A new isotopically normal heavy noble gas component in presolar diamonds from Boriskino revealed by grain size separation

Conference or Workshop Item

A NEW ISOTOPICALLY NORMAL HEAVY NOBLE GAS COMPONENT IN PRESOLAR DIAMONDS FROM BORISKINO REVEALED BY GRAIN SIZE SEPARATION. A.V. FISENKO[1], A.B. Verchovsky[2], L.F. Semjonova[1], U. Ott[3], I. P. Wright[2] and C.T. Pillinger[2]. *[1]Vernadsky Institute RAS, Moscow, Russia; [2]Planetary and Space Sciences Research Institute, The Open University, Milton Keynes, UK.,[3]MPI fûr Chemie, Mainz, Germany.*

Abstract. Xe-Ar systematics in grain-size fractions of presolar diamonds separated from the Boriskino carbonaceous chondrite show the presence of an isotopically normal component released at low temperatures (in addition to P3).

Introduction. Analysis of presolar diamonds separated into grain-size fractions by means of ultracentrifugation [1] provides an insight into the mechanism and history of how the isotopically different components have been incorporated in the diamonds. For instants, it has been shown [2-4] that P3 and HL noble gases have been implanted into diamond grains with different energies. This causes not only the observed differences in concentrations but also the relative abundance of the components in different grain size fractions. In the present study we focus on the variations of the elemental noble gas compositions revealed during stepped pyrolysis and combustion of different grain-size fractions of pesolar diamonds separated from Boriskino (CM2).

Experimental. The samples were prepared using two-step ultracentrifugation of colloidal diamonds. After the first centrifugation (10^5 g for 4 hours) two fractions were isolated as the upper (BD-2) and lower (BD-3) half of the supernatant. The sediment was transformed into a colloid again and centrifuged at 10^4 g for 4 hours. After that, three more fractions were isolated designated as BD-4, BD-5 and BD-6 for the upper and lower parts of the supernatant, and sediment respectively. Noble gases were analysed using a combination of stepped pyrolysis (up to 700°C) followed by stepped combustion (in the range 400-900°C) in all the fractions including BD-1 (the original unseparated diamond). The analyses were performed at the Open University and at MPI of Chemistry (Mainz).

Results. According to the separation procedures the average grain size of the fractions are in the sequence: BD-2<BD-3<BD-4<BD-5<BD-6. We estimated the grain size of the fractions BD-2 and 3 to be about 2 nm and fraction BD-6 about 4 nm on the basis of a comparison with Efremovka diamonds [2] produced by similar separation conditions. Similar to the Efremovka results [2], there is observed a systematic increase of noble gas concentrations and decrease of $^{136}Xe/^{132}Xe$ ratio with increasing grain size (see the table) that can be explained as a result of implantation of isotopically different components at different energies. It is known that most of the P3 noble gases in CM meteorites can be released during pyrolysis at 700°C [5]; therefore the extraction procedures described above provide a certain separation of the P3 and HL noble gases, which can be seen from the $^{136}Xe/^{132}Xe$ ratios (table).

An important observation is that the $^{36}Ar/^{132}Xe$ ratios in contrast to the Xe isotope show no apparent variation with grain size. (table) This indicates that the Ar/Xe systematics of the samples do not represent a simple binary mixture of HL and P3 components. This becomes obvious when the data are considered on the three-isotope diagram (see Figure): points for the bulk grain-size fractions do not form a straight line, but require one more component in addition to P3 and HL to be present. The data for combustion and pyrolysis steps show even higher variations strengthening the conclusion about the presence of the third noble gas component. Obviously, in order to explain the observed variations on the three-isotope diagram, it is necessary to suggest that the third component has practically normal Xe isotopic composition ($^{136}Xe/^{132}Xe$~0.3) and relatively high $^{36}Ar/^{132}Xe$ ratio. The most enriched examples of the component turn out to be the pyrolysis steps for all fine-grain size fractions. Taking into account that the most primitive meteorites, such as CM2's, show a separate peak release in the range 300-700°C with a maximum at about 500°C, we can conclude that this gas is mostly associated with the high $^{36}Ar/^{132}Xe$ component. It is important to note that it is only the analysis of grain size fractions, which reveals the presence of the third noble gas component; unseparated bulk BD-1 sample does not show any indication of that.

