



Publication Year	2016
Acceptance in OA	2020-05-22T15:40:33Z
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Authors	Manzari, P., DE ANGELIS, Simone, DE SANCTIS, MARIA CRISTINA
Handle	http://hdl.handle.net/20.500.12386/25105

Hyperspectral micro-imaging in the Visible-Infrared range of enstatite chondrite: preliminary investigation on thin section of Sahara 97072

P.Manzari¹, S.De Angelis¹, M.C.De Sanctis¹, Space Astrophysics and Planetology Institute - INAF-IAPS, via Fosso del Cavaliere, 100 – 00133, Rome (Italy)

(paola.manzari@iaps.inaf.it)

Introduction. The analyses of the minute quantities of meteorites and the samples returned from next space missions makes it vital to develop non-invasive or semi-invasive diagnostic research methods to study these materials. The reasons stand not only in the preservation of sample of extraterrestrial material, but also for opening the possibilities to investigate the same sample by new technologies developed in time for comparing and interpreting old data at the light of new data.

The present study focused on the spectral analyses of an enstatite chondrite EH3, Sahara 97072 previously investigated by [1]. Enstatite chondrites have important implications for constraining conditions in the early solar system and for understanding the evolution of the Earth and other inner planets. They are among the most reduced solar system materials as reflected in their mineral compositions and assemblages. In fact, they are characterized by a highly reduced mineralogy that is dominated by nearly pure enstatite, with lesser Fe-Ni metal (kamacite) and Fe sulfide (troilite). It has been suggested that Mg and Ca sulfides could contribute to Mercury's low reflectance, given the high abundance of sulfur and apparent correlations among S, Mg, and Ca (Nittler et al. 2011; Weider et al. 2012). Given the lack of meteorites that sample the surface of Mercury, spectral studies of meteorites with reduced mineral assemblage like EC could be useful for interpreting Mercury remote sensed data. The objective of this study focused on the capability of the Spectral Imaging (SPIM) facility at INAF-IAPS, Rome [2,3] to perform spectral analysis (range 0.4-5 micron) on thin section.

Instrument setup. The imaging spectrometer installed in SPIM is a spare of the spectrometer on Dawn spacecraft [4]. It works in the 0.22-5.05 μm spectral range, with a spatial resolution of 38x38 μm on the target. Two bidimensional focal plane arrays, one for the visible between 0.22 and 1.05 μm (spectral resolution of 2 nm) and one for the IR between 0.95 and 5.05 μm (spectral resolution of 12 nm) allow to obtaining the spectral coverage. Thanks to the alignment of the bidimensional focal planes with the spectrometer's slit axis (the slit is 9x0.038 mm in size), it is possible to acquire the target's image of 0.038x9 mm at different wavelengths. Hyperspectral cubes are built up observing the target moving on a scanning sample holder. Two lamps provide the light sources for the VIS channel (120 W) and the IR channel (108 W). The illuminating system supports two distinct optical fibres for the VIS and IR channel; the illumination and emission angles are 30° and 0° with respect to the normal to the sample surface, respectively.

Sample description. As a preliminary test we collect data on a small area near the edge of the sample (fig.1). Previously investigations by optical microscopy and scanning electron microscopy (fig. 2-3) on this thin section showed a composition dominated by radial pyroxene, porphyritic pyroxene and porphyritic pyroxene-olivine chondrules within the kamacite-sulfide matrix. Minor phases occur like troilite, oldhamite, niningerite, schreibersite (Manzari, PhD thesis, 2010) within the matrix and the chondrules. The pyroxene is always enstatitic and the olivine is forsteritic.



Fig.1. RGB image acquired with SPIM on the thin section (R:0.70 μm , G:0.53 μm , B:0.44 μm).

Analysis and results. Data were collected on a region that comprehend fusion crust of this meteorite to sample also alteration minerals. Since the minerals more abundant in enstatite chondrites show their characteristic absorptions in the visible-near infrared range, only this range is showed. This area is dominated by a big olivine-pyroxene chondrule, named S2AC1, hosting troilite, niningerite and a metal-sulfide matrix. The spectral analysis of the thin section showed occurrences of four spectral classes: enstatite (fig.1), forsterite (fig.2), sulfides (fig.3), but also oxides and hydro-oxides (fig.4).

In all the spectra occur 1.9 μm feature related to water content in the sample. Furthermore, iron oxides and hydro-oxides strongly affect the resulting spectra of these different mineralogical phases.

