UV and Visible Wavelength Reflectance Spectroscopy of Aerogel and of Stardust Grains

Conference or Workshop Item

UV AND VISIBLE WAVELENGTH REFLECTANCE SPECTROSCOPY OF AEROGEL AND OF STARDUST GRAINS:

C. D. Fernandes[1], John C. Bridges[1] and Monica M. Grady[1], [1]PSSRI, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK (c.d.fernandes@open.ac.uk).

Introduction: We have measured the reflectance spectrum between 200 and 800 nm of a sample returned from comet Wild 2 by the Stardust mission. The sample was extracted from track C2054,0,35,1,0 and pressed into gold foil. Aims of the work were to determine (i) whether the UV-Vis spectrum of a grain could be measured through aerogel; (ii) whether there were any variations between spectra within the sample; (iii) the composition of the Stardust grains, and (iv) whether the Stardust grains within the sample contained any organic material.

Method: We used an optical microspectrophotometer system supplied by Craic Technologies. The system is based on a Leica DMR microscope fitted with Cassegrain reflecting mirrors. The light source is a 75W xenon lamp. The square aperture through which light was focused can be varied in size with selected magnification, from 10 x 10 µm to 2 x 2 µm.

The system allows non-destructive measurement of spectra across the UV-Visible range in both transmittance and reflectance modes. Samples can be analysed as powders, single grains or polished mounts. Measurements were made over the range 200 to 800 nm at a spectral resolution of 2 nm. At the start of every period of data collection, the system was calibrated using a NIST white standard. We report reflectance data relative to this standard, rather than absolute reflectance.

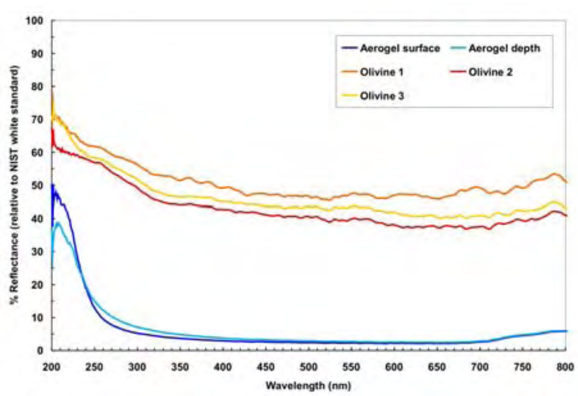

Figure 1: Reflectance spectra of aerogel and a terrestrial synthetic olivine (Fo_{70}), given as a percentage relative to the NIST white standard.

Results: Prior to analyzing the sample, we took spectra from a range of minerals [1], including olivine. Spectra from unpolished grains of olivine (Fo_{70}) sprinkled onto an SEM stub are shown in Figure 1, along with data from aerogel. The aerogel was similar density to that used in the Stardust mission. Data were acquired from a broken fragment of aerogel, which has a very flat and featureless spectrum, apart from a rise in reflectivity below 250 nm at the UV end of the wavelength range. The olivine has a higher reflectivity than aerogel, and although the spectra show many fine-scale features, these are likely to be present because of the unpolished nature of the grains.

Data from grain C2054,0,35,1,0 (given the local designation 'Brickhill', after the street on which the Open University is located) are shown in Figure 2. Spectra were acquired from 6 locations across the sample; the spectra were all similar to each other, but different from both the aerogel and olivine spectra. The SEM images show that the grain was embedded within aerogel: the only elemental data acquired from the grain were for Au, Si and O; no Mg, Fe or Ca. The reflectance spectra from Brickhill were much brighter than from the laboratory aerogel fragment, possibly because the grains (and surrounding aerogel) had been flattened and were therefore more reflective. Even so, the shape of the spectra were not simply that of aerogel, although they did exhibit the sharp rise below 250 nm shown by the control aerogel. Between 250 – 500 nm, the spectra reach a broad, flat minimum; above 500 nm, there is a monotonic rise in reflectance up to 800 nm. This is not shown by aerogel or olivine, or any other silicates (including anhydrous minerals such as pyroxene, and feldspar, or hydrated silicates such as saponite or montmorillonite) or oxides (spinel, hibonite) [1].

