ON POSSIBLE DIVERSITY OF ASTROPHYSICAL SOURCES OF METEORITIC DIAMONDS

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Presolar relics: The galactic molecular clouds, the mass of which can achieve 10^6 $M_{\odot}$, are the most massive objects in the Galaxy. They are formed under the ejections of the evolving stars and supernova explosions, and they consist of a mixture of gas, mainly, molecular hydrogen, and interstellar dust being a mixture of the matter of various stellar sources. It is natural that just such gas-dust nebulae are the most active regions of star formation themselves [1]. In particular, the base of the protosolar matter was that of a giant gas-dust nebula, which, during ~ 10 My of its existence before the collapse to protosun, was uniformly mixed by supersound turbulence with the products of nucleosynthesis of about ten supernovae [2]. It was supposed in the early condensation models [3, 4, et al.] that the energy of the gravitational collapse was sufficient for evaporation of all the presolar dust that was recondensed later under the equilibrium conditions in the accretion disk, which led to the chemical and isotopic homogeneity of the protoplanetary nebula. However, the numerous isotopic anomalies found in meteorites forced scientists to refuse the conception of homogeneity of the protoplanetary nebula [5]. Indeed, modeling and analyzing possible processes at the early stage of the solar system lead to the conclusion that the protoplanetary nebula was not uniform in its physical and chemical conditions [6-8]. For instance, due to the radial gradient of the thermal and radiant energy, the evaporation of the presolar dust was not total and uniform at different distances from the protosun. It is natural that the grains of the presolar dust are not representative samples in the bulk composition of the protosolar nebula. Their content in the primitive chondrites is extremely small: for the most abundant grains of the presolar diamond it is ~1400 ppm on the average; for those of silicon carbide (SiC) ~14 ppm, for those of graphite ~10 ppm, for those of spinel ($MgAl_2O_4$) ~1 ppm, for those of corundum (Al_2O_3) – 0.05 ppm, for those of silicon nitride (Si_3N_4) >0.004 ppm [9]. The supposition of the presolar nature of these grains is based on the specific isotopic anomalies, conditioned by the peculiarities of the isotopic compositions of their stellar sources. Thus, the enrichment of the most part of the SiC grains with the isotopes of ^{13}C, ^{14}N, ^{22}Ne and the *s*-process elements points out to their origin in the atmospheres of the AGB-stars, whereas the enrichment of graphite with the isotopes of ^{12}C, ^{15}N, ^{18}O, ^{28}Si and the extinct radionuclides of ^{26}Al, ^{41}Ca и ^{44}Ti may be an indicator of supernovae and Wolf-Raye stars [9, 10]. At the same time, there is not still a single opinion on the origin of the most abundant grains of presolar diamond in chondrites [9-12 et al.].

Presolar diamond: The median value of the meteorite diamond size is ~ 3 nm (that is 10-1000 times less than for other presolar grains), which does not allow us to study the individual grains and derive information on the mechanism of their formation (all the isotopic data on the meteorite nanodiamonds are based on the analysis of elements and gases extracted from billions of individual grains [11]). On the other hand, the laboratory experiments on synthesis of artificial nanodiamonds demonstrate an extremely large spectrum of the physical and chemical conditions (possible combination of temperature, pressure and initial matter) for realization of this process [13]. Indeed, the synthetic nanodiamonds are obtained in the processes of detonation synthesis at high pressure and temperature (ultradispersed nanodiamond, or UDD) [14], as well as by low-pressure condensation being similar to chemical vapor deposition at moderate temperatures (CVD-techniques which are used for the epitaxial growth of ultra nanocrystalline diamond films, or UNCD) [15], as well as by irradiation of carbonaceous materials with laser, intensive ultraviolet radiation (UV) or high energy particles [13]. In view of the variety of the admissible astrophysical conditions one may anticipate ubiquitous distributions of nanodiamonds in cosmos. Thus, the observations of the interstellar extinction testify to the fact that up to 10% of the interstellar carbon could be bound up in the interstellar diamond [16]. Nanodiamonds with the lognormal size distribution being similar to that for meteoritic ones are observed in circumstellar disks in the systems of Herbig emission stars of HD97048 and Elias 1 [17], in the carbon-enriched protoplanetary clouds [18] and even in the interplanetary dust [19]. Laboratory experiments show also that diamond nucleation is possible due to UV photolysis of the interstellar icy mixtures (H_2O, CO, NH_3, and CH4) in the molecular clouds as well as their further growth under the UV radiation in the diffuse clouds [20]. It is natural that such a variety of possible astrophysical sources is reflected in numerous diversity of the elaborated models of the nanodiamond synthesis in different astrophysical processes. A number of mechanisms of the nanodiamond generation in supernova is proposed: by low-pressure condensation (similar to CVD-process) in the expanding gas envelopes [21]; by shock metamorphism of graphite or grains of amorphous carbon due to high energy collisions of grains in the interstellar shock waves [22]; by etching graphite particles with the intensive UV radiation of the type II supernova (SNII) [23]; by transformation of the carbon grains under irradiation with high-energy ions [24]; etc. Some models of nanodiamond condensation in the CVD process in the atmospheres of carbon stars [25] and in the protosolar nebula [19] are suggested. Some possibilities of nanodiamond genesis and its enrichment with anomalous xenon in the regions of the red giant star evolution at the stage of formation of the binary system and further explosion of the carbon-detonation supernova (SnI) are considered [26]. The ample opportunities of the nanodiamond synthesis in cosmos testify to the existence of several populations of the nanodiamond grains, differing in their structure conditioned by the mechanism of their genesis [12], as well as, above all, in their isotopic composition being an exact indicator of their astrophysical sources [10]. In this connection, the population of nanodiamond grains, containing the anomalous xenon component Xe-*HL*, the isotopic relations of which could indicate to the enrichment by the products of *p*- and *r*- processes at the supernova SnII explosion (whereas the C isotope relations are practically solar) attracts the greatest attention [21,27,28].

