

Impact into a graphite-bearing regolith: A dynamic shock recovery study. A. N. Stojic¹, J. - G. Moreau², T. Kohout³, A. Morlok¹, A. Joeleht², A. Penttilä⁴, H. Hiesinger¹, K. E. Bauch¹, J. H. Pasckert¹, M. P. Reitze¹, N. Schmedemann¹, I. Weber¹, and J. Helbert⁵ ¹Westfälische Wilhelms Universität Münster, Institut für Planetologie, Geologische Planetologie, Münster, Germany (a.stojic@uni-muenster.de), ²Department of Geology, University of Tartu, Tartu, Estonia. ³Department of Geosciences and Geography, University of Helsinki, Finland, ⁴Department of Physics, University of Helsinki, Finland, ⁵Institut für Planetenforschung, Deutsches Luft – und Raumfahrtzentrum (DLR), Berlin, Germany

Introduction: Mercury's surface is exposed to a multitude of surface altering effects that have a significant influence on its optical properties. Impact events – small or large – are one of the major surface-altering agents. Inferred from hypothetical modal abundances [1] graphite can comprise up to 4 wt% on Mercury's surface. Graphite as a possible stable phase on Mercury can explain the relatively low albedo of the planet [2]. Our experimental setup probes the hypothetical impact into a graphite- and olivine-bearing, pyroxene-rich (Px (En87) = 68 wt%; Ol (Fo91) = 29 wt%, C = 3 wt%) surface. The effect of post-shock heating and pressure on a powder comprised of silicates with grain sizes $\leq 125 \mu\text{m}$ and hexagonal graphite was simulated in a classic shock recovery experiment [3].

The experiments were performed in the framework of the BepiColombo mission to Mercury. The onboard Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) will send thermal emissivity data once it reaches the Hermean orbit in 2025. A spectral database for mid infrared data is currently set up at the Institut für Planetologie in Münster. Published mid infrared data will soon be available and sample related spectral information of interest can be traced via assigned IDs (e.g., IDxxx).

Experimental set-up and micro-FTIR: One aliquot of the prepared powder mixture served as a blank (ID 467) and was not shocked, the second (ID 464) aliquot was filled into an ARMCO-Fe - container. The cavity ($\phi = 16 \text{ mm}$; depth = 2 mm) that held the powder was lined with tantalum foil (thickness = 50 μm) in order to avoid Fe⁰-metal contamination from the container. Graphite foil particles vary in size (mean = 500 μm). The foil was cut with a razor to avoid smearing. The calculated peak pressure at the steel/sample interface reached ca. 60 GPa. Pore space was crushed upon impact and contributed to increase the post-shock temperature significantly [4]. Preliminary spectral results were obtained with a Bruker Hyperion 3000. The spectra were measured in reflectance between 3950–700 cm^{-1} . Reflectivity was calculated by measuring a gold standard equaling the sample's surface roughness. We used a 100×100 μm^2 knife edge aperture to limit obtained spectral data from defined regions of

interest (ROIs) and integrated over 256 scans to improve the signal/noise ratio.

Preliminary spectral results were obtained from both aliquots, ID 467 (blank) and ID 464 (shocked). ID 464 material was extracted from the steel container, from which spectral information were obtained (Fig.1 bottom) and are compared to spectral data of the unshocked aliquot (Fig.1 top).

Results and discussion: ID 464 compacted entirely during impact (Fig. 2). Thermal infrared measurements (Fig. 1 top and bottom) show a clearly distinguishable Christiansen feature (CF; a material characteristic reflectance minimum) at 1187 cm^{-1} (similar to CF (En87) = 1193 cm^{-1}). The CF of ID 467 (blank) is difficult to determine. The shallowing of the OH-related absorption band [5] at 3677 cm^{-1} steepens the slope towards shorter wavenumbers.

Glassy material was identified in many areas. However, crystalline pyroxene surviving the impact is easily distinguished in the electromagnetic range between 1187 – 700 cm^{-1} , where vibrational normal-modes or Reststrahlenbands (RBs) of silicates typically occur.

RB1 of the shocked ID 464 (see Fig. 1 bottom) has a shoulder at 1131 cm^{-1} , a double peak at 1103 cm^{-1} and 1074 cm^{-1} , and another shoulder at 1043 cm^{-1} . RBs of both silicate starting materials occur in this range (En87 at 1131 cm^{-1} , 1107 cm^{-1} , and 1056 cm^{-1} , and Fo91 at 1063 cm^{-1} and 1056 cm^{-1}). The envelope of the RB1 region is identical in ID 464 and 467, however, a shoulder peak at 1043 cm^{-1} missing in the unshocked, appears in the shocked aliquot and broadens the base of RB1. Pure En87 has a remarkably invariant (energy-wise) RB at 1010 cm^{-1} (ID 467) that shifted to 1006 cm^{-1} in the shocked ID 464. RB3 of the Mg-pyroxene typical “triplet-RBs” (RB3, RB4, RB5 in Fig. 1 top) at 979 cm^{-1} is similarly invariant, however, olivine has a stable RB nearby, at 981 cm^{-1} [6]. This band is shifted to a weak shoulder at 973 cm^{-1} , either indicating the absence of olivine due to melt formation, or a shock related shift of the En87-associated RB3. Augmenting chemical analyses will help to disambiguate this. Silicate material in direct contact with graphite displays a foam like texture (Figs. 2 and 3). Graphite is an excellent thermal

