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論文 / 著書情報
Article / Book Information

題目(和文)	高圧力下超音波測定に基づく地球深部の化学組成の制約
Title(English)	Constraints on the composition of the deep Earth based on high-pressure ultrasonic measurements
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	地球惑星科学 系 地球惑星科学 コース	申請学位（専攻分野）： Academic Degree Requested	博士 （理学） Doctor of
学生氏名： Student's Name	若松 達也	指導教員（主）： Academic Supervisor(main)	太田 健二 准教授
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The knowledge on the chemical composition of the deep Earth is key information to understanding the origin, evolution, and dynamics of our planet. By comparing the observed seismic wave velocity profile of the Earth's interior with laboratory-based sound velocity data in candidates, we can provide tight constraints on the composition of the deep Earth. In this thesis, we performed high-pressure ultrasonic measurements on candidate materials of the lower mantle and the core via a combination of the femtosecond pulse laser pump–probe technique and a diamond anvil cell (DAC).

In chapter 1, the compositional model of the lower mantle and the core and previous studies on high-pressure acoustic velocity determinations were summarized. For the lower mantle, two major models have been proposed, which are characterized by the Si/Mg ratio. One is the pyrolitic model with the homogeneous composition as the upper mantle. Another model is the perovskitic lower mantle with a higher Si/Mg ratio than that of the upper mantle. The core is thought to be made of Fe-alloy with a considerable amount of light element(s) as well as Ni, but the detailed composition is still unclear. The longitudinal wave velocity (V_P) at high pressures is the effective parameter to explore the deep Earth composition since it is sensitive to the impurity and the spin state of the sample. However, previous experimental work on the V_P in candidate materials of the deep Earth is limited because of some technical problems in the conventional methods.

In chapter 2, we developed new methods to measure the V_P of non-metal samples using the femtosecond pulse laser pump–probe technique and examined the V_P of $MgSiO_3$ and $Mg_{0.88}Fe_{0.13}Al_{0.11}Si_{0.91}O_3$ bridgmanite (bdg). The coupled incorporation of Fe and Al decreased the V_P of bdg by 3-4% compared to that of $MgSiO_3$ under our experimental pressures. Our results indicated that there was no significant effect of the spin transition of Fe on the V_P in Fe and Al-bearing bdg. The modeled V_P and shear wave velocity (V_S) in $Mg_{0.88}Fe_{0.13}Al_{0.11}Si_{0.91}O_3$ bdg along the geotherm gradually increases with depth and remains 2-3% and 1-2% higher than the seismic observation throughout the lower mantle, respectively. This implies that $Mg_{0.88}Fe_{0.13}Al_{0.11}Si_{0.91}O_3$ bdg is the dominant phase in the lower mantle, but some amount of other minerals, such as (Mg,Fe)O ferropericlase (fp) and/or $CaSiO_3$ perovskite (Ca-pv), would coexist.

In chapter 3, we investigated the V_P of $Mg_{0.81}Fe_{0.19}O$ fp, a second-major lower mantle mineral. The V_P of $Mg_{0.81}Fe_{0.19}O$ fp significantly decreased at the pressure range of the spin transition of Fe^{2+}. We modeled the V_P and V_S along the geotherm taking the effect of spin transition into account, of which validity was confirmed by high-temperature V_P measurements to 750 K using an externally resistive heated DAC. It was found that the reduction of the V_P in $Mg_{0.81}Fe_{0.19}O$ fp can occur at the middle to lower part of the lower mantle, while the influence of the spin transition on V_S was small. Such a notable reduction of the V_P in fp may affect the aggregate seismic properties of the lower mantle.

In chapter 4, we measured the V_P of hexagonal-close-packed (hcp) structured Fe, Fe–5 wt% Ni, and Fe–15 wt% Ni, a main component of the core. We found that the effect of Ni on the V_P of Fe-based alloy is weaker than that determined by a previous experimental study. Our extrapolated V_P-density (ρ) data indicate that ~4.7% and ~5.2% density deficit and ~5.5% and ~4.6% reduction in V_P are required to match the seismic observation for Fe-5 and 15 wt.% of Ni at the inner core boundary (ICB), respectively.

In chapter 5, we measured the V_P of iron hydrides up to Mbar pressure. The hydrogen incorporation into Fe increases the V_P of Fe at the constant pressure (P) and ρ. The slope in the V_P-P and V_P-ρ relationship of face-centered-cubic (fcc) FeH changes abnormally around 60 GPa and 8.8 g/cm^3, respectively, corresponding to the reported condition of magnetic transition. Extrapolated V_P-ρ relation of nonmagnetic fcc-FeH showed that hydrogen has a significant effect on decreasing both V_P and ρ of Fe alloy under ICB conditions. We found that V_P and ρ in Fe-Ni alloy with 1.07(10) wt.% H can match the seismic observation at ICB if hydrogen is a sole light element in the core.

In the final chapter, we discussed the compositional model of the lower mantle and light element(s) in the core based on present high-pressure ultrasonic measurements. Our results suggested that bdg-rich (Si-rich) lower mantle with ~88 vol.% bdg, ~5 vol.% fp, and ~7 vol.% Ca-pv can better reproduce the seismic observation, which is a distinct composition from the upper mantle. Besides, the Si content in the core was estimated to be 1.20-3.70 wt.% from our Si-rich lower mantle compositional model, assuming that the Earth's building material is mainly carbonaceous chondrites. The value of 3.70 wt.% Si can be the upper limit in the inner core. Based on the V_P-ρ relationship at ICB, the possible H amount in the inner core was calculated to be 0.53-1.07 wt.%, indicating that the core can be a large reservoir of hydrogen.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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