EXPERIMENTAL STUDIES ON CONDENSATION KINETICS OF MAGNESIUM SILICATES AND METALLIC IRON. S. Tachibana[1], [1]Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan. tachi@eps.s.u-tokyo.ac.jp

Introduction: Condensation of solid from gas is a crucial process for formation of solid in circumstellar environments. For instance, silicate dust particles observed around evolved stars by infrared spectroscopy should be formed by condensation of gas, and such circumstellar silicates have been observed in chondrites as presolar silicates. It has been believed that condensation of solids occurred in the proto solar disk as well. Amoeboid olivine aggregates, irregular shaped aggregates of Mg-rich olivines, and metallic iron grains with Ni zoning in CH chondrites may be condensates formed in the proto solar disk. Condensation with accompanying separation of solids also played an important role in making volatility-controlled chemical diversities in solar-system materials.

Although equilibrium condensation calculations provides a set of stable minerals under a certain physical and chemical condition, condensation does not necessarily occur in equilibrium. Dust forming conditions and environments vary with time in circumstellar environments, and thus it is quite important to understand condensation kinetics of solids.

Kinetic condensation: When a surface reaction is a rate-limiting process, the net condensation flux J_c is expressed by the Hertz-Knudsen equation based on a classical kinetic theory of gases [1];

$$J_c = \frac{\alpha_c p - \alpha_e p^{eq}}{\sqrt{2\pi mkT}},$$

where p is the pressure of condensing gas species, p^{eq} is the equilibrium vapor pressure, m is the weight of the condensing gas molecule, k is the Boltzman constant, and T is the absolute temperature. α_c and α_e are condensation and evaporation coefficients, which represent kinetic hindrances of condensation and evaporation. α_c and α_e should be a function of pressure, temperature, and gas compositions, which makes it difficult to predict them theoretically, and thus they should be determined experimentally.

Condensation Experiments: Condensation experiments of magnesium silicates and metallic iron under circumstellar conditions have been carried out to clarify heterogeneous nucleation of gas species, containing metallic elements produced by heating minerals such as forsterite, olivine, and metallic iron, on a substrate put in a cooler region of a vacuum furnace [e.g., 2-4]. However, it has not been easy to make quantitative discussion on kinetic processes of heterogeneous nucleation and growth, such as dependences on partial pressures of condensing gas species and supersaturation ratio, due to experimental difficulties. We have been working on improvements of experimental techniques to obtain kinetic data on growth of magnesium silicates and metallic iron, both of which are major solid components in the system of solar abundance.

Condensation of Metallic Iron: Condensation experiments of metallic iron under a controlled supersaturation ratio (S) have shown that α_c ranges from ~0.5 to ~1 at ~1240 K for S≈4-30, suggesting that metallic iron grows without large kinetic hindrance [4, 5]. Moreover, it has been found that metallic iron nucleates on a corundum substrate easily even at S of 4. This indicates that metallic iron can form without significant nucleation delay that was suggested by a homogeneous nucleation theory due to its large surface tension [e.g., 6].

Condensation of Magnesium Silicates: Condensation of Mg silicates occurs in a multi-component system, and encounter of different gas species such as Mg, SiO, and oxygen is required to form Mg silicates, while metallic iron forms in a simple one-component system. Our preliminary results on condensation of Mg silicates under controlled supersaturation conditions [7] implies that formation of Mg silicates under low pressure conditions close to outflows from evolved stars requires extremely high supersaturation even for heterogeneous nucleation in order to increase the probability of encounter of different gas species.

Implication to condensation in circumstellar environments: Condensation kinetics seems to be different for metallic iron and Mg silicates, where metallic iron forms much easier than Mg silicates, in spite of their similar equilibrium condensation temperatures. This difference would have significant effects on fractionation of major elements [e.g., 8], a thermal structure of protoplanetary disk, formation of planetesimals and so on, and thus combination of cosmochemical experiments and theoretical and modeling studies is important for understanding of solid evolution in circumstellar environments.

References: [1] Hirth, J.P. and Pound, G.M. (1963) Condensation and Evaporation, Nucleation and Growth Kinetics. [2] Nagahara et al. (1988) *Nature 331,* 516. [3] Tsuchiyama, A. (1998) *Mineral J. 20,* 50. [4] Ikeda Y. et al. (2007) *LPS XXXVIII,* #2403. [5] Nomura R. et al. (2008) *LPS XXXIX,* #2127. [6] Kozasa T. and Hasegawa H. (1987) *Prog. Theor. Phys., 70,* 1402. [7] Tachibana S. et al. (2009) *MetSoc09,* A5391. [9] Nagahara H. and Ozawa K. (2009) *LPS XXXX*, #2158.