Experimental determination of AlAl-SiMg interdiffusion coefficient in orthopyroxene

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Elemental diffusion in minerals provides quantitative information on geologic processes such as exhumation rate of the crust and upper mantle materials through analysis of chemical zoning in minerals. Aluminum zoning developed in orthopyroxene in mantle peridotites is thought to be a good indicator of P-T-t path for mantle material (Ozawa, 2004; Al-in-orthopyroxene geospeedometry). Because of the slow diffusivity, temperature range that we can investigate on the basis of such Al zoning is expected to be much higher than that based on Mg-Fe diffusion in mantle minerals. This is a great advantage if one wants to know high temperature thermal and decompression history, but its application is fairly qualitative and limited because of difficulty in determination of its diffusivity. In this study, we have experimentally determined the diffusion coefficient of Al in orthopyroxene along the c- and a-axes.

Diffusion experiments were performed along the enstatite (Mg2Si2O6) - pyrope (Mg3Al2Si3O12) binary join, where AlAl - MgSi diffusion is expected to occur along with reaction between pyrope and pure enstatite producing aluminous enstatite (MgAlAlSiO6). A single crystal of synthetic enstatite and synthetic polycrystalline pyrope were put into a platinum capsule and were heated at 1400-1550C and 2.6 - 3.1 GPa by a piston cylinder. Diffusion profiles of aluminum in enstatite were examined by EPMA along the c- and a-axes, and the orientation was determined by electron backscattered diffraction (EBSD).

The obtained Al diffusion coefficient (D) along the c-axis of orthoenstatite is D[m2/sec] = 0.621(+5.35,-0.576)exp(-501+-35[kJ/mol]/RT), where R is the gas constant, and T is the absolute temperature. This is within the range of the diffusion coefficient constrained by Smith and Barron (1991), whose estimation is based on Al zoning patterns in natural orthopyroxene. The diffusivity of aluminum along the a-axis is about one order of magnitude smaller than that along the c-axis, which well explain the anisotropy of Al zoning observed in natural orthopyroxene.

The results were applied to Al-in- orthopyroxene geospeedometry to estimate the cooling rate of the Lower Zone of the Horoman peridotite complex. Conditions to preserve M-shaped aluminum zoning in orthopyroxene (Ozawa and Takahashi, 1995) requires cooling rate of 6x10-6 C/year at temperatures 950 - 800C, which is slower by an order of magnitude than that by olivine-spinel geospeedometry at temperataures of 800 - 500C (Ozawa, 1984). This result suggests that the Hroman complex emplaced into the Hidaka lower crust with significantly cooling acceleration.