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Experimental condensation of crystalline magnesium rich silicate

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Silicate dusts are abundant components in the astrophysical environments, which are thought to be directly condensed from gas. ISO discovered the existence of crystalline Mg-rich silicates (forsterite and enstatite) and amorphous silicate around discs or stellar shells of young and in the outflow from evolved stars (Molster et al. 1996). The phase, size, shape, crystallinity and chemical compositions of the dust grains are important factors that control the IR spectrum. In this study, in order to investigate phase and crystallinity of condensates as a function of temperature and gas flux, we carried out condensation experiments of magnesium-rich silicates. Though nucleation is an important process for condensation from gas, we only consider the grain growth process. Condensation experiments were conducted in a vacuum chamber made of stainless steel with a high temperature tungsten mesh heater. The chamber is evacuated by a rotary pump and a turbo molecular pump. Single crystal of forsterite for the starting material was cut into rectangular parallelepipeds. The sample was heated at 1580oC to evaporate in an aluminum tube and condensates ware obtained on a molybdenum substrate. Forsterite evaporates congruently all though the experiments and therefore the gas should have a composition of Mg2SiO4. Pressure in the chamber during experiments is 10-4 to 10-3Pa. The experimental duration ranged from 8 hours to 60 hours. Condensates on the molybdenum substrate were observed with an FE-SEM, the chemical composition were quantitatively obtained with EDS, and the crystallinity and phase identification were done with electron back scatter diffraction patterns (EBSD). Condensates were observed on the Mo wire along a temperature gradient from about 1150oC to 900oC regardless of experiment duration. The size of the condensates becomes larger with increasing experimental duration. Condensates at high temperature (1150oC) in shorter experiments (8 and 16 hours) were platy in shape and the size of grain was about 10 micron whereas in longer experiments (24, 40, 60 hours) were irregular in shape. They homogeneously covered the molybdenum substrate and condensates at lower temperature were and intergrowth with molybdenum grain which was from substrate. The chemical composition of the condensates, which was obtained by averaging the about 30 point analyses with EDS, decreases with decreasing temperature. Mg/Si ratio of the highest temperature condensation was about 2, which is crystalline forsterite. At lower temperature, Mg/Si ratio of shorter temperature condensates were about from1.5 to 1, which were mixture of crystalline forsterite and amorphous silicate, which composition was Mg/Si=1. At longer experiments condensates was a few crystalline forsterite and clinoenstatite. The amount of clinoenstatite is larger in longer experiments. Those results show that the bulk composition of the condensates varied with temperature and experimental duration. The change of composition can be explained by fractionation of gas within the tube, where molecular velocity of Mg gas is faster than SiO gas. It is for this reason that evaporated gas from forsterite, evaporated congruently, becomes SiO rich gas than forsterite composition. For shorter experiments, forsterite was directly condensed from SiO rich gas at high temperature, whereas forsterite and amorphous silicate were condensed at lower temperature. For longer experiments, amorphous silicate was annealed to clinoenstatite and also forsterite at lower temperature reacted with SiO rich gas to form clinoenstatite. The present results are suggestive of the change of composition of condensates in outflow of evolved stars, where large temperature and pressure gradients are present which is similar to this experimental condition such as the highly kinetic condensation. The observation by IR, forsterite, enstatite and amorphous silicate often coexist around evolved stars.