

論文 / 著書情報
Article / Book Information

題目(和文)	高圧下における液体鉄ニッケル硫黄合金の弾性波速度・密度測定
Title(English)	Sound velocity and density of liquid Fe-Ni-S alloy at high pressure
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種別(和文)	論文要旨
Type(English)	Summary

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論文要旨

THESIS SUMMARY

専攻： Department of	地球惑星科学	専攻	申請学位 (専攻分野)： Academic Degree Requested	博士 (理学)
学籍番号： Student ID Number	12D04017		指導教員 (主)： Academic Advisor(main)	廣瀬 敬
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The liquid Earth's outer core is mainly constructed of iron (Fe)-nickel (Ni) alloy. The Earth's core was found to be less dense than pure iron comparing the core density with density of solid pure iron estimated from its equation of state, which is called core density deficit problem. From cosmochemical abundances and geochemical model, hydrogen (H), carbon (C), nitrogen (N), oxygen (O), silicon (Si), and sulfur (S) are thought to be possible candidates to induce the core density deficit. The density contrast between the outer core and the pure iron has been estimated to be 5-10%, depending on the assuming outer core geotherm. Both the nature and the amount of core light elements have been left as one of the biggest enigma of the Earth science for more than 60 years. In this thesis, sulfur is focused on as a light element in the core. Sulfur has high solubility to liquid iron even at low pressure and missing in the mantle compared to the other volatile elements. This implies that sulfur has been trapped into the liquid iron during metal-silicate partitioning in magma ocean. Through this thesis, density and sound velocity of liquid (Fe,Ni)₃S have investigated under high pressure and high temperature conditions to constrain the chemical composition of the Earth and the other planetary cores. In Chapter 1, we introduce the history of research for the chemical composition of the Earth's core, density and sound velocity of pure iron as a reference to discuss the density deficit problem. In addition, previous works were reviewed which investigated the phase relations, physical properties, and chemical properties of the iron-light element(s) alloys. In Chapter 2, principles of density determination from diffused scattering in X-ray diffraction patterns and sound velocity measurements via inelastic X-ray scattering spectroscopy are mentioned. Experimental development was introduced to achieve sound velocity measurement on liquid iron alloy at high pressure in diamond anvil cell (DAC) high pressure apparatus. In Chapter 3, density of liquid Fe_{46.5}Ni_{28.5}S₂₅ was measured and reported in a pressure range of 25-70 GPa at 3200 K by X-ray diffraction method using laser-heated DAC. Obtained density data were fit to the third-order Vinet equation of state, and determined bulk modulus and its pressure derivative at 1 bar to be $K_0=17.06(626)$ GPa and $K_0'=6.96(150)$ with fixed $\rho_0=4680$ kg/m³. Our data indicate that alloying 25 at% sulfur reduced density about 14% from liquid pure iron. In Chapter 4, the project on sound velocity measurements of liquid (Fe,Ni)₃S was described via high-resolution inelastic X-ray scattering spectroscopy in DAC up to 46 GPa. Density dependence of sound velocity of liquid (Fe,Ni)₃S was determined using density data obtained in Chapter 3. In this study, significant temperature effect on sound velocity was not observed in the experimental temperature range from 1500 K to 2500 K. Such a small temperature dependence is consistent with the conclusion in previous theoretical studies. Our study reveals that alloying sulfur increases the sound velocity of liquid iron-nickel alloys. In Chapter 5, the density and sound velocity of liquid (Fe,Ni)₃S were estimated under the Earth's outer core pressure-temperature conditions, combining with present density and sound velocity data, and thermal expansion coefficient proposed in previous study. It was found that the sound velocity of liquid (Fe,Ni)₃S is slightly faster than P wave speed of PREM, and density of liquid (Fe,Ni)₃S is almost consistent with the density of the Earth's outer core. Only Fe-Ni-S system can not explain the density and sound velocity of the outer core perfectly. Sulfur strongly partition in liquid iron in equilibrium of silicate melt and iron alloy, and has been found in iron meteorite as FeS troilite, iron-sulfur alloy. Sulfur is depleted in silicate Earth from CI chondrite, which is accepted as a building block of the Earth. In addition, liquid Fe-S alloy has a similar bulk modulus to that of the outer core. Therefore, though there should be the other light elements to explain both the density and sound velocity in the outer core, we conclude that sulfur is a major light element in the Earth's core from the consideration of geochemistry and physical properties of liquid iron-the other light element(s) proposed in previous works. The combination technique of inelastic X-ray scattering spectroscopy and diamond-anvil cell that we developed will provide sound velocity data of liquid iron alloys with various chemical compositions. Mar has long been believed to have sulfur enriched core relative to the Earth. The Martian interior model was also considered using our density data of liquid (Fe,Ni)₃S combined with estimated mineral assemblages in the Martian mantle. Our modeling indicates magnesium silicate perovskite layer would be a few tens kilometer thick. Such thin magnesium silicate perovskite layer would have little influence to the thermal convection in the Martian mantle. We also calculate the heat flow at the core-mantle boundary to be 0.4 TW using thermal conductivity of MgO (Appendix 3), magnesium silicate perovskite, and garnet.

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 2 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 2 copies of 800 Words (English).