

NEAR – FAR IR SPECTRA OF REFRACTORY MINERALS RELEVANT TO COMETS C. A. Hibbitts¹, S. Jauhari¹, S. Hagaman¹, C. Lisse¹, ¹JHU-APL, 11100 Johns Hopkins Rd., Laurel, Md., 20723, karl.hibbitts@jhuapl.edu

Introduction: The Spitzer Space Telescope observed the mid-IR (~5-40 μm) spectra of ejecta from the hypervelocity impact of the Deep Impact projectile with comet 9P/Tempel-1. Spectral modeling demonstrates that there are abundant minerals present in the ejecta including Ca/Fe/Mg-rich silicates, carbonates, phyllosilicates, water ice, amorphous carbon, and sulfides [1,2]. Precise mineralogical identifications are somewhat hampered by the lack of spectral measurements, particularly of transmission and of the associated derived absorption coefficient, for these materials in the 5 – 40 μm range over which Spitzer is sensitive. Additionally, a broader compositional range of carbonates, sulfides, and clays are needed to be measured over this full 5-40- μm spectral range.

Here, we present our results for transmission spectra from ~ 2 – 200 μm and derived absorption constants for these and other materials relevant to comets, including pyrrhotite, other sulfides, carbonates, and several clay minerals. This follows on initial results presented at DPS2008 [3]. Measuring the transmission of materials over the full spectral range sensitive by Spitzer requires the use of KBr pellets for measurements from 5 – 24 μm , and for the 20 – 40 μm range of Spitzer, polyethylene pellets. We have successfully acquired transmission spectra of these minerals ground to micron and sub-micron sizes from 2 – 200- μm . Transmission measurements of sub-micron sulfides are particularly difficult to obtain because the minerals oxidize rapidly upon grinding and subsequent handling unless special care is taken, although we have demonstrated initial success in obtaining spectra of unoxidized sulfides.

Laboratory Procedures and Results: Measurement success has been achieved only after a continual process of refining our sample preparation methodology. We have used transmission spectroscopy, measuring the absorption of light by the sample that is contained in an optically neutral matrix, to derive the imaginary component of the complex index of refraction. For the mid-infrared (20 - 200 μm), the matrix is ultra-high molecular weight polyethylene (PE). KBr is used for the near infrared (1.5 - 24 μm). Transmission is obtained by dividing a sample-bearing pellet by a sample-free blank.

Sample and pellet preparation, and measurement are similar for both the near and mid-IR. It is essential that the sample grain size is smaller than the wavelength of light to reduce scattering. We achieve micron

to sub-micron particle size by powdering ~ 3 mg of sample in a slurry with acetone using a McCrone micronizing mill. Using acetone instead of water for the slurry reduces the oxidization of sulfides. The sample slurry is then dried in an N₂-purged oven. Using this procedure there is little evidence of oxidation in the below spectra of pyrrhotite, though pyrite may have oxidized somewhat (Figure 1 – mid-far IR only).

It is also essential to obtain a uniform mixture of the sample and matrix (either KBr or PE) in order to obtain a uniform pellet - no clumping of sample - which can result in large effective particle sizes, or self-shadowing, both of which would result in lowered absorption. Also, because many of these samples are nearly opaque at these wavelengths (especially the sulfides) a very small amount of sample is required to avoid optical saturation. We have found that for mid and far IR measurements using PE, it is necessary that the pellet contain < 1% of sample by mass, for a pellet with a total mass of ~ 120 mg. Mixture uniformity is achieved by thorough mixing of the sample and matrix via a dental amalgamator in which we shake a mixture of the PE and sample in a stainless steel vial.

The pellet is finally formed using a hydraulic press and 13mm die. After placing the sample mixture in the die, it is evacuated for 5 min. Then the die is pressed to 18000 psi while heating with a heat gun to ~ 120C (note: melting point of PE ~ 138C) for about 4 min. and pressure is continued for an additional 6 min. A blank PE pellet should be translucent and a sample-bearing pellet should be uniformly dark.

Infrared spectra were taken using an N₂-purged Bruker Vertex-70 FTIR at 1 cm⁻¹ resolution (for KBr) and 2 cm⁻¹ resolution for PE pellets (Figures 1 and 2). The two spectra overlap from ~ 20 to 24 μm ; and one can see agreement is good in both figures, after a single multiplicative scaling of the far-IR spectrum to the NIR spectrum to account for the different amounts of sample used in the two pellets. Sometimes, a small multiplicative offset remains which we currently attribute to imprecise mass measurements. That error will be mitigated with a use of an improved balance.

Conclusions: We have demonstrated an effective procedure for obtaining NIR through far IR spectra of carbonates, silicates, and to some extent sulfides. Procedural improvements (such as more sample preparation under an N₂ purge and more accurate mass measurements) are being implemented. Strong spectral features occur from the NIR to about 40 μm in sulfides, to

about 60 μm in carbonates, and to beyond 100 μm in clays and may be important for interpreting Spitzer, Herschel [4], and other longwave IR measurements of comets, dust clouds, etc.

Acknowledgments: We are grateful for support of this project from DDAP grant # NNX07AG01G.

References:

[1] A'Hearn et al. (2005) *Science*, 310, 258-264. [2] Lisse et al., 2006; [3] Jauhari et al. (2008), *DPS2008*; [4] Peale et al. (2008)

