DYNAMICAL COMPRESSION OF SERPENTINE IN MEMBRANE-DRIVEN DIAMOND ANVIL CELLS: INSIGHTS INTO AMORPHIZATION BY SYNCHROTRON XRD.

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Introduction: Minerals of the serpentine-subgroup are important water-bearing phyllosilicates in primitive meteorites, and hydrous interplanetary dust particles (IDPs). They form through the reaction of ferromagnesian silicates with aqueous fluids at low to moderate temperatures. Samples to be returned by Hayabusa2 and OSIRIS-REx from the C-group near-Earth asteroids 162173 Ryugu and 101955 Bennu will shed light on the behavior of these minerals during space weathering due to solar radiation and meteoroid impacts. This understanding is crucial for assessing the spectroscopic properties of asteroid regoliths with remote techniques. The physical state of dust within planetary debris disks around stars other than the Sun provides additional, important insights into planetary evolution. Its understanding relies on computational simulations, which require reliable material models.

Because serpentine minerals can be altered by a variety of physicochemical processes, such as thermal metamorphism, particle irradiation, and impact-generated shock loading, it is important to understand how their structural and spectroscopic properties change in response. Here, we focus on the pressure-induced changes by applying rapid compression in membrane-driven diamond anvil cells (mDACs) to tens of GPa within <150 sec (e.g., [1-4]).

Methods: Starting material was natural serpentine of the composition $(Mg_{2.70},Fe_{0.16},Al_{0.12})(Si_{1.89},Al_{0.12})O_5(OH)_4$, collected from the Totalp serpentinite (Davos, Switzerland). It was gently powdered in ethanol and dynamically compressed under non-hydrostatic conditions in mDACs at beamline P02.2 of PETRAIII at DESY Hamburg. During compression XRD patterns were recorded at 25.6 keV using a Perkin-Elmer XRD 1621 fast flat panel detector. Powdered gold served as an internal pressure standard. The starting materials and recovered samples were analyzed using a Witec alpha300M+ Raman microspectrometer equipped wih a 532 nm laser operated at <10 to 40 mW.

Results: The Raman spectrum of the starting material shows OH stretching vibrations at 3589, 3682, and 3705 cm^{-1} as expected for lizardite and/or polygonal serpentine [5]. Synchrotron XRD patterns acquired during rapid compression in the mDACs show that changes in structure and/or grain size occur at pressures as low as 4 GPa at a compression rate of ~0.1 GPa/s (Fig. 1). Complete amorphization is attained at about 25 to 30 GPa at a compression rate of ~0.3 GPa/s. After recovery of the gasket, the amorphized samples do not show discernable Raman bands but display continuous scattering spectra with intensity maxima between 1000 and 3000 cm^{-1}.

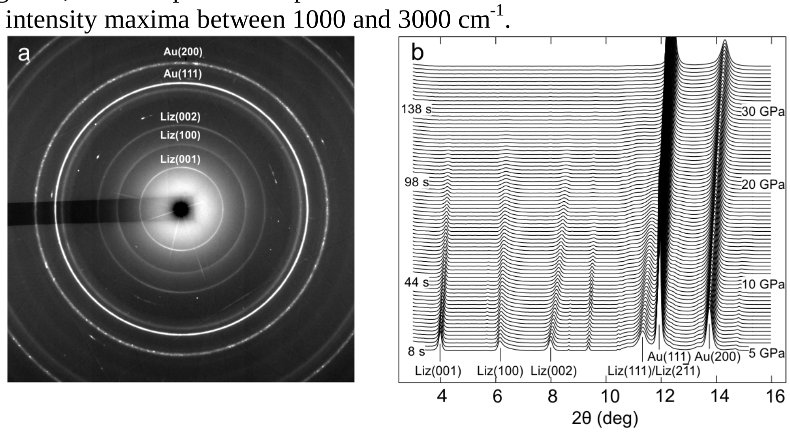

Fig. 1: (a) Single synchrotron XRD pattern of lizardite/polygonal serpentine in the mDAC. (b) Shift of Bragg peaks and eventual loss of diffraction intensity during compression of lizardite/polygonal serpentine in the mDAC.

The results are somewhat in contrast to shock experiments using gun-driven shock wave generators [6], from which it was inferred that shock does not produce significant structural damage in serpentines at pressures below 32 GPa. However, lizardite samples subjected to peak pressures of 16.1 GPa and 26.3 GPa by the gun method showed evidence for partial, heterogeneous amorphization, suggesting that mDAC experiments with small, homogeneously compressed sample volumes are well-capable of monitoring the amorphization process despite of the difference in compression rates. Further characterization of the structural states by TEM is ongoing and additional synchrotron mDAC+XRD experiments and structural and spectroscopic studies of partially amorphized samples will be conducted, including Fe-rich cronstedtite as a starting material.

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