Kinetics of dust growth under protoplanetary-disk conditions: Forsterite (Mg_2SiO_4)

S. TACHIBANA[1]

[1]Department of Natural History Sciences, Hokkaido University. E-mail: tachi@ep.sci.hokudai.ac.jp

Chemical fractionation processes in the early Solar System are the key to understand the chemical diversity of chondrites and terrestrial planets. Dust particles in protoplanetary disks experience various physicochemical conditions, such as temperature, pressure, and gas chemistry, over various timescales. In the evolving protoplanetary disk, dust condenses, evaporates, or reacts with gas to cause elemental and/or isotopic fractionations. In order to understand fractionation processes in protoplanetary disks, solid-gas reactions and their kinetics should be properly understood under protoplanetary disk-like conditions.

Forsterite (Mg_2SiO_4), a major dust-forming silicate, is known to evaporate with a large kinetic hindrance (1/10-1/100 of the ideal rate predicted by the kinetic theory of gases) [e.g., 1], but its growth kinetics has not yet fully understood. In this study, vapor growth experiments of forsterite in the presence of low pressure hydrogen gas were conducted to determine its growth kinetics quantitatively in an infrared vacuum furnace. A mixed gas of hydrogen and water vapor (H_2O/H_2~0.015) was flowed into the system, continuously evacuated, at a controlled rate to keep a pressure constant (~5 $x10^{-5}$ bar). Synthetic forsterite powder in an Ir 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 (~1350 K) in the chamber.

Chemical compositions and EBSD patterns of condensates were consistent with stoichiometric crystalline forsterite. The growth flux of forsterite was evaluated from the weight gain of condensates. Based on the incoming flux onto the substrate surface and the equilibrium flux at the experimental condition, we could estimate the kinetic hindrance for vapor growth of forsterite as a condensation coefficient of the Hertz-Knudsen equation. The estimated condensation coefficient of forsterite seems to be smaller (<0.01) than the evaporation coefficient at similar conditions [1] and much smaller than the condensation coefficient of metallic iron [2]. This difference in vapor growth efficiency between forsterite and metallic iron might have led to metal-silicate fractionation in the early Solar System that is recorded in chondrites.

[1] Takigawa A. et al. (2009) *ApJ* **707,** L97. [2] Tachibana S. et al. (2011) *ApJ* **736,** 16.