Concentration dependence of water diffusion in silica glass at 50 bar H_2O pressure

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Water diffusion in silicate melts is one of the main controlling factors of magmatism in subduction zones. Water diffusivity in silicate melts has been known to depend on its own concentration. However, the details of atomic-scale processes responsible for concentration dependence of water diffusion have not yet been fully understood. In this study, in order to understand the mechanism of water diffusion and its concentration dependence in silicate melts, we carried out diffusion experiments of water in SiO_2 glass at 650-850°C and the water vapor pressure of 50 bar. SiO_2 glass was used as a diffusion medium to discuss the role of water on diffusion without any other compositional effects.

Diffusion profiles of ^{1}H and ^{30}Si were measured on the cross section of a run product with a 5-micron step using Cameca ims-6f ion microprobe at Hokkaido University. Glasses with known water contents were used to convert secondary ion counts ratios of $^{1}H/^{30}Si$ to the water contents in the samples.

The diffusion profiles of water obtained in this study in a H_2O concentration range of 0.25-0.001 wt% cannot be simply explained by previous models, especially at the low concentration region, and show much stronger water concentration dependence. We propose following mechanisms in order to explain this stronger water concentration dependence of water diffusion in SiO_2 glass: (1) The main diffusion species is molecular H_2O, and its relative abundance to OH groups decreases with lowering the water content in the glass; (2) The number of pathways available for diffusion is controlled by the number of non-bridging oxygen atoms (NBO) that are produced by the formation of OH groups. Because the water diffusivity is proportional to the above two factors and both depend on the total water content in the glass, the water concentration dependence of water diffusion is larger than the previous models. The smaller water concentration dependence that observed for water diffusion in multi-component silicate glasses as shown in natural glasses can be attributed to the little dependence of NBO concentration on the water content because it is controlled extrinsically by other network modifier cations.