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High pressure deformation experiments using deformation-Cubic Anvil, D-CAP 700, with synchrotron 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. However quantitative experimental studies were limited up to about 4 GPa until recently due to technical limitations.

A new deformation apparatus had been proposed by Durham et al. [1] and the new apparatus is capable of deforming samples under confining pressure up to 15GPa. Basically, the new apparatus consists of the cubic-anvil apparatus known as the DIA and two differential rams. The system has been introduced into synchrotron X-ray beamlines [2], and a procedure for measuring stress and strain using synchrotron X-rays had been developed [3], in order to quantify the experimental data. So far, experiments using the deformation DIA with synchrotron X-rays have been conducted at only two beamlines, the GeoSoilEnviro CARS 13-BM-D beamline of the Advanced Photon Source and the X17B2 beamline of the National Synchrotron Light Source. Some results using these techniques are controversial. In order to obtain undoubted results and to advance further the experimental studies on rheological properties of the deep mantle, we installed a deformation cubic anvil, D-CAP 700 at the 14C2 beamline of the Photon Factory, which is basically 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.

Experimental

We have developed a technique for measuring stress and strain using monochromatic X-rays. Stress 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). The strain rates were measured by the change of the sample length using X-ray imaging system which consists of the YAG single-crystal phosphor and a CCD camera. The sample length is defined by gold foils located at the sample and piston interface. We determine lattice strain, $\varepsilon(\psi, hkl) = [d_0(\psi, hkl) - d(\psi, hkl)]/ d_0(\psi, hkl)$, where ψ is the true 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, $\varepsilon(\psi, hkl)$ is fitted to $\varepsilon(\psi, hkl) = \varepsilon_P - \varepsilon_t(hkl)(1\text{-}3\cos^2\psi)$ to obtain differential ($\varepsilon_t(hkl)$) lattice strains.

Preliminary results of fayalite deformation

Example deformation experiments are conducted to study rheological properties of fayalite. We confirmed the sample was deformed at constant strain rate using X-ray images. An example of the azimuth dependence of lattice strain is shown in Figure 1. The preliminary results suggest that stress can be accurately measured and further deformation experiments will be conducted in the future.

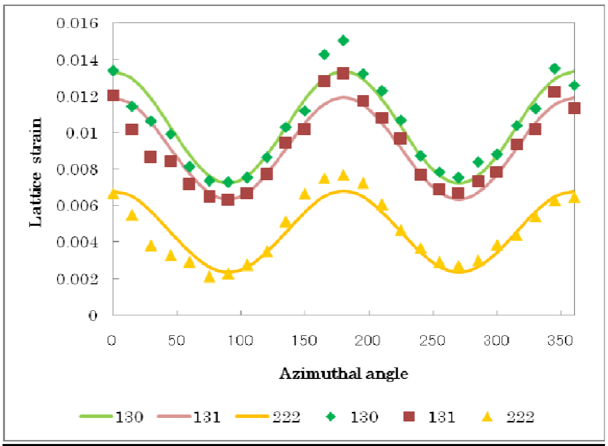

Fig.1 The azimuthal distortion of lattice strain for 130, 131 and 222 taken from deformed fayalite at 3GPa and 873K.

References

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