A Coordinated Shock Recovery and TEM study: The Effects of Impact Pressures on Melt and npFe Production and Migration Behavior in Porous Materials. Aleksandra Stojic[1], Andreas Morlok[1], Juulia Moreau[2], Tomas Kohout[2], Iris Weber[1], Harald Hiesinger[1], [1]Institut für Planetologie, Wilhelm-Klemm Strasse 10, 48149, Germany, [2]University of Helsinki, Department of Physics, D331 Helsingin Yliopisto, Finland.

Introduction:

BepiColombo is a joint mission by ESA/JAXA scheduled for launch to Mercury in 10/2018. Onboard is a mid-infrared spectrometer (MERTIS-Mercury Radiometer and Thermal Infrared Spectrometer), which will map spectral features in the 7-14 µm range, with a spatial resolution of about 500 meters [1-4].The IRIS (Infrared and Raman for Interplanetary Spectroscopy) laboratory at the Institut für Planetologie in Münster generates spectra for a database that will serve as a reference for the data, which will be obtained by MERTIS once it reaches its orbit around Mercury. These spectra will allow to determine the mineralogical composition of the planetary surface of Mercury via remote sensing. Mercury's surface experienced impact cratering at different scales (macro to micro impactors over an extended period of time). The tenuous exosphere and Mercury's magnetic field allow solar wind particles and micro impactors to reach its surface and hence, alter its mineralogical composition in a significant way over a given period of time. Most of these processes are referred to as 'space weathering' (for an extended review, see [5] and references therein). In order to investigate the effects of these processes in the MERTIS relevant mid-infrared range on a given mineralogical composition, terrestrial analog material is altered under laboratory conditions. Shock recovery, laser, and ion irradiation experiments have been used in combination with synthetic and natural analog material in the past to simulate the altering effects of (micro)meteorite and ion bombardment on atmosphere - free bodies. Yet, detailed TEM data from these experiments remain scarce. In a previous experiment, we used a pulsed IR laser to produce distinct melt layers on grain boundaries, which appear similar to agglutinate glasses containing npFe known from the lunar surface. The production of npFe in the melt layers affects the corresponding infrared spectra of these samples (Fig. 1) [6]. Melt layers and npFe production were investigated in the TEM. Here we report on a suite of classic shock recovery experiments, using the same analog material to investigate whether impact melt that is created during moderate shock conditions in porous material (estimated porosity ~ 65%) will develop similar melt layers along grain boundaries as have been observed on material exposed to laser irradiation. TEM results from this experiment are compared to the laser irradiated samples (batch of sample material is identical) to see whether changes at nanoscale are comparable; at least where melt production – important for the formation of agglutinate glasses – is concerned. The question we try to address is: Are processes simulated by laser irradiation, e.g., melt formation with simultaneous production of npFe on grain boundaries by heat dissipation, and impact melt (sensu strictu) produced by shock recovery experiments comparable in terms of their production in npFe particles?

Samples and Techniques:

Sample Production: San Carlos olivine (Fo_{93}) and Bamble pyroxene (En_{87}) crystals were ground into powder. Both obtained powders were not sieved and are comprised of individual grains < 250 µm. The sample container set-up for the shock recovery experiment as described in [7] was slightly modified to match the requirements of porous samples. In order to avoid contamination by the surrounding iron from the steel container, the powder was wrapped in aluminum foil (Fig. 2). Experimental conditions are calculated with a shock wave front of ~30 GPa in the steel container, which will result in a range of peak pressures within the target material. The pressure experiments will be conducted at the Fraunhofer Institut für Kurzzeitdynamik, EMI, in Kandern.

TEM: Focused ion beam cut TEM samples will be prepared from selected grains of the altered sample material. Different stages of alteration (different degrees of melt production stages) will be sampled for TEM from both minerals, olivine and pyroxene. Analytical TEM investigation will be performed on a FEI Tecnai™ F20X-Twin at the Deutsches GeoForschungszentrum in Potsdam.

Discussion: Conditions prevailing on atmosphere - free planetary bodies are difficult to simulate in a terrestrial laboratory. Laser experiments have been conducted to simulate the effect of vapor - recombination processes that result in the formation of vapor derived npFe as a top layer on 'space weathered' planetary surfaces [e.g., 8]. Additionally, heat dissipation in these experiments causes the formation of underlying melt layers that can be associated with the production of agglutinate glasses. NpFe is observed in these melt layers, too. Weak effects on the corresponding infrared spectra of altered material were observed by [6]. Although classic shock deformation features in sample grains cannot be reproduced with a pulsed IR laser, melt production and hence iron partition behavior between crystal and melt, should be comparable to real impact processes that cause incipient melting when pore space is crushed in a planetary regolith during (micro)impacts. Although the resulting peak pressure within the powder cannot be calculated accurately, due to the porosity of the sample, the resulting range of pressures generated is going to comprise incipient grain boundary melting and sample portions that will melt completely during impact. Comparing the TEM images of the resulting melt stages from shock recovery experiments from this experiment with TEM images of melt from laser-irradiated samples from previous experiments will probably answer the question whether laser induced melting in irradiation experiments can be compared to impact melts from shock recovery experiments. Because shock recovery experiments are time consuming and expensive, our results at nanoscale can help to clarify whether agglutinate formation can be simulated accurately by using a laser irradiation set up.

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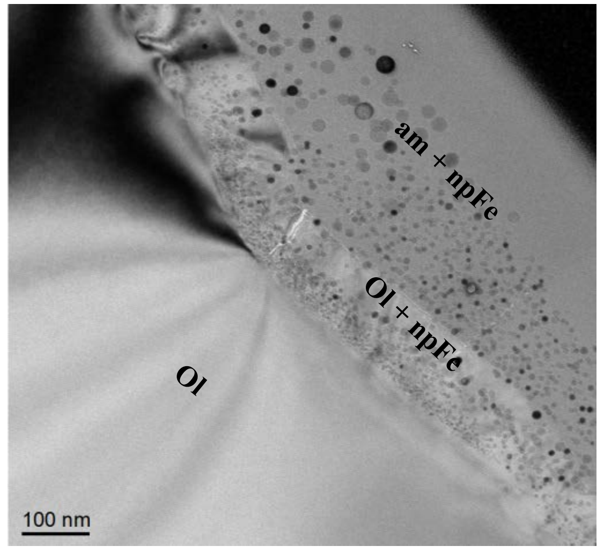

Figure 1: Cross section through a laser irradiated olivine grain (TEM bright field image). Dark 'spots' are metallic npFe. Ol = unirradiated olivine crystal, Ol + npFe = olivine coexists with npFe, and am+npFe = npFe embedded in amorphous groundmass.

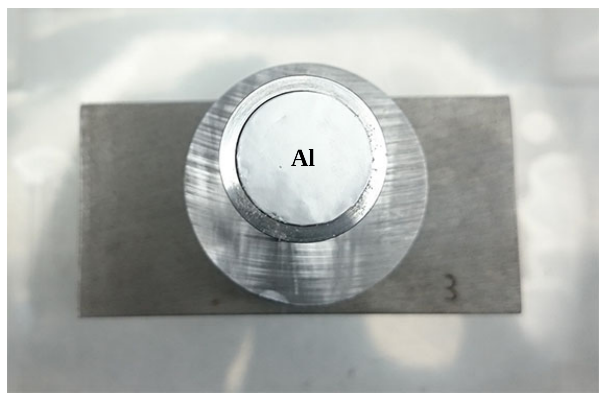

Figure 2: Aluminum foil (Al) containing sample powder embedded in ARMCO Fe container.