Density measurement of MORB melt under dry and hydrous condition by using X-ray absorption method

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The density of magma is one of important properties for discussion about magma differentiation and volcanic action. It is generally believed that magma is less dense than mantle minerals and therefore magma moves upward. However, the density of magma would become close to or even higher than that of coexisting mantle minerals in the planetary interior because the bulk modulus of the mantle minerals are sufficiently smaller than that of magma. Therefore, it is necessary to measure the density of magma at high pressure and temperature for discussions about migration of magma.

In the Earth, most of water is trapped in the mantle, especially in the transition zone. Water has a property that it melts into the magma rather than mantle minerals. Therefore there is a probability that magma, which is generated under hydrous condition, becomes hydrous magma. Water is much lighter than magma, so that water may have a large effect on the density of hydrous magma. For understanding the effect of water on the density of magma, we have measured the density of dry and hydrous MORB melts at high temperature and high pressure using X-ray absorption method. These experiments were carried out using a DIA-type cubic press on BL22XU beamline at the SPring-8. X-ray absorption method is much more accurate method for the density measurement of magma under desired pressure and temperature condition than the others. This method for density measurements by means of X-ray absorption under high pressure and high temperature using a multi-anvil apparatus, combined with a synchrotron radiation source, was developed by Katayama et al. (1993). This method is based on the Lambert-Beer's law. To overcome the effect of the variation of the sample thickness under pressure, the sample was put in a diamond capsule to calibrate the thickness and the intensity of the transmitted X-ray beam was measured as a function of sample position.

We succeeded in measuring the density of dry MORB melt up to 4.6 GPa and up to 1727C. Calculated compression curve based on the results of dry MORB melt (bulk modulus K=25.6 GPa) is different from the compression curve reported by Agee (1998) (K=19.3 GPa). The difference can be seen at about 5 GPa, which indicates that the structure of MORB melt may change resulting from an increase of Al coordination number from 4 to 5 at about 5 GPa. We succeeded in measuring the density of hydrous MORB melt up to 4.0 GPa at 1400C. The partial molar volume of H2O was calculated by using the obtained densities of dry and hydrous MORB melt. Using calculated values at several pressures, we obtained the compression curve of the partial molar volume of H2O. The densities of crystals, such as olivine, pyroxene and anorthite, were compared with that of dry and hydrous magma. The lunar crust consists of anorthosite while the Earth's crust doesn't consist of anorthite. Therefore the anorthite is the lighter than lunar magma ocean and heavier than the Earth's magma ocean. This difference might be explained by the water content in the magma ocean. This shows that lunar magma ocean occurred under dry condition and the Earth's magma ocean occurred under hydrous condition.