AFM-IR-Based Nanoscale Chemical Imaging

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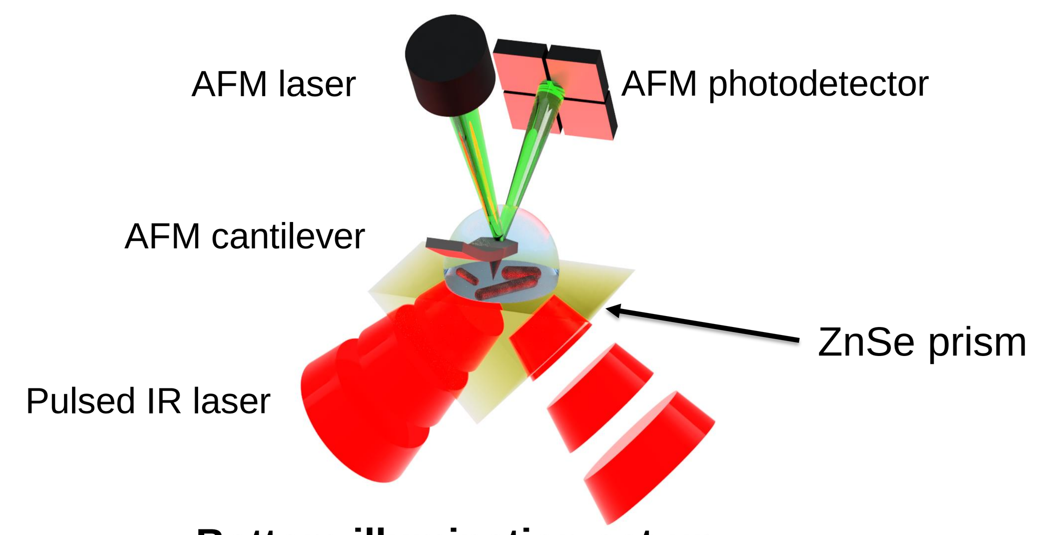
What is AFM-IR?

AFM-IR combines the spatial resolution of an Atomic Force Microscope with the chemical information provided by Mid-IR spectroscopy to achieve a resolution of 20 nm in optical spectroscopy.

An AFM-IR setup consists of a conventional AFM setup and a pulsed tunable laser.

Atomic Force Microscopy (AFM) is a type of scanning probe microscopy that generates a topographic image of the sample´s surface probing it. In an AFM the key player is a cantilever attached to a support on one end and with a tip (probe) in the other. Changes in the cantilever deflection are monitored by an optical lever [1].

