**INTERSTELLAR DIAMONDS AND SILICON CARBIDE IN ENSTATITE CHONDRITES;** Gary R. Huss and Roy S. Lewis, Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637

As part of a broader study of interstellar grains in chondritic meteorites, we have examined the Qingzhen (EH3), Indarch (EH3,4), and Abee (EH5) enstatite chondrites. Our objectives included determining which of the pre-solar grains identified in ordinary and carbonaceous chondrites (diamonds, SiC, etc.) are present in enstatite chondrites, estimating their abundances as a function of petrologic type, and characterizing recovered pre-solar components. Bulk meteorite samples were dissolved following the procedure described in [1], and the resulting residues were oxidized with $Cr_2O_7^=$ to remove organic matter and 'normal planetary' noble gases. Etched residues were measured for noble gases and examined by SEM. The Qingzhen residue was further oxidized with hot perchloric acid and the diamonds were removed as a colloid [1].

Qingzhen diamonds are essentially identical to those previously isolated [2] from Allende (CV3), Ragland (LL3), ALHA77214 (L3), and Dimmitt (H3) in noble gas amounts and detailed isotopic composition, allowing us to accurately infer diamond abundances from Ne and Xe in the etched residues (Table 1). The recovered diamond fraction constituted 61 ppm of Qingzhen, 87 % of the inferred abundance. Ne-E, Kr-S, and Xe-S were also detected in the Qingzhen and Indarch etched residues (Table 1), and SiC, their supposed carrier, was observed in Qingzhen by SEM. If SiC in enstatite chondrites is like that in CM chondrites, SiC abundances can be estimated from the $^{22}$Ne-E content of the etched residues (Table 1).

Table 1: Interstellar components in enstatite chondrites compared to type 3 ordinary and CM2 chondrites.†

| Meteorite | Class | Diamonds (ppm) | $^{22}$Ne-E ($10^{-10}$ ccSTP/g) | $^{82}$Kr-S ($10^{-14}$ ccSTP/g) | $^{130}$Xe-S ($10^{-14}$ ccSTP/g) | $^{130}$Xe-S / $^{22}$Ne-E | SiC (ppm) |
|---|---|---|---|---|---|---|---|
| Qingzhen | EH3 | 70 ± 5 | 2.5 ± .3 | 21 ± 10 | 31 ± 8 | 0.0012 ± .0003 | 6.4 ± 0.7* |
| Indarch | EH3,4 | 52 ± 4 | 2.1 ± .3 | 29 ± 14 | 30 ± 8 | 0.0014 ±.0004 | 5.2 ± 0.8* |
| Abee | EH5 | <0.3 | <0.008 | ND | ND | – | <0.02* |
| Ragland | LL3.4 | 85 ± 5 | 0.15 ± .02 | ?? | 0.37 ± .07 | 0.00025 ±.00006 | 0.37 ± .05* |
| ALHA77214 | L3.4 | 53 ± 8 | ?? | ?? | ?? | – | 0.25 ± .20 |
| Tieschitz | H/L3.6 | 35 ± 4 | 0.10 ± .02 | ?? | ?? | – | 0.26 ± .06* |
| Murchison | CM2 | 360 ± 75 | 2.6* ± .6 | 2.8 ± .5 | 5.0 ± 1.0 | 0.00020 ± .00004 | 6.6 ± 1.3 |

* Calculated assuming $^{22}$Ne-E content of 4000 X$10^{-8}$ ccSTP/g (with 10% uncertainty). † Concentrations to bulk meteorite.

Qingzhen and Indarch have $^{82}$Kr-S and $^{130}$Xe-S contents that are 5 to 6 times higher than those observed in Murchison, while Ne-E contents are similar (Table 1). The $^{130}$Xe-S/$^{22}$Ne-E ratio in sized SiC separates from Murchison and Murray increases by nearly a factor of 100 as grain size decreases [1,3]. However, the observed $^{130}$Xe-S/$^{22}$Ne-E ratios in Qingzhen and Indarch are higher than those of all CM samples except for the smallest size fraction from Murray [1,3]. SiC in enstatite chondrites may be smaller than SiC from CM and ordinary chondrites. However, the $^{82}$Kr-S/$^{130}$Xe-S ratios in Qingzhen and Indarch are similar to those observed in Murchison size separates, and this ratio and preliminary SEM observations suggest SiC grain sizes similar to those in CM meteorites. Possible explanations for the variations in $^{130}$Xe-S/$^{22}$Ne-E ratios between chondrite classes include: 1) preferential loss of $^{22}$Ne-E as a function of grain size (surface siting?), or 2) presence of a 'super-carrier' (fine-grained SiC?) [4] containing most of the Kr-S and Xe-S that is fractionated by accretion-disk or planetary processes from the Ne-E carrier.

