THE NIR SPECTRAL VARIATIONS OF ION IRRADIATED PHYLLOSILICATES DEPEND ON OBSERVATION GEOMETRY.

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Introduction: Sample return missions Hayabusa2 (JAXA) and OSIRIS-REx (NASA) found evidence of hydrated silicates on the surface of C and B-type asteroids Ryugu [1] and Bennu [2]. This detection relied on the study of the Near-IR spectra from remote sensing observations of the asteroids' surfaces. Specifically, the 2.7 µm feature due to the O-H stretching mode of the metal-OH units was observed. This feature is often used as a proxy for aqueous alteration. Its position is related to the composition and structure of hydrated silicates [3]. Laboratory studies simulating the effects of space weathering (SpWe) on carbonaceous chondrites [4] and terrestrial phyllosilicates [5] have also shown that the feature's position can vary under ion implantation, shifting towards longer wavelength for implanted surfaces. Spectroscopic surveys of the Small Carry-on Impactor (SCI) crater impact on Ryugu showed that the subsurface material of the asteroid exhibits a 2.7 µm feature that is stronger and with a band position shifted towards shorter wavelength, in comparison to the one observed for multiple regions surrounding the impact site [4]. This confirms that space weathering (SpWe) is active at the surface of water-rich asteroids. All SCI-crater's observations were performed with a similar phase angle (corresponding to the difference between the directions of illumination and observation), varying from 31.7° to 35.7° [6]. Because SpWe is a surface process, it is relevant to investigate how the geometry of observation can affect the hydration feature on space weathered surfaces, since it is common in spectroscopic surveys to observe the same feature at different geometries. Here, we report new laboratory Bidirectional Reflectance Distribution Function (BRDF) measurements on pristine and ion-bombarded phyllosilicate pellets, to monitor the evolution of the 2.7 µm feature with varying observation geometry.

Samples and method: We performed ion bombardment experiments on a serpentine sample consisting mostly of antigorite. Serpentines are particularly abundant in carbonaceous chondrites [7] which have been used as analogs to surface materials on primitive asteroids [8, 9]. Samples were prepared as pellets, which reproduce best rock-covered surfaces, rather than a loose regolith. The ion bombardment experiments were conducted at room temperature in the INGMAR vacuum chamber at 10E-7 mbar on pellets made from serpentine. We used He+ and Ar+ at 40 keV. These choices were made to emulate the ion irradiation by some components of the slow solar wind and the solar energetic particles (SEP). The penetration depth was estimated using the SRIM code [10] and was found to be of 310 +/- 90 nm for He and 40 +/- 12 nm for Ar. Details and results from these implantation experiments are presented in [5].

We measured the BRDF with the SHADOWS spectro-gonio radiometer [11]. We set four illumination angles (0°, 20°, 40° and 60°) and acquired a series of spectra by varying the observation angle, from -70° to 70° with a 10° step. The angles are set according to the normal to the surface. A total of 56 optical configurations per pellet were measured.

Results: We studied the behavior of the 2.7 µm band as a function of observation geometry. We found that, as we approach specular reflection, the feature gets deeper, as shown in Figure 1.

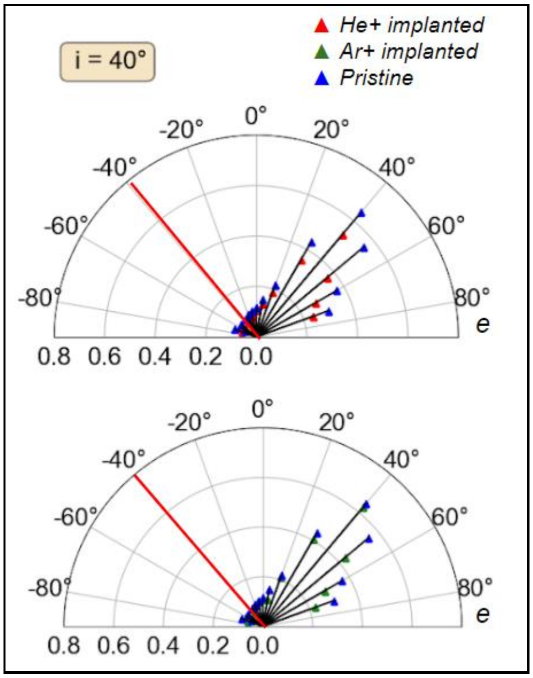

Figure 1. Evolution of the 2.7 µm band depth at illumination i = 40° for different observation angles e

The 2.7 µm band depth for the ion bombarded pellets is lower than for the pristine one.

The band position, for the He+ implanted pellets, shifts towards longer wavelengths as we approach specular reflection, as shown in Figure 2.

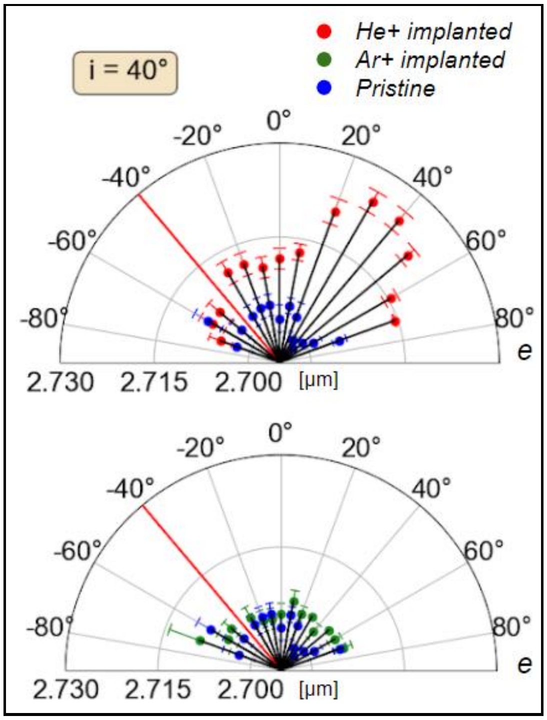

Figure 2. Evolution of the 2.7 µm band position at illumination i = 40° for different observation angles e

For the Ar+ implanted pellet, only a small shift at specular configuration can be identified. We also note that the pristine sample has a small "negative" shift at specular reflection. This is probably due to the band changing shape due to interferences at specular configuration.

Discussion and conclusion: We think that the spectral shift is due to chemical and physical changes induced by ion implantation effects in the first hundreds of nanometers of our phyllosilicate pellets. The diversity in the observed amplitude of the shift means that different depths of the implanted matter are probed depending on the observation angle with respect to the non-bombarded matter. This is especially true when measuring in specular conditions, where photons mostly probe the very top surface (implanted layer) of the samples, hence the larger shift measured. The penetration depth of Ar+ being much smaller than that of He+ and also than that of the skin depth of penetration of infrared light at the peak wavelength (~2µm in the 2-3 µm wavelength region for serpentines), the effect on the Ar+ bombarded material is much smaller. Our results indicate that the geometry of observation can induce a certain bias in the interpretation of remote sensing data from space-weathered bodies.

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