Time dependent response of amorphous olivine thin films determined by on-chip nanomechanical testing

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Olivine is a major constituent of the earth upper mantle. More precisely, this mineral ensures the mechanical coupling between the ductile asthenospheric mantle which is involved in mantle convection and the lithospheric plates. Olivine - $(Mg,Fe)_2SiO_4$ - is a polycrystalline material whose viscoplastic behavior is not fully understood. Recent work has proved the possible stress-induced amorphisation at the grain boundaries [1]. The presence of this amorphous phase could potentially play a major role in the high temperature rheology of polycristalline olivine.

In this study, the rheology of amorphous olivine (a-olivine) films deposited by pulsed laser deposition has been determined at ambient temperature by an on-chip technique dedicated to freestanding specimen. The objective is to shed light on the mechanical behavior that can be expected in such an amorphous layer. For this purpose, microfabrication techniques are used to pattern the amorphous olivine film into hundreds of specimen beams. These specimens are then deformed at different stress levels owing to the release of tensile internal stresses in actuator beams connected to each specimen. The release is performed by etching of the underlying silicon substrate in a gas phase XeF_2. The elongation of each specimen is measured right after release to extract the full stress-strain curve of the amorphous olivine thin films from small strain to fracture. The deformed test structures are then monitored for several months in order to extract the time dependent response of the a-olivine films.

Stress relaxation is found at all imposed prestrain levels for films with thicknesses in the range 150-300 nm. Relaxation experiments on the deformed specimens enable the extraction of the strain rate sensitivity of amorphous olivine for strain rates in the range from 10^{-7} to 10^{-9} s^{-1}. The viscoelastic behaviour is also characterized through the relaxation of the test structures deformed in the elastic regime where the strain rate reaches values as low as 10^{-11} s^{-1}.

[1] K. Kranjc, A.S. Thind, A.Y. Borisevich, R. Mishra, K.M. Flores, P. Skemer, Amorphization and Plasticity of Olivine During Low-Temperature Micropillar Deformation Experiments, J. Geophys. Res. Solid Earth. 125 (2020) 0–3. https://doi.org/10.1029/2019JB019242.