ESRF	**Experiment title:** Sound velocity measurements at high pressure and temperature in a "synthetic" Earth's inner core	**Experiment number**: HS-3750
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Report:

We performed sound velocity and density measurements on polycrystalline $Fe_{0.89}Ni_{0.04}Si_{0.07}$ in the hcp phase, up to 108 GPa.

Polycrystalline homogeneous samples of silicon bearing iron-nickel alloy have been synthetised at high pressure and high temperature in a piston cylinder press. Silicon and nickel content, 3.7 wt% and 4.3 wt% respectively, have been quantified by electron microprobe analysis. Compacted pellets of about 90 μm diameter and 20 μm thick have been loaded in diamond anvil cells (DAC) equipped with Re gasket, using 300 μm flat anvils and neon as pressure transmitting medium for measurements up to 50 GPa, and 150/300 μm beveled anvils with no pressure transmitting medium for higher pressures. Pressures were determined by ruby fluorescence and, most importantly, the densities (ρ) were directly obtained from diffraction measurements.

Inelastic x-ray scattering measurements have been performed on the ID28 beamline, using the Si(8,8,8) instrument configuration, which provides the best compromise between flux and energy resolution (5.5 meV full width half maximum, FWHM) for polycrystalline samples compressed in DAC. Spectra have been collected in transmission geometry, with the x-ray beam impinging on the sample through the diamonds, along the main compression axis of the cell, and hence probing exchange momenta q perpendicular to the cell-axis. The transverse dimensions of the focused x-ray beam of 30x90 μm^2 (horizontal x vertical, FWHM) were further reduced by slits on the vertical direction. Momentum resolution was set to 0.25 nm^{-1}.

We collected data at 27, 37 and 47 GPa on quasi-hydrostatically compressed samples, and at 32, 73 and 108 GPa on non-hydrostatically compressed samples. At each investigated pressure point, we mapped the longitudinal acoustic phonon dispersion throughout the entire first Brillouin zone collecting 8-9 spectra in the 3.5-12 nm^{-1} range (Figure 1). The energy positions of the phonons were extracted by fitting a set of Lorentzian functions convolved with the experimental resolution function to the IXS spectra, utilizing a standard χ^2 minimization routine. We then derived the aggregate compressional sound velocity V_P from a sinus fit to the phonon dispersion [1], with error bars between ±2 and ±3% (Figure 1). Combining our measurements of V_P and ρ with the values of bulk modulus K [see experimental report of proposal HS3411] we also obtained the aggregate shear sound velocities V_S [1], but due to the propagation of the errors, with indeterminations around ±15%.

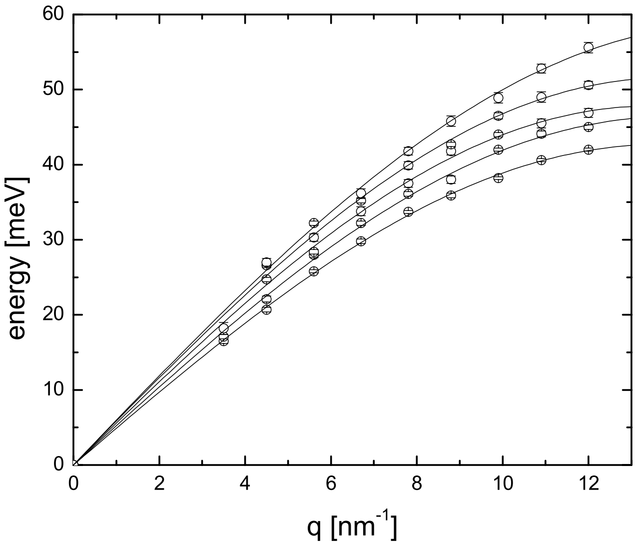

Figure 1: Longitudinal acoustic phonon dispersion of $Fe_{0.89}Ni_{0.04}Si_{0.07}$ at ambient temperature and pressures of 27, 37, 47, 73 and 108 GPa (bottom to top).

The measured compressional sound velocity is plotted as a function of density in Figure 2, together with values for pure iron [1,2] and $Fe_{0.78}Ni_{0.22}$ alloy [3]. In order to be able to resolve variations down to few percent, we only considered results obtained by IXS and for which densities were directly measured. Thus, we can compare the data without having to deal with possible systematic differences associated to the use of different techniques, nor to different pressure scales or approximations in the employed equation of state. While no systematic offsets can be observed between data on pure iron and iron-nickel alloy, the values measured for $Fe_{0.89}Ni_{0.04}Si_{0.07}$ are systematically higher, as better highlighted by the linear fits to the experimental data. Over the investigated pressure range, $Fe_{0.89}Ni_{0.04}Si_{0.07}$ is ~9% faster then pure iron at the same density.

Extrapolation to core densities and comparison with seismic velocity and density profiles from PREM allow us to place an upper bound on the silicon amount in the inner core to ~4 wt% and to sustain an inner core compositional model containing 4-5 wt% of Ni and 2-3 wt% of Si [4].

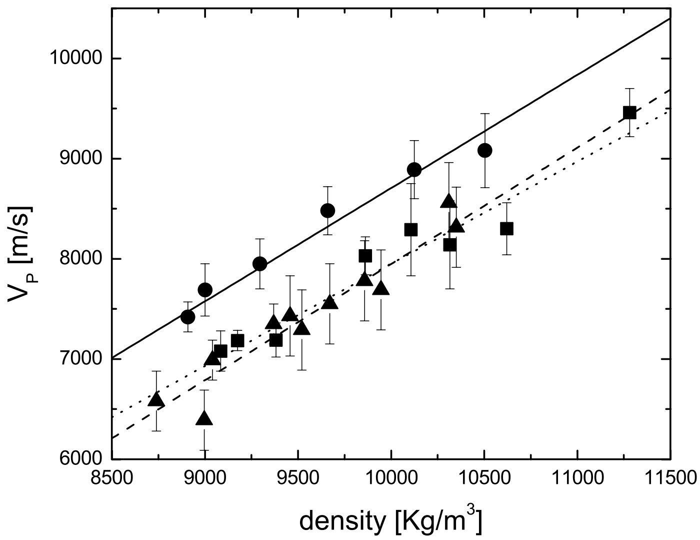

Figure 2: Aggregate compressional sound velocity as a function of density. Circles: $Fe_{0.89}Ni_{0.04}Si_{0.07}$; squares: Fe [1,2]; triangles: $Fe_{0.78}Ni_{0.22}$ [3].
The uncertainties in the densities are smaller than the symbols. Lines are linear regressions to the experimental data (solid - $Fe_{0.89}Ni_{0.04}Si_{0.07}$; dotted - Fe; dashed - $Fe_{0.78}Ni_{0.22}$).

References:

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[2] G. Fiquet et al., Science 291, 468 (2001).
[3] A.P. Kantor et al., Phys. Earth Planet. Inter. 164, 83 (2007).
[4] J. Badro et al., Earth Planet. Sci. Lett. 254, 233 (2007).