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Experimental study of shock melting process at the time of planetary formation

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In recent studies on earth building processes, it is proposed that the separation of core and mantle occurred at the bottom of the deep magma ocean which exceeds a depth of 1000km (e.g. Wood & Halliday,2005). However, the presence of siderite and the stony-iron meteorite indicates that the separation of metallic core took place even in the asteroid-sized body. In order to understand the melting and the metal-silicate separation processes after collision of meteorites, we carried out two types of experiments; 1) shock melting, 2) melting at 1GPa by instantaneous heating with piston-cylinder apparatus at Titech. Shock melting experiments were carried by Nishio (2008, Master's thesis at Tokyo-tech) using a propellant gun at the NIMS. Mixtures of Fe(sponge) and peridotite(KLB-2) (with 50:50, 40:60, 30:70(wt%)) were used as the starting material to simulate chondrite-like source material of terrestrial planets.In shock experiments, although heating duration may be less than 1/100sec, Fe melt spherules grew up to 50 micrometer . We carried out more than 40 new experiments using non-endloaded piston-cylinder apparatus. In the piston-cylinder experiments, the grain size of the starting material was varied and the heating duration was varied between 10 sec and 1800 sec.

In the experiments with graphite capsules, we examined the distribution texture of Fe melt with starting materials with variable ratio of Fe and peridotite (Fe and peridotite mixing ratios are 60:40,50:50,40:60,30:70(wt%)). Two series of starting materials different in grain size (less than 75 micrometer and 75 to 150 micrometer) were also used. The starting material was enclosed in a graphite capsule. After the sample temperature was kept at 1300C for 10min, it was raised instantaneously (in less than 20 sec) to 1600C and kept there for 1min before quenhing. In the experiment using the stating material of small particle size, the degree of parital melting was relatively high and many small olivine crystals were formed. Fe metal sponge was connected in three dimensions and formed large grobules by instantaneous heating. As shown in Figure1, although retention time at 1600C is as short as 10 sec, maximum size of Fe melts is 1mm or larger in diameter. In the experiment using the starting material of large particle size (75-150 micrometer), large olivine crystals were remained unmelted and Fe melts are surrounded preferentially by olivine crystals. In other word, silicate melt tends to avoid Fe melts. Accordingly, texture of the run products is similar to that of pallasite.

Because graphite capsule reacts with Fe melts, MgO capsule was used instead of graphite capsule in experiments longer than 10 min. In the MgO capsule experiments, we used the coarse grained staring material (75˜150 micrometer) and heating time at 1600C was varied from1 to 30 minutes. Similar to experiments with graphite capsule with coarse grained starting materials, large olivine residues were remained in the experiments with MgO capsule. It is important to note that the pallasite-like texture of Fe melt and olivine residue (with silicate melt distributes preferentially between olivine crystals) was established in the first 1 min and unchanged for 30 min. Separation of silicate melt from olivine did not take place in the 30 min runs probably due to insufficient run duration. From this experimental result, it is thought that the pallasite meteorites which is the assembly of olivine and Fe melt is the trace of shock melting formed immediately after the impact of small asteroidal bodies during planet formation.