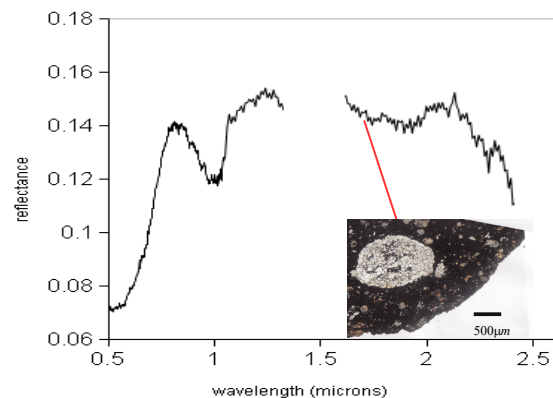


Fig.2. Spectrum of chondrule rim grain (x141y23). The

composition of chondrule rim is enstatite. The spectrum is dominated by features near $1\ \mu\text{m}$ and $2\ \mu\text{m}$ typical of that of enstatite. Data in 1.4 and $2.5\ \mu\text{m}$ regions have been removed because of overlapping with instrumental artifacts.

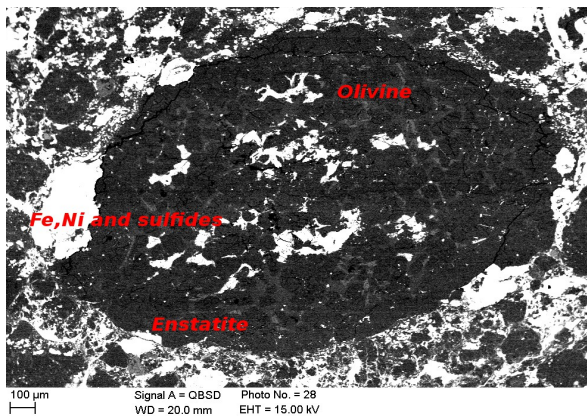


Fig.3. Backscattered electron image of S2AC1 chondrule showing sulfide phases in chondrule core.

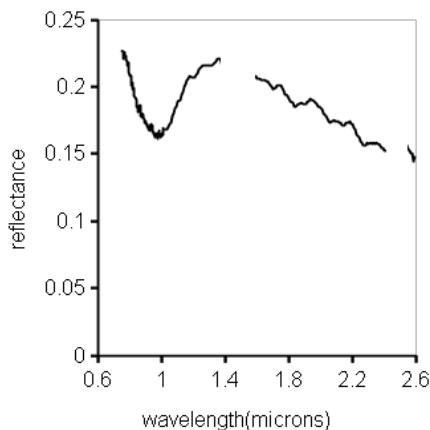


Fig.4. Pixel spectrum of olivine (x109y37). The spectrum is dominated by features near $1\ \mu\text{m}$. The other spectral features are related to water absorption. Data in 1.4 and $2.5\ \mu\text{m}$ regions have been removed because of overlapping with instrumental artifacts.

Other pixels, such as x154y17 in fig.5 showed almost featureless profiles with an exception related to a strong absorption near $0.65\ \mu\text{m}$ that could correspond to the occurrence of niningerite grains (fig.3) [5]. Among the sulfides, totally featureless spectra were found that are related to troilite occurrence.

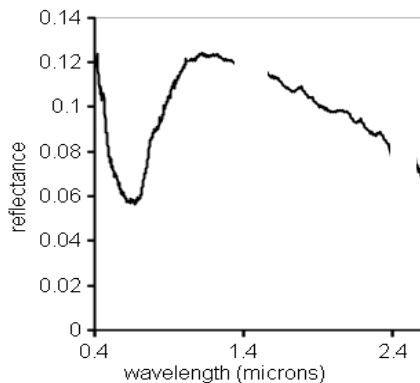


Fig.5. Pixel spectrum of sulfide grain (x109y37), probably MgS [5]. Data in 1.4 and $2.5\ \mu\text{m}$ regions have been removed because of overlapping with instrumental artifacts.

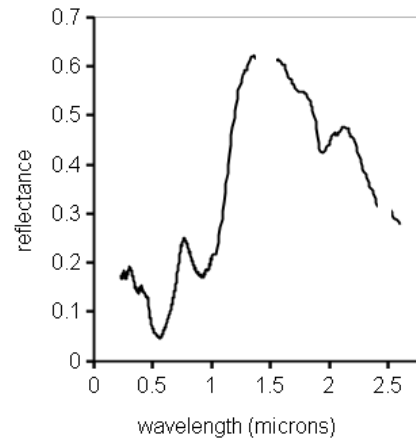


Fig.6. Pixel spectrum of goethite formed by terrestrial weathering in areas near to the fusion crust.

Conclusions and future work. The preliminary results of this investigation demonstrate that capability of the SPIM facility to act as a spectral microscope, that in turns means an easier comparison with other analytical methods. Further investigations are on going on areas far from the fusion crust of this chondrite for a more closer identification of the different sulfides that occur in this chondrite.

References. [1] P. Manzari, PhD thesis, 2010 [2] Coradini A., et al., EPSC Abstracts, EPSC-DPS2011-1043, vol.6, 2001. [3] De Angelis S., et al., Rev. Sci. Instrum., 86, 093101, 2015. [4] De Sanctis M.C., et al., Space Sci. Rev., 163, 329-369, 2011. [5] Domingue D. L. et al., Space Science Reviews, 181, 121-214, 2014.

Acknowledgements. We thanks ASI – Italian Space Agency for supporting this work.