

CHALLENGES TO UNDERSTAND AEROGEL CONTAMINATED BY HYPERVELOCITY-IMPACTED COMET WILD 2 DUST. Frans J. M. Rietmeijer¹ (fransjmr@unm.edu), ¹Department of Earth and Planetary Sciences, University of New Mexico, MSC03-2040, Albuquerque, NM 87131, USA

Introduction: The successful STARDUST mission brought many challenges to understanding the mineralogy of dust from Jupiter-family comet Wild 2 [1], although “intact capture” was not achieved during the 6.1 km/s hypervelocity impacts in aerogel. The aerogel then studied was the first developed material but the impact velocity was only 3.9 km/s, and yet there was no intact capture of a projectile of forsterite, FeS and hollow aluminosilica glass spheres but S-loss and formation of the high-temperature mineral diopside [2]. Hypervelocity impact experiments prior to Wild 2 dust arrival confirmed dust modification and aerogel melting. We have to be alert that new minerals could be produced from reactions among Wild 2 dust and aerogel during capture. In fact, ~100nm spheres of iron silicides, FeSi_2 to Fe_7Si_2 , in aerogel from hedgehog-type track #44 formed by mixing melted Fe-Ni-S comet phases and aerogel [3].

Aerogel Compositions: The aerogel in four allocations (see caption Fig. 1) is fairly typically riddled with Fe-Ni-S phases (<100nm) trending from troilite and pyrrhotite to almost pure low-Ni iron due to progressive S-loss [1] probably due to impact heating of aerogel and comet dust. The glassy aerogel material, *i.e.* it shatters when ultramicrotomed, is (1) vesicular and (2) invariably contains trace to low-percentage amounts of Mg, Fe and S, and occasionally traces of Ca, Al or K, either dissolved in quenched molten aerogel or as minute inclusions too small to see in a 70-nm thick section and too small to analyze individually.

I here report on data for aerogel ranging from almost pure silica to aerogel with inclusions smaller than the analytical probe sizes of 5 and 10 nm used for ATEM analyses of the allocations. I will not here report on Fe-Ni-S phases and silicates >10 microns.

Working Hypothesis: Wild 2 dust were loose aggregates of nm-sized entities, 1- μm grains and less common crystalline grains up to ~10 μm [1], *i.e.* it resembles 10- μm aggregate IDPs and cluster IDPs [4]. IDP-like ferromagnesian silicate matrix constituents (~90 to 500nm) would be the most abundant Wild-2 debris followed by ~1- μm Fe,Ni-sulfide, Mg-rich (Mg,Fe)-silicate and amorphous (Ca,Mg,Fe)-aluminosilica grains [4]. I will allocate all Mg, and trace amounts of Ca, to silica and Fe+Ni, and traces of Cr, to S.

Fe-Ni-S phases: The compositions show mostly sub-S and few FeS grains and Fe-Ni-Cr metal or oxides (Fig.1). The typically low-Ni Fe-S phases favor

two eutectic and a deep metastable eutectic (DME) compositions based on a revised Fe-S diagram [3]. The data show rare FeS_2 stoichiometry and “sulfur hot spots” (<10nm) suggesting sulfur redistribution in aerogel.

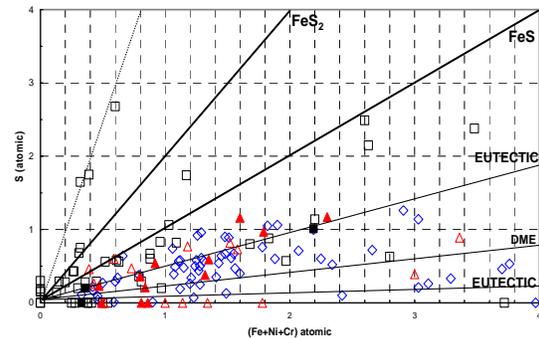


Figure 1: $(\text{Fe}+\text{Ni}+\text{Cr})$ vs. S (at) in vesicular aerogel of C2054,0,35,44,6 (squares), C2054,0,35,24,1 (solid squares), C2004,1,44,4,3 (triangles; solid triangles: massive aerogel, see below) and #2,1,6 (diamonds).

Zoned Fe-Ni-S phases. These grains that are NOT included in Fig. 1 have a subhedral crystalline core and a mantle that provides an ellipsoidal shape. This feature is not unique to the allocations here discussed. The core contains less S than the rim as shown for two representative zoned Fe-Ni-S phases with one mantle that has an identical composition (blue) as a pyrrhotite crystal fragment of surviving Wild 2 dust (Fig. 2). There are also very high-S mantle compositions. These seemingly rare mantles are yet another sink for sulfur from modified Fe-Ni-S phases in aerogel distant from track walls.

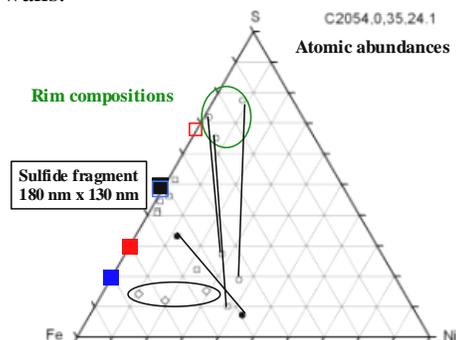


Figure 2: Fe-Ni-S diagram with two core (red & blue squares) - mantle (open squares) grains, a FeS fragment (black square), high-S mantle compositions (green), several other core-mantle grains (tie lines), and Fe-Ni-S phases in GEMS-like objects (diamonds).

