ESRF	**Experiment title:** Anelasticity and attenuation in olivine at upper mantle conditions and seismic frequencies	**Experiment number**: ES 33
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Report:

The goal of proposal ES33 was to provide the first estimate of the anelasticity and shear attenuation (Q_G^{-1}) in olivine at upper mantle conditions, and seismic frequencies. To date, such measurements were only accessible by cyclic loading technique in gas vessel apparatus limited to 0.3 GPa [1]. We proposed to extend these forced-oscillation measurements to higher pressure thanks to the recent development of the RoToPEC [2] device.
The 15 allocated shifts were dedicated to ***(1)* set-up the experimental procedure** = design of the sample assembly, tuning of the anvil rotation angle / speed for different frequencies (0.001 – 0.1 Hz); ***(2)* assess the accuracy and reproducibility of the technique** = space and time resolution of strain measurements by X-ray radiography, comparison to the available G and Q^{-1} data for olivine at low pressure [3]; ***(3)* acquisition of data on olivine** under a wide range of P-T conditions and seismic frequencies.

Preliminary results

Starting materials were polycrystalline powder of San carlos olivine sintered under HP-HT before the synchrotron session at Université Lyon1, with grain sizes in the range 5-15 µm as measured by SEM. These samples were prepared as cylinders (∅ = 2mm, l = ~ 700 µm) with flat and polished top and bottom faces, and loaded in series with an Al_2O_3 rod (=elastic standard) in a boron epoxy gasket. A tungsten wire (∅ = 70 µm) was located at the rim of the sample as a strain marker (**Figure 1**).
Six runs were performed at 300 K in the pressure range 0.1 – 2.5 GPa. A sinusoidal shear was set to the sample by the periodic rotation of the bottom anvil of the RoToPEc module by 0.5 – 5° at periods of 100 – 1000 s. While the sample was under cyclic loading, X-ray images were recorded with a time resolution as low as 100ms in order to monitor the deformation of both the sample and elastic standard (Al_2O_3) (**Figure 1**). X-ray diffraction patterns were acquired before and after the deformation cycle for pressure calibration.

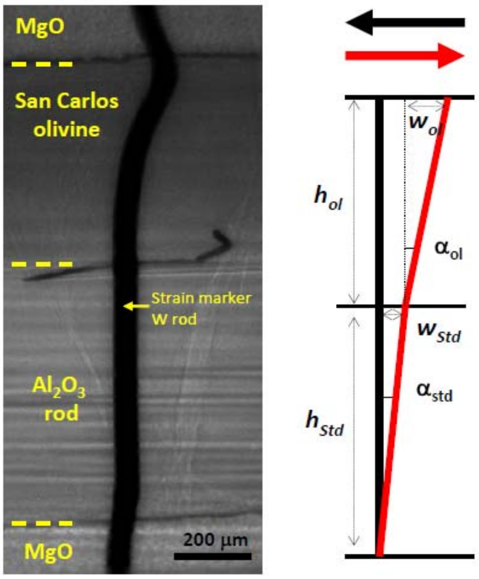

Figure 1 – Radiography of the sample assembly and description of the strain measurements.

X-ray images were processed with the imageJ software to determine the shift (w) of the tungsten wire (in microns), the length (h) and the apparent twist angle (α) on the sample/standard. **Figure 2** shows the apparent twist angle of the sample (α_{Ol}) and Al_2O_3 (α_{Std}) *vs.* time (s) for sample Sc3a.