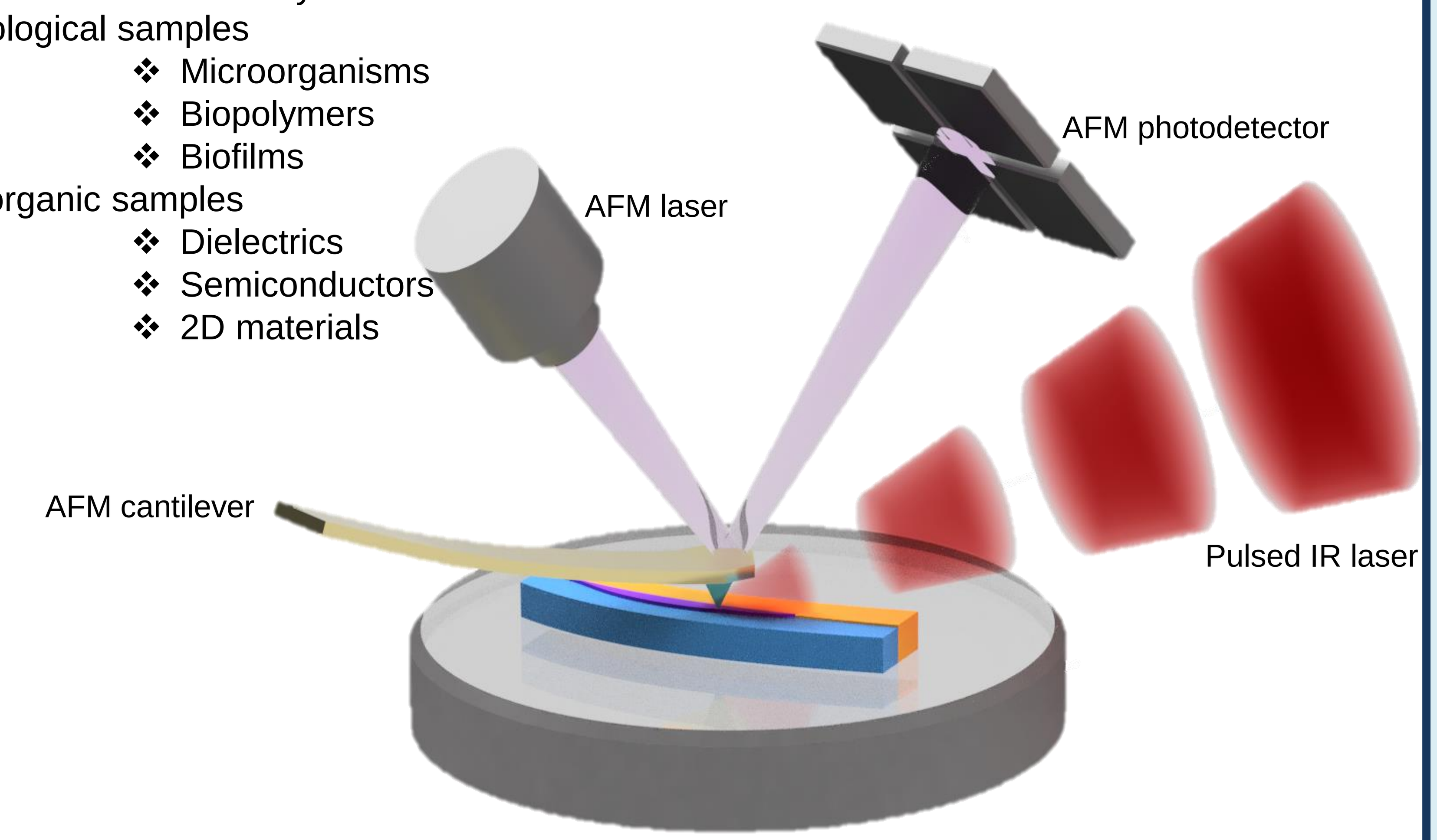
In an AFM-IR a pulsed IR laser is aimed at the sample area under the tip. IR absorption by the sample leads to local thermal expansion which is detected by the AFM cantilever. Since the thermal expansion is detected by the AFM cantilever in the near-field region, the spatial resolution of this technique is independent of the size of IR laser spot. This allows for optical imaging resolutions below the diffraction limit and up to 20 nm. As the IR laser sweeps through the chosen wavelengths, a photothermal induced resonance (PTIR) spectrum is obtained which is directly comparable to the more traditional far-field FTIR spectra. This technique thus yields qualitative and quantitative information on a functional group level which can be obtained in both ambient and liquid conditions [2].



Bottom-illumination set-up

AFM-IR finds broad applications in a wide variety of samples including:

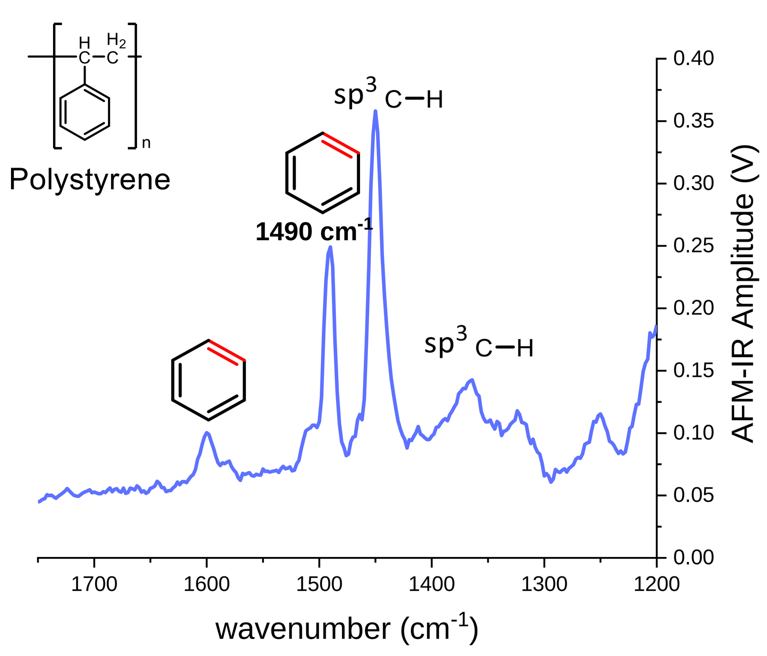
- Organic samples
  - Polymer films
  - Organic fibers
  - Monolayers
- Biological samples
  - Microorganisms
  - Biopolymers
  - Biofilms
- Inorganic samples
  - Dielectrics
  - Semiconductors
  - 2D materials

