ε鉄の自己拡散に関する予備的結果

Preliminary result on iron self-diffusion in ε-iron

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Viscosity of the inner core is a key to understand the dynamics and structure of the core. The inner core super-rotation respect to the mantle is significantly related to the viscosity (e.g., Buffett, 1997). The seismic anisotropy observed in the inner core may be caused by the lattice preferred orientation of constituting materials (Morelli et al., 1986) formed during deformation of the inner core and hence viscosity is essential to understand the deformation rate. Recent seismic observations revealed that the seismic attenuation is heterogeneous in the inner core. The attenuation is larger in the western side of the inner core than that in the eastern side (Monnereau et al., 2010). Because the seismic attenuation can be regarded to be a function of viscosity, it is important for interpretation of the observed attenuation to estimate viscosity from the mineral physics. Diffusion is the most fundamental transportation properties and it is main controlling factor for deformation rate in any deformation mechanism. However, because of the difficulty for diffusion experiment on ε-iron, which is main constituting material of the inner core (Tateno et al., 2012), due to the limited stability of ε-iron higher than 40 GPa at >1300 k, direct measurement is not is available yet.
In this study, by using sintered diamond anvils, we conducted diffusion experiments at pressure ~50 GPa in a Kawai-type multianvil apparatus, “6-axis press”, installed at Okayama University, In the experiments, the natural isotopic iron and ^{54}Fe enriched iron was used as diffusion couple. On the recovered sample after diffusion annealing, diffusion profiles were obtained by the isotope imaging technique using SIMS1270 at Hokkaido University.
Diffusion coefficient at 1400 K was determined to be ~10^{-17} m^2/s in the present study although our result at present is preliminary one because diffusion length is small compared with the length of convolution effect and data is limited. The obtained value is 2-3 order smaller than self-diffusion coefficient in γ-iron at same temperature but ambient pressure. When homologous temperature scaling is applied, diffusion coefficient in the inner core condition is estimated to be ~10^{13} m^2/s by using $T/T_m = 0.9$ (where T_m is melting temperature) and melting curve of iron (Anzellini et al., 2013).
The estimated diffusion coefficient suggests that Harper-Dorn creep may be the dominant deformation mechanism among dislocation creep, diffusion creep and Harper-Dorn creep. Assuming the dominant of Harper-Dorn creep, viscosity of the inner core is calculated to be 10^{12} Pas consistent with previous estimations based on mineral physics (Van Orman, 2004) and geophysics (Buffett, 1997). In the future work, effect of light element on diffusion will be investigated to understand the origin of the heterogeneity observed in seismology.

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