# Experimental study on behavior of the Fe-S system during chondrule formation.

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Chondrules are silicate spherules contained in chondrites. They formed by melting of solid precursors at temperatures ranging between 1400 and 1800C [e.g., 1]. Many chondrules contain troilite (FeS). In the early solar system condition, sulfur is volatile and first condenses as FeS at ~710K through a reaction between H2S and Fe-Ni metal [e.g., 2]. At chondrule-forming temperatures sulfur could be easily lost if it was present in chondrule precursors so that heating-cooling conditions to retain sulfur are critical. However, since sulfur is mobile even at lower temperatures, troilites within chondrules may have formed during cooling as a secondary phase. Thus it is important to disitnguish primary and secondary troilites in chondrules. In this study we experimentally reproduce chondrules and observe the behavior of sulfur and iron in chondrule analogue materials such as evaporative loss of sulfur, texture of the Fe-FeS assemblage that crystallizes from the Fe-S melt, and its textural relationship with silicate phenocrysts in order to determine the comprehensive criteria for primary troilite within chondrules and to understand heating and cooling history of chondrules.

Starting material was made by mixing different proportions of olivine, orthopyroxene, clinopyroxene, and spinel from Ichinomegata peridotite nodule, anorthite from Miyakejima, and pyrrhotite from Chihuahua, to approximate the type IA chondrule composition used by Yu et al. [3] except for alkali contents. The powdered starting materials were pressed into pellets (5 mm in diameter). They were melted on Pt wire loops at 1400C or 1554C in a one-atmosphere furnace with fO2 controlled by a mixing of H2 and CO2 (IW-0.3 and IW-0.7 at 1400 and 1554C, respectively). They were heated for 20 seconds, 1 minutes, 5 minutes, and 1 hour for both temperatures, and cooled at a rate of ~5000C for runs at 1554C and quenched for runs at 1400C. They were observed with SEM and analyzed with EDS for chemical composition.

The charges show porphyritic olivine or micro-porphyritic olivine texture, and overgrowth of olivine was observed in most of the charges. However, zoning of olivine was less obvious for c shorter heating durations at lower temperature. About a few to several micron-sized FeS spherules were observed in mesostatis for charges heated at 1554C except for the one heated for 1 hour, where FeS was only found inside the olivine phenocrysts. In general, the size of FeS decreased with increasing heating time for charges at 1554C. No large Fe metal grains were observed most probably due to incorporation of Fe into Pt wires. For charges at 1400C, large rounded FeS grains were observed and the largest size seems to increase with increasing heating time, indicating that molten FeS grains were coagulated. Several micron-sized Fe metal was observed inside the sulfide, suggesting a small degree of evaporation of sulfur from the charges.

Our preliminary results indicate that primary FeS can be retained within chondrules if they were heated for relatively short durations and cooled rapidly as suggested by [3]. Even if most of sulfur would have been lost due to heating for 1 hour at 1554C, a small amount of troilites could have survived by being incorporated into growing olivine phenocrysts. Troilites embedded in silicate phenocrysts are sometimes observed within natural chondrules and such texture has been used as one of the criteria for primary troilite [4]. Further experimental study and comparison with natural chondrules is needed for understanding thermal history of chondrules based on the Fe-S system.

References: [1] Lofgren G. (1989), GCA, 53, 461. [2] Lauretta D.S. et al. (1996), Icarus, 122, 288. [3] Yu Y. and Hewins R. H. (1998), GCA, 62, 159. [4] Rubin A. E. et al. (1999), GCA, 63, 2281.