

原始惑星系円盤におけるアモルファスフォルステライト粒子表面での含水鉱物形成 Hydration of amorphous forsterite grains in protoplanetary disks

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Hydrous silicate dust can be thermodynamically stable at low temperatures ($\sim 200\text{K}$) in protoplanetary disks with the solar-system abundance of elements. Theoretical and experimental investigation (Fegley and Prinn, 1989; Imae et al., 1999) have shown that the hydration reaction between crystalline Mg-silicates and water vapor is too sluggish to occur during a lifetime of protoplanetary disks. However, infrared spectroscopic observation and investigation of extraterrestrial materials have shown that both crystalline and amorphous Mg-silicates may be present in protoplanetary disks and in the protosolar disk. Amorphous silicates are thermodynamically unstable, and thus could be hydrated more rapidly at higher temperatures than crystalline silicates (Nagahara and Ozawa, 2011). If hydration of amorphous silicates occurs within a disk lifetime, hydrated dust could be a source of water to terrestrial planets.

In this study, in order to investigate hydration of amorphous Mg-silicates, we conducted closed-system reaction experiments of amorphous forsterite and water vapor in sealed glass tubes at temperatures of 1023-423K and $P_{\text{H}_2\text{O}}$ of 0.05 -50 bar for 2-1344 hours. Run products were analyzed with FT-IR and XRD. We found that samples reacted at temperatures below 723K and $P_{\text{H}_2\text{O}}$ of 5-50 bar showed sharp $3\mu\text{m}$ absorption features, clearly suggesting the formation of hydrous phase(s). XRD analyses of some run products showed that the hydrous phase was serpentine. Because the stable temperature of hydrous phase(s) at $P_{\text{H}_2\text{O}}$ of 5-50 bar is $\sim 523\text{K}$, the present results indicate that hydrous Mg-silicates can be formed metastably from amorphous forsterite at higher temperatures than the thermodynamic prediction. Moreover, hydration of amorphous forsterite occurred after 2-hour heating at 623K and $P_{\text{H}_2\text{O}}$ of 5 and 50 bar, implying that the activation energy for hydration of amorphous forsterite is much smaller than that for crystalline forsterite.

Hydration reaction seems to have little $P_{\text{H}_2\text{O}}$ dependence at $P_{\text{H}_2\text{O}}$ of 5-50 bar, indicating that hydration is controlled by a reaction between amorphous forsterite with saturated adsorbing water molecules. No hydration occurred, however, at 523K and $P_{\text{H}_2\text{O}} < 1$ bar, which could be due to less effective adsorption of water molecules at low-pressure conditions.

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