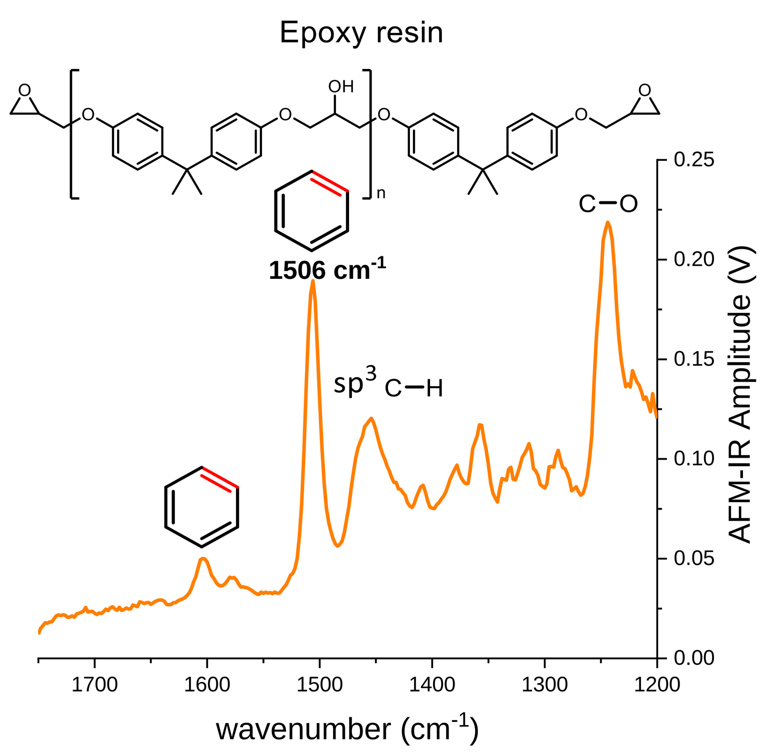


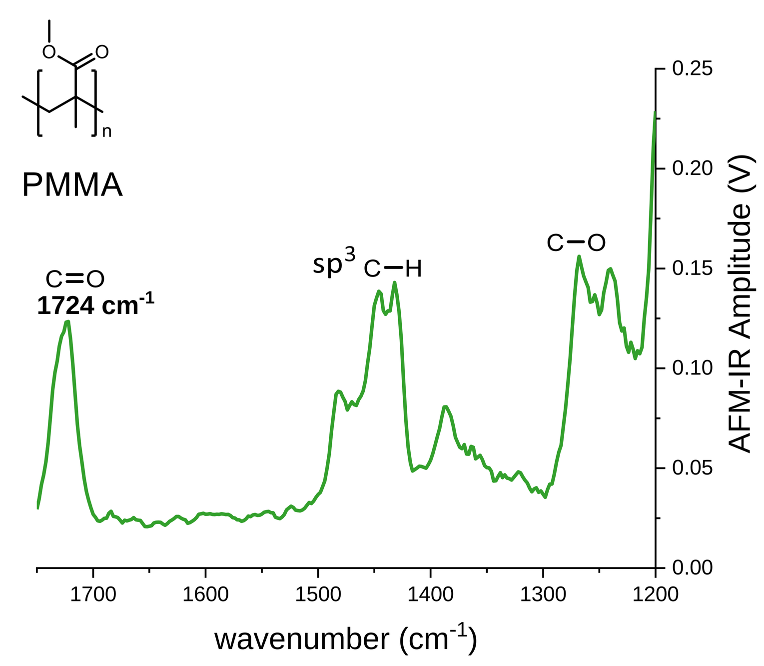
Top-illumination set-up

What information does it provide?

