SHOCK EXPERIMENTS OF SYNTHETIC EUCRITE WITH VARIOUS INITIAL TEMPERATURES.

Akira Yamaguchi1, Toshimori Sekine2, and Hiroshi Mori3, 1Antarctic Meteorite Research Center, National Institute of Polar Research, Tokyo 173-8515, Japan (yamaguch@nipr.ac.jp), 2National Institute for Research in Inorganic Materials, Ibaraki 305-0044, Japan, 3Faculty of Science, Ehime University, Ehime 790-8577, Japan.

Introduction: Almost all eucrites are shocked and brecciated rocks, indicating that impact event is a dominant process on the parent body. Recently, Yamaguchi et al. [1] suggested that those impacts occurred during early metamorphism and volcanism. In general, impacts on hot bodies may result in different shock textures [e.g., 2, 3]. To improve our understanding of shock effects with various initial temperatures, we performed shock recovery experiments on synthetic eucrite at pre-shock temperatures up to 863 °C.

Experiments: Because there is no unshocked, unmetamorphosed eucrite, we synthesized eucrite as a starting material of the shock experiment. A starting material with the bulk composition of the Juvinas eucrite was prepared from a mixture of reagent grade oxides. The oxides were thoroughly mixed and then pressed hydrostatically under a pressure of 1 ton/cm² into a rod about 10 mm in diameter and 80 mm long. The rod was sintered in a resistance furnace at 1000 °C under a mixed gas flow of CO₂ and H₂, each at 300 ml/min. Growth of synthetic eucrite was performed using a lamp-image floating-zone furnace. The sintered rod, suspended from the upper part of the furnace, was used as a nutrient, and fed on a seed rod through the molten zone. The atmosphere during crystallization was controlled by passing a mixture of CO₂ and H₂ diluted with N₂ through the quartz growth tube. The growth rate was 0.5-1.0mm/h, and the seed and the sintered rod were rotated in opposite directions, each at 10 rpm. As grown boules were typically 50-60 mm long and 8-10 mm in diameter.

The shock recovery experiments were performed by using a single stage 30-mm bore propellant gun at the National Institute for Research in Inorganic Materials. The projectile is a 2-4 mm-thick plate made of stainless steel SUS 304 or aluminum, bedded at the front of a polyethylene sabot. The peak shock pressure is determined as an equilibrated value with that of container and is determined from the velocity of projectile measured just before impact and the known Hugoniot. Details of shock-experimental procedures are described by Sekine et al. [4]. For shock experiments with high initial temperatures, sample container was externally heated and the temperature was measured just before the passage of shock waves [5]. Polished thick and thin section (PTS) (~20-30 μm thick) was made from each recovered sample by cutting along the shock compaction axis. These samples (except for the extreme edges) were examined by optical microscope, SEM/EDS, and EPMA.

Results and discussion: Unshocked, synthetic eucrite shows a microporphyritic texture, with microphenocrysts of pyroxenes (~0.4 x 0.7 mm) in very fine-grained (~30 x 200 μm) intergrowth of pyroxene and plagioclase. Almost all crystals are oriented toward the shaft of the synthesized rod (i.e., the direction of shock wave propagation). Except for the preferred orientation, the petrographic texture of the starting material is similar to that of unequilibrated eucrites. Chemical compositions of pyroxenes are variable from Wo₅En₅₅ to Wo₂₀₅₃En₃₅, which are slightly Fe-richer than those in natural unequilibrated eucrites. Plagioclase compositions vary in a range from Anₘ₆-ₙ₆.

In the shock experiments at room temperature, the shock effects observed in minerals of the recovered samples are similar to those of the previous works for natural basalt recovered from the same pressure [6]. The sample shocked at 11.4 GPa and room temperature is slightly brecciated but preserves almost original igneous textures (Fig. 1). Samples shock-loaded at 13.4 GPa and 22.6 GPa and room temperature are fragmental breccias with well-defined clast-matrix boundaries. Pyroxenes in the sample shock-loaded at >11.4 GPa show mottled extinction and some of them are mechanically twinned. In the sample shock-loaded at 22.6 GPa, most of the plagioclases are converted into glassy phase. Plagioclases in the samples recovered from >27.4 GPa are totally converted into glass phases and are almost unfractured with smooth surface. This is related to the fluid-like behavior of plagioclase glass by shock [7]. These samples contain abundant veins of thin mixed mineral melts (microfaults) offset about several hundred μm, and clastic matrix observed in the <22.6 GPa samples is rarely observed. The degrees of deformation, defined as the diameter ratio of sample disk before and after shock, increase up to 1.12-1.42 with increasing shock pressures.

The sample shocked to 84.0 GPa at room temperature is highly deformed and 80-90 vol% of the sample is vesiculated (Fig. 2). It consists of pyroxene fragments, clasts of eucrites, and eucrite ghosts, set in a complicated melt matrix. Pyroxene fragments and pyroxenes in eucrite clasts are heavily shocked,
SHOCK EXPERIMENTS OF EUCLITE: Yamaguchi A. et al.

showing a strong mosaic extinction. Euclite ghost is deformed basalt under SEM, but is composed of vesiculated plagioclase glass and partly vesiculated pyroxene (glass). This suggests that the basalt ghosts was super-heated, once melted and solidified without significant mixing. The post-shock temperature may be locally more than ~1400-1500 °C. Clasts with similar origin have been found in impact melt rock of the ordinary chondrite, Ramsdorf [8].

We observed slightly different shock effects at higher initial temperatures (611-863 °C). The samples recovered from 14.8 GPa preheated at 611 °C and from 13.1 GPa preheated at 849 °C are texturally similar to the samples shock-loaded at <22.6 GPa at room temperature. However, in the samples shock-loaded at 22.6 GPa at 607 °C (Fig. 3) and the sample at 863 °C, plagioclases are totally converted into glassy phase in contrast to unpreheated samples shocked to 22.6 GPa in which some plagioclases remain crystalline. This suggests that the pressure of glass-crystal transition of plagioclase is lower when the ambient temperature is higher. The samples shock-loaded at >27.0 preheated at >607 °C are highly deformed and monomineralic melts of pyroxene and plagioclase were locally formed. In contrast to the samples shock-loaded at above 20-30 GPa at room temperatures, the samples shocked at high temperature tend to (plastically?) deform without the formation of abundant microfaults (or glass veins) by shock. Chemical analyses of the shocked samples are in progress.

Figure 1. Back-scattered electron image (BEI) of synthetic eucrite, shock-loaded at 11.4 GPa and room temperature, showing a brecciated texture. Plagioclase: dark gray; pyroxene: light gray; black: epoxy. Scale bar is 100 µm.

Figure 2. BEI of the eucrite shock-loaded at 84.0 GPa and room temperature. Ghosts of basalt clasts (middle-bottom) are composed of vesiculated monomineralic melt of plagioclase (dark gray) and pyroxene (light gray). Scale bar is 100 µm.

Figure 3. BEI of the eucrite shock-loaded at 22.6 GPa and preheated at 607 °C. It is deformed, but is unbrecciated. Scale bar is 50 µm.