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Iron nanoparticles detection in Ordinary Chondrite samples

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Abstract

1. Introduction

S-type asteroids are identified as the parent bodies of the Ordinary Chondrites (OCs): this association is based on comparison of their infrared spectra (0.4-2.5 μm) [1, 2]. However, some differences between the asteroid spectra and the meteorite ones arise, since the former show a marked reflectance increase with increasing wavelength. This phenomenon, called reddening, is probably due to iron nanoparticles (npFe), produced on S-type asteroids by Space Weathering (SW) processes [3], such as vaporisation and re-deposit of iron silicates caused by micrometeoroid impacts [4], sputtering from solar wind particles [5] or shock-induced phase transformations on Fe-Ni alloys [6].

The aim of this work is to identify regions potentially hosting npFe and to study the morphology, the role and the optical properties of metallic inclusions. This analysis could allow us to obtain information about their formation. For this purpose, a high spatial resolution nanoimaging of OCs has been performed at different wavelengths.

2. The SNOM technique

Scanning Near-field Optical Microscopy (SNOM) makes it possible to obtain simultaneously a topographic and a reflectance image of the analysed sample. This technique is capable of very high spatial resolution, well below the conventional diffraction limit (i.e. a half wavelength) [7]. A light beam is passed through an optical fiber, placed very close to the sample surface and ending in a tip (apical radius of 100 nm), moved by piezoelectric motors in resonant oscillation with the sample. In the adopted configuration, the SNOM tip acts as both illuminator and light collector (fig. 1).

This experiment is the first multi-colour SNOM analysis ever performed on extraterrestrial samples, i.e. every sample is analysed at different wavelengths. We chose to consider the wavelengths correspondent at maximum/minimum reflectance bands of olivine and pyroxenes, the most important constituents of OCs (476 nm, 516 nm, 908 nm, 1300 nm, 1500 nm). Thus, in principle, these kinds of silicates could be recognised by comparing optical images collected at different wavelengths.

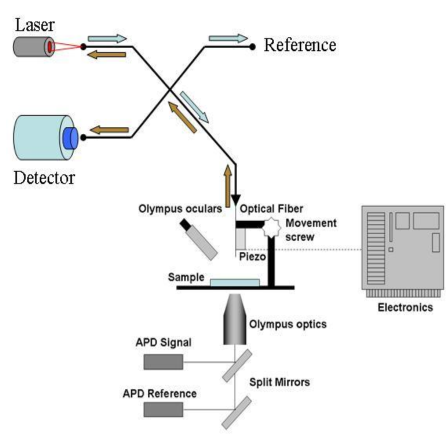

Figure 1: SNOM schematic representation.

3. Data analysis

Since images of the same sample collected at different wavelengths have a slight different spatial scale due to small (but unavoidable) mechanical drifts occurred during the acquisition, our first operation was to calculate the spatial shift between the optical images, by means of a cross-correlation analysis. After a satisfactory image alignment, the presence of metallic inclusions has been performed.

A region is considered as potentially hosting metallic inclusion if both the following requirements are satisfied: a) its optical properties are not compatible with silicates (whose optical properties are well known at the considered wavelengths); b) its reflectance is higher at the larger wavelengths and lower at the smallest ones. The second requirement arises from [8] and from our simulation results. The latter were obtained by means of a software package which models the interaction between the electromagnetic radiation and the sample.

Some regions which could host npFe have been identified (fig. 2).

The next step will be to perform a more quantitative analysis. Hence, it is necessary to obtain images absolutely calibrated in reflectance: This can be achieved by collecting optical images of a sample possessing known reflectance (i.e. an aluminium film). This process is currently in progress.

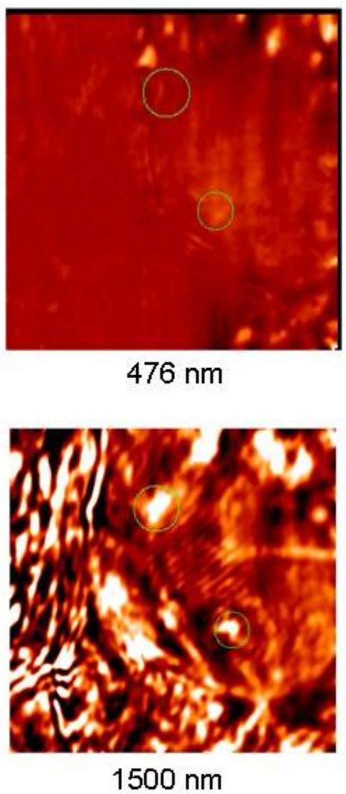

Figure 2: Reflectance images obtained at 476 nm and 1500 nm of a sample of Ordinary Chondrite. Regions contained in the green circles can host metallic inclusions. It can be noted that reflectance of these regions is higher at the larger wavelength and lower at the smaller one.

Once both morphological and optical properties of metallic inclusions have been known, it is possible to compare them with morphological and optical properties of npFe produced by different SW processes.

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