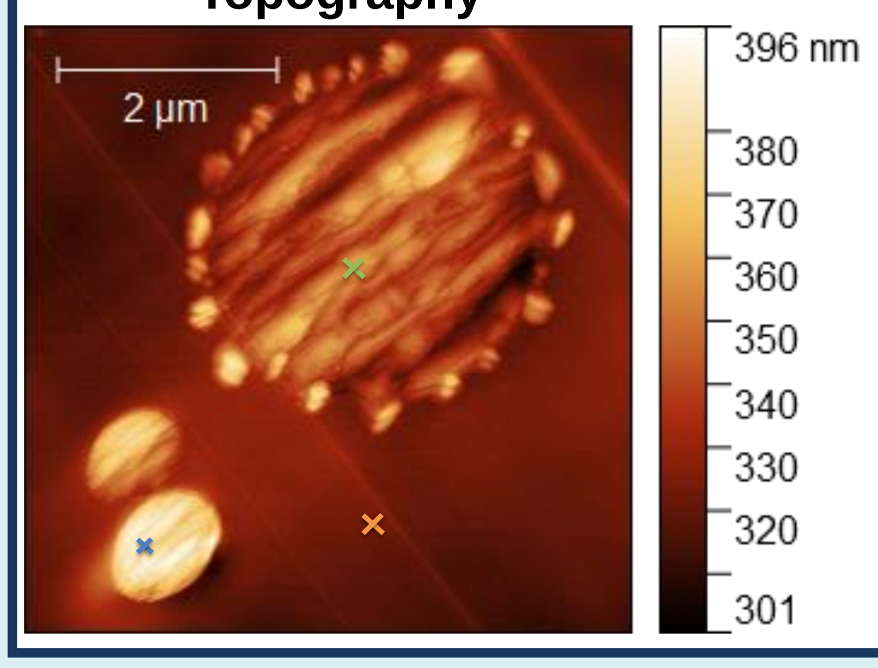
Tuning the laser wavelength while keeping the AFM tip in one location provides **local infrared spectra**. Scanning the AFM tip while keeping the laser wavelength constant provides **infrared absorption images** and AFM **topography images**, concurrently. **Infrared bands** can be assigned to vibrations of **functional groups** using well established **spectra-structure correlations**.



