

MID-INFRARED INVESTIGATIONS OF LASER PRODUCED IMPACT MELT ANALOGS OF BASALT.

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Introduction: The Infrared and Raman for Interplanetary Spectroscopy (IRIS) laboratory at the Institut für Planetologie in Münster produces, among others, spectra for a database for the mid-infrared spectrometer MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer) onboard of the ESA/JAXA BepiColombo mission to Mercury. MERTIS will map spectral features of the surface in the 7-14 μm range, with an average spatial resolution of ~ 500 m [1,2]. Thus, the mineralogical composition of the planetary surface can be determined via remote sensing. Mercury has been exposed to heavy impact cratering [3,4]. Therefore, impact products like glass are an important component of its surface. Impact products like glass make up possibly up to 45% of the surface regolith of Mercury [5]. Hence, we are studying a series of shocked, i.e., basaltic material in the mid-infrared, in order to interpret future MERTIS measurements [6-8]. Here we present results of a study [9] in which thermal effects of shock metamorphism due to high velocity impacts on basalt were simulated using laser irradiation (Fig.1).

Samples and Techniques: Hoffelder basalt (Hoffelder, Germany) was used as starting material, a basaltic, porphyritic rock consisting of 200–800 μm size olivine phenocrysts set in an aphanitic groundmass (≤ 100 μm grain size) of mainly labradorite, Fe, Ti oxides (ulvöspinel \pm rare ilmenite), and feldspatoids [9].

In this work, the impact melting of basaltic materials was simulated by using a pulsed Nd:YAG laser at Technische Universität Berlin and a continuous-wave (CW) infrared fiber laser at Fraunhofer Ernst-Mach-Institut, Freiburg [9] (Fig.1). Basalt samples were irradiated along 15 mm long and 1 mm wide lines. To optimize the melt production the laser settings were: 0.9 kW for emitted power over 15 s at a wavelength of 1064 nm, a pulse frequency of 25 Hz, and a pulse duration of 2.5 ms for the pulsed setup, and 8 kW, 1064 nm, and 6 s total irradiation time for the CW setting. Afterwards, the sample runs were collected, embedded in resin, sectioned and polished, and analyzed using a JEOL JXA-8530F Hyperprobe electron probe microanalyser (EPMA). For IR analyses, we used a Perkin-Elmer Spotlight400 FTIR spectrometer at the University of Manchester. Spot analyses (25×25 μm) were made in the wavelength range from 2.5–15.4 μm in the reflectance mode, using a cooled mercury-cadmium

telluride (MCT) detector. For mapping, an adjoining micro spectroscopy mapping unit was used [10] (Fig.2).

Results: The chemistry of the glass from the pits or craters on the basalt block and a melt glass droplet is increasingly fractionated depending on the volatility of the components (Fig.3) [11,12].

The micro-FTIR spectrum of the bulk melt from the pit (Fig.2,4) has a dominating RB at 10.3 μm and a CF at 8.4 μm . An outlier spot (C5; Fig.2) has the CF at 8.5 μm and the RB at 10.5 μm . The powdered bulk glass fraction of the melt glass droplet (Fig.4; cf. Fig.1) has a CF at 8.9 μm and a strong RB at 10.3–10.5 μm . The general shape is similar to those of basaltic impact melt glasses [13–15]

Summary and Conclusions: The melt droplet resulting from the CW experiment has been contaminated by Ca due to the experimental set-up, which explains the difference in chemistry and shift of spectral features compared to the glass in the pits. The chemistry of the uncontaminated glass (Fig.3) in the pits resulting from the pulsed reference experiments shows high contents in refractory elements (Al, Ca and Ti) indicating a possible fractionation owing to evaporation of lighter elements [11,12]. The resulting spectra of the melt glasses could thus be useful as indicators of evaporation processes e.g. in impact events. Alternatively, the variations could be explained by incomplete mixing or melting of starting material.

References: [1] Benkhoff, J. et al. (2010) *Planetary and Space Science* 58, 2–20 [2] Hiesinger H. et al. (2010) *Planetary and Space Science* 58, 144–165 [3] Marchi S. et al. (2013) *Nature* 499, 59 [4] Fassett C.I. (2016) *JGR Planets* 121, 1900–1926 [5] Warrell et al. (2010) *Icarus* 209, 138–163 [6] Maturilli A. (2006) *Planetary and Space Science* 54, 1057–1064 [7] Helbert J. and Maturilli A. (2009) *Earth and Planetary Science Letters* 285, 347–354 [8] Weber I. et al. (2018) *LPSC* 49, Abstract 1430 [9] Hamann C. et al. (2016) *Journal of Geophysical Research* 43, 10602–10610 [10] Martin, D.J.P. (2017) *Meteoritics & Planetary Science* 52, 1103–1124 [11] Gerasimov M.V. et al. (2012) *Petrology* 20, 399–407 [12] Nagahara H. et al. (1989) *NIPR Symposium* 2 [13] Morlok A. (2017) *Icarus* 296, 123–138 [14] Morlok A. et al. (2016) *Icarus* 278, 162–179 [15] DuFresne C.D.M. et al. (2009) *American Mineralogist* 94, 1580–1590

