Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS24-P04 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

Mg2SiO4-H2-H2O 系でのフォルステライト凝縮速度論
Kinetic condensation of forsterite in the system of Mg2SiO4-H2-H2O

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Equilibrium condensation calculations provide a set of stable minerals under a certain physical and chemical condition, condensation does not necessarily occur in equilibrium in time-variant circumstellar systems, where pressure, temperature, and gas chemistry vary with time. It is thus important to understand the kinetic aspect of dust formation processes, especially the vapor growth kinetics of dust. In this study, we report a quantitative estimate of the condensation coefficient, non-dimensionless parameter representing kinetic hindrance for condensation, for vapor growth of forsterite under protoplanetary disk-like conditions in the system of H2?H2O?forsterite.

An infrared vacuum furnace was used in this study. A mixed gas of hydrogen and water vapor was flowed into the system at a controlled rate to keep a pressure constant. Synthetic forsterite powder in an iridium crucible was heated as a gas source. A part of evaporated gases were condensed on a substrate of platinum mesh located at a cooler region in the chamber. The pressure and temperature conditions during the experiment were close to those of protoplanetary disks. The total pressure of the system was kept at 5.6 Pa, and the substrate temperature was ˜1235 K. The gaseous H2O/H2 ratio was set at ˜0.015, which was ˜15 times larger than the solar H2O/H2 ratio. The experimental duration ranged from 5 to 115 hours.

The platinum mesh was fully covered with sub-micron to micron-sized condensates. Chemical compositions of condensates were consistent with stoichiometric forsterite. A variety of EBSD patterns corresponding to crystalline forsterite were obtained from the condensates. We thus conclude that the condensates are a thin film of polycrystalline forsterite.

The gaseous SiO/H2 ratio in the flux onto the substrate was estimated to be 5.5 x 10-7 that corresponds to 7.7 x10-3 of the solar SiO/H2 ratio. The supersaturation ratio for the present experiment was ˜230. Based on the incoming flux of SiO onto the substrate and the ideal evapo-ration flux, the condensation coefficient of forsterite was evaluated to be 0.038 +/- 0.005 at 1235 K and the supersaturation ratio of 230.

The condensation coefficient at 1235 K is well consistent with the evaporation coefficient for forsterite in hydrogen gas and is smaller than that of metallic iron. The difference in condensation and evaporation coefficients for metallic ion and forsterite may be attributed to the difference in atomic bonds in metallic iron (metallic bonds) and silicates (ionic and/or covalent bonds). This difference implies that the growth of forsterite dust, for instance AOAs in chondrites, occurs less efficiently than that of metallic iron dust in circumstellar environments although they have similar equilibrium condensation temperatures.

キーワード: フォルステライト, 凝縮, 速度論, ダスト, 原始惑星系円盤
Keywords: forsterite, condensation, kinetics, dust, protoplanetary disk