Nano-FTIR Studies of a Cometary Dust grain and Murchison Meteorite

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Infrared (IR) spectroscopy is considered the “gold standard” for chemical identification, providing us with perhaps the most direct connection between chemical compounds found in the laboratory and those in astrophysical environments such as molecular clouds. However, the use of infrared spectroscopy for characterizing functional group distributions in planetary materials at nano-scales has heretofore been non-existent. Other techniques, such as XANES and micro-Raman are capable of limited functional group mapping at the tens to hundreds of nanometers, however, their use is restricted by access to synchrotron beamlines or their sample altering effects. This situation is particularly dire for studies of unique micron-sized natural samples such as those brought back by sample return missions like NASA’s Stardust mission and the recent JAXA Hayabusa mission, interplanetary dust particles (IDPs), and atmospheric aerosol particles, since these samples and/or their heterogeneity are typically comparable in size (or smaller) to the diffraction limited beamsizes of IR beamlines.

Here, we describe a general nano-FTIR imaging and analysis technique that we have developed which circumvents the well-known diffraction limit heretofore hampering chemical mapping of micron-scale samples using IR radiation. We show for the first time that 1) near-field scattering spectra obtained from an AFM tip illuminated with focused laser radiation can be used to obtain the equivalent of FTIR absorption spectra at spatial scales much smaller than the wavelength of IR radiation used, 2) this technique can record subtle shifts in cation concentrations as evidenced by changes in the frequencies of phonons at sub-micron scales, and 3) our technique can identify regions of crystalline and semi-crystalline materials using IR spectra alone as demonstrated in our analysis of a cometary dust grain. This work has implications for interpretations of astronomical observations and adds a new technique to the suite available for non-destructive characterization of valuable terrestrial and extraterrestrial samples.