NANOSCALE IMAGING ANALYSIS OF ORGANIC-MINERAL ASSOCIATION IN THE MURCHISON METEORITE BY NANOIR.

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Introduction: Organic matter in carbonaceous chondrites is reported to be associated with clay minerals by scanning electron microscope (SEM) observation with osmium labeling, which may have had important trapping and possibly catalytic roles in the evolution of organics in the early solar system [1]. Fourier transform infrared (FTIR) microspectroscopy is useful for characterizing both organic and mineral structures, but its spatial resolution is limited to ~1 µm. We have been applied near-field infrared (NFIR) microspectroscopy to chondrite samples to permit infrared spectral imaging beyond the optical diffraction limit [2,3], but the near-field signals were too weak to detect without any contributions of scattered IR. Here we report IR imaging analyses of the Murchison meteorite by atomic force microscopy-based infrared spectroscopy (AFM-IR), “NanoIR2” (Anasys Instruments) that provides IR imaging with spatial resolution far below conventional optical diffraction limits.

Methods: The Murchison meteorite power was embedded in sulfur and ultramicrotomed into roughly 70-90 nm-thick. The sections were placed on a ZnS plate and sulfur was sublimated off by mild heating before NanoIR analysis. NanoIR consists of a tunable infrared laser that is focused onto a sample in the proximity of a probe tip from an atomic force microscope [e.g., 4]. When light is absorbed by the sample, the temperature increase causes a thermal expansion of the sample. This thermal expansion drives the cantilever into oscillation. The oscillation amplitude of the cantilever is directly proportional to the amount of light absorbed.

Results and Discussion: NanoIR measurements of the Murchison meteorite is presented in Fig 1. IR absorption spectra (Fig. 1a,b) were obtained at locations indicated in Fig. 1c. Fig 1d-g shows 3 x 3 µm IR absorption images with the IR source tuned to 3400 cm^{-1} corresponding to OH, 2920 cm^{-1} corresponding to aliphatic CH, 1150 cm^{-1} corresponding to sulfates, and 1000 cm^{-1} corresponding to SiO. A sulfate area was surrounded by silicates. Some part of the silicates (lower right in Fig. 1g) overwrapped with OH-rich area that indicated phyllosilicates. The aliphatic CH area (Fig. 1e) overwrapped on the phyllosilicate area. It is consistent with the previous IR imaging measurements of carbonaceous chondrites that showed the association of organic matter and phyllosilicates [e.g., 2,3,5], but with much higher spatial resolution. The sulfate area ~1.5 µm was clearly distinguished from surrounding silicate area and did not overlap with organics. It is the first time to show the organic-mineral associations including fine scale overlapping of the organic matter and phyllosilicates in less than 100 nm spatial resolution.

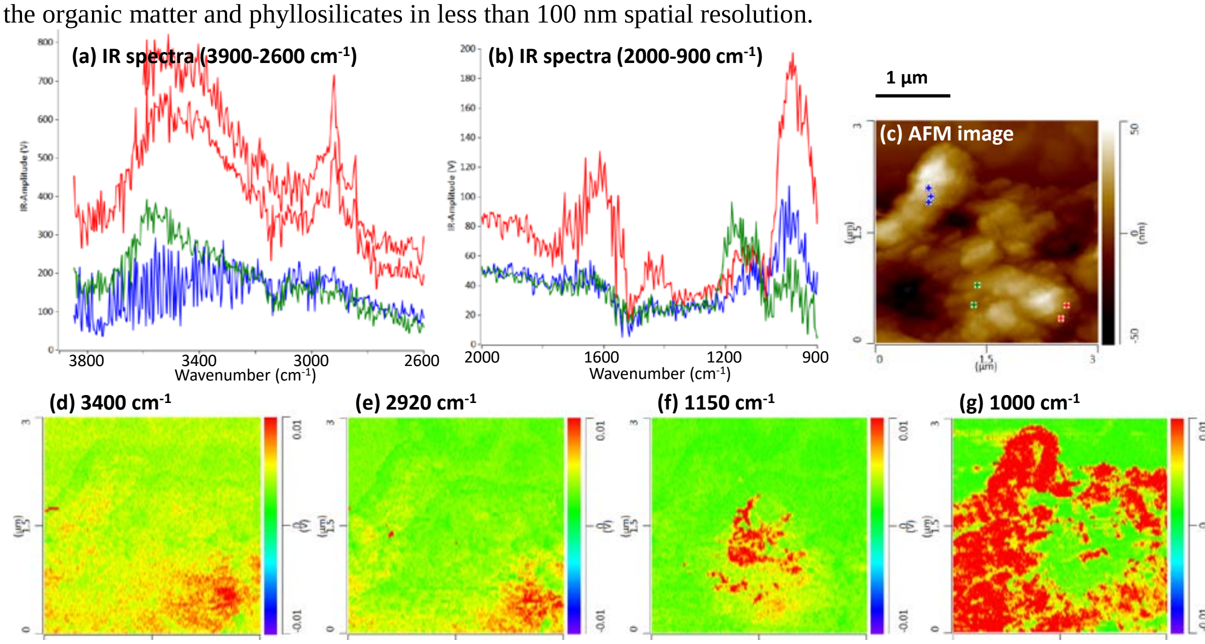

Fig. 1: NanoIR measurements of the Murchison meteorite.

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