NE5C/2004G047

Structural study on hydrous ultrabasic magma in MgO-SiO_2-H_2O with pressures

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Introduction

We have found that the liquidus phases drastically change to more silica-rich composition with increasing pressure under hydrous condition. As the result, the composition of liquid generated in the deep mantle is enriched in MgO component (e.g. [1]). This implies the structural changes of the hydrous melts and the changes of mechanism on water solution in magma, because liquidus phases and melting relations of silicates are strongly affected by melt structures. However, direct observational studies on hydrous silicate melts under high pressure have not been conducted so far because of experimental difficulties. Hydrous silicate glasses quenched from hydrous melts at high pressure have been used for experimental constrains (e.g. [2]). In order to perform direct measurement of hydrous magma under high pressure, we had developed the new capsule system for the in-situ X-ray experiment using synchrotron X-ray radiation for structural study on hydrous magma under high-pressure and temperature conditions [3].

In the present report, we introduce the structural change on the hydrous melt in Mg_2SiO_4-$MgSiO_3$-H_2O determined by using the new capsule system, which corresponds to eutectic composition of major mineral in the Earth's mantle.

Experimental

Starting materials were prepared by mixing $Mg(OH)_2$ and SiO_2, in order to be the compositions of Mg_2SiO_4-$MgSiO_3$-H_2O (Fo-En-W), which is 18.3 wt% H_2O baring system. The experiments were conducted using MAX80 cubic type press installed at AR-NE5C beamline. Pressure transmitting medium were made of Boron + epoxy resin or pyrophyllite with the shape of 9- and 7-mm cubes. Sample chamber was put in the center of pressure transmitting medium and thermocouple were not used in order to get high quality diffraction data. Instead of no use of thermocouple in diffraction experiments for hydrous melts, we carried out temperature calibration experiment using the same cell assemblage.

Diffraction angles were fixed at several arbitrary angles within the range form 4° to 25° to obtain wide scattering vector Q range (Q= $4\pi E\sin\theta/12.398$, where E is energy). Effective X-ray source intensity in the AR-NE5C bending magnet beamline was determined by Monte Carlo method developed by [4] from each diffraction patterns.

The hydrous magmas were enclosed in single crystalline diamond sleeve whose ends were sealed by Pt lids under high P-T condition. The details were described in [3].

Results

The striking features in the structure factors, S(Q)s, were found in the FSDP (First Sharp Diffraction Peak) which may be related to SiO_4 tetrahedral network in silicate melts(e.g. [5]). New peak at around 3 $Å^{-1}$ appeared and became intense with increasing pressure. The position of FSDP shifted to higher Q position from 2.16 to 2.27 $Å^{-1}$ at pressures between 1.92 and 6.5 GPa. Those positions of FSDP were very high Q but the significant pressure dependence on the shift of the position was not observed comparing with anhydrous Mg-silicate melt reported by [6]. These observations indicate that nearly all network of the melt seems to be depolymerized by the H_2O and MgO component.

We can derive real space information of local structure in the melt from the Radial Distribution Function (RDF) by Fourier transform of S(Q)s. Almost no change in first peaks in the RDFs was observed (i.e. 1.63 Å). This result indicates that SiO_4 tetrahedron exists mainly as the local structural units of present melt at least to 6.5 GPa. On the other hand, the distance of Si-Si pair shifted significantly from 3.14 Å to 2.91 Å at pressures between 1.92 and 3.06 GPa. However, at higher pressures between 3.06 and 6.5 GPa (across 5 GPa), the peak did not change so much, which was approximately 2.91 Å. That may be an evidence for the change of mode that H_2O dissolve to silicate melt. Indeed the liquidus phase in hydrous magma was changed at around 5 GPa reported by [1].

Our analyses suggest that, in the low-pressure region where silica-rich magma is ganerated, H_2O may dissolve with dividing Si-O-Si network in magma (i.e. Si-OH). Oppositely, in the region where MgO-rich magma is generated, water may prefer to dissolve with divalent cation to form Mg-OH, which was suggested by [2].

References

[1] T. Inoue, Phys. Earth Planet. Inter. 85, 237-263 (1994)
[2] X. Xue et al., Geochim. Cosmochim. Acta., 68, 5027-5057 (2004)
[3] T. Inoue et al., PF Activity Report 2004, 22, 206, (2005)
[4] K. Funakoshi, PhD Thesis, Tokyo Inst. Technol., (1997)
[5] S. Susman et al., Phys. Chem. Glasses., 31, 144-150 (1990)
[6] N. Funamori et al., Geophys. Res. Lett. 109, B03203 (2004)
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