Diamond abundances are similar in primitive enstatite and ordinary chondrites, but are 4 to 5 times higher in CMs (Table 1). This difference correlates with matrix abundance, which is 10 - 15 % in ordinary and enstatite chondrites vs about 50 % in CM chondrites, and suggests a nearly constant diamond abundance in primitive chondrite matrix [2]. In contrast, the nominal SiC contents (Table 1), normalized to matrix content, decrease by a factor of 20 from enstatite to CM to ordinary chondrites. (If SiC in Qingzhen and Indarch has lost Ne-E, as suggested above, then the actual SiC abundances may be greater than inferred.) Possible explanations for difference in the relative proportions of diamond and SiC include: 1) initial heterogeneities within the accretion disk with respect to SiC (but not diamonds?), but this seems unlikely because mixing times in the parent molecular cloud and in the accretion disk during collapse seem to be short compared to the timescale of collapse [5]; 2) fractionation in the accretion disk, either physically (e.g., by grain size) or by preferential destruction; 3) fractionation during accretion; 4) preferential destruction on parent bodies. Within chondrite classes there is some indication that SiC disappears more rapidly with increasing metamorphic grade than diamond. The most primitive ordinary chondrites may have seen temperatures as high as 200 to 400 C after accretion for brief periods [6] and CM and CI chondrites reached about 0 to 100 C after accretion [7]. Both of these classes have oxidized mineral assemblages, whereas enstatite chondrites are highly reducing and perhaps more amenable to SiC survival.

Scanning electron microscopy of SiC in Qingzhen revealed three distinct morphologies. A few grains are large, up to about 10 microns in diameter, and have a broken appearance and relatively smooth surfaces. The vast majority of the SiC is small, from a few tenths to about 2 microns in diameter. The small grains occur both individually, some with beautiful crystal forms, and as aggregates, some of which include spinel grains. The aggregates do not appear to have resulted from our chemical procedure and may be pre-solar. Similar aggregates have also been observed in ALHA77214. The surfaces of the smaller grains are often covered with nobs and hummocks. This characteristic has also been observed in SiC from ordinary chondrites. It is not clear if this texture is primary or has been caused by our chemical procedure.

Ne-E was observed in all temperature fractions from 350 C up in both Qingzhen and Indarch. Low-temperature Ne-E has traditionally been assigned to a separate, graphitic carrier called C-alpha. However, low-temperature Ne-E has also been observed in a SiC-spinel separate from the Ragland LL3.4 chondrite, which had been treated twice with hot perchloric acid, presumably destroying any C-alpha [8]. Identification of the carrier of low-temperature Ne-E in enstatite chondrites must await completion of additional work.

The etched residue from Abee apparently does not contain either diamonds or SiC (Table 1). The residue consists almost entirely of carbon, which exhibits a platy morphology in the SEM reminiscent of graphite. The noble gas concentrations in this etched residue are about 40 % of that in the unetched residue from Tieschitz and, after subtracting gases attributable to diamond from the Tieschitz residue, the elemental and isotopic ratios are similar. The etched residue contains about 8 % of the total Xe in Abee. The isotopic ratios are similar to those in an unetched residue from Abee [9], but the latter has increasingly more of the lighter gases. Most of the Ar, Kr, and Xe were released from the etched residue above 1200 C, with peak release at successively higher temperatures for Ar, Kr, and Xe. Significant Xe was still being released at 1950 C, the highest temperature obtainable in our extraction system. The graphitic appearance of the carrier and the high release temperature are similar to the characteristics of the major gas carrier from the ALHA 78019 ureilite described by Wacker [10]. The elemental and isotopic ratios differ slightly in the two samples, however. One model for the origin of this gas-rich graphite in Abee is *in-situ* graphitization of a carbonaceous 'normal planetary' gas carrier that originated as grain mantles in the pre-solar molecular cloud [11].

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