Grain boundary diffusion of tungsten in lower mantle phase

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The time scales and mechanisms for the core formation of the planets can be quantified using the radioactive decay of short-lived isotopes. Hf-W isotope system is thought to be suited for dating the core formation in planetary bodies. 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 over the age of the Earth. Especially, the grain boundary diffusion of W is three orders of magnitude higher than the other siderophile elements. It means that grain-boundary diffusion of W 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 in post-spinel and bridgmanite aggregates was determined.

The starting material for experiments to determine the grain boundary diffusion was mixture of San Carlos olivine or orthopyroxene and Pt powder (~20μm). Postspinel or bridgmanite aggregates with tiny amount of Pt particle were synthesized 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. Diffusion experiments were also performed using a Kawai-type multianvil press at 25 GPa and between 1673 and 2173K. The concentration of W in the Pt sink was quantified using electron microprobe analyzer. The diffused W 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 in post-spinel, which includes grain boundary effect, increase from 10e-16 to 10e-12 m^2s^{-1} with increasing temperature from 1873 to 2173K, whereas those in bridgmanite aggregates are at least three orders of magnitude slower than in post-spinel. This difference attributes to large contribution of the bridgmanite-ferropericlase grain boundaries to the tungsten grain boundary diffusion. Activation energy for the tungsten grain boundary diffusion in postspinel is found to be around 400 kJ/mol. Considering that temperature at the core-mantle boundary is 4000K, tungsten diffusivity in grain boundaries would be fast enough to induce chemical interaction at the core-mantle boundary.