Effect of the metallic melt on the mantle rheology

*Atsuro Okamoto[1], Takehiko Hiraga[1]

1.Earthquake Research Institute, The University of Tokyo

The region around core-mantle boundary is estimated to be composed of post-perovskite phase with some fractions of outer core material. It is unclear that how these two different materials interact with each other chemically and dynamically. To understand these interactions, it is important to know the effect of a metallic melt on the viscosity of silicate rocks.
According to Hirth & Kohlstedt (2003), strain rate is an exponential function of melt fraction ($d\varepsilon/dt \propto \exp(\alpha\varphi)$) under a constant stress. With larger melt fraction, polycrystalline silicate becomes softer. Hustoft et al (2007) performed creep experiments on olivine+Fe-S and olivine+Au showing that the melt fraction factor αis approximately one-fifth relative to the value of αreported for olivine+MORB (Scott & Kohlstedt, 2006). However we don’t know how the rock viscosity is affected by a relative size of metallic melt against olivine grains and by strain. To understand these effects, we performed creep experiments on olivine+Au and compared the viscosity obtained from our experiments with the viscosity reported by Hustoft et al (2007).
We synthesized Fe-free olivine polycrystals with Au particles as follows; (i) We mixed fine powders of $Mg(OH)_2$, SiO_2 and Au. (ii) We made forsterite+enstatite from calcination of $Mg(OH)_2$ and SiO_2. (iii) We sintered the formed samples under a vacuum condition. Sintered materials contain forsterite, enstatite and Au with volume fractions of 81 %, 9 %, 10 %, respectively. Grain sizes of olivine and Au are 0.7 and 0.8 μm, respectively. We performed high-temprature and uni-axial compressional creep experiments on these materials at atmospheric pressure. We changed the stress from 10 MPa to 20 MPa, 40 MPa and 80 MPa at the constant temperatures (1200℃ and 1300℃). Under each stress level, we measured a strain rate where the relationship between time and strain became linear (steady state creep). We observed microstructures of the aggregates after the experiments using scanning electron microscope (SEM).
Based on stress versus strain rate data, we obtained a relationship of $d\varepsilon/dt \propto \sigma^{1.7}$. We observed that equiaxed Au particles became flattened against compressional direction after the experiments. The samples exhibited 4~8 times softer than Au-free samples which were synthesized by the same method we used. Our samples are even 3~4 times softer relative to the aggregates used in Hustoft. In our experiments, Au particles deformed considerably, while the shape of the Au phases was not substantially changed at Hustoft’s experiments. We attributed this difference to relatively larger size of Au particles to olivine grains in our study compared to that in Hustoft’s sample. Substantial deformation of soft Au particles can increase the stress for olivine grains which enhanced creep rate.

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