Linking occurrence and texture of dense silicate minerals in shocked meteorites with laser-shock experimental results of Mg_2SiO_4 analyzed by XFEL probe

*Takuo Okuchi[1], Narangoo Purevjav[1], Norimasa Ozaki[2], Takeshi Matsuoka[2], Yusuke Seto[3], Yoshinori Tange[4], Toshinori Yabuuchi[5], Naotaka Tomioka[6], Toshimori Sekine[7], Ryosuke Kodama[2]

1. Institute for Planetary Materials, Okayama University, 2. Graduate School of Engineering, Osaka University, 3. Graduate School of Science, Kobe University, 4. Japan Synchrotron Radiation Research Institute, 5. RIKEN Harima Branch, 6. Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, 7. Center for High Pressure Science and Technology Advanced Research

Primitive meteorites often show features of shock metamorphism, including occurrences of dense polymorphs of major mineral phases. By previous transmission electron microscopy studies it was demonstrated that olivine (alpha-Mg_2SiO_4) often had transformed into its denser polymorphs such as ringwoodite (gamma-Mg_2SiO_4), and as a recently-discovered new structure (epsilon-Mg_2SiO_4: Tomioka and Okuchi, Sci. Rep. 2017). The impact events that produced these polymorphs played essential roles in the history of early solar system evolution. Here we tried to reproduce such a dynamic transformation process starting from forsterite olivine single crystals by using very strong laser beam and x-ray free electron laser (XFEL) beam in combination at SACLA, SPring-8, Japan. A transformation process has been successfully observed with sub-nanosecond resolution by x-ray diffraction using femtosecond XFEL pulses. We discovered an ultrafast transformation process completing only within few nanoseconds, which was not expected to occur during shock metamorphism of meteorites. It can be a shear-induced fast lattice slipping proceeding without any atomic diffusion process. We conclude that formation processes and environments of some of dense Mg_2SiO_4 polymorphs in heavily shocked meteorites are needed to be reconsidered to involve this fast process.

Keywords: dense silicate minerals, laser shock experiments, shock metamorphism, Mg2SiO4

