A MINIATURE GAS CHROMATOGRAPH MAS SPECTROMETER (GCMS) FOR PLANETARY ATMOSPHERES IN SITU STUDIES.
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Introduction: There is a particular need for the development of miniaturized, high-G load tolerant, low-mass, low-power instruments for in situ studies of trace organic compounds, small inorganic molecules and their isotopes in planetary materials. Presented herein are the latest achievements in developing an instrument with the same analytical performance of commercial GCMS systems but approximately an order of magnitude smaller and optimized for space missions. The Jet Propulsion Laboratory (JPL) Planetary Surface Instruments (PSI) group has developed an instrument consisting of a quadrupole ion trap (QIT) Mass Spectrometer (MS), integrated with a Micro-Electro-Mechanical Systems (MEMS) Gas Chromatograph (GC), developed for human spaceflight applications for NASA Advanced Exploration Systems (AES).

JPL's miniaturized GCMS has been under continuous development at JPL's PSI Group for the last decade. The instrument inherits its basic design from the Vehicle Cabin Atmosphere Monitor (VCAM)[1,2], an autonomous GCMS operated continuously aboard the International Space Station (ISS) for monitoring the cabin atmosphere for major constituents and trace species from 2010 to 2012. VCAM has intrinsic characteristics comparable to commercial Earth-based analytical GCMS systems with total mass of 30 kg and average power consumption of 100W. It has a unique design enabling it to perform two very different tasks: a) trace organic measurements at parts-per-billion (ppb) concentrations; b) major constituent analysis (MCA) where the percent concentration of major gases present in ISS atmosphere, specifically N_2, O_2, CO_2 and Ar, are measured.

Compared to VCAM, our current GCMS instrument embodies several major improvements. The MS is redesigned to be more compact and robust using a unique wireless design in which all electrical connections to the electrodes are achieved through the mounting posts, thus eliminating the need for electrical wires, which represent liability in high-G environment. Also the end-cap electrodes of the QIT are electrically-isolated from the instrument's ground to enable supplemental modes of operation using additional dipole radio frequency (RF) field[3]. The MS uses electron impact ionization for producing ions inside the QIT by means of a redesigned electron gun, consisting of tantalum disc cathode emitter and three focusing electrodes. The electron gun can now be utilized either in traditional axial geometry, where a parallel electron beam traverses the central z-axis of the QIT through the holes in the top and bottom caps, or side geometry, where the ionization is achieved through the hole in the ring electrode. In the effort to minimize the size of the instrument, MS is hosted in a 3D printed Titanium vacuum chamber and sandwiched between two custom made flanges with electric feedthrough pin patterns exactly matching the electrical contacts of the MS. Operational vacuum level of $1.5x10^{-10}$ torr was achieved using a combination of ion-getter pumps which allows us to further reduce mas, power consumption and eliminate the risk of mechanical failure of turbo-molecular pump in high-G environment. As well, the GC system is fundamentally changed by implementing a new MEMS technology. The MEMS GC technology requires less material (grams instead of kilograms), much less power and a low carrier gas flow, and at the same time enables faster injection times.

The new instrument, the Spacecraft Atmosphere Monitor (S.A.M.) with miniaturized vacuum chamber, pumps, and all the electronics presently weighs around 6.8 kg and has a volume of 10.2L. During operation S.A.M. consumes approximately 35W of power. The QIT-MS resonant ejection operation and precise control of the ionization of the neutral gas sample achieves an improvement in the analytical performance of the instrument, a sensitivity of 10^{15} counts/Torr/sec and dynamic range of 10^6 [4]. The low instrument mass, coupled with its high analytical capabilities, makes the instrument ideally suitable for wide range of applications such as trace contaminant and major constituent monitoring in crewed space exploration vehicles or robotic planetary missions.

References: [1] A. Chutjian, M. Darrach, et al., SAE Technical Paper Series 2007- 01-3150, (2007), [2] M. Darrach et al. SAE Technical Paper Series 2008-01-2045, (2008), [3] J. MacAskill, et al. AIP Conf. Proc. 1336, pp. 127-131, [4] M. Darrach et al, IEEE Aerospace Conference Proceedings, Big Sky, MT, 2015, pp. 1-13.