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Thermal properties of hydrous minerals under pressure

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We measured thermal diffusivity, thermal conductivity and heat capacity of hydrous minerals, and found their particular behavior in the thermal property. Among hydrus minerals, serpentine ($Mg_6Si_4O_{10}(OH)_8$) and talc ($Mg_3Si_4O_{10}(OH)_2$) are thought to be important, because their water exchange among major components, olivine or peridotite. Measurements were conducted using a pulse heating method in the Kawai apparatus. Antigorite has much lower thermal diffusivity and thermal conductivity (less than half) of the major dry mantle minerals such as olivine. The pressure derivative of thermal diffusivity or thermal conductivity is small compared with olivine. On the other hand, talc has relatively higher thermal conductivity compared with antigorite. Antigorite and talc are quite similar hydrous sheet minerals. Although talc, one of the softest mineral, has lower acoustic velocity than antigorite, thermal conductivity of talc is two to three times greater than that of antigorite. This apparent contradiction may be attributed to alternating wavy structure in antigorite with a few nanometer wave length. In terms of a simple calculation, phonons excited at 300 K tend to have wavelengths shorter than 1 nm. Therefore, phonons may be trapped in a wavy segment of the antigorite crystal structure. This can cause lower thermal conductivity for antigorite. Heat capacity is obtained from the simultaneous measurement of thermal diffusivity and thermal conductivity. The heat capacity of antigorite at ambient temperature is ca. 1.0 x 10^3 $Jkg^{-1}K^{-1}$ and nearly independent of pressure increase, that is, the pressure derivative of heat capacity of antigorite is nearly zero. This value contrasts with the negative value for olivine. On the other hand, preliminary results for talc showed the positive pressure derivative. From the pressure derivatives of heat capacity, we can evaluate characteristics of the thermal expansivity. We can expect nearly constant thermal expansivity for antigorite for some assumptions. In other words, the volume of antigorite increases almost linearly with temperature. From lattice dynamic theory, we can define the mode Grueneisen parameter for the normal mode of lattice vibration. Note that the positive parameter contributes to positive thermal expansion, and vice versa. Thus, the majority of the parameter for olivine is expected to be positive. On the other hand, some of the parameter for antigorite and talc are expected to be negative. It is quite probable that the hydrous mode, or normal mode related with hydrogen and hydroxyl groups, may have a negative mode Grueneisen parameter. Thus, hydrous minerals reveal particular thermal properties and its behavior is different from major mantle minerals such as olivine.

Keywords: thermal diffusivity, thermal conductivity, heat capacity, high-pressure, hydrous mineral