

# THE MINERALOGY, PETROGRAPHY AND CHEMISTRY OF COMET DUST: SULFIDES.

Chisato Sekigawa<sup>1</sup> and Lindsay P. Keller<sup>2</sup>, <sup>1</sup>Faculty of Science, Kobe University, 1-1, Rokkodai, Nada-ku, Kobe JAPAN 657-8501,,<sup>2</sup>ARES, Mail Code KR, NASA Johnson Space Center, Houston, TX 77058. ([098s415s@stu.kobe-u.ac.jp](mailto:098s415s@stu.kobe-u.ac.jp))

**Introduction:** Interplanetary dust particles (IDPs) are among the most chemically and mineralogically primitive meteoritic materials currently available for laboratory investigation, with components that formed in the early solar nebula and presolar environments [e.g. 1, 2]. There are two major types of chondritic IDPs, chondritic porous (CP) IDPs and chondritic smooth (CS) IDPs and the former are anhydrous and the latter are hydrous. CP IDPs are composed predominantly of loose fluffy aggregates of submicrometer silicates (En, Fo), Fe (+Ni) sulfides, GEMS (glass with embedded metal and sulfides), and carbonaceous material [1].

The mineralogy and petrography of CP IDPs have been studied for over 2 decades, yet few systematic studies have been reported. One of the goals of this study was to determine the mineralogy, mineral compositions and grain sizes for several CP IDPs in order to provide a database for comparison with other primitive meteoritic materials such as carbonaceous chondrites and Stardust samples (comet Wild-2 particles). Our initial measurements focused on the sulfide grains within these particles. Although sulfides are a common mineral in IDPs, details of their composition (and crystal structures) have remained elusive. Most of the sulfur in primitive meteoritic materials resides in Fe,Ni-sulfide grains in the form of troilite ( $\text{FeS}$ ), pyrrhotite ( $\text{Fe}_{1-x}\text{S}$ ), and pentlandite ( $[\text{Fe,Ni}]_9\text{S}_8$ ) [1]. In this study, we analyzed the sulfide mineralogy of the particles and compared our data to other primitive materials such as carbonaceous chondrites and comet Wild 2 samples.

**Sample and methods:** Three individual CP IDPs (W7190C28, L2005AL5 and L2001B10) and matrix fragments from a meteorite (Acfer 094) were embedded in low viscosity epoxy or elemental sulfur and microtome thin sections (~70 nm) were prepared by ultramicrotomy. The IDP samples are typical CP IDPs, while the Acfer 094 matrix samples were selected because this meteorite is among the most primitive carbonaceous chondrites in terms of its content of presolar grains [3]. The thin sections were placed on TEM grids with continuous carbon films and analyzed using the JSC JEOL 2500SE scanning-transmission electron microscope (STEM). Bright field and dark field images of the thin sections were taken at 100KX magnification and were used to aid in the identification of the individual grains. We obtained quantitative elemental maps (spectrum images) of the samples using a Noran thin-window energy dispersive X-ray spectrometer (EDX) to determine the chemical composition of the mineral phases (Fig. 1). We also measured par-

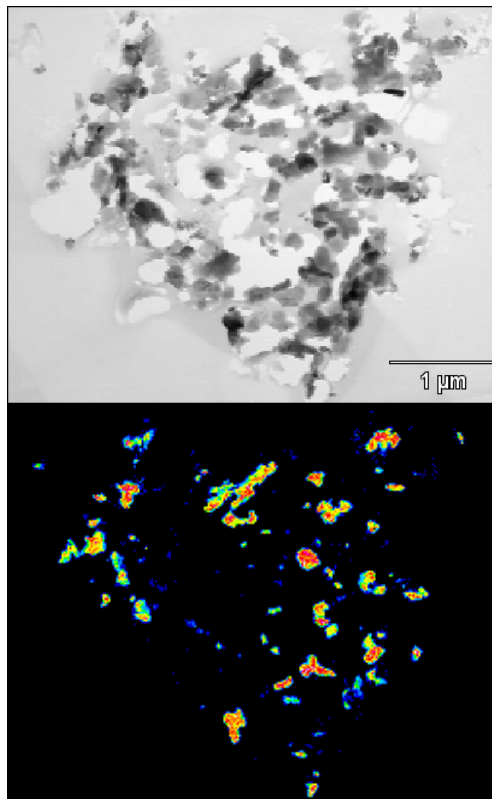


Fig. 1: upper: BF (bright field) image of W7190C28 thin section, lower: X-ray map of sulfur in W7190C28

ticle sizes of the different minerals by image processing of the elemental images using a publicly available software package (Image J, from the NIH, Figure 1).

**Results:** Each IDP samples contains Mg-rich silicates, sulfide grains, and carbonaceous materials. Acfer 094 contains abundant amorphous Mg-Fe silicates, tiny enstatite and forsterite grains along with numerous sulfide grains (carbonaceous materials is rare). Figure 2 shows the size distribution of sulfide grains for each sample. L2011B10, L2005AL5 and Acfer 094 all show an approximately log-normal size distribution with a maximum peak at ~10 nm. W7190C28 shows a much different distribution with a much wider variation in sizes with few small grains and more grains in the larger size fraction. L2005AL5 contains highest % of Ni (~15 at. %) among these three IDP samples. In addition, AL5 also contains tiny Fe metal (kamacite) grains. Unlike the IDP samples, Acfer 094 matrix contains Ni-rich sulfides (pentlandite) in addition to pyrrhotites.

Figure 3 shows the sulfide compositions plotted on a Fe-Ni-S at. % ternary diagram. We analyzed mineral composition for 20, 20, 19 and 50 sulfide grains for W7190C28, L2011B10, L2005AL5 and Acfer 094, respectively. The three IDP samples contain pyrrhotite which is typical for anhydrous IDPs [5,6]. Sulfide grains in W7190C28 and L2011B10 are generally Ni-poor (<5 at. %) and these data plot close to the S-Fe binary join. L2005AL5 contains more Ni-rich (~15 at. %) grains compared to the other two IDP samples. The data show that there are also some Fe metal grains (kamacite) in AL5. Acfer 094 shows a broader compositional range compared to all IDP samples. This meteorite sample includes more abundant sulfide grains that contain higher Ni contents (~20 at. %) compared to the other three IDP samples.

**Discussion:** Our grain size distributions are consistent with earlier results by [4]. However, there is an obvious difference between W7190C28 and other three samples. The larger grains sizes and abundance of polycrystalline sulfide aggregates in W7190C28 are likely caused by annealing and growth of sulfide grains prior to accretion in the solar nebula. Coagulation and grain growth has modified the mineralogy and grain size of the silicate aggregates in W7190C28 [3].

#### Mineral composition of sulfide grains

The compositions of the sulfide grains analyzed in this study are in excellent agreement with a previous study of IDP sulfide grain compositions [1, 4]. Zolensky and Thomas [5] analyzed anhydrous (CP) and hydrous (CS) IDPs and their Fe-Ni-S atomic % ternary diagram show that anhydrous IDPs contain mainly low-Ni (<2 at.%) pyrrhotite. In contrast, their hydrated IDPs contained mainly pyrrhotite plus more Ni-rich varieties including pentlandite. In this study, we found that Acfer 094 matrix sulfides show the same trends as the hydrous IDPs. Ni-rich sulfides in CS IDPs were produced during an aqueous alteration event on the parent body, while the CP IDPs sulfides reflect an origin in the early nebula [5]. Although the range of aqueous alteration in Acfer 094 is not as pronounced as in the CS IDPs, the sulfide compositions reflect a similar elemental redistribution.

#### Comparison to comet Wild 2 sample

Zolensky et al. [6] plotted Fe-Ni-S atomic % ternary diagram of comet Wild 2 samples. A plot of analyses of its Fe-Ni sulfides shows that many have composition close to that of FeS, with less than 2 atom % Ni (two pentlandite grains are exceptions). Basically, most Wild 2 sulfides are mixture of troilite and pyrrhotite. The Fe-Ni sulfide compositional range of Wild 2 grains is the same as that of anhydrous chondritic IDPs in this study.

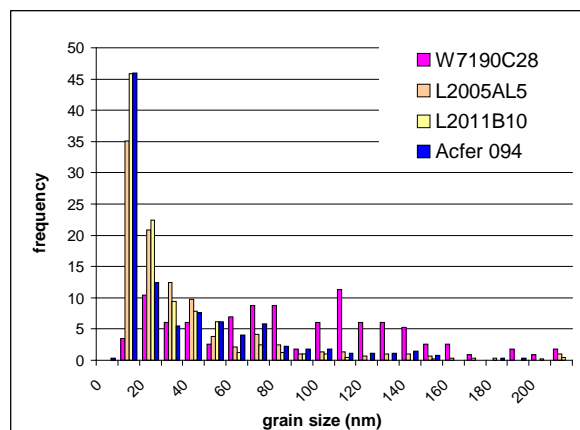


Fig. 2: Size distributions for the three IDP samples and one meteorite sample.

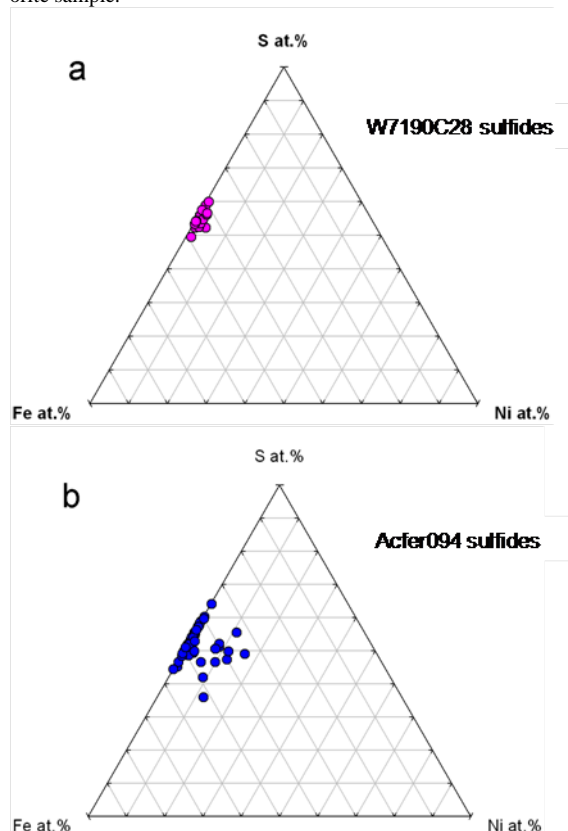


Fig.3: Fe-Ni-S atomic % ternary diagram a) W7190C28 (anhydrous IDP), b) Acfer 094 matrix (meteorite).

**References:** [1] Dai, Z. and Bradley, J. P. (2001) *GCA* 65, 3601-3612. [2] Keller, L. and Messenger, S. (2007) *MAPS* 42, #5297. [3] Nguyen, A. et al. (2007) *Ap.J.*, 656, 1223. [4] Keller, L. et al. (2009) *LPSC* 40, #5371. [5] Zolensky, M. and Thomas, K. (1995) *GCA* 59, 4707-4712. [6] Zolensky, M. et al. (2008) *MAPS* 43, 261-272.