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# Characterization of polymer brushes deposited on gold surfaces by 1D and 3D-AFM in liquid

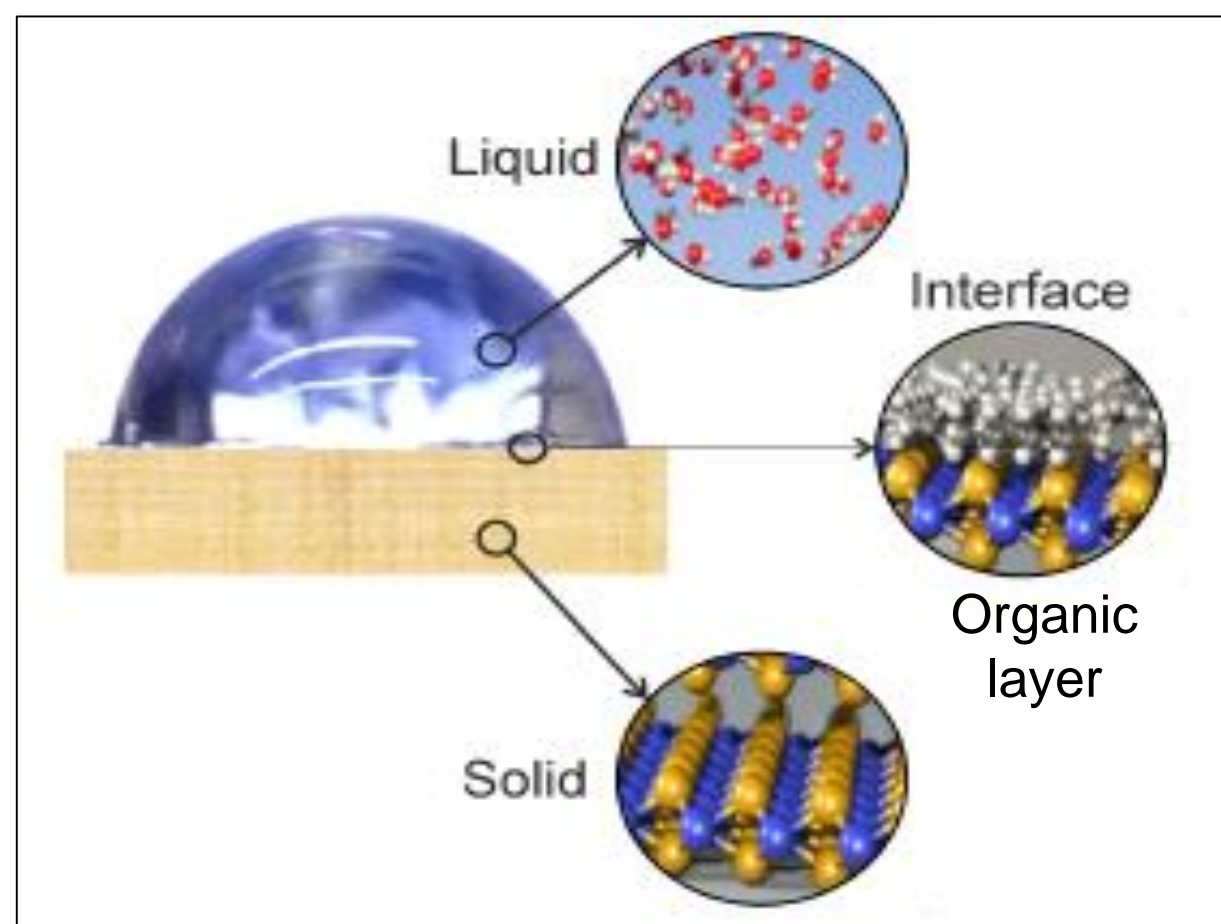
Characterization of gold/thiol layer/liquid interfaces in different liquid environments by 1D-AFM and 3D-AFM to analyze their behavior for applications in biosensing and tribology

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## Solid/Organic layer/liquid Interfaces

