Research Interest by Eiji Ohtani

Eiji Ohtani's contributions can be summarized as follows.

1) *Melting behavior of Earth and planetary materials and properties of melts at high pressures and temperatures.*

One of the significant contributions of Eiji Ohtani is to investigate the melting behavior and properties of silicate melts at high pressure and temperature. Because of Ohtani's significant contributions to understanding the melting behavior of silicate melts, the VGP section of AGU honored him with the Norman L. Bowen Award in 2007. In early 1980s Ohtani pioneered melting experiments of silicates at pressures above 10 GPa, and conducted melting experiments of some minerals and rocks, such as fayalite, forsterite, and peridotite at high pressure exceeding 10 GPa. He proposed a model of formation and crystallization of deep magma ocean whose depth extended to the lower mantle on the basis of his experiments. Since then, the deep magma ocean hypothesis was repeatedly discussed by several authors. Ohtani estimated magma density based on melting curves of silicates and demonstrated possible existence of the crystal-magma density crossover at the base of the upper mantle and also at the core-mantle boundary. A possible existence of a dense magma at the core-mantle boundary (CMB) is extensively debated by many scientists at present.

Ohtani also conducted the density and viscosity measurements of silicate and metallic melts at high pressures above 5-20 GPa range which is the highest pressure ever conducted. Ohtani and co-workers determined the density of magmas and metallic melts at high pressure using the sink-float test, X-ray absorption, and X-ray radiography methods at high pressure. These experiments were conducted by using innovative unique methods using diamond as a density marker for the sink-float test and as a sample container for the X-ray absorption method. Ohtani et al. also determined the effect of volatiles such as H_2O and CO_2 on magma density. They clarified the change of partial molar volumes of H_2O and CO_2 up to pressures above 20 GPa and showed that H_2O is more compressible than CO_2 in magmas. Ohtani et al. also determined the viscosity of magmas and metallic melts at high pressure by using the in-situ X-ray viscometry. The highlight of this topic is the report of existence of the discontinuous change of magma density and viscosity minimum at around 4-5 GPa in basaltic magmas associated with their structural change.

2) *Global circulation of water and other volatiles in the earth's interior*

Ohtani and co-workers made contributions to understanding the role of water in the deep earth interior. They discovered new hydrous phases such as hydrous phase G (reported simultaneously as phase D by another research group) and hydrous phase δ-AlOOH. These phases can function as water carriers into the deep lower mantle. The discovery of these hydrous phases provides evidence for hydrogen transport by these phases in subducting slabs penetrating into the core-mantle boundary region. The recent exciting contribution on this topic is discovery of an important carrier of water to the base of the lower mantle, δ-AlOOH-$MgSiO(OH)_2$ solid solution coexisting with post-perovskite. Ohtani and Co-worker further studied the stability of $MgSiO(OH)_2$ phase H in the lower mantle

Ohtani et al. also clarified the solubility of hydrogen in nominally anhydrous minerals such as olivine, wadsleyite, ringwoodite, majorite, and perovskite, and the effect of water on the phase boundaries in the mantle transition zone. Using in situ X-ray diffraction study at high pressure, they demonstrated that water can shift the phase boundaries, and that the topography of the 410 km and 660 km discontinuities can be explained by the amount of water together with temperature. Ohtani and his coworkers clarified the hydrogen localities in the mantle transition zone and presented a model of the deep dehydration and formation of dense hydrous magmas at the base of the upper mantle. They recently clarified the hydrogen partitioning between dense high pressure hydrous silicates and nominally anhydrous minerals and clarified the strong partition of hydrogen into hydrous silicates resulting in dry nominally anhydrous minerals and dry rheology even under the wet conditions.

Ohtani and co-workers also clarified the role of hydrogen at the base of the lower mantle and they clarified fate of carbon in the slabs and reported formation of diamond at the base of the lower mantle.

