COMPRES Multi-Anvil Synchrotron Program

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This proposal is to continue the COMPRES Multi-Anvil Synchrotron Program and to expand the synchrotron access to the community and broaden the available capabilities to include 3D *in-operando* possibilities. The current program includes equipment at two beamlines: 6 BMB at APS and XPD at NSLS II.

6BMB Currently the workhorse of the 6BMB beamline is the D-DIA. This is a machine that can compress a sample to nominally 10 GPa and heat it to 1500°C. In addition, a uniaxial stress can be superimposed, driven positive or negative as the experiment requires. White X-rays are used to measure stress and strain in a 2-D projection. Assuming cylindrical symmetry, this is the complete 3-D stress and strain field. By using white X-rays, the stress in a polycrystalline sample is obtained from a volume as small as 10x10x500 μm^3. Although stresses measured by X-ray diffraction are complicated by anisotropy of the material, that complication represents a rich stream of information about plastic deformation mechanisms operating in the sample. Precision of 10 MPa has been obtained. This system works best with grain size smaller than 20 μm. An ultrasonic system is available to measure acoustic velocities. We use 50% of the beamtime for the high-pressure program.

XPD At the NSLS II we operate an 1100 ton press as a partner user on the XPD beamline. This is a monochromatic beamline on a damping wiggler. It generally operates at energies between 55 and 72 keV. The DT-25 system offers very similar scientific capabilities with the exception that it is a multi-anvil uniaxial device built within the framework of a Kawai geometry, that is 8 anvils compressing an octahedron, a system designed by our COMPRES program. This system is capable of up to 30 GPa confining pressure with a uniaxial stress capability like that of the D-DIA. On average, we use a total of about 25% of the total user beamtime at XPD for the high-pressure program.

The two system provide the ability to conduct many types of experiments. Through the years results have been obtained for the following research areas: PVT equations of state, thermal diffusivity at P and T, Young's modulus as a function of frequency for seismic frequencies, Q of the Young's modulus in this frequency region, kinetics of solid-solid phase transitions, kinetics of partial melting, P and S velocities as a function of P and T, stress dependence of P and S velocities, bulk modulus at millihertz frequencies, stress induced phase transformations, P and S velocities through phase transitions, rheological properties (stress vs strain rate), activation energy and volume for plastic flow, lattice preferred orientation associated with plastic flow, strength of diamond at high temperature, and many more.

Expanded program Synchrotron access is a key ingredient to making synchrotrons part of everyone's scientific program. We are on a path to double the amount of beamtime that we can use at the APS, going to 100% of the beamtime after the upgrade (2024). We will need one additional beamline scientist to run 6BM(A+B).

We are proposing to add equipment to conduct 3D imaging. We will need a rotating sample stage, and we propose to rotate the pressure system, so this stage must be able to support sufficient weight. Our design can hold up to 500 kg. The vision is to provide a platform and work with the community to design and fund sample holder systems that address a range of specific scientific questions. We also budget for a triaxial device that has been developed in France and operates to 200 MPa and 210°C. It is designed to be used with fluid flow through the sample. We will also commission an existing PE type press to use with the PE style pressure vessel. This should afford experiments to 10 GPa and 1400 C. We hope to add a uniaxial stress capability. These two vessels should be capable of 3D imaging. Our goal is to achieve a full 3D data set in one second so that these can be truly '*in-operando*'. We seek to follow several strategies to provide new insights into material behavior, such as: 1) distributing point markers such a 1-micron rhenium spheres in the sample (100 or so) can allow us to map the 3-D strain field as a function of time. This allows definition of when and where strain localization occurs. Stress measurements could be also coupled with strain; 2) Dissolving high – Z elements in fluids to track fluid flow in the sample; 3) Identification of pores and voids in the sample; 4) Identification of minerals may be identified with sufficient contrast and grain motion, growth, or disappearance. Both current programs at XPD and 6BM will continue.