

CONDENSATION KINETICS OF METALLIC IRON: AN EXPERIMENTAL STUDY.

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Metallic elements in gaseous state in a hot interstellar environment condense into dusts during cooling of the gas. In recent IR surveys, existence of magnesium silicates around either evolved stars or young stars have come to be evident. Although there has been no observation so far clearly indicating the presence of crystalline Fe, it is expected to be present as dusts because Fe is one of the most abundant metallic elements in the solar composition. We have studied condensation kinetics of Fe for the better understanding of condensation processes in the circumstellar environment. It is unclear how much atoms, once collided with the already condensed solid surface, stick there as a new part of solid. The ratio of atoms that incorporate into the crystalline structure to incoming atoms is called a condensation coefficient that is critical to determine the growth rate of solid when considering the 'gas to solid' condensation. In this study, the condensation coefficient of metallic iron is directly estimated experimentally by the measurement of weight loss of evaporation source and weight gain of a target due to condensation. In this study, growth state is mainly considered, not nucleation.

The condensation experiments were carried out in a vacuum chamber. Gaseous iron was produced by heating a metallic iron plate in the chamber. The iron gas condenses on a molybdenum substrate set apart from the gas-source plate. The temperature of the substrate varies depending on the distance from the source. The heating temperature of the iron source was 1170°C. The substrate was set either at two different distances away from the source and the measured temperatures are 1020°C and 415°C for the closer and farther distance, respectively. Condensates were examined by observing its surface morphology, analyzing phase, crystallinity and measuring change of the weights.

The phase and crystallinity of the condensates analyzed are metallic iron regardless of the experimental conditions, and any other phases were not observed. The temperature of substrate greatly affects morphology of condensates. Loosely grown dendritic Fe metal covered the substrate at 415°C, but compactly packed Fe metal grew at 1020°C. In 415°C experiments, in which crystal size can be easily measured, crystal size increases with experimental time, although the size change cannot be determined in 1020°C experiments due to the compact surface.

The surface microstructure of condensates gives some implications about the growth process. In the 415°C experiments, Fe atoms are inferred to have condensed to cause growth of already existing crystals with very minor formation of nuclei, because the average size increases with experimental duration. The loosely packed dendritic structure of condensates suggests a high condensation coefficient at this temperature because the high sticking probability inhibits Fe atoms from going deep inside the dendrite. On the other hand, at 1020°C, the condensates are likely to be annealed due to the higher temperature of substrate, although a lower condensation coefficient might facilitate the compact structure. Based on the incoming flux calculated from the weight loss of the source and the furnace configuration, the condensation coefficient is estimated to be 0.5~0.6 at 1020°C. Similar calculation on the substrate gives the condensation coefficient of ~0.8 at 415°C. The larger condensation coefficients at lower temperatures may be explained as follows. The incoming Fe atom exchanges its thermal energy efficiently with the surface of substrate. If this thermal accommodation is efficient for iron gas and solid, it is difficult for the atom stuck on the surface to re-evaporate especially at lower temperatures. Those stuck atoms may incorporate into the crystalline structure without moving on the substrate surface, resulting in efficient growth of condensates. More detailed and systematic experiments are needed for more quantitative discussion.