Olivine interface distributions in static and dynamic equilibrium; effects of diffusion vs. effects of dislocation motion

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The character and plane distribution of interfaces in ceramics, mineral aggregates and rocks markedly influences macroscopic properties. Olivine is the dominant phase of the upper mantle. Transport along interfaces controls element redistribution and viscosity in diffusion creep. The strength of olivine single crystals differs significantly compared to that of polycrystalline olivine aggregates during plastic deformation. Until recently, neither the anisotropic interface frequency distribution nor its dependence on chemical composition has been studied for rock forming minerals. The lack of knowledge is even more severe when it comes to the distribution of interfaces that evolve in response to continuous deformation.

To investigate the effect of grain boundaries in olivine aggregates resulting from static grain growth as well as plastic deformation we performed a series of experiments: static, in diffusion creep, in dislocation accommodated grain boundary sliding (disGBS).

We characterized interfaces in aggregates with varying chemical compositions ranging from Mg_2SiO_4 forsterite to $Mg_{1.8}Fe_{0.2}SiO_4$ and $Mg_{1.0}Fe_{1.0}SiO_4$ and different additions of incompatible elements that are known to segregate to the interfaces. We analysed the grain boundary character and plane distribution (GBCD and GBPD).

The samples where characterized using electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM).

We found that (i) starting materials show a preference for low index planes in agreement with observations on other materials (e.g. MgO, TiO_2, $SrTiO_3$, $MgAl_2O_4$). (ii) The GBPD varies systematically between pure and doped samples. (iii) doped olivine aggregates are systematically weaker compared to pure aggregates. (iv) The interaction of dislocations of the dominant slip system result in a characteristic GBPD during disGBS.

Statistic microstructural data allow to better understand the coupling of inter and intragranular deformation mechanisms.