Ultrafast time-resolved XFEL diffraction study on shock-compressed corundum

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X-ray Free Electron Lasers (XFEL) allow us ultrafast observations due to its quite short X-ray exposure time of <10 fs (10^{-14} s) with extremely high peak brilliance of >10^{30} photons/sec·mm^2·$mrad^2$·0.1%b.w., which corresponds to 10^9-times higher compared to synchrotron radiation X-rays made by undulators in third-generation radiation facility such as SPring-8 in general. These extremely-intense and ultrashort-pulsed X-ray flash lamps made it possible to probe samples before the samples are damaged by external forces, conditions, and also XFEL itself.

In an XFEL facility SACLA, constructed at next to SPring-8, laser-driven shock-compression experiments are available with a high-power long-pulse laser system installed by Dr. N. Ozaki's group and the Photon Pioneers Center in Osaka university. Using the high-power laser system (Nd:YAG, 532 nm, Hamamatsu Photonics K.K.) with the maximum energy of 50 J and pulse width of <10 ns (10^{-8} s), now we are able to reproduce ultrahigh-pressure and ultrahigh-temperature conditions to 1000 GPa (1 TPa) and >10,000 K regime. Here we show a result of in situ observation of shock-compressed polycrystalline corundum utilizing the high-power ns-pulsed pump laser with fs-pulsed intense probe X-ray based on pump-probe techniques.

The pump-probe measurements were carried out varying delay times of XFEL-probe exposure after flashing pump laser to generate shock wave on the surface of targets, which were composed of polypropylene ablator and corundum sample. After series of the pump-probe measurements, pseudo time-resolved profiles were obtained as a function of elapsed time after shock wave arrival to the sample through the ablator. As a result of the pump-probe laser-shock experiments, elastic/plastic compression, uniaxial/quasi-hydrostatic compression, and dynamic recrystallization were observed during shock-wave propagation in the corundum sample with the passing time in the maximum time-resolution of 0.2 ns. In the presentation, we will show the experimental setups and features of XRD profiles of the shock-compressed material in detail.

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