EPSC Abstracts
Vol. 13, EPSC-DPS2019-521-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

A shock recovery experiment: Tracing Spectral Fingerprints of Impact Melt, npFe and Element Migration in Shocked Porous Materials.

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Abstract

Here we present Micro FTIR data from ongoing work on shocked olivine (San Carlos) and pyroxene (Bamble) powders that will complement the mid-infrared database for the next ESA/JAXA mission BepiColombo to Mercury [1,2]. Apart from "classic" mineral mixtures that will comprise the database, also Mercury's specific surface conditions and their various effects on the exposed planetary regolith have to be taken into account. This is important, when it comes to the qualitative and quantitative interpretation of spectral information that we will obtain from the MERTIS instrument once BepiColombo reaches the Hermean orbit.

1. Introduction

Mercury lacks a shielding atmosphere and its peculiar magnetic field allows for cosmic radiation, solar wind and (micro-) meteorite impactors to hit the planetary surface to full extent in vast areas. These processes are commonly known as space weathering (SW) [3], which is a considerable factor, altering unshielded planetary regolith significantly. Not only in terms of structural decay of the regolith comprising minerals, melt production, solar wind implantation and the numerous intermediate states, but also in terms of their spectral signature that such a "re-worked" surface will give us. Considering the long exposure times, these changes (extreme discrepancy of day – and night time temperatures, proton implantation, impactors, etc.) can probably obscure characteristic mineral spectra as we know them under terrestrial conditions to the point of no recognition. In order to interpret the awaited MERTIS data correctly and quantitatively, our intention is to incorporate "Mercury-adjusted" analog material in our MERTIS database. We therefore conducted classic shock recovery experiments to account for impact events that cause interstitial melt or complete melting of regolith grains.

1.1 Shock experiment, samples and treatment

We ground San Carlos olivine and Bamble pyroxene crystals in an agate mortar to obtain a powder containing all size fractions up to 260 µm. The powder samples were set into an ARMCO Fe – cylinder following the procedure given by [4] Explosives then accelerated a flyer plate towards the Fe-cylinder with the inset powder. Hugoniot calculations for this particular set-up generate pressures of up to 33 GPa, enough to melt our porous sample entirely [5]. We estimated the sample porosity by taking into account mineral density, weight and space of the sample chamber to ~ 35%. Cavities between powder crystal surface and Fe-cylinder surface prevented the loss-free transfer of the plane shock wave onto the target material and sample peak pressures remained much lower than 30 GPa. We opened the cylinder with a handsaw and abstained from coating the obtained slice with carbon due to pending Raman measurements. We also produced thin sections to identify melt production, interstitial melt and specific shock stages of the olivine and pyroxene crystals.

2. Preliminary mid-infrared data of "bulk" sample areas

We characterized both samples with a SEM and obtained BSE overview images (inset in MIR spectra) of the cut open cylinder - sample slices and used a Bruker Hyperion 1000/2000 System for Micro FTIR measurements, subsequently. Spectra were generated in the range between 2 and 15 µm. We used a 512 × 512 µm sized aperture and integrated 256 scans to obtain a better signal to noise ratio. The spectra are

not smoothed. The noisy appearance of olivine probably can be explained by a higher porosity, when compared to the pyroxene sample (Figs. 1 a, b).

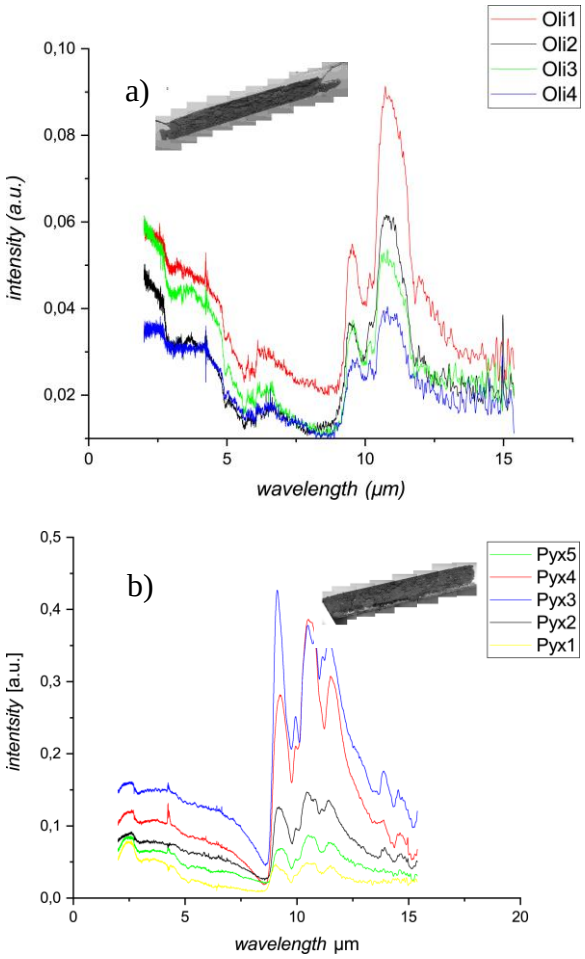

Fig. 1 a): The Christiansen Feature (CF) is located at 8.8 µm and Restrahlenbands (RBs) are characteristic for Fe-poor olivine at 9.5 µm, 10.2 µm and 10.7 µm. Stitched BSE image inset. **1 b)** The CF is located at 8.6 µm and RBs are characteristic for Fe-poor pyroxene at 9.2 µm, 9.9 µm, 10.5 µm and 11.5 µm a shoulder at 11.1 µm is missing in Pyx 1, 4 and 5. Stitched BSE image inset.

3. Summary and Outlook

We observed melt pockets and thin melt veins in olivine, whereas the pyroxene sample shows only few interstitial melts that yet lack confirmation by higher resolution analytical tools. Both mineral types show irregular fractures and fragmentation. Deduced from the olivine sample, heat excursions are not uniform within the sample and "nests" of melt cumulate at statistically distributed areas close to the upper 100 µm of the sample cross-section (Fig. 2). Although shock signs are more prominent within the olivine sample (e.g., melt production, fragmented grains, etc.) the corresponding MIR spectrum (Fig. 1a) remains hardly altered. We observe spectral irregularities in the pyroxene sample (Fig. 1b) where one shoulder at 11.1 µm is missing in 3 out of 5 spectra. Although the sample shows hardly any melt production, grains are irregularly fractured, which probably results in a subdued RB at 11.1 µm. Dedicated smaller areas in both samples will be scanned with a higher resolution Micro FTIR to hopefully discern effects of melt production, and/or shock stress within the respective minerals.

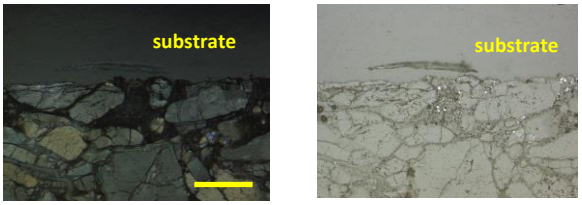

Fig. 2: Petrographic images of olivine (interference colors subdued due to non-typical thickness of sample) left: crossed polarizers, right: parallel polarizers. Scale bar is 100 µm. Melt pocket located in image center.

Acknowledgements

This study is embedded in the framework of the BepiColombo DLR grant FKZ QW 1701. We thank Prof. Alexander Deutsch and Dr. Kai Wünnemann for useful advice during the experimental set-up of this work, Ulla Heitmann for careful handling and preparation of the samples and Michael Feldhaus for resourceful solutions for non-trivial challenges.

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