

**DUST GRAINS AND CARBONACEOUS ANALOGS AVAILABLE FOR EXPERIMENTS AND ANALYSES.** N. M. Johnson<sup>1</sup>, J. A. Nuth III<sup>2</sup> and F. T. Ferguson<sup>1,3</sup>, <sup>1</sup>Astrochemistry Laboratory, Code 691, NASA's Goddard Space Flight Center, Greenbelt, Maryland, USA ([natasha.m.johnson@nasa.gov](mailto:natasha.m.johnson@nasa.gov)), <sup>2</sup>Solar System Exploration Division, Code 690, Goddard Space Flight Center ([joseph.a.nuth@nasa.gov](mailto:joseph.a.nuth@nasa.gov)), <sup>3</sup>Chemistry Department, The Catholic University of America, Washington, D.C ([frank.t.ferguson@nasa.gov](mailto:frank.t.ferguson@nasa.gov)).

**Introduction:** Our collective understanding of early solar nebula processes is primarily derived from thermodynamic equilibrium modelling, spectroscopic observations of nascent nebulae, and analyses of primitive meteorites. However, these same reactions are not fully understood in terms of chemical order or kinetics. Experiments involving the earliest condensates would be a boon to unraveling processes that may have occurred in protostellar nebulae. While micrograms of such condensates might be found in the heart of rare, unprocessed, primitive meteorites such as Acfer 094, much larger quantities of material are required in order to conduct multiple experiments at a variety of temperatures and pressures. To solve the problem of obtaining sufficient unadulterated material, we synthesize several different varieties of “natural” simulants from flowing hydrogen gas seeded with appropriate metals and exposed to a hydrogen-oxygen flame. These samples range from simple SiO<sub>x</sub> smoke, to more complex Fe<sub>a</sub>-SiO<sub>x</sub>, Mg<sub>a</sub>SiO<sub>x</sub> and Fe<sub>a</sub>Mg<sub>b</sub>SiO<sub>x</sub> smokes that mimic the reactivity and spectral properties of fresh, vapor-phase condensates such as those that might form in circumstellar outflows or from vaporized materials formed by energetic processes in protostellar nebulae.

We also produce “unprocessed” carbonaceous material formed from a flowing stream of CO on surfaces of various catalysts during surface mediated reactions in an excess of hydrogen and in the presence of N<sub>2</sub>. These carbon deposits do not form continuous coatings on the catalytic surfaces, but instead form extremely high surface area per unit volume “filamentous” structures. While these structures will form slowly but over longer times in protostellar nebulae than in our experiments (due to the lower CO pressure), such fluffy coatings on the surfaces of chondrules or CAIs could promote grain-grain sticking during low velocity collisions and might provide carbonaceous feedstock for the synthesis of biochemical precursors to life during metamorphism within meteorite parent bodies.

The silicate smokes as well as the carbonaceous solids are available to the scientific community for use in cosmochemical experiments thanks to support from the Planetary Science Division at NASA Headquarters.

**Methods for Sample Generation:** All samples described herein are manufactured in the Dust Nucleation Lab at Goddard Space Flight Center.

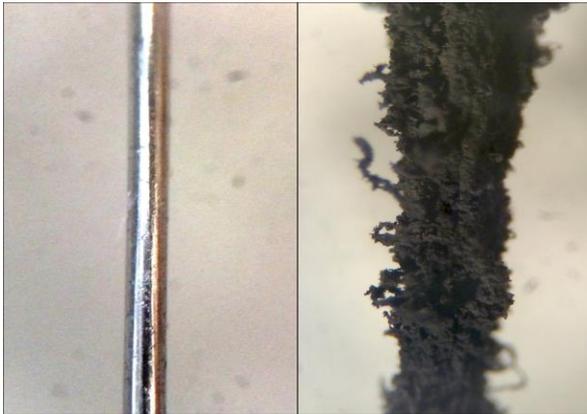
*Amorphous silicate smokes.* We form dust grains by mixing silane, pentacarbonyl iron, trimethyl aluminum, and other metal vapors such as magnesium, calcium, sodium and potassium in hydrogen at high temperatures and low pressures [1]. Molecular oxygen is typically used as the oxidant. The reaction occurs across a flame front within a resistively heated furnace at temperatures between 500 - 1500K. Condensates are rapidly quenched and are collected on an aluminum substrate downstream of the furnace at temperatures below 350K. Grain formation and growth occurs in microseconds and is rapidly quenched. Individual grains are small (20 - 50nm) and highly amorphous (lots of internal energy). We can make a wide compositional range of smokes by varying the input gas mixture. Although the bulk composition of smokes is controllable, the compositions of individual grains are not; some compositions are favored while others seem to be forbidden. Favored compositions are those found at metastable eutectics in phase diagrams [1].