Discussion. An important question is whether the component described above is new or represents one of those already known, for instance, P6. To answer this question we need to take into account the following observations: (a) P6 is a high temperature component seen at more than 1340°C during pyrolysis [5] and more than 500°C during combustion [6]; (b) P6 has a $^{36}Ar/^{132}Xe$ ratio of about 400 [5]. Thus, the component described herein is genuinely new and we suggest calling it P7 (in line with the established nomenclature). The estimated $^{36}Ar/^{132}Xe$ ratio for P7 is about 1800. We believe that possible diffusive fractionation during pyrolysis play a minor role for the ratio as at 700°C most fraction of the component is released.

There are no reasons to think that the P7 component has been acquired in a different way from the other components. Therefore we believe that it was added to the pre-existing diamonds by ion implantation in interstellar space. Judging from the grain size of the fractions that P7 is associated with, we propose that the implantation energy was lower than for P3 but higher than for HL. Thus, at least three different implantation events can be postulated in order to explain the noble gas components in the diamonds. If for origin of HL we need to suggest a source which had the r-process in operation (supernova [7]) than for P3 and P7 a less exotic mechanism is required.

The other important question is whether all components were implanted into the same or different populations with similar grain-size distributions. Koscheev et al. [8] showed that noble gases implanted at low energy into synthetic analog of presolar diamonds are released during pyrolysis at two discrete temperature ranges. Therefore they argued that P3 and HL noble gases are located in the same diamond population, having been implanted in two different events with gases (ions) from different environments. Our implantation experiments with similar synthetic diamonds [9] showed that the most critical parameter affecting release of implanted noble gases is the total radiation dose. The higher the dose the lower the release temperature. Therefore, if gases are implanted in two separate events with different doze, the release temperature will follow the total doses for both implanted species (our unpublished experimental results). Therefore we believe that at least HL noble gases are located in a separate population. P3 and P7 might be located in the same population as they are both released at similar, relatively low, temperature.

In conclusion, separation of presolar diamonds into grain size fractions using ultracentrifugaton has revealed a new trapped component which cannot be detected without such separation.

References. [1] Fisenko A.V. at al. (1998) *Geochimia*, N5, 1372; [2] Verchovsky A.B. et al. (1998) *Science*, 281, 1165-1168; [3] Verchovsky A. B. et al. (1999) *LPSC XXX*, abstr #1746; [4] Verchovsky A. B. et al. (2001) *Nuclear Physics*, A688, 106c; [5] Huss G.R. and Lewis R.S. (1994) *Meteoritics* **29**, 791-829; [6] Verchovsky et al. 1991, *LPSC XXII*, 1439; [7] Clayton D. D. (1989) Astrophys. J., 340, 613; [8] Koscheev A.P. et al. (2001) *Nature*, 412, 615; [9] Verchovsky A. B. at al. (2000*), J. Conf. Abstr*. 5, 1050.

Table. Xe and Ar in grain-size fraction of Boriskino diamonds

Sample	Pyrolysis (200-700°C)			Combustion (400-900°C)			Bulk		
	^{132}Xe 10^{-8}cc/g	^{36}Ar/^{132}Xe	^{136}Xe$_{x100}$/^{132}Xe	^{132}Xe 10^{-8} cc/g	^{36}Ar/^{132}Xe	^{136}Xe$_{x100}$/^{132}Xe	^{132}Xe 10^{-8} cc/g	^{36}Ar/^{132}Xe	^{136}Xe$_{x100}$/^{132}Xe
BD-1	20.7	570	30.4 ±0.5	21.1	360	52.8 ±0.7	41.8	460	41.7 ±0.6
BD-2	0.36	900	42.5 ±4.6	2.1	190	62.0 ±2.4	2.5	290	59.1 ±2.7
BD-3	0.35	950	52.0 ±2.2	2.3	180	67.6 ±2.0	2.6	290	65.5 ±2.0
BD-4	7.4	1070	31.7 ±0.8	16.1	340	58.0 ±1.1	23.5	570	49.7 ±1.1
BD-5	9.9	930	32.0 ±0.8	17.4	340	57.8 ±1.0	27.3	550	48.4 ±0.9
BD-6	47.3	450	31.0 ±0.5	34.8	320	50.0 ±1.0	82.1	390	38.9 ±0.7