Periodic dynamic oscillations of iron in diamond anvil cells

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Abstract

Dynamic diamond anvil cells (dDACs) are devices that can generate time-controlled stress. We used them to create periodic stress oscillations in order to study the viscoelastic behavior of hexagonal close-packed (hcp) iron. Iron with an hcp structure is considered to be a main component of the Earth's inner core[1]. Consequently, viscoelastic effects in iron are related to seismic attenuation deep within the Earth[2]. However, hcp iron only exists at pressures above ~15 GPa. For this reason, we had to perform experiments in a DAC.

Here, we compress iron foils in different pressure-transmitting media (PTMs) and apply different stress amplitudes at varying frequencies to observe the viscoelastic response of the system. The periodic stress oscillations are generated by a remotely controlled piezo element that pressed the DAC at pressures between 25 and 110 GPa. We derive the magnitude of the stress/strain oscillations in the pressure chamber by analyzing the variation in interplanar distances and peak widths by in-situ X-ray diffraction. Although our results require further investigation, we clearly observed a time shift in strain and stress between the iron and the different PTMs. This proves the fundamental possibility of studying viscoelasticity by dynamic oscillations in a DAC.

Periodic time dependencies of interplanar distances and peak widths show the time shift in these parameters between PTMs and iron sample. This time shift in periodic effects between PTM and iron points out to the occurrence of viscoelastic relaxation in the sample assembly. Based on the frequency of oscillation, we can recalculate the time shift to the phase lag and thus derive a version of quality factor Q. The experiments raise many questions regarding the origin of the observed quality factor Q. Therefore, our experimental work is being complemented with elasto-viscoplastic self-consistent (EVPSC) modeling of the deformation of iron and its response, as measured using X-ray diffraction. Ultimately, we expect to gain an understanding of the processes involved in periodic dynamic oscillations in a DAC. This should pave the way for the use of dDAC for viscoelasticity measurements under high-pressure conditions.

References:

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