conductor. Silicates and graphite have a large density gradient, when shock waves traverse the individual phases, graphite-grains experience significantly higher post-shock temperatures, and thus help in melting the cooler silicate fraction [7]. A graphite-bearing regolith surface that experiences continuous bombardment of impactors at different velocities can shift the glass production efficiency in favor of the vitreous phase. ID 464 shows dark shock-related “pumice” that pressed toward the outer cylinder margins, and has large, entrained cavities. Future chemical and micro-FTIR analyses of the entire ID 464 will improve our understanding of how graphite though chemically inert “catalyzes” processes that either not/or only insufficiently take place in its absence.

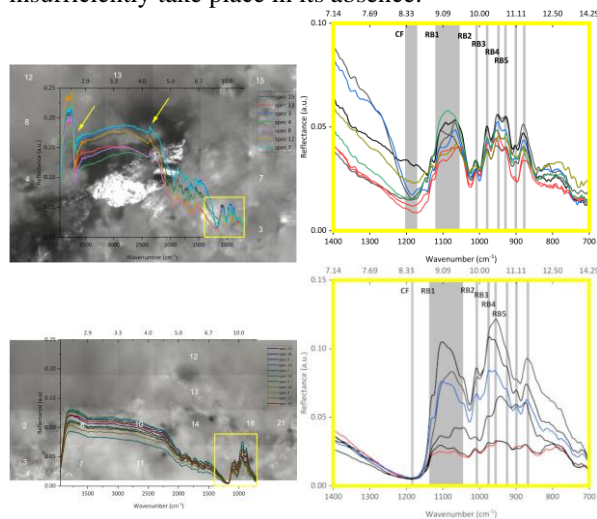


Figure 1: ID 467 (blank) spectra (top). Graphite (bright material) embedded in light grey silicate matrix. Areas with indices in micrograph correlate with spectra of same numbering. Yellow highlighted rectangles are magnified for clarity, RBs are labelled and discussed in text. ID 464 (shocked) spectra are plotted below. Pyroxene is the dominant in both aliquots. The CF is located at 1187 cm^{-1} in ID 464. Both aliquots show comparable reflectance intensities. Yellow arrows denote OH-related adsorption in ID 467.

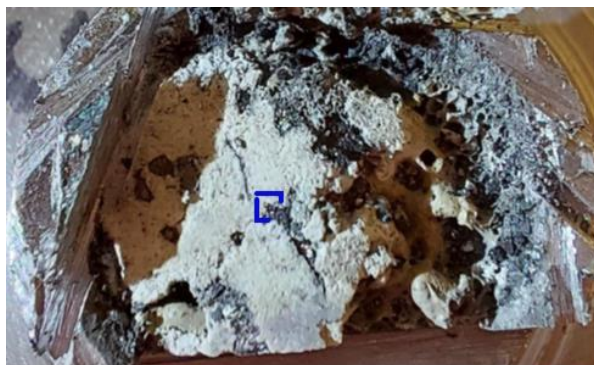


Figure 2: ID 464 compacted entirely after impact. Sample is inset in steel cylinder, darkish protruding mass (arrow) is “pumice”, brighter sample parts dominantly amorphous

silicate portion with dark entrained graphite. Blue square denotes roughly the magnified transition area in Fig. 3. Field of view approximately 3 cm.

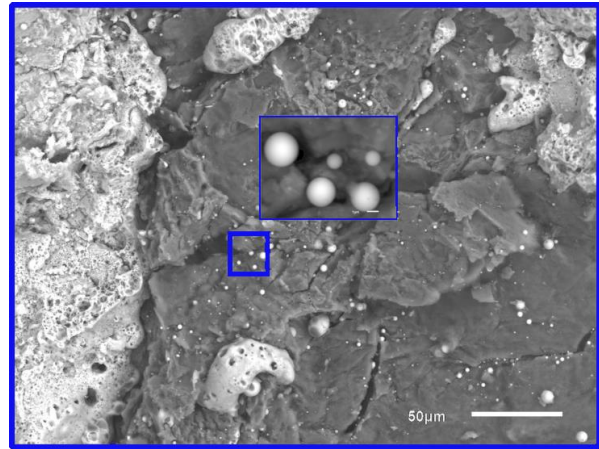


Figure 3: Interface between silicate matrix (bright) and graphite (dark). Bright beads on graphite (inset: higher magnification image) are pure SiO_2 beads. Fe-Mg - silicate portion around graphite is porous with many entrained cavities of varying size ($\geq 1\text{ nm}$).

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