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Applications Collection

Nanoanalysis of Inorganic Materials

IR spectroscopy of oxides, minerals & ceramics at 10 nm scale

NANOSCALE ANALYTICS
advanced imaging & spectroscopy

Recommended Product: *IR*-neaSCOPE+s

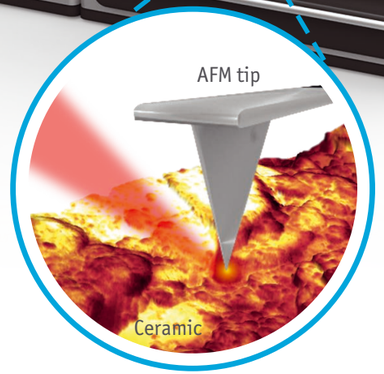
IR-neaSCOPE+s is designed for providing complete chemical analysis and field mapping at 10 nm spatial resolution. It utilizes state-of-the-art technologies of near-field microscopy to measure both IR absorption and reflectivity, as well as amplitude and phase of local electromagnetic fields.

It provides IR nanoimaging, point-spectroscopy and hyperspectral analysis with CW illumination sources as well as nano-FTIR spectroscopy using broadband lasers and synchrotron sources. *IR*-neaSCOPE+s excels in both organic and inorganic materials analysis providing the broadest range of demonstrated applications and novel near-field methodologies such as quantitative s-SNOM or sub-surface measurements.

IR-neaSCOPE+s

- universal performance on all samples
  → by detecting simultaneous absorption & reflection
- highest throughput without compromise on quality
  → using fastest & most reliable s-SNOM technology
- unlimited configuration options
  → combining multi-port beam-path design with best-patented technologies

Enables nanoscale infrared (IR) imaging and nano-FTIR spectroscopy.



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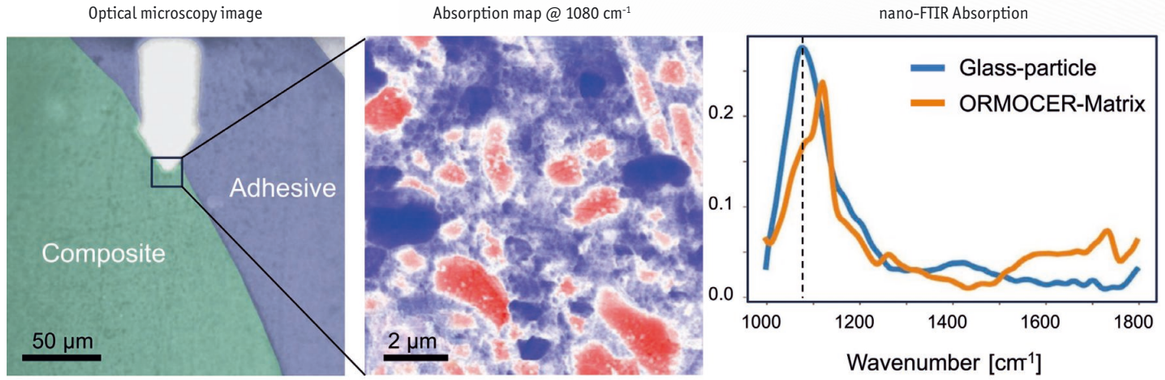
Nanoscale interface analysis of dental filling for high-performance adhesives

neaSCOPE utilizes tapping-mode AFM and low radiation for non-invasive nanoimaging and nano-FTIR spectroscopy, achieving sub-10 nm resolution with high sensitivity, regardless of whether the material is of organic or inorganic nature.



Dental morphology and chemical composition

The s-SNOM absorption map image at 1080 cm^{-1} highlights glass particles within the ORMOCER matrix near the composite-adhesive interface, which are easily identifiable in the high-resolution optical inspection image. nano-FTIR spectroscopy provides accurate chemical analysis of organic polymers and inorganic ceramic domains, essential for the development of dental fillers with enhanced mechanical strength, chemical resistance, and flexibility.

