Rheology of dhcp-FeH_x: An experimental study using a D111-type high-pressure deformation apparatus at SPring-8, BL04B1

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Based on seismic observation, it has been widely known that the Earth's inner core contains certain amounts of light elements as well as the outer core. Among the light element candidates, hydrogen is one of the most important candidates in the core (e.g. Wang et al., 2021). If, in the early Earth magma ocean, their exist water supplied from the Earth’s source material, it is reasonable that core-forming iron contain large amount of hydrogen because of its partition coefficient (e.g. Li et al., 2020). Seismic observations have revealed presence of strong anisotropy in the Earth’s inner core. Although many hypotheses have been proposed for the origin of the inner core seismic anisotropy, there is no general consensus for its origin partly due to lack of accurate information of viscosity in the inner core (e.g. Lasbleis and Deguen, 2015). In this study, we have studied effect of hydrogen on the rheology of iron based on high-pressure and high-temperature deformation experiments.
A high-pressure deformation apparatus D111-type apparatus, which is a larger version of the deformation T-Cup (Hunt et al., 2014) was recently installed on a synchrotron beamline BL04B1, SPring-8. In this apparatus, well-controlled deformation experiments can be conducted up to ˜30 GPa by driving two opposed second-stage anvils in the Kawai-type multi-anvil assembly (Nishihara et al., 2020).
High-pressure and high-temperature deformation experiments with quantitative stress and strain measurements have been carried out using the D111-type apparatus in conjunction with synchrotron radiation. In this study, we have conducted in-situ high-pressure deformation experiments on double hexagonal close-packed (dhcp) iron hydride (FeH_x) using this apparatus. In the experiments, rod-shaped polycrystalline iron was surrounded by NH_3BH_3 hydrogen source. The dhcp-FeH_x was synthesized by heating the iron sample and the hydrogen source and deformed uniaxially.
Steady-state deformation of dhcp-FeH_x with x˜0.8 was observed at 17 conditions in pressure of 12.7-16.1 GPa, temperature of 623-823 K, and strain rate of 0.3-6.5 x 10^{-5} s^{-1}. Stress values of dhcp-FeH_x were only slightly lower (˜0.5-0.7 times) than those of hcp-Fe at same conditions. This result suggests that influence of hydrogen on the inner core viscosity is limited. On the other hand, the effect of hydrogen in the hcp-FeH_x with lower hydrogen content can be intrinsically different, and thus, the inner core viscosity should be discussed more carefully.

Keywords: rheology, iron hydride, inner core, high-pressure deformation experiments

