SESSION 5

Refractory Materials in the Evolving Protosolar Disk

DAY 3 – Feb.15, 2017
8:30 am – 11:25 am

Water Vapor Pressure-Dependent Crystallization of Amorphous Enstatite

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Introduction: Infrared spectroscopic observations show that both crystalline and amorphous silicate dust is present in protoplanetary disks, while silicate dust in the interstellar medium is mostly amorphous [1, 2]. This indicates that amorphous silicates transform into crystalline silicates due to thermal annealing in protoplanetary disks. Crystallization of amorphous silicates has been investigated experimentally [e.g., 3], but the effect of disk gas, especially water vapor, has not yet been fully understood except for amorphous forsterite that crystallizes efficiently in the presence of water vapor [4]. Here we performed crystallization experiments of amorphous enstatite at various water vapor pressures.

Experiments: Amorphous enstatite powder synthesized by an induced thermal plasma method was annealed at 780-850°C in air (P_{H2O}~10^{-3} bar), in vacuum (P_{H2O}~10^{-10}-10^{-9} bar) and at P_{H2O} ~10^{-5} bar. Run products were examined with FT-IR, XRD, and TEM.

Results and Discussion: Quantitative analysis of crystallization degree was made by infrared spectral fitting of the 10-μm infrared absorption feature. The time evolution of the fraction of crystalline enstatite was fitted with the Johnson-Mehl-Avrami equation. The obtained Avrami parameter (a parameter related to the reaction mechanism) *n* in air was ~2.5, suggesting the 3-dimensional diffusion-controlled growth with heterogeneous nucleation. This is consistent with previous crystallization experiments of amorphous enstatite in air [5, 6]. The crystallization rate was larger than that in air in vacuum, and *n* of ~1.5 was obtained, Which suggests that three-dimensional diffusion-controlled growth of crystalline enstatite after heterogeneous nucleation. This was supported by TEM observations, where crystalline enstatite was only identified at the surface of the grains in the sample heated at 800°C in vacuum for a short duration. Selective evaporation of Mg and O from the grain might promote to form SiO_4 chain structures at the surface, leading to heterogeneous nucleation of crystalline enstatite at the grain surface. We also found that crystallization of amorphous enstatite at P_{H2O} ~10^{-5} bar occurs more rapidly than that in vacuum, indicating that water molecules diffusing into the amorphous structure cut atomic bonds and promotes the crystallization as in the case of amorphous forsterite [4].

References: [1] Waelkens, C. et al. (1996) *A&A* 315, L245. [2] Kemper, F. et al. (2004) *ApJ* 609, 826. [3] Hallenbeck, S. L. et al. (1989) *Icarus* 131, 198-209. [4] Yamamoto, D. (2016) *Master thesis*. [5] Murata, K. et al. (2009) *ApJ* 697, 836-837. [6] Imai, Y. (2012) *PhD thesis*.