Mochii Portable Spectroscopic Electron Microscope on ISS: Progress Toward Flight

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Your EM samples analyzed *in-situ* on ISS

Electron microscopy (EM) and energy-dispersive spectroscopy (EDS) are powerful tools for research and engineering. EM offers strong optical scattering, high native resolution, large depth of focus, and multiple available signals including X-rays for chemical ID.

NASA routinely uses ground-based EM's to:

- Understand the origin and evolution of the solar system, esp. rocky bodies
- Visualize architecture of tissues and cells
- Characterize particulate debris in air/water, observe catalyst pore sizes, study fibers, and characterize micro-textures
- Guide critical adaptive mission planning via forensic imaging and microanalysis for life support and mechanical systems

Coauthors are working together in partnership with the ISS program to bring this powerful capability to ISS. Voxa is entering into an agreement with CASIS to make EM analysis available to terrestrial users as a National Laboratory facility after its initial demonstration mission. This facility supports in-situ engineering analysis and microgravity science benefiting humankind.

Out of the lab and into the field:

EM is traditionally a high-end large facility lab tool:

- Complex to operate and maintain, needs vacuum and stable environment.
- Training, long queues, and geography limit access, speed to result, and the extent to which many analyses can be executed.
- Field samples must be sent back to a facility, despite potential chemical or morphology changes over time and/or damage in transit.

Voxa has developed Mochii™, the world's first truly field-portable nano-imaging platform to address limitations bringing EM out of the lab.

Mochii is tiny and versatile and suitable for space use:

- Ultra-portable: 260 mm tall, <12 kg, <80 W
- Low accelerating potential (10 kV) provides capable imaging
- Wireless tablet interface: multi-user collaboration
- Chemical ID via energy-dispersive X-ray spectroscopy (EDS) enabled in Mochii 'S' model
- Easy sample preparation using integrated metal coater
- Low initial procurement, operating, and maintenance costs

Mochii's unique balance of features enables it to perform analyses in extreme field environments, such as outdoors under battery power, on moving vehicles such as ocean vessels, and in the most extreme of environments: space.

We report on preparing Mochii 'S' for manned space flight, the first instrument of its kind in this frontier.

www.projectvoxa.com

mochii

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[1] Chiaramonti, Goguen, Garboczi. Microscopy & Microanalysis 23 (2017), 2194-2195.
[2] Own, et al, Microscopy & Microanalysis (2015), 57.
[3] Own, Murfitt, US Patent No. 9,564,291 (2017).
[4] Own, Murfitt, US Patent No 9,899,186 (2018)
[4] Fontana, Pettit, Cristoforetti, Journal of Crystal Growth 428 (2015), 80-85.
[5] Fontana, Schefer, Pettit, Journal of Crystal Growth 324 (2011), 207-211.
[6] Own, US Patent App No. 14/607,079 (2015).
[7] This work was supported by Voxa, NASA, and Jacobs.

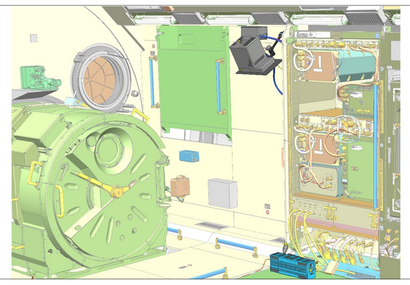
Applications

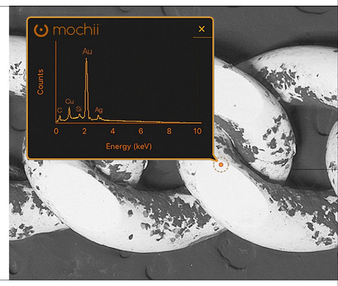
Mochii: a new ISS Microgravity research facility for the benefit of humankind

Science: Mochii will enable novel research on board ISS, including EM visualization of samples prepared in microgravity, characterization of new and existing materials, and in the longer term tissue and cell architecture.

Engineering: Mochi will enable mission-critical engineering on board ISS, such as characterizing debris in life support and mechanical systems to reduce crew and vehicle risk.

Future missions: Mochii will serve as a development platform for future missions, including deep space manned and robotic exploration by enabling actionable analysis when sample return to Earth-based labs is not possible.





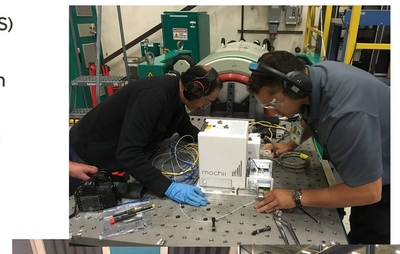
Progress Toward Flight

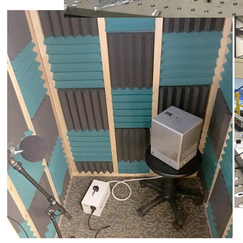
Flight verification testing

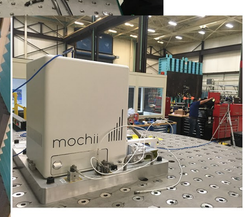
Mochii payload is flying as commercial off-the-shelf (COTS) hardware subject to ~150 ISS engineering integration and crew/vehicle safety verification requirements.

To reach technology readiness level (TRL) 9 and to achieve flight readiness, Mochii is undergoing rigorous testing. Tests that simulate the spaceflight environment increase safety to crew and vehicle, and reduces risk of failures on orbit. Included are EMI, thermal, command & data handling, and power quality. Vibration and acoustic testing examples are to the right.

In tandem, we are performing science verifications with our research partners to prepare the Mochiifor National Laboratory service.

