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3D-AFM imaging of the liquid-solid interface at the nanometric scale

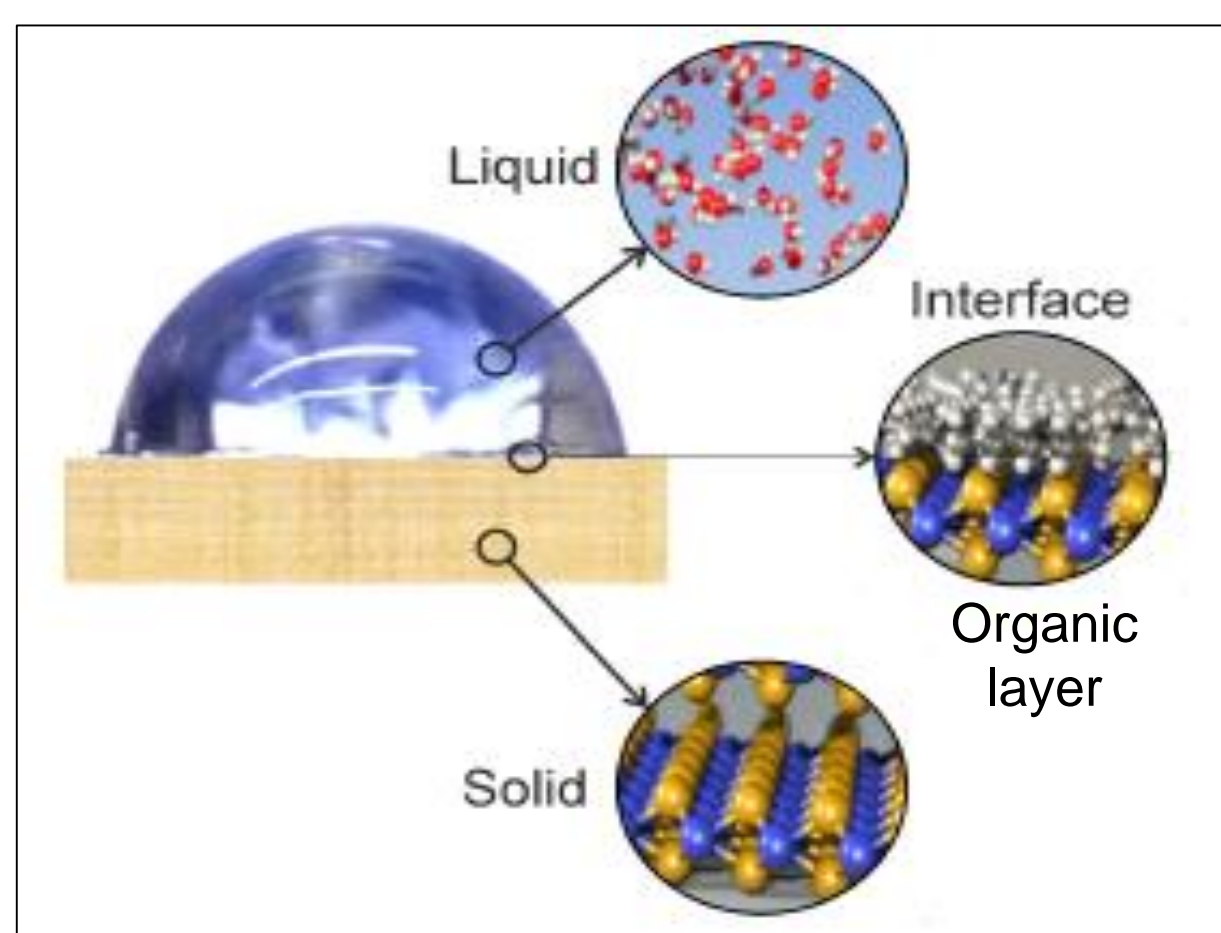
Characterization of gold/thiol layer/liquid interfaces by 1D-AFM, force spectroscopy, and 3D-AFM, a newly developed technique for interfacial characterization at the nanometric scale, in different liquid environments

