THE PETROGRAPHY OF METEORITIC NANO-DIAMONDS.

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Introduction: At least some meteoritic nano-diamonds are likely of presolar origin because of their association with anomalous Xe-HL and Te isotopic components indicative of a supernova (SN) origin [1,2]. But the abundance of Xe is such that only ~1 in 10^6 nano-diamonds contains a Xe atom, and the bulk $^{13}C/^{12}C$ composition of nano-diamond acid residues is chondritic (solar) [3]. Therefore, it is possible that a significant fraction of meteoritic nano-diamonds formed within the solar nebula. Nano-diamonds have recently been detected for the first time within the accretion discs of young stars by the Infrared Space Observatory (ISO) [4]. No comparable evidence of nano-diamonds in the interstellar medium has yet been found. We have identified nano-diamonds in acid *etched* thin-sections of meteorites, polar micrometeorites, and interplanetary dust particles (IDPs) with the goal of determining their distribution as a function of heliocentric distance [5]. (It is assumed the meteorites and the polar micrometeorites are from asteroids at 2-4 AU and at least some of the IDPs are from comets at >50AU). We found that nano-diamonds are heterogeneously distributed throughout carbon-rich meteoritic materials (we identified them in some IDPs and not in others), and that their abundance may actually decrease with heliocentric distance, consistent with the hypothesis that some of them formed within the inner solar system and not in a presolar (SN) environment.

In order to gain further insight about the origins of meteoritic nano-diamonds we are currently investigating their distribution in *unetched* thin-sections. We have examined a chondritic cluster IDP (U220GCA), fragments of the Tagish Lake (CM1) meteorite, and a SN graphite spherule (KE3d8) isolated from the Murchison (CM) meteorite. We selected U220GCA because its nano-diamond abundance (in acid etched thin-sections) appears to be as much as ~10X higher than in Murchison matrix, Tagish Lake because it has a higher reported nano-diamond abundance than other carbonaceous chondrites (~3650-4330 ppm) [6], and KE3d8 because it is a carbon spherule with an isotopic composition suggesting that it is a *bone fide* presolar SN grain [7].

Experimental procedures: Fragments of IDP U220GCA, Murchison matrix, and Tagish Lake were embedded in sulfur and thin sectioned using ultramicrotomy. SN graphite spherule Ked38 was embedded and sectioned in epoxy. The sections were mounted on continuous carbon films on gold and copper mesh TEM grids and examined using a 400 keV JEOL4000EX TEM and a 200 kV Hitachi HF2000 field emission TEM. Lattice-fringe imaging was used to determine the crystal structures and energy-dispersive x-ray spectroscopy (EDS) was used to probe the compositions of regions immediately surrounding individual nano-diamonds. Lattice-fringe image calibration was obtained *in-situ* using gold <111> and graphitic carbon (002) spacings.

Results: Figure 1 is a lattice-fringe image of a nano-diamond in IDP U220GCA. The crystal is embedded within amorphous carbonaceous material that forms a coating on an FeNi sulfide crystal on the surface of a GEM(S). Most of the nano-diamonds we observed in U220GCA are concentrated within amorphous carbonaceous mantles on the surfaces of GEMS. Figure 2 (upper) shows a lattice-fringe image of nano-diamonds within an etched section of fine-grained matrix of Murchison. Both crystals are associated with amorphous carbonaceous material. Figure 2 (lower) is a lattice-fringe image of SN graphite spherule KD3d8 from Murchison. In contrast to the Murchison matrix carbon (Fig 2 (upper)), the SN spherule consists mostly of relatively well-ordered graphitic carbon displaying concentric ~3.4 Å (002) fringes (Fig. 2 (lower)). Despite a systematic examination of multiple thin sections of the SN spherule we did not identify any nano-diamonds. Figure 3 is a lattice-fringe image of carbonaceous material in Tagish Lake. We have observed both amorphous and graphitic carbon in Tagish Lake but we have yet to identify nano-diamonds.

Discussion: Despite the analytical difficulties inherent in detecting low concentrations of individually dispersed nano-diamonds, we can offer preliminary remarks about the petrography of meteoritic nano-diamonds in IDPS and meteorites. The carrier of nano-diamonds in chondritic IDP U220GCA (and in three other IDPs [5]) is a disordered (amorphous) carbonaceous material (Fig. 1), and it is likely that the carrier contains organic components, e.g. polyaromatic hydrocarbons (PAHs) [8]. The carbonaceous carrier coats the surfaces of GEMS suggesting that the GEMS are older than the nano-diamonds. Nano-diamonds appear to be preferentially associated with disordered carbonaceous material in Murchison matrix (Fig. 2 (upper)), and they are also associated with disordered carbonaceous material in two "CM-like" polar micrometeorites that we have examined [5]. The absence of observable quantities of nano-diamonds in the Murchison graphite spherule is surprising considering its presolar SN origin (Fig. 2 (lower)). However, carbon condensation conditions in the SN environment may have favored graphite rather than nano-diamond (and amorphous carbon) nucleation. A fundamentally important question arising from our observations to date is whether meteoritic nano-diamonds are preferentially associated with an (amorphous) organic carrier rather than a (graphitic) inorganic carrier. But our data set of electron microscopic observations remains limited and we emphasize that the petrographic picture for nano-diamonds may change significantly as additional etched and unetched thin-sections are examined.

