論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Electrical and thermal conductivity of the Earth's core
著者(和文)	五味斎
Author(English)	Hitoshi Gomi
出典(和文)	学位:博士(理学), 学位授与機関:東京工業大学, 報告番号:甲第9392号, 授与年月日:2014年3月26日, 学位の種別:課程博士, 審査員:廣瀬　敬,綱川　秀夫,高橋　栄一,太田　健二,丸山　茂徳
Citation(English)	Degree:Doctor (Science), Conferring organization: Tokyo Institute of Technology, Report number:甲第9392号, Conferred date:2014/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

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 Doctor of　（　理学　）
学生氏名： Student's Name	五味　斎	指導教員（主）： Academic Advisor(main)	廣瀬　敬
		指導教員（副）： Academic Advisor(sub)	丸山　茂徳

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

Earth's magnetic field is re-generated by dynamo action via convection currents in the liquid metal outer core, which are in turn driven by a combination of thermal buoyancy associated with secular cooling (along with possible radioactive heating) and buoyant release of incompatible light alloying components upon inner core solidification. Prior to the crystallization of an inner core, the energy for maintaining a geodynamo must be supplied in excess of the heat conducted down the isentropic gradient that develops in the presence of convection, placing tight constraints upon the core's thermal evolution.

We measured the electrical resistivity of iron at room temperature up to 100 GPa in a diamond-anvil cell (DAC). Electrical resistance was measured by means of four-terminal method. While a sharp resistivity increase was observed during the body centered cubic (bcc) to hexagonal close packed (hcp) phase transition, the resistivity diminished with increasing pressure above 20 GPa in the stability range of the hcp phase (figure 2.3.2). A heating experiment was also conducted in a muffle furnace, which shown a liner temperature dependence and confirmed the Bloch-Grüneisen law up to 383 K at 65 GPa (figure 2.4.2). Experimental results show an excellent agreement with first-principles calculations at high pressure (figure 2.3.2 and 2.4.3). The resistivity was measured for Fe + 4 at.% Si to 70 GPa at 300 K, demonstrating a large effect of Si impurity (figure 3.3.1). Furthermore, resistivities of Fe-Ni alloys (5, 10, 15 wt.%Ni) were measured up to 80 GPa (figure 4.3.1), which shown a linear concentration dependence and confirmed the Matthiessen's rule. Resulting Ni impurity resistivity is negligible for the Earth's core composition.

We modeled the resistivity of iron alloys in the core, considering the effects of 1) pressure and temperature, 2) impurity resistivity of silicon and other possible core light alloying elements, and 3) resistivity saturation. Our model successfully reproduces previously reported shock wave data (Matassov, 1977) (figure 3.3.2). This is the first study that considers the saturation resistivity in geophysical literature, although it is a well-known effect in metallurgy (see Gunnarsson et al., 2003 for a recent review). The most important consequence of the saturation is that the resistivity of almost all kinds of metals cannot exceed 1.5 μm. This imposes a lower limit on the core's thermal conductivity through the Wiedemann-Franz law.

Assuming that silicon is the single light element in the core, the core conductivity is estimated to be 90.1(+9.9/-3.6) and 148(+28/-9) W/m/K at CMB and ICB, respectively. In order to evaluate the impurity resistivity of sulfur, oxygen, and carbon, we apply Norbury-Linde's rule for iron-based alloys as a rough estimate. Predicted thermal conductivities are in the range 84.2-130 and 136-220 W/m/K at the CMB and ICB, respectively (Table 3.4.1 and 3.4.2). These values are substantially higher than the conventional estimates of 28 and 29 W/m/K (Stacey and Loper, 2007), but consistent with recent first-principles calculations (de Koker et al., 2012; Pozzo et al. 2013) (figure 3.3.3). Our saturation model also predicts strong depth dependence of the core conductivity.

Since it suppresses the thermal convection in the Earth's core, such a large and depth increasing thermal conductivity have strong impacts on thermal structure, dynamics and evolution of the Earth's core. The possibility of convection in the Earth's solid inner core has long been discussed previously. We simply calculated the adiabatic heat flow at the top of the inner core (e.g. Yukutake, 1998; Cottaar and Buffett, 2012). Corresponding core-mantle boundary (CMB) heat flow, which is estimated from energy balance of the core (Labrosse 2003), is significantly higher than conventional estimate. This implies that thermal convection in the inner core is unrealistic. Large and depth increasing thermal conductivity also suppresses thermal convection in the fluid outer core, implying rapid secular core cooling higher than 9 TW at present. The energy balance in the core implies a young inner core (less than 1 Ga) and high initial CMB temperature (more than 4500 K). It suggests that the lowermost mantle must have been molten during the early Earth, which is consistent with the basal magma ocean model (Labrosse et al. 2007). An enhanced conductivity with depth suppresses convection in the deep core, such that its center may have been stably stratified prior to the onset of inner core crystallization.