Dahlia SAAD^{1,2}, Frédéric DUBREUIL¹, Magali PHANER-GOUTORBE²

¹ Univ Lyon, Ecole Centrale de Lyon, LTDS, UMR5513, 69134 Ecully Cedex, France

² Univ Lyon, Ecole Centrale de Lyon, CNRS, INSA Lyon, Université Claude Bernard Lyon 1, CPE Lyon, INL, UMR5270, 69134 Ecully Cedex, France
(dahlia.saad@ec-lyon.fr, magali.phaner@ec-lyon.fr, frederic.dubreuil@ec-lyon.fr)

Solid/Organic layer/liquid Interfaces



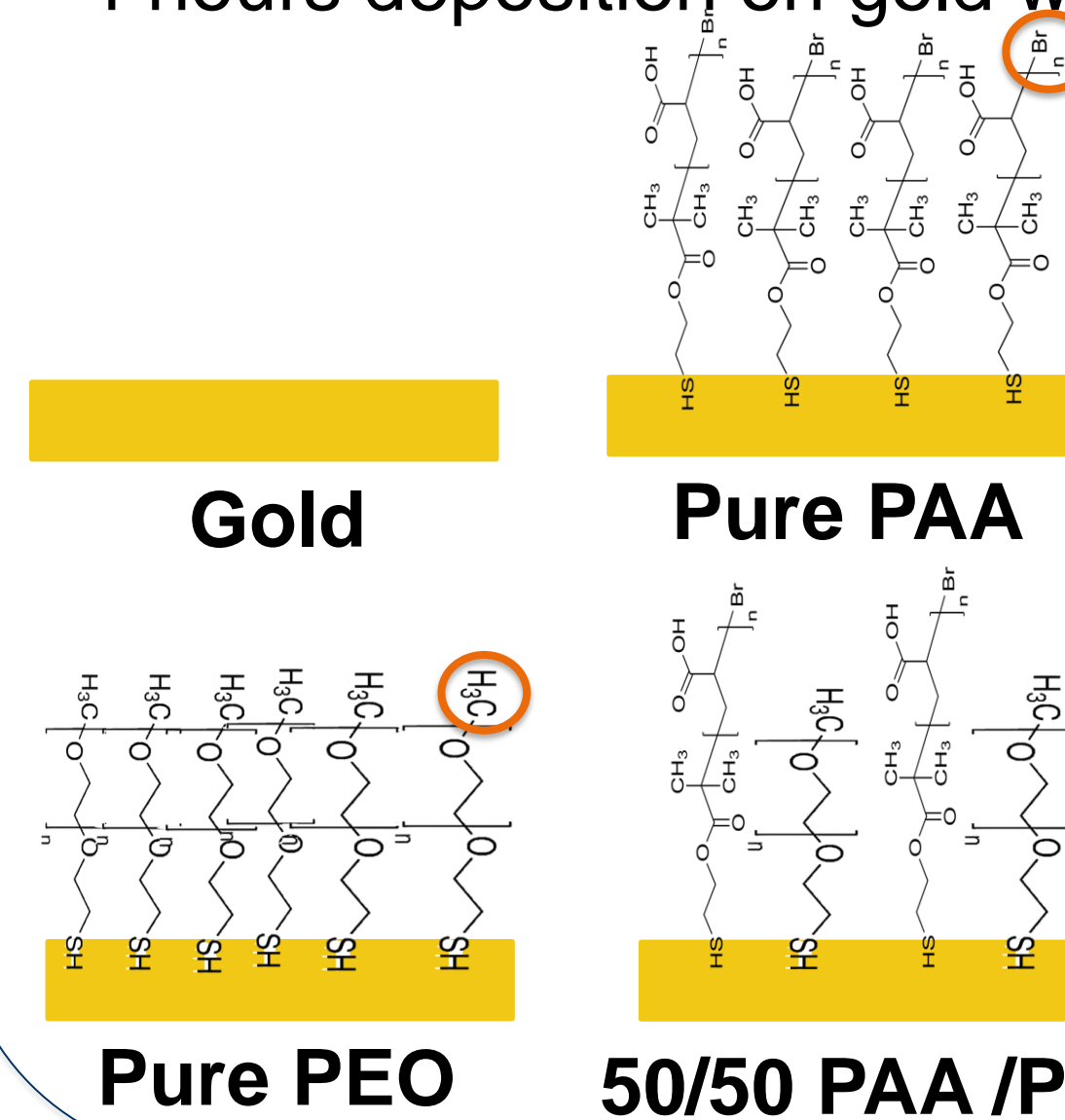
“Grafted onto” Organic layers

- Sensing layers in biosensors
- Protective layers for tribology applications

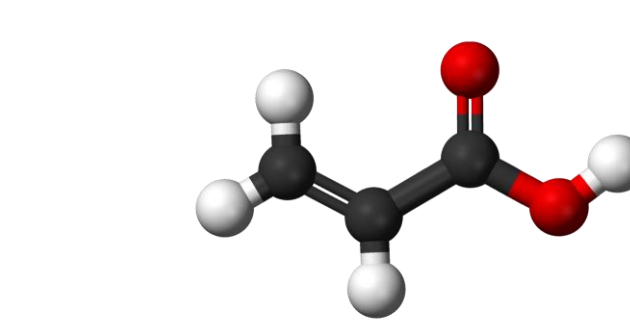
M. Ralph Uhlig (Thesis, Instituto de Ciencia de Materiales de Madrid, 2019) Page 18

Sample preparation

- Polymers dissolved in distilled water (C = 1,5 g/L)
- 4 hours deposition on gold wafers

