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Grain boundary diffusion of noble metal elements in mantle composites

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So far, it is not clear whether Earth's core and mantle have been chemically isolated through geological time. It has been believed that highly incompatible elements such as siderophile elements in the mantle minerals have not been moved from the core to the mantles so that the elemental abundance of highly siderophile elements (HSEs) in the core and mantle were determined when both were separated. Although HSEs are refractory, amounts of HSEs are very little in the mantle (Wood, 2006) so that these elements are expected to be highly concentrated in the core relative to the silicate mantle. However, a recent study has shown that incompatible elements can be concentrated and quickly diffuse at grain boundaries (Hiraga et al., 2004). If HSEs can diffuse from the core to the mantle, the concentration of HSEs in the mantle can change through Earth's history. Therefore, HSEs can be a good tracer to detect the chemical interaction of the core and the mantle.

We conducted grain growth experiments on Au particles in forsterite (Fo) aggregates at 1 atmosphere pressure and temperature of 1360 ℃. We prepared several sintered bodies which were made by dispersing 10vol% Au particles in Fo aggregates and then annealed for several hours. We observed these bodies using a scanning electronic microscope. In the result, Au particles changed their shape from spherical to polygonal. This is due to a balance of interfacial tensions between Au and Fo phases. Further, average grain size of Au particles was found to increase with time. Based on these observations, we conclude that Ostwald ripening of grains, by which Au atoms move from small particles to larger ones to minimize entire interfacial energies of the system, occurred in our experiment. Grain boundaries as diffusion paths should be responsible for Au diffusion. In this case, grain growth of Au particles will follow the relationship of d^4-$d_0{}^4$=kt, where d is the average grain size of Au particles after annealing, d_0 is the initial average grain size, k is the grain growth coefficient, and t is annealing time. Using the average grain size of each body, we calculated k. In addition, we estimated the interfacial energy of the system from the shape of Au particles and calculated the product of concentration of Au particles at grain boundaries, c, and diffusivity of Au atoms at grain boundaries, D.

Keywords: grain boundary diffusion, grain growth, core-mantle interaction