Physics of the Earth and Planetary Interiors, 7 (1973) 217–218

ELECTRICAL CONDUCTIVITY OF MOLTEN Fe–Ni–S–C CORE MIX

M.J.S. JOHNSTON * and R.G.J. STRENS

Department of Geophysics and Planetary Physics, School of Physics, The University, Newcastle upon Tyne (England)

Accepted for publication 28 October 1972

The electrical conductivity of liquid $(Fe_{90}Ni_{10})_3S_2$ saturated with 2.6 weight percent carbon averages $2.7 \cdot 10^5$ mho/m at 1000°C and zero pressure. This may imply a slightly lower electrical conductivity for the earth's core than that obtained by extrapolating the properties of pure liquid iron and solid iron alloys to core pressures and temperatures. Although a sulphur-rich core would have a smaller proportion of sulphur, the effect of lowering the sulphur content of the Fe–Ni–S–C liquid to about 15 weight percent would be unlikely to increase the conductivity above $5 \cdot 10^5$ mho/m.

1. Introduction

It has been suggested on both geochemical and geophysical grounds that the presence of sulphur in the outer core contributes the 15% of light elements required to lower the density from that expected for a liquid nickel–iron mixture to that inferred from seismological and shock-wave work (McQueen and Marsh, 1966; Balchan and Cowan, 1966; Haddon and Bullen, 1969; Murthy and Hall, 1970; Hall and Murthy, 1971; Lewis, 1971; Stacey, 1972). By analogy with iron meteorites (Wood, 1963), small amounts of carbon and phosphorus would also be expected. The presence of these light elements reduces the zero-pressure liquidus temperature to about two-thirds the melting point of pure iron. The electrical properties of Fe–Ni–S–C liquids are not well known, and it is the purpose of this note to provide a starting point for the extrapolation of the conductivity of such melts to core pressures and temperatures.

Gardiner and Stacey (1971) have estimated core conductivity by extrapolating the properties of pure liquid iron and solid iron alloys, whilst Stacey (1972) has attempted to place geophysical limits on the range of allowed values. The theory of the self-sustaining dynamo yields a rather crude lower limit of about 10^4 mho/m, by the requirement that substantial convection, as well as diffusion, of the magnetic field should occur. A more stringent upper limit on the conductivity of the outer core comes from the relation between electrical and thermal conduction (Wiedemann Franz law), since to obtain a realistic heat flux from the core an upper limit of about $8 \cdot 10^5$ mho/m is placed on the electrical conductivity.

* Now at U.S. Geological Survey, National Center for Earthquake Research, Menlo Park, Calif., U.S.A.

2. Experimental techniques and results

Experimental work was confined to the vicinity of the eutectic composition in the Fe–S system, which lies very near Fe_3S_2 at 1 atm. and 990°C (Brett and Bell, 1969). Material of composition M_3S_2 (where $M = Fe_{90}Ni_{10}$) was prepared by heating iron and nickel powders with sulphur in an evacuated silica tube until reacted, and then holding the molten mixture in a graphite crucible for 6 hours at 1000°C to ensure reduction of any oxides and saturation with carbon (the electrode material). The effect of nickel on the solidification point was negligible, but about 2.6 weight percent of carbon entered the melt, reducing the onset of melting to 920°C.

The mixture was placed in semi-cylindrical alumina boats 9 cm long and 5 mm wide. A stabilised current of 100 ± 0.1 mA was passed through it by means of graphite electrodes set in the ends of the boats, and