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Shear instability triggered by the olivine-ringwoodite transformation under uniaxial deformation at MTZ pressures

[1]Tomoaki KUBO, [1]Rikuto HONDA, [2]Takuya IWASATO, [3]Yuji HIGO,
[1]Yuta GOTO, and [1]Yumiko TSUBOKAWA
[1]Dept. of Earth and Planetary Sciences, Kyushu University, Fukuoka 812-8581, Japan
[2]Shin-Nippon Nondestructive Inspection Co.,Ltd., Fukuoka 803-8517, Japan
[3]Japan Synchrotron Radiation Research Institute, Hyogo 679-5198, Japan.

1 Introduction

The transformation of olivine (Ol) to ringwoodite (Rw) has been proposed as one of the possible mechanisms for the deep-focus earthquakes [e.g., 1, 2]. Previous studies with analogues have demonstrated shear instability associated with the olivine-spinel transformation [e.g., 3], however, the pressure conditions are still low (2-5 GPa) and close to the brittle-plastic transition. Here we report experimental results on the transformation of mantle olivine at mantle transition zone (MTZ) pressures under uniaxial stress.

2 Experiment

We conducted deformation and transformation experiments using D-111 type apparatuses at PF-AR NE7A beamline and Kyushu University. The starting material of polycrystalline San Carlos olivine was compressed to ~20 GPa and uniaxially deformed at ~1183-1673K. KMA-type 8ch acoustic emission (AE) measurement system (Fig. 1 and 2) was newly developed, and attached to the D-111 apparatus to record AEs during deformation. We obtained stress-strain curves and reaction kinetics by measuring 2D-XRD patterns and radiography images every ~1-5 min using 60 keV mono X-ray. The final strains reached ~25-53% with strain rates of 0.4-9.8 x10-5 s^{-1}.

3 Results and Discussion

The Ol-Rw transformation proceeded above ~1200K at ~20 GPa under uniaxial deformation. In contrast to the high strength of olivine (~5 GPa), the newly appeared Rw is very weak (~0.5-1.5 GPa) at ~1400K. Rw strength is almost constant with increasing temperatures to 1673K, whereas it shows hardening during isothermal deformation. These creep behaviors in Rw can be reasonably interpreted by diffusion creep associated with grain growth.

We observed slip displacements at 1183-1423 K forming nano shear bands (NSBs). AEs were detected from the sample region only at the lowest temperature of 1183K, in which NSBs are very thin less than ~100 nm thick, and orient at ~45° to σ1 direction. No AEs were detected at higher temperatures, where NSBs become thicker and the orientation shifts to higher angles.

In this study, we directly demonstrated that the olivine-ringwoodite transformation triggers shear localization and shear instability at MTZ pressures. This is essential to understand the process of deep-focus earthquakes and the rheological weakening of slabs.

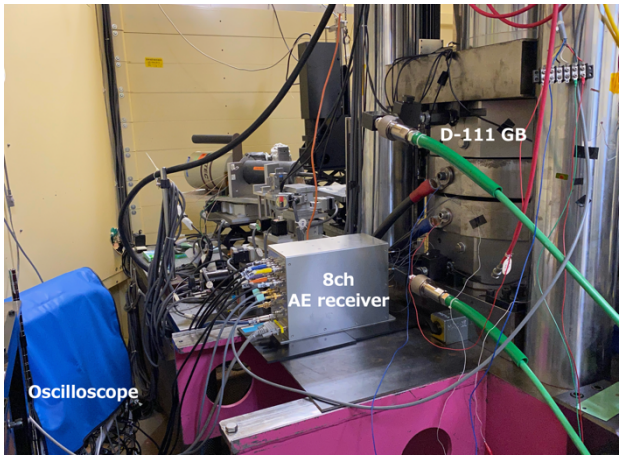

Fig. 1: 700 ton uniaxial press (MAX-III) combined with D-111 type guide block and AE measurement system.

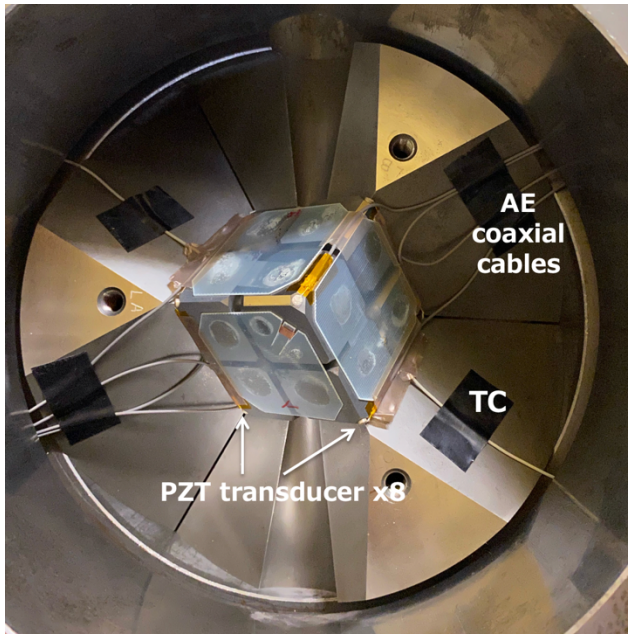

Fig. 2: KAWAI-type 8-ch AE system inside the D-111 type guide block.

References
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* kubotomo@geo.kyushu-u.ac.jp