

In situ X-ray observations of diamond formation process in C-H₂O-MgO system

Taku Okada[1], wataru uthumi[2], Kenichi Funakoshi[3], Osamu Shimomura[1]

[1] SPring-8/JAERI, [2] JAERI, [3] JASRI

In order to clarify the mechanism of diamond-formation in the Earth's mantle, we studied the diamond-formation in the H₂O-fluids by in situ X-ray observation with the simple C-H₂O-MgO system. The results suggest that the solubility of MgO component increases greatly as a function of pressure. However, the generation of fluid is not a sufficient condition for diamond-formation, because the carbon quantity in fluid is not increased drastically until just before the diamond-formation temperature. We could conclude that diamond-formation in MgO-H₂O fluid is different from that with metal catalysts.

The mechanism of diamond-formation in the Earth's upper mantle is still a subject of controversy. Previous studies on the origin of xenocrystal diamonds and the inclusions in natural diamonds have suggested a genetic linkage between formation of diamond and mantle-fluids [e.g., Navon et al., 1988]. The formation mechanism that "carbon dissolves in the liquid metal and it separates as diamond" is generally accepted in the field of the industrial diamond synthesis using metal catalysts. In order to clarify whether the diamond-formation mechanism in the mantle-fluids is the same or not, we studied the diamond-formation in the H₂O-fluids by in situ X-ray observation using synchrotron radiation.

We adopted magnesium as one of the mantle components, and carried out experiments with the simple C-H₂O-MgO system. As a starting material, we used a mixture of brucite (Mg(OH)₂) and graphite (C). This mixture was loaded into graphite and molybdenum double capsules to prevent the leakage of volatile components during the experiments. In situ X-ray diffraction experiments were carried out using a cubic anvil-type high pressure apparatus installed on BL14B1 beamline at the SPring-8. The diffracted X-ray was detected by the energy dispersive method with a Ge-SSD. The sample assembly used in this study was composed of a boron-epoxy pressure-medium, a LaCrO₃ sleeve and a graphite cylindrical furnace. Temperature was measured with a W3Re-W25Re thermocouple, which was placed close to the sample capsule. Pressure was calculated using NaCl scale. The recovered samples were investigated using a SEM/EDS and an X-ray diffractometer.

At 3.6 GPa, it was clearly observed that brucite decomposed into periclase (MgO) and H₂O above 950 degrees C. At 6.1 GPa, however, periclase did not form even when the diffraction peaks of brucite disappeared above 1150 degrees C. This result is different from that by previous quench experiments and DTA study on simple Mg(OH)₂ [e.g., Kanzaki, 1991]. This difference might be caused by the addition of carbon or the difficulty in the determination of the coexisting phases under high pressures-temperatures based on the information from the quenched samples. Present in situ study suggests that the solubility of MgO component increases greatly as a function of pressure in C-H₂O-MgO system.

The decomposition of brucite without the appearance of periclase was observed at 8.5 GPa and 1150 degrees C. Diamond peaks began to appear suddenly when temperature was further increased up to 1835 degrees C. These in situ observations demonstrate that generation of fluid is not a sufficient condition for the diamond-formation. This result is contrast to the behavior of metal catalyst such as nickel and cobalt, which trigger diamond-formation at their respective melting point. The carbon solubility in fluid can be estimated from the decrease of the graphite peak intensity. The carbon quantity in fluid was not increased drastically until just before the diamond-formation temperature. We could conclude that diamond-formation in MgO-H₂O fluid is different from that with metal catalysts.