Sound velocity measurement of metals under high pressure conditions

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Physical properties (e.g., sound velocity, density) of metals are fundamentally important in basic and applied sciences. It depends on the nature of the interatomic interactions and thus provides fundamental information in solid state physics. At the same time, it can provide basic thermodynamic properties.

We used the Si (9 9 9) backscattering optics, which provides an incident photon energy of 17.79 keV. The beam was well focused and its size is less than 15 × 15 μm. The scattered x-rays were analyzed by 24 crystals, which are arranged in a two-dimensional (4 × 6) array. The momentum transfer \( Q = 2k_0 \sin(2\theta/2) \), where \( k_0 \) is the wave vector of the incident photons and \( 2\theta \) is the scattering angle, is selected by rotating the spectrometer arm in the horizontal plane. IXS spectra were collected in the range of \( Q = 6.0 \) to \( 10.0 \) nm\(^{-1} \) at each experimental pressure. The XRD patterns were also obtained under the same experimental conditions as IXS using a flat panel area detector installed at BL43LXU. Pressure is calculated on the basis of XRD patterns using the equation of state of sample.

In 2018, we have conducted the sound velocity measurements of the two polycrystalline metal samples, pure hcp-Fe and rhenium, both of which have fundamental importance in geophysics and high-pressure science.

Iron is one of the most important metals because its knowledge can be applied not only for basic physics but also for Earth Science. The Earth’s core, which is the deepest region of the Earth, is mainly composed of iron. Although the seismic models provide the average structure of the inner core, its anisotropy has also been reported. It can be caused by preferred orientation of iron crystals. For better understanding of the detailed structure of inner core, we need to reveal the effect of texture on the sound velocity of hcp-iron at high pressure.

We have tested DAC with large window for high pressure generation (Figure 1). A beryllium plate was used as a gasket in order to insert the incident beam parallel to the gasket. In this case, the X-ray passes through a direction perpendicular to compression axis. We measured the IXS of the standard setup; X-ray entered the sample through the diamond anvils. Comparing with IXS results obtained from different directions, we can discuss the texture effect of sample due to the uniaxial compression by DAC.

Rhenium is also one of the most important materials for high-pressure science as a pressure standard under the multi-Megabar conditions. We have measured the sound velocity of polycrystalline rhenium at high pressure and room temperature by using the IXS method of BL43LXU.

Under high pressure conditions of the Earth’s core (>125 GPa), IXS measurement has many difficulties, especially over 200 GPa. For example, the intensity of IXS from the sample is too weak due to thinning of the sample, strong elastic scattering and background noise. To collect only the scattering from the sample, we tried to install collimator in downstream side of the diamond anvil cell, and we succeeded to obtain better sample IXS spectra. The installed collimator worked well and reduced the elastic scattering and the background signals effectively (Figure 2).

We have determined the compressional sound velocity \( V_p \) and density of polycrystalline rhenium, at ambient temperature and high pressure up to 286 GPa based on the equation of state of rhenium by Anzellini et al [1]. This is the highest pressure ever measured using the IXS method. The relation between \( V_p \) and density of rhenium keeps a linear function referred as Birch’s law [2] (Figure 3).

References