In-situ Synchrotron X-ray Diffraction Study of Quartz Deformation Using the D-DIA Apparatus

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Introduction
Deformation is a rock's mechanical response to external parameters such as temperature and pressure. Knowledge of deformation is necessary to understand geodynamic processes. The behavior of rocks and minerals during deformation depends on the behavior of individual mineral grains within the rock and how they interact. The purpose of this study is to better understand such grain-to-grain interactions.

Deformation - DIA
We use the D-DIA apparatus located at the X17B2 beamline at the National Synchrotron Light Source (NSLS) to conduct deformation experiments. The D-DIA module is installed in a large volume hydraulic press. It consists of 6 WC anvilis, the top and bottom of which move independently, and compress a cube-shaped sample assembly and induce deformation at a controlled rate (cf. illustration below).

Our sample is polycrystalline quartz, novaculite, which has grain sizes varying from 6 to 9 microns. We study novaculite deformation at temperatures ranging from 500°C to 850°C and up to confining pressures of 2.5 GPa.

To determine the temperature we have established a watts versus temperature relationship from numerous experiments.

Detectors and D-Spacing
During the experiment, synchrotron x-rays pass through openings between the anvils and diffracted x-rays are measured by ten detectors. The output files include d-spacings of the diffraction peaks, which are fitted via Piot85. The changes in d-spacing allow us to determine the elastic deformation of the crystal lattice. Using the following equation we can calculate the lattice strain:

\[ \varepsilon^d = \frac{(D_x - D_0)}{D_0} \]

\( D_x \) : D-spacing at time \( t = x \)
\( D_0 \) : D-spacing at time \( t = 0^* \)

\(*t = 0 : \text{sample is in hydrostatic equilibrium}\)

Sample Assembly
Radiographs are taken before, during and after the experiment to determine the sample strain. We measure the sample's inner and outer pixel lengths using platinum metal foils as length markers. Once measured, the two lengths are averaged and the following equation is applied to calculate the strain:

\[ \varepsilon_{sample} = -\frac{(L_x - L_0)}{(L_0)} \]

\( L_0 \) : Average length at time \( t = 0^* \)
\( L_x \) : Average length at time \( t = x \)

Sample Strain

Results
- The elastic slope can be reproduced in each independent experiment.
- The yield strength, the point where the sample begins to deform plastically, is temperature-dependent.
- All three lattice planes display a similar behavior and temperature-dependency.

Future Work
- Completion of data analysis for SiO2_18 and detectors 1, 3, 5, and 6 for SiO2_16
- Microstructural analyses using electron backscatter diffraction (EBSD) mapping
- Elastic plastic self-consistent (EPSC) modeling, which correlates D-DIA (information on stress distribution in grains) and EBSD (information on operating deformation mechanisms) results
- Use results to create a model of polycrystalline deformation
- Fit D-DIA data, run EPSC models for Al2O3 and compare with SiO2 results

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