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IN SITU X-RAY OBSERVATION OF THE POST-GARNET TRANSFORMATION KINETICS OF PYROPE USING SINTERED DIAMOND MULTI-ANVIL APPARATUS

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Introduction

Garnet is a major constituent of the subducted oceanic crust in the Earth's mantle transition zone. Garnet-perovskite transformation (post-garnet transformation), which occurs at the depth of ~700-800 km, greatly affects on dynamics of the subducting oceanic crust and chemical heterogeneities in the deep mantle. In order to reveal mechanisms and kinetics of the post-garnet transformation, we performed high pressure and temperature in situ X-ray diffraction experiments using sintered diamond multi-anvil apparatus. We report preliminary results on decomposition reaction kinetics of pyrope garnet into aluminous perovskite and corundum.

Experimental method

In situ X-ray diffraction experiments were conducted using "MAX-III" multi-anvil (MA) high pressure apparatus installed in the synchrotron radiation beam line BL14C2 at the Photon Factory (PF) of High Energy Accelerator Research Organization (KEK). MAX-III is a 700-ton uniaxial press, with a DIA type guide-block. Pressure was generated by the double-stage system consisting of six outer anvils (MA6) and loading an assembly of eight truncated cubic anvils (MA8). The edge length of the first-stage anvil is 18.5 mm. Sintered diamond anvils of 10 mm edge length were used as the second-stage anvil. The truncated edge length of the second-stage anvil is 2.0 mm. White X-ray from synchrotron radiation was used as the incident X-ray beam and the diffracted beam was measured by the energy dispersive method using a Ge solid state detector (SSD) in the vertical direction through the sintered diamond anvil. The sample assembly used in this study is shown in Fig. 1.The starting material is a sintered mixture of $Mg_3Al_2Si_3O_{12}$ pyrope and gold. It was compressed to the desired pressure at room temperature, then heated to the desired temperature at constant oil pressure. When the temperature reached to the desired value, it was kept constant and time-resolved X-ray diffraction profiles were taken every 10-200 seconds. We observed the dissociation of pyrope to perovskite and corundum at 26.0-31.0 GPa and 1000-1400°C.

Results and discussion

Fig. 1 shows changes of X-ray diffraction profiles from pyrope garnet into aluminous perovskite and corundum with time obtained at 31.0 GPa and 1200°C. The transformation proceeded by about 50% in 4 and 130 minutes at 31.0 GPa and 1200°C, and 30.3 GPa and 1000°C, respectively. At 26.0 GPa and 1400°C, the transformation completed in 10 seconds. These preliminary kinetic data qualitatively suggest that kinetics of the post-garnet transformation in pyrope is significantly slower than those of the post-spinel transformation. Microstructural observations of the recovered sample indicate the grain-boundary reaction of the post-garnet transformation. It is necessary to analyze the obtained kinetic data more qualitatively based on the observed transformation mechanisms.

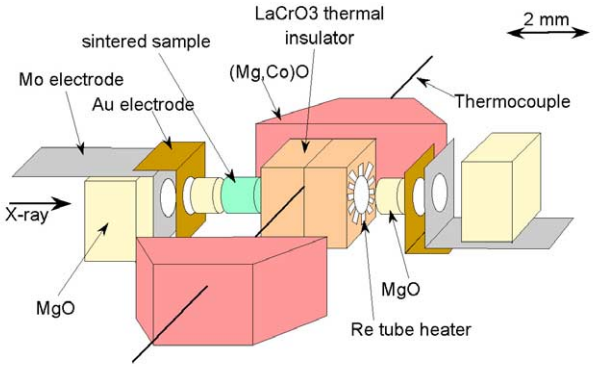

Fig. 1 Central parts of the sample assembly used in this study.

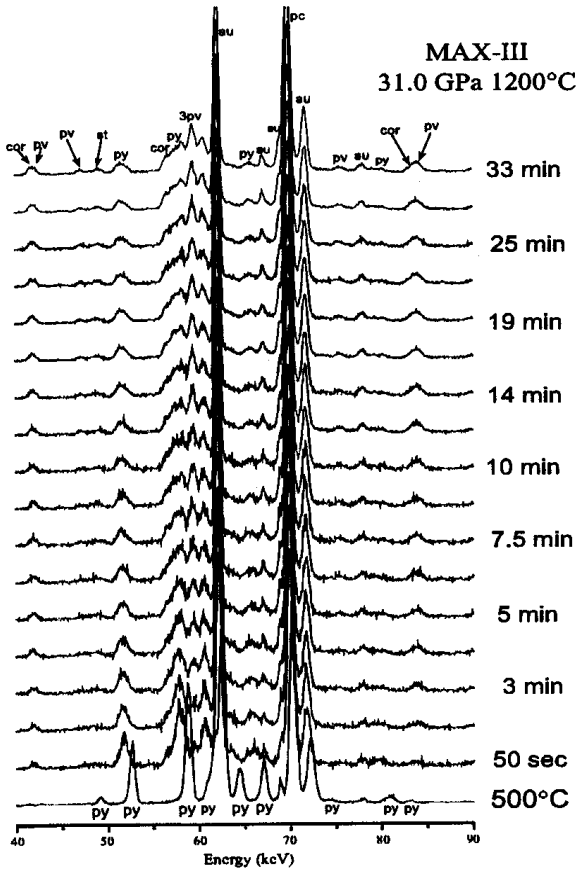

Fig. 2 Changes of X-ray diffraction patterns (2θ = 5.0°) of the sample during the post-pyrope transformation at 31.0 GPa and 1200°C obtained by MAX-III (py, pyrope; pv, perovskite; cor, corundum; st, stishovite; au, gold).

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