AKIMOTOITE AND SILICATE-PEROVSKITE IN L5-6 S6 CHONDRITE ACFER 040 SUGGESTTING A HIGH SHOCK PRESSURE OF 25GPA. J. Hu[1], T. Sharp[1], R. Tricky[1], K. Leinenweber[2], [1]School of Earth and Space Exploration, [2]Department of Chemistry and Biochemistry, Arizona State University, Tempe, AZ 85287-1404 jinping.hu@asu.edu

Introduction: Shock features in meteorites can constrain the conditions of impact events on their parent bodies. Highly shocked meteorites generally contain shock-induced melt veins associated with high-pressure mineral assemblages that can constrain the shock pressure, temperature and duration of the shock event [1]. In shock veins, the high-pressure minerals occur as either melt crystallization assemblages or solid-state transformed host-rock fragments. In most highly shocked L chondrites, the high-pressure crystallization assemblages are dominated by wadsleyite, ringwoodite and majorite-garnet and magnesiowüstite, suggesting a shock pressure up to about 22GPa [2-4]. However, small amounts of akimotoite and silicate-perovskite/perovskite glass are found in some samples such as Acfer 040, Tenham and Umbarger [5-7]. These minerals suggest even higher shock pressure in L chondrites. Here we report detailed morphological and mineralogical study of the shock-induced melt veins of Acfer 040 to better understand the origins of silicate-perovskite and akimotoite and estimate the shock pressure.

Background: Acfer 040 is a highly shocked (S6) L5-6 chondrite with numerous melt veins and pockets. We investigated a thin section of ACFER040 using polarized light microscopy, Raman spectroscopy and field emission scanning electron microscopy (FESEM) with energy dispersive x-ray spectroscopy (EDS). Focused ion beam (FIB) techniques were used to prepare sections for transmission electron microscopy (TEM) and electron diffraction. Micro X-ray diffraction is performed at the Advanced Photon Source of Argonne National Laboratory.

Results: In Acfer 040, olivine and pyroxene inside the melt vein are transformed to their high-pressure polymorphs such as ringwoodite and akimotoite. Ringwoodite occurs as rims and lamellae in partially transformed olivine at margins of melt veins [8]. Pyroxenes are mostly transformed to glass-looking materials with complicated micro-structures, which are proved to be akimotoite by X-ray diffraction. As for the melt vein crystallization assemblages, we can identify 1) akimotoite + ringwoodite 2) vtrified silicate-perovskite + ringwoodite and 3) akimotoite + vtrified silicate-perovskite +ringwoodite.

Solid state transformation of pyroxene. All the investigated low-Ca pyroxenes in shock veins of Acfer 040 are transformed to akimotoite relying on synchrotron X-ray diffraction data. Their compositions are identical in aluminum-free and low Na and Ca content. However, these akimotoites are different in interior textures. First, cells defined by tiny bright particles inside some akimotoite fragments can be observed in FESEM BSE images (Fig. 1). Composition and mineralogy of the bright particles are still in question. The other interior feature is distinct iron heterogeneity. In some cases, the iron heterogeneity can be associated with the cell structure. In one akimotoite grain, the cells surrounded by bright particles may have lower iron content than the parts with no cells. In other cases, the iron rich regions are distributed in parallel lines and form networks in akimotoite grains. A difference of 1 mol% iron content is measured by EDS between the iron rich and depleted regions. Regions among the iron-rich networks are often glass-like. However, X-ray diffraction patterns of these grains show pure akimotoite signal.

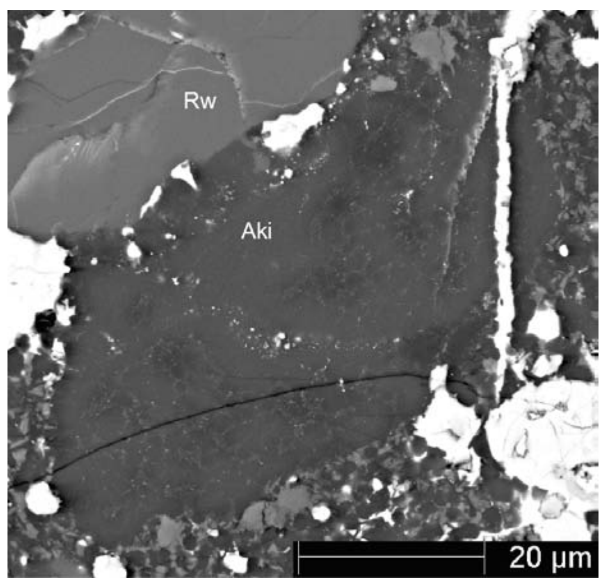

Fig. 1 FESEM image of akimotoite showing cell structure and iron content heterogeneity.

