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A coordinated study on structures of liquids/glasses using synchrotron radiation in Paris-Edinburgh and the diamond cell

WANG, Yanbin[1*] ; YU, Tony[1] ; PRAKAPENKA, Vitali[1] ; PRESCHER, Clemens[1] ; KONO, Yoshio[2] ; JING, Zhicheng[3] ; ENG, Peter[1] ; STUBBS, Joanne[1] ; SHEN, Guoyin[2]

[1]CARS, Univ. Chicago, USA, [2]HPCAT, CIW, USA, [3]Case Western Reserve Univ., USA

Structures of geo-liquids at temperature and pressure conditions of the deep interior of the Earth fundamentally control the physical properties of these liquids, which, in turn, profoundly influence chemical and thermal evolution of the Earth. We have developed a suite of monochromatic x-ray diffraction techniques using both a Paris-Edinburgh press (PEP) and a diamond anvil cell (DAC) at the GSECARS beamlines. With two high resolution Si (111) and (311) monochromators, a multi-channel collimator (MCC) assembly, and two Kirkpatrick-Baez focusing mirrors, we have an exciting opportunity for liquid and glass structure studies in both the PEP and the DAC. A new PEP anvil geometry has been adopted which is capable of generating pressures in excess of 15 GPa on 0.5 mm diameter samples. Cell assemblies have been developed and temperatures up to 2000 C have been maintained over hours. A simple analysis shows that with a finely collimated or tightly focused incident beam of 0.05 mm, a collimation depth of 0.5 mm can be achieved at two-theta angles above ˜10 degrees with the MCC. The PEP is mounted on the general-purpose diffractometer (GPD) in 13-ID-C, with the sample located at the center of the six-circle diffractometer, which allows scanning an area detector (e.g., MAR CCD) to cover maximum Q range up to 30 $Å^{-1}$,with x-ray energies above 60 keV. Ultrasonic acoustic velocity measurements can be conducted in-situ at high pressure and temperature to study elasticity of liquids using either the PEP or other large-volume, high-pressure devices. Applying a similar diffraction setup for the DAC technique, we can now study structural evolution of super-cooled liquids (glasses) to pressures in excess of 150 GPa both at room temperature and high temperatures. With a focused incident beam on the order of 0.03 mm, the MCC effectively reduces unwanted Compton scattering of the diamond anvils by a factor of 10, thereby allowing more accurate extraction of x-ray total scattering signals from tiny samples. Furthermore, online Brillouin spectroscopy allows acoustic velocities to be measured under the same pressure and temperature range. We will present results on structural responses and densification mechanisms of a number of silicate liquids and glasses at high pressures. Implications for melt dynamics in the Earth's interior will be discussed.

Keywords: synchrotron, high pressure, liquid structure, diffraction, early earth, mantle dynamics