Mass Spectrometers for In-Situ Resource Utilisation

Conference or Workshop Item

Mass Spectrometers for In-Situ Resource Utilisation. A. D. Morse[1], F. Abernethy[1], S. J. Barber[1], S. Lim[1], H. Sargeant[1], S. Sheridan[1], I. P. Wright[1], [1]Affiliation School of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK. Email: andrew.morse@open.ac.uk

Introduction: The Open University has a heritage in developing small mass spectrometers for planetary lander payloads. The first was a 6 cm radius magnetic sector instrument for light element isotopic analysis (H, C, N, and O), part of the Gas Analysis Package (GAP) on the Beagle 2 Mars lander [1]. The second was the Ptolemy ion trap mass spectrometer (ITMS) on the Philae lander which successfully operated and returned results during the comet landing in November 2014 [2]. The Ptolemy ion trap unit fits within a 10 x 10 x 10 cm cube, including RF, detector and ion source electronics and is capable of a mass range from 10 to 150 amu at unit resolution. Development is continuing for purposes ranging from lander instruments (ProSPA and LUVMI), to rugged deployable probes (penetrators) and for process monitoring within ISRU plant. Many of the planned developments are aimed at the various stages of lunar ISRU, from resource prospecting to demonstration and optimisation of extraction processes.

ProSPA: is a versatile laboratory for *in situ* analysis of samples drilled from high-latitude regions of the Moon in the Roscosmos Luna-27 mission scheduled for 2023 [3]. ProSPA will receive regolith samples of ~50 mg and seal these in miniaturised ovens, to be imaged and then subjected to thermochemical processing for extraction of volatiles. The released gases are identified and quantified in an ITMS derived from Ptolemy, and isotopically characterised in a development of the GAP isotope ratio mass spectrometer. ProSPA will also perform an ISRU experiment aimed at extracting water from regolith through reduction of ilmenite by hydrogen, in which the ITMS will identify and quantify any water produced in the process.

LuVMI: (Lunar Volatile Mobile Instrumentation) Is a light weight rover designed to explore polar regions of the Moon and drive into a permanently shadowed region. It will insert an analysis package into the soil. The soil will be heated to release volatiles into a Ptolemy type ion trap mass spectrometer to determine the amount of trapped water.

Penetrators: The small compact size of an ion trap mass spectrometer opens up opportunities for a remote deployable instrument [4]. A more robust design of the Ptolemy ion trap has been developed and field tested on rocket sledge at Pendine. Following impact testing at 300 m s^{-1} the mass spectrometer was extracted from the penetrator and successfully operated. In addition to deployment by high speed penetrators, such a low mass instrument is suitable for surface launch into inaccessible or difficult to access locations such as permanently shadowed regions or lave tube skylights.

ISRU Process monitoring: The small size and versatile nature of the ion trap mass spectrometer make it ideal for monitoring the gas composition during ISRU production of oxygen by hydrogen reduction of ilmenite [5] or carbothermal reactions. A vacuum microwave facility has just been commissioned at The Open University to investigate the use of microwaves to sinter lunar regolith for 3D printing habitats. The microwave facility includes a mass spectrometer to quantify the release of volatiles during heating. Adding hydrogen during the heating will also investigate the potential of oxygen production by reduction of ilmenite.

References: [1] Wright I. P. et al. (2013) *Acta Astronautica*, *52*(2-6), 219-225. [2] Wright I. P. et al. (2015) *Science*, 349(6247), doi:10.1126/science.aab-0673 [3] Barber S. J. et al. (2018) *Lunar Planet. Sci. Conf.*, p. 2172 [4] Gowen R. et al. (2008) *Proceedings of 59th International Astronautical Congress* (Vol. 7), 4359-4369). [5] Sargeant, H. M. et al. (2018) *European Lunar Symposium* Abstract.