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ダスト形成実験，プレソーラー粒子分析，赤外線観測から探る宇宙鉱物の形成と進化
Astromineralogy from dust formation experiments, analysis of presolar grains, and infrared spectroscopy

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In these twenty years, space and ground based infrared spectroscopic observations have revealed the common presence of circumstellar and interstellar dust grains such as silicates, oxides, carbides, ice, and organics. Presolar grains are rare components of primitive meteorites identified on the basis of their highly anomalous isotopic compositions. They have formed around evolved stars as circumstellar dust grains and have survived the processing in the interstellar medium and the protosolar disk before their incorporation into the meteoritic parent bodies.

It is, howver, difficult to directly compare presolar grains with circumstellar dust emissions because (1) infrared (IR) dust emission reflect an enormous number of dust grains with various composition, size, shape, crystallinity, and aggregation degree, (2) dust properties are poorly constrained due to lack of laboratory studies on dust formation processes, and (3) there are limited mineralogical and crystallographical studies on presolar silicates and oxides. The grain morphology and crystal structure of circumstellar dust may reflect condensation conditions in circumstellar envelopes of asymptotic giant branch (AGB) stars and that of presolar grains additionally reflect processing in the interstellar medium (ISM) and protosolar disk. Corundum (alpha-Al_2O_3) is predicted to be the most abundant refractory dust species condensed in envelopes around oxygen-rich AGB stars. In this talk, we summarize our recent results of corundum condensation and evaporation experiments, calculation of the IR spectrum of condensed corundum around AGB stars, and analysis presolar alumina grains in order to link the mineralogical and astronomical investigations on circumstellar dust formation and evolution.

Evaporation experiments of single crystals of corundum in vacuum at 160-1785 deg C and condensation experiments at 1575 deg C and a supersaturation ratio of around 4 were performed to obtain anisotropic evaporation and condensation coefficients of corundum. The IR spectra of anisotropically condensed corundum grains were calculated assuming the ellipsoidal shapes. Presolar alumina grains were identified from acid residues of unequilibrated ordinary chondrites (QUE97008 LL3.05, RC075 H3.1, and Bishunpur LL3.15) by oxygen isotopic measurements. The focused-ion-beam sections of the presolar grains were prepared and observed with a transmission electron microscopes.

Evaporation coefficients of corundum are 0.02-0.2 at 1600-1785 deg C, which increase with temperature. The evaporation coefficient along the crystallographic m-axis is largest and that along the c-axis smallest irrespective of temperature. The obtained condensation coefficients along the c-, a-, and m-axes at 1575 deg C and a supersaturation ratio of about 4 are 0.04-0.06, 0.06-0.08, and 0.1-0.2, respectively. Eighteen presolar alumina grains were identified and the average size was 1 um, and neither whiskers nor extremely flat grains were observed. All presolar alumina grains are corundum but some of them have distorted crystal structures. Fifteen grains have irregular shapes covered with rough surfaces. The distorted crystal structures and rough surface structures may indicate that these grains have experienced the cosmic ray irradiation in the interstellar medium or solar wind irradiation in the early solar system.

The condensed corundum is most likely to be oblate slightly flattened to the c-axis, consistent with the fact that no presolar corundum with eccentric shapes has been found. The mass absorption coefficient of oblate corundum slightly flattened to the c-axis shows a peak at 13 um without any accompanying strong peaks, which correspond to the unidentified 13-um feature of around O-rich evolved stars. These results strongly indicate that corundum condensed anisotropically in circumstellar environments and have experienced space weathering prior to their incorporation into the meteoritic parent bodies.

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