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Condensation anisotropy of corundum in circumstellar environments

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Mass-loss from evolved stars plays an important role in galactic chemical evolution. Dust grains form in the outer layer of the stellar atmosphere, interact with the stellar radiation field, and accelerate the mass-loss wind due to radiation pressure. It is not clear, however, how this dust-driven wind contributes to wind acceleration because of uncertainty in dust formation processes and their kinetics in mass loss winds.
Equilibrium condensation models in the system of solar abundance predict that corundum (Al_2O_3) is one of the first condensates both in protoplanetary disks and around evolved stars, and presolar corundum grains in chondrites give a strong evidence of corundum formed by condensation in mass loss winds. Moreover, corundum grains provides their surfaces as heterogeneous nucleation sites for other dust species condensing at lower temperatures, which include major dust species such as silicates and Fe-metal constrains. Thus condensation of corundum may control the size and number density of major dust grains. However, because of the lack of experimental data on condensation kinetics, the formation conditions of circumstellar corundum are still poorly constrained.
In this study, we focus on the morphology of corundum and conducted condensation experiments of corundum because an anisotropic crystal may have a specific morphology depending on the anisotropy in formation processes and conditions and because such specific morphologies reflecting forming conditions may be deduced from infrared spectroscopy. Condensation experiments of corundum were conducted in a vacuum chamber made of stainless steel with a tungsten mesh heater. The chamber was evacuated using a rotary and a turbo molecular pump to high vacuum (about 10^{-4}Pa). Alumina powder (about 1 mg) put on the bottom of an iridium crucible (15 mm in diameter and 60 mm in height), which set in the chamber as an evaporation source, was heated at 1505-1695°C for 9-360 hours. Gas evaporated from the powder condensed on two molybdenum substrates (20 x 2 mm^2), each of which was placed at 40 and 60 mm from the bottom of the crucible. Temperature range of the substrates were 1260-1590°C. The supersaturation ratios (S) of Al-bearing gas species at the surface of the substrates were calculated from differences in equilibrium partial pressures of Al-bearing gas species at gas and substrate temperatures.
EDS analyses showed that all the condensates had the chemical composition of $Al_2O_3$and EBSD analyses showed that they were corundum crystals (alpha-alumina). Corundum condensed on substrates at S of larger than 70 are mainly columnar shapes elongating along the c-axis, while granular or platy corundum flattened along the c-axis condensed on the substrate at S of smaller than 10 regardless of the condensation temperature. Such a difference in shape of condensates clearly shows the change of anisotropy depending on the supersaturation ratio, and we found that anisotropically condensed corundum should show observable changes in features in infrared spectra. This suggests that formation conditions of corundum in circumstellar disks around oxygen-rich AGB stars can be evaluated by combining experimental results and infrared observations.

Keywords: dust, condensation, experiment, evolved star, corundum