CONNECTION OF SUBSURFACE STRUCTURE OF H⁺- AND LASER-IRRADIATED SAMPLES TO THE SPECTRAL EVOLUTION. K. Chrbořková1,2,3, P. Halodová4, T. Kohout1,3, J. Ďurech2, K. Mizohata5, P. Malý4, V. Dědič7, A. Penttilä8, F. Trojánek6, and R. Jarugula4, 1Department of Geosciences and Geography, University of Helsinki, Gustaf Hällströmin katu 2, 00560 Helsinki, Finland (katerina.chrboerkova@helsinki.fi), 2Astronomical Institute of Charles University, V Holešovičkách 2, 18000 Prague 8, Czech Republic, 3Institute of Geology, The Czech Academy of Sciences, Rozvojová 269, 16500 Prague 6, Czech Republic, 4Research Centre Řež, Hlavní 130, 25068 Husinec-Řež, Czech Republic, 5Department of Physics, Faculty of Science, University of Helsinki, Pietari Kalmin katu 2, 00560 Helsinki, Finland, 6Department of Chemistry and Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague, Czech Republic, 7Institute of Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 12116 Prague, Czech Republic, 8Department of Physics, Faculty of Science, University of Helsinki, Gustaf Hällströmin katu 2, 00560 Helsinki, Finland.

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 2x10¹⁷ H⁺/cm² (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.](image)

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. $\lambda$ stands for wavelength. Pyroxene irradiated by laser shows a different behavior to the three other cases.

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