FINE-GRAINED RIMS OF Y-791198 ARE TEXTURALLY, MINERALOGICALLY AND COMPOSITIONALLY SIMILAR TO GEMS-TYPE IDPS. L. J. Chizmadia. Institute for Astronomy, University of Hawai'i, 2680 Woodlawn Dr., Honolulu, HI 96822 (lchiz@ifa.hawaii.edu).

Introduction: Carbonaceous chondrites are complex mixtures of components which have lead to decades of puzzlement and fascination. These components reveal numerous processes including condensation, melting and evaporation, parent-body and nebular alteration, fluid-mediated and thermal metamorphism. The fine-grained materials are especially sensitive to many of these processes because of their high surface area to volume ratios and disequilibrium assemblage of phases. Fine-grained materials (interchondrule matrix and fine-grained rims) comprise 20 to 50 vol% of carbonaceous chondrites [1] this is where the organic molecules [2] and pre-solar grains [3] are found. Silicate dust is a major component of interstellar dust and the extent to which this materials survived processing in the solar nebula is unknown.

Until recently, many researchers have assumed that fine-grained materials were initially similar to the crystalline matrices of CV chondrites [4]. Over the last decade, TEM studies of primitive carbonaceous chondrites [5-6] and IDPs [7-9] have shown that a significant proportion of the fine-grained materials is amorphous. This important observation provides a possible link between amorphous silicate material in the interstellar medium and primitive solar system materials. However, there are several astrophysical environments and processes that can result in the formation of amorphous materials, including disequilibrium condensation and irradiation. Consequently, establishing genetic links between interstellar amorphous matter and materials of local solar system origin is challenging. Here, the possible relationships between amorphous materials in chondritic IDPs and meteorites is examined.

Previous Work: Interplanetary dust particles (IDPs) have been collected since 1974 from the lower stratosphere and their textures range from highly porous to collapsed aggregates [7]. Fluffy aggregate IDPs (aIDPs) contain many components with differing compositions, mineralogy and textures. The ultrafine-grained components of aIDPs contain the so-called GEMS-type IDPs as dubbed by [8]. These GEMS consist of nanoscale kamacite grains and sulphides (Ni-bearing pyrrhotite) embedded in a groundmass of non-stoichiometric amorphous silicate [8-10] (Fig. 1). Rare relict forsteritic olivine can also be found [10]. They have similar mineralogical, optical and physical properties to those of interstellar amorphous silicates [8] and based on isotopic anomalies (H, O, C, N), some GEMS have been determined to be pre-solar [9]. However, because they have chondritic bulk compositions, it is thought that most originated in the solar system [8]. GEMS have a higher abundance of metal grains as compared to chondritic fine-grained materials; otherwise, the mineralogy, composition and textures of GEMS are unexpectedly similar to the fine-grained materials of ALH77307 [5] and Acfer094 [6].

Results: EMP analyses show that the fine-grained rims of Y-791198 are homogeneous on the 10-μm-scale [11], similar to ALH77307 [5]. However, TEM analyses reveal that Y-791198 rims are composed of two types of regions: sulphide-poor and sulphide-rich [12]. The sulphide-poor areas are dominated by non-stoichiometric amorphous material and nano-crystalline serpentine. The amorphous materials have diffraction patterns consisting of diffuse rings and have compositions similar to serpentine. The nano-crystalline serpentines are 2-5 lattice planes in thickness with ~0.7 nm spacings. The sulphide-rich regions contain 1-200 nm rounded Fe-Ni sulphides (usually pentlandite with some Ni-bearing pyrrhotite) embedded within amorphous material (Fig. 2). Rare rounded to anhedral olivine (Mg-rich, Fe-rich and LIME), rounded low-Ca pyroxene and rounded kamacite [13] grains are found among the sulphide grains. These rare grains are always >100 nm in size. These findings are also strikingly similar to those for primitive carbonaceous chondrites [5-6].

In order to compare the bulk composition of GEMS-type IDPs (quantitative EDS data from [8,14-17]) with the matrices and fine-grained rims of the primitive carbonaceous chondrites, Acfer094 (EMP data from [5]) and ALH77307 (EMP data from [6]), several Si-normalized element plots were created. There is a very good agreement between the GEMS data and the fine-grained materials of ALH77307 (CO3.0), Acfer094 (unique) and Y-791198 (CM2) for all the Si-normalized elemental ratios. In Ca/Si vs. Al/Si (Fig. 3) and S/Si vs. Ca/Si plots, there is considerable overlap between the ALH77307, Acfer094 and Y-791198 datasets and the GEMS-type IDPs. In the plots with Fe/Si, the chondrites form distinct populations that form a linear array from Acfer094 (Fe/Si~0.6) to ALH77307 (Fe/Si~1.1) to Y-791198 (Fe/Si~1.6), consistent with [19], while the GEMS Fe/Si ratio extends from 0.01 up to ~2.0. The Mg/Si and Cr/Si ratios are again very comparable between the chondrites and the GEMS.

