CHARACTERIZATION OF PRESOLAR GRAINS IN CLUSTER CHONDRITE CLASTS FROM UNEQUILIBRATED ORDINARY CHONDRITES. J. Leitner[1], K. Metzler[2], and P. Hoppe[1], [1]Max Planck Institute for Chemistry, P.O. Box 3060, 55020 Mainz, Germany (jan.leitner@mpic.de), [2]Institute for Planetology, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany.

Introduction: Primitive solar system materials contain small amounts of ancient circumstellar dust [e.g.,1]. These so-called presolar grains formed in the winds of evolved stars or in the ejecta of stellar explosions and were incorporated in the molecular cloud from which our Solar System formed. They are distinguished from Solar System material by their highly anomalous isotopic compositions. Presolar grain abundances vary among different materials and even among individual meteorites of the same class.

The presolar oxide inventory of unequilibrated ordinary chondrites (UOCs) has been studied in some detail from grain separates [e.g.,2–4]; however, only few in situ studies of presolar silicates have been conducted for UOCs. Mostefaoui et al. [5] reported three presolar silicate grains in Bishunpur and Semarkona, resulting in a matrix-normalized abundance of ~15 ppm. Another study by [6] of five UOCs revealed presolar silicate abundances of 1 to 9 ppm (Fig. 1).

Recently, it was shown that many UOCs contain clasts of a specific type of chondritic rock, with sizes up to 10 cm. This lithology is characterized by close-fit textures of interlocking deformed and undeformed chondrules and contains only low abundances of fine-grained material, and has been dubbed “cluster chondrite” [7,8]. These cluster chondrite clasts (CCCs) seemingly represent texturally unaltered fragments of accretionary rocks that accreted and consolidated only hours to a few days after chondrule formation. Their fine-grained fraction might still resemble closely the material present during formation, and thus contain presolar materials. We present results from a study of fine-grained chondrule rims (FGR) in CCCs in the UOCs Northwest Africa (NWA) 1756 (LL3.10) and Krymka (LL3.2).

Samples and Experimental: Polished thin sections of NWA 1756 and Krymka were characterized by optical microscopy and SEM-BSE-imaging to identify fine-grained material. For oxygen isotope analysis, a primary Cs^+ beam (d~100 nm) was rastered over 10×10 µm²-sized areas (256×256 px, ~55 min integration time) in the NanoSIMS 50. $^{16,17,18}O^-$, $^{28}Si^-$, and $^{27}Al^{16}O^-$ ion images were acquired in multicollection mode. O-anomalous grains are considered as presolar if the anomaly is more than 4σ away from the average of the surrounding matrix and visible in at least two subsequent image planes. One large presolar grain (KRY#I_37) was re-measured with ~60 nm lateral resolution. Secondary ion images (256×256 px, ~130 min integration time) with the same set of masses were collected in multi-collection mode by rastering a 0.1-0.2 pA Cs^+ primary ion beam over a 5×5 µm^2-area. EDX spectra of the grain and the surrounding area were obtained at an acceleration voltage of 3 kV (~150 nm lateral resolution) with an Oxford X-max SDD EDX-detector using the Aztec software package.

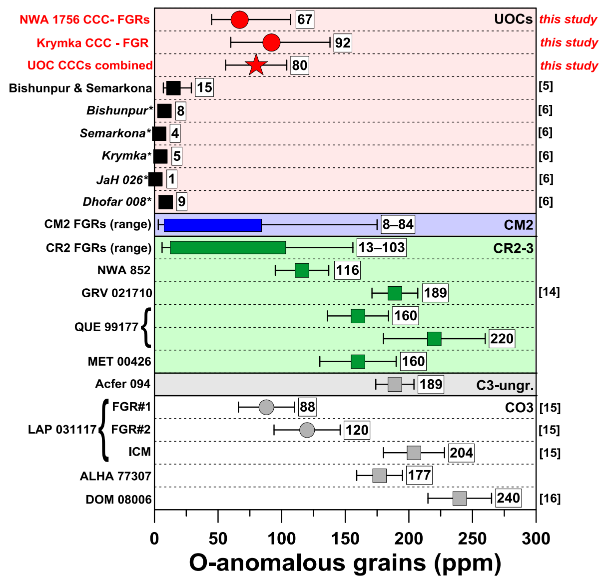

Figure 1*. Presolar O-anomalous grain abundances for CCCs, with data for other UOCs and primitive carbonaceous chondrites. *Studied by IMS-1270+SCAPS, all other by NanoSIMS. Modified after [12,13]; additional references are given in brackets. FGR: fine-grained chondrule rims; ICM: interchondrule matrix.*

Results and Discussion: *Presolar silicate and oxide inventory*. Areas of 4,120 µm² and 4,330 µm² have been scanned in CCCs of NWA 1756 and Krymka, respectively. Nine presolar silicates (2 in NWA 1756 and 7 in Krymka) have been identified, together with one Al-oxide in NWA 1756 and one complex grain in Krymka. Nine grains fall into Group 1 of presolar O-anomalous grains [9,10] and come from 1.2–2.2 M_{sun} asymptotic giant branch (AGB) stars. One silicate in NWA 1756 belongs to the rare Group 3 grains and has a significant depletion in $^{17}O/^{16}O$, together with ~solar $^{18}O/^{16}O$. For these grains, formation around AGB stars with low masses (<1.4 M_{sun}) and $Z \leq Z_{sun}$ has been proposed, although an origin from Type II supernovae (SNeII) is discussed for some grains [11]. Finally, one silicate grain in Krymka falls into Group 4. It is enriched in $^{18}O/^{16}O$, originating from a SNeII.

