DYNAMIC DEFORMATION OF OLIVINE IN A DIAMOND ANVIL CELL: A NEW EXPERIMENTAL APPROACH TO REPRODUCE SHOCK DEFECTS

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Introduction: Samples returned by the Hayabusa spacecraft from near-Earth asteroid 25143 Itokawa are space-weathered by the solar wind and micrometeoroid impacts [1, 2]. Traces of micrometeoroid impact are sub-micrometer-sized impact craters and subsurface shock effects in major meteoritic minerals such as olivine [3, 4]. The shock effects in olivine are surface melting, formation of nanoparticulate iron ($npFe^0$), production of lattice defects (planar fractures, dislocations), and recrystallization. These effects are commonly reproduced in laser experiments [5]. We present here an alternative approach to simulate the formation of lattice defects by dynamic diamond anvil cell experiments.

Experiment and Material: A dynamic non-hydrostatic deformation experiment was conducted at room temperature in a membrane-driven diamond anvil cell (mDAC). The Re gasket hole was loaded with olivine from the Jepara pallasite and Au flakes for internal pressure calibration. In order to generate non-hydrostatic conditions the experiment was run without pressure medium. In-situ high-pressure X-ray powder diffraction patterns were taken with an exposure time of 2 seconds during compression and decompression at the Extreme Conditions Beamline (ECB) P02.2 at PETRA III, DESY, Hamburg, Germany [6]. The olivine sample was compressed to 45 GPa at a rate of 12 GPa per minute.

Results and discussion: X-ray powder diffraction patterns are consistent with the olivine structure up to the highest pressure of 45 GPa. Due to non-hydrostaticity and/or grain size reduction the X-ray diffraction lines become broadened and textured with increasing pressure. Neither wadsleyite nor ringwoodite, the high-pressure polymorphs of olivine, were detected in the experiment. Further transmission electron microscopic (TEM) observations are under way to reveal the defect microstructure such as dislocations and planar fractures.

Although strain rates in our DAC experiments are still several orders of magnitude smaller than those in natural impact events and shock experiments, the dynamic compression is fast enough too suppress phase transformations to high-pressure polymorphs. This is in line with previous dynamic DAC experiments which resulted in a known shock effect, i.e. amorphization of quartz [7]. The texturing of X-ray diffraction patterns indicates activation of dislocation glide in olivine. Further experiments are in progress to explore the limitations of the new experimental approach.

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