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Heat Flow in the Cores of Terrestrial Bodies from High P,T Resistivity Experiments on Liquid Fe Alloys

RICK SECCO

Western University

Presenting Author: secco@uwo.ca

Many terrestrial bodies have or had magnetic fields generated by dynamo action within a liquid core. Two important sources of energy driving a dynamo are thermal convection and chemical convection arising from the growth of a solid inner core. Prior to inner core nucleation, dynamo action relies on thermal convection which can only occur when the adiabatic core heat flow (Q_{ad}) is less than the heat flow through the core mantle boundary (Q_{CMB}). Determination of the thermal conductivity of core mimetic liquids at relevant pressure-temperature conditions allows calculation of Q_{ad}. Along with estimates of Q_{CMB}, the likelihood of thermal convection can be assessed.

We have determined the thermal conductivity of several pure metallic elements, including Fe and Ni as well as binary and ternary alloys of S and/or Si by experimental measurements of the electrical resistivity in large volume multi-anvil presses. Using a four-wire technique, where current-voltage electrodes are made of thermocouples, and a polarity switch, measurements of electrical resistivity in are made in both solid and liquid states. Microprobe analyses of samples recovered from P up to 24 GPa and T up to 2350 K verify containment of the liquid and show that samples maintain compositional fidelity up to the melting temperature. Contamination of the sample by the metal disk shielding the thermocouple/electrodes from the sample begins after melting and depends on P,T and time spent in the liquid state.

Our resistivity results are used to assess variation of resistivity along the P,T melting boundary and to calculate the electronic thermal conductivity using the Wiedemann Franz relationship. Core conductive heat flow values are calculated and compared with estimates of heat flow through the core-mantle boundary. Our heat flow calculations indicate when and for how long thermal convection operated in the cores of Earth, Moon, Mercury, Ganymede and asteroid 4 Vesta.