MID-INFRARED REFLECTANCE SPECTROSCOPY OF CALCIUM-ALUMINIUM-RICH INCLUSIONS: A WAY TO DETECT PRIMITIVE ASTEROIDS? M. Melwani Daswani[1], A. Morlok[2, 3], S. D. Wolters[1] and M. M. Grady[1, 2]. [1]Department of Physical Sciences, The Open University, Milton Keynes MK7 6AA, UK (mohit.melwani-daswani@open.ac.uk) [2]Department of Mineralogy, The Natural History Museum, Cromwell Road, London SW7 5BD, UK [3]Institut für Planetologie, Wilhelm-Klemm-Strasse 10, 48149 Münster, Germany.

Introduction: Astronomical infrared spectra allow determining the mineralogical composition of the surfaces of planetary bodies. Most remote sensing studies of asteroids so far were made in the visible and near-infrared range. The mid-infrared range (3 - 25 micron) was so far neglected due to technical difficulties in obtaining spectra of these bodies. Only recently a larger amount of surface spectra in the mid-IR range was obtained for Trojan asteroids [e.g. 1].

IR laboratory measurements of minerals and rocks are necessary to interpret these remote sensing IR data. There are abundant emission and reflectance studies available for pure minerals and bulk meteorites [e.g. 2]. Detailed studies of the single components like chondrules or CAI in primitive meteorites are scarce [3]. This is a significant gap, since the clear identification of these components would allow placing the observed bodies much clearer into an evolutionary sequence.

Of special interest among the components of primitive meteorites are the calcium-aluminum-rich inclusions (CAIs), because they are formed very early in the solar system. Furthermore, findings of a mid-IR transmission/absorption study of CAI were that minute changes in refractory minerals due to aqueous alteration can lead to significant changes in the spectral features of spinel/hercynite [3]. So the identification of these components would allow to identify the most primitive and pristine asteroids in our Solar System. This would be also of advantage e.g. for targeting future sample return missions (e.g. Marco Polo).

Samples and Techniques: We used samples of three carbonaceous chondrites: Allende (CV3.3) (BM1969,148), Vigarano (CV3.3) (BM1911,174), and Ornans (CO3.3) (BM1985,M149) (BM is the catalogue number of the Natural History Museum in London, UK). The CAI were characterized using an SEM/EDX [3]. Figure 1 shows the important phases in a CAI from Vigarano.

In-situ specular reflectance measurements were made using a Perkin Elmer Autoimage FTIR microscope at The Natural History Museum in London.

Spectra were measured in the mid-infrared range at 2.5 µm to 16.0 µm wavelength with a resolution of 4 cm^{-1} using a Perkin Elmer AutoIMAGE FT-IR microscope. Further details can be found in Morlok et al. [4]. Spectra are presented in normalized reflectance R. The spectrum of each sample is an average of 50 scans. In this study we focus on the mineralogical and observationally relevant spectral range from 8 µm to 16 µm.

For the identification of spectral features in the CAI spectra, we used laboratory data of pure mineral phases from the The Keck/NASA RELAB database (Brown University) and the ASTER spectra library (Johns Hopkins University).

Here we present Mid-IR data from asteroids 253 Mathilde (SMASSII C-type), 243 Ida (S-type), and 1917 Cuyo (Sl-type). The asteroids were targeted in low resolution mode by the Infrared Spectrograph on the Spitzer Space Telescope in Staring Mode and cover a range wavelength range of ~5.3 – 36 µm. The data were reduced in the SMART package [5] and flux spectra were extracted and joined for each of the exposures using the Advanced Optimal Extraction [6]. Physical parameters of the asteroids were derived by fitting a Near Earth Asteroid Thermal Model (NEATM) to the flux. To produce emissivity plots, the absolute flux obtained by optimal extraction were divided by the modelled flux. To reduce noise, sample points were binned in fixed intervals for each of the wavelength ranges in low resolution.

Features identified in the CAI were directly compared to the emissivity spectra of the asteroids. The reflectance spectra of the meteorite samples were also converted to emissivity applying Kirchhoff's law to qualitatively compare the features between asteroids and samples.

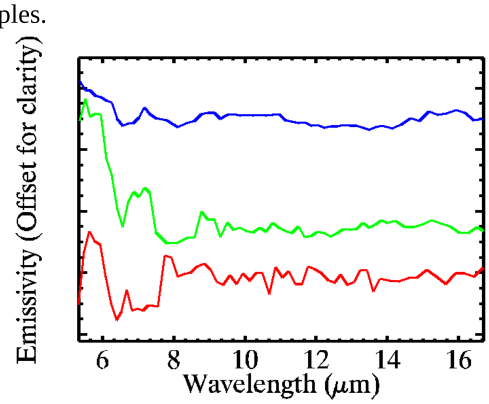

Fig. 3. Emissivity spectra obtained by Spitzer from asteroids. Blue: Mathilde, green: Ida, red: Cuyo.

