

HETEROATOM DISTRIBUTIONS IN METEORITIC NANODIAMOND RESIDUES

R. M. Stroud¹, C. M. O'D Alexander². ¹Code 6360, US Naval Research Laboratory, Washington, DC, 20375 USA. E-mail: rhonda.stroud@nrl.navy.mil. ²Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA.

Introduction: The origin of meteoritic nanodiamonds as circumstellar condensates, interstellar grains and/or early solar system materials remains controversial [1]. Although the nanodiamond separates contain noble gases and other trace elements indicative of a supernova nucleosynthetic component, the average C and N isotope compositions are consistent with solar system values. Thus, only a minor component of the residues is necessarily presolar in origin. Furthermore, ultrafine density separates and different separation methods yield separates with different noble gas contents, although exactly how the separates differ otherwise, i.e., different subpopulations of diamonds or other acid-resistant phases, is not yet known. Aberration-corrected scanning transmission electron microscopy (STEM) has revealed that separates from the Allende and Murchison meteorites contain ~50% amorphous C and abundant heteroatoms (atoms other than C), in addition to diamond [2]. We present here new STEM measurements to assess whether the population of associated heteroatoms are different between the amorphous carbon and the nanodiamonds, and whether there are sub-populations of nanodiamonds with different heteroatom contents.

Methods: The nanodiamond separate used in this study was isolated from the Murchison (CM2) carbonaceous chondrite, as previously reported [2]. An aliquot of the separate was pipetted onto a lacey C coated TEM grid, and then analyzed with PRISM, the Nion UltraSTEM at the Naval Research Laboratory, operated at a voltage of 60 kV. Elemental analysis was performed on scales ranging from micrometers to individual atoms with the attached Bruker SDD energy dispersive spectrometer (EDS). Electron energy loss spectroscopy was used to measure the ratio of amorphous to diamond C, and to look for species that are not detectable by EDS.

Results: In addition to C, the micrometer-scale EDS analysis revealed the presence of variable amounts of N, O, F, Al, Mg, Si, S, Cl, Ca, and possibly Ar. The most abundant impurity after N and O was Si, and the distribution varied at the sub- μm -scale, spanning both diamond and amorphous carbon phases. At the nm-scale, the N, O, Si and S were randomly distributed across both phases. Individual Si and S atoms were identified by EDS with acquisition times as low as 10s. No distinct sub-populations of diamonds were observed, although the total number of diamonds analyzed to date is too small to rule out their presence.

Conclusions: Aberration-corrected STEM imaging and spectroscopy are promising methods for assessing the partitioning, or lack thereof, of impurity species in nanodiamond separates, and differences in the contents of different separates. Ultimately STEM measurements may lead to a better understanding of the origin(s) of the nanodiamonds. The present data indicate that the reported Si photoluminescence [3] in meteoritic nanodiamond likely results from Si impurities from the separation processing, rather than ion implantation in the interstellar medium.

References: [1] Davis A. M., 2011. *PNAS* 108:19142-19146. [2] Stroud, R.M. et al. 2011 *ApJ Lett.* 738:L27. [3] Shiryayev A. A., et al. *GCA* 75: 3155-3166.