Discussion: The mineralogy, composition and textures of fine-grained materials of primitive chondrites are surprisingly similar to that of GEMS-type IDPs. However, the bulk compositions of chondritic matrices are, to first order, complimentary to that of the chondrules, such that the meteorite as a whole has a chondritic (solar) composition. So is it realistic to think of GEMS of solar composition being genetically related to the fine-grained materials of chondrites? It would seem so. First, GEMS tend not to be chondritic, but are enriched in Fe, Al (Fig. 3) and S, similar to the meteoritic materials. Also, the variation between meteorite groups is comparable with that within the GEMS dataset. In fact, both datasets are statistically indistinguishable from each other, usually with the meteorites lying within the GEMS field.

[9] have showed experimentally that GEMS IDPs can be produced by irradiation of free-floating crystals (*e.g*. olivine and/or pyroxene) which resulted in amorphous silicates and reduced metal and sulphides. In order to account for the textural, mineralogical and compositional similarities, this irradiation event may have also affected those materials which would be incorporated into the fine-grained rims and matrices of carbonaceous chondrites. However, this model cannot adequately explain the presence of S or Ni which are not major elements in olivine or pyroxene.

Another possible formation mechanism has been proposed to explain the textures and mineralogy found in aIDPs, formation of Mg-Si-O amorphous smokes from vapor phase deposition [19]. Since the solar nebula contained additional elements, these amorphous smokes would presumably have contained other elements such as Al, Ca, S and Mn, as observed in aIDPs and fine-grained chondritic materials. These condensed smoke reproduce the fluffy aggregate texture seen in aIDPs as well as the amorphous nature. Crystalline olivine was produced through annealing and the annealed material matches the IR spectra of grains in typical circumstellar outflows [19]. In addition, metastable eutectic compositions were produced, such as serpentine and smectite without their OH groups, similar to those found in CI and CM chondrites. Therefore, it is plausible that comets and meteorites share a fine-grained component that formed from condensation early in the history of the solar nebula.

References: [1] Wasson (1985) Meteorites; [2] Irvine W. M. (1998) *Orig. Life Evol. Biosph.* 28, 365; [3] Lewis R. S. *et al.* (1987) *Nature* 326, 360; [4] McSween H. Y. (1987) *GCA* 51, 2469; [5] Brearley A. J. (1993) *GCA* 57, 1521; [6] Greshake A. (1997) *GCA* 61, 437; [7] F. J. M. Rietmeijer (2004) *JASR* in press; [8] Bradley J. P. (1994) *Science* 265, 925; [9] Messenger S. *et al.* (2003) *Science* 300, 105; [10] Westphal A. J. and Bradley J. P. (2004) *Ast. J.* 617, 1131; [11] Chizmadia L. J. and Brearley A. J. (2004) *LPS XXXV* abstract #1735; [12] Chizmadia L. J. and Brearley A. J. (2003) *LPS XXXIV* abstract #1419; [13] Chizmadia *et al.* (2003) *MetSoc* 66 abstract# 5264; [14] Bradley J. P. (1988) *GCA* 52, 889; [15] Bradley J. P. (1994) *GCA* 58, 2123; [17] Keller L. P. and Messenger S. (2004) *LPS XXXV* abstract #1985; [19] J. A. Nuth III *et al.* (2002) *MAPS* 37, 1579.

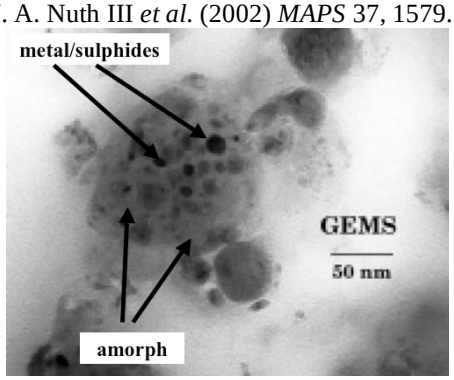

Figure 1. HRTEM image of GEMS-type IDP from NASA's Stardust website.

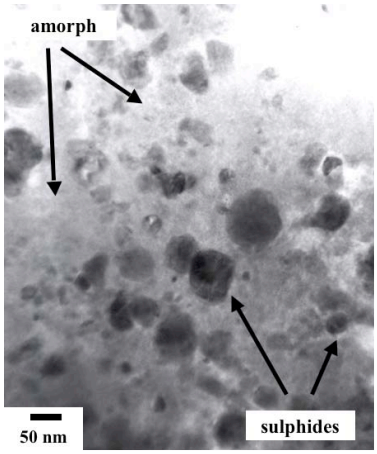

Figure 2. HRTEM image of fine-grained rim of Y-791198 from Chizmadia and Brearley (2003).

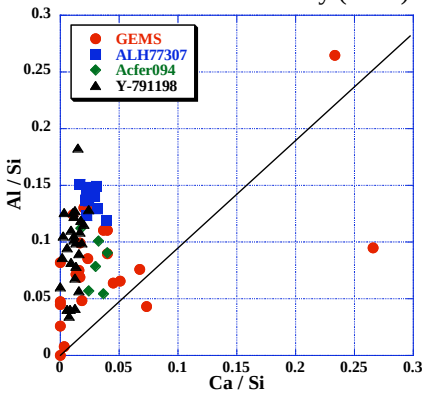

Figure 3. Ca/Si vs. Al/Si plot comparing GEMS to meteoritic materials with line = solar ratio.