Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SIT38-15 Room:304 Time:May 23 16:15-16:30

Al, Si interdiffusion in majoritic garnet and the dislocation microstructures.

Nobuyoshi Miyajima[1*]

[1]Bayerisches Geoinstitut, Universitat Bayreuth, D-95440 Bayreuth, Germany

Plastic deformation by dislocations and atomic diffusion by vacancies of minerals at high pressures are important for the rheology of the Earth's mantle. Because those processes are controlled by moving of two agents (line and point defects) in deformations at high temperature, the post-mortem examination by analytical transmission electron microscope is indispensable for evaluating those agents (carriers). Majoritic garnet (MajGt) and magnesium silicate perovskite (MgPv) are major constituents in the mantle transition zone and the lower mantle, respectively. Diffusivity differences of the slowest species between these mantle minerals are very important to understand the changes of the nature of chemical heterogeneity, viscosity through those creep raw, and other various transport properties across the upper and lower mantle boundary.

Here I report an Al + Al = Si + Mg interdiffusion between MajGt and pyrope garnet. The diffusion couples using a multi-anvil press are pre-synthetic $Mg_3Al_2Si_3O_{12}$ pyrope and majoritic garnet. The annealing condition is at 18.5 GPa and 1750-1950 degree Celsius for 120-300 minutes, corresponding to a MajGt-single phase region in the binary system $MgSiO_3$-$Al_2O_3$3. Diffusion profiles of the recovered sample were examined with electron probe microanalyser (EPMA), scanning electron microscopes (SEM) and scanning transmission electron microscopes (STEM) equipped with an energy dispersive X-ray spectrometer (EDXS). Dislocation microstructures were also examined in weak-beam dark-field images using the thickness-contour fringe method (Ishida et al., 1980; Miyajima and Walte, 2009).

MajGt displays $<100>$ and 1/2 $<111>$ free dislocations and subgrain textures consisting of a dislocation array, suggesting that climb of dislocations was occurred during diffusion annealing. The obtained Al + Al = Mg + Si interdiffusion coefficient (D_{Al}) of MajGt at 18.5 GPa and 1750 degree Celsius is 6.2(4) x 10^{-19} (m^2/s), which is comparable with those of Mg and Si self-diffusion coefficients in MgPv under lower mantle conditions (Xu et al., 2011). However, the DAl is significantly higher than those of in previous studies in majoritic garnets at temperatures less than 1750 degree Celsius (e.g., Nishi et al. 2013). The preliminary obtained activation energy in this study is much higher in the temperature from 1750 to 1950 degree Celsius, where is likely to be the intrinsic regime in the interdiffusion. Comparisons with Al, Si interdiffusion in Fe-bearing majoritic garnets are given to highlight the effect of impurities and temperature on those diffusion rates. Considerations for further diffusion experiments in MajGt and aluminous MgPv are discussed toward the rheology from the transition zone from the lower mantle. I thank the generous support from BGI colleagues for commissioning of this study.

References:
Ishida et al. (1980) Determination of the Burgers vector of a dislocation by weak-beam imaging in a HVEM. Philos. Mag. A, 42, 453-462.
Miyajima, N., and Walte, N. (2009) Burgers vector determination in deformed perovskite and post-perovskite of $CaIrO_3$ using thickness fringes in weak-beam dark-field images: Ultramicroscopy, 109, 683-692.
Nishi et al. (2013) Slow Si-Al interdiffusion in garnet and stagnation of subducting slabs. Earth and Planetary Science Letters, 361, 44-49.
Xu et al. (2011) Silicon and magnesium diffusion in a single crystal of $MgSiO_3$ perovskite. J. Geophys. Res., 116, B12205.

Keywords: majoritic garnet, Al, Si interdiffusion, analytical transmission electron microscope, weak-beam dark-field image, dislocation microstructures