HIGH-TEMPERATURE SHOCK EFFECTS ON CARBONACEOUS CHONDRITES; T. Nakamura[1], K. Tomeoka[2], T. Sekine[3] and H. Takeda[4] (1) Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, Hakozaki, Fukuoka 812, Japan, (2) Department of Earth and Planetary Sciences, Faculty of Science, Kobe University, Nada, Kobe 657, Japan, (3) National Institute for Research in Inorganic Material, Tukuba, Ibaragi 305, Japan, (4) Mineralogical Institute, Faculty of Science, University of Tokyo, Hongo, Tokyo 113, Japan.

High-temperature shock experiments on Allende and Leoville CV3 carbonaceous chondrites were carried out to see the effects of impacts on carbonaceous chondrites at high temperature using a single-stage propellent gun. The experimental conditions (peak shock pressures and pre-heated temperatures) are following; 11GPa initially at 300 °C, 21GPa at 300 °C and 21GPa at 600 °C for the experiments on Allende, and 21GPa at 660 °C and 21GPa at 800 °C for Leoville. Leoville is known to show preferred orientation of flattened chondrules [1], which was probably produced by impacts [2, 3]. We chose a direction perpendicular to the foliation for the direction of experimental shock propagation in order to observe progressive shock metamorphism on carbonaceous chondrites.

Shock loading on Allende CV3 chondrites

11GPa at 300°C : Chondrules, which were more or less spherical before shock loading, are uniformly flattened with an average ratio (long axis / short axis) 1.6 and show a recognizable preferred orientation. Olivine and low-Ca pyroxene in chondrules show irregular fractures and undulatory extinction. Mesostasis glasses in all chondrules are devitrified. Fe-Ni metal and sulfide inclusions in chondrules are fractured and partially melted; the partial melt occasionally intrudes into the fractures of silicates in chondrules. Chondrules containing many opaque inclusions tend to show higher degree of flattening. A noteworthy feature in matrix is the generation of numerous subround or irregularly-shaped grains of glassy material ranging in diameter from 10 to 30 μm. The glassy grains occupy 10 vol% of the matrix. Each grain is surrounded by relatively compacted olivine grains, suggesting that the glassy material might be produced by *in situ* melting of interstitial material between olivine grains. The glassy grains are rich in Si and Ca and have compositions close to high-Ca pyroxene.

21GPa at 300°C : Chondrules are clearly more flattened than the above product with an average aspect ratio 1.8 and display strong preferred orientation. Olivine and low-Ca pyroxene in chondrules show irregular fractures and exhibit undulatory extinction. Planar fractures are also observed in some olivine grains. Furthermore, in some chondrules, oval or rectangular grains of olivine and low-Ca pyroxene are aligned in a direction perpendicular to the compacting axis of chondrules. They appear to have rotated within chondrules during shock loading due to increase of plasticity of mesostasis glass. Like the product at 11GPa and 300 °C, Fe-Ni metal and sulfide inclusions in chondrules are deformed and partially melted. The matrix also contains numerous glassy grains which are bedded in strongly compacted olivine grains. The glassy grains are relatively larger and occupy greater volume of matrix (16 vol%) than those in the products at 11GPa. They range in diameter from 10 to 50 μm and occasionally up to 500 μm. Chemical compositions of the glassy grains are similar to those of the product at 11GPa at 300 °C. TEM observations on olivine grains in the matrix reveal the presence of high densities of cracks and dislocations.

21GPa at 600°C (the results for this condition have been already presented at the last Meteoritical Society meeting [4], but they are shown here again briefly for comparison): Chondrules are remarkably flattened with an average aspect ratio 1.8. Some olivine grains in chondrules show planar fractures. A remarkable feature that was not observed in the previous two products is that almost all chondrules show blacking. High-magnification SEM observations reveal that optically blackened olivine and low-Ca pyroxene contain numerous cracks filled with Fe-Ni-S melt. Si- and Ca-rich glassy grains ranging typically from 10 to 50 μm and occasionally up to 500 μm in diameter occur in many places in the matrix. The glassy grains occupy 18 vol% of the matrix. Sulfide grains are apparently melted to form network-like veins in the matrix. In places, the Fe-S melt is segregated in areas ~ 400 μm across.

Shock loading on Leoville CV3 chondrite

21GPa at 660 °C : Flattening of chondrules does not appear to be enhanced by shock loading. Fe-Ni metal and sulfide inclusions in chondrules are partially melted and form many veins in chondrules, resulting in shock blackening. Notable additional shock features are not observed except those indigenous to Leoville. The glassy material that was observed in the matrix of shocked Allende at high temperatures is not observed in this matrix.

21GPa at 800 °C : Shock effects in chondrules are similar to those in shocked at 660 °C. But, shock blackening occurs in larger areas and the matrix has a smoother appearance in SEM images, being consistent that they were more compressed and sintered. In many places in the matrix, shock veins are observed with typically from 10 to 30 μm and occasionally up to 150 μm in width. Most of these veins are filled with Fe-Ni melt, and some with Fe-Ni-S melt. One large Fe-Ni-S vein contains numerous inclusions of low-Ca pyroxene, voids and Ca-Al-Si-rich melt. In the vein, kamacite occurs as fine grains less than 10 μm in diameter, suggesting that the Fe-Ni melt was rapidly cooled down from a high temperature.

The shock-loaded Allende and Leoville at high temperatures show many features different from those of shock-loaded Allende at room temperature [4]. The following are the features observed in the shocked samples at high temperatures but not in the shocked samples at room temperature [4]. (1) Shock blacking of chondrules caused by melting of Fe-Ni metal and sulfide in chondrules. (2) Generation of high-Ca pyroxene-like glassy grains in porous matrix. (3) Production of shock veins filled with Fe-S or Fe-Ni-S melt. These features can be ascribed to the shock at high temperature.

Some of the textural and mineralogical features of shock-loaded samples are different between Allende and Leoville. Deformation and elongation of chondrules are enhanced only in shocked Allende. Shock veins are produced in both shocked Allende and Leoville, but the compositions and the occurrences of the veins are different . Localized melts occur only in the matrix of shocked Allende. These differences may be due to the textural and mineralogical differences in the matrices of Allende and Leoville; the matrix of Allende is porous and contains many sulfide grains, whereas that of Leoville is much less porous and contains many Fe-Ni metal grains. Numerous pores in the matrix of Allende may have provided a room for chondrule deformation and contributed to the preferential temperature increase in the matrix. Sulfide grains in the matrix of Allende are probably responsible for the formation of Fe-S-rich shock veins. In contrast, the low abundance of pores in the matrix of Leoville restricted chondrule deformation and hindered temperature increase in the matrix. Fe-Ni metal grains in the matrix of Leoville are responsible for the formation of Fe-Ni rich shock veins.

References: [1] Kracher A. et al. (1985) *JGR, 90,* 123-135. [2] Nakamura T. et al. (1992) *EPSL, 114,* 159-170. [3] Scott E. R. D. et al. (1992) *GCA, 56,* 4281-4293. [4] Nakamura T. et al. (1993) *Meteoritics, 28,* 408.