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Thermal diffusivity of olivine-group minerals at high temperature

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ABSTRACT

Thermal diffusivity (D) data from 12 oriented single crystals and seven polycrystalline samples of olivine group minerals were acquired with the laser-flash method at temperatures (T) of up to ~1500 °C. Samples included forsterite, Fe-Mg binary olivines, sinhalite, and chrysoberyl; specimens were characterized using infrared spectroscopy and electron microprobe analysis. Crystal orientation and chemistry both affect D. For our single crystals, $D_{[100]} > D_{[001]} > D_{[010]}$ at all temperatures. Thermal diffusivity decreases with increasing T and becomes virtually constant at high temperatures. At room temperature, $D_{[001]}$ of pure forsterite has the highest observed values, but substitution of a small amount of Co in forsterite (0.3 wt% CoO) lowers D by ~20%. Substitution of ~10% Fe for Mg in forsterite, as in typical mantle olivine, lowers D by ~50%. At room temperature, mantle olivine has D = 3.25, 1.66, and 2.59 mm^2/s for the [100], [010], and [001] orientations, respectively. The values decrease to 0.93–0.87 mm^2/s at 790–985 °C for [100], 0.54–51 mm^2/s at 590–740 °C for [010] and 0.83–0.79 mm^2/s at 740–890 °C for [001]. Two dunite samples have D of 0.55–0.56 mm^2/s at 890–1080 °C, showing the effect of preferred orientation of grains dominated by [010]. Thermal diffusivity of polycrystalline samples is controlled by the large amounts of olivine present; minor phases offset the curves for $D(T)$ from the value of the olivine mineral. Our laser-flash measurements isolate the phonon component of heat transfer from radiative transfer and show that the phonon contribution becomes nearly constant for the high temperatures expected in the mantle. The other microscopic component (diffusive radiative transfer) depends strongly on temperature and this temperature dependence likely exerts greater control on mantle convection.

Keywords: New technique, laser-flash method, high-temperature studies, thermal diffusivity of olivine, olivine-group minerals