Cr-Al diffusion in chromite spinel

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Introduction

Spinel is stable in a wide range of temperature and pressure of the upper mantle and the crust, and is present in various mafic to ultramafic rocks, such as peridotites, gabbros, basalts, and meteorites. Compositional zoning of constituent elements in spinel has been reported from these rocks, which give us important information about thermal and deformation history: Mg-Fe2+ zoning for thermal history (Ozawa, 1984), and Cr-Al zoning for deformation history (Ozawa, 1989). For the estimation of thermal and deformation history, diffusivity of elements is a critical parameter. Although the Mg-Fe2+ interdiffusion coefficient in MgAl2O4 spinel has experimentally studied by Freer & O'Reilly (1980) and Liemann & Ganguly (2002), that in chromite spinel and Cr-Al interdiffusion coefficient have not been determined yet. In this study, we have determined the Cr-Al interdiffusion coefficient in chromite spinel for the first time by using diffusion couple of MgAl2O4 spinel and chromite.

Experimental method

Experiments were carried out with the multi-anvil type (MA-8 type) high-pressure apparatus at the Earthquake Research Institute, University of Tokyo. As a starting material, a pair of single-crystal of spinel from Myanmar (MgAl2O4, Cr/(Cr+Al)=Cr#=0.006-0.02) and single-crystal of chromite spinel from the Esashi, Hokkaido ((Mg,Fe)(Cr,Al)2O4, Cr#=0.87-0.93) was used. They have octahedral morphology with {111} facets. One of the {111} facets of each single crystal was polished with chemical mechanical polishing method by using silica suspension. They were cored to cylinder with 1.5mm diameter and about 1mm length, and set tightly into a cylindrical graphite capsule keeping their polished surfaces in direct contact. The furnace assembly is the same as that used by Yasuda et al. (1990), of which temperature difference across the sample cell was estimated about 15 degrees at 1500 degree C. The experiments were performed at a pressure of 3GPa and various temperatures with run duration up to 2days. After experiments, the sample was cut perpendicular to the contact plane and analyzed with EPMA for the area and line elemental analyses and with EBSD for lattice orientation.

Results

The map analyses show that diffusion took place perpendicular to the contact surface without any chemical modification along the capsule, thus grain boundary diffusion was negligible. Cr, Al, Fe3+, Fe2+, and Mg show diffusion profile perpendicular to the contact plane, where the Cr-Al diffusion profiles are complementary with each other and asymmetric with steeper profile in the MgAl2O4 spinel side suggesting a compositional dependence of Cr-Al diffusion in spinel.

The Cr-Al interdiffusion coefficient was estimated by the Boltzmann-Matano method. The coefficient decreases with Cr# (=Cr/(Cr+Al)) of spinel, which varies more than one order of magnitude as the Cr# changes from 0.1 to 0.85 at 3GPa and 1600 degree C. With an assumption of constant self-diffusion coefficient, it is concluded that the self-diffusion coefficient of Al is more than one order of magnitude larger than that of Cr. This large difference in self-diffusion coefficient of Al and Cr in chromite spinel is consistent with the Cr-Al zoning observed in chromite spinel, which is supposed to have formed by diffusion creep (Ozawa, 1989).