SPACE-WEATHERING ON VESTA: ION-IMPLANTATION INDUCED SPECTROSCOPIC CHANGES ON HEDs

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Introduction: The NASA/Dawn mission explored Vesta between 2011 and 2012 [1], confirming the asteroid to be the parent body of the howardite, eucrite, diogenite (HED) clan of meteorites [2]. Dawn allowed the first extensive high spatial resolution mapping of Vesta's surface, shedding light on its mineralogy and spectral properties [3]. Space-weathering (SpWe) on Vesta still constitutes a significant conundrum as Vesta's spectroscopic features in the near-IR appear to be less affected compared to lunar-type space-weathered features [4]. This suggests the absence of lunar-like nanophase iron on Vesta as a product of SpWe (observed on the Moon and Itokawa samples [5]). Regolith resurfacing processes at the surface of Vesta may also contribute to diluting the spectral effects on classical SpWe tracers - such as slope reddening and darkening - of older, more weathered materials. Hence, to better identify the weathering state of surfaces on V-type asteroids, there is a need to investigate SpWe effects on such materials while expanding and redefining this set of parameters. In this work, we look for the optimal parameters for distinguishing between fresh and weathered materials on Vesta and other V-type objects. To perform these investigations, we emulate the effects of SpWe on Vesta in a laboratory environment. This study can be done by using HEDs as analog material for Vesta's surface. In particular, we focus on emulating the effects of the solar wind component of SpWe via ion implantation.

Material and Methods: We performed ion-implantation experiments on four pellets made by compressing powder from four HEDs meteorites: NWA-4968 (E), NWA-6909 (E), NWA-7234 (E), and NWA-6232 (D) (bulk and mineral compositions available in [6,7]). We used the INGMAR (IrradiatioN de Glaces et Météorites Analysées par Réflectance, Institut d'Astrophysique Spatiale (IAS) - Laboratoire des deux Infinis Irène Joliot Curie (IJCLab), Orsay) vacuum chamber, at room temperature and under vacuum (P ~ 10^{-7} mBar), using 40keV He^+ ions provided by the SIDONIE (IJCLab - Orsay) ion-implanter. We then monitored the spectroscopic evolution of our samples in the visible/near-IR range (0.3 to 4 µm) with increasing fluences up to 6×10^{16} ions/cm² (10^3 - 10^4 years of exposure at 3AU). We also acquired additional spectroscopic data in the mid-IR (2 to 12 µm) both before and after the weathering of our samples using an infrared microscope. Finally, we traced the evolution of 25 spectral parameters in the visible/near-IR range and 3 in the mid-IR range to investigate their behavior upon weathering and determine the best parameter space with which we could separate compositional differences and ion-implantation-induced changes.

Results and Implications: In the visible/near-IR range, we observed all samples darken and redden, as well as a substantial decrease in band I (feature at 1.0 µm typical of pyroxenes [8]). This is consistent with previous ion-bombardment experiments on HEDs [9]. We have found a combination of spectral parameters that maximize the separation of the HED data points according to their composition, distancing their ion-implantation trends as well. These parameter spaces are a combination of reflectances at specific wavelengths (380 - 465 - 550 nm), spectral parameters associated with band I, and spectral slopes in the visible and near-IR. Data in the mid-IR shows variations of the Si-O stretching feature at 10 µm, more specifically a shift towards longer wavelengths of the peak positions of the feature. Using specific spectral parameters to "spread out" data points and identify clusters/correlations as a complementary method to multivariate statistical techniques like PCA or K-mean clustering, allows us to directly and more easily apply and test these results to remote-sensing data from Vesta's surface.

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