Kinetic and rheological properties of Earth and planetary materials studied by time-resolved X-ray diffraction

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I will present three topics on kinetic and rheological properties of Earth and planetary materials examined by high-pressure time-resolved diffraction method using Kawai-type high-pressure apparatus MAX-III at BL14C2 of Photon Factory.

The First topic is the mineral plagioclase breakdown as an indicator for shock conditions of meteorites. Time-resolved X-ray diffraction measurements by energy dispersion method using white X-ray have revealed that amorphization pressures in plagioclase decrease with increasing temperature, and that the crystallization kinetics in the amorphous plagioclase is different among the high-pressure phases. Jadeite first crystallizes, and nucleation of the other phases is significantly delayed. These findings have important implications that the plagioclase breakdown can constrain the pressure-temperature-time history of shock events, and thus help to reconstruct the collisional history of asteroids in the early Solar System.

The second topic is the watching nucleation and growth of individual grains during phase transformation at high pressures based on time-resolved two-dimensional X-ray diffraction (2DXRD) measurements using high-energy monochromatic X-ray. The number of diffraction spots on two-dimensional detector that fulfill the Bragg condition is proportional to the grain density, and the intensity of each spot is proportional to the volume of the grain. We expect to observe nucleation and growth kinetics of individual grains from the evolution of numbers and intensities of diffraction spots as a function of time. Nucleation and growth kinetics during phase transformations are very important processes for mechanical properties of polycrystalline materials, and have important implications for Earth's mantle convection with high-pressure transformations. Preliminary results on kinetics of the coesite-stishovite transformation will be presented.

The third topic is the coupling of high-pressure transformation and plastic deformation examined by using the deformation cubic anvil guideblock (D-CAP 700) newly installed at the 14C2 beamline. High-pressure transformation often causes grain-size reduction, which leads rheological weakening. Deviatoric stress and plastic deformation also affects on the transformation mechanisms and kinetics. These coupling processes have important implications for the understanding of dynamics of subducting oceanic plates and origin of the deep earthquakes. We have carried out transformation experiments under deviatoric condition. Transformation kinetics and the stress-strain curves can be simultaneously observed by time-resolved 2DXRD measurements using high-energy monochromatic X-ray. 2DXRD patterns are used to estimate the transformed fraction and stress from lattice strain of the sample. Plastic strain of the sample was measured from the X-ray radiography images. Preliminary results on decomposition reaction of the mineral albite will be presented.