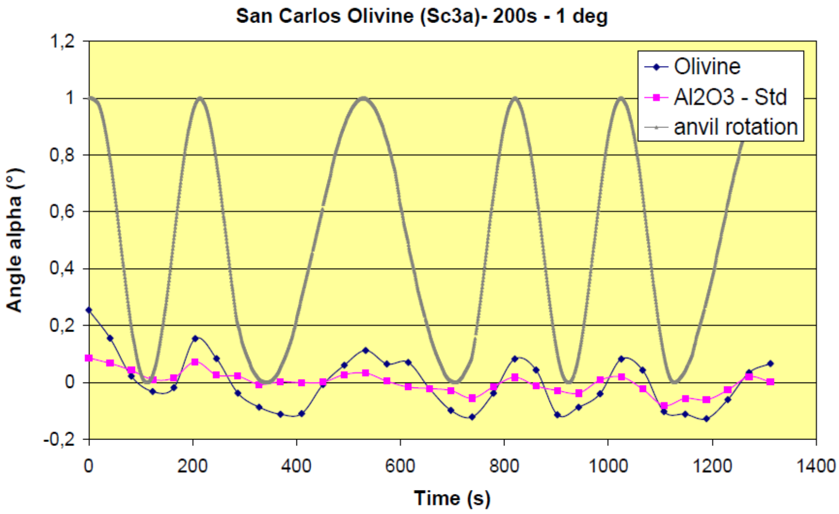

Figure 2 – Strain of San Carlos olivine vs. that of alumina as a function of time.

The experimental conditions were P=0.5 GPa T=300 K, rotation angle of the anvil= 1degree, and oscillation period = 200 s.

(*NB: while the time resolution was 100 ms, only data at 50s interval have been processed to date and plotted*).

The whole dataset is still under analysis but preliminary results are very encouraging and show the viability of this innovative technique:

(1) The rotation of the anvil (monitored by the optical encoder) did not follow perfectly the defined sine wave. This deviation is related to difficulties for the rotation motor to follow the target rotation angle and speed owing to PID issues. A fine-tuning of PIDs in a next session should solve this problem.

(2) Moreover, the twist angles of both sample and standard (< 0.3°) are lower than the 1° rotation of the anvil. It can be explained by the deformation of the other parts of the cell assembly, and a potential slip at the gasket-anvil interface.

(3) Despite these limitations, the olivine sample and standard deform in phase with the rotation of the anvil. In details, the amplitude of the twist angle is higher for the olivine than for Al_2O_3 as expected from the higher shear modulus of alumina. Based on this amplitude ratio (R), one can estimate the shear modulus of olivine from the known modulus of the alumina standard, *i.e.* $G_{ech} = G_{Std} \times R$. From the very preliminary results of run Sc3a, it gives a modulus G_{Ol}=85 GPa using R=0.56 and G_{Al2O3}=152 GPa. This value is in broad agreement with the G_{Ol}=79 GPa determined by ultrasonic techniques [4]. The complete analysis of run Sc3a data should precise this estimate.

(4) In the forced-oscillation technique, the attenuation of the sample (Q^{-1}) is determined from the phase lag (δ) between the deformation of the elastic standard and the sample, according to $Q^{-1} = \tan\delta$. Unfortunately, in our experiments the deviation of the anvil rotation to prefect sine waves (see above) prevented to fit the data with sine functions and to estimate δ. However, considering the space and time sensitivity we achieved for strain measurements in these preliminary experiments, we are confident to succeed in further works.

Conclusions – Further works

This experimental session was really satisfactory and encouraging as we demonstrated the ability of the experimental set-up to investigate the shear modulus and anelasticity of minerals under mantle conditions and seismic frequencies. Improving the rotation of the anvil by fine-tuning of PIDs in further works will enable the acquisition of G and Q^{-1} data for olivine under a wide range of P-T conditions and seismic frequencies.

References

[1] Jackson, I., Laboratory measurements of seismic wave dispersion and attenuation at high pressure and temperature, in *Advances in High-Pressure Technology*, Elsevier, 2005. **[2]** Alvarez-Murga M. et al., In situ X-ray Micro-Diffraction Computed Tomography(XRD-CT) under extreme conditions using a new rotating tomography Paris-Edinburgh cell (RoToPEC) ESRF Report MI-1086. **[3]** Jackson, I. *et al.*, Seismic waves attenuation in polycristalline olivine, *J. Geophys. Res.*, 107-B12, 2360, 2002. **[4]** Bass, J.D. Elasticity of Minerals, glasses and melts, in *AGU Handbooks of Physical Constants*, 45-63.