Temperature- and pressure-dependent radiative thermal conductivity of transition zone minerals – Implications for the Earth's interior

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Optical absorption spectra of high-pressure minerals can be used as indirect tools to calculate radiative conductivities of the Earth's interior [e.g., 1]. Recent high-pressure studies imply that e.g. ringwoodite, γ-$(Mg,Fe)_2SiO_4$, does not become opaque in the near infrared and visible region, as previously assumed, but remains transparent to 21.5 GPa [2]. Therefore, it has been concluded that radiative heat transfer does not necessarily become blocked at high pressures of the mantle and ferromagnesian minerals actually might contribute to the heat flow in the Earth's interior [2]. However, experimental results on temperature effects on radiative heat transfer are not available.

We studied the effect of both, pressure and temperature, on the optical absorption of hydrous Fe-bearing ringwoodite, γ-$(Mg,Fe)_2SiO_4$, and hydrous Fe-bearing wadsleyite, β-$(Mg,Fe)_2SiO_4$, which are the main components of the Earth's transition zone. Gem-quality single-crystals were synthesized at 18 GPa and 1400 °C in a 5000t multianvil apparatus. Crystals were analyzed by Mössbauer and Raman spectroscopy, electron microprobe analysis and single-crystal X-ray diffraction.

For optical absorption measurements in the IR - VIS - UV spectral range (400 – 50000 cm^{-1}) 50 µm sized single-crystals of ringwoodite and wadsleyite were double polished to thicknesses of 13 µm and 18 µm, respectively, and loaded in resistively heated diamond-anvil cells with argon as pressure medium. After taking measurements at high pressure and room temperature, ringwoodite was studied at 26 GPa up to 650 °C and wadsleyite spectra were recorded at 16 GPa up to 450 °C.

At ambient pressure the absorption spectrum of ringwoodite reveals a crystal field band (Fe^{2+}) at 12075 cm^{-1}, an intervalence charge transfer band (Fe^{2+} to Fe^{3+}) at 16491 cm^{-1}, and an absorption edge due to ligand-metal charge transfer close to 30000 cm^{-1}. The wadsleyite spectrum is characterized by a similar absorption edge in the VIS-UV range and by two broad bands at ~10000 cm^{-1} and ~15000 cm^{-1}, which are crystal field and intervalence charge transfer band, respectively. With increasing pressure the absorption spectra of both compositions change uniformly, crystal field and intervalence charge transfer bands continuously shift to higher frequencies. This has been observed for ringwoodite [2] but is contrary to earlier presumptions for wadsleyite [3].

Here, we present radiative conductivities calculated from high-pressure/high-temperature optical absorption spectra. We discuss the contribution of transition zone minerals to radiative heat transfer in the Earth's mantle.

References:
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