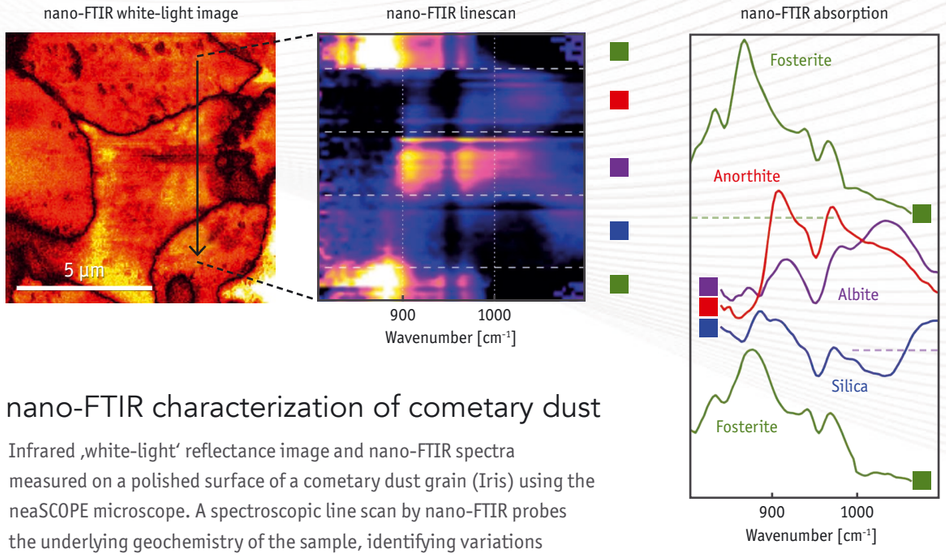
IR-neaSCOPE^{+s} allows nanoscopic assessment of dental materials

S. Amarie et al., *Beilstein J. Nanotechnol. 2012, 3, 312.*

M. Beddoe et al., *Acta Biomater. 168, 309-322 (2013)*

Chemical structure of chondrites and comets

Broadband nano-FTIR spectroscopy and hyperspectral imaging perform nanoscale chemical analysis of any AFM-ready sample. The nano-FTIR spectra can be directly compared to standard databases, allowing for straightforward chemical identification.



nano-FTIR characterization of cometary dust

Infrared ‚white-light' reflectance image and nano-FTIR spectra measured on a polished surface of a cometary dust grain (Iris) using the neaSCOPE microscope. A spectroscopic line scan by nano-FTIR probes the underlying geochemistry of the sample, identifying variations observed in the reflectance image as crystalline and amorphous materials coexisting at the micron scale. These findings are indicative of a rapid cooling from a melt and provide evidence for a high temperature formation of comets.

nano-FTIR provides evidence for common high-temperature formation history of chondrites and comets

F. Natalio et al., *Chemical Geology 2021, 582, 120427.*

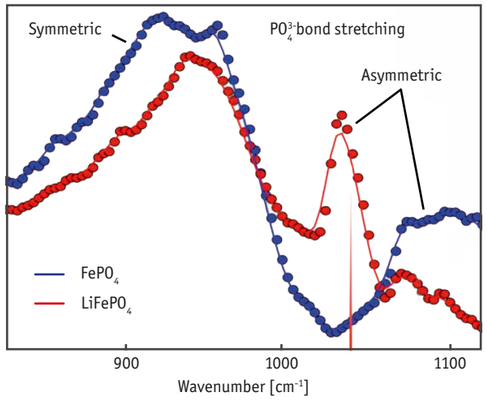
J. M. Young et al., *JGR Planets 2022, 127, e2021JE007166.*

G. Domingues et al., *Nature Comm. 2014, 5, 5445.*

Direct observation of delithiation in Li-ion battery electrode materials at the nanoscale

nano-FTIR spectroscopy and nanoimaging allow for monitoring chemical processes with 10 nm spatial resolution and unique capability of performing nondestructive subsurface tomography of crystal orientation.

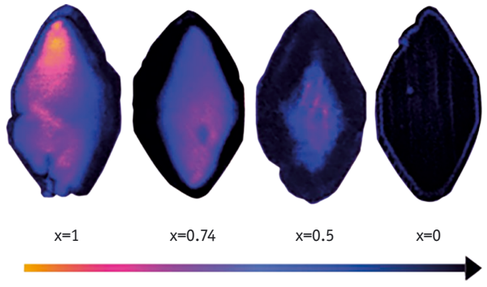
nano-FTIR reflectance



Delithiation of $LiFePO_4$

nano-FTIR spectroscopy and IR nanoscopy of Li-ion battery electrode material provide direct evidence for the coexistence of $LiFePO_4$ and $FePO_4$ phases in partially delithiated microcrystals. Surrounded by a $FePO_4$ shell, the diamond-shaped $LiFePO_4$ inner core gradually shrinks in size upon delithiation of the Lithium iron phosphate crystal. This data reveals information about the charge & discharge performance of conventional Li-ion electrode materials and relates their electrochemical efficiency to material design.