Akimotoite and silicate-perovskite in melt vein matrix. The melt-vein crystallization assemblages and textures vary throughout the sample. The matrix of thinnest veins, ranging from 10μm to 50μm in thickness, is dominated by finely-granular crystals, small amount of amorphous materials with pyroxene composition and ringwoodite (Fig. 2). These submicron granular crystals were hoped to be crystalline silicate-perovskite. This is because silicate-perovskite is very unstable under low pressure and high temperature and it may only survive in fast quenched thin veins. The thicker veins contain either an intergrowth of akimotoite and ringwoodite laths or pyroxene-composition glass plus granular ringwoodite. The glass is inferred to be vitrified silicate-perovskite because pyroxene and its other high-pressure polymorphs are relatively stable in quenching. X-ray diffraction patterns of the melt matrix show no more than akimotoite, ringwoodite plus metal-sulfide. The result partially supports our hypothesis that large amounts of silicate perovskite are vitrified. However either the very thin veins do not quench fast enough for the survival of silicate-perovskite or the shock temperature and pressure in thin veins dominated by akimotoite and ringwoodite are not high enough to form silicate-perovskite.

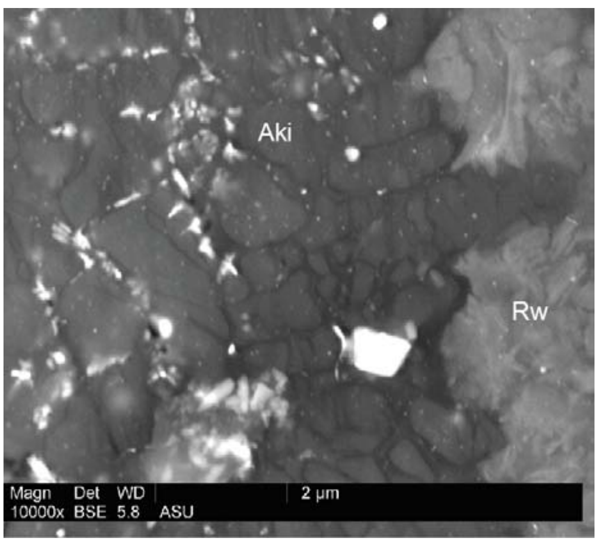

Fig. 2 Crystallized finely-granular akimotoite in the thinnest veins. The adjacent ringwoodite has bright contrast and and needle shape.

Discussion: Most highly shocked L6-S6 chondrites have melt-vein crystallization assemblages dominated by majorite and either magnesiowüstite or ringwoodite. If the pyroxenes are transformed, they are generally transformed to majorite. In Acfer 040, the crystallization assemblage is dominated by akimotoite or vitrified silicate perovskite plus ringwoodite. Almost all of the pyroxenes are transformed to akimotoite but we cannot rule out vitrified silicate perovskite. These assemblages indicate a shock pressure that is higher than those of most S6 chondrites. Based on phase equilibrium, the presence of akimototite and perovskite indicates that the peak shock pressure was limited to about 25 GPa. If the shock pressure were higher than 25 GPA, we would expect the crystallization assemblage to be dominated by silicate perovskite and magnesiowüstite. The low-Ca pyroxenes would be silicate perovskite and the high-Ca pyroxenes would be vitrified Ca-silicate perovskite. Olivines would have transformed to a mixture of silicate perovskite and magnesiowüsite, as seen in Dar al Gani 735 by Miyahara et al, 2011 [9]. Acfer 040 is one of the most highly shocked L6 chondrites studied up to date, but it only experienced about 25 GPa. This suggests that L chondrites shocked to higher pressures were either too badly fragmented to be transported to Earth as meteorites or they were too hot after shock release for high-pressure minerals to survive.

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