Experiment title: Sound velocity of iron carbide (Fe_3C) at megabar pressures : implications for the Earth's inner core chemical composition		Experiment number: HS2903
Beamline: ID28	**Date of experiment**: from: 15/02/2006 to: 21/02/2006	**Date of report**:
Shifts: 18	**Local contact(s)**: M. Krisch (J. Serrano)	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

James Badro*, **Guillaume Fiquet***

Département de Minéralogie, IMPMC et IPGP, Université Paris 6, Université Paris 7, CNRS, Campus Boucicaut, 140 rue de Lourmel
75015 Paris

Evgueni Gregoryanz*

School of Physics, CSEC, University of Edinburgh,
Erskine Williamson Building, Mayfield Road, Edinburgh EH9 3JZ, UK

Florent Occelli*

CEA/DIF, Département de Physique Théorique et Appliquée, BP12, Bruyères-le-Chatel, 91680 France

Report:

Light elements are assumed to be present in the Earth's core to account for the discrepancies between seismological models such as PREM [1] and pure Fe or Fe-Ni alloys. Among these possible alloying elements, Si, O, H, S and C are considered to be the most likely additional components, as indicated by several lines of arguments such as cosmochemical abundances and high-pressure siderophile behaviour [*e.g.*, 2, 3]. The possibility that carbon might be an important constituent of the Earth's core has been recently examined by Wood [4]. Carbon stability in carbides is indeed greatly enhanced at high-pressure, and extrapolation to inner core pressure indicates that Fe_3C is expected to crystallize rather than hcp-iron, which could make of Fe_3C a major phase in the Earth's inner core.

In this report, we describe the first measurements of longitudinal acoustic velocity obtained for Fe_3C at high-pressure using inelastic X-ray scattering (IXS). IXS experiments were carried out at high-pressure on a polycrystalline sample of Fe_3C at the inelastic scattering beamline ID28 of ESRF. The undulator x-ray beam was monochromatized by a cryogenically cooled silicon (111) crystal and by a very-high-energy resolution monochromator. This beam, with an energy of 15.817 keV and an energy resolution of 5.5 meV, is focused down to 25 µm (horizontal) and 60 µm (vertical). The scattered photons are collected by 5 spherical silicon crystal analysers operating in backscattering and Rowland circle geometry at the same reflection order as the high-resolution monochromator.

The dispersion of longitudinal acoustic phonons have been measured from 19 to 68 gigapascals at momentum transfers Q varying from 4 to 12 nm^{-1} on a polycrystalline sample compressed in a diamond-anvil cell. Acoustic velocities can be directly derived from the LA phonon branches represented in Figure 1. The observed increase of the phonon frequencies corresponds to an increase of the longitudinal wave velocity (V_P) from 6100 to 9375 ms^{-1}.

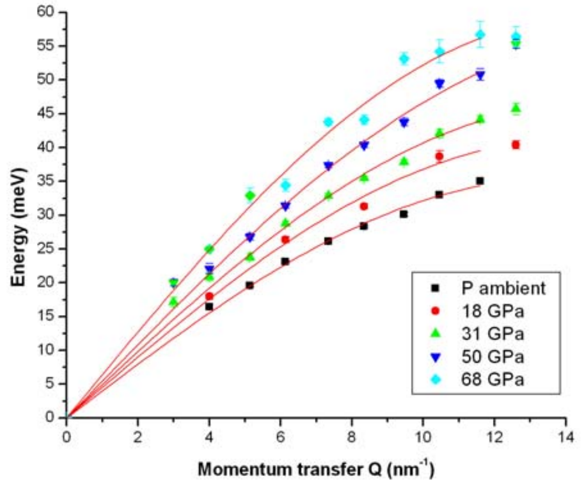

Fig. 1: Typical dispersion curves for polycrystalline Fe_3C to 68 GPa. The LA wave velocity V_P was determined at each pressure by fitting the dispersion curve with a sine function such as :

$$E[meV] = 4.192 \times 10^{-4} V_P[m/s] \times Q_{\max}[nm^{-1}] \sin\left(\frac{\pi}{2} \frac{Q\left[nm^{-1}\right]}{Q_{\max}\left[nm^{-1}\right]}\right)$$

from which V_P as well as the position of the edge of the first Brillouin zone, Q_{MAX}, can be derived. Data recorded at five to ten momentum transfers have been used in each dispersion curve to constrain V_P within an estimated error of 3%. The fitted values of Q_{MAX} are in very good agreement with those obtained from X-ray diffraction.

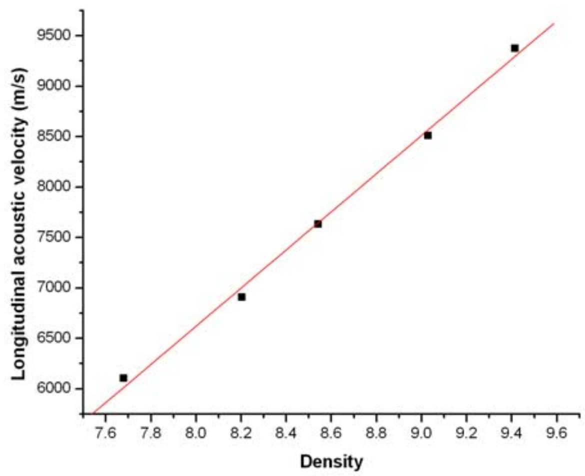

Fig. 2: Longitudinal acoustic wave velocities of Pnma Fe_3C as a function of density. As shown by the solid line, the experimental points move along a straight line. This linear relation between velocity and density is known as the Birch's law [5].

We show that Fe_3C follows a Birch's law [5] for V_P, namely a linear dependence between velocity and density regardless of particular values of pressure and temperature. These results have now to be confronted to seismic data, and combined with data already obtained for other iron alloys [see ref. 6]. It should allow us to constrain the relative abundance of carbon in the Earth's core, not only on the basis of density systematics but also using the strong constraints provided by such acoustic sound velocity measurements.

References

[1] Dziewonski, A.M. and Anderson, D.L. 1981. Phys. Earth Planet. Int., 25, 297.

[2] Allegre, C.J. et al. 1995. Earth Planet. Sci. Lett., 134, 515.

[3] Poirier, J.P. 1994. Phys. Earth Planet. Int., 85, 319.

[4] Wood, B.J. 1993. Earth Planet. Sci. Lett., 117, 593.

[5] Birch, F. 1952. J. Geophys. Res., 57, 227.

[6] Badro, J., Fiquet, G., Guyot, F. et al. 2007. Earth Planet. Sci. Lett., 254, 233–238.