Characteristics of olivine fabric in diffusion creep and its comparison to the mantle peridotites

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Olivine crystallographic preferred orientation (CPO) is the primary source of seismic anisotropy in the upper mantle. Recent studies have shown that olivine CPO can develop during diffusion creep. At temperatures above 0.92 ×solidus temperature, olivine grains with anisotropic shape develop their long and flat boundaries parallel to certain low-index crystallographic planes (i.e., *b*-plane), which is thought to be the plane for the preferential grain-boundary sliding (GBS) due to the less viscosity than other general grain boundaries. Hence, the preferential GBS along the *b*-plane allows grain rotation toward shear directions and results in CPO formation. To investigate olivine grain morphologies in three dimensions and explore the development of olivine fabric patterns in detail, we conducted pure shear tests and for some tests, we repeated the pure shear tests to apply larger strain using samples that were already deformed by pure shear tests. Additionally, to explore the characteristics of olivine CPO during diffusion creep and compare it with mantle peridotites fabrics, Equal Channel Angular Pressing (ECAP) was used. The ECAP deformed sample contains areas where continuously different strains occur which is ideal for observing strain dependency in CPOs. Through pure shear tests, we found that depending on temperature, duration, and strain of the test conditions, anisotropic olivine grains varied in their 3D morphologies from oblate (plate-like) to prolate (pencil-like). Samples with anisotropic olivine grains displayed a crystallographic preferred orientation (CPO), while samples with weakly anisotropic grains had uniform CPOs. The CPO patterns ranged from AG-type (i.e., a uniaxial [010] concentration in the direction of sample shortening) to A-type (i.e., [010] and [100] concentrations in the directions of sample shortening and stretching, respectively) fabrics; intermediate types being most common. The fabric transition from AG-type to A-type was accompanied by a change in grain morphology from oblate to prolate morphology. The direct correlation between olivine morphology and fabrics is explained by preferential grain-boundary sliding (GBS) on the grain with anisotropic morphologies. Oblate morphologies with well-developed grain boundaries parallel to (010) provide easy GBS on the (010) plane along [h0l] directions while relatively prolate morphologies with boundaries parallel to (010) and elongated to [100] provide easy GBS on the same plane along [100] directions. Through an ECAP test, deformed samples exhibited A-to AG type fabrics with an increase in the fabric strength as strain increases. All experimental samples exhibited either random or AG-, A-type fabrics with P-wave (V_{P}) anisotropy (up to 16% within a given strain range which is comparable to that measured from mantle rocks. The GBS-CPO model explained that about 25% of grains will participate in grain boundary sliding not along their *b*-plane while others align their *b*-planes parallel to shear direction; this can explain the observed upper bound for V_{P} anisotropy. The transition in grain morphology was accompanied by grain growth. From the estimation of olivine grain growth in the oceanic upper mantle during diffusion creep, the dynamic grain growth below mid-ocean ridges through upper mantle corner flow is large enough to produce anisotropic morphologies (i.e., prolate to oblate). Hence, we propose AG- to A-type CPO can develop in the upper mantle as the result of the corner flow in diffusion creep condition.

Keywords: Olivine fabric, Crystallographic preferred orientation, Diffusion creep, Seismic anisotropy