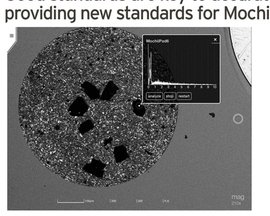


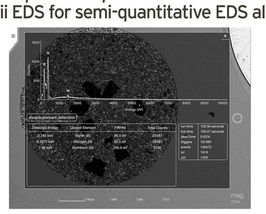


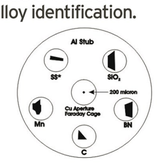


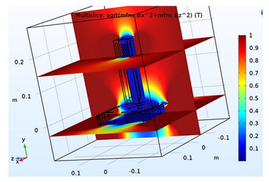
Science verification testing

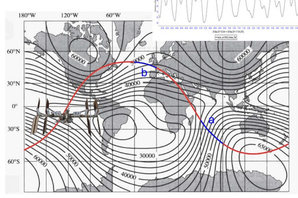
Good standards are key to accurate spectroscopic chemical ID on-station. We are providing new standards for Mochii EDS for semi-quantitative EDS alloy identification.

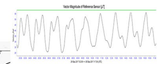






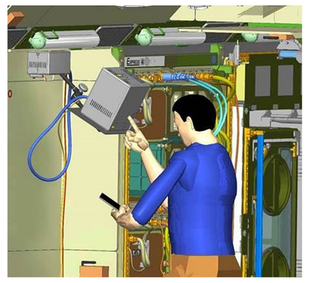






Earth's magnetic field varies from 200-600 mG, potentially impacting the beam stability. Mochii incorporates magnetic shielding to reduce this by orders of magnitude. We test ISS orbits for a) High gradients (~7 isopotentials) and b) Low gradients (~1.5 isopotentials).

ISS Topology



Mochii will be aisle-deployed in the Japanese Experiment Module (JEM) and will be powered by 120VAC inverter (95th percentile male shown, see also center image in banner above).

Mochii is accessed wirelessly by crew, and accessed by ground National Lab users using iPads over JSL uplink through Huntsville Operations and Voxa servers. Multiple users are supported.

National Laboratory Utilization

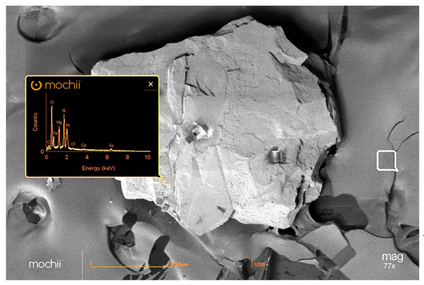
Please share with us your microgravity experiment ideas utilizing Mochii on ISS!

Voxa may serve as your implementation partner for novel microgravity research on ISS

Basic research: Extraterrestrial Samples

Mochii is an excellent analytical tool for the morphological, textural and chemical characterization of extraterrestrial samples and impact craters produced by exposure to the space environment. Of particular interest are lunar, cometary, asteroidal and Martian samples. EDS can identify components necessary for supporting life on other worlds and aid in study of planetary geological processes.

Energy-dispersive X-ray (EDS) spectrum acquired with Mochii S on a ~1mm fragment of Martian meteorite Nakhla. Compounds needed to support life have previously been detected on cleaved surfaces of Nakhla.



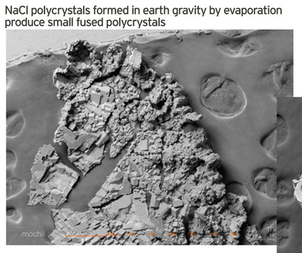
This data was acquired on Mochii at last year's LPSC in the speaker ready room in 30 minutes!

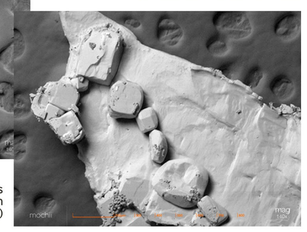
Industrial science: Microgravity Crystallization

The ISS platform supports orbital microgravity science experiments catalyzing technology development on Earth. This example demonstrates EM's advantages for studying crystallization dynamics. NaCl is optically transparent so its surface cannot be clearly imaging by light. The strong surface sensitivity of EM elucidates tiny structures and amplifies sensitivity to conditions during crystal growth.

ISS "Table salt"imaged with Mochii

NaCl polycrystals formed in earth gravity by evaporation produce small fused polycrystals

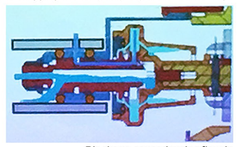




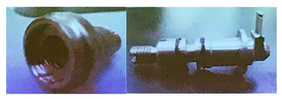
In contrast, large monolithic crystals of NaCl with blunted faces form in microgravity by evaporation (right)

Crew safety: Water leak buildup in EMU 3011

On a routine maintenance extra-vehicular activity (EVA) on 7/16/2013, crewmember Luca Parmitano detected a water leak buildup in his extravehicular mobility unit (EMU) helmet. EVA was terminated and Dr. Parmitano returned to airlock safely. The investigation of his suit was executed on-ground more than six months later after the suit returned to Earth via Russian Soyuz. Meanwhile, NASA suspended all EVA's, resuming only in October 2014 after root cause was found. EDS on-orbit could have identified this inorganic debris clogging the fan pump separator same-day.



Blockage caused water flow to travel from inside to outside.



Aluminum silicate contamination debris built up in EMU fan pump separator. Imaged and subsequently identified by SEM/EDS. Courtesy Kevin Wells, EC111 EVA Chief Engineer.