Rheology of amorphous olivine thin films characterized by nanoindentation

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The mechanical properties of olivine $(Mg,Fe)_2SiO_4$ control the rheology of the upper mantle which ensures the mechanical coupling between the ductile asthenospheric mantle (which is involved in mantle convection) and the lithospheric plates. The subject is therefore of primary importance in geodynamics. Despite years of research, the viscoplastic behaviour of olivine is still insufficiently understood. It has been recently shown that amorphization of the grain boundary layer can occur under particular pressure and temperature conditions [1]. Amorphous grain boundaries might play a major role in governing the resistance to deformation of the polycrystal by high temperature grain boundary sliding (GBS), close to the glass transition.

In this study, the rheology of amorphous olivine (a-olivine) films deposited by pulsed laser deposition has been explored by nanoindentation, at ambient temperature, in order to shed light on the mechanical behaviour that can be expected in such an amorphous layer.

More precisely, a stress relaxation method via nanoindentation is used in order to extract the room temperature rheology. The contact stiffness is controlled in order to keep a constant contact area between the Berkovich's tip and the material's surface [2]. During this step, the load decreases and therefore, the mean contact pressure decreases as well. With this method, the strain rate sensitivity and activation volume can be accurately determined, as important characteristics of the atomistic mechanisms controlling the viscoplastic deformation. The major advantage of the stress relaxation method coupled to standard nanoindentation measurement is to access to strain rates from 10^{-7} to 10^{-1} s^{-1}.

Results highlight that a-olivine is five times more rate sensitive than crystalline olivine. When extrapolating this result to tectonic strain rates (between 10^{-16} to 10^{-14} s^{-1}), the yield stress of a-olivine is shown to be almost five times lower than the crystal strength. This result is of primary importance for geophysics since it supports the hypothesis of plastic deformation mediated by grain boundary sliding within olivine polycrystals. The trend is already present at ambient temperature and should be enhanced when temperature increases to a significant portion of the a-olivine glass transition. As a perspective, more work will be performed with a high temperature nanoindentation set-up in order to characterize the limit temperature where GBS can be triggered.

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