EXPERIMENTAL SPACE WEATHERING OF OLIVINE AND PYROXENE

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Introduction: Space weathering (SW) effects can be observed on all solar system bodies that lack a protective atmosphere [1, 2]. This includes asteroids, comets and satellites, but also planets, like Mercury that has only a tenuous exosphere. An overview over all surface modifying influences is given by [3]. SW has an impact on the structural and thus spectral properties of materials. It is therefore important to know these effects for the interpretation of remote sensing data, like for the upcoming ESA/JAXA BepiColombo mission which will arrive at Mercury in 2024. Also, well characterised samples are needed to link the spectral changes to structural changes in the materials.

Techniques: We follow the approach of [4, 5] to simulate thermal effects of impacting (micro) meteorites on surface regolith material. Therefore we irradiated pellets of comminuted olivine (Ol) and pyroxene (Px) with an infrared laser and investigated the altered areas by transmission electron microscopy (TEM) and VIS/NIR and MIR spectroscopy. The focused ion beam (FIB) technique was used to cut out TEM specimens (Figs. 1, 2) from irradiated areas to investigate the effects of irradiation damage at nanoscale. Our goal is to correlate the induced damage documented by TEM with the corresponding VIS/NIR and MIR spectra.

Results and discussion: Ol and Px exhibit a different internal layering in their respective weathered rims when exposed to identical irradiation conditions. As inferred from previous spectral observations [e.g., 2, 3, 4, 5], both, experimental laboratory study and asteroidal remote sensing, Ol is reddened more efficiently than Px. This difference is also seen in TEM results from this study resulting in a distinct developed nanostratigraphy throughout the respective weathered rims. Although Px contains only few metal nanoparticles (compared to Ol), spectral reddening, though less pronounced than in Ol, can also be observed in its VIS/NIR spectrum. The vesiculated rims occurring in Px are probably linked to the volatile content in its crystal structure. Unfortunately, this makes a direct comparison to Mercurian regolith difficult as it is considered volatile poorer compared to volatile containing terrestrial samples. A generalization of the results obtained from the Px therefore requires further studies. Probably a similar nanostratigraphy (as seen in the Px TEM HAADF micrograph), could occur in regolith grains that were aqueously altered prior to being exposed to a heat source.

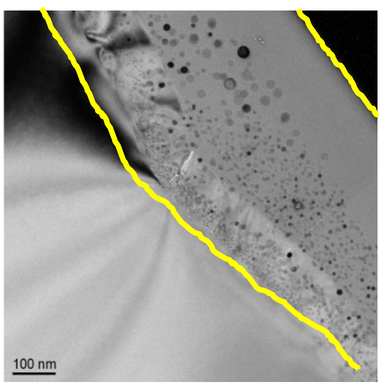

Figure 1: TEM BF micrograph of Ol FIB lamella after irradiation at ~ 2 J cm^{-2}. FIB cut was carried out perpendicular into irradiated grain surface, thus a depth profile of the radiation damage is obtained. Weathered rim is framed in yellow underneath, the unscathed ol crystal (lower left) is preserved.

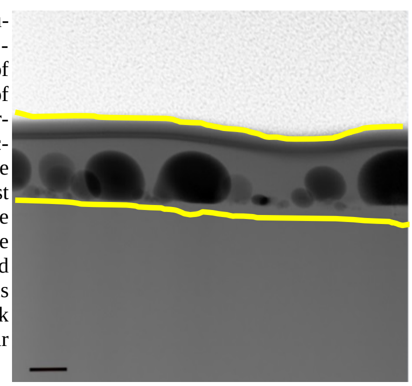

Figure 2: A high angle annular dark field (HAADF) Z - contrast TEM micrograph of a representative portion of the px weathered rim after irradiation. Here, a cross section of a radiation damage depth profile of the most abundant weathering feature in px is shown. Again the weathered rim (area affected by laser irradiation) is framed in yellow. Black holes are vesicles. Scale bar is 100 nm

References: [1] Pieters et al. (1993) *JGR: Planets*. 20817 - 20824 [2] Noble et al. (2001) *MAPS*. 31 - 42 [3] Domingue et al. (2014) *Space Sci Rev*, 121 – 214 [4] Yamada et al. (1999) *Earth, Planets Sp*. 1255 – 1265 [5] Sasaki et al. (2002) *Adv Sp Res*., 783 - 788