INFRARED SPECTRAL NANOSCOPY: A NEW TOOL FOR THE CHARACTERIZATION OF PLANETARY MATERIALS

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Introduction: The spatial resolution of conventional mid-infrared (λ=25-2.5 μm) spectroscopic techniques used in the analysis of planetary materials is generally set by the wavelength of light (~ λ). Given that many planetary materials exhibit chemical heterogeneity at the sub-micron scale, the ability to map the distribution of functional groups at the sub-micron scale is highly desired.

Scanning Scattering Near-field Infrared Microscope (S-SNIM): We have recently implemented a laboratory instrument that is capable of mapping IR functional groups with ~ 10 nanometer spatial resolution [1]. This capability is provided by the use of an atomic force microscope (AFM) with a metalized AFM tip (radius of curvature ~10 nm), an IR laser, and an IR detection system. The interaction of the metalized tip with the incident electromagnetic radiation of frequency ω ($=2\pi c/\lambda$) creates an oscillating charge distribution on the AFM tip which in turn induces the formation of a "mirror dipole" charge distribution in the material directly underneath the AFM tip. This charge distribution and its amplitude are sensitive functions of both the tip-sample distance and the dielectric properties ($n(\omega)$) of the sample directly underneath the AFM tip, thus providing the basis of infrared nanoscopy [2].

Functional Group Capabilities: We have recently demonstrated the ability of our instrument to distinguish between Si-Si and Si-O at the 10 nm spatial scale. In addition, we have shown that the spectral response of Embed-812, a commonly used sample preparation reagent (epoxy) for planetary samples, is "flat" at and near the SiO_2 resonance at ~1100 cm^{-1}, allowing us to discriminate between SiO_2 nanospheres embedded in Embed-812 [1].

Using a second tunable Quantum Cascade (QC) laser at λ~4.5 microns (Daylight Solutions), we have demonstrated the feasibility of performing broadband IR spectral imaging from (4.5-10 microns) using the same optical setup. This broadband approach has allowed us evaluate the scattering properties of both amorphous and crystalline SiO_2. We have confirmed that, as theoretically expected, these have distinct broadband spectral signatures and that the scattered IR amplitude are accurately described by models of the tip-sample interaction. These results are the first experimental demonstration of the ability of scanning-near-field imaging to distinguish between crystalline and amorphous SiO_2.

Near term goals for this instrument development program include assessment of in-situ mapping capabilities in planetary materials and extensions of IR nanoscopic mapping to other functional groups. We emphasize that this analytical technique, because of its reliance on IR photons rather than high energy (keV) electrons, is expected to be non-destructive. Future work will focus on characterizing to what extent, if any, volatile functional groups may be altered as a result of exposure to QC IR laser radiation.

References: [1] Andreev G. *et al.*, in prep. [2] Taubner, T. et al. 2002. *Journal of Microscopy* 210:311 (2002).