Li concentration maps in Li_xFePO_4 microcrystals



NANO LETTERS — M. A. Huber et al., *Nano Lett. 2016, 16, 1421.*

APPLIED MATERIALS & INTERFACES — A. Dopilika et al., *ACS Appl Mater Interfaces. 2023, 15(5), 6755.*

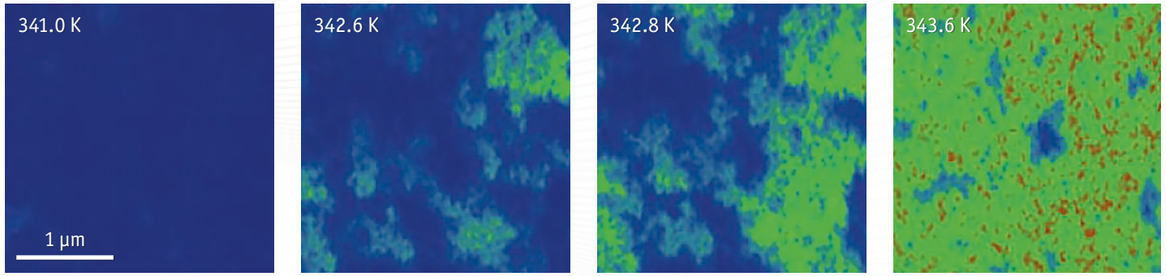
nature COMMUNICATIONS — Xin He et al., *Nature Comm. 2022, 13, 1398.*

neaSCOPE enables development of efficient energy storage materials

Real-space mapping of the insulator-to-metal transitions

IR nanoimaging directly maps sample conductivity at the nanoscale, providing strong contrast between metallic and insulating phases. The method is completely non-invasive and free of any artifacts due to mechanical or thermal crosstalk.

Reflectance image



Insulator to metal phase transition in VO_2

IR nanoscopy images recorded at representative sample temperatures during the insulator-to-metal phase transition of vanadium dioxide (VO_2). Upon heating, nanoscale metallic regions nucleate (green), then grow with increasing temperature, and eventually connect. Such measurements provide new insights into VO_2 by disentangling structural & electronic properties and reveal information about the influence of local strain or defects on the localization of electrons.

NANO LETTERS — M. A. Huber et al., *Nano Lett. 2016, 16, 1421.*

nature COMMUNICATIONS — S. Gilbert Corder et al., *Nature Comm. 2017, 8, 2262.*

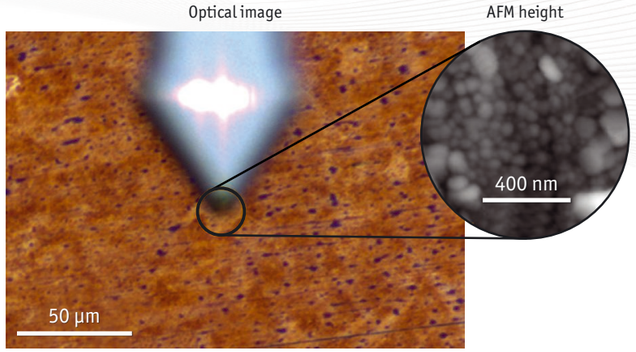
AIP Applied Physics Letters — M. Lewin et al., *Appl. Phys. Lett. 2015, 107, 151902.*

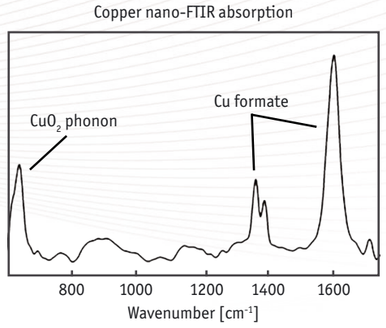
Science — M. Qazilbash et al., *Science 2007, 318, 1750.*

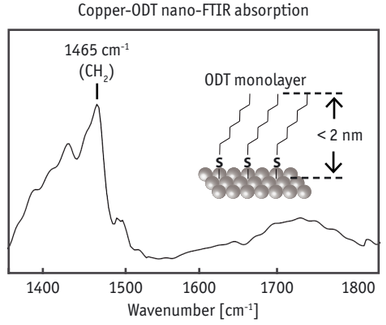
IR nanoscopy provides fundamental insights into phase transitions in strongly correlated materials

Investigation of functional protective surface coatings

Patented nano-FTIR technology delivers broadband spectroscopy from the mid-IR to the visible at the 10 nanometer length scale. State-of-the-art interferometric detection provides ultra-high sensitivity and allows for reliable recording of artifact-free absorption and reflection spectra even from a single monolayer.







Copper surface corrosion

Optical and AFM images of corroded copper reveal nanoscale grains at the surface. Unmatched spectral bandwidth of nano-FTIR allowed chemical identification of the grains as corrosion products featuring strong absorbance from the CuO_2 phonon and Cu formate. Surface protection by Octadecanethiol (ODT) monolayer was tested as a corrosion inhibitor.
The ODT can be clearly identified by the CH_2 bending vibration and its functionality demonstrated by the absence of Cu formate peaks at 1600 cm^{-1}.

