

Pure to impure and dry to wet olivine rheology based on high temperature dependency of diffusion creep

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There has been a large discrepancy in creep properties of olivine aggregates in dry diffusion creep regime between Minnesota group (Hirth and Kohlstedt, 1995) and ANU group (Faul and Jackson, 2007). Our recent deformation experiments on undoped and doped olivine aggregate synthesized by a new method different from previous studies demonstrate (i) the activation energy of grain boundary diffusion creep of undoped olivine is 465 kJ/mol, (ii) the creep rate is enhanced by doping of Ca and Al above ~ 1200 C with very high temperature sensitivity well represented by activation energy of ~ 700 kJ/mol, and (iii) presence of melt phase had little contribution to the change in the creep strength. Such observations are consistent with Yamauchi and Takei (2016) which attributed the observation to pre-melting at near solidus.

In this study, we compile all rheological data of olivine diffusion creep based on solidus which changes with the chemical compositions and amount of water. The solidi of dry samples are estimated from experiments and/or phase diagrams. The solidi of wet samples are calculated by cryoscopic approach following Hirshmann et al. (2009). We demonstrate that not only dry but also wet data are well explained by the operation of grain boundary diffusion creep with activation energy of 465 kJ/mol at $< \sim 0.93 \times$ solidus and 700 kJ/mol at $> \sim 0.93 \times$ solidus. The controversy on the effect of water on grain boundary diffusion by Mei and Kohlstedt (2000) and Fei et al. (2016) is explained by the experimental temperatures with respect to the solidus of their systems. The viscosity depth profile in the upper mantle based on our new diffusion creep model will be presented.

Keywords: mantle rheology, olivine aggregates, diffusion creep