CORUNDUM AND CORUNDUM-HIBONITE GRAINS DISCOVERED BY CATHODOLUMINESCENCE IN THE MATRIX OF ACFER 094 METEORITE. T. M. Nakamura[1], N. Sugiura[1], M. Kimura[2], A. Miyazaki[1], and A. N. Krot[3], [1]Department of Earth and Planetary Science, Graduated School of Science, University of Tokyo, Tokyo 113-0033, Japan. (takahiro@eps.s.u-tokyo.ac.jp), [2]Faculty of Science, Ibaraki University, Mito 310-8512, Japan, [3]Hawai'i Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, University of Hawai'i at Manoa, Honolulu, HI 96822, USA.

Introduction: Equilibrium thermodynamic condensation calculations for a cooling solar gas at total pressure < 10^{-2} atm shows that corundum should be the first major condensate [1]. With continued cooling, corundum is predicted to react with the nebular gas to form hibonite. Corundum-bearing CAIs are extremely rare: only seven occurrences have been previously reported in detail, three in the CM carbonaceous chondrite Murchison (M98-8, BB-5, GR-1) [1-4], one in the CM chondrite Murray (F5) [5], two in the ungrouped carbonaceous chondrite Adelaide (#32 and #50) [6], and one in the ungrouped carbonaceous chondrite Acfer 094 (s2) [7]. Some of these corundum grains are considered to be direct condensates from the solar nebula gas, whereas others may have been melted after condensation. Condensation processes in the solar nebula may be elucidated from detailed studies of corundum-hibonite grains. Ten small solar corundum grains (500 nm to 5 μm) have been previously reported in the LL3.1 unequilibrated ordinary chondrite Krymka [8], but their petrographic information was not provided.

Here we report textural observations, chemical compositions, and oxygen isotopic compositions of corundum and corundum-hibonite grains in Acfer 094. Acfer 094 is one of the most primitive chondrites that contain high abundance of presolar grains in the fine-grained matrix [e.g. 9-11].

Experimental Methods: To detect corundum and corundum-hibonite grains in matrix of Acfer 094, two carbon-coated thin sections (#1 and #2) with a surface area of ~34 and ~170 mm^2, respectively, were examined by cathodoluminescence (CL) imaging [8] and backscattered electron (BSE) imaging using a JEOL JMS-5310 scanning electron microscope (SEM) equipped with a CL detector (Gatan) at the University of Tokyo. CL from corundum is so bright that the presence of a small corundum grain can be easily detected with CL. BSE images of the detected grains were taken and the compositions were examined by SEM equipped with EDX spectrometer. Some of the corundum grains were found to be overgrown by hibonite.

Quantitative analysis of corundum (#2-11), and corundum-hibonite (#2-17, #2-23 and #2-26) grains were performed with a JEOL 733 electron probe microanalyzer (EPMA) at the Ibaraki University

Several grains were subjected to oxygen isotopic imaging using a resistive anode encorder (RAE) attached to a CAMECA ims-6f secondary ion microprobe. For oxygen isotopic ion imaging, we prepared two Cs^+ primary beams whose intensity differ by a factor of ~500. The weak beam was used for ^{16}O imaging and the strong beam was used for ^{17}O, ^{18}O and ^{27}Al imaging. The ^{16}O and ^{18}O count rates were approximately 2×10^4 cps. The area of the ion imaging corresponds to 50×50 μm on the sample. The exit slit was narrowed enough to eliminate the contribution of interference ions ^{16}OH to the ^{17}O images. A normal incidence electron gun was used for charge compensation.

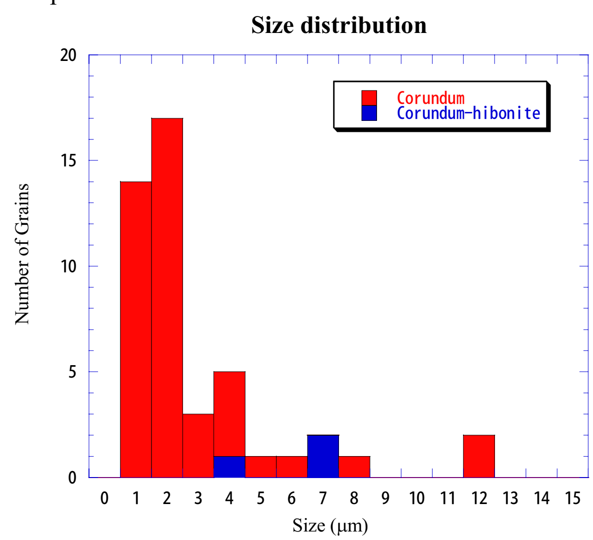

Fig.1. Size distribution of corundum and corundum-hibonite grains. For round grains, the size is the diameter. For non-round grains, the size was taken as $2\times(A / \pi)^{1/2}$, where A is the estimated cross-sectional area of the grain.

Results and discussion: By CL and EDX analyses Acfer 094 #1 yielded 2 corundum grains and Acfer 094

#2 yielded 41 corundum and 3 corundum-hibonite grains in the matrix, excluding corundum in a CAI. The abundance of the corundum grains was calculated to be ~8 ppm relative to the matrix fraction (35 vol% of the entire chondrite [12]). This abundance is slightly higher than that (~6ppm) of corundum grains in the Krymka matrix fraction [8]. The corundum and corundum-hibonite grains or their aggregates occur as individual objects and are not associated with the minerals commonly observed in CAIs, such as melilite, spinel, Al-Ti-diopside, or perovskite.

