CONNECTION OF SUBSURFACE STRUCTURE OF H^+- AND LASER-IRRADIATED SAMPLES TO THE SPECTRAL EVOLUTION.

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Introduction: Space weathering, i.e. mainly solar wind irradiation and micrometeoroid bombardment, influences surfaces of airless planetary bodies. As a result, the reflectance spectra are altered. If we consider the very common silicate-rich bodies, the visible (VIS) and near-infrared (NIR) spectra darken, the spectral slope increases, and the mineral absorption bands diminish as a result of space weathering. See [1, 2, 3] for more details.

In the presented work, we want to connect the spectral changes to the subsurface alteration of the olivine and pyroxene samples induced by individual space weathering agents. For that, we did electron microscopy of H^+- and laser-irradiated pellets.

Methods: We used pellets of olivine and pyroxene irradiated by $2x10^{17}$ H^+/cm^2 (energy of ions was 5 keV) and by individual femtosecond laser pulses (energy of one pulse approx. 1.5 mJ, spot area approx. 50 μm). All of these were measured at the VIS and NIR wavelengths. For more details, see [4].

We examined surface features and chemical changes of these samples using Tescan Lyra 3GMU Dual-Beam Scanning Electron Microscope (SEM). Then we prepared thin sections and did high resolution and analytical scanning transmission electron microscopy (STEM) using a Jeol JEM 2200FS FEG microscope.

After that, we compared our observations to the spectra of the irradiated pellets.

Results: Our observations indicate that the surfaces of the pellets do not suffer from chemical changes. H^+ irradiation causes predominantly blistering, which is more abundant in pyroxene. Laser irradiation induces more significant and extended surface changes especially in the areas of craters.

STEM images revealed that both materials, when irradiated by H^+, develop subsurface vesicles in (partially) amorphous layer. The vesicles are more tightly packed in olivine than in pyroxene. Of all the samples, only olivine irradiated by laser contains nanophase iron particles below the amorphous layer. Pyroxene irradiated by laser developed significant amorphous layer containing large vesicles. See Fig. 1 for a comparison of different STEM images of our samples.

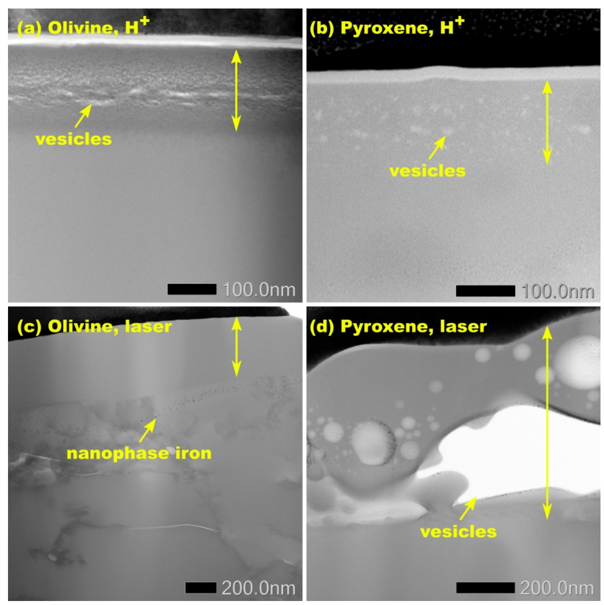

Fig. 1: STEM bright-field images of our samples. Olivine irradiated by laser (c) contains nanophase iron particles, shown as black dots. Other samples show significant vesiculation – white areas. Double-headed arrows mark (partially) amorphous areas.

Conclusions: If we compare the observed STEM profiles to the spectra evolution, Fig. 2, we see that the spectral changes are mainly connected to the presence of fine subsurface structures, such as the vesicles in H^+-irradiated samples or the nanophase iron particles in laser-irradiated olivine. These fine structures agree with the wavelength-dependent evolution of the spectral curves. Laser-irradiated pyroxene on the other hand does not show any fine structure, only large vesicles, which explains the absence of the wavelength-dependent component in the spectra evolution.

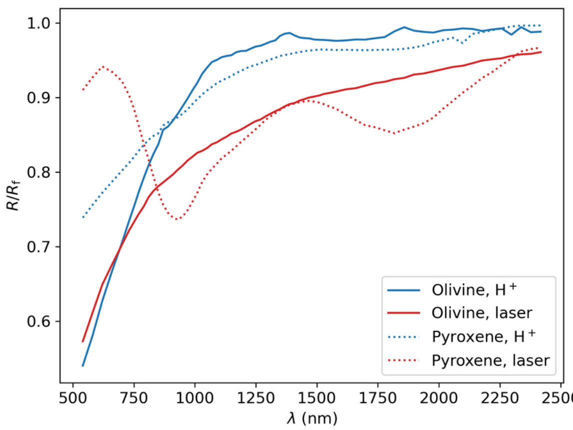

Fig. 2: Ratio of reflectance, R, of irradiated to fresh, R_f, material. λ stands for wavelength. Pyroxene irradiated by laser shows a different behavior to the three other cases.

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