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Nucleation process in a system controlled by diffusion

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The nucleation of nuclei under a high density condition is numerically investigated on the base of a nucleation model proposed by Toramaru (i.e.,Toramaru 1995, J.Geophys.Res.,100B2,1913-1931). With the help of the model, we can perform a simulation of nucleation by improving basic equations describing the nucleation and growth of nuclei. Besides, the semianalytic expression for number density of nuclei formed in a very dense material such as solution is derived by the use of the theoretical method established by Yamamoto and Hasegawa (Yamamoto & Hasegawa 1977, Prog. Theor. Phys.,58, 816-828), who investigated the nucleation phenomena in a rarefied gas.

Nucleus formation of a new phase occurs in supersaturated solution which contain some amount of volatile component. In dense solution, the nucleation process would be different from that in a rarefied gas. In a rarefied gas, since the mean free path is very large, a large number of molecules are immediately consumed in order to form the new phase and the degree of supersaturation in the solution decreases together. On the other hand, in dense solution, the dissolved volatile reaches nuclei by diffusion from the surrounding solution due to the shortness of the mean free path. This diffusion process delays the depletion of volatiles and the reduction of supersaturation. Therefore, many nuclei can be nucleated there.

The nucleation processes under a high density condition can be applied to the nucleation and growth processes of bubbles in magma. The nucleation and growth of bubbles in magma are deeply related to the wide variety of eruption mechanisms and degassing processes. Toramaru(1995) suggested the nucleation model in order to analyze the nucleation of bubbles and obtained the experimental expression for the number density of bubbles from his simulation. Then, Toramaru assumed that the concentration of volatile decreases homogeniously in a whole system. However, it is thought in the solution controlled by diffusion that the diffusion process causes an inhomogenious spatial concentration profile of volatile.

First, we improve the nucleation model and derive the semianalytic expression for the number density of bubbles under a high density condition in accordance with Yamamoto & Hasegawa theory. The expression is very agreeable with the numerical result. Therefore, the number density of bubbles can be simply estimated in the wide parameter region. This results show that bubbles can be nucleated about ten times as many as predicted by Toramaru in the ascending magma with a small velocity. Besides, we improve the nucleation model in order to evaluate the effect of the assumption that the concentration of volatile decreases homogeniously and calculate the number density of bubbles. The inhomogeneous model shows that the number density of bubbles is formed severalfold more than the homogeneous model. Therefore, it can be predicted that the number density of bubbles would be nucleated about ten times more than that given by Toramaru when the saturated time is very long. Although the nucleation rate is not well determined, the uncertainty has little effect on the number density of bubbles.