Comparison of ion- and laser-weathered spectra of olivines and pyroxenes

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Introduction: Irradiation by solar wind ions and impacts of micrometeoroids are the leading processes that weather surfaces of airless planetary bodies in the solar system. As a result, key diagnostic features of their spectra get altered. The most prominent changes in the silicate-rich bodies in the visible (VIS) and near-infrared (NIR) wavelengths are increase in the spectral slope, reduction of the albedo, and flattening of the mineral absorption bands (see, for example, [1]).

Our laboratory experiments aimed at understanding what are the similarities and differences between the effect of the solar wind ions and micrometeoroid impacts on the final spectra of the silicate-rich bodies.

Methods: We have used two different terrestrial minerals, olivine and pyroxene, which we ground , dry-sieved, and pressed into pellets.

Hydrogen (H) irradiations proceeded at the Accelerator Laboratory of the University of Helsinki, using 5 keV ions with varying fluences from 10^{14} to 10^{18} ions/cm^2. Helium and argon irradiations were done using the INGMAR set-up (IAS-CSNSM, Orsay) with 20 and 40 keV ions and with fluences from 10^{15} to 10^{17} ions/cm^2.

Individual 100-fs laser pulses were shot into a square grid on the pellets' surface to simulate the micrometeoroid impacts (as in [2]) in the laboratories at Charles University. Various densities of the pulses per cm^2 simulated different weathering stages.

Subsequent spectral measurements covered wavelengths from 0.54 to 13 µm, i.e. VIS to mid-infrared wavelengths. After the measurements, we evaluated the evolution of the spectral parameters estimated using the Modified Gaussian Model [3, 4].

Results: We found that the variation of the spectra in the VIS range was similar for H+- and laser-irradiated samples, but we have identified a difference in the NIR wavelength range. Laser irradiation caused greater changes in NIR than any of the ions we used, see Fig. 1. The reason for such difference in behaviour may be that the penetration depth of the laser pulses is much larger than in the case of the ions. The relative contribution of the irradiated material in the spectra is then smaller in the ion case than in the laser case.

Otherwise, we found that the original mineralogy of the surface is the leading factor influencing the evolution of the spectral parameters. While olivine and pyroxene showed albedo variations of a similar order, the evolution of pyroxene's spectral slope was negligible when compared to olivine. This has implications for olivine-pyroxene mixtures and their evolution. E.g. in the case of asteroid (433) Eros, the variation of the spectral slope is minor, but other spectral parameters show some variation. As the surface of Eros is old, we hypothesise that spectral slope changes induced by olivine alteration already saturated and the leading source of the spectral variation is pyroxene, which does not show large variations in the slope. In contrast asteroid (25143) Itokawa is younger and thus still shows variations in the spectral slope as it has not saturated yet.

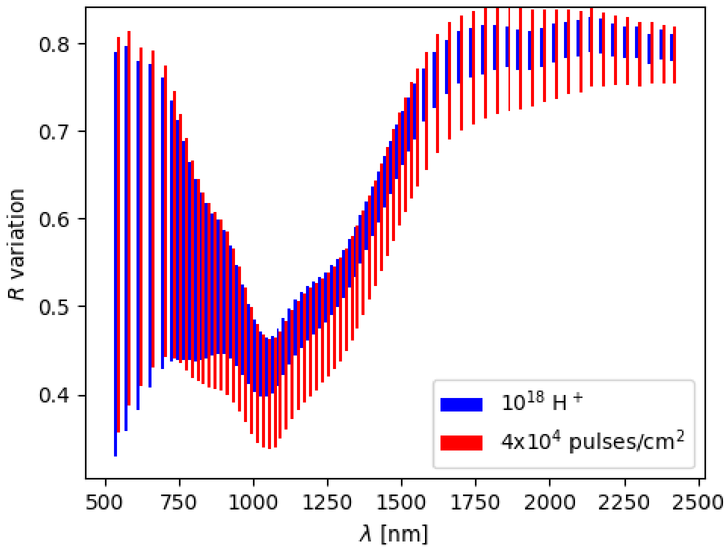

Figure 1. Spectral differences caused by laser and hydrogen ion (H+) irradiation. Each bar connects at the upper end the reflectance, *R*, of the fresh material and at the lower end *R* of the material weathered to the level marked in the legend.

References

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