A New Deformation Mechanism in Olivine? Ex-Situ and In-Situ TEM Studies

Olivine, (Mg, Fe)2 SiO4 is a silicate mineral having orthorhombic symmetry and is present in the earth's mantle down to 410 km depth. There is evidence that in the convective mantle, olivine deformation involves dislocation glide and climb. However, due to its low symmetry, this mineral does not possess enough slip systems to satisfy the Von Mises criterion [1,2]. Several recent studies have focused on the possible contribution of grain boundaries (GBs) (sliding, migration) to the deformation of olivine aggregates, but so far, the mechanisms at play are not yet clarified.

To study the deformation mechanisms, deformed olivine samples synthesized from mixed, cold-pressed, and sintered SiO2 and Mg(OH)2 powders, were used for ex-situ TEM investigations. Deformation was carried out using a Paterson press (high-pressure high-temperature deformation apparatus) under a confining pressure of 300±5 MPa, at temperatures between 900-1200 °C, and a constant displacement rate. A detailed HRTEM microstructural investigation revealed the ductile behavior of GBs facilitated by intergranular amorphous layers that accommodate the strain during deformation. For this purpose, we used the PI-95 TEM Pico-indenter holder and the Push-to-Pull (PTP) device (Bruker. Inc) to perform a quantitative in-situ TEM tensile test. The deformation of the pristine olivine samples which do not have an amorphous layer at the grain boundary by in-situ nanomechanical testing in the TEM provides further opportunity to gain information on the acting mechanisms. To observe this grain boundary mechanism, bi-and tri-crystal nano tensile test olivine samples were prepared from the bulk pristine olivine via FIB. The samples were then mounted on the PTP holder, and used for nano tensile testing. The results show the evidence of amorphization in the GBs at room temperature in absence of other deformation mechanisms.

References

[1] R. E. Bernard, W. M. Behr, T. W. Becker, and D. J. Young, "Relationships Between Olivine CPO and Deformation Parameters in Naturally Deformed Rocks and Implications for Mantle Seismic Anisotropy," Geochemistry, Geophys. Geosystems, vol. 20, no. 7, pp. 3469–3494, 2019, doi: 10.1029/2019GC008289.

[2] M. Thieme, S. Demouchy, D. Mainprice, F. Barou, and P. Cordier, "Stress evolution and associated microstructure during transient creep of olivine at 1000–1200 °C," Phys. Earth Planet. Inter., vol. 278, no. February, pp. 34–46, 2018, doi: 10.1016/j.pepi.2018.03.002.