

Grain boundary diffusion of siderophile elements in lower mantle phases

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Abundance of siderophile elements, especially platinum group elements, in the Earth's mantle, is fairly higher than that expected from the distribution coefficients between Fe alloy and silicate minerals determined at low pressure. There are several explanations to solve this problem. The most popular hypothesis is late veneer. The amounts of siderophile elements would have been supplied after the core was formed by later meteorite bombardment. The other possible explanation is that before the core separation re-equilibration of Fe alloy and silicate minerals was established at the bottom of magma ocean. So far we have not paid attention to the siderophile element process after core formation. Hayden and Watson (2007) studied grain-boundary diffusion of siderophile elements through polycrystalline MgO at 2.5 GPa, and suggested that the diffusivities were high enough to allow transport of a number of siderophile elements over geologically significant length scales (tens of kilometres) over the age of the Earth. It means that grain-boundary diffusion as a potential fast pathway for chemical communication between the core and mantle. However, the dominant mantle mineral is not periclase but bridgmanite at the core-mantle boundary. In this study, grain boundary diffusion of W and Re in bridgmanite aggregates is determined.

The starting material for experiments to determine the grain boundary diffusion was mixture of San Carlos olivine or orthopyroxene with Mg#90 and 3 wt.% Al₂O₃ and Pt powder. Synthesis experiments of aggregates of postspinel or bridgmanite with tiny amount of Pt particle were conducted in a Kawai-type multianvil press at 25 GPa and 1873K. The synthesized aggregates were sliced into several disks with a few hundreds of micrometers. The disk was sandwiched by diffusion source (meta foil). This mixture was placed in an MgO cylinder. Hot-press and diffusion experiments were also performed using a Kawai-type multianvil press at 25 GPa and 1873 or 2073K. Experimental durations were more than 20 hours. The concentration of W and Re in the Pt sink was quantified using electron microprobe analyzer. The diffused siderophile element was recorded by the Pt particles behaving here as sink, which are implanted in the aggregate. A semi-infinite model for diffusion was used to calculate D from the concentration profile. The effective diffusivities of W and Re, which includes grain boundary effect were around 10^{-16} or 10^{-14} m² s⁻¹ at 1873K for bridgmanite and postspinel. These effective diffusivities are several orders of magnitude slower than the published diffusion data for MgO aggregates. On geological scales and for coarse-grain rocks, siderophile element diffusivity in grain boundaries is not fast enough to induce chemical interaction at the core-mantle boundary. The relative large grain size of mantle rocks will ensure a very limited siderophile element transport by effective diffusion, and a good conservation of siderophile element in the Earth's core. However, to estimate more reliable grain boundary diffusivities at the core-mantle boundary, more knowledge on effect of temperature and pressure on the siderophile element diffusivities is needed.

Keywords: siderophile element, lower mantle, grain boundary diffusion