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Effect of surface roughness on the reflectance spectra of metallic meteorites

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Abstract

We studied the spectral effect (0.5-2.4 µm) of surface roughness on a sample of the Gibeon iron meteorite, using bidirectional reflectance spectroscopy around the specular direction, in the visible and near-infrared range. Photometry and spectral slopes for different illumination-emergence-azimuth configurations are compared.

1. Introduction

Visible and near-infrared reflectance spectra of M-class asteroids and metallic meteorites tend to present a strong red slope, typically associated to their iron-rich nature. Previous measurement on iron meteorite powders and comparison to M-type observations has led to the idea that the M-type surfaces are covered by fine regolith. Here we explore an alternative, that the signatures can be caused by a highly rough surface. For that, we conducted laboratory measurements to analyze the effect of geometry and surface roughness on reflectance spectroscopy of metallic meteorites, from polished surface to coarse grained rough surface.

2. Sample preparation

A sample of a few cubic centimeters of the Gibeon metallic meteorite was used for our study. This meteorite is in majority composed of iron mixed with 8% of nickel [1]. The first step was to polish one of the flat surfaces of the sample, resulting in a smooth mirror-like surface. Then SiC abrasive disks of increasing grain sizes were used to create roughness on the same surface (see fig.1). After each roughening step, bidirectional reflectance spectra were taken around the specular direction.

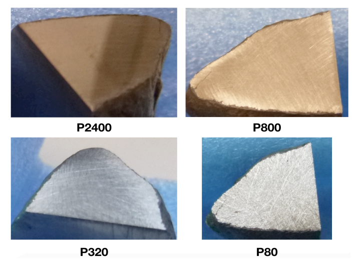

Figure 1: Pictures of the flat surface of the sample of the Gibeon meteorite after the four alterations by the abrasive disks P2400, P800, P320 and P80.

3. Bidirectional reflectance spectra

The reflectance spectra were acquired with the spectrogonio radiometer SHADOWS [2] installed at IPAG. To observe the modification of the spectra around the specular direction, the illumination angle has been set to 20°, and spectra were acquired at emergence angles from 10° to 30° by 2° steps, in and outside the principal plane. The two detectors of the goniometer caught the reflected light in a 1.6° solid angle around the emergence position. The spectral range was set from 500 nm to 2400 nm with a step of 100 nm. The spectrogonio radiometer measures the reflectance of any sample, compared to a lambertian surface.

3.1 Decrease of reflectance

The rougher the surface, the lower the reflectance. This effect can be represented by drawing the bidirectional reflectance distribution function, or BRDF (see fig. 2).

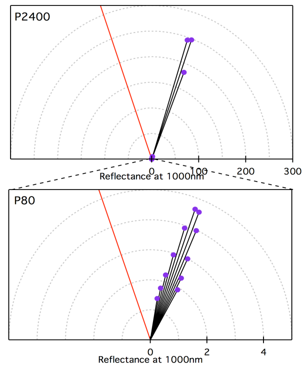

Figure 2: BRDF at 1000nm of the Gibeon meteorite, polished (disk P2400, top panel) and after alteration by the roughest abrasive disk (disk P80, bottom panel). The illumination direction of 20° is represented by the red line, the purple dots are the reflectance measurements at each emergence angle (note the measurements around 0 on the top panel). The grey doted semi-circles represent values of reflectance.

A highly polished or fine-grained surface behaves like a mirror and almost all the incident light is reflected in the specular direction in the principal plane. Compared to a lambertian surface, we measured at 2400 nm a reflectance of 35300 % in the specular direction and a reflectance of 4% at an emergence angle of 10° (phase=10°). We observed a factor of 10 between the reflectance measured in the specular direction in the principal plane and with an azimuth angle of 10°. For the roughest surface, we measured reflectance between 100% and 700% in the principal plane, including the specular reflectance, and the factor between the reflectance in the principal plane and at an azimuth angle of 10° decreases to 1.

3.2 Spectral slope

We observed a strong dependence of the spectral slope with the roughness of the surface, as well as with the geometry (see fig. 3).

For the polished surface, the specular reflection tends to present a red slope, while spectra outside the specular position present a strong blue slope. This

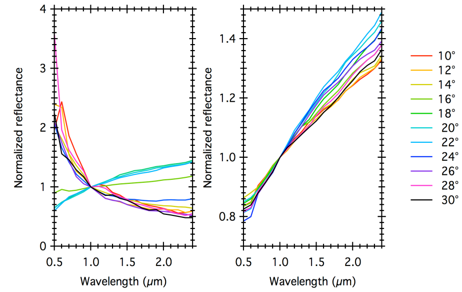

Figure 3: Normalized reflectance spectra in the principal plane of the Gibeon meteorite after being polished (left) and after alteration (right) for different emergence angles. The specular reflection is at emergence 20°. Note the different scales for the reflectance axis.

blue slope rapidly disappears after the abrasions of the surface, until all spectra become red, with a geometry dependant slope. In the case of the roughened samples, the surface becomes a diffuse reflector and all spectra roughly present the same spectral reddening and slope.

4. Conclusion

We conducted bidirectional reflectance spectra on a sample of the Gibeon meteorite. Spectra show a strong variability du to the surface roughness of the meteorite and the geometry of the system, incidence, emergence and azimut angles. Value of reflectance, as well as the spectral slope is impacted. Fine-grained or polished surfaces show a high and red specular reflection, while other geometries present low and blue reflectance spectra. For coarse grains, the differences between spectra in and out of the specular reflection decrease and all spectra tend to present a rather low reflectance coupled with a soft red slope.

References

[1] Weller M., Wegst U. Fe-C Snoek peak in iron and stony meteorites: Metallurgical and cosmological aspects, Materials Science and Engineering A, vol.521-522, pp 39-42 (2009)

[2] Potin S., et al.: SHADOWS: spectrogonio radiometer for bidirectional reflectance studies of dark meteorites and terrestrial analogues, EPSC Abstracts, Vol. 11, EPSC2017-243 (2017)