Interpretation of XRD and IR features in amorphous $MgSiO_3$ before crystallization of enstatite with heat treatment.

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Anhydrous silicate dust such as enstatite ($MgSiO_3$) or forsterite (Mg_2SiO_4) are observed around the circumstellar environment [1]. In contrast the interstellar dust is almost amorphous [2]. They were incorporated into the circumstellar disk of young stars, and crystalline silicates could form by heating. In order to understand the formation and evolution of the circumstellar dust, crystallization of amorphous silicates have been performed (e.g., [3-6]). Imai [3] carried out heating experiments of amorphous $MgSiO_3$ prepared by an induction thermal plasma (ITP) technique. Powder X-ray diffraction (XRD) and infrared (IR) absorption were used for identification of the phase and estimating the degree of crystallization. These results suggested structural changes in the amorphous silicates before the crystallization of enstatite. Thus, we measured high energy X-ray diffraction (HEXRD) data and X-ray absorption fine structure (XAFS) spectrum of the amorphous samples to investigate bond distance. Previous heating experiments of amorphous Mg-silicates synthesized by sol-gel method showed the similar features in their starting materials by XRD [4-6]. The sol-gel method is performed with water, suggesting the peak features may be related to the effect of water. We examined the effect of hydration to the XRD and IR features, by performing hydrothermal experiments too.

Total correlation functions obtained in the HEXRD show that Mg-O distance is slightly expanded and contracted before enstatite crystallization. The XRD pattern of the run product on the hydrothermal experiment at 150 ºC for 3 weeks with a water/rock ratio of 0.1 by weight is very similar to the result of the heating experiments using the starting material prepared by the ITP technique. These results suggest that the weak peaks correspond to hydrous phyllosilicates and should relate to the mixed-layer mineral of serpentine and stevensite [7], for example. In the ITP method, H_2O or OH molecules (or H and O separately) which were originated by decomposition of $Mg(OH)_2$ of the starting material, should be incorporated into the amorphous $MgSiO_3$ during the rapid condensation. In this case, a possible scenario is follows: (1) phyllosilicate minerals crystallized from the O and H bearing amorphous silicate, (2) they were dehydrated and became amorphous, and finally (3) anhydrous silicate (enstatite) crystallized.

The present results suggest that H_2O (or H and O) should be included in amorphous silicates condensed in circumstellar regions and hydrous silicates may form by mild heating, such as at ~1000 K for a few hours, although more kinetic experiments are needed.

References: [1] Tielens et al. (1997) Ap&SS, 255, 415-426 [2] Kemper et al. (2004) ApJ, 609, 826-837 [3] Imai (2012) PhD thesis [5] Murata et al. (2009) ApJ, 697, 836-842 [5] Matsuno et al. (2012) ApJ, 753, 141-147 [6] Thompson et al. (2012) A&A, 545, A60 [7] Takahashi et al. (2013) JpGU Meeting, PPS24-P14