Discussion: Near UV-Vis spectroscopy concerns the excitation of valence electrons within an atom, where transitions between energy levels result in absorptions (or emission) of energy at wavelengths below ~ 1 µm. The transitions can either be within the molecular orbitals formed during bonding (most significant for organic compounds), or by charge transfer between cations (inorganic compounds). So, for example, bonding in unsaturated organic species (C=C, C≡C, C=O, etc) involves electrons in the p molecular orbitals, and there are many transitions that can take place giving features at wavelengths between 200nm and ~ 1 µm. In inorganic compounds, electronic transitions are dominated by charge transfer effects. These effects are particularly significant in mineral species, where the 'cages' of SiO_4^{4-} are held together by arrays of metal ions (Mg^{2+}; Ca^{2+}, etc). Charge transfer effects generally yield spectra at slightly higher wavelengths than the molecular orbital effect, producing features in the visible part of the spectrum. Given this information about how spectra are produced, we can infer that (a) the aerogel contains unsaturated organic compounds; (b) there are inorganic compounds present in which charge transfer is occurring between metal ions. At the moment, it is difficult to be any more precise about the results. We have shown, though, that spectra can be acquired from areas down to 2 µm across. We have also shown that although spectra can be acquired from a grain through the aerogel, if we wish to acquire better quality spectra, particularly at the lowest wavelengths where we would hope to see the signature of organic compounds, then as much aerogel as possible should be removed from the cometary material.

Reference: [1] Fernandes et al. (2006) *Int. J. Astrobiol.* (in press).

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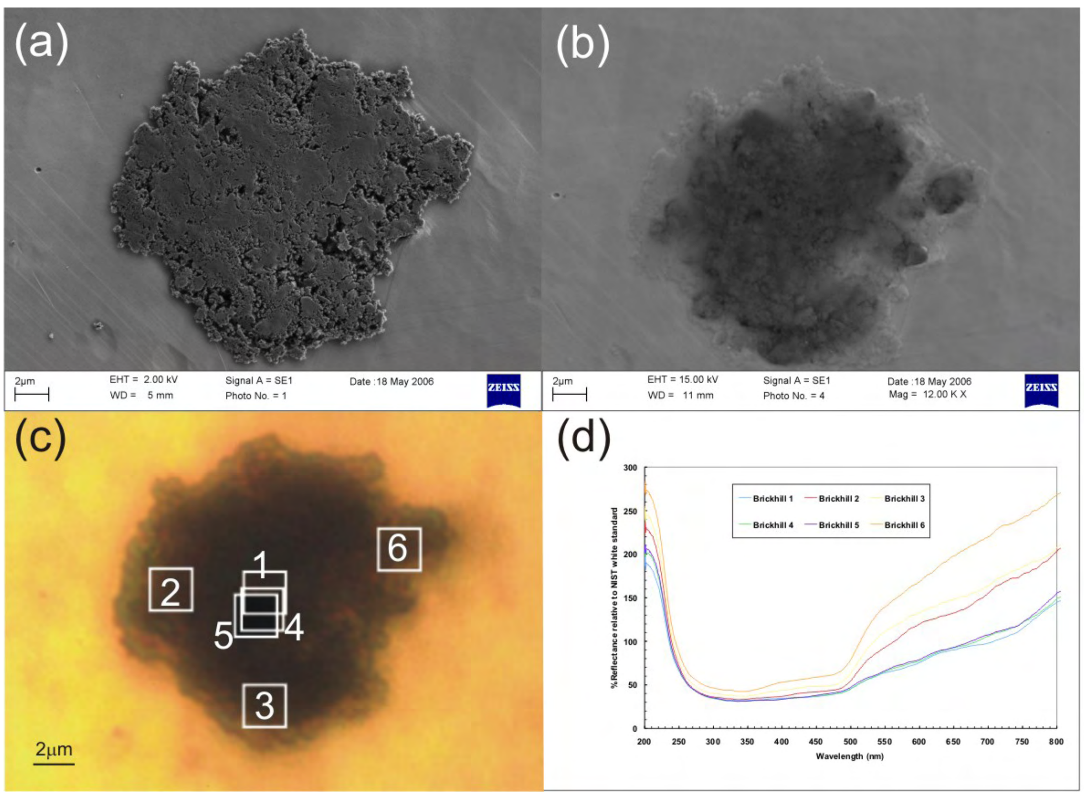

Figure 2: The Brickhill grain pressed into gold foil (a) secondary electron image (SEI), taken at low acceleration voltage (2keV); (b) SEI at 15keV. The difference between (a) and (b) shows the extent to which the fragmented cometary grain is completely embedded within and surrounded by aerogel. (c) reflected light image. The white squares are the shape and size of the microspectrophotometer aperture, and indicate the areas from which reflectance spectra were obtained. Each square is 2 x 2 µm across. (d) reflectance spectra of Brickhill, releative to the NIST white standard.