HIGH-NICKEL IRON-SULFIDES IN ANHYDROUS, GEMS-RICH CP IDPs.

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Introduction: Chondritic porous interplanetary dust particles (CP IDPs) that were not severly heated during atmospheric deceleration are the best preserved samples of the solids that condensed from the Solar protoplanetary disk, as well as pre-Solar grains thatr survived incorporation into the disk, currently available for laboratory analysis [1]. These CP IDPs never experienced the aqueous and/or thermal processing, gravitational compaction, and shock effects that overprinted the record of Solar nebula processes in meteorites.

Zolensky and Thomas [2] analyzed 186 sulfide grains in 9 anhydrous and 22 hydrated IDPs. They found no Ni-rich sulfides in the anhydrous IDPs, and suggested Ni-rich sulfides, which they found in hydrated IDPs, were produced by aqueous processing on asteroid surfaces. The Fe-sulfides in anhydrous IDPs had Ni <2 at. %. Since then, *identification of Ni-rich sulfides has been taken as an indicator of parent body aqueous processing*. For example, Berger et al. [3] used the Zolensky and Thomas [2] result and the identification of Ni-rich sulfide in a Wild 2 particle collected by the Stardust spacecraft as one line of evidence for aqueous processing on this comet. Dai and Bradley [4] analyzed sulfides in 9 anhydrous CP IDPs and one hydrated, smooth IDP, reporting a correlation between grain size and Ni content in CP IDPs, with small sulfides generally having Ni/Fe <0.05, the Solar (CI) value. They identified one large (2x5µm) polycrystalline sulfide with a wide range of Ni/Fe, 0.002 to 0.38 with a mean of 0.17 (3xCI), in an anhydrous IDP. They suggested only the smaller, low-Ni Fe-sulfides might be cosmochemically primitive. However, Schrader et al. [5] noted high-Ni Fe-sulfide can form from cooling of a Ni-rich Fe-Ni-S melt.

Analytical Method: The Hard X-ray Nanoprobe (HXN), recently commissioned at the *National Synchrotron Light Source II* (Brookhaven National Laboratory), permits x-ray fluorescence (XRF) analyses at a resolution of ~15 nm [described in 6]. The HXN delivers a monochromatic beam tunable from 6 to 25 keV (K-lines of elements from Fe to In), with a high flux, giving spectra showing minor element peaks in ~100 nm thick ultramicrotome sections with dwell times of ≤3 s/pixel. To determine if high-Ni Fe-sulfides form directly from the Solar protoplanetary disk, we performed XRF element mapping of ultramicrotome sections of two GEMS-rich CP IDPs using the HXN.

Results: We identified Fe-sulfides from the overlap of Fe and S in the HXN element maps, selected regions-of-interest focusing on the center of each grain (to avoid contributions from other minerals adjacent to the sulfide), and extracted XRF spectra. After subtracting the instrumental background from a particle free area adjacent to the sulfide, we determined the Ni/Fe ratio in each grain. We observed a wide range of Ni contents in these Fe-sulfides. The most Ni-rich Fe-sulfide, an ~200 nm grain shown in Figure 1, has a Ni/Fe ratio of 0.12 in the central ~100 nm region, much higher than the Ni/Fe reported for sub-micron Fe-sulfides in anhydrous IDPs in other analyses.

Conclusions: The presence of GEMS, which are rapidly hydrated on exposure to water vapor or liquid water [7], in these CP IDPs demonstrates that sub-micron high-Ni Fe-sulfides were not produced by aqueous processing after assembly of the dust particles and incorporation into a parent body. This indicates that small high-Ni Fe-sulfides were present in the Solar protoplanetary disk before aggregation of the CP IDPs.

References: [1] Ishii et al., Science, 319, 447ff. [2] Zolensky, M.E. and K.L. Thomas (1995) Geochim. Cosmochim. Acta, 59, 4707–4712. 1997. [3] Berger et al. (2011) Geochimica et Cosmochimica Acta, 75, 3501-3513. [4] Dia, Z.R and J.P. Bradley, Geochimica et Cosmochimica Acta, 65, 3601-3612. [5] Schrader et al. (2015) 46th Lunar and Planetary Science Conference, Abstract # 2951. [6] Schoonen et al. (2016) 47th Lunar and Planetary Science Conference, Abstract # 2951. [7] Nakamura et al. (2005) Meteoritics & Planet. Sci., 40, Supplement, Abs. #5235.

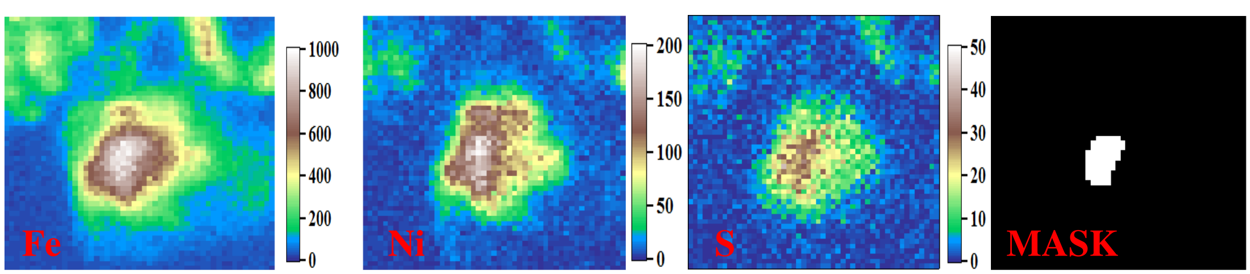

Figure 1: Fe, Ni, and S X-ray fluorescence maps (3 s/pixel dwell), each 500x500 nm, of a high-Ni Fe-sulfide in a CP IDP, taken using the HXN. The rightmost image shows the mask, corresponding to the most intense Fe and S signals, used to extract the XRF spectrum of this sulfide grain. (Count rate scale to right of each map.)