Phase transitions from graphite to lonsdaleite and diamond

K. Katagiri[1], N. Ozaki[1], Takahiro Matsuoka[2], Takeshi Matsuoka[1], K. Miyanishi[1], Y. Seto[3], Y. Inubushi[4], T. Yabuuchi[4], T. Togashi[4], M. Yabashi[5], R. Kodama[1]

[1] Osaka University, Suita, Japan
[2] Gifu University, Gifu, Japan
[3] Kobe University, Kobe, Japan
[4] JASRI, Sayo, Japan
[5] RIKEN, Sayo, Japan

Graphite is the most stable form of carbon materials, and it transforms to diamond or lonsdaleite when it is under high pressure and high temperature. Natural diamonds are synthesized in deep inside of the earth where is hydrostatically pressured, but natural lonsdaleite (also called hexagonal diamond) crystals are only found in meteorite impact sites. Meteorite impacts make anisotropic high pressure for nanoseconds at the collisional surface and give an instant high distortion field in the materials due to their uniaxial compression. Therefore, graphite is likely to require hydrostatic pressure to form diamonds and instant and anisotropic pressure for the formation of lonsdaleite. Researchers are keen to synthesize those materials, because of their extremely high hardness, through methods such as chemical vapor deposition, using diamond anvil cells (stressing statically), or even by utilizing high-intensity lasers.

One approach reported by S. J. Turneaure and his colleagues is that Highly Oriented Pyrolytic Graphite (HOPG) would change its form to lonsdaleite at 50 GPa by shocking the material with a gas gun [Turnature *et al.*, *Sci. Adv*. (2017)]. Lonsdaleite did not form when another group laser shocked less oriented pyrolytic graphite to a similar pressure, instead resulting in diamonds [Kraus *et al.*, *Nat. Commun*. (2016)]. Those results suggest that orientation in graphite would affect the phase transition thresholds, but the detail of phase transition mechanism is still not clear.

We will present the recent study of phase transitions from HOPG to diamond and lonsdaleite. The experiment was carried out at EH5 of SACLA, where the drive laser and the X-ray Free Electron Laser (XFEL) were introduced together. We successfully observed nanosecond formation of lonsdaleite with pressure over 30 GPa, but it is impossible to tell if the formed lonsdaleite was accompanied with diamond because diamond has a very similar structure to lonsdaleite and they share some lattice constants. Therefore, we brought XFEL observation with transmission geometry as an addition to the reflection geometry. Our results indicate that the high compression speed is necessary for the formation of lonsdaleite because the rapid nucleation of high distortion field in graphite lattice would inhibit the corrective slides of graphite layers to form a cubic system which would most likely result in diamond formation.