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Ideal method for asteroid compositional analysis - mid-infrared spectral work with DRIFTs for HERA mission

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Abstract

Earth laboratory based analysis of meteorite powder supports the interpretation of asteroid spectra, especially in the case of nearby recording by spacecrafts. The HERA (formerly named AIM) mission of ESA targets Didymos asteroid and planned to use a middle infrared detectors for the analysis of mineralogy and granular plus thermal properties of the regolith. Diffuse reflectance infrared fourier transform spectroscopy (DRIFTs) is a newly used technology for meteorite powder analysis. In the mid-infrared (2.5-25 µm) region it allows the analysis of the main meteorite minerals (e.g. olivines, pyroxenes and plagioclase feldspar) and meteorite groups as analogues of asteroids. However in order to we can get reliable estimation for the grain size, chemical composition, physical state and temperature dependence of the measured meteorite samples we should suitably know the spectral effects of these parameters.

1. Introduction

Analysis of different meteorite minerals is important in order to get information about surface characteristics of asteroids (Table 1). DRIFTs is an infrared sampling method, using a complex process, which covers absorption, transmission, reflection and diffusion, and mainly used to analyze powders and solid samples [4] for qualitative analysis, but it also provides quantitative information by the absorption bands. The most prominent absorption bands in the spectra of meteorites are expected from the most common minerals: olivine, pyroxene and plagioclase feldspar [11]. The change in spectral parameters of bands (e.g. peak position, band shape, FWHM) provide information about grain size, chemical composition (like Fe^{2+}, Mg/(Fe+Mg), H_2O), physical state and target temperature of the meteorite in the laboratory and of the asteroid by the mission. Below effects of these parameters are discusses.

2.1 Grain size effect

The properties of infrared spectrum significantly depend on grain size, with increasing grain size the reflectance decreases, effect weaker absorption bands and the apparent loss of spectral detail [3, 11]. The grain size must be smaller than the wavelength of the incident IR radiation (middle IR region <5-10 µm). Samples with smaller average particle sizes (<10 µm) give better spectra with reduced peak widths compared to samples with large average particle sizes (>90 µm) [4].

2.2 Chemical composition and physical state

The number, wavelength position and strength of bands change in complex ways, partly with changing of the chemical composition [8]. In case of The amount of Fe^{2+} and the rate of Mg/(Mg+Fe) significantly influences the spectral parameters of mafic silicates (olivine and pyroxene) [2, 6]. At plagioclase feldspar the amount of anorthite (An) endmember also cause similar effects [9]. The occurrence of H_2O both in hydrated and anhydrous minerals (without structurally bedded water) (such as olivine, pyroxene) is important, because contaminating water can slightly distort the spectral features [11]. The overall spectrum of crystalline material (physical state) show sharper bands than those of the amorphous [7]. In shocked samples (with deformed crystalline lattice) the band strengths are reduced with increasing shock pressures [5].

2.3 Temperature effect

Along with the increasing temperature the bands get broader and weaker, some bands are lost and others are shifted in wavenumber. These effects are due to diffusion of the infrared beam on the sample, which decreases with increasing temperature and the signal-to-noise ratio accordingly decreases [1]. The variations in temperature produce a number of significant spectral effects on the wavelength positions, shapes, and intensities of the absorption bands, the reflectance spectra of several mafic silicates vary with temperature [10].

2. Summary and Conclusions

DRIFTs is a newly used technology for meteorite powder analysis. In the mid-infrared (2.5-25 μm) region it allows the analysis of the main meteorite minerals and meteorite groups as analogues of asteroids. The DRIFTs spectra are mainly influenced by grain size, chemical composition, physical state of the sample and the recording temperature. Samples with smaller particle sizes give better spectra with reduced peak widths compared to samples with large average particle sizes. The chemical composition, so the occurrence of H_2O and in case of mafic silicates the amount of Fe^{2+} and the rate of Mg/(Mg+Fe) can cause the distortion of spectral features and the appearing and disappearing of some bands. The spectrum of crystalline material will have much sharper bands than the spectrum of amorphous material. With the increasing temperature the bands get broader and weaker, some bands are lost, and all the bands are shifted to longer wavelengths.

First results of the authors' measurements on meteorite samples with DRIFT detector will be presented at the meeting.

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Table 1: Examples of mineral observations in laboratory based meteorite powder and telescopic based asteroid data [12]

Name of mineral	IR spectral band position	Meteorite example	Asteroid example
Pyroxene	1, 2 μm	L, LL, H chondrites	Eros
Olivine	1 μm	L, LL, H chondrites	Eros