OPTICAL DARKENING OF DUNITE BY SULFIDE MOBILIZATION

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Introduction & Methods: Asteroids are spectrally diverse objects. This diversity is related mainly to their distinct mineralogical composition. However, parameters like temperature, phase angle and grain size additionally influence their classification. Processes like, e.g., shock pressure, post shock heating, and space weathering (SW; [1]) alter such initial asteroidal compositions, and thus influence their spectral appearance. Distinct spectral slopes and absorption bands in the visible and near infrared (VNIR) are related to the respective asteroidal lithology and its SW background [2]. For example, S-type asteroids show silicate absorption bands similar of ordinary chondrites (OC) with typical absorption features in the NIR at ~ 1 and ~ 2 µm. SW affects the absorption depth of these bands, as well as the entire spectral slope. Impact related post shock heating on the other hand is known to cause shock-darkening, which implies either whole rock melting or pervasive metal and iron sulfide melt mobilization within the silicate ground mass and leads to attenuated spectra [3]. We produced analog material in order to improve our understanding of the mobilization processes of metal and metal-sulfide phases involved in mafic-silicate rich, as well as opaque rich asteroids [2,3], and to monitor in detail the spectral effects of the sulfide re-distribution in the VNIR and mid infrared range (MIR).

Methods & Early Observations: We used dunite rock as an ordinary chondrite analog material to provide a sulfide and FeNi metal free silicate ground mass that was "doped" with synthetic troilite (FeS) [4] at different vol% (see Fig. 1c-f). Each sample was cut into cubes of varying side lengths (between 13-20 mm), FeS powder was inserted into a drilled cavity (5 mm deep) in the centre of the cube in amounts of 0.2 vol%, 0.4 vol%, and 0.6 vol% (Fig. 1d-f). Each dunite cube was heated with an untreated reference cube (Fig. 1c) at 1325°C (10°C/min) in N_2(g) atmosphere, and cooled to room temperature at increments of 5°C/min. All samples were darkened, except for the reference cube (Fig. 1c). Figs. 1a and 1b show a fragment of the light (a) and naturally-shock-darkened lithology (b) of the Chelyabinsk meteorite in comparison with the experimentally darkened dunite samples (Fig. 1d-f). We observe an overall darkening, which was confirmed to be related to the sulfide mobilization by scanning electron microscope analyses, energy dispersive microscopy [5]. Darkening is more intense in the naturally shocked chondrite (Fig. 1b), this effect is likely correlated to the higher density of cracks and the volume of iron sulfide and metal melt that migrated between cracks. The initial modal abundance of FeS in the total volume is decisive for the darkening efficiency.

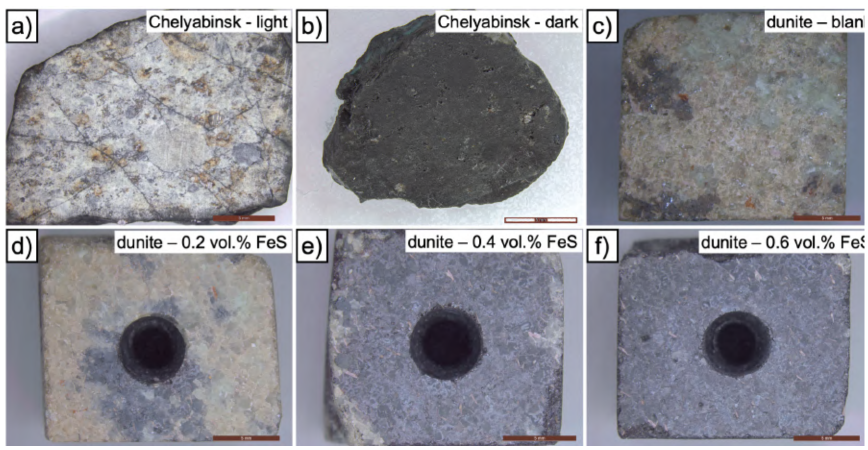

Fig. 1. Selected samples from the study with a,b) natural samples of the Chelyabinsk LL5 meteorite, b) a dunitic sample heated at high temperature, 1325°C, and d-f) dunitic samples impregnated with iron sulfides heated at high temperature, 1325°C. The dark lithology of the meteorite is the consequence of pervasive melting of metals and iron sulfide propagating between silicate cracks. The amount of troilite inserted in the dunitic samples is correlated to the total volume of darkening. The darkening of dunite is less intense than that in the dark meteorite; this may be a consequence of density of cracks or volume of iron sulfide and metal melt rather than initial lithology. Scale bars: 5 mm.

Future laboratory work includes the detailed spectral analysis from thin sections of the run products to preserve the petrographic context of darkening in the VNIR and MIR using µ-FTIR (Fourier-transform infrared microscopy) and bulk analyses from powdered run products in the UV/VNIR and MIR spectral range.

References: [1] Domingue D. L. et al. (2014), *Space Science Reviews*, 181:121-214. [2] DeMeo F. E. and Carry R. P. (2014) *Nature*, 505:629-634. [3] Kohout T. et al. (2020), *Astronomy & Astrophysics*, 639:A146. [4] Moreau J. et al. (2021) *Meteoritics & Planetary Science*, 57(3):588-602. [5] Moreau J. et al. (2022), *53rd Lunar and Planetary Science Conference*. abstract #1029.