Mg-silicate phases: Aggregate IDP matrix is a random mixture of four silicate entities, viz. olivine, serpentine, pyroxene and smectite, and used for IDP classification [4]. Aerogel compositions measured in the same allocations as in Fig. 1 show clear preferences for one of these four compositions (Fig. 3) as a function of the (Mg+Ca)/Si. The distributions of data points along these mixing lines is encouraging with regard to unraveling the dust sources of the pervasive low-Mg abundances throughout aerogel where finding 100% pure vesicular aerogel is very difficult.

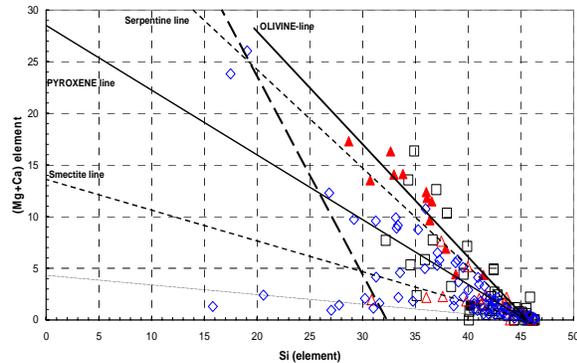


Figure 3: (Mg+Ca) vs Si (at) for the same aerogel spot analyses in Fig. 1 (identical symbols used). Olivine and pyroxene (solid), smectite and serpentine (dashed) mixing lines; a long-dashed line connects the pure-Mg end-members. These mixing lines intersect at pure silica. The solid red triangles are a massive aerogel partial rim on forsterite.

Massive impure aerogel. Sub-micron forsterite with a partial rim of massive aerogel are discrete textural features within vesicular aerogel. The contacts between (a) olivine and massive aerogel and (b) massive and vesicular aerogel are typically razor sharp. It might indicate that melted aerogel doesn't mix with mineral grains at a micron scale [5] or it could be unmelted compressed aerogel. In either case, a continuous compositional gradient between forsterite and vesicular aerogel (Fig. 3; the OLIVINE-line, $r^2 = 0.83$), as it is preserved in the partial massive aerogel rim, shows that element transport was possible across a distance of at least ~ 150 nm. When not due to transport through molten aerogel, it supports solid-state diffusion. Not visible in Fig. 3 but the massive aerogel mixing line does not intersect at pure silica.

The chemically contaminated massive aerogel (Fig. 3) at any location is amorphous non-stoichiometric silicate material that was not indigenous to the comet. When a textural relationship between such amorphous silicate material and a co-existing silicate mineral cannot be established, considerable caution should be

taken when deciding on its origin. GEMS-like objects in aerogel [1] could be pockets of quenched, mixed comet-dust and aerogel melts. In allocation C2054,0,35,24,1 such objects have a narrow glassy rim from a reaction between a GEMS-like object and its vesicular aerogel matrix (Fig. 4, blue mixing line). The deep metastable eutectic ferromagnesian compositions of the glassy rims suggest that kinetically controlled behavior during hypervelocity impact can be understood.

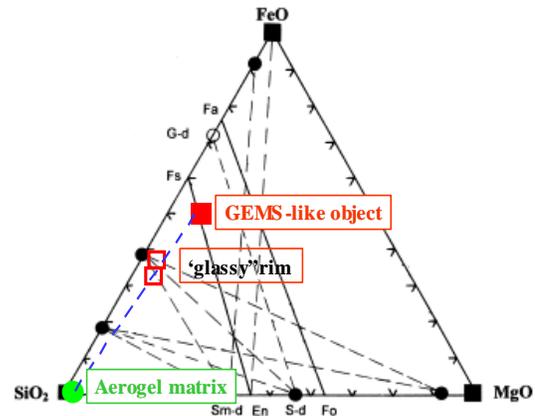


Figure 4: SiO₂-MgO-FeO diagram with mixing lines (black) between deep metastable eutectic dust compositions [4] and "GEMS"-rim-aerogel compositions.

Conclusions: Random ATEM spot analyses in vesicular and massive aerogel revealed Mg,Ca mixing lines for Wild silicate dust in aerogel suggesting that the finest fraction of its dust resembled the matrix constituents in aggregate IDPs. The Fe-Ni-S nanophase compositions that indicate distinct compositional preferences mimic the trends displayed by the larger Fe-Ni-S phases [cf. 1] in vesicular aerogel. Sulfur "hot spots" and mantled grains suggest S-redistribution within the capture cells but very little S-loss. Clearly with the continued petrological analyses of the samples and, in an ironic twist aggregate IDPs as ground-truth, much detail will yet emerge for the dust of Wild 2.

References: [1] Zolensky M.E. et al. (2006) Science, 314, 1735-1739. [2] Rietmeijer F.J.M (1988) LPI Tech. Rpt. 88-01 (Mackinnon I.D.R & Carey W.C. eds), 53-54. [3] Rietmeijer F.J.M. et al. (2006) *Meteoritics & Planet. Sci. Spec. Issue*, submitted. [4] Rietmeijer F.J.M. (2000) *Chemie der Erde*, 62, 1-45. [5] Brownlee D.E. et al. (2006) Science, 314,1711-1716.

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