Phase relation in $MgCO_3$-SiO_2 system up to the lowermost mantle

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Diamond is an evidence for deep carbon in the Earth. Some diamonds are considered to have originated at various depth ranges from the mantle transition zone to the lower mantle (e.g., Brenker et al., 2007; Harte and Richardson, 2012). These diamonds from ‘super-deep’ regions have been paid attention because they are possible to carry significant information about the interior of the Earth (e.g., Pearson et al., 2014). We have to take account of an unusual environment to form such diamonds when interpreting information from super-deep diamonds. However, we do not have enough clues to speculate processes or environments of super-deep diamond formation.

Subduction has been considered to be related to diamond formation in the lower mantle (e.g., Harte, 2010), and a reaction of $MgCO_3$ and SiO_2 was suggested to form diamond in slabs descending into the lower mantle (Seto et al., 2008; Takafuji et al., 2006). Therefore, we determined the phase relations in an $MgCO_3$-SiO_2 system up to 152 GPa and 3100 K in order to reveal an origin of super-deep diamonds. Seto et al. (2008) suggested that a reaction between $MgCO_3$ magnesite and SiO_2 stishovite could react with each other in the lower mantle in hot slabs and might subduct to the lowermost mantle in cold slabs without any reactions. However, their experimental results were limited to the middle lower mantle conditions up to ~80 GPa. We extended the pressure range to the lowermost mantle and estimated their reaction up to the lowermost mantle.

We used a double-sided laser-heated diamond anvil cell (LHDAC) combined with in situ synchrotron X-ray diffraction at beamline BL10XU of Spring-8 in Hyogo, Japan. Starting materials were a natural magnesite and a reagent quartz. They were ground to >10 μm in diameter and mixed 1:1 by mole fraction using agate mortar. We loaded the powder mixture into a sample chamber in a tungsten gasket which was pre-compressed to 40–80 μm in thickness and drilled a 30–100-μm hole in diameter. Culet diameters of diamond anvils used were between 100 and 350 μm. A Size of a sample chamber was decided based on a culet diameter of anvils. Double-sided laser heating was conducted using a fiber laser equipped at BL10XU. We used Pt powder, foil or doughnut as a laser absorber. Experimental pressures were determined using a thermal equation of state of Pt (Fei et al., 2007) and thermal pressures were calculated using Mie-Grüneisen-Debye model (e.g., Fei et al., 1992). XRD patterns were analyzed using IPAnalyzer and PDIndexer software (Seto et al., 2010).

Magnesite reacted with stishovite or $CaCl_2$-type SiO_2 to form $MgSiO_3$ bridgmanite and maybe CO_2 above ~2000 K. These results almost corresponded to Seto et al. (2008) below 80 GPa. The phase relation was drastically changed above 80 GPa: diamond and bridgmanite were observed below 2000 K near 80 GPa and the reaction temperature seemed to gradually increase above 80 GPa. $MgCO_3$ was reported to transforms from magnesite to a high-pressure polymorph, phase II, above 82 GPa (Oganov et al., 2008). We actually observed $MgCO_3$ phase II above 80 GPa and at high temperature, and thus the phase transition of $MgCO_3$ might be related to the change of the phase relation.

We speculate a reaction between $MgCO_3$ and SiO_2 in a subduction process based on the present phase diagram. $MgCO_3$ and SiO_2 can react in hot or cold slabs up to 1900-km depth in the middle lower mantle, which forms high-pressure CO_2 polymorph or diamond. On the other hand, $MgCO_3$ and SiO_2 are possible to subduct up to the lowermost mantle in a very cold slab. Their reaction is expected at the lowermost

mantle due to heating from the core in this case. Therefore, their reaction in a cold subduction can explain a formation process of some super-deep diamonds having an especially deep origin (e.g., Harte and Richardson, 2012; Hayman et al., 2005; Wirth et al., 2014).

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