3) *Mineralogy, geochemistry, and physical properties of the core and core-mantle boundary*

Ohtani's recent research focused on the constitution and formation of the core and the nature of the core-mantle boundary. He studied phase and melting relations of the iron-light elements (Si, O, and S) systems and metal-silicate partitioning at the conditions relevant to the central region of the Earth. He and his coworkers clarified the reaction between molten metallic iron and silicates at high pressure and showed that both oxygen and silicon can be dissolved into metallic iron at high pressure, indicating that these light elements are premium candidates of the light elements in the outer core. Ohtani and coworkers clarified the phase and melting relations of Fe-S, Fe-Si, and Fe-S-O systems to the outer core conditions. The recent outstanding results include the determination of the phase relations and melting curves of the Fe-Fe_3S and Fe-Si and Fe-Ni-Si systems up to the pressure of 180 GPa Based on these melting relations, they estimated the temperatures of ICB and CMB. They revealed that the temperature of the outer core is lower than that estimated previously. Ohtani et al. made experiments on reactions of metallic iron and water, and hydrous minerals, and discovered formation of iron hydride (FeH_x) at high pressure and temperature. These reactions are important for exploring hydrogen transport into the core.

Recent important research in this topic is to measure the physical properties of metallic iron alloys. Ohtani et al. measured the compressional velocity of hcp-iron and other iron-light element alloys by the inelastic X-ray scattering (IXS) method using DAC at high pressure. They measured the velocity of hcp-Fe up to 174 GPa the highest pressure by this method at room temperature. They also measured compressional velocity and density of several iron-light alloys such as hcp-$Fe_{0.83}Ni_{0.09}Si_{0.08}$alloy, Fe_3S, and Fe_xH at high pressure. They also made challenging measurements of compressional velocity of hcp-Fe to extreme conditions of 160 GPa and 3000 K using double sided laser heating DACs combined with IXS spectroscopy and to 327 GPa at ambient temperature.

4) *Phase transformation kinetics and discovery of high-pressure minerals in shocked meteorites*

Ohtani and co-workers made extensive studies on high pressure polymorphs of olivine and silica minerals in shocked meteorites by using intense synchrotron X-ray. Ohtani clarified the kinetics of formation of the high-pressure phases in the shocked meteorites such as L6 chondrite, Lunar and Martian meteorites because they contain records of phase transformations during the shock events. They reported coesite, stishovite, and seifertite in lunar meteorites, and the decomposition of olivine into feropericlase and perovskite in shocked Martian meteorites for the first time. Observations made by Ohtani and co-workers strongly indicate that the results of the static experiments are applicable for interpretation of the formation processes in shocked meteorites due to relatively long duration of shock events induced by the large-scale collisions and impact events on their parental asteroids, the Moon, and Mars. They discovered large diamond grains in ureilites, which suggest a large parent body of the ureilites. Ohtani and co-workers conducted shock experiments together with the impact simulation to reveal the deformation twin texture in iron meteorites.

Ohtani et al. made important contributions to clarify the phase transformation kinetics of mantle minerals based on in situ synchrotron X-ray observations and HRTEM techniques. They made several important observations such as metastable decomposition of ringwoodite into periclase and stishovite, and periclase and ilmenite which are observed in the beginning of the phase transformation. They applied the effect of kinetics to the dynamics of the cold subducting slabs.

5) Development of novel techniques for experimental in situ X-ray observation at high pressure

Ohtani has made several crucial developments on high-pressure experimentation using the multianvil apparatus, i.e. generation of very high temperature using $LaCrO_3$ as the heating material, introduction of a new guide-block system at both Australian National University (ANU) and Ehime University, the use of sintered diamond anvils for pressure generation by the multianvil high-pressure apparatus. These techniques which he developed provided significant contributions to develop and establish techniques for high pressure experimentation using the multianvil apparatus. Ohtani introduced a system made of a 1500 ton multanvil press system in Sobolev Institute of Geology and Mineralogy, Russian Academy of Science.

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*Numbers correspond to those in the publication list, and important papers are indicated as bold numbers.