FORMATION OF METASTABLE ALUMINA DUST AROUND AGB STARS: CONDENSATION EXPERIMENTS USING INDUCTION THERMAL PLASMA SYSTEMS.

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Introduction: Presolar grains identified in primitive meteorites and cometary dust are survivals of the circumstellar dust of evolved stars formed prior to the birth of the solar system. Mid-infrared spectroscopic observations of evolved stars provide complementary information on circumstellar dust. Many of oxygen-rich asymptotic giant branch (AGB) stars display a broad dust feature at ~11–12 μm [1]. Chemically synthesized amorphous alumina (Al_2O_3) is widely accepted as the source of this emission, whereas few presolar amorphous alumina was reported previously [2]. Moreover, it is not obvious that amorphous alumina can condense in circumstellar conditions. There are more than eight transition aluminas, which are metastable alumina phases with different crystal structures, other than the stable phase of Al_2O_3, corundum (α-alumina). Even from gases undergoing very high cooling, metastable transition alumina, rather than amorphous alumina, might condense [3, 4]. Alumina that forms under strong disequilibrium might contain other abundant elements in their structures, such as Mg or Si.

Experiments: An induction thermal plasma (ITP) system provides ultrahigh-temperature plasma to vaporize refractory materials and a high cooling rate for gases with a sharp temperature gradient where nanoparticles condense [5]. We performed condensation experiments of Al–Si–O, Al–Si–Mg–O, and Mg–Al–O gases using ITP systems. The crystal structures of the condensed particles are examined with X-ray powder diffraction (XRD; Rigaku SmartLab) and a field-emission transmission electron microscope (FE-TEM; JEOL JEM-2100F). Their MIR spectra are then measured with a Fourier transform infrared spectroscopy (FT-IR; JASCO MFT-680 and Thermo Nicolet iS5) and compared with the dust emission of the alumina-rich star T Cephei [6].

Results and discussion: The condensed nanoparticles from the Al and O gases were neither amorphous nor corundum but transition aluminas based on face centered cubic (fcc) packed oxygen (δ- and λ-alumina, and an unknown phase; Fig. 1). Sharp peaks of their FT-IR spectra are not observed from circumstellar dust. The fcc oxygen frameworks were maintained in many of the condensed alumina grains containing small amounts of Mg and Si. Condensates from Al-rich gases containing a few percent of Mg had δ- and γ-alumina structures. The condensed transition alumina containing ~10% Si had λ- and γ-alumina structures and showed similar MIR spectral shapes to the observed dust emission from alumina-rich AGB stars (Fig. 2). Based on the present results, it is reasonable that the source of 11–12 μm broad emission of alumina-rich stars is not amorphous alumina but is transition alumina containing ~10% Si.

No presolar transition alumina grain containing Si was reported previously. This is probably because of the sample selection for isotopic analysis. Most of the presolar alumina were identified from acid residues of meteorites [e.g., 2, 7-9]. Corundum is acid resistant but amorphous and transition alumina are easily dissolved into HF and $HClO_4$ [9]. Even if presolar metastable alumina were present in primitive meteorites, they had been lost during acid processing, which also explains the rarity of amorphous presolar alumina. Careful studies both on the chemical composition and crystal structure of individual presolar alumina grains without chemical treatment and prior to the destructive isotopic measurements are needed to conclude the presence of presolar Si-containing transition alumina grains in chondrites.

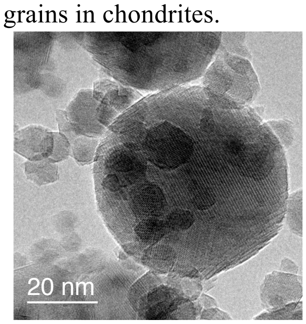

Fig. 1: TEM image of condensed δ-alumina (Al_2O_3 composition).

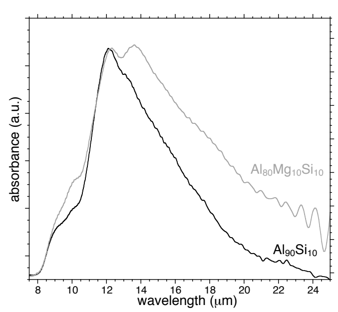

Fig. 2: FT-IR spectra of condensed alumina containing ~10% of Si. Gray and black curves compare the difference in Al:Mg:Si ratio.

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