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論 文 要 旨
THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The Earth's solid inner core is thought to be composed of predominantly iron, ~5 wt. % of nickel and some minor amount of light elements. After discovery of P wave traveling ~3-4 % faster along polar direction than that along equatorial direction, various seismological explorations have revealed its complicated anisotropic structure. Viscous flow in the inner core can induce lattice preferred orientation of iron alloys composing the inner core, which would eventually lead to elastic anisotropy suggested by seismological observations. Several geodynamic models have been suggested to clarify possible driving forces and details of the viscous flow. However, despite that robustness of each mechanism is critically dependent on viscosity and thermal conductivity of the inner core, the two physical parameters of the inner core are yet poorly estimated. This thesis focuses on estimating diffusivity and anisotropic thermal conductivity of the inner core, which put constraints on inner core viscosity and thermal conductivity respectively.

We first present our new experimental technique combining secondary ion mass spectroscopy and internally resistive heated diamond anvil cell (IRHDAC). This technique allows us to conduct preliminary experiments on self-diffusion of iron under high pressure at 25 GPa and stable temperature conditions higher than 1500 K. Our preliminary results show three distinctive distribution of iron isotope tracers in the specimens characterized by 1) lattice diffusion, 2) diffusion along high diffusivity paths and 3) melting of the specimen respectively. We estimated lattice diffusion coefficient from the specimen showing aspects of lattice diffusion. Our result is the first experimental estimation of self-diffusion coefficient of iron under high pressure of 25 GPa. Estimated diffusion coefficient shows consistent result with previous studies on Fe-Ni inter-diffusion at similar pressure and temperature conditions. Our finding implies that Fe-Ni inter-diffusion is more or less equivalent to self-diffusion of iron.

Since the inner core contains certain amount of light elements including silicon, we further evaluate effects of light element on diffusivity in the inner core from Fe-Ni inter-diffusion experiments in Fe-Si 2 wt.% alloy. For heating diffusion couple, we used IRHDAC having identical geometry with the one employed in self-diffusion experiments of iron. Owing to the IRHDAC, temperature profiles show stable and homogeneous temperature across heated specimens compare to traditional laser heated diamond anvil cell. After diffusion experiments, we analyze the specimen using energy dispersive X-ray spectroscopy mounted on transmission electron microscope (TEM-EDS). Elements mapping using TEM-EDS reveals both lattice diffusion and grain boundary diffusion in a wide range of specimen. We obtained diffusion profiles across the diffusion boundary of specimens by TEM-EDS and estimated lattice diffusion coefficients. Diffusion coefficients estimated in this study are self-consistent and follow homologous temperature relationship. We also estimated activation volume of diffusion, which is consistent with an experimental estimation on Fe-Ni inter-diffusion employing multi-anvil press. We further predict diffusivity of the inner core from homologous temperature relation.

Next, we present our experimental results on texture development of hexagonal closed packed (hcp) iron under high pressure in a DAC for our further study on its anisotropic thermal conductivity. We first prepared foils of single crystal iron (body centered cubic, bcc iron) having three different orientations and loaded it into DAC to produce hcp iron having different crystallographic textures. X-ray diffraction experiments and texture analysis on the specimens reveal that there are relationships between bcc iron and hcp iron, which can be attributed by Burgers model of phase transformation. Selecting pressure medium having high hydrostaticity is important to avoid deformation of specimens and resulting destruction of characteristic crystallographic texture.

Specimens having distinctive crystallographic textures enable estimation of anisotropic physical properties. We measured thermal conductivity of the hcp irons transformed from single crystal bcc irons and further evaluate anisotropy in thermal conductivity of hcp iron. Our result can reconcile discrepancy between experimental estimations on thermal conductivity of hcp iron under core conditions. We argue that combined effects of texture development and anisotropic thermal conductivity of hcp iron result the discrepancy between previous studies. We further estimate thermal conductivity of the inner core by reconcile the previous studies.

From estimated diffusion coefficient and anisotropic thermal conductivity of iron and its alloy, we put constraints on the upper bound of viscosity and thermal conductivity of the inner core, which are ~4.23 x 10^{15} Pa s and ~330-479 W/mK respectively. First, this high thermal conductivity will lead to stable stratification of the inner core and make its thermal convection implausible. Combining stably stratified inner core with low viscosity estimated in this study suggest viscous flow driven by Lorentz force as a likely mechanism inducing inner core anisotropy.