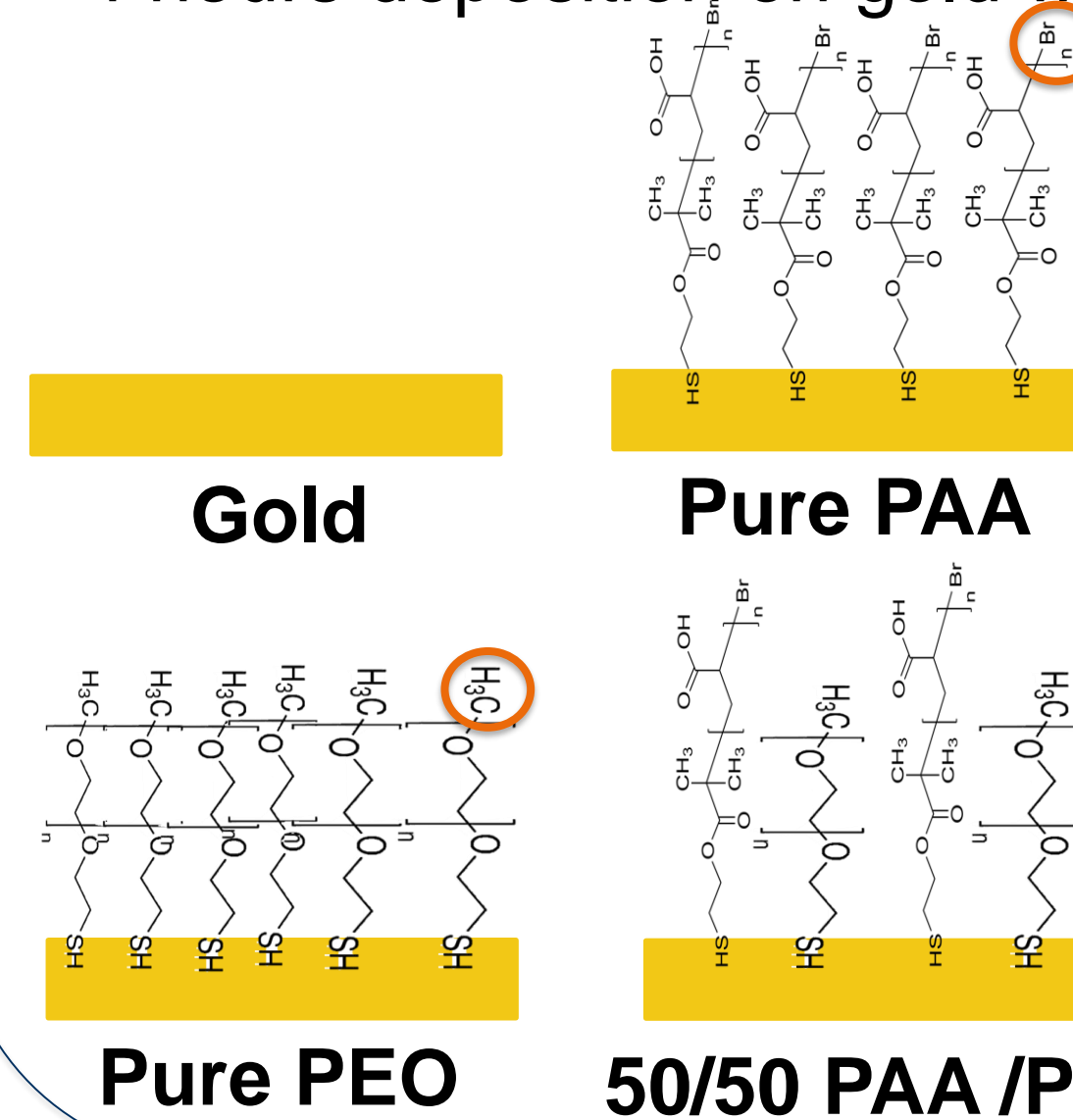


- “Grafted onto” Organic layers**
- Sensing layers in biosensors
  - Protective layers for tribology applications

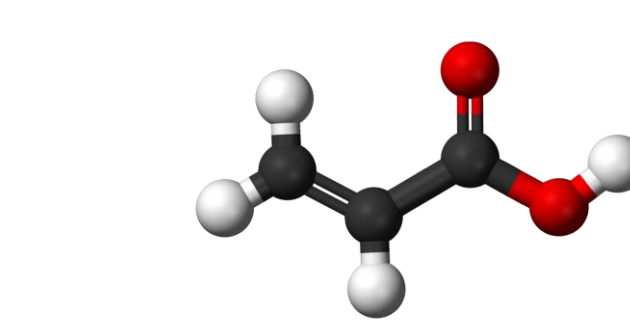
M. Ralph Uhlig (Thesis, Instituto de Ciencia de Materiales de Madrid, 2019) Page 18

