LASER-EXPERIMENTS ON ORIENTED OLIVINE CRYSTALS: EVIDENCE OF SPACE WEATHERING

A. Fazio[1], D. Harries[1], S. Nolte[2], G. Matthäus[2], H. Mutschke[3], and F. Langenhorst[1] [1]Institute of Geoscience, Friedrich Schiller University Jena (FSU), Carl-Zeiss-Promenade 10, 07745 Jena, Germany, [2]Institute of Applied Physics, FSU, Albert Einstein-Str. 15, 07745 Jena, Germany, [3]Institute of Astrophysics, FSU, Schillergässchen 2-3, 07745 Jena, Germany (*Agnese.Fazio@uni-jena.de*)

Introduction. The term space weathering encompasses a set of processes that operate on the surfaces of atmosphere-free bodies in the solar system (e.g., Moon and asteroids) producing irreversible modifications of mineral surfaces at micro- and nanometer scales (i.e., the formation of iron nanoparticles ($npFe^0$s), melting, recrystallization, and development dislocations). The main causes of space weathering are solar wind exposure and micrometeorite impacts. The damages induced by space weathering affect the reflectance spectra of any airless body in the solar system, impeding the correct interpretation of their surface mineralogy (e.g., [1], [2]).

Space weathering can be reproduced through ion irradiation and laser experiments. The former are a direct reproduction of solar wind irradiation effects. The latter are assumed to simulate micrometeoroid impacts (e.g., [3], [4], [5]). Although the results of the previous laser experiments are encouraging, the mechanisms of mineral damages are still unclear. In order to constrain the mineralogical modifications of the space weathering, we are carrying out new high energy and short pulse laser experiments on oriented single olivine crystals.

Samples and Methods. Single crystals of Pakistani olivine ($Fo_{94.5}$) were cut perpendicular to the three main crystallographic axes [100], [010], and [001]. Thick polished sections (300-500µm) were irradiated under vacuum (10^{-3} mbar) with a Ti:sapphire laser at a wavelength of 800 nm. On each sample, one 1 x 1 mm grid of single shots (center to center distance 100 µm) at a pulse energy of 3 mJ (spot size ~35 µm) and two 0.5 x 0.5 mm grids of single shots (center to center distance 100 µm) at pulse energies of 2 mJ and 1 mJ were produced.

Initially, spectral features of irradiated and non-irradiated areas were acquired in NUV-vis-NIR range. The morphology of samples was studied by white light interferometry and SEM. FIB-lamellae were prepared on selected single craters produced at different energies and in different orientations. They were observed by the TEM in order to evaluate the defect microstructures at the nanometer scale.

Results. Laser produced craters are covered by a glass layer at each orientation and pulse energy. Diameter and depth of the craters increase with increasing pulse energy. Their diameter varies between 85 µm and 54 µm and their depths between -2.8 µm and -1 µm. The damage is higher on the slice perpendicular to the direction [100]. Spectral measurements in the range of NUV-vis-NIR show a slight darkening (overall reduction in spectral intensity) and reddening (relative spectral intensity increasing at higher wavelength).

At the current stage, one laser crater was studied by FIB-TEM. In cross-section three different layers can be identified from top to bottom: a glass layer (~500 nm), a polycrystalline layer (~700 nm), and defect-rich single crystal olivine (> 15 µm). The polycrystalline layer can be divided into two sublayers, at the base very small, polygonal olivine crystals (~50 nm) occur, which grade into larger, palisade-like olivine crystals at the glass interface. Iron nanoparticles ($npFe^0$s) occur in the lower part of the glass layer and on the topmost sublayer of the polycrystalline layer.

Discussion and Future Work. The layered structure and the occurrence of $npFe^0$s are features found in naturally space weathered samples from the Moon [6] and from asteroid Itokawa [7], indicating that our experimental setting is suitable to reproduce space weathering effects. Next steps will be completing the FIB-lamellae preparation and the TEM study on laser irradiated olivine. In particular, we will devote our attention to the formation of $npFe^0$ and the defect microstructures in the shocked olivine substrate.

References: [1] Chapman C.R. 2004. *Annual Review of Earth and Planetary Sciences* 32: 539-567. [2] Bennett C. J. et al. 2013. *Chemical Reviews* 113: 9086-9150. [3] Yamada M. et al. 1999. *Earth Planets and Space* 51: 1255-1265. [4] Sasaki S. et al. 2001. *Nature* 410: 555-557. [5] Brunetto R. et al. 2006. *Icarus* 180: 546-554. [6] Noble S. K. et al. 2015. Abstract #2034. *Space weathering of Airless Bodies*. [7] Noguchi T. et al. 2014. *Meteoritics & Planetary Science* 49:188-214.

Acknowledgements: This work was supported by the Gottfried Wilhelm Leibniz Programme (LA 830/14-1) and the research unit FOR 2285 “Debris Disk in Planetary Systems” of the Deutsche Forschungsgemeinschaft (LA 830/20-1 to FL). A. F. thanks the Alexander von Humboldt Foundation for providing a research fellowship. The authors are grateful to E. Gnecco and V. Herold (Institute of Material Science, FSU Jena) for their help in surface measurements.