

### CRYSTALLIZATION OF AMORPHOUS FORSTERITE PROMOTED BY WATER VAPOR.

D. Yamamoto<sup>1\*</sup> and S. Tachibana<sup>1</sup>. <sup>1</sup>Department of Natural History Sciences, Hokkaido University, Japan. \*E-mail: daiki@ep.sci.hokudai.ac.jp

**Introduction:** Both amorphous and crystalline silicates are present in the matrices of primitive chondrites. Infrared spectroscopic observations of protoplanetary disks have also shown the existence of both crystalline and amorphous silicates [e.g. 1]. In contrast, silicate dust in the interstellar medium is mostly amorphous [2]. Amorphous silicates are therefore considered to be precursors of crystalline silicates in protoplanetary disks. Crystallization of amorphous silicates has been investigated experimentally [e.g. 3], but the effect of disk gas such as H<sub>2</sub>O on the crystallization behavior has not yet been investigated in detail. In this study, we investigated the effect of water vapor on the crystallization kinetics of amorphous forsterite in protoplanetary disk.

**Purpose:** We performed crystallization experiments of amorphous forsterite powder, synthesized by a thermal plasma method, in vacuum condition ( $\sim 10^{-4}$  Pa) using a gold-image vacuum furnace (thermo-Riko GFA430VN) at 953, 1003, and 1023 K. We also made experiments in sealed glass tubes, where the water vapor pressure (P<sub>H<sub>2</sub>O</sub>) was kept at 0.65 bar either by a Ca(OH)<sub>2</sub>-CaO buffer system at 773 K or by complete dehydration of Mg(OH)<sub>2</sub> at 823 and 873 K. The sealed glass tubes were heated in a box furnace. Run products were analyzed with FT-IR (KBr pellet method). Quantitative analysis of the degree of crystallization was made with spectral fitting of run products, and the time evolution of crystallization was fitted with the Johnson-Melch-Avrami (JMA) equation.

**Results and Discussion:** The temperature dependence of the time constant of crystallization ( $\tau$ ), which represents the time required for the crystallization degree of  $\sim 63\%$ , in vacuum showed the Arrhenius relationship at 953–1023 K, and the activation energy for crystallization was 410 kJ/mol. On the other hand, the activation energy for crystallization at P<sub>H<sub>2</sub>O</sub>=0.65 bar was smaller than that in vacuum ( $\sim 89$  kJ/mol). The obtained value of  $\tau$  at 773 K and P<sub>H<sub>2</sub>O</sub>=0.65 bar was  $\sim 16$  hr. When  $\tau$  in vacuum was extrapolated to the lower temperature assuming that the kinetic parameter of  $n$  in the JMA equation ( $\sim 1.5$  at 953–1023 K) was constant irrespective of temperature, it would be  $\sim 8 \times 10^6$  hr that is  $\sim 5$  orders of magnitude larger than that at P<sub>H<sub>2</sub>O</sub>=0.65 bar. This clearly indicates that the crystallization of amorphous forsterite is promoted in the presence of water vapor.

In the structure of Mg<sub>2</sub>SiO<sub>4</sub>-composition glass [4], MgO<sub>x</sub> units act as a network former and SiO<sub>4</sub> units form polymer and dimer. We propose that water molecules diffuse into the amorphous structure to break Si-O-Si bonds and MgO bonds as a network modifier and promote the crystallization of amorphous forsterite as suggested for SiO<sub>2</sub> glass [5].

Present results imply that the crystallization of amorphous silicates may take place more effectively in the presence of water vapor in protoplanetary disks.

**References:** [1] Henning Th. 2010. *Annual Review of Astronomy and Astrophysics* 48:21–46. [2] Kemper F. et al. 2004. *Astrophysical Journal* 609: 826–837. [3] Brucate J. R. and Nuth J. A. 2010. *Protoplanetary Dust* (Apai and Lauretta, Eds.) [4] Kohara S. et al. 2004. *Science* 303:1649–1652. [5] Wagstaff F. E. and Richards K. J. 1966. *Journal of The American Ceramic Society* 49:118–121.