The influence of sulfur on the electrical resistivity of hcp iron: implications for the core conductivity of Mars and Earth

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Abstract

Paleomagnetism and astrophysical studies disclosed the present or past existence of a magnetic field in telluric planets and satellites in our solar system [*Stevenson*, 2003; *Busse and Simitev*, 2015; *Connerney*, 2015]. The core dynamo process that converts kinetic energy into magnetic energy by dynamic motions in the liquid core is the most plausible mechanism for generating a long-lived magnetic field in the rocky planets and satellites [*Stevenson*, 2003]. In order to understand the mechanism of the Earth's core dynamo action, many efforts have been made to determine the electrical resistivity (the inverse of electrical conductivity) of the Earth's core materials. Still, there is no report of the electrical resistivity of iron-sulfur (Fe-S) alloy at high pressures, despite the fact that S is a major light element(s) candidate in the Earth's core because of its depletion in the crust and mantle relative to elements with similar volatilities [*Rama Murthy and Hall*, 1970; *Poirier*, 1994]. In addition, S may be an important light element in the Martian core [*Wanke and Dreibus*, 1988; *Lodders and Fegley*, 1997], and the influence of S on the conductivity of Fe alloy may have important implications for the ancient dynamo action and thermal evolution of the Martian core. In this study, we measured the electrical resistivity of Fe-Si-S alloy with hexagonal-closed-packed (hcp) structure to 110 GPa in a diamond anvil cell (DAC). The obtained electrical resistivity of the hcp Fe-Si-S was analyzed to reveal the influence of S on the electrical resistivity of Fe alloy in combination with the reported resistivities of Fe and Fe-Si alloy at high pressures [*Gomi et al.*, 2013, 2016]. We determined the impurity resistivity that does not have temperature dependence of S in a hcp Fe matrix at high pressures. We found that the impurity resistivity of S is lower than that of Si and unpredictable from the Norbury-Linde rule. Therefore, S is a weaker influence on the conductivity of Fe alloy, even if S is a major light element in the planetary cores. To the best of our knowledge, this is the first demonstration of the electrical and thermal conductivity profiles of the Mars's and Earth's cores including S as a major light element, which would help to study thermal evolution and dynamics in the core of telluric planets.

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