In situ X-ray diffraction study on kinetics of decomposition of spinel Mg_2SiO_4 at high pressure and temperature

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Decomposition of spinel Mg_2SiO_4 is one of the most important reaction occurred in the Earth's interior. The kinetics of the reaction is especially important for understanding the effect of the reaction on mantle convection, i.e., rheology of the descending slabs and ascending hot plumes. It is also important to understand the origin of the deep focused earthquakes often observed in the transition zone and the uppermost part of the lower mantle, since the earthquakes may be triggered by instability due to transformation. Therefore, we have conducted an in situ X-ray diffraction study of kinetics of decomposition reaction of spinel Mg_2SiO_4.

We have conducted the experiments using SPEED 1500 multianvil apparatus installed in BL04B1 of SPring 8. The white X-ray beam with the height of 100µm and the width of 200 µm was collimated to the sample and the reflected X-ray was detected by the solid state detector with a glancing angle 2θ= 5.0˚C. The starting material was a sintered mixture of Mg_2SiO_4 spinel and fine grained gold powder. The grain size of spinel was about 10 µm in diameter. Pressure was evaluated from the volume of gold which was mixed with the spinel sample. After compression, temperature was increased to the desired value by a rate of 500˚C/min. and held constant for in situ X-ray diffraction.

We made successful measurement of the rate of the decomposition reaction at 27 GPa and above 1000˚C using the in situ X-ray diffraction technique for the first time. Figure 1 shows the example of the X-ray diffraction profiles measured at 27.1 GPa and 1020˚C, which implies that the reaction was completed in 1000 seconds. Observation of the texture of the partially transformed run product by transmission electron microscopy implies that the reaction proceeded by a nucleation and growth mechanism.

We have made three successful runs for measuring the reaction rate with different conditions, which imply that the reaction is enhanced strongly by increase in temperature and pressure. The present results suggest that it takes more than 10^6 years to complete the present reaction at 600~800˚C, temperature of the slabs at the 660 km depth in the mantle. Thus, the metastable spinel phase may exist in the uppermost part of the lower mantle due to the sluggish reaction.

Table 1. X-ray diffraction profiles obtained at 27.1 GPa and 1020˚C