Nitrogen in the core from sound velocity measurements of liquid Fe-N at high pressure

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The Earth's liquid outer core is mainly of iron, alloying with ~5wt.% nickel and ~10wt.% some light elements [1]. Geochemical observations show that the silicate mantle is depleted in nitrogen relative to primordial meteorites which are believed to have similar composition of the bulk earth. This indicates that a large portion of nitrogen in bulk earth can be stored in the core [2,3]. In order to examine the possibility of nitrogen in the core, it's benefit to compare the sound velocity of liquid Fe-N alloy under high-pressure and –temperature corresponding to the core conditions with seismological observations. In this study, we have performed inelastic X-ray scattering (IXS) measurements to determine the longitudinal velocity of the liquid Fe-N alloy under high-pressure and –temperature conditions.
We carried out IXS measurements up to 76 GPa and 2200 K, using a laser-heated diamond-anvil cell (LH-DAC) at the RIKEN Quantum NanoDynamics beamline BL43LXU of SPring-8 [4]. We used a Fe80N20 foil as a starting sample and single crystal Al2O3 discs as thermal insulator. We judged the sample melting based on X-ray diffraction measurements during heating, and then measured IXS of the liquid sample. The IXS spectra was collected in a momentum transfer range of 3-5.7 nm-1 with an energy resolution of ~2.8 meV at 17.94 keV. The longitudinal sound wave (P-wave) velocity of liquid Fe80N20 was determined from the dispersion relation of the longitudinal acoustic phonon mode of the sample. We fit the P-wave velocity data for liquid Fe80N20 with an equation of state, which enabling to extrapolate the present velocity date to core pressures and also calculate the destiny and bulk modulus under high pressure conditions . Compared with pure Fe [5], the P-wave velocity of liquid Fe80N20 is faster by ~10% and the density is lower by ~8% in the present experimental conditions. By extrapolating the present results to the Earth's outer core conditions and then comparing with seismological observations, we found that the upper limit of nitrogen is ~3.3 wt% in the outer core.

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