## Sample preparation

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



### Poly (acrylic acid) PAA

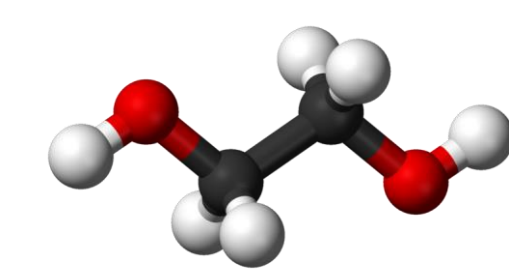


● Carbon ● Hydrogen ● Oxygen

### Protein adsorption and trapping

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

### Poly (ethylene oxide) PEO

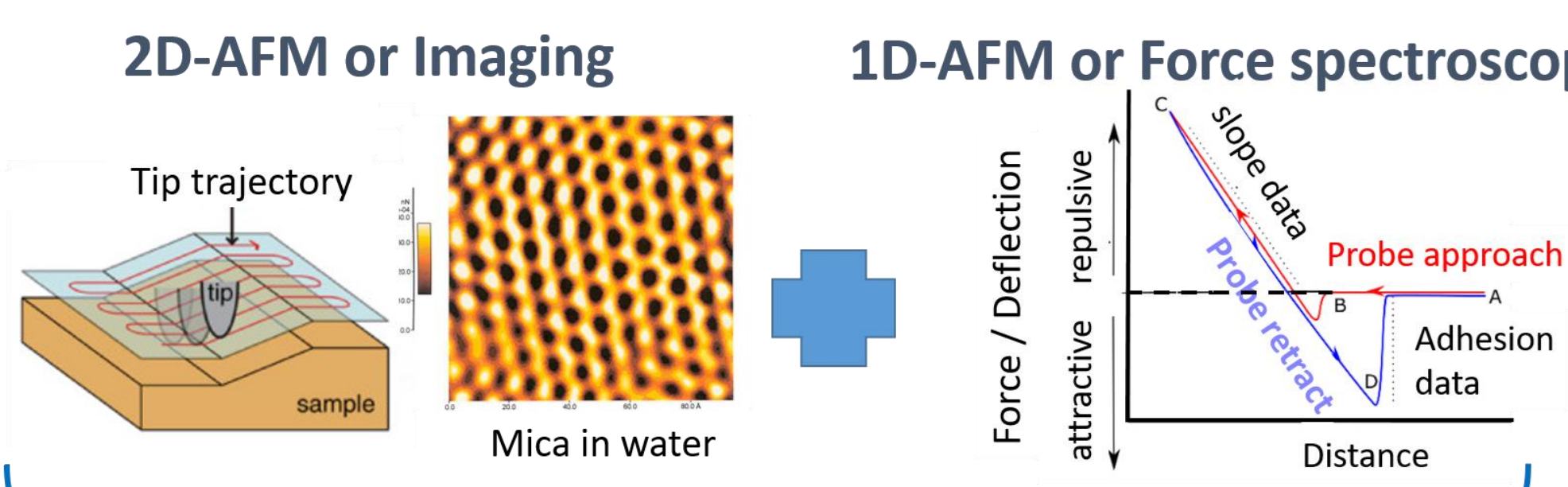


