IN SITU X-RAY OBSERVATION OF THE POSTSPINEL TRANSFORMATION KINETICS OF Mg_2SiO_4

Tomoaki Kubo*, Eiji Ohtani, Takumi Kato[1], Akio Suzuki, Takumi Kikegawa[2]

Institute of Mineralogy, Petrology, and Economic Geology, Tohoku University, Sendai 980-8578, Japan
[1]*Institute of Geoscience, University of Tsukuba, Tsukuba 305-8571, Japan*
[2]*Photon Factory, High Energy Accelerator Research Organization, Tsukuba 305-0801, Japan*

Introduction

Dissociation of (Mg, Fe)$_2$SiO$_4$ spinel into (Mg, Fe)SiO$_3$ perovskite and (Mg, Fe)O ferro-periclase (the postspinel transformation) is one of the most important transformation in the Earth's mantle which is believed to be the cause of the 660 km seismic discontinuity dividing the mantle into the upper and lower parts. It has been suggested that the postspinel transformation kinetics greatly affect on dynamics of the subducting slab and the style of mantle convection. However, there is no kinetic data of this transformation. We present the first data on the kinetics of the postspinel transformation in Mg_2SiO_4 obtained by in situ X ray diffraction at high pressure and temperature.

Experimental method

In situ X-ray diffraction experiments were conducted using "MAX90" multi-anvil (MA) high pressure apparatus installed in BL14C at the Photon Factory (PF) of High Energy Accelerator Research Organization (KEK). Pressure was generated by the double-stage system consisting of six outer anvils (MA6) and loading an assembly of eight truncated cubic anvils (MA8). Sintered diamond anvils of 10 mm edge length were used as the second-stage anvil (Kato et al., 1995). The X-ray diffraction pattern of the sample was measured by the energy dispersive method using a Ge solid state detector. The starting material is a sintered mixture of Mg_2SiO_4 spinel 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 X-ray diffraction profiles were taken separately with an interval of every 60-600 seconds. Pressure and temperature conditions of the present study are in the range from 21.0 to 28.2 GPa and from 1020 to 1200°C.

Results and discussion

Fig. 1 shows changes of X-ray diffraction profiles from Mg_2SiO_4 spinel to $MgSiO_3$ perovskite and MgO periclase with time obtained at 28.2 GPa and 1010°C. We often observed $MgSiO_3$ ilmenite and SiO_2 stishovite during the postspinel transformation. TEM observations of the recovered sample revealed that ilmenite and periclase, and stishovite and periclase assemblages grew with lamellar textures (Kubo et al., 2000). Formation of these metastable assemblages are considered to be the intermediate step in the transformation from spinel into perovskite and periclase.

The growth rate and its temperature dependence were estimated by analysis of the kinetic data obtained by in situ X-ray observations (Kubo et al., 2001). Because the growth rate is estimated to be enough large even at low temperatures of ~700°C, which is the lowest temperature in the cold slab at ~700 km depth, the depth of the postspinel transformation in the cold slabs is possibly controlled by the nucleation kinetics involving formation of metastable assemblages.

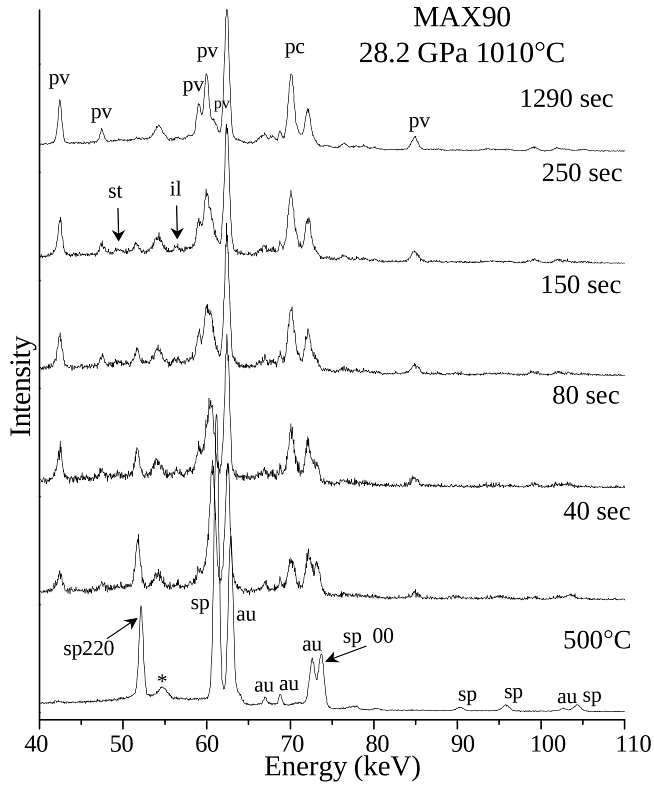

Fig. 1 Changes of X-ray diffraction patterns (2θ = 5.0°) of the sample during the postspinel transformation at 28.2 GPa and 1010°C obtained by MAX90 (sp, spinel; pv, perovskite; pc, periclase; il, ilmenite; st, stishovite; *, heater).

References

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*tkubo@mail.cc.tohoku.ac.jp