Noble gases: It is assumed that the isotopic compositions of noble gases can reflect the sources of their origin. About 4% of individual grains of the main population of SiC are carriers of the anomalous component Ne-*E(H)*, consisting practically from pure ^{22}Ne, which could be produced in the reaction ^{14}N +2α in the He shell of the AGB-stars. A characteristic feature of those stars is the *s*-process, leading to the relative enrichment of the even isotopes in comparison with the odd ones, which is really observed in the isotopic systems of Kr-*S* and Xe-*S* in separate grains of SiC [29]. Rare grains of the presolar graphite are carriers of the anomalous component Ne-*E(L)*, consisting also from practically pure ^{22}Ne, which could be produced by *in situ* decay of the radioactive ^{22}Na at the nova explosions [28]. The anomalous Xe-*HL* component (as well as He-*HL,* Ne-*HL,* Ar-*HL* and Kr-*HL*), side by side with the noble gases of the solar compositions, is observed only in the nanodiamond grains, pointing out to their origin at the supernova explosions [27, 28].

The main problem, arising at the consideration of the noble gas data, consists in the following question: how were the gases embedded into the presolar grains? The natural processes – capture/trapping and implantation – are constrained with the generation mechanisms of the presolar grains themselves. Since the Xe-*HL* component is observed only in the meteoritic nanodiamonds and it is absent in the other presolar relics, it is natural to suppose that this component was formed under the same conditions, in which the nanodiamond was synthesized. The most consistent mechanism of that process is the formation and capture of the anomalous Xe-*HL* component simultaneously with the nanodiamond synthesis in the conditions of the shock wave propagation from the supernova explosions [30]. The synthesis of a nanodiamond and its enrichment with Xe-*HL* are possible in the extreme *PT*-conditions at the prefront of the shock wave, as well as by nucleation in the range of rarefaction behind the front of the shock wave, as well as by irradiation of carbonaceous grains with high-energy particles. The anomalous isotopic composition of the Xe-*HL* is conditioned by amplifying the rigidity of the energy spectrum of nuclear active particles and enrichment of the spectrum with heavier ions under their acceleration in shock waves [31, 32].

The following question is of equal importance as well: how could the noble gases be preserved in the presolar grains that survived in the extreme *PT*-conditions of collapse of the protosolar nebulae into the protosun? It was shown earlier [33, 34] by studying the genesis of the anomalous Ne-*E* components that the observable content ranges of Ne-*E(H)* in SiC (2060-35800) 10^{-8} cc/g and Ne-*E(L)* in graphite spherules (4240-14000) 10^{-8} cc/g in the Murchison chondrite [35, 36], most likely, were formed by nuclear-active particles accelerated at the front of the giant shock wave from the explosion of the last supernova. The presolar grains had to loose inevitably the thermonuclear and radiogenic ^{22}Ne of all the previous generation, as well as ^{21}Ne of the presolar irradiation of those grains, because the temperatures of some local processes in the collapsing protosolar nebula could exceed 1500-2000 K [8, 37]. Analogously, one may expect that the presolar nanodiamond also lost, probably, the noble gases of all the previous generations, and the observable nanodiamond population containing the anomalous Xe-*HL* component had to be generated during the propagation of the giant shock wave from the last supernova explosion [30]. According to the data of [32], the last supernova before the formation of the solar system was a carbon detonation supernova (SnI), the conditions at origin and explosion of which could be considered as the most favorable ones for the synthesis of nanodiamond and its enrichment with anomalous xenon [26]. At last, the suggested conception is in accordance with the results of the interplanetary dust study [19] that the nanodiamond abundance decreases with the increase of the heliocentric distance, and that it is absent in the dust of comets. It allows us to get associated with [19] and question whether all the nanodiamond grains are presolar.

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