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Elemental diffusion along chromite-olivine boundary; Experiments at high pressure

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Multi-polar zoning of Cr and Al in chromite spinel in peridotites has been attributed to diffusion creep (Ozawa, 1989). Which can be an indicator for deformation history of not only spinel but also the host mantle peridotites. Diffusion coefficients of Cr and Al within lattice of spinel and in grain boundaries are the crucial parameters that clarify the history of deformation and compositional zoning of spinel. Degree of relative contribution of the two diffusion paths can be dependent of temperature, which enables us to elucidate quantitatively the deformation history on the basis of observed Cr-Al zoning in spinel. We have already obtained the lattice diffusion coefficients of Cr and Al in chromite spinel by diffusion couple experiments (Suzuki et al., 2005 AGU Fall Meeting). In this study, we experimentally determine diffusion coefficients along phase boundaries between chromite spinel and olivine.

Experiments were carried out with a multi-anvil type (MA-8 type) high-pressure apparatus at the Earthquake Research Institute, University of Tokyo. Starting materials are single crystals of spinel from Myanmar ($MgAl_2O_4$, Cr/(Cr+Al)=Cr#=0.006-0.02), chromite spinel from the Esashi, Hokkaido ($(Mg,Fe)(Cr,Al)_2O_4$, Cr#=0.87-0.93) and synthetic forsterite. Two crystals were fabricated as semicircular columns with 1.5mm diameter and about 1mm height, and their flat column faces were joined together to be a cylinder. Another crystal was cored to a cylinder as the same size with the coupled cylinder. The two cylinders were set tightly into a cylindrical graphite capsule keeping their polished surfaces in direct contact. In order to fulfill the condition of the semi-infinite diffusion, the same amount of powdered chromite and olivine were mixed and put beneath combined the cylinder of forsterite and chromite spinel. The furnace assembly is the same as that used by Yasuda et al. (1990). After experiments, the sample was cut perpendicular to the two contact planes and analyzed with FE-SEM and EPMA for the area and line elemental analyses.

In experimental charges, Al and Cr distributions in spinel are controlled by lattice diffusion from the spinel-chromite boundary and from the spinel-olivine boundary. The latter diffusion is due to deep penetration of Al or Cr diffusion along the phase boundary. We estimated the ratio of dD_{gb}/D_v (d: width of phase boundary diffusion path, D_{gb}: phase boundary diffusion coefficient, D_v: lattice diffusion coefficient, Joesten, 1991) from the Al and Cr distribution in spinels, and obtained the effective diffusion coefficient for diffusion creep $D_{eff}=D_v(1+(pi/h)(dD_{gb}/D_v))$ (h: grain size). We evaluate the contribution of lattice and phase boundary diffusions in the formation of multi-polar zoning induced by diffusion creep.