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In-situ X-ray observations of high-pressure transformations under shear deformation using D-111 type deformation apparatus

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1 Introduction

It has been suggested that high-pressure transformations in mantle transition zone and D" region cause rheological weakening and large deformation of subducted slab materials [e.g., 1, 2]. However, there have been few direct experimental evidences so far largely because of the difficulties in quantitative deformation experiments under such conditions. Here we report preliminary results on the olivine-spinel transformation experiments under shear deformation up to mantle transition zone pressures. D-111 type high-pressure deformation apparatus was newly used for this purpose combined with high-energy synchrotron mono X-rays (50-60 keV) at Photon Factory (PFAR NE7 beamline), which enables in-situ observations of the transformation and creep behaviors.

2 Experiment

We carried out deformation and transformation experiments with synchrotron X-ray using a D111-type apparatus (MAX-III) installed at PF-AR NE7 beamline. The starting material was polycrystalline Mg_2SiO_4 forsterite [3]. The sample was first deformed at 15-25 GPa at 600°C in shear, and subsequently heated to higher temperatures (~0.2°C/s) to cause the olivine-spinel transformation under shear deformation. We obtained 2D-XRD patterns and radiography image (Fig. 1) every ~3-5 minutes using a 60 keV monochromatic X-ray to measure stress-strain curves and reaction kinetics.

3 Results and Discussion

The transformation started at much lower temperatures under shear deformation (~900-1100°C depending on the overpressure from the phase boundary) compared to that without deformation (~1400°C), suggesting that the shear deformation enhances the olivine-spinel transition rate. The shear strain rate in the sample monitored by X-ray radiography was ~3-4e-6 (s^{-1}) at 600°C, and increased up to ~2-3e-4 (s^{-1}) with ramping temperatures even keeping the anvil displacement rate constant (200 micron/h) (Fig. 2).

We observed that, reflecting on the initiation of the olivine transition, the shear weakening occurs at lower temperatures when the overpressure is large. Also, the weakening effects become significant at larger overpressures (and low T). This implies that the weakening of the shear zone induced by the grain-size reduction due to the olivine-spinel transition. Further evidences from microstructural observations are required. Although we have not obtained any evidences for shear localization and instability so far, we plan to install 8-ch acoustic emission measurement system attached with D-111 apparatus to capture them.

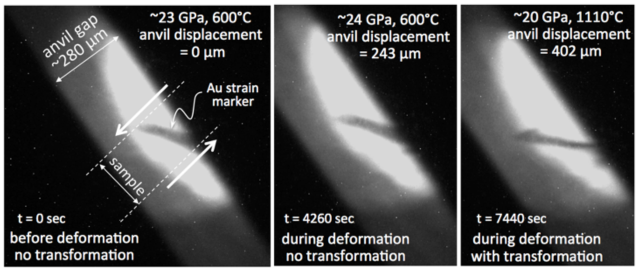

Fig. 1: Changes of radiography images of the sample region during the high-pressure transformation under shear deformation.

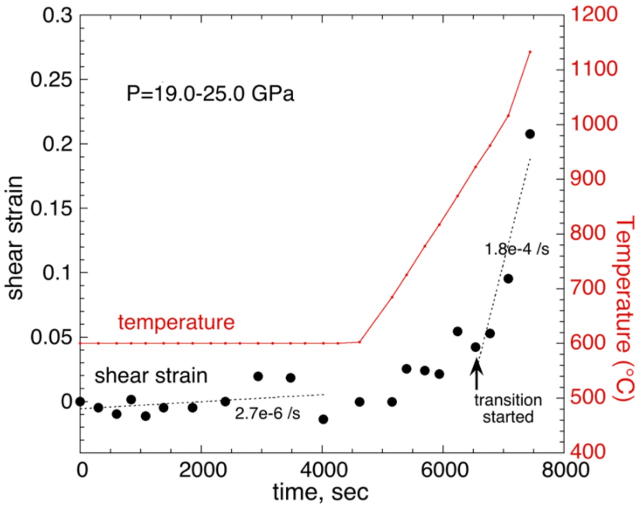

Fig. 2: Plots of temperature and shear strain as a function of time during the high-pressure transformation under shear deformation at 19-25 GPa with a constant anvil displacement rate of 200 micron/h. The timing for the initiation of the olivine transformation is arrowed.

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References

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