Thermal equation of state of calcium ferrite-type NaAlSiO4

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Density difference of the subducted mid oceanic ridge basalt (MORB) relative to the ambient peridotitic mantle is very important to understand the geodynamics and chemical evolution of the Earth (e.g., Irifune and Ringwood, 1987). In the lower mantle conditions, MORB composed of Mg-perovskite, Ca-perovskite, stishovite and Al-phase with Ca ferrite-type structure (Ca ferrite phase) (e.g., Kesson et al., 1994; Ono et al., 2001). The stability condition and physical properties of Ca ferrite phase are less investigated than the other phases. MgAl2O4 and NaAlSiO4 are the most important end-members of Ca ferrite phase in MORB. In order to study the dynamics of subducted oceanic crust, we have measured lattice parameters of Ca ferrite-type NaAlSiO4 at wide range of P-T condition, and determined its thermal equation of state.

Ca ferrite-type NaAlSiO4 was synthesized from reagents by using a multi-anvil apparatus SEDI-1000 installed at Tokyo Institute of Technology at 25 GPa and 1873 K for 2 h. The reagents of Na2CO3, Al2O3 and SiO2 are mixed to possess desired ratio, decarbonated, heated at 1373 K for one night and used for synthesis experiment. In situ X-ray observation experiments were conducted using the MAX-3 multi-anvil apparatus installed at the synchrotron beam line (BL14C2) in the Photon Factory at National Laboratory for High Energy Accelerator Research Organization, Tsukuba, Japan. Double-stage compression was made with seven WC and one sintered diamond (ADC, for X-ray window) cubic anvils (10 x 10 x 10 mm3). Sample assembly with LaCrO3 pressure transmitting medium, Re sheet heater, W-Re thermocouple and WC cubic anvil (TEL = 2 mm) were used. Careful attention was made to achieve hydrostatic sample environment even at high pressures. A sintered chip (not powder) of sample was used. The sample and pressure marker (mixture of Au and MgO) were packed into NaCl sample chamber separately. Only the data collected after heating above 873 K were used for subsequent calculation. Pressures were calculated by the EOS of Au (Anderson et al., 1989).

The lattice parameters were calculated from 8-10 isolated diffraction lines of Ca ferrite-type NaAlSiO4. P-V-T data were collected at 23 conditions up to 20 GPa and 1073 K. Derived P-V-T data were fitted to high-temperature Birch-Murnaghan EOS. Derived thermoelastic parameters are isothermal bulk modulus KT = 147(4) GPa, pressure derivative of bulk modulus K' = 8.7(8), with assumed temperature derivative of bulk modulus dK/dT = -0.03 GPa/K, and volumic thermal expansivity with alpha = a + bT with values of a = 3.2(5) x 10-5 K-1 and b = 1.0(8) x 10-8 K-2. The pressure derivative of bulk modulus is relatively higher than typical values for mantle minerals (from 4 to 5). The derived value for bulk modulus is extremely lower than that expected for such a dense lower mantle mineral (from 200 to 300 GPa). We are trying to clarify the reason of this elastic behavior of Ca ferrite-type NaAlSiO4 from the viewpoint of crystal chemistry.