DENSITY AND SOUND VELOCITY OF IRON-SULFUR ALLOYING LIQUIDS AT HIGH PRESSURES AND IMPLICATIONS TO PLANETARY CORES. Z. Jing[1], Y. Wang[1], T. Yu[1], T. Sakamaki[1], Y. Kono[2], C. Park[2], [1]Center for Advanced Radiation Sources, The University of Chicago, 9700 S Cass Ave, Bldg 434-A, Argonne, IL 60439, jing@cars.uchicago.edu, [2]HP-CAT, Geophysical Laboratory, Carnegie Institution of Washington, 9700 S Cass Ave, Bldg 434-E, Argonne, IL 60439.

Introduction: Liquid Fe-light element alloys are likely present in the Earth's outer core and the cores (or outer cores) of other terrestrial planets such as Moon, Mercury, and Mars, suggested by geophysical and geochemical observations [1, 2, 3]. In order to determine the abundances of light elements and their effects on the structure, dynamics, and evolution of planetary cores, it is crucial to determine the equation of state for Fe-light element alloying liquids under core conditions. However, density data on liquid Fe-light element alloys at core pressures are very limited and no sound velocity or bulk modulus data are available for these liquids at high pressures. This makes it difficult to extrapolate the equation of state to core pressures. As a result, density data on solid Fe alloys are often used in the literature to compare with seismological observations by making rough corrections for the volume of melting. In this study, we determine the density and sound velocity for Fe-S liquids with different sulfur contents at high pressure and temperature conditions up to 8 GPa and 2173 K using synchrotron X-ray techniques.

Sound Velocity Measurements: In-situ sound velocity measurements were conducted in the T-25 double-stage multianvil apparatus at GSECARS beamline 13-ID-D of Advanced Phonon Source, Argonne National Laboratory, and in the Paris-Edinburgh Cell at HP-CAT beamline 16-BM-B. We have studied three different liquid compositions: Fe-10wt%S, Fe-20wt%S, and Fe-27wt%S. The starting materials of the experiments were prepared by mixing Fe and FeS_2 powders. Samples were contained in BN sleeves. Pressure of the experiments was obtained by the energy dispersive X-ray diffraction of the MgO pressure standard. Temperature was monitored by a W5Re-W26Re thermocouple. Experimental conditions were from 1 to 8 GPa and 1473 to 1973 K.

Fig. 1. shows the experimental setup for measurements conducted in the Paris-Edinburgh Cell. Ultrasonic sound waves were generated and received by a $LiNbO_3$ transducer (10º Y-cut) attached to the back of an anvil. The P-wave resonant frequency of the transducer was 50 MHz. An Al_2O_3 buffer rod was placed between the sample and the anvil to ensure the perfect contact and impedance matching. A waveform generator and a digital oscilloscope were employed for waveform generation and recording.

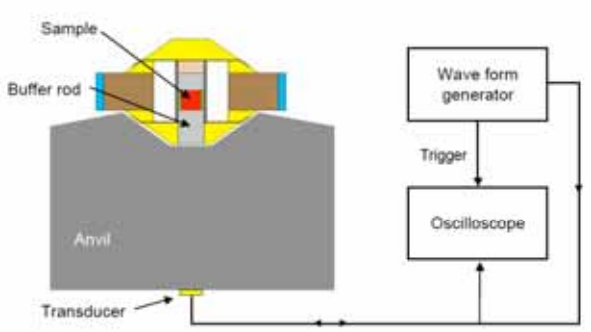

Fig. 1. Experimental setup for ultrasonic sound velocity measurements

Fig. 2. shows the typical ultrasonic signals obtained from sound velocity measurements. The travel time of sound waves in the liquid sample was then determined by the cross correlation of the buffer rod echo and the sample echo. Sample lengths were determined by X-ray radiographic imaging. Then the sound velocity of Fe-S liquids was calculated.