The corundum grains range from 1 μm to 12 μm, the typical size being 2 μm (Fig. 1). Corundum grains shown in Fig. 2 are among the largest. The corundum-hibonite grains range in size from 4 μm to 7 μm and are generally larger than the average size of the corundum grains. No corundum-bearing grains smaller than 1 μm have been detected. We are not sure if smaller grains are absent or are present but escaped our detection.

Some of the corundum grains exist as aggregates. Six aggregates were found, each consisting of 2 to 6 grains. The remaining 26 grains are isolated. Fig.2 shows an aggregate consisting of 6 grains. We note that the size of constituent grains in an aggregate is similar.

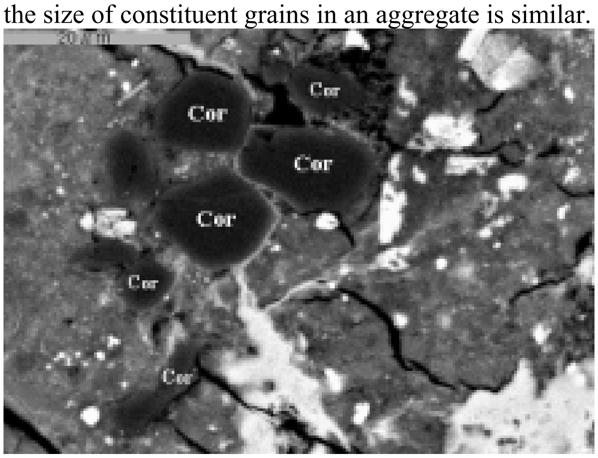

Fig. 2. BSE image of an aggregate of six corundum (cor) grains (#2-11).

Because of the small grain size, accurate determination of chemical compositions of corundum and corundum-hibonite grains is difficult. Reliable data were obtained only for a limited number of relatively large grains. EPMA analysis on the corundum #2-11 indicates that it is chemically pure Al_2O_3, similar to those reported by [1] and [6]. EPMA analyses of the corundum-hibonite grains #2-17, #2-23 and #2-26 confirmed that corundum is overgrown by hibonite. The hibonte grains contain small amounts of TiO_2 and MgO (0-0.18 and 0.06-0.08 wt %, respectively), but contain detectable amounts of FeO (>1 wt%).

Oxygen isotopic ion imaging (Fig. 3) indicates that all corundum and corundum-hibonite grains examined so far have solar oxygen isotopic composition, similar to those of CAIs.

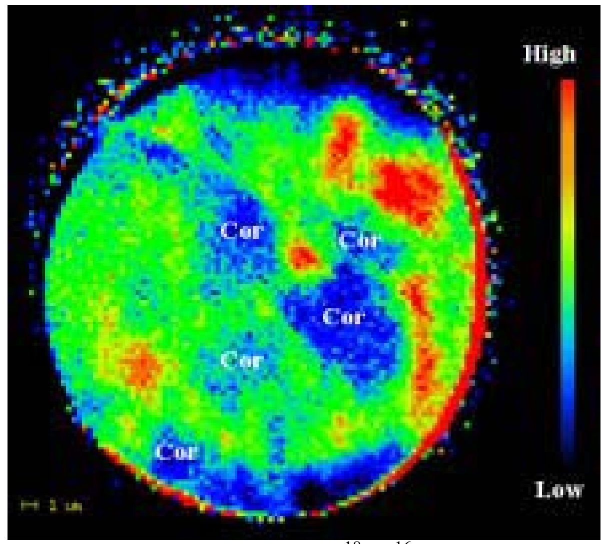

Fig. 3. Oxygen isotopic image ($^{18}O/^{16}O$) of #2-11. Red color represents high isotope ratios and blue color represents low isotope ratios.

The presence of pure corundum grains in the Acfer 094 matrix suggests that either these grains were quenched before condensation of hibonite, or that they were physically isolated from the hot nebular gas, or that they formed from chemically fractionated (Ca-poor) nebular gas. In either case, presence of large (4-7 μm) hibonite grains and absence of hibonite overgrowth on smaller corundum suggest that these oxide grains formed under widely different conditions.

Reference: [1] Simon S. B. *et al.* (2002) *Meteoritics & Planet. Sci.,* 37, 553-548. [2] Bar-Matthew M. *et al.* (1982) *GCA*, 46, 31-41. [3] MacPherson G. J. *et al.* (1984) *JGR*, 89, C299-C312. [4] Hinton R. W. *et al.* (1988) *GCA*, 52, 2573-2598. [5] Fahey A. J. (1988) Ph.D. thesis, Washington Univ. [6] Krot A.. N. *et al* (2001) *Meteoritics & Planet. Sci.,* 36, *Supplement,* A105. [7] Krot et al. (2004) *GCA*, 68, 2167-2184. [8] Strebel R. *et al.* (2001) *LPS XXXI*, 1585-1586. [9] Newton J. et al. (1995) *MAPS* 30, 47-56. [10] Greshake A. (1997) *GCA*, 61, 437-452. [11] Nagashima K. et al. (2004) *Nature*, 428, 921-924. [12] Newton J. et al. (1995) *Meteoritics*, 30, 47-51.