CHONDRULE PRECURSORS: THE NATURE OF THE S- and NI-BEARING PHASE(S)

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Abstract Lauretta and Fegley (1) showed that troilite made by S condensation on kamacite should include a significant amount of Ni, but they reported being unsuccessful in their search for Ni-bearing troilite in chondrites (2). In (3), we showed the various opaque associations (OAs) found in veneers around chondrules in primitive and less primitive chondrites to be the result of parent body decomposition under different conditions of an initial Ni-bearing monosulfide solid solution (Ni-MSS). OAs in the less melted (finest grained) Semarkona chondrules are similar to the ones in veneers and differ from those in coarser grained chondrules. As fine-grained chondrules must have kept a better memory of their precursor minerals, this indicates that the dominant opaque phase in chondrule precursors was Ni-MSS, the logical end member of S condensation on kamacite in the solar nebula.

Method We did a systematic study of the finest-grained chondrules in Semarkona section USNM 1805-4. FeO contents of the olivines as well as nature and compositions of opaque phases were determined. In addition, bulk analysis were performed by broad beam techniques and nominal crystal sizes were determined (see 4, for more details) in order to be able to rank chondrules as a function of their degree of melting.

Results The finest-grained chondrules have crystal sizes ranging from <1 up to ~30 μm (yielding nominal sizes in the 2-4 μm range) (Fig. 1a). They are often zoned and appear unevenly melted. Clear igneous textures are present together with apparently unmelted relict patches (Fig. 1b & 2a). They may be heavily fractured, and their opaque mineralogy is particular: in addition to troilite and scarce Fe-Ni (kamacite + awaruite), pentlandite is present, as well as magnetite and cohenite. Moreover, rather than forming blebs or displaying melted textures as in coarser chondrules, these opaques tend to exhibit a xenomorphic texture, interstitial to the silicate crystals (Fig.2). The finest-grained chondrules have a bulk composition close to CI. For FeO-poor chondrules, this composition gradually evolves with increasing grain-size towards "typical" type I compositions in good agreement to those of (5), as abundances of volatile K, Na, Fe, Ni, P and S decrease (4). Bulk analysis of FeO-rich chondrules is still in progress and it is as yet too early to draw any conclusion on them except that the composition of the finest grained ones is surprisingly similar to that of FeO-poor ones and CI.

Discussion The gradual evolution of composition from the finest-grained to porphyritic and barred olivine for FeO-poor chondrules indicates a genetic link between these, the coarser ones beeing derived from the finer ones through more extensive melting and evaporative loss (4). Being less evolved, the finest grained chondrules better record the bulk composition and mineralogy of their precursor material. Bulk composition of precursors appears to have been close to CI. Troilite-pentlandite-awaruite associations are clearly low temperature and must have been formed in parent-body processes: we derived a metamorphic temperature of 230 °C for Semarkona from the abundance of Ni in the pentlandite in the veneers around its chondrules (3). In the case of the veneers, we indicated that the starting material from which these 3-phase associations were derived must have been Ni-MSS formed by S recondensation on peripheral kamacite after chondrule formation, in agreement with predictions of (1). Similarly, in the case of the finest-grained chondrules, the pre-parent-body opaque mineral from which troilite-pentlandite-awaruite associations originated logically was Ni-MSS. The scarcity of metal in these objects has two implications: (i) only minor sulfur loss can have taken place (if any) during their formation, and the nature of their sulfide mineral prior to parent-body transformation (Ni-MSS) must closely reflect that of their precursors. That Ni-MSS should have been the initial S-bearing phase integrated in chondrule precursors is, in any case, a logical consequence of following the condensation sequence down to S, as shown by (1). (ii) Metal in chondrules must have been formed mostly by desulfurization with a possible contribution of reduction, and the Ni-bearing phase in chondrule precursors was not Fe-Ni, but Ni-MSS.

References: (1) Lauretta D. S. and Fegley B. Jr (1995) *LPS XXVI*, 831-832 (2) Lauretta D. S. Kremser D. T. and Fegley B. Jr (1995) *NIPR*, 134-137 (3) Zanda et al. (1995), *Metoritics* 30, 605 (4) Hewins et al. (1996), *this vol.* (5) Jones R. H. and Scott E. R. D. (1989) *Proc. LPSC 19th*, 523-536.