*Carbonaceous Grains.* We generate organics by using various industrial reactions as models for nebular processes; *e.g.*, the Fischer-Tropsch reaction:  $\text{CO} + 3\text{H}_2 \Rightarrow \text{CH}_4 + \text{H}_2\text{O}$ ; the Haber-Bosch reaction:  $\text{N}_2 + 3\text{H}_2 \Rightarrow 2\text{NH}_3$ ; the water-gas shift reaction:  $\text{CO} + \text{H}_2\text{O} \Rightarrow \text{CO}_2 + \text{H}_2$ ; or the Boudouard Reaction:  $2\text{CO} \Rightarrow \text{CO}_2 + \text{C}_{\text{solid}}$ . Clearly, reactions on grain surfaces in protostellar nebulae are much more complex and it can be misleading to discuss a specific model reaction in isolation when describing natural reactions. To avoid confusion as to which “model reaction” applies to the materials we generate we have adopted the practice of discussing surface mediated reactions.

We do not claim that surface mediated reactions constitute the single – or even the most important - mechanism that forms the full distribution of organic molecules in asteroids, comets or those that are found in meteorites or IDPs. There are many different processes that can be important sources for particular compounds in many different meteorite types. However, surface mediated reactions are an efficient mechanism for converting nebular CO or CO<sub>2</sub> into solid carbonaceous materials [2]. Such solids should be easy to incorporate into planetesimals and these carbonaceous grains could then serve as the feedstock that is transformed by various thermal or hydrothermal processes

on parent bodies into the myriad organic molecules found in natural sources [3].

The system used to generate carbonaceous grains is essentially a semi-closed circulating gas experiment in which a predetermined reactive gas mix (typically CO, N<sub>2</sub>, and H<sub>2</sub>) constantly flows over and through a solid substrate or “catalyst” heated to a controlled temperature [2]. The initial substrate can be selected from natural minerals, our synthesized amorphous smokes, or simple metals/alloys depending on the desired outcome in the resulting organics. Upon completion of the experiment, this system produces an intimate mixture of the substrate and the carbonaceous coatings. More recently, we have produced carbonaceous solids using iron wire as the reactive surface at controlled temperatures ranging up to 1000K. The iron wire surface is not “coated” by the reaction products. Rather, the surface serves as a growth surface (Figure 1) and the carbonaceous material is easy to remove.



**Figure 1.** An optical microscope image of iron wire (.009” Diam.) before (left) & after (right) use as a catalyst for one 873K run of CO + N<sub>2</sub> + H<sub>2</sub> => products.

Depending on the substrate, temperature and length of experiment, the resulting organics can run the gamut from saturated and unsaturated hydrocarbons, alkyl-benzenes, phenols, styrenes, traces of polycyclic aromatic hydrocarbons [2,4], to graphite whiskers [5], to metal dusting (*i.e.*, scavenging metal from the substrate into graphite) [6].

**Summary:** We are able to supply limited quantities of both amorphous silicate smokes as well as carbonaceous solids to planetary science researchers. The most readily available products include amorphous silicate, Fe-silicate, Mg-silicate and Fe-Mg silicate smokes, carbonaceous solids intimately mixed with Fe-silicate smoke and carbonaceous solids on Fe wire. Custom compositions may also be possible. If interested in samples of these materials please contact one of the authors.

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