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Electrical and thermal conductivity of the Earth's core

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 DAC. While a sharp resistivity increase was observed during the bcc to hcp phase transition, the resistivity diminished with increasing pressure above 20 GPa in the stability range of the hcp phase. A heating experiment was also conducted, which confirmed the Bloch-Grüneisen law up to 383 K at 65 GPa. Experimental results show an excellent agreement with first-principles calculations at high pressure. The resistivity was measured for Fe + 4 at.% Si to

70 GPa at 300 K, demonstrating a large effect of Si impurity. Furthermore, resistivity of Fe-Ni alloys were measured to 80 GPa. Resulting Ni impurity resistivity is negligible. 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). 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 μΩm. 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. 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).