THE FIRST 2-50 µm INFRARED SPECTRUM OF AN INTERPLANETARY DUST PARTICLE (IDP).

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Introduction: IDPs (<50 µm diameter) from comets and asteroids are collected in the stratosphere. Some of them are among the most chemically and isotopically primitive meteoritic materials available for laboratory investigation. Studies of IDPs provide insight about grain dynamics in the early Solar System and presolar interstellar and circumstellar environments. Processes like grain condensation, chemical and physical evolution, and grain density distribution in the proto-planetary disk can be investigated through studies of IDPs. It is now also possible to directly compare the properties of IDPs with those of dust around other young stars using infrared (IR) spectral properties. Most of the vibrational band structures associated with astronomical dust are in the IR wavelength range. The direct comparison of laboratory and astronomical dust data defines the new discipline of "astromineralogy".

The Infrared Space Observatory (ISO) collected spectral data from several young stars surrounded by dust [see e.g. 1,2], and the Space Infrared Telescope Facility (SIRTF) to be launched in January 2003 will implement two large programs dedicated to the observation of dust around young stars [3,4]. In order to meaningfully compare spacecraft IR data with laboratory IR data from IDPs it is highly desirable to obtain the data over a similar spectral range. Essentially all of the existing IR spectroscopic data on IDPs has been collected over the 2-25µm wavelength range, in contrast to the ISO data that covers the 2.4-200µm range and the SIRTF data that will span the 5-40µm range. Two problems have hindered acquisition of spectral data beyond 25µm from IDPs, the small size of individual IDPs relative to the wavelength of the incident radiation, and the lack of detectors sensitive beyond ~25µm. Here we report a significant improvement in our ability to compare laboratory data from IDPs with observational data from ISO and SIRTF by showing the first IR spectrum of an IDP taken over the important "mineral fingerprint" region of 20-50µm.

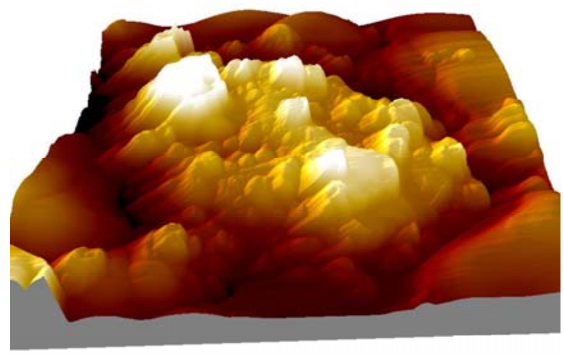

Figure 1: AFM image of IDP L2036 V25. Image size is 10x10 µm; maximum height difference is 3 µm.

Experimental procedures: Figure 1 shows an atomic force microscope (AFM) of IDP L2036-V25 (diameter +/- 10µm) pressed onto a CsI window. The high IR transparency of CsI allows us to also measure the infrared absorption properties of L2036-V25 out to extended wavelengths, but its small size demands the use of a high-brightness synchrotron light source. Unfortunately the detectors on IR microspectrophotometers at synchrotron facilities are sensitive to ~25µm. Recently the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory installed a He-cooled bolometer and a custom made Si-beamsplitter, which enabled us to go far beyond the usual 25µm. Using this setup we have obtained an IR spectrum of L2036-V25. Two sets of spectra were acquired, one covering the 2.5-28µm range (with the normal Ge:Cu detector) and the other the 22-60µm range (with the He-cooled bolometer). The spectral overlap between the two measurements is such that only a very slight multiplication factor was necessary to splice the two regions together (see Fig 2). Beyond 50µm the signal-to-noise becomes too low. Figure 2 is the IR transmission spectrum of the IDP measured out to 50µm (200 cm^{-1}).

The absorption spectrum of L2036-V25 is similar to the emission spectrum of comet Hale Bopp obtained by ISO [5] (Fig. 2). The similarity is not unexpected since highly porous, fragile IDPs like L2036-V25 are suspected to be from comets or "comet-like" outer asteroids.

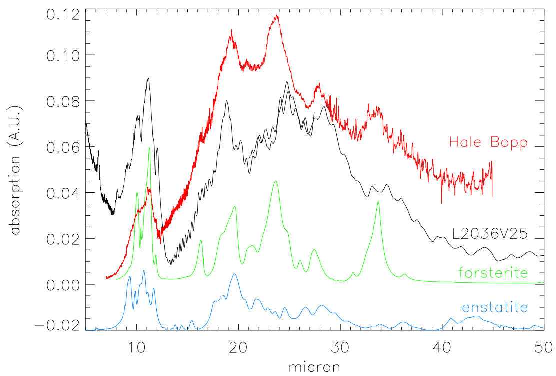

Figure 2: The infrared absorption of IDP L2036-V25 (black line) compared to the absorption profile of forsterite (green line) and enstatite (blue line). Also plotted is the ISO (Infrared Space Observatory) spectrum of the comet Hale Bopp[5] (red line).

The strongest features in the spectrum of IDP L2036-V25 at 11.2, 24.8 and 28.6µm are due to olivine. Also weaker features at 10.1, 12.1, 16.4, 20.1 and 34.9µm are present and support this identification (see also Figure 2). Most pyroxene features blend with the olivine features, but the weak feature at 9.1µm, the strength of the feature at 28.6µm and a possible feature around 43.5µm give hint for the presence of pyroxenes. Most weak features of olivine and pyroxene are unfortunately hidden in residual spectral fringing. A very strong feature at 18.7µm is likely be caused by a metal-oxide, for example secondary magnetite (Fe_3O_4) formed by heating during atmospheric entry. The peak positions of the features, especially the ones at the longer wavelengths (>20µm), provide information about the Mg/Fe ratio of the minerals [e.g. 6]. The features suggest an Mg/Fe ratio of about 3:1 for the olivine crystals. The lack of strong features in the IDP spectrum attributed to the pyroxenes makes the determination of the Mg/Fe ratio more difficult, but it seems that the Mg/Fe ratio is at least 3:1 and maybe even higher. N.B. The peak positions in the ISO spectrum of Hale Bopp are consistent with pure Mg-olivine, i.e. forsterite. There is no evidence for pyroxenes in the ISO spectrum of Hale Bopp, but ground based spectra show the presence of pyroxenes also with a very high Mg-content, i.e. the Mg/Fe ratio is larger than 9:1. If the identification is right, the 18.7µm feature in the IDP spectrum corresponds to an iron-magnesium-oxide with an Mg/Fe ratio of about 2:3

Discussion and Conclusions: We have demonstrated that it is now possible to obtain infrared spectra of individual IDPs over a spectral range extending out to ~50µm. Silicate minerals like olivine and pyroxene can be unambiguously distinguished and their Mg/Fe contents can be estimated. The above results are encouraging because IDP L2036-V25 was prepared as a calibration standard for the AFM "micro imaging dust analyzing system" (MIDAS) onboard Rosetta and not as a sample optimized for IR spectroscopy. We anticipate that dedicated IR sample preparation techniques will minimize fringing effects and recovery of IDPs from CsI substrates followed by more detailed analyses in the TEM (transmission electron microscope) will significantly improve data quality and interpretation. Our ultimate goal is to routinely measure electron-transparent thin sections rather than whole IDPs over the extended spectral range, assuming such thin samples can yield sufficient signal-to-noise at longer wavelengths for meaningful interpretation.

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