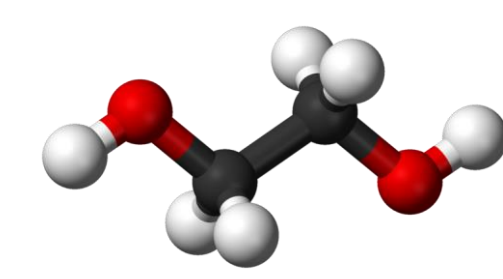


Poly (acrylic acid) PAA



● Carbon ● Hydrogen ● Oxygen

Poly (ethylene oxide) PEO



Protein adsorption and trapping

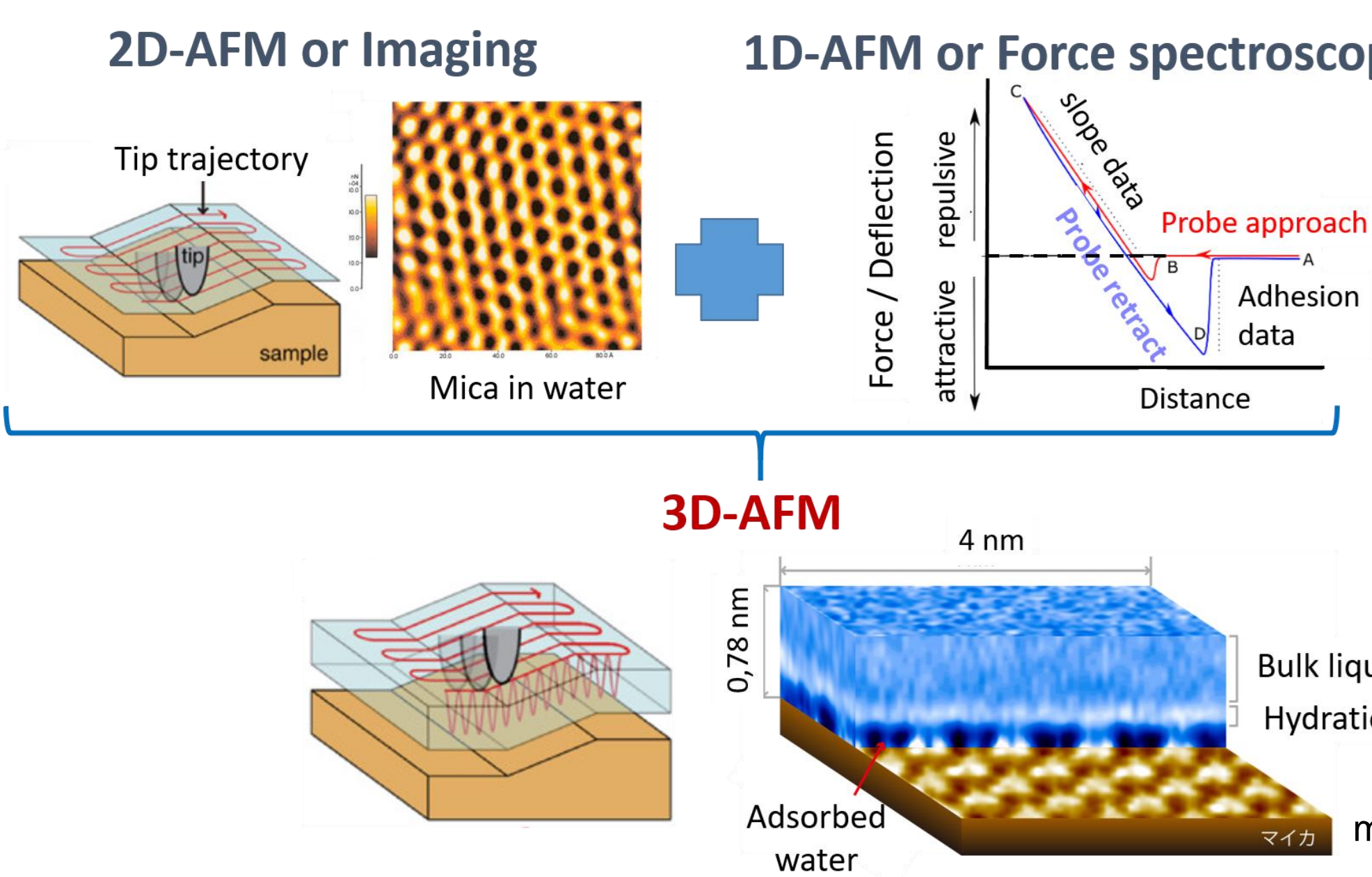
- Biocompatible, non-toxic, biodegradable
- Interesting swelling properties