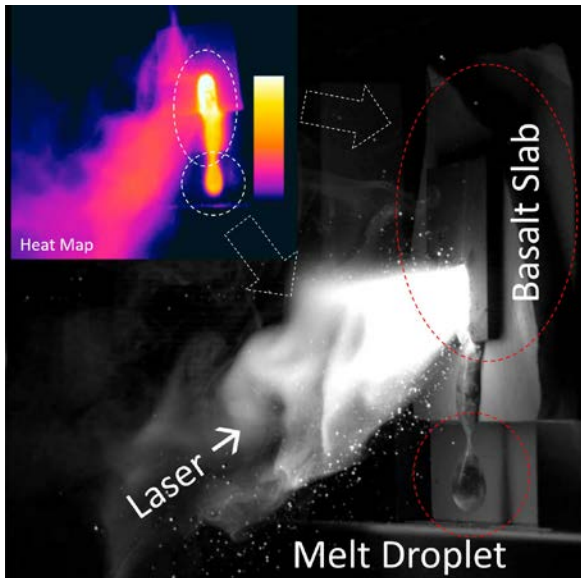


Fig.1: Images of the CW laser melting experiment [9]. The Basalt slab is on top, with a separate melt glass droplet on the bottom, which was used for the powder analyses. In-situ FTIR analyses were made from laser pits on the basalt slab.

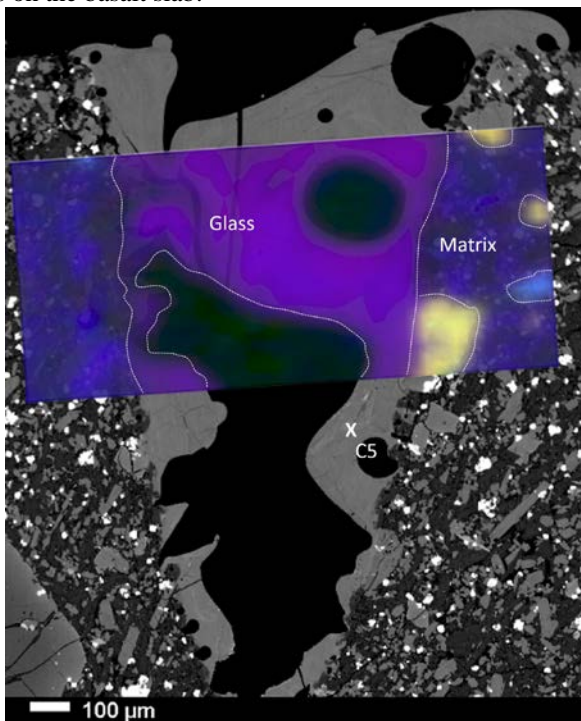


Fig.2: Micro-FTIR analyses of a pit on the slab. The colored part was mapped using the FTIR mapping unit in a resolution of $25 \times 25 \mu\text{m}$. Phases were identified using a multivariate statistical procedure. Resulting spectra of this and other mapped areas are compared in Fig.4 with bulk powder measurements of the melt. C5 is a $25 \times 25 \mu\text{m}$ sized spot analyzed separately in point analysis.

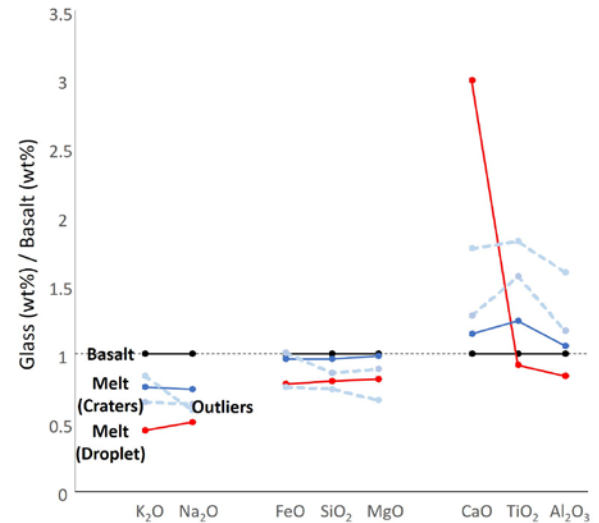


Fig.3: Comparison of the compositions (EMPA data) of the droplet (red) and the crater melt average (dark blue), the two outliers B5 and C6 (light blue dotted lines) normalized on the bulk unprocessed basalt [6](black). The oxide components are arranged following their expected volatility, ranging from high (K₂O, Na₂O), moderate (FeO, SiO₂, MgO) to low (CaO, TiO₂, Al₂O₃) [12].

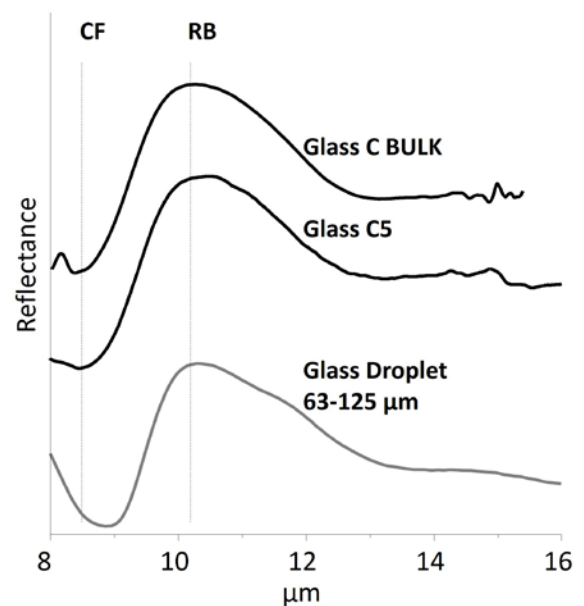


Fig.4: Micro-FTIR spectra from the melted parts of the basalt slab.

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