

Condensation and evaporation of circumstellar corundum: the carrier of the 13 μm features observed from AGB stars

Aki Takigawa (Department of Terrestrial Magnetism, Carnegie Institution of Washington; Department of Geology and Mineralogy, Kyoto University), Shogo Tachibana (Department of Natural History Sciences, Hokkaido University), Hiroko Nagahara (Department of Earth and Planetary Science, University of Tokyo), and Kazuhito Ozawa (Department of Earth and Planetary Science, University of Tokyo)

Infrared spectra from many oxygen-rich Asymptotic Giant Branch (AGB) stars show characteristic 13 μm emission features (e.g., Sloan et al. 1996). The origin of the 13 μm emission features has been discussed in previous studies but have not been determined yet. Possible carriers of this feature are spinel, corundum, amorphous silica, and composite grains with corundum cores and silicate mantles (e.g., Kozasa and Sogawa 1997; Speck 1998; Posch et al. 1999; Fabian et al. 2001; Zeilder et al. 2013).

IR spectral features of dust grains strongly depend on the grain size and shape (e.g., Bohlen and Hoffman 1983; Takigawa and Tachibana 2012). However, these parameters are not theoretically predictable because the size of circumstellar dust grains is determined by condensation and evaporation processes, and the dust shape is controlled by the anisotropy in those processes (Ozawa et al. 1996; Takigawa et al. 2009). In this study, we conducted evaporation and condensation experiments of corundum in vacuum to determine the anisotropy in evaporation and growth rates of corundum, respectively. Using these parameters, we calculated a possible shape of condensed corundum in circumstellar environments and an emission spectrum from condensed corundum grains and examine if condensed corundum could reproduce the 13 μm emission feature.

We performed evaporation and growth experiments of single crystalline corundum plates in a vacuum furnace. Rectangular parallelepipeds of single crystalline corundum, of which largest surfaces were {0001}, {11-20}, and {1-100} planes were used in the experiments. Evaporation temperatures were 1600, 1680, and 1790°C, and evaporation rates along crystallographic a-, b-, and c-axes were obtained from weight losses and dimensions of the three plates, respectively. Condensation experiments were conducted in an iridium crucible located in a vacuum furnace. Single crystalline corundum plates were used as substrates and a pellet of Al_2O_3 powder was put at the bottom of the crucible as a gas source. The iridium crucible had a temperature gradient, and the temperatures of the gas source and substrates were 1710°C and 1580°C, respectively.

We found that corundum condenses and evaporates anisotropically. The ratio of the evaporation rates along the a- and c-axes is 1.5 at 1600-1800°C, and that of the condensation rates along the a- and c-axes is about 0.8 at a supersaturation ratio of <5. Based on the anisotropic rates of evaporation and condensation, we calculated the corundum growth in an outflow from an AGB star and the shape change of corundum grains. The IR spectrum of anisotropically condensed corundum grains shows a peak at $\sim 13 \mu\text{m}$ and the grain growth of corundum in the outflow can also explain the peak width of the 13 μm feature.