DYNAMIC DIAMOND ANVIL CELL EXPERIMENTS ON OLIVINE: A NOVEL APPROACH TO SIMULATE SHOCK-METAMORPHIC EFFECTS.

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Introduction: Olivine is one of the most abundant minerals in most meteorite classes and its shock-metamorphic effects are widely used as important pressure indicators in the shock classification of ordinary chondrites [1]. The shock-metamorphic effects in olivine are mosaicism, planar fracturing, dislocation glide, recrystallization, and formation of high-pressure polymorphs (wadsleyite, ringwoodite). Except the formation of high-pressure polymorphs requiring melting and crystallization at eventually longer pressure pulses, these effects have been reproduced in high-explosive and laser shock experiments [2, 3]. We present here an alternative approach to simulate the formation of shock-metamorphic effects in olivine by synchroton-based dynamic diamond anvil cell experiments.

Experiment and Material: A dynamic non-hydrostatic deformation experiment was carried out at room temperature in a membrane-driven diamond anvil cell (mDAC). The Re gasket hole was loaded with powdered olivine from the Jepara pallasite. Au flakes were added 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 [4]. The olivine sample was compressed to 45 GPa at a rate of 12 GPa per minute.

X-ray diffraction, SEM and TEM results: Synchroton X-ray powder diffraction patterns are consistent with the olivine structure up to the highest pressure of 45 GPa. X-ray diffraction lines are progressively broadened and textured with increasing pressure, probably due to the non-hydrostatic nature of the experiment, grain size reduction, and defect development. Neither wadsleyite nor ringwoodite, the high-pressure polymorphs of olivine, were detected in the synchroton X-ray diffraction experiment.

Scanning electron microscopic (SEM) observations reveal the complete compaction of the olivine powder. To obtain information on the defect microstructure we prepared a thin foil by focused ion beam (FIB) milling. Inspection of the FIB foil by transmission electron microscopy (TEM) showed that olivine grains are very defect-rich, containing planar fractures, dislocations and sometimes fine-grained recrystallized rims.

Discussion: Although the loading in our DAC experiments is distinctly longer than in natural impact events and shock experiments, dynamic DAC compression under non-hydrostatic conditions produces a defect microstructure in olivine that is very similar to that observed in naturally shocked olivine [5]. The absence of high-pressure polymorphs indicates furthermore that the compression is fast enough to suppress the equilibrium phase transformations. This behavior is consistent with observations on meteorites, which contain wadsleyite and ringwoodite only in special melt zones, i.e. shock veins and pockets. The successful reproduction of shock-metamorphic effects in olivine line is in line with previous dynamic DAC experiments on quartz, which resulted in another known shock effect, i.e. amorphization [6]. The main strength of the new synchroton-based experimental approach is the capability to capture the processes occurring during loading and unloading in real time. Further experiments are in progress to explore the limitations of the new experimental approach.

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