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Annealing of deformed olivine single-crystals under 'dry' conditions

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Knowledge of rheological properties of Earth's materials is essential to understand geological processes. Open questions are the water content and crystallographic orientation dependences of dislocation creep rate, because the dominant slip system changes with increasing water content, which suggest different dislocations have different water content dependence. This project focuses on olivine, which is the most abundant mineral of the upper mantle. It is also considered to be the weakest phase and hence should control the rheology of the upper mantle. Several slip systems were reported for olivine, which are [100](010), [001](010), [001](100) and [100](001), each of which appear under different water content and stress conditions [1].
For this purpose we started to obtain data for 'dry' conditions, providing basic knowledge to understand the effect of water.
Variation in dislocation creep rate according to change in physical conditions can be estimated by dislocation recovery experiments [2]. In this technique, deformed crystals are annealed, in which the dislocation density is expected to decrease due to coalescence of two dislocations. Dislocation densities are measured before and after the annealing. Dislocation mobility, which should be directly proportional to the dislocation creep rate, is estimated based on the change in dislocation density and duration of annealing. This technique has significant advantages partly because informations of strain rate and deviatoric stress, which are difficult to measure, are unnecessary, and partly because dislocation annealing is conducted under quasi-hydrostatic conditions, which allows wide ranges of P and T conditions.
The first step of the experiments is to deform a single crystal of olivine. For this purpose, we developed an assembly, which deforms a single crystal in simple-shear geometry and prevent breakage, sub-grain formation and recrystallization of the crystal. Olivine single-crystals were placed in the high-pressure assembly so that a particular slip system is activated. The assemblies were compressed to 3 GPa. The shear deformation was conducted at 1600 K. EBSD measurements indicate that the recovered crystals are single crystals and sub-grain formation did not occur in most cases.
The second step is to anneal the samples under the same P-T conditions as those of the deformation experiments. Annealing experiments are also performed at ambient pressures at 1600 K. Dislocation density was measured by means of the oxidation decoration technique [3]. The samples were firstly polished and then oxidized at 1200 K for 50 min. The dislocations are preferably oxidized, so that presence of dislocation can be observed using SEM.
First Results indicate that the dislocation density decreased by annealing by 1/4 with an annealing period of 10 h for dislocations with b = [001].

References
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