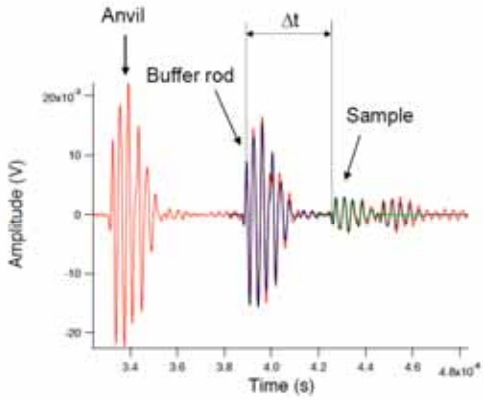

Fig. 2. Ultrasonic signals from sound velocity measurements

Density Measurements: In-situ density measurements of Fe-S liquids were conducted in the DIA-type cubic-anvil apparatus at GSECARS beamline 13-BM-D using the X-ray absorption technique [4]. The density of two liquid compositions (Fe-20wt%S, and Fe-27wt%S) was determined. In the X-ray absorption technique, the density can be determined from the Beer-Lambert law, which is given as $I/I_0 = \exp(-\mu\rho t)$, where I_0 and I are the intensities of the incident and transmitted X-ray beams, μ is the mass absorption co-

efficient, ρ is density, and t is sample thickness. The high-intensity monochromatic X-ray beam at 13-BM-D was used for the density measurements. In order to reduce the X-ray absorption by the surrounding material, we used boron-epoxy as the pressure medium, graphite as the heater material and boron-nitride outer sample capsules. The X-ray energy was tuned to 40 keV to achieve optimum absorption contrast between the sample and the surrounding materials. The intensities of the incident and transmitted X-rays were measured by two ion chambers on the X-ray path that were placed in front of and behind the press. Ar gas was used in the ion chambers. An X-ray absorption profile was obtained for each measurement by moving the incident slits perpendicular to the X-ray beam direction. Collimated X-ray beams about 0.05 x0.05 mm was used for intensity scans to ensure sufficient spatial resolution. A high-resolution camera was also used to obtain the 2-D absorption profile in addition to the 1-D results obtained by the ion chambers. The mass absorption coefficient was calibrated at ambient conditions by the density of the starting materials. The sample thickness was determined by using single-crystal sapphire inner capsules as demonstrated by Katayama et al. [5] and Sanloup et al. [6]. The cell assembly, X-ray radiographic image, the absorption profile from shown in Fig. 3. Pressure and temperature conditions of the experiments were from 1-7 GPa, and 1273-2173 K. Density of the liquid was calculated by fitting the absorption profile using the mass absorption coefficients of the sample and sapphire, the measured size of the sapphire sphere, and the equation of state of sapphire.

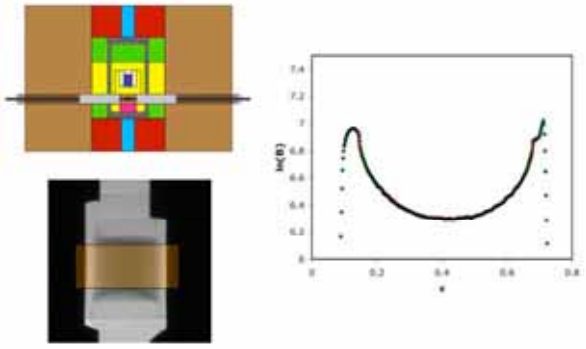

Fig. 3. Cell assembly, radiographic image, and absorption profile for density measurements

Results and Discussion: Sound velocities of Fe-S liquids were determined at six different frequencies (20 MHz, 25 MHz, 30 MHz, 40 MHz, 50 MHz, and 60 MHz) and show no frequency independency, which confirms that the liquids are fully relaxed. Results show that the sound velocity of Fe-S liquids is weakly dependent on temperature, but increases significantly with increasing pressure and decreases with increasing sulfur content. Bulk modulus and equation of state at high pressures were obtained by combining the sound velocity and density results. Results are consistent with that of [6].

The density and sound velocity of Fe-S liquids can then be compared to geophysical observations such as the lunar seismic data [1] for the Moon and the MESSENGER mission for Mercury (e.g., [7]) to provide constraints on the composition and structure of planetary cores.

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