Physical and chemical constraints on the formation of a shock vein containing high-pressure minerals

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Introduction: High-pressure minerals, such as ringwoodite, majorite-pyrope garnet, and lingunite, have been found in the shock melted veins of many chondrites. Their occurrence indicates shock-induced melting and crystallization in veins under high-pressure and -temperature conditions. The duration of the high-pressure conditions are estimated to be about 4 seconds [1]. Here, we present not only mineralogical data of the shock vein in the H6 chondrite Y75100, but also bulk elemental abundances of the vein and host. Furthermore, we determined sulfur isotopic compositions of troilite in the vein and host chondrite. Sulfur isotopic compositions have previously been used to estimate the physical conditions prevalent during chondrule formation [2]. Here, we applied this method to evaluate the formation conditions of a shock vein.

Petrography: Y75100 contains shock-induced melt veins. Our laser micro Raman study indicates that olivine in the vein is mostly transformed into wadsleyite with ringwoodite. Pyroxene in the vein is abundantly transformed into majorite-pyrope garnet with a trace amount of akimotoite. Tomioka and Kimura [3] reported the first discovery of breakdown products from high-Ca pyroxene under high-pressure conditions in this chondrite. Most grains of plagioclase composition can be identified as jadeite. Lingunite is present, but rarely encountered in the vein.

Chemical composition: We used ICPOES and ICPMS for the chemical analysis of physically separated Y75100 host and vein materials. Results show depletions of up to 50% in the thermally labile elements Zn, Bi and Cd. Curiously, we found little difference between vein and host In and Tl contents. Rb and Cs show substantial enrichments of 20%, while K and Na demonstrate only slight enrichments in the vein material.

Sulfur isotopic composition: We measured S isotopic compositions of troilite in the shock vein and the host by SIMS. Analytical methods are described in [2]. Vein troilites do not show any significant isotopic fractionations (lower than 2 permil/amu) relative to troilite grains in the host material.

Discussion: The assemblage of wadsleyite plus majorite-pyrope garnet in the shock vein of Y75100 constrains the pressure and temperature to be about 15GPa and 1800C [4,5]. Except for some highly labile elements, the vein largely preserves the chemical composition of the host chondrite. This indicates that there was very little elemental migration on the timescale of the estimated duration of the high-pressure conditions [1]. Kimura et al. [6] demonstrated shock veins with high-pressure minerals have high cooling rates and show no evidence for secondary heating. Thus, it is unlikely that the lack of S isotopic fractionation in the vein troilite is due to later isotopic homogenization within the parent body. On the other hand, we would expect isotopic fractionation under vacuum conditions, such as on the surface of the parent asteroid. It is, therefore, probable that the shock vein formed within the parent asteroid, but was soon excavated from the interior. This scenario would have preserved the high-pressure minerals observed in Y75100.

References: [1] Ohtani et al. (2004) EPSL 277:505-515. [2] Tachibana and Huss (2005) GCA 69: 3075-3097. [3] Tomioka and Kimura (2004) EPSL 208:271-278. [4] Zhang and Herzberg (1989) JGR 99: 17729-17742. [5] Agee et al. (1995) JGR:100, 17725-17740. [6] Kimura et al. (2007) MAPS 42, A82.