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Time-resolved 2DXRD observations of rain nucleation and growth during the coesite-stishovite transformation

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Introduction

Subducting slabs undergo various phase transformations in the mantle transition zone. Nucleation and growth kinetics of the phase transformations largely affects microstructural evolutions and rheological properties of the slab material. We have developed the experimental method to observe nucleation and growth of individual grains during phase transformation at high pressure and temperature by using time-resolved two-dimentional X-ray diffraction (2DXRD) measurements. The number of diffraction spots on two-dimensional detector that fulfill the Bragg condition is proportional to the grain density, and the intensity of each spot is proportional to the volume of the grain. We expect to observe nucleation and growth kinetics of individual grains from the evolution of numbers and intensities of diffraction spots as a function of time. Here we report preliminary results on kinetics of the coesite-stishovite transformation obtained using this method.

Experimental method

The experiments were carried out using multi-anvil high-pressure apparatus MAX-III at BL14C2 of Photon Factory, Tsukuba, Japan. We used monochromatic X-ray (45 keV, collimated to 200x200 microns) from synchrotron radiation and obtained time-resolved 2DXRD patterns every 15 minutes using imaging plate. The starting material of quartz powder was first annealed at around 6 GPa and 1473 K for 60 min in the stability field of coesite. Grain growth of polycrystalline coesite was confirmed by changing of the 2DXRD patterns from ring to spotty ones with time. Following the annealing, we have observed kinetics of the coesite-stishovite transformation at two conditions, 10.1 GPa and 1273 K, and 9.5 GPa and 1473 K.

Results and discussion

At 10.1 GPa and 1273 K, ring patterns of stishovite were observed without the incubation time, which implies many stishovite grains nucleate at the initial stage of the transformation. This is consistent with the fact that the n-value in the Avrami rate equation is about 1. SEM observations also show many stishovite grains are actually present along the coesite grain boundaries. On the other hand at 9.5 GPa and 1473 K, we have observed appearance of spotty patterns of stishovite after incubation time of about 60 min. The number of diffraction spots increased after the incubation time and become constant after about 120 min, whereas the intensity of the spots continued to increase (Fig. 1). These observations suggest that saturation of the nucleation site occurred in 120 min and the transformation proceeded only by growth after the site saturation. The n-value in the Avrami rate equation is about 2.6. SEM observations of the recovered sample indicate limited nucleation and extensive growth of stishovite grains.

These preliminary results suggest that the time-resolved 2DXRD method can provide the unique information on the grain nucleation and growth processes during the transformation. Further quantitative analyses make it possible to determine nucleation and growth rates of individual grains

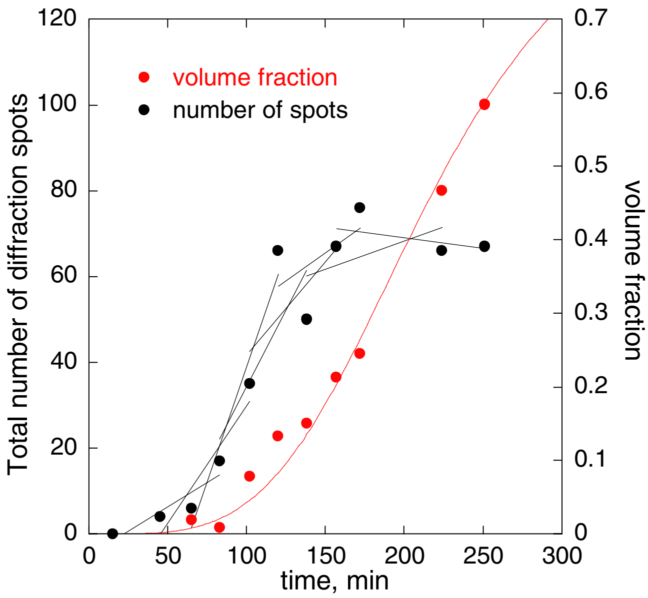

Fig. 1 Time-dependence of transformed volume fraction (red) and total number of diffraction spot (black) in stishovite (110) during the coesite-stishovite transformation at 9.5 GPa and 1473 K.

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