Results: Figure 2 shows a series of spectra from a Vigarano CAI. They cover some of the typical CAI components analyzed in this study.

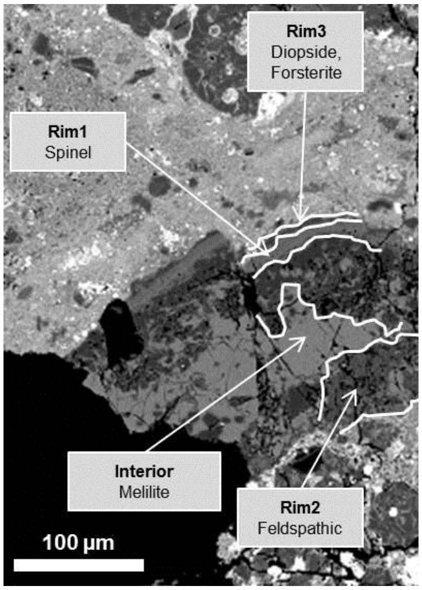

Fig. 1. SEM/BSE image of a CAI from Vigarano.

The CAI (Fig. 1, 2) shows a Wark-Lovering Rim around a melilite-rich interior [3]. No appropriate reference for melilite was available, comparison to a transmission study of the same material [3] indicate that the bands at 9.8, 10.2, 11.0, 11.7, 12.4 and 14.1 micron are probably all melilite features. The spinel-rich layer Rim 1 (Fig. 2) shows a strong spinel band at ~14.2 micron. Also, minor melilite bands occur between 9.8 and 11 microns. Anorthite-rich layer rim 2 (Fig. 2) is dominated by a strong feature at 10.3 microns. A shoulder at 10.7 is similar to the strongest anorthite band in this region. However, the 10.3 micron band does not occur in this strength in anorthite. Since the material is not stoichiometric anorthite (e.g. high Mg content), this indicates an unaccounted mineral phase or an amorphous phase. The generally featureless spectrum would support this point.

Layer Rim 3a (Fig. 2) is pyroxene–rich, shown by bands at 9.4, 10.3, 11 and 15.1 microns, similar to diopside. RIM 3b (Fig. 2) also shows olivine features, the strong intensity of the 11 micron feature confirms the olivine content by the main feature of this phase at ~11 micron [7]. Furthermore, the broad feature at 13.4 points towards spinel [8].

Spitzer emissivity spectra exhibit features that differ between the asteroids (Fig. 3). Statistical analysis will be performed shortly to deconvolute a possible signature coming from CAI. For now, a qualitative study of the spectra show that though the primitive asteroid Mathilde is nearly featureless, Cuyo and Ida contain features in the wavelengths indicative of pyroxene and olivine in Vigarano.

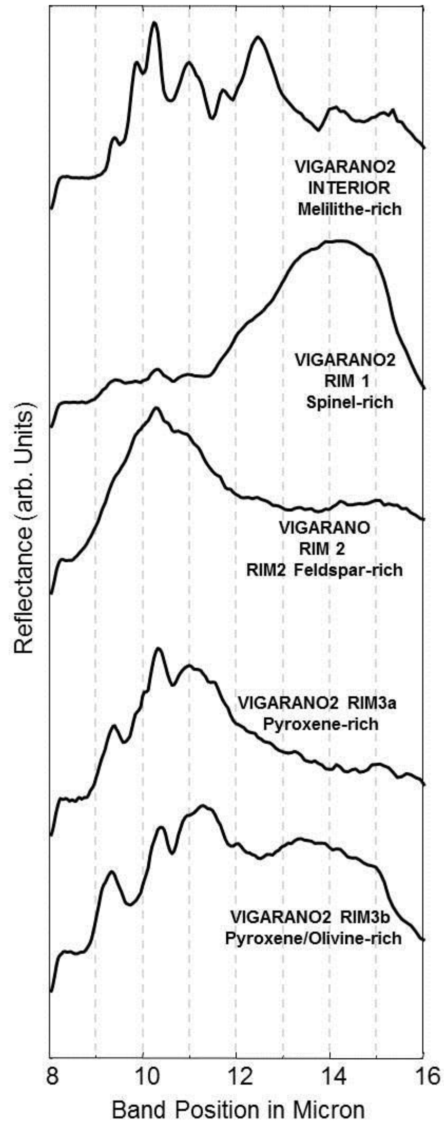

Fig. 2. Mid-infrared spectra from a Vigarano CAI with a Wark-Lovering rim (Fig.2). The spectra are presented in relative reflectance.

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