THE MOCHII ISS NATIONAL LABORATORY: THE FIRST SPACECRAFT BASED SCANNING ELECTRON MICROSCOPE

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Introduction: Scanning electron microscopy (SEM) in concert with element identification by energy dispersive X-ray (EDX) spectroscopy has become an indispensable tool in the analyses of extraterrestrial materials. Nevertheless, to-date, SEM-EDX instrumentation has remained purely in the purview of terrestrial laboratories due to their size, complexity, and operational requirements. However, in January 2022 a miniaturized SEM-EDX called MOCHII became the first successful space-based instrument of its kind, following its deployment onboard the International Space Station (ISS). It represents the culmination of nearly 40 years of technological development. We have performed an on-orbit study with MOCHII with the goal of evaluating its potential as the progenitor of a new generation of spacecraft-based instruments for use in future manned and robotic planetary exploration missions. Out goal has been to validate the on-orbit investigation of samples relevant to astromaterials and astrobiology. We have performed *in-situ* analyses on standards and a freshly fractured fragment of the Martian meteorite Allan Hills 84001 which was first analyzed, prior to launch, using an engineering MOCHII ground unit located at Johnson Space Center in Houston. Results of both imaging and compositional analyses substantiates the utility of remote SEM-EDX analyses in low Earth orbit (LEO).

Results and Discussion: Spectra quantification was performed using the National Institute of Standards and Technology (NIST) DTSA-II (release 2021) program ([1]; NIST DTSA-II is open-source software).

Standards. **S**emi-quantitative results of the compositions of standard compounds obtained by MOCHII on Earth and in LEO were in good agreement with accepted values [2]. Results for standards spectra lacking Fe are nearly identical to the reported values. For Fe-bearing compounds, element abundances are reported using both Fe metal (Fe^0) and hematite (Fe_2O_3) as standards. A relative deviation from the expected value for Fe ($RDEV_{Fe}$) was used to compare the Fe abundance of the unknown to the standard value [3].

ALH84001 Orthropyroxene (OPX). ALH84001 OPX composition is relatively invariant based on literature values [4-6]. EDX data from both ground and on-orbit instruments compare well with those previously reported with $RDEV_{Fe}$ within ±10 %. Two OPX spectra were collected using MOCHII$_{ISS}$, one near a carbonate doublet and another near a single carbonate disk. Quantification of MOCHII$_{ISS}$ OPX spectra using Fe^0 and Fe_2O_3 showed the average values were nearly identical to those of MOCHII$_{Earth}$ apart from the lack of detectable Cr and Mn.

ALH84001 Carbonate Disks. Compositions of ALH84001 disk Fe-rich rims, Ca-bearing cores and Mg-rich bands acquired using MOCHII$_{Earth}$ and MOCHII$_{ISS}$ compare favorably with previous literature reports [7, 8]. Due to the complex nature of the carbonate disks, these data will be discussed in detail at the meeting.

Summary: Relative spectra compositions for standards acquired using MOCHII$_{Earth}$ were in good agreement with standard values. Due to the complex nature and fine-scale heterogeneity of the ALH84001 carbonate cores and rims, compositional heterogeneity can be observed on a tens-of-nanometer scale so it can be difficult to achieve an equivalent analysis spatial position between ground and on-orbit analysis sessions **--** this was evident in compositional variations between ALH84001 analysis locations using MOCHII$_{ISS}$ and MOCHII$_{Earth}$. However, the average ALH84001 OPX analyses and carbonate compositions were very similar for MOCHII$_{ISS}$, MOCHII$_{Earth}$ and those of previous studies indicating MOCHII$_{ISS}$ has accuracy for replicating ground-based compositional measurements using an *imperfect* sample (*i.e.*, unpolished surface with irregular topography) in LEO. This study provides a basis for future reliable semi-quantitative analyses of a variety of abiotic and biogenic samples on ISS.

References: [1] Ritchie N.W. M. (2018) available at: https://github.com/usnistgov/EPQ. [2] SPI Supplies Standards for Microanalysis (2spi.com) and PELCO® XCS EDS Calibration Standards (tedpella.com). [3] Newbury D.E. and Ritchie N.W.M. (2021) *Microscopy and Microanalysis* **27**, 1375-1408. [4] Mittlefehldt D.W. (1994) *Meteoritics* **29**, 214-221. [5] Treiman A.H. (1995) *Meteoritics* **30**, 294-302. [6] Gleason J.D. et al. (1997) *Geochimica et Cosmochiica Acta* **61**, 3503-3512. [7] Halvey I. *et al*. (2011) *Proceeding of the National Academy of Sci*ence **108**, 16895-16899. [8] Thomas-Keprta K.L. *et al*. (2009) *Geochimica et Cosmochimica Acta* **73**, 6631-6677.