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Spin Crossover in Ferropericlase at High Pressure: A Seismologically Transparent Transition?

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The characterization of pressure- and temperature-induced transitions of mantle minerals, and their link with seismic discontinuities, is one of the most striking contributions provided by mineral physics for the understanding of Earth's interior. Emblematic in this sense is the series of phase transformations that occur in olivine, which ultimately define the main seismic discontinuities of the upper mantle.

On the contrary, the spin transition in ferropericlase and perovskite has not yet been clearly associated to any seismic signature, even though effects on mantle's density and seismic wave velocity have been anticipated. With specific regard to ferropericlase, the spin transition occurs without change in the structure, but experimental [1-3] and theoretical studies [4] indicate large softening of all the elastic moduli and consequently significant softening of the aggregate sound velocities. Such an effect should result in a seismic discontinuity or anomaly, albeit broad, depending upon the range of the pressure and temperature over which the spin crossover occurs [5]. However, no seismic anomalies are observed at relevant depth.

Here we present measurements of the complete elastic tensor of $(Mg_{0.83}Fe_{0.17})O$ ferropericlase up to 70 GPa by inelastic x-ray scattering [6]. From the initial slope of the phonon dispersion of longitudinal and transverse acoustic modes, we directly derived the three independent elements of the elastic tensor. While a clear softening of the shear modulus C_{44} occurs across the spin transition, along with a small anomaly for C_{12}, we observe no softening for the longitudinal modulus C_{11}, and the obtained density dependence of the aggregate compressional and shear sound velocities does not show any significant deviation from a linear trend. This provides a clear explanation for the lack of any one-dimensional seismic signature in the lower mantle directly related to the spin crossover. Conversely, the elastic shear anisotropies of high-spin and low-spin ferropericlase are profoundly different, and should contribute to the shear wave anisotropy within the lower mantle.

References

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