

CONDENSATION AND EVAPORATION KINETICS OF FORSTERITE UNDER PROTOPLANETARY DISK CONDITIONS. S. Tachibana¹ and A. Takigawa²
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Evaporation from solid and condensation from vapor are responsible for phase transition and elemental fractionation in protoplanetary disks. Evaporation and condensation do not necessarily occur in equilibrium because pressure, temperature, and gas chemistry vary with time in protoplanetary disks. The presence of refractory components in chondrites such as CAIs and AOAs (amoeboid olivine aggregates) cannot be predicted solely by thermodynamic calculation for equilibrium condensation, and should be explained by kinetics of dust formation processes possibly with physical separation of dust particles from the reaction system. In this study, we report quantitative estimates of evaporation and condensation kinetics of forsterite (Mg_2SiO_4), one of the major mineral species in the Solar System materials, from condensation and evaporation experiments of forsterite under protoplanetary disk conditions.

Evaporation experiments of single crystal forsterite were done at 1383 and 1317 K and hydrogen pressure of 2×10^{-5} bar. The evaporation conditions were close to typical temperatures and pressures of protoplanetary disks and lower than those in previous experimental studies [e.g., 1]. We obtained the evaporation coefficient, a non-dimensionless parameter representing kinetic hindrance for evaporation, of ~ 0.02 – 0.04 at 1383 and 1317 K, which is consistent with that obtained at higher temperatures [1].

Condensation experiments of forsterite were done in the system of forsterite– H_2 – H_2O system using an infrared vacuum furnace. A mixed gas of hydrogen and water vapor ($H_2O/H_2 \sim 0.025$) was flowed into the system at a controlled rate to keep a pressure constant ($\sim 5.5 \times 10^{-5}$ bar). 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 (~ 1350 K). The pressure and temperature conditions during the experiment were close to those of protoplanetary disks.

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 electron back-scattered diffraction (EBSD) patterns corresponding to crystalline forsterite were obtained from the condensates, and the condensates are thus a thin film of polycrystalline forsterite.

The supersaturation ratio for the present experiments ranged from ~ 15 to ~ 30 . Based on the incoming flux of SiO onto the substrate and the ideal evaporation flux, the condensation coefficient of forsterite was evaluated to be ~ 0.005 at ~ 1350 K. The obtained condensation coefficient is much smaller than that of metallic iron [2] and similar to that for corundum [3].

We will present details of experimental results and their implication for dust formations in protoplanetary disks at the meeting.

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ORIGIN OF VOLATILE ELEMENT DEPLETION IN EARLY SOLAR SYSTEM MATERIAL. E. A. Pringle¹, F. Moynier¹, P. Beck², R. Paniello³, and D. Hezel⁴, ¹Institut de Physique du Globe de Paris (1 rue Jussieu, 75005 Paris France; pringle@ipgp.fr), ²Institut d'astrophysique et de planétologie de Grenoble, ³Washington University in St. Louis, ⁴Universität zu Köln.

Planetary materials are characterized by specific abundances of moderately volatile lithophile elements, with volatile element depletions observed in differentiated bodies and most chondrite groups when compared to CI chondrites [1]. Hypotheses for this volatile element depletion in bulk chondrites include incomplete condensation from the solar nebula, volatile loss during accretion, or mixing of distinct reservoirs consisting of a volatile-rich CI component and a volatile-poor refractory component. The stable isotope systematics of moderately volatile elements can be used to trace the origin of volatile element abundance variations among planetary materials.

Zinc is a moderately volatile element with a 50% condensation temperature of ~ 730 K [2]. Samples with significant volatile element depletions, including the Moon and terrestrial impact rocks, display heavy Zn isotope compositions possibly indicating Zn isotope fractionation during evaporation [3, 4]. However, Luck et al. [5] found a negative correlation between $\delta^{66}Zn$ and $1/Zn$ among CV, CM, CO, and CI chondrites, opposite to what is expected if evaporation was the cause of Zn abundance variations between chondrite groups, suggesting that nebular processes caused the volatile element variability in chondrites.

We have analyzed the Zn isotopic composition of an extended range of carbonaceous chondrites: CI (4), CM (4), CO (4), CV (3), CB (2), CH (2), CK (4), and CR (1). Bulk samples define a negative correlation in a $\delta^{66}Zn$ vs Mg/Zn or Ca/Zn plot, which further confirms that Zn abundance variations between carbonaceous chondrites are not due to evaporation but rather due to nebular processes. The exceptions are CB and CH, which display Zn systematics consistent with a collisional formation mechanism that created a re-enrichment in heavy Zn isotopes relative to the trend defined by CI-CR. Therefore, Zn isotopes support the origin of CH and CB parent body by collisional accretion.

In addition, we present the first Zn isotope analyses of individual chondrules, including chondrules from Allende (CV3) and Mokoia (CV3) and an aliquot of Allende matrix. The Zn isotope data for Allende components show a chondrule-matrix complementarity, indicating that the accretion of chondrite components was a localized process. Furthermore, all chondrules exhibit light Zn isotope enrichments relative to the bulk, suggesting that the Zn depletion observed in chondrules is not due to evaporation. We suggest sulfide removal was the mechanism responsible for the Zn systematics of chondrite components.

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