GSECARS Diamond Anvil Cell Program

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Understanding the complex nature of the deep interiors of the Earth and other planets requires knowledge of physical and chemical properties of their constituting elements and compounds at relevant extreme P-T conditions. To provide new constraints on models for planetary evolution and origin, essential properties (melting, structure, phase relation, chemical reactions and kinetics, transport, elastic, electronic properties) of a wide range of minerals must be studied *in-situ* at pressures up to 1 TPa and temperatures up to 10,000 K.

Most of the experiments at ultra-extreme P-T conditions are very challenging and require dedicated synchrotron beamlines, like GSECARS, where state-of-the-art high-pressure on-line and off-line techniques have been implemented and are currently being developed. At GSECARS we have three beamline stations dedicated for the DAC program:

- **13-ID-D** is based on an undulator x-ray source (3 µm x-ray focused beam at 14-70 keV, XRD and XES in the DAC combined with coaxial, double-sided, CW or pulsed laser heating and time-resolved optical spectroscopy
- **13-BM-C** is a side-deflected bending magnet station with a fixed x-ray energy of 28.6 keV and a beam size ~ 15 µm. A six-axis large diffractometer is used for high resolution single crystal XRD combined with resistive or laser heating and optical spectroscopy
- **13-BM-D** is based on a bending magnet x-ray source providing wide energy range from 6 to 110 keV and focused beam to ~ 5×12 µm. XRD is combined with Brillouin and Raman spectroscopy systems

More than 425 papers were published in period of 2017-2021(Sept.), which include 6 masters theses and 37 Ph.D. theses, see the full list of DAC publications here.

The DAC program is the largest among the GSECARS techniques and will be supported by beamline scientists Vitali Prakapenka, Stella Chariton, Sergey Tkachev, Dongzhou Zhang and Jingui Xu. In addition to the experimental stations, we support off-line facilities including gas-loading, Raman, laser ultrasonic, off-line laser heating and cutting systems, and preparation labs. We share administrative and technical assistance among the different programs.

In this proposal we highlight current capabilities and accomplishment as well as future comprehensive technical developments to study properties of planetary materials with unprecedented accuracy and precision in well controlled and calibrated high P-T conditions. We plan to focus mainly on static and dynamic high energy XRD experiments in combination with time-domain optical spectroscopy in a wide temperature range with optional x-ray spectroscopy utilizing various techniques. These include: time-resolved, laser-heated single-crystal diffraction; electrical conductivity with impedance spectroscopy; viscosity with X-ray photon correlation spectroscopy; thermal conductivity with time-resolved temperature and reflectivity/emissivity measurements; sound velocity with Brillouin, acoustic and laser ultrasonic measurements; high spatial resolution radiography and microtomography; phase contrast X-ray imaging with coherent X-ray beam; PDF analysis. We will also develop X-ray Raman spectroscopy and XES/EXAFS/XANES combined with XRD in the DAC at various temperatures in the 13-ID-C and 13ID-E stations**.**

We propose upgrades of the on-line instruments and off-line capabilities to make possible these measurements and to take full advantage of APS-U super-bright beam. This includes: high resolution, high energy efficient, large area gated x-ray detectors; sophisticated optical and laser tools; submicron focused beams; vibration free high precision sample control; specially designed DACs; sample microfabrication and synthesis.