Protein repulsion and friction decrease

- Non-toxic
- Interesting repulsion properties

Principle of 3D-AFM

Combination between 1D-AFM and 2D-AFM

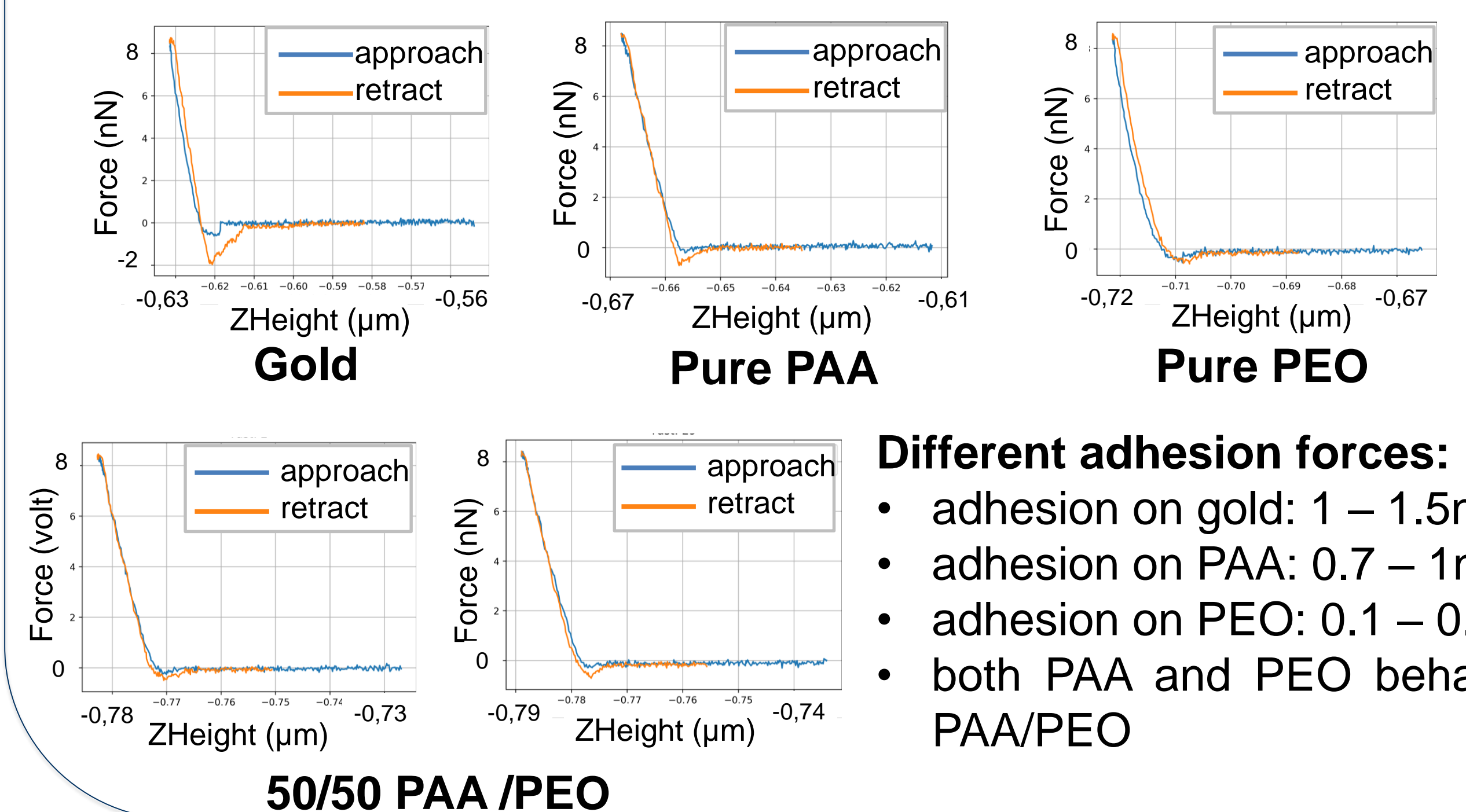


- Technique for high resolution interfacial characterization
- Implementation in a conventional 2D-AFM
- Additional sine wave signal to the z-piezo (Lock-in amplifier)
- Image of the first liquid layers above the surface

