CHARACTERIZATION OF PRESOLAR GRAINS FROM THE CARBONACEOUS CHONDRITE NINGQIANG. X. Zhao[1,2], F. J. Stadermann[1], C. Floss[1], M. Bose[1], and Y. Lin[2], [1]Laboratory for Space Sciences and Physics Dept., Washington University, One Brookings Dr., St. Louis, MO 63130, USA (xzhao@physics.wustl.edu), [2]Key Laboratory of Earth's Deep Interior, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China.

Introduction: As the major constituents of O-rich dust around young stars and in outflows from evolved red giant stars [1], presolar silicate grains can give us important information about stars that existed before the formation of our solar system. The isotopic compositions of these grains allow us to investigate the nucleosynthetic processes of the parent stellar sources, while the physical and chemical conditions in stellar atmospheres during condensation may be reflected in the elemental compositions and mineralogies of the grains. Since their discovery in IDPs [2], presolar silicate grains have been found in a number of primitive meteorites [3-6].

Presolar silicates are typically small (less than 500 nm), which makes their analysis challenging. The NanoSIMS ion microprobe allows us to analyze the isotopic compositions of presolar silicates. Subsequently, we use the Auger Nanoprobe, with its high spatial resolution (10s of nm), as a complement to the NanoSIMS for elemental analysis. Here, we report on five presolar silicate grains that we have found *in situ* in the Ningqiang carbonaceous chondrite.

Experimental: Ningqiang is an ungrouped carbonaceous chondrite that shares many petrologic and bulk O-isotopic characteristics with the CV and CK chondrites. As a result, it has been classified as both CV-anomalous and CK-anomalous [e.g., 7]. Ningqiang has a high abundance (50%) of fine-grained matrix, which is suitable for *in situ* searches for presolar grains.

A polished thin section of the Ningqiang carbonaceous chondrite was first screened by optical microscopy to select appropriate matrix areas for study. Next, we used the Washington University Cameca NanoSIMS 50 for isotopic mapping. A ~1 pA focused Cs^+ primary ion beam, with a diameter of ~100 nm, was rastered over 10×10 μm^2 areas. Negative secondary ions of the two C and three O isotopes were collected simultaneously, along with secondary electrons. The total area of matrix analyzed was 14,000 μm^2. Carbon and O isotopic compositions were normalized to the average matrix composition, which was assumed to be solar. Grains were considered presolar if their compositions deviated from the average surrounding material by more than 3σ and the anomaly was present in three consecutive image layers [e.g., 6].

The elemental compositions of isotopically anomalous grains were then obtained using the Washington University PHI 700 Auger Nanoprobe. Following sputter cleaning with a defocused Ar^+ ion beam to remove surface contamination, complete elemental Auger energy spectra from 50 to 1750 eV were obtained following standard procedures [8]. High resolution elemental distribution maps for selected major elements were also acquired for all grains. These maps give detailed information about elemental distributions within and around the grains of interest, and allow inhomogeneous elemental distributions and rims to be recognized.

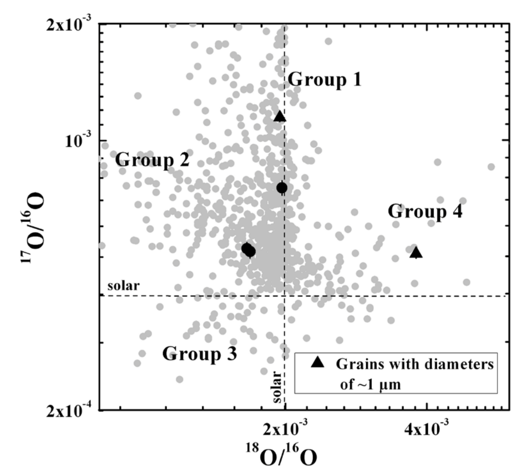

Figure 1. O isotopic compositions of presolar silicates from Ningqiang. Error bars are 1σ.

Isotopic compositions: We found five O isotopic anomalous grains and one grain with an anomalous C isotopic composition in the matrix of Ningqiang. The O isotopic ratios of the five O-anomalous grains are plotted in Fig. 1. Based on the classification system of [9], four of the grains belong to Group 1, with enrichments in ^{17}O and close to solar $^{18}O/^{16}O$ ratios. The fifth grain has a large excess in ^{18}O and belongs to Group 4. Group 1 grains are believed to have formed in the atmospheres of low- to intermediate-mass red giant branch and asymptotic giant branch stars [9], whereas the origin of Group 4 grains is more uncertain, but could be in supernovae or high metallicity asymptotic giant branch stars [9].

The single C-anomalous grain has a $^{12}C/^{13}C$ ratio of 61 ± 6, similar to the compositions of mainstream SiC grains [10].

