# **Environmental and correlative microscopy workshop**

Organized by Marek Malac and Misa Hayashida
Sponsored by Hitachi High Technologies Canada

The aim of the workshop is to provide participants with examples and demonstration of newest developments of *in-situ* and correlative microscopy. *In-situ* experiments examining samples by optical, x-ray and electron microscopies provide the tools needed to answer question posed by both fundamental science and practical applications. The workshop is divided in two segments. First, an example of exciting science investigated by in-situ electron microscopy will be presented by Prof. Jane Howe. Her talk will be followed by presentation and demonstration by Dr. Stas Dogel and Mr. Mr. Hooman Hosseinkhannazer on the recently developed MEMS devices for in-situ and correlative microscopy. In both segments ample time will be devoted to discussion and questions.

**A Step-by-step guide on how to cook meteorites in microscope: Insights from *In-situ* Heating Experiments**

Prof. Jane Howe (University of Toronto)

Chondritic meteorites are the oldest rocks in the solar system (> 4.55 billion years). Thermal metamorphism arguably played an important role in the active processes on the surfaces and within the parent asteroids of meteorites in the early solar system. Here we report results from *in situ* heating of meteorite samples that provide insight into the effects of heating on the composition and microstructure of their volatile-rich components. Fine grains of the meteorite were deposited onto Norcada heating chips. Using the Hitachi Blaze heating holder, we carried out *in situ* heating in a Hitachi SU9000 scanning transmission electron microscope (STEM/SEM) in vacuum at temperatures up to 1075˚C. Simultaneous secondary electron (SE), bright-field (BF) and dark-field (ADF) imaging showed that flash heating to 800ºC caused melting and a reduction of the overall size of the grains. Heating also caused the formation of nanoparticles. EDS mapping at each step shows migration of the Fe into the nanoparticles and loss of volatile elements, such as sulfur from the iron sulfide grains (Fig. 1). In summary, *in situ* heating lead to significant changes to their microstructure and elemental compositions, such as melting and formation of Fe-Ni metal nanoparticles. Heating up to 1075°C caused a significant loss of volatiles (e.g., S) and the graphitization of the carbonaceous matter. This work demonstrates that *in situ* STEM/SEM is a vialble method that provide new insights in planetary science research. Acknowledgments: This work supported by NASA Grants NNX15AD94G (NExSS EOS program) and NNX15AJ22G, and NSF Grant 1531243, was carried out at the Kuiper Core Imaging and Microscopy Facility, University of Arizona.

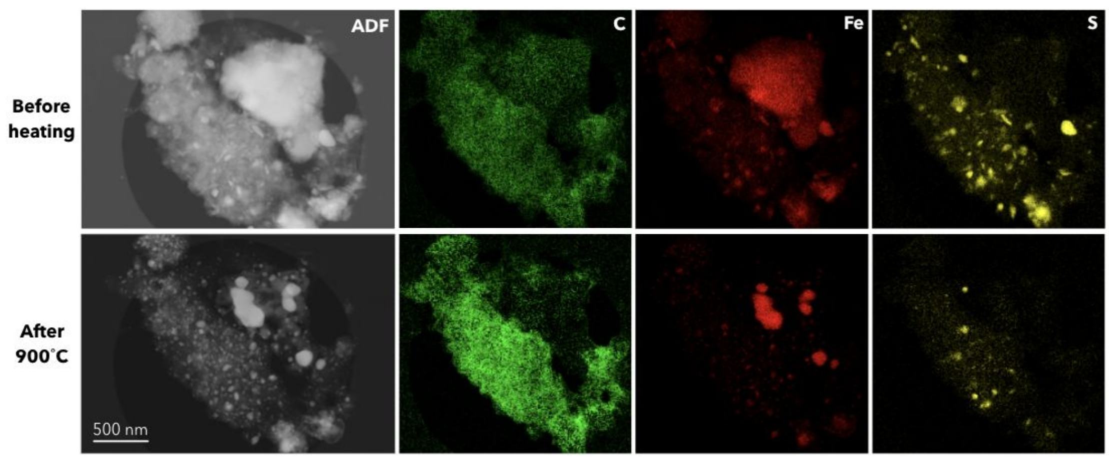


Fig. 1. *STEM dark-field (ADF) images and false-color EDS maps (green = C, red = Fe, and yellow = S) of a Tagish Lake sample on the heating chip before and after heating up to 900°C.*

**_In-situ_ MEMS Accessories for Correlative Microscopy.**

Dr. Stas Dogel (Hitachi High Technologies Canada) and Mr. Hooman Hosseinkhannazer (Norcada)

**Dr. Stas Dogel** is a manager of Nano Accessory Product Development Group (NAPG) at Hitachi High Technologies Canada (HTC). Through his research career in ultra-high vacuum and surface sciences building advanced and unique cutting edge research equipment Stas has accumulated years of experience in engineering, design, manufacturing and the art of product development. Stas is now leading an enthusiastic team of creative designers and engineers to develop and bring to market auxiliary products for SEM and TEM. Our products range from software and automation to nano positioning and probing, cleaning technology as well as a portfolio of in-situ TEM holders. Latest additions to in-situ TEM holder family are MEMS heating and liquid flow/static TEM/SEM specimen holders jointly developed with Norcada, Inc.

**Hooman Hosseinkhannazer (PMP, PEng)** is a business executive with experience in advanced technology, oil and gas and the not-for- profit sectors. As the Vice President Business Development at NORCADA in Edmonton, Hooman oversees a broad portfolio of high-tech product solutions with applications in genomics, X-ray optics, vacuum technology, quantum sciences, microscopy and spectroscopy. Hooman's engineering career started in the field of health robotics before engaging in micro/nano-fabrication and product development via graduate studies at the University of Alberta. Over the last few years at Norcada, Hooman has dedicated his career to the development and commercialization of a number of nanotechnology and MEMS product lines for industrial and research applications, while expanding the market reach to over 40 countries. During Hooman's tenure, in-situ microscopy and microanalysis have become a major product line, with co-developed solutions entering Hitachi and Norcada product families since 2011. Building on the collaborative product development platform with Hitachi, Norcada is now engaged in completing the road-map to a true correlative product platform that combines Optical, X-ray and Electron beam analysis on the same sample. Norcada's dedicated engineering team in Edmonton, Canada, has delivered in-situ solutions in electrochemistry, heating, biasing, bio-sample analysis and electromagnetic field testing with a market reach in more than 500 electron microscopy laboratories and 35 synchrotron facilities.