In-situ stress measurement during high pressure deformation experiments in D-DIA using Pyrope stress sensor

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X-ray diffraction has been used for decades to study mechanical properties of polycrystalline samples during in-situ high-pressure deformation experiments. When polycrystalline materials are deformed, stress in grains leads to lattice distortion. Using X-ray diffraction we can estimate the lattice strain for each (hkl) diffraction planes and calculate the stress applied on each (hkl), using (Singh et al., 1998) relation. However, this method does not consider the possible plastic anisotropy of polycrystalline sample. As a result of plastic anisotropy in the material, stress estimated using Singh et al. (1998), can be largely different depending on (hkl) diffraction planes (Karato, 2009), sometimes as large a factor of 3. To estimate the strength of a material, an average stress estimated from various (hkl) planes is calculated. When plastic anisotropy is large, such an average stress results in a large uncertainty on the estimated stress, depending on the plastic anisotropy of the material used to measure the stress. For example, during D-DIA deformation experiments, stress is often measured using X-ray diffraction performed on the alumina piston, that present a large plastic anisotropy and can produce stress uncertainty up to 50%.

To improve stress resolution and decrease the uncertainty on stress measurements, in this study we propose to use pyrope as stress sensor. Pyrope is known to be nearly plastically isotropic and thus would greatly improve our stress resolution. To test pyrope stress sensor, we conducted in-situ uniaxial deformation experiments in D-DIA at 6-BM-B beamline at APS. Our polycrystalline samples (San Carlos olivine and olivine Sol-Gel) were loaded with synthetic polycrystalline pyrope discs. Each sample was sandwiched between two platinum foils that are used as strain marker. The strain was measured in-situ using X-ray radiography image analyses. Stress was estimated from energy dispersive X-ray diffraction collected on our pyrope stress sensor as well as olivine samples.

Here we present our results that show that stress estimated from various (hkl) planes in pyrope present much smaller anisotropy and thus much smaller uncertainty than the sample (San-Carlos olivine and Sol-Gel olivine). Our results show that the average stress estimated using various (hkl) planes in pyrope is closer to the stress estimated from the (hkl) plane that shows the highest stress in olivine samples. This is a great technical improvement for stress estimation during high pressure deformation experiments and will result in much better characterization of rheological flow laws.

References:

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