Elemental compositions: The five O-anomalous grains were analyzed using the Auger Nanoprobe and have Auger spectra show that they are Fe- and/or Mg-bearing silicates. Two of the grains have (Fe + Mg)/Si ratios that are similar to olivine ([Fe + Mg]/Si ≈ 2). A third grain has a similar (Fe + Mg)/Si ratio, but is Al-rich. The single Group 4 grain is depleted in Si ([Fe + Mg]/Si ≈ 3.4) relative to olivine and pyroxene. Finally one grain has no Fe and contains significant amounts of Ca, with a bulk composition similar to diopside ($MgCaSi_2O_6$). Figure 2 shows the Auger elemental distribution map for this diopsode-like grain, and demonstrates the fine-scale detail that can be obtained. The mg#s of the Fe-bearing silicates range from 29 to 45.

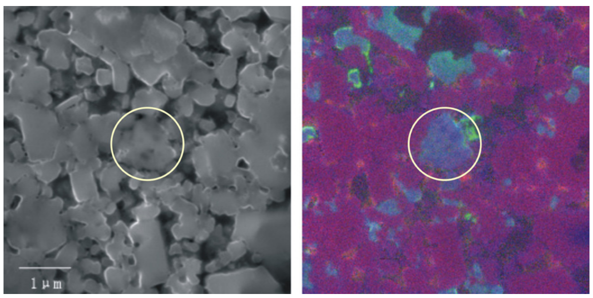

Figure 2. Secondary electron (left) and composite RGB (red = Mg, green = Ca, blue = Si) Auger elemental image (right) of a 5×5 μm^2 area of the thin section of Ningqiang. The presolar silicate grain is circled.

Discussion: Based on the surface areas of the grains and the total area of matrix material measured in Ningqiang, we calculate a presolar silicate abundance in this meteorite of 115 ppm, which is close to the 125–220 ppm seen in other primitive carbonaceous chondrites [4-6, 11, 12]. However, it should be noted that this abundance estimate is dominated by the fact that two of the five presolar silicates are unusually large, with diameters of ~1 µm (e.g., Fig. 2). The uniqueness of this occurance is illustrated in a comparison with presolar silicates from other meteorites (Fig. 3). However, a more exhaustive search for presolar silicates in Ningqiang is needed to confirm that this observation is statistically significant.

Ningqiang has a very low abundance of C-anomalous grains. Based on the single C-anomalous (SiC?) grain found, we calculate an abundance of 1 ppm. In contrast, presolar SiC abundances in the CR chondrites are significantly higher (~65 ppm) [13]. Ningqiang shares many characteristics with the oxidized subgroup of CV3 chondrites and has experienced complex alteration processes [7]. Thus, the low abundance of C-anomalous grains in Ningqiang, compared to other primitive meteorites such as the CR chondrites, may be due to their lower survival rate in an oxidizing environment. For example, it has been noted that presolar SiC abundances are lower in the oxidized CV chondrites than in the reduced ones [14].

The presolar silicates in Ningqiang are relatively Fe-rich, with low mg#s. Although the origin of Fe-rich presolar silicates remains uncertain [e.g., 6, 11], in Ningqiang the Fe-enrichment may be related to the secondary alteration processes experienced by this meteorite. Matrix olivines in Ningqiang are more Fe-rich than those in Allende and this meteorite appears to have undergone Fe-alkali-halogen metasomatism similar to that which has been experienced by the CV3 chondrites [15]. Such metasomatism could enrich presolar silicate grains in Fe and might also be responsible for the low SiC abundances [e.g., 14].

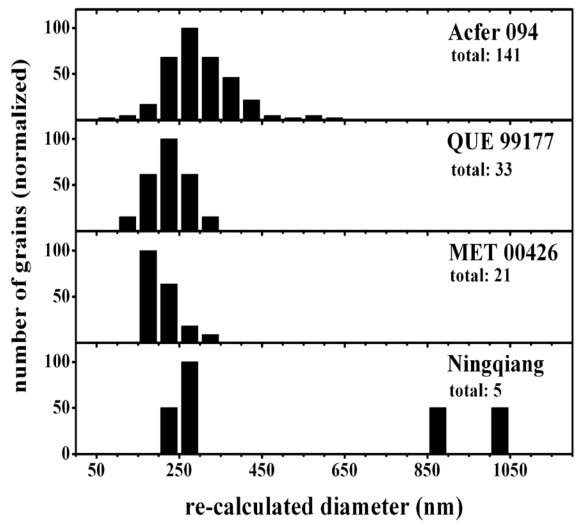

Figure. 3. Size distribution of presolar silicates in different meteorites. (Maximum peaks normalized to 100). Data for other meteorites from [6, 11]

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