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The effect of partial melting on the mantle viscosity and electrical

SUEYOSHI, Kenta[1*] ; HIRAGA, Takehiko[1]

[1]Earthquake Research Institute, University of Tokyo

In this study, in order to know the change in mantle viscosity and electrical conductivity during partial melting, which corresponds to decompression melting of ascending mantle beneath mid-ocean ridge, mantle analogue sample was synthesized and used to measure its viscosity and electrical conductivity under atmospheric pressure and high temperature conditions. The sample has lherzolite composition of olivine (50%), orthopyroxene(40%) and clinopyroxene(10%) with addition of 0.5 vol% spinel. Constant force was applied to the sample under increasing the temperature where its range includes sample solidus. Sample viscosity and the electrical conductivity by the impedance measurement were calculated for every temperature. We particularly examined how viscosity and conductivity change when the sample transforms from melt-free to melt-bearing system. Temperature ranged from 1100 to 1390 ℃, which resulted in the change of melt fraction (ϕ) from 0 to 0.09, where the melt composition becomes enriched in clinopyroxene component as the temperature increases.

We observed a continuous and gradual reduction of sample viscosity with increasing temperature. The effect of the increasing melt fraction on the sample viscosity should have been added to the viscosity change simply due to thermally activation process. There is a linear relationship between measured 1/T and log($1/\eta$) ,which goes well with the previous proposed empirical expression of flow law that, which is an function of melt fraction.

Analyzing the observed viscosity change with temperature with this law, the apparent activation energy of 970 kJ/mol is obtained at a temperature range of 1220 ℃ to 1340 ℃ and the effect of increasing melt fraction on sample viscosity roughly corresponds to the activation energy of ˜+35 kJ/mol. The activation energy on the melt ?free system is estimated to be 935 kJ/mol. This value is close to the activation energy of the dislocation creep of orthopyroxene and clinopyroxene indicating that the sample viscosity was essentially controlled by deformation of pyroxenes.

Electrical conductivity did not change dramatically when the experimental temperature reached and exceeded the sample solidus. Grain size dependency on the conductivity was observed at all temperature conditions indicating that the conductivity is simply determined by grain boundary conductivity even at higher melt fraction condition, probably due to fine grain size of the samples. Compared with previously reported grain boundary conductivity in the melt-fee forsterite system, grain boundaries in our sample have 3 to 4 times higher conductivity indicating that the pyroxene grain boundaries have a large effect on the bulk sample conductivity in our experiment.

In this study, it was demonstrated that previously proposed empirical flow law as a function of melt fraction can approximate the viscosity change of the mantle during its transition from melt-free to melt-bearing Taking into account of the incremental rate of melt fraction with temperature and the connectivity of intergranular melt in the mantle highly depend on the volume fraction of the pyroxenes and spinel phases, mineral mode in the mantle should have substantial effects on the mantle rheology and electrical conductivity during mantle melting.

Keywords: rheology, rhelzolite, melt, viscosity, electrical conductivity