T. Fukuma, Y. Ueda, S. Yoshioka, H. Asakawa, Phys. Rev. Lett. 104 (2010) 016101

1D-AFM

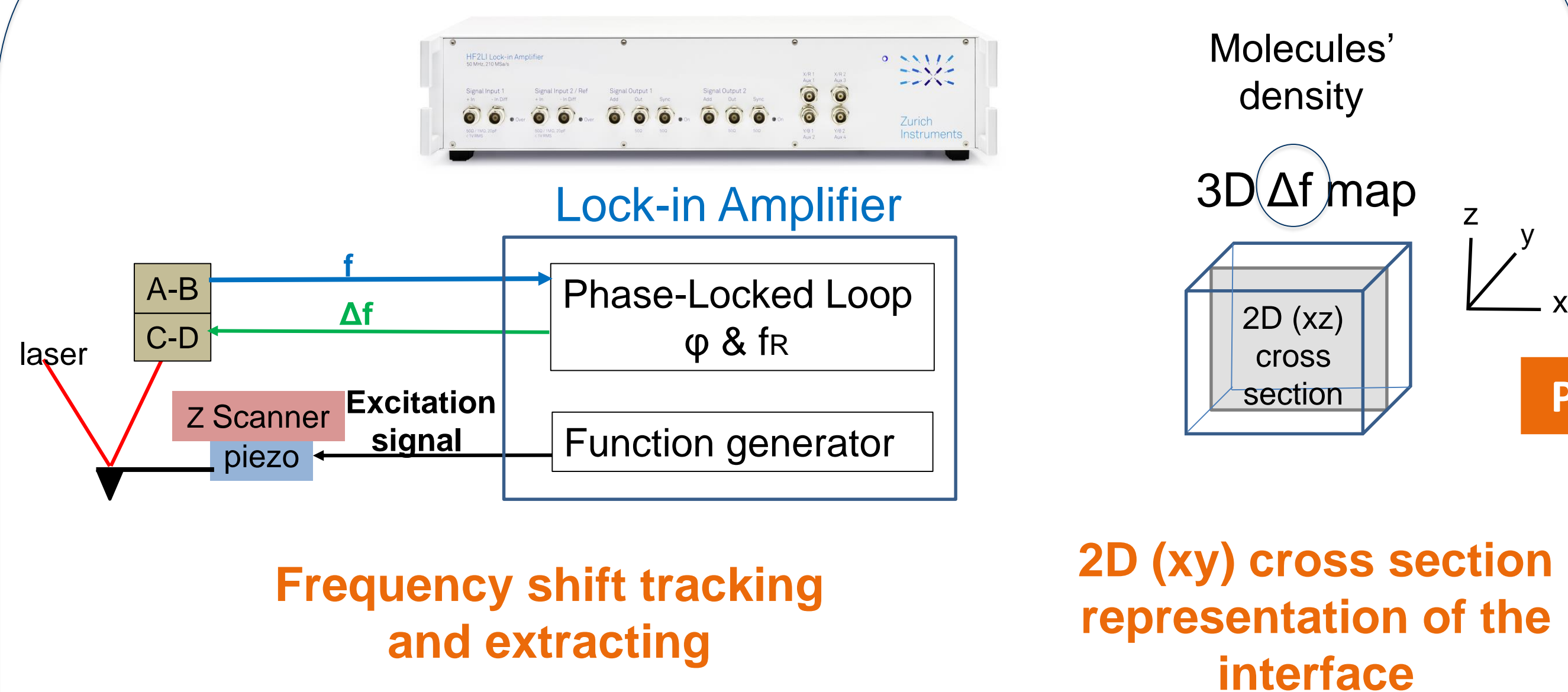
Force curves in pure water



Different adhesion forces:

- adhesion on gold: 1 – 1.5nN
- adhesion on PAA: 0.7 – 1nN
- adhesion on PEO: 0.1 – 0.5nN
- both PAA and PEO behaviors on PAA/PEO

