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Developments in Highly Compact Ion Trap Mass Spectrometers and Micromachined Gas Chromatographs for Planetary Missions

Darrach, M., Madzunkov, S., Schaefer, R., Neidholdt, E., Simcic, J., Bae, B., Kidd, R., Rellergert, W., Planetary Surface Instruments Group, Jet Propulsion Laboratory, California Institute of Technology.

Mass spectrometers (MS) and gas chromatographs (GC) are invaluable tools for identifying and quantifying the constituents of planetary atmospheres. While some species are amenable for other measurement technologies (e.g. tunable laser spectrometers (TLS)), a mass spectrometer remains the only viable measurement technology for the noble gases and homonuclear dipole species (e.g. N₂). Noble gases are tracers of planetary evolution, illuminating processes such as the original supply of volatiles from the solar nebula, delivery of volatiles by asteroids and comets, escape rate of planetary atmospheres, degassing of a planet's interior, and its timing. Inventorying a planet's noble gases is typically the highest-priority investigation identified in the Decadal Survey. Further for completing an analytic survey of a planet's atmospheric species and abundances the GCMS is the recognized standard. For example, GCMS offer analytic capabilities for identifying and quantifying unexpected trace species that targeted measurement techniques (e.g. TLS) are unable to perform.

We report herein on the development at Jet Propulsion Laboratory (JPL) of quadrupole ion trap mass spectrometers (QITMS) and micro-electrical-mechanical (MEMS) GCs that now represent new ultra-compact MS and GCMS instruments capable of measuring fundamental geochemical properties of planetary atmospheres. These new instrument developments have been impelled by the challenging low-resource, low-cost requirements that have been levied upon planned NASA robotic planetary and crewed space missions. Recent developments at JPL have been supported by two upcoming missions, the lunar Resource Prospector Mission (RPM) and the Micro Total Atmosphere Monitor (μ TAM), as well as internal JPL funding. RPM is a low cost mission in 2018 to the moon comprising a soft lander, and a rover carrying a GCMS designed to detect and quantify volatiles in the lunar regolith. The μ TAM instrument is a low cost GCMS which will be deployed in 2018 on-board the International Space Station to autonomously monitor the atmosphere of crewed space vehicles for the major constituents and trace organics. Presented herein are scientific and engineering data derived from prototype QITMS and MEMS GCs that are of specific interest to planetary science goals. Examples include experimental QITMS data demonstrating a multi-day precision of better than 10 parts-per mille for noble gas isotopic ratios and MEMS GC data demonstrating chromatographic separation of complex organic cocktails. The QITMS has a very high resolution ($R > 2000$) and a sensitivity greater than $1e14$ cps/Torr, without the addition of a cooling gas and consumes approximately 30W. This work has been performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.