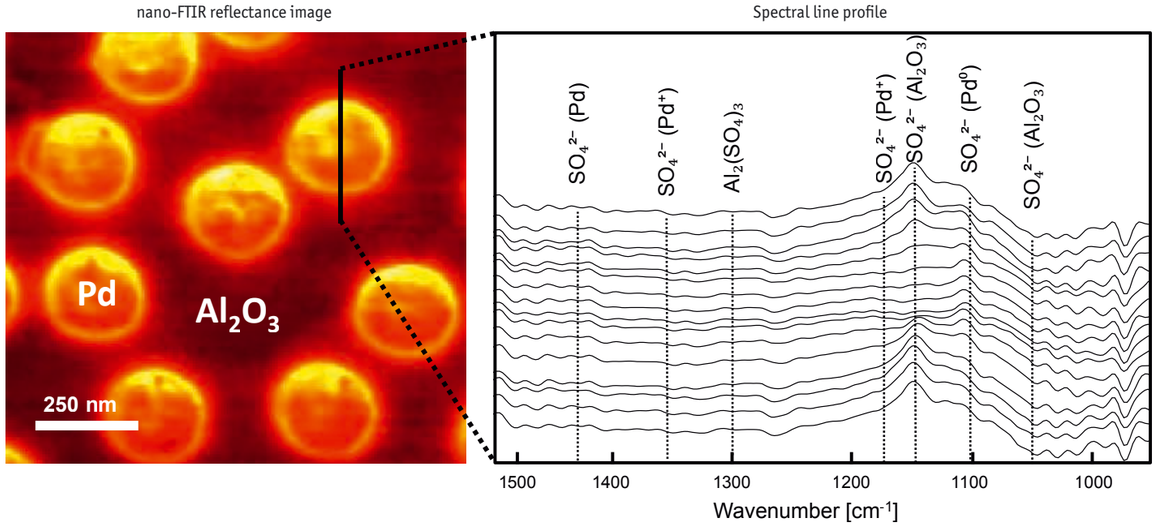
nano-FTIR enables analysis of single molecule layers

ELSEVIER W. Zhao et al., *Corrosion Science 2022, 195, 109995.*

ELSEVIER C. M. Johnson et al., *Corrosion Science 2016, 108, 60.*

Analysis of nanoscale catalytic reaction sites

nano-FTIR's ultimate sensitivity achieves accurate identification of highly localized adsorption sites on catalyst particles. It provides unique information on catalytic poisoning of metal/metal-oxide interfaces at nanometer-scale spatial resolution.



Sulfur-poisoning of Pd nanodisk

nano-FTIR reflectance image of Pd/Al_2O_3 allows for a rapid mapping of regions of different chemistry. nano-FTIR spectra revealed significant enhancement of sulfate adsorption on the Pd nanoparticles as evidenced by the 1150 cm^{-1} peak. This indicates sulfur poisoning of the catalyst and provides insights crucial for developing longer-lasting sulfur-resistant catalysts used in industrial processes like emission control and fuel cells.

nano-FTIR provide critical molecular-level insights on metal catalysts

J|A|C|S Say et al., J. Am. Chem. Soc. *144, 19, 8848–8860 (2022)*

JOURNAL OF CATALYSIS Yang et al., J. Catal. *387, 119-128 (2020)*

Other Applications realized with *IR*-neaSCOPE+s

nano-FTIR for Polymers

chemical characterization at the nanoscale

Nanocomposite polymers, multilayer thin films, nanofibers and other polymer nano-forms often offer new properties or enhanced performance compared to bulk materials, demanding tools for chemical analysis with nanoscale spatial resolution for their investigations. nano-FTIR and s-SNOM are two leading techniques for nanoscale chemical mapping and identification.

nano-FTIR for Biomaterials

nanoscale compositional and structural analysis

nano-FTIR can perform in-situ study of melanine in human hair for cosmetics treatment analysis. Shed light on bio-chemistry of cell membranes & improve efficiency of drug delivery. Analyze protein secondary structure in amyloid fibrils. And elucidate the nuclear organization of white-blood cells.

Nano-characterization of Semiconductors

free charge carrier profiling at 10 nm scale

IR and THz nanoimaging allows for direct analysis of charge carriers, providing detailed insights into device composition, doping levels, and carrier dynamics. This overview highlights applications in device engineering and failure analysis, including doping concentration mapping, real-time carrier dynamics in nanowires, correlative analysis of electronic devices, and studies of quantum effects in nanomaterials.

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