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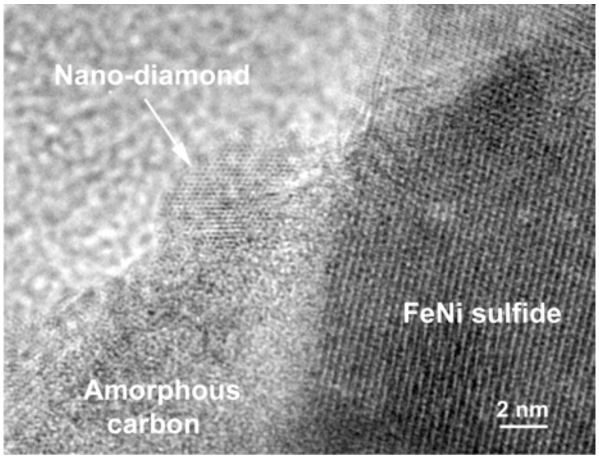

Figure 1. Lattice fringe image of a nano-diamond embedded in amorphous carbonaceous material that coats the surfaces of GEMS in cluster IDP U220GCA.

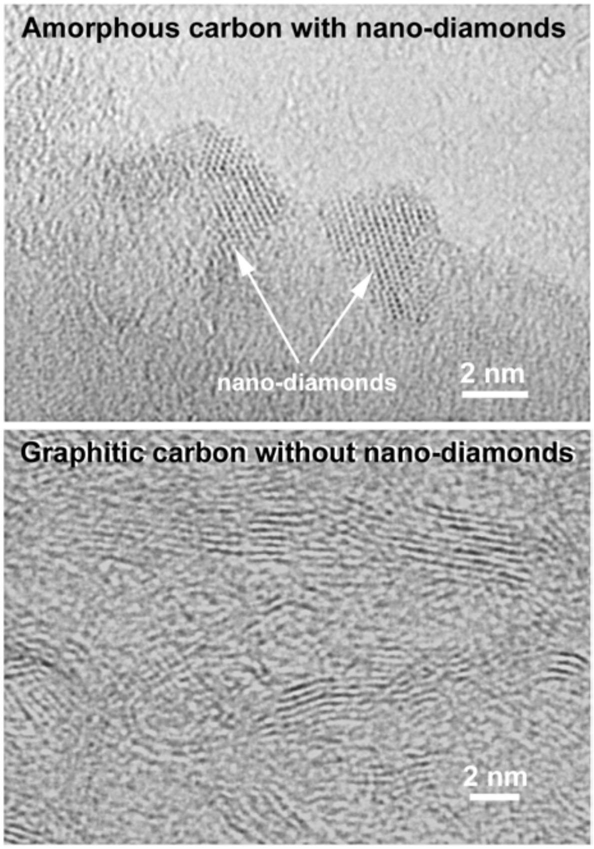

Figure 2. Nano-diamonds, amorphous carbon, and graphitic carbon in the Murchison meteorite. (Upper) Nano-diamonds embedded in amorphous carbon from the fine-grained matrix. (Lower) Graphitic carbon without nano-diamonds in SN graphite spherule KE3d8.

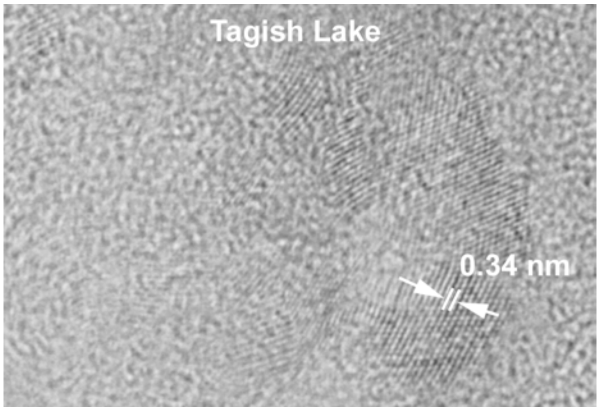

Figure 3. Graphitic carbon without nano-diamonds in the Tagish lake meteorite.