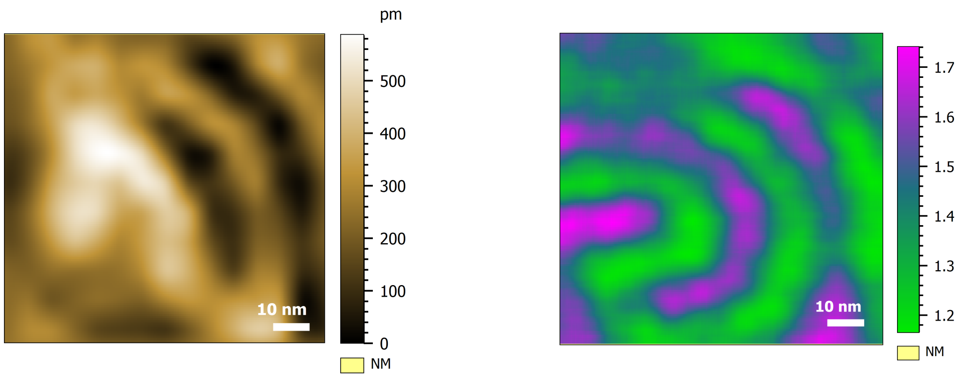
AFM-IR :
When Atomic Force Microscopy meets Infrared

Prof. Alexandre Dazzi, Dr. Ariane Deniset-Besseau, Dr. Jérémie Mathurin
Institut de Chimie Physique – Université Paris-Saclay – 91400 ORSAY-FRANCE

The invention and the development of the AFM-IR technique has begun because of a strong willing to go beyond the resolution and to push away the limit of infrared microscopy in the Free Electron Laser facility center in 2004 at Orsay. The idea of AFM-IR is based on the coupling between a tunable infrared laser and an AFM (Atomic Force Microscope). The sample is irradiated with a pulsed nanosecond tunable laser. If the IR laser is tuned to a wavenumber corresponding to sample absorption band, the absorbed light is directly transformed into heat. This fast heating results in a rapid thermal expansion localized only in the absorption region. The thermal expansion is then detected by the AFM tip as a shock inducing the cantilever to oscillate on its own resonance modes. The 4-quadrants detector of the AFM finally records these oscillations. Thus, the detection scheme is analogous to photo-acoustic spectroscopy, except that AFM tip and cantilever are used to detect and amplify the thermal expansion signal instead of a microphone in a gas cell. As oscillations amplitude detected by the AFM is rigorously proportional to the local absorption, recording for one tip position, the oscillations maximum as a function of laser wavenumber allow to build up local IR absorption spectra. These spectra use to correlate very well conventional IR absorption spectra collected by FT-IR spectroscopy. In addition, mapping oscillations amplitude versus tip position, for one specific wavenumber, gives a spatially resolved map of IR absorption that can be used to localize specific chemical functions[1].

After 16 years of development and improvement the AFM-IR technique becomes now a robust and efficient tool for infrared analysis at nanometer scale. The AFM-IR system can now work in contact or tapping mode[2,3,4] with sensitivity and resolution around 5-10 nm with spectra bandwidth about 0.5 cm^{-1} (linked to the pulsed laser properties). The domain of applications is really huge, covering many diverse research areas like materials science, life science, astrochemistry, and culture heritage.



Chemical analysis of PS-b-P2VP (copolymer polystyrene-block-poly (2-vinylpyridine)) by ICON-IR. (left) topography image. (right) Chemical map ratio of 1492/1588 cm^{-1} revealing the spatial distribution of PS (violet color) and P2VP (green color).

References:
[1] A. Dazzi, C.B. Prater, ***Chem. Rev.,*** 117, 7, 5146–5173, (2017).
[2] J. Mathurin et al., ***Analyst***, 143, 5940-5949, (2018).
[3] J. Mathurin et al. ***A&A***, 622 (2019).
[4] D. Kurouski et al., ***Chem. Soc. Rev.*** 49, 3315-3347, (2020).