Effect of iron sulfides on space weathering: Lessons from the Itokawa particles and laboratory simulations

M. Okazaki[1], S. Sasaki[1], A. Tsuchiyama[2], A. Miyake[2], T. Matsumoto[2], T. Hirata[2], and T. Hiroi[3]

[1]Department of Earth and Space Science, Osaka University
[2]Division of Earth and Planetary Sciences, Kyoto University
[3]Department of Geological Sciences, Brown University

Space weathering is the process invoked to explain the spectral mismatch between S-type asteroids and ordinary chondrites: darkening, spectral reddening, and attenuation of absorption bands in the reflectance spectra. These changes of optical properties of the surface of airless silicate bodies are explained by nanophase metallic iron (nanoFe) particles, which are formed on regolith particles by high-velocity dust impacts as well as irradiation of the solar-wind ions (Hapke 2001). Those nanoFe particles were discovered in lunar soils, Kapoeta meteorite, and regolith grains from the surface of S-type asteroid Itokawa. Experimental studies using a nano-second-pulse laser confirmed that nanoFe should control the spectral darkening and reddening. The observed reddening of S-type asteroid families is correlated with dynamical asteroid ages after family-forming disruption (Jedicke, et al. 2004). Still, experiments showed that the weathering degree should depend on the composition such as the olivine/pyroxene ratio (Hiroi and Sasaki 2001).

In ordinary chondrites, iron sulfides, typically, troilite FeS is the main sulfur-bearing mineral. TEM observation of a dust grain of Itokawa showed the presence of not only iron, but also nanophase FeS particles, which are embedded within a vapor-deposited thin surface layer (thinner than 10-15 nm; Noguchi et al. 2011). One of the Itokawa grains is composed mainly of FeS (about 40 microns) with smaller olivine and pyroxene particles (Yada et al., 2014). On the other hand, the surface sulfur depletion of S-type asteroid Eros was explained by the same mechanism (high-velocity dust and solar-wind particle impacts) of space weathering (Loeffler et al. 2008).

To examine the effect of FeS on the surface optical properties of silicate bodies, we conducted pulse-laser irradiation experiments on mixtures of olivine (and pyroxene) and FeS particles with typical sizes of 45–75 micron, for varying FeS fractions (0–0.2 by weight). We find that the addition of Fes should promote the change of optical properties in accordance with space weathering, especially darkening. As compared to the cases where iron particles are mixed, darkening occurs characteristically in the infrared region.

According to preliminary observations by the FESEM and HR microscopes, surfaces of olivine particles — after laser irradiation — are likely to be coated with vapor-deposited material. Moreover, some grains are covered by a smooth thicker FeS coating, which would contribute to the overall darkening. We suppose that iron sulfides may promote space weathering initially, even if some of the sulfides are, in time, decomposed to a lower surface sulfur abundance on small asteroids.

References: [1] Hapke, B. et al., J. Geophys. Res.106, 10039 (2001). [2] Jedicke, R., et al., Nature 429, 275 (2004). [3] Hiroi, T. and Sasaki, S., Meteoritics and Planetary Science 36, 1587. [4] Noguchi, T. et al. (2011) Science 333, 1121. [5] Yada, T. et al. (2014) LPSC 45th, 1759. [6] Loeffler, M. J. et al. (2008) Icarus 195, 622.