Thermal conductivity of the deep Earth's minerals

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Knowledge of thermal conductivity of the deep Earth's materials is critical for understanding of the Earth's thermal structure, evolution, and dynamics. Here we report on direct measurements of the lattice and radiative thermal conductivity of mantle and core materials under the pressure-temperature (*P*-*T*) conditions approaching those in the Earth's mantle and core by using optical spectroscopy and pulsed laser techniques in diamond anvil cells (DAC).

We developed and tested a new flash-heating high-pressure technique to measure thermal diffusivity, which involves time-resolved radiometry combined with a pulsed IR laser source [Beck et al., 2007]. The results for MgO, NaCl, and KCl obtained to 32 GPa and 2600 K agree with previous studies at low pressure and high temperature and enable tests of models for the combined pressure-temperature dependence of thermal conductivity. Preliminary results on the thermal conductivity of magnesium silicate perovskite to 125 GPa and 4000 K and [Goncharov et al., 2010] suggest a larger value than what was previously estimated, although the uncertainty is very large. Future accurate experimental measurements of the phonon contribution to the thermal conductivity of lower mantle materials will require a number of carefully crafted experiments under high pressure and temperature conditions to determine the thermal conductivity of all the materials used in the DAC. Measurements of the thermal conductivity of Ar are currently in progress and they will be presented at the meeting.

To determine the thermal conductivity of Fe and its temperature dependence at high pressures we use combined continuous and pulsed laser heating techniques. A thin plate of Fe is positioned in a medium (e.g., Ar), laser heating is applied from one side and the temperature is measured from both sides of the sample radiometrically. The thermal conductivity is determined by fitting the results of finite element calculations to the experimental results. This work is currently in progress.

Another technique of measurements of the thermal conductivity, time-domain thermoreflectance (TDTR), has been recently applied for the DAC studies [Hsieh et al., 2009]. A collaborative study of the thermal conductivity of MgO single crystal (as a benchmark sample) at high pressures with a group of Prof. D. Cahill (University of Illinois) is currently in progress, and the preliminary results will be reported at the meeting.

We will also present optical absorption data for lower mantle minerals to assess the effect of composition (including iron oxidation state), structure, temperture, and iron spin state on radiative heat transfer. The ultimate goal is to determine through these measurements the radiative thermal conductivity of the Earth's lower mantle. Optical absorption spectra have been measured at pressures up to 133 GPa for major mantle minerals, including ferropericlase (Mg, Fe)O, silicate perovskite $(Mg_{0.9}Fe_{0.1})SiO_3$, and postperovskite $Mg_{(1-x)}Fe_xSiO_3$ (x=0,1÷0,3). We find that optical absorption spectra of lower mantle minerals depend on composition (including iron oxidation state), structure, and iron spin state. We find that the presence of ferric iron in perovskite and ferropericlase strongly affects the optical properties, while the effect of the spin pairing transition may be more secondary [Goncharov et al., 2006; 2008; 2009; 2010]. We also show that post-perovskite exhibits larger than perovskite optical absorption in the near infrared and visible spectral ranges which may have a profound effect on the dynamics the lowermost mantle. Absorption spectra of ferropericlase up to 800 K and 60 GPa show minimal temperature dependence.

The estimated pressure-dependent radiative conductivity, k_{rad}, from these data is 2—5 times lower than previously inferred from model extrapolations [Goncharov et al., 2009], with implications for the evolution of the mantle such as generation and stability of thermo-chemical plumes in the lower mantle. Further work is required for an accurate assessment of the radiative component of the thermal conductivity of lower mantle minerals, including the study of compositional and structural properties, as well as the iron spin state. These include (but are not limited to) study of mantle minerals with compositions more realistic for the Earth's interior (e.g., containing Al).

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