Ion irradiation of carbonaceous chondrites for a Vis-IR space-weathering study on primitive objects: CV Allende and CM Murchison

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The exposition of airless bodies to the harsh spatial environment in which they evolve (solar ion irradiation, micrometeorite bombardment, etc.) leads to surface alterations affecting the compositional interpretation made from spectra. This effect is known as space weathering (SW). A lot of studies have been made of SW on high-albedo asteroids [1], but little is known about SW of carbonaceous asteroids as previous studies have struggled to define a general spectral trend among dark surfaces [2]. In order to understand the influence of SW on primitive asteroids (while waiting for sample returns), we conduct laboratory simulations on meteorites: the goal of this work is to provide a model of the spectral alterations caused by SW of CM meteorite parent bodies and to assist OSIRIS-REx/NASA and Hayabusa-2/JAXA asteroid sample-return missions.

Here we present irradiations of the Allende and Murchison meteorites exposed to 40 keV He^+ and Ar^+ ions, as a simulation of solar-wind irradiation of primitive bodies surfaces, using different fluences up to 3.10^{16} ions/cm^2 (implantation platform SIDONIE at CSNSM Orsay) corresponding to short timescales of $\sim 10^3$–10^4 yrs in the main asteroid belt. Samples were analyzed ex situ before and after irradiation using visible to far-IR (0.4–50 µm) reflectance spectroscopy. Reflectance spectra where acquired through fibers, allowing measurements at different phase angles. Allende and Murchison show different spectral behaviors after irradiation. Similarly to what has been observed in previous experiments [3], a reddening and darkening of Vis-NIR reflectance spectra is observed in the case of Allende. In the case of Murchison, spectral variations are negligible with respect to other spectral variations due to viewing geometry, grain size, and sample preparation, suggesting an explanation for the contradictory SW studies of dark asteroids.

After irradiation on Allende, the infrared bands of the matrix olivine silicates shift to positions corresponding to a higher Fe/Mg abundance ratio, possibly as a consequence of a preferential sputtering effect (lighter and more volatile species are preferentially sputtered backwards) and/or preferential amorphization of Mg-rich olivine. Spectral variations are compatible with the Hapke weathering model and with the production of nano-phase metallic iron as reported in the lunar space alteration. Raman spectroscopy shows that the carbonaceous component is substantially affected by irradiation. All observed modifications seem to scale with the nuclear elastic dose.

The three main alteration processes we observe reach asymptotic trends at similar damage values, corresponding to very short astrophysical timescales of 10^3–10^4 yrs at 3 au. This indirectly confirms the high efficiency of rejuvenating processes that must take place on C-complex asteroids. Further studies will be necessary, and are programmed, to better separate the carbon from the silicate effects on visible spectra, and to propose an estimation of alteration degree of the darkest surfaces.

References: [1] Brunetto et al. (2006, Icarus 184); Hiroi et al. (2006, Nature 443); Noble et al. (2007, Icarus 192). [2] Moroz et al. (2004a, Icarus 170; 2004b, LPS XXXV); Kanuchova et al. (2012, Icarus 221); Lantz et al. (2013, A&A 554). [3] Moroz et al. (1996, Icarus 122); Lazzarin et al. (2006, AJ 647).