EXPERIMENTAL SHOCK LITHIFICATION OF POROUS POWDER MIXTURE. N. Hirata¹, K. Kurita² and T. Sekine³, ¹Institute of Geoscience, the University of Tsukuba, Tsukuba, Ibaraki, Japan 305, e-mail: hiratana@arsia.geo.tsukuba.ac.jp, ²Department of Earth & Planetary Physics, the University of Tokyo, Hongo, Tokyo Japan 113, ³National Institute for Research in Inorganic Materials, Tsukuba, Ibaraki, Japan 305.

Embryos of planetesimals are considered to start as aggregates of micro-scale dust grains. Their physical state is characterized as highly porous, unconsolidated one. Sometime they are called as fluffy dust ball [1].

On the other hand, present meteorites and possibly asteroids are not dust balls but ‘rocks’ with sufficient cohesive strength. Several investigations were made on the mechanical strength and the porosity of chondrites [2-5]. Chondrites generally have porosities less than 10 %. Thus, their parent bodies should have experienced significant transformation from a porous, fragile grain mixture to a cohesive rock at the early stage.

Impact process has been considered as the driving force of lithification of primitive materials. Some L chondrites show a correlation between the shock grade and the porosity [6]. Shock lithification of planetesimals is one of the most important problem in their growth history.

We report the results of shock recovery experiments, which were carried out on porous powder media using a single-stage propellant gun. The experiments are designed to explore the shock lithification process.

Two types of the powdered sample (silicate-metal powder mixture, silicate powder) are chosen as starting materials for the simulation of the primitive planetesimals. They are; Type I sample, mixture of peridotite (70 %), Fe (27 %) and Ni (3 %), Type II sample, peridotite powder. These samples are charged in stainless steel container with porosity. The charging pressure was about 10 MPa, and the initial porosity was typically 30 - 35 %. The shock pressures range 2.5 - 22 GPa.

Figure 1 shows the shock pressures vs. the porosities of shocked type I samples. The pressure less than 5 GPa is enough for the promotion of shock lithification. The porosity of the shocked type I sample at 2.5 GPa is evidently reduced as compared with the initial value. The dominant mechanism of the porosity reduction is fragmentation of silicate grains and their rearrangement in this pressure region. Fine silicate grains formed by shock fragmentation seem to fill up effectively the pore spaces between large grains. Brittle silicate grains are easily to be shattered by shock compression. The fragmentation is most effective at 2.5 GPa. At P > 5 GPa, each grain is deformed and stick together. Porosity decreases with pressure at 4.1 - 12 GPa, and shock compaction is completed at 22 GPa.

Morphological analysis of metal grains in shocked samples shows that metal grains are quite sensitive to the magnitude of shock compression, so the degree of the deformation of metal grain is good indicator of the shock pressure. Figure 2 shows the average aspect ratios of metal grains in the shocked type I samples. Metal grains in the type I samples show plastic elongation along the plane perpendicular to the pressure axis of shock loading. The degree of deformation correlates with the shock pressure. At P > 15 GPa, the metal grains are highly deformed and have an apparent preferred orientation.

By comparison between type I and II samples, the role of metal phase in shock lithification can be estimated. The porosity reduction of the type II samples doesn’t differ from that of the type I samples. The deformation of metal grains doesn’t have much contribution to the porosity reduction. This can be explained by fact that volume fraction of the metal phase is not so large to sustain the entire deformation.

As well as the progress of porosity reduction, shocked samples gain the mechanical strength. Even the type I sample shocked at the lowest pressure 2.5 GPa is no more a simple powder mixture, it has cohesive strength. It cannot be easily broken by hand or finger crushing. Since intergranular shock melting is not obvious at these low pressures, the strength is probably gained by mechanical locking, electrostatic attraction and pressure welding.

The shocked type II samples also gain some strength, but their strengths are apparently lower than those of the type I samples. The large surface area of contacting grains enhances the cohesive strength. Deformed metal grains enlarge the contact area more than silicate grains, and the silicate-metal mixture samples probably gain strength effectively by shock. Metal phase plays as glue in shock lithification. The pressure lower than 5 GPa is enough for effective shock lithification, both compaction and cementation. This result is an experimental confirmation of the model proposed by [6].

Most chondrites are moderately shock-metamorphosed (S3, 10 - 20 GPa, [7-8]), but the shapes of metal
grains in chondrites are less deformed in comparison with their shock grade. The metal grains in porous materials shocked at the pressures corresponding to S3 should have highly elongated shape based on our experiments. This means that the lithification of porous chondritic materials must be completed at the early stage of their evolution by repeated actions of weak shock events. Efficient deformation of grain needs spaces in its surround. If pore spaces are extinct by lithification at very weak pressure, metal grains can preserve their original shape. The opportunities of weak shock events are common in the early stage of solar system evolution where the relative velocity is kept low in the thick, dense proto solar nebulae. This idea conforms to evolutionary history of the solar system.