### Protein repulsion and friction decrease

- Non-toxic
- Interesting repulsion properties

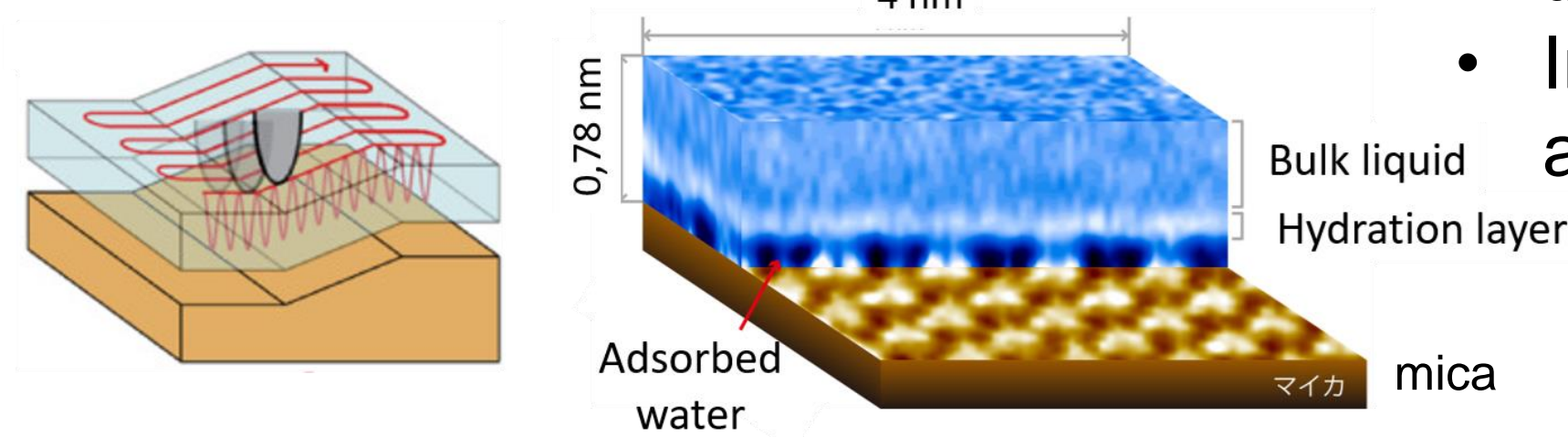
## Principle of 3D-AFM

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

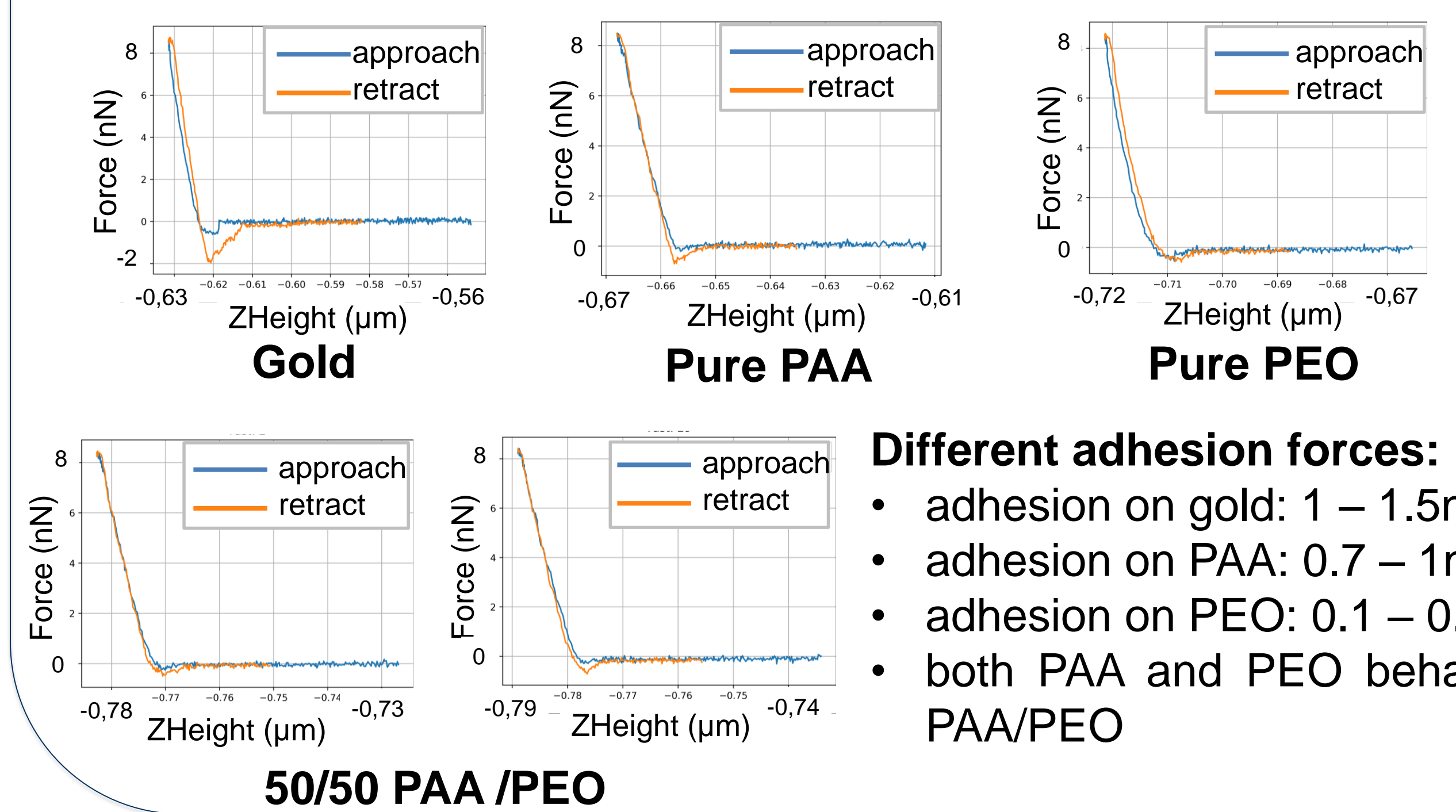
### 3D-AFM



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

## 1D-AFM Measurements