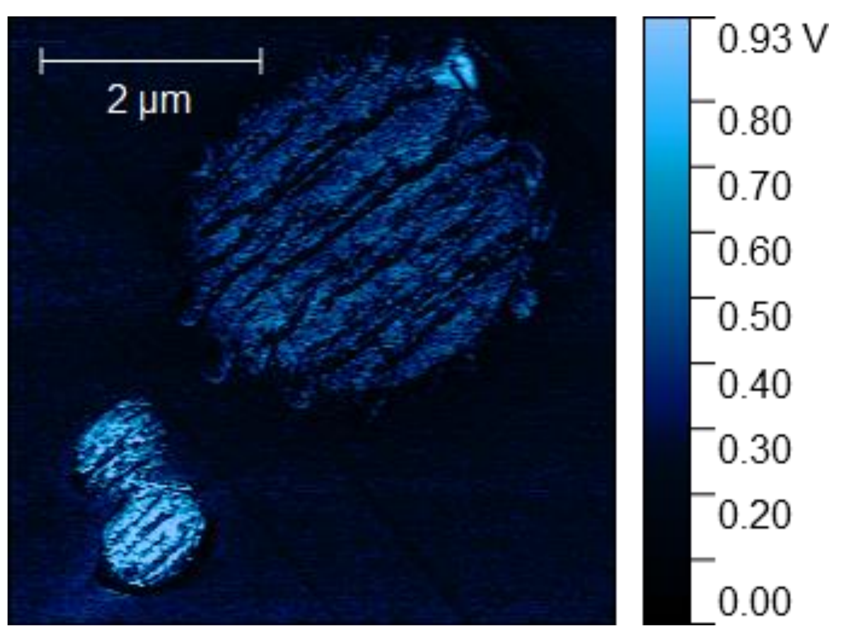




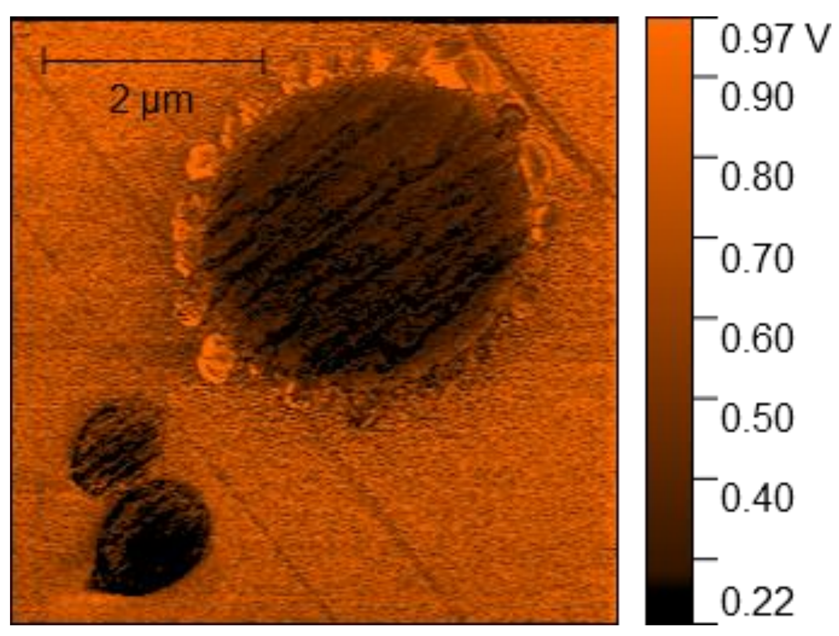
Topography



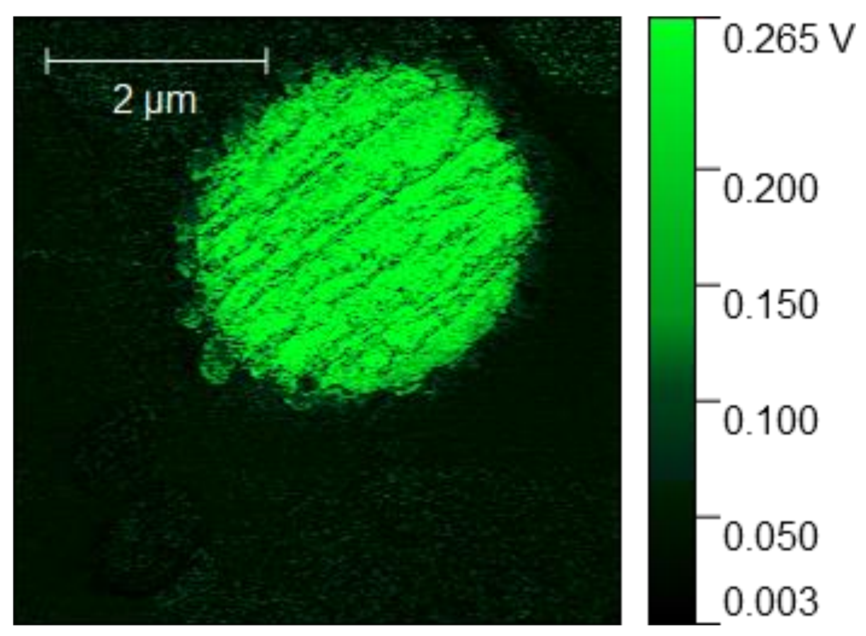
1490 cm–1



1506 cm–1



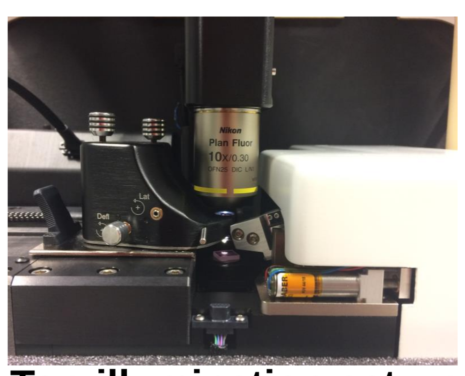
1724 cm–1



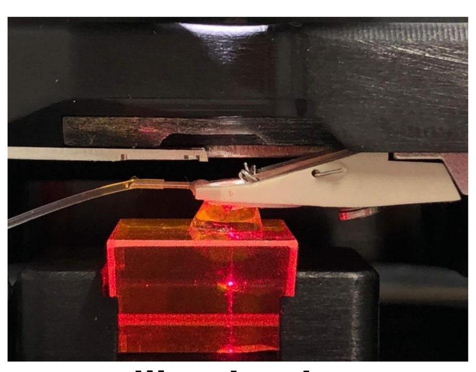
How does an AFM-IR look like?

- Anasys nanoIR 3 - top-illumination
  - Contact and Tapping mode AFM (<1 nm resolution) and AFM-IR (20 nm resolution), s-SNOM, scanning Joule expansion (SJEM).
- Anasys nanoIR 1 - bottom-illumination
- External cavity quantum cascade laser (EC-QCL) MIRcat from daylight solutions with a tuning range between 892-1758 and 2770 to 2930 cm^{-1}.

Anasys nanoIR 3



Top-illumination set-up



Bottom-illumination set-up

Outer view of EC-QCL MIRcat laser

Inner view of EC-QCL MIRcat laser

References

[1] Eaton, P.; West, P. Atomic Force Microscopy; Oxford University Press, 2010.

[2] Dazzi, A.; Prater, C. B. AFM-IR: Technology and Applications in Nanoscale Infrared Spectroscopy and Chemical Imaging. Chem. Rev. 2017, 117 (7), 5146–5173.

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