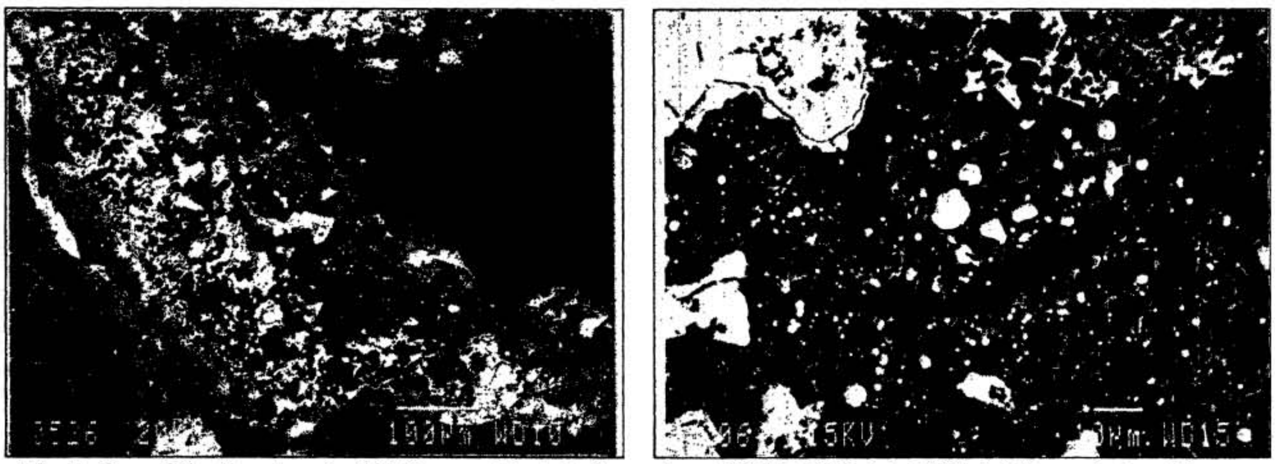

Fig. 1: One of the finest-grained FeO poor objects in Semarkona USNM 1805-4 in BSE. (a) General view. Very fine-grained objects tend to be zoned. General shape and layering rather than concentric-zoning tend to suggest this is only a fragment of initial object. (b) Detail of the silicates showing igneous texture with presence of glass.

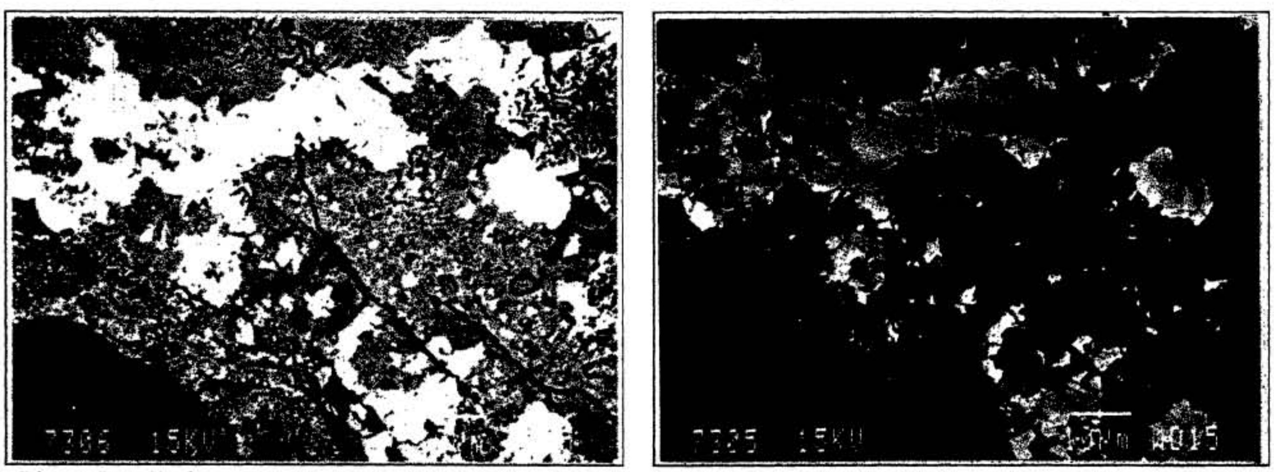

Fig. 2: Detail of another one of the finest FeO-poor objects in BSE. (a) Contrast shows the silicates and how the opaque minerals are pasted between the silicates instead of exhibiting rounded shapes (b) Contrast is set to show opaque phases as much as possible. The 5 different phases present are however hard to distinguish. The darker grey is magnetite. Two shades of medium grey are pentlandite (lighter) and troilite (darker). White is kamacite and FeNi2. (Apparent horizontal color zoning of grains is only an electronic artefact.)