14C2, NE7A/2007S2-002

Deformation experiments on fayalite using deformation cubic anvil press and monochromatic X-rays

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Introduction

Studies of the rheological properties of rocks and minerals are important for understanding the dynamics and evolution of the Earth's mantle. It is necessary to conduct deformation experiments to get flow law of minerals. We installed a deformation cubic anvil press, D-CAP 700 at the 14C2 beamline of the Photon Factory, which is essentially similar to the conventional D-DIA system. The differential rams are driven by micro-discharge pumps, and the deformation cubic anvil component is driven by MAX-III 700ton press installed at the 14C2 beamline.

There are many previous works of mantle olivine rheology, however little has been explored on the rheology of fayalite, Fe_2SiO_4 olivine. So, we have conducted the deformation experiments of fayalite using this new deformation apparatus, D-CAP 700.

Experimental

Stress and Strain Measurement with monochromatic X-rays

An incident X-ray beam was monochromatized at energy of 50 keV by a Si (220) monochromater. Strain is observed from transmitted X-ray imaging of the sample using the YAG single crystal phosphor and the CCD camera. We used gold foils located at the sample and piston interface as strain marker and measured a change of length between two gold foils with time. Stress was measured by the X-rays diffraction peak shift (i.e. distortion of Debye rings). The two-dimensional (2-D) diffraction peaks were collected by imaging plates. Detector orientation relative to the incident beam direction, a wavelength and a camera length were calibrated using a diffraction standard (CeO_2). After detector orientation correction, we get a series of 1-D diffraction patterns with respect to 10º of azimuth angle ψ. We defined ψ=0 is perpendicular to the maximum principal stress axis, the compression direction. Then, we determined the lattice strain,

$$\varepsilon(\psi, hkl) = [d_0(\psi, hkl) - d(\psi, hkl)]/d_0(\psi, hkl) ,$$

where ψ is the azimuth angle and $d_0(\psi, hkl)$ and $d(\psi, hkl)$ are d-values of the sample at ambient conditions and at a certain pressure and stress state, respectively. The lattice strain is fitted to

$$\varepsilon(\psi, hkl) = \varepsilon_P - \varepsilon_t(hkl)(1-3\sin^2\psi)$$

to obtain hydrostatic (ε_P) and differential ($\varepsilon_t(hkl)$) lattice strains.

Experimental protocol

The sample is first compressed at room temperature using the main ram and then heated to the desired temperature. After the sample is annealed for an hour, the differential rams are advanced at a constant speed to start deformation, while diffraction patterns and sample images are repeatedly recorded with exposure time of 3~10 and 0.5~2 minutes, respectively. Experiments were conducted at confining pressure of about 2~5GPa and temperature of 773 ~ 1073 K. Final strain reached from 10 to 30 %. Strain rate is about 10^{-5}~10^{-4} s^{-1}.

Results

Representative stress-strain curves of fayalite deformation are shown in Figure 1. We used diffraction peaks 130, 131 and 112 for the stress calculation. The average of the stress values derived from different diffraction peaks were regarded as the sample stress under a steady-state condition. These data are still insufficient for discussing the details of the deformation mechanism. More experiments and analysis are in progress to understand the rheology of fayalite.

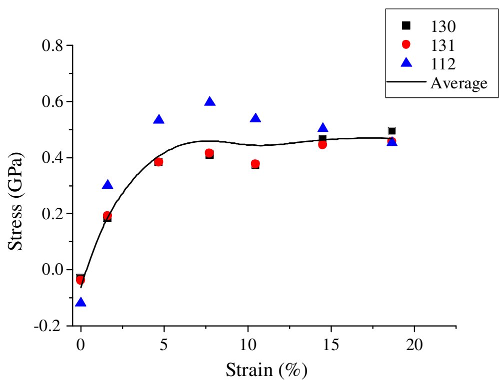

Figure 1. An example of the stress-strain curves for the deformed faylite at 873K and a 2.8GPa

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