The stability of hydrous SiO2 stishovite in the deep mantle

*Goru Takaichi¹, Yu Nishihara¹, Kyoko N. MATSUKAGE², Masayuki Nishi³, Yuji Higo⁴, Noriyoshi Tsujino⁴, Sho Kakizawa⁴

1. Geodynamics Research Center Ehime University, 2. Department of Natural and Environmental Science, 3. Graduate School of Science Osaka University, 4. Japan Synchrotron Radiation Research Institute

The stishovite, a major mineral of sedimentary rocks and basalts, is stable under a wide range of pressures from 10 to 70 GPa. Its water content greatly affects water distribution and water transport efficiency deep in the mantle. The water content in stishovite, which is also related to Al content, was previously thought to be at most 0.3 wt% (Litasov et al., 2007). However, a recent study reported that up to 1 wt% of water can dissolve in the CaCl2-type SiO2 phase containing Al (Ishii et al., 2022). On the other hand, it has been pointed out that large amounts of water (>3 wt%) may also dissolve in the Al-free SiO2 high-pressure phases (Lin et al., 2020; Nisr et al., 2020). In addition, Lin et al. (2022) calculated that SiO2 stishovite retains about 3 wt% water from the mantle transition zone to the uppermost part of the lower mantle, based on density functional theory (DFT). However, experimental studies conducted with multi-anvil apparatus and laser-heated DAC have been interpreted differently, and the stability of hydrous SiO2 high-pressure phases at high temperatures and pressures is not accurately understood. In this study, silicic acid (SiO2-xH2O) with a water content of 9.8 wt% was used as the starting material and heated to 1300°C at a pressure of 13-29 GPa by the high-pressure apparatus SPEED-1500 installed in BL04B1 at SPring-8. X-ray diffraction patterns of the samples were obtained by an energy dispersive system under high temperature and high pressure, and the water content was estimated from the calculated cell volume. Observed SiO2 phase after heating was always stishovite. At initial stage of heating, cell volume at low temperature was much larger than that of anhydrous stishovite, with a maximum difference of +2.6%. The difference rapidly decreased as the temperature increased, and the cell volume became close to that of anhydrous stishovite at temperatures above 550°C. In addition, time-resolved X-ray observations at a constant temperature showed that the lattice volume decreased with time, suggesting that the dissolution of water into stishovite may be a metastable phenomenon. Therefore, it is unlikely that SiO2 stishovite retains more than 1 wt% water as a stable phase at mantle temperatures at least to the top of the lower mantle.

Keywords: SiO2 high pressure phase, Mantle transition zone, Lower mantle