Presolar grain abundances. For NWA 1756 and Krymka, we obtain O-anomalous grain abundances of 67 ppm and 92 ppm, respectively. The combined abundance for the CCCs in both meteorites is 80±24 ppm (based on 11 grains; for grain KRY#I_37, an exceptionally large grain (see below) a size of 300 nm was assumed). This is remarkably higher than the previously reported values for UOCs [5,6]. However, for a thorough comparison of the different abundances, several things have to be taken into account: (i) The abundance from [5] is based on 3 grains, introducing large statistical uncertainties. (ii) The lateral resolution applied by [6] was about 5–10 times lower compared to the NanoSIMS; therefore, comparatively small presolar grains may not have been detected. (iii) Many UOCs also contain "clastic" matrix, i.e., reworked material and fragments of larger constituents. Here, the abundance of presolar material should be very low. For none of the previous studies a distinction between clastic matrix, "fine-grained" ICM, or FGRs is made. Thus, clastic matrix may have been included in the abundance calculations. In addition, heterogeneous grain distributions have to be taken into account.

The presence of significant amounts of presolar stardust in the studied CCCs indicates the primitive nature of the fine-grained matter in these regions. Moreover, chondrules must have cooled quite rapidly after accretion; otherwise, the present presolar dust would have been largely destroyed by melting and sintering processes. The presolar grain inventories of "regular" areas of fine-grained ICM and FGRs in the UOC samples will be studied for comparison. However, these first results indicate that the investigated CCCs are remnants of primary accretionary rocks that formed quite early in the solar nebula and retained significant amounts of presolar dust.

Complex grain KRY#I_37. One particular large (~800×3750 nm) presolar grain was identified in Krymka (Fig. 2a,b). High-resolution ion imaging revealed a complex structure. The grain consists of a central bar-shaped region containing Al and O (Fig. 2c), surrounded by a Si-bearing "mantle" (Fig. 2d). EDX spectral analyses support this observation; the central part contains only Al and O above detection limit; the surrounding mantle features Mg, Si, and O. (Mg+Fe)/Si ratios range from 0.3 to 0.4, significantly below the value for pyroxene, indicating Si-rich material. The O/Si-ratio varies from 2.2 to 2.9, which supports the Si-rich nature of the mantle. The Fe signal, which would be diagnostic for interference from the surrounding Fe-rich matrix, was negligible in the grain-related spectra. Therefore, the obtained elemental data can be regarded as quite robust. From its average O-isotopic composition, we infer an origin in a ~1.5 M_{sun} AGB star of ~solar metallicity. The grain composition (an Al_2O_3 core embedded in Mg-rich silicate) resembles a condensation sequence. A similar observation was made by [17] for two complex grains. Ca-Al-rich phases are expected to condense from a solar composition-gas before major silicate formation [e.g., 18] and can serve as seed nuclei. Accreting grain and cooling gas are not in chemical equilibrium, since forming grains are removed kinetically [17]. Si-rich silicate, as observed for I_37, is also considered indicative for non-equilibrium condensation. Due to its size, this grain offers the opportunity to study the characteristics of the rare complex presolar grains in greater detail.

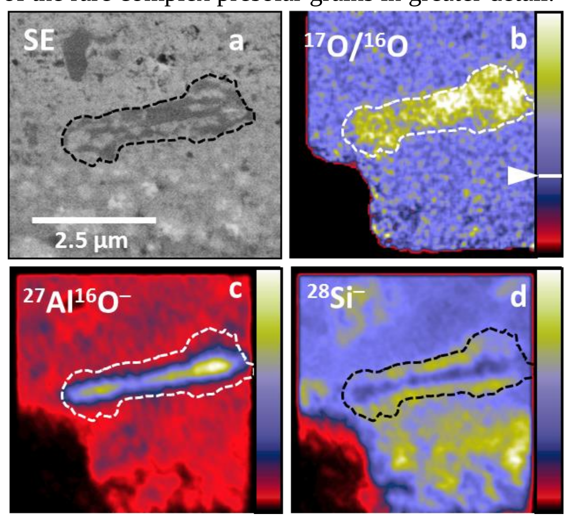

Figure 2*. Complex grain KRY#I_37 (dashed outline). (a) Secondary electron image. (b) $^{17}O/^{16}O$ ratio image. Solar system composition is denoted by the white arrow. (c) $^{27}Al^{16}O$ ion image. (d) ^{28}Si ion image.*

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