. The sample is maintained at electrical ground, with an adjustable negative bias on the flight tube for positive ions. The desorption laser wavelength is either 266 nm, 355 nm, or 1064 nm. A long focal length objective system focuses the laser normal to the sample surface, maximizing depth of field and chemical imaging resolution. An optional second laser with an optical parametric oscillator (OPO) permits post-ionization of neutrals in the range 235 nm to 390 nm. A dual detector design produces simultaneous spectra of linear and reflectron ions.

We present additional instrument descriptions, recent proof-of-concept measurements from the various APL prototypes, and linkages between our results and expected in situ science goals.