3D-AFM implementation



Frequency shift tracking and extracting

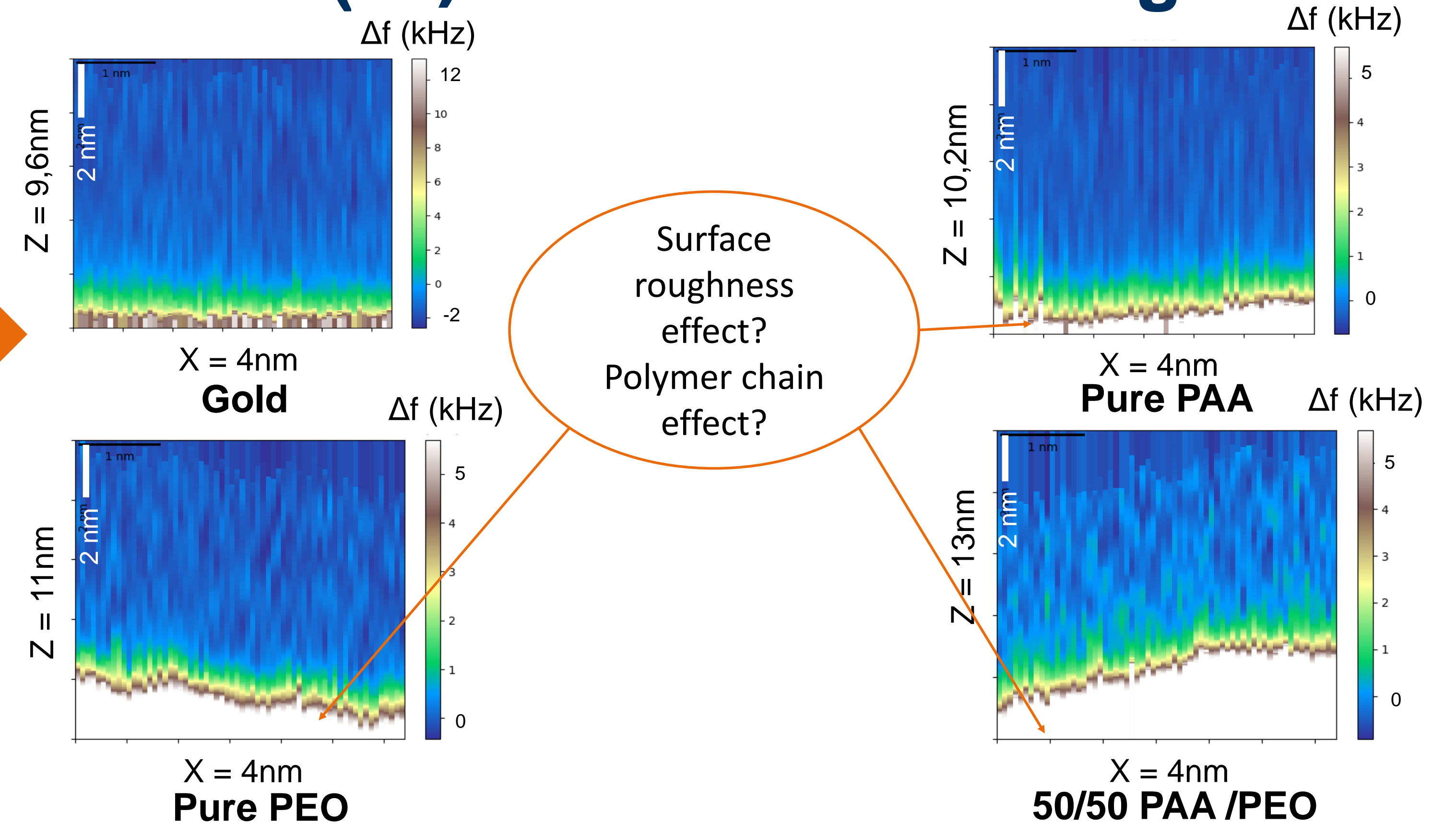
2D (xy) cross section representation of the interface

$\Delta f \rightarrow \Delta F \rightarrow$ 3D force maps

$$F(z) = 2k \int_z^\infty \left(1 + \frac{a^{1/2}}{8\sqrt{\pi(t-z)}} \right) \Omega(t) - \frac{a^{3/2}}{\sqrt{2(t-z)}} \frac{d\Omega(t)}{dt} dt$$

Sader et al. Appl. Phys. Lett. 84, 1801 (2004)

2D (xz) cross-section images



- Successfully implemented 3D-AFM
- Successfully generated 2D vertical images representing the interface
- Result analysis still in process

This 3D-AFM method is appropriate to visualize the interface between solid/polymer chains/liquid. It is promising to interpret the difference in behavior depending on the polymers' headgroups and the nature of the liquid. Our future work consists in improving the technique (vertical resolution, surface roughness,...) and calculating the force between the tip and the samples' surfaces and then generating a 3D force map of the interfaces. Furthermore, we are going to develop new interfaces by functionalizing silicon wafers with silane and then analyzing them using the improved version of 3D-AFM.

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