Application of Synchrotron X-ray radiation to Earth Science

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Synchrotron X-ray radiation has been applied to various areas in Earth and Planetary Sciences. One of the major directions of application of synchrotron X-ray in Earth and planetary sciences is high pressure mineral physics. In situ X-ray observation at high pressure and high temperature has been extensively made to study solid and liquid phases of silicates and metals composing crust, mantle, and core of the Earth and planets. An important direction in high pressure mineral physics will be in situ X-ray observation for study the central part of the Earth. We have currently successfully generated 374 GPa and 700 K, which is the pressure exceeding the center of the Earth. One of the challenging targets in mineral physics is to conduct X-ray diffraction and spectroscopic studies under the conditions of the center of the Earth, i.e., 5000-6000 K at 365 GPa, which is one of the frontiers in Earth Sciences. Major target materials will be metallic iron alloys. Some volatile components such as H_2, H_2O, CH_3, and NH_4 are also important materials relevant to the internal structures of the objects in the outer solar system.

Studies of structures and physical properties of silicate liquid (magma) and metallic liquid (outer core) at high pressure are also challenging targets. Various techniques including X-ray radiography and tomography are essential to study the melt properties such as liquid miscibility, equation of state, viscosity, and interfacial energy of the liquids. Several technical developments have been currently conducted to expand the pressure range and resolution for determination of theses physical properties of liquids at high pressure and temperature. Studies on fracturing and rheological properties of geo-materials are also an important target, since these properties are the basis for understanding the dynamic behavior of the Earth such as seismicity and mantle convection which drives the plate tectonics. Development of imaging techniques such as X-ray radiography and tomography under the deformed and stressed conditions at high pressure and temperature is essential for this direction. The imaging and tomography are also applied in volcanology to study the properties of silicate magmas containing volatiles to monitor distribution of bubbles in magmas due to decompression and eruption and to study of the connectivity of the melt in their host rocks.

Microanalysis of trace element abundances in small areas of meteorites and rock samples and characterization by X-ray imaging and diffraction of micro-samples such as cosmic dusts are additionally important applications to Earth and Planetary Sciences. Silicate minerals, FeNi, and FeS have been detected in the tiny dust samples recovered from comets in the Stardust mission. Imaging and tomography is also used for observation of the micro-textures of the samples with geological interests. Internal textures of meteorites such as chondrules and some natural rocks samples have been successfully imaged without destruction of the samples.