CRYSTALLINITY OF FE-NI SULFIDES IN CARBONACEOUS CHONDRITES

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Introduction: The main long-term goal of this research is to understand the physical conditions in the early solar nebula through the detailed characterization of a key class of mineral present in all primitive materials: Fe-Ni sulfides [1&2]. Fe-Ni sulfides can take dozens of structures, depending on the temperature of formation, as well as other physico-chemical factors which are imperfectly understood. Add to this the additional varying factor of Ni content, and we have a potentially sensitive cosmothermometer [3]. Unfortunately, this tool requires exact knowledge of the crystal structure of each grain being considered, and there have been few (none?) studies of the detailed structures of sulfides in chondritic materials. We report here on coordinated compositional and crystallographic investigation of Fe-Ni sulfides in diverse carbonaceous chondrites, initially Acfer 094 (the most primitive CM2 [4]) Tagish Lake (a unique type C2 [5]), a C1 lithology in Kaidun [6], Bali (oxidized CV3 [7]), and Efremovka (reduced CV3 [7]).

Analytical: In the past we have always attempted synchrotron X-ray diffraction (SXRD) work on crystals with no prior indication of their degree of crystallinity, which resulted in **many** wasted days of work. This time we first examined each candidate crystal by electron backscattered diffraction (EBSD), using a newly installed Oxford CHANNEL5 EBSD system attached to a FEG-SEM at JSC. This equipment can provide a rapid initial measure of degree of crystallinity and crystal structure identification for most phases (in polished sections) larger than 1 µm. We also collected microprobe analyses and made element maps of some candidate crystals, all using an SX100 electron microprobe. We used a special Laue single crystal X-ray camera for SXRD, developed for use with synchrotron radiation, designed specifically for use with micron-sized (and larger) grains. The work was performed at the Photon Factory, Tsukuba, Japan (for analytical details see [8]). In all instances where we experienced sample movement during the SRXD exposures (usually about 1 hour), we re-microprobed the entire analyzed area to verify the composition.

Results: We located and analyzed a wide range of Fe-Ni sulfide compositions in each meteorite, to determine whether there was a correlation of degree of crystallinity with composition. Also, we collected diffraction data from different regions of all crystals. Our SXRD data are currently being reduced, so we are permitted to present only preliminary conclusions in this abstract.

Bali: The Bali CV3 chondrite contains both unaltered and altered lithologies (the latter are close to CV2 in regions), and we examined sulfides in both lithologies. In the unaltered lithology we found all 4 examined sulfides to be non-crystalline at the micron scale. By contrast, the sole analyzed sulfide in altered Bali was well-crystalline. Since the crystals we analyzed in Bali were all mixtures of subhedral to anhedral domains, of varying Fe-Ni ratios, we presume that these sulfides possessed some degree of long-range order when they formed. Thus these sulfides probably record an episode of shock sufficiently severe to disturb sulfides but not silicates. This is a trend common to all of the carbonaceous chondrites we examined.

Efremovka: The Efremovka reduced CV3 chondrite contains both troilite (probably – but we will see!) and pentlandite, intergrown in anhedral masses. All of the portions of the 4 masses that we examined were crystalline – Efremovka's sulfides were the most consistently well crystalline of any meteorite we examined for this study.

Acfer 094: We have data for 8 sulfides in Acfer 094, including pyrrhotite and pentlandite. As with Bali, some grains are very poorly crystalline, but most have some degree of crystallinity. There is no correlation or degree of crystallinity with composition. One grain is sufficiently crystalline to permit a crystal structure analyses to be performed – fortunately, for this particular grain we have good XRD data for coexisting constituent pyrrhotite and pentlandite.

Tagish Lake: We have data for 5 sulfides in Tagish Lake, including pyrrhotite and pentlandite. A minority of grains have very poor crystallinity. There is no correlation or degree of crystallinity with composition. For one grain we have good XRD data for coexisting pyrrhotite and intermediate-Ni sulfide - the latter phase is a priority target of this study.

Kaidun C1: We have data for 6 sulfides in Kaidun C1, all pyrrhotite, and half are well crystalline. It has taken us years to find **any** crystalline sulfides in Kaidun, probably a testament to the shock this meteorite has experienced because the sulfides often have euhedral forms in this meteorite.

Structure Determination and Conclusions: Our current work centers on the calculation of the crystal structures from the SXRD data. We expect surprises. For example, the EBSD data for Kaidun suggests that these "pyrrhotites" are in reality the poorly understood mineral smythite. We have determined that all the examined carbonaceous chondrites contain sulfides that are amenable to structure analysis, but that most are dominated by poorly-crystalline sulfides, suggesting the action of shock metamorphism. The exception to this trend is Efremovka, which may therefore be the least shocked of these carbonaceous chondrites.

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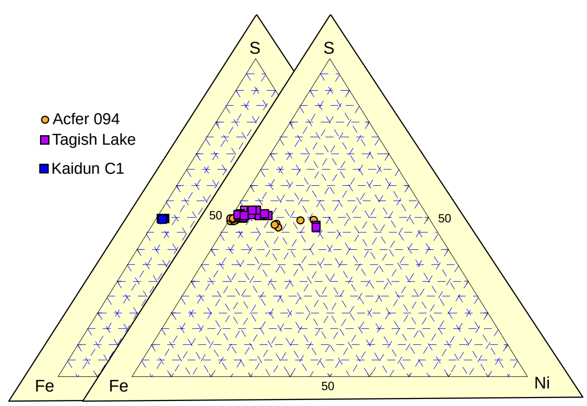

Figure 1 Triangular diagrams (atom %) of Fe-Ni sulfides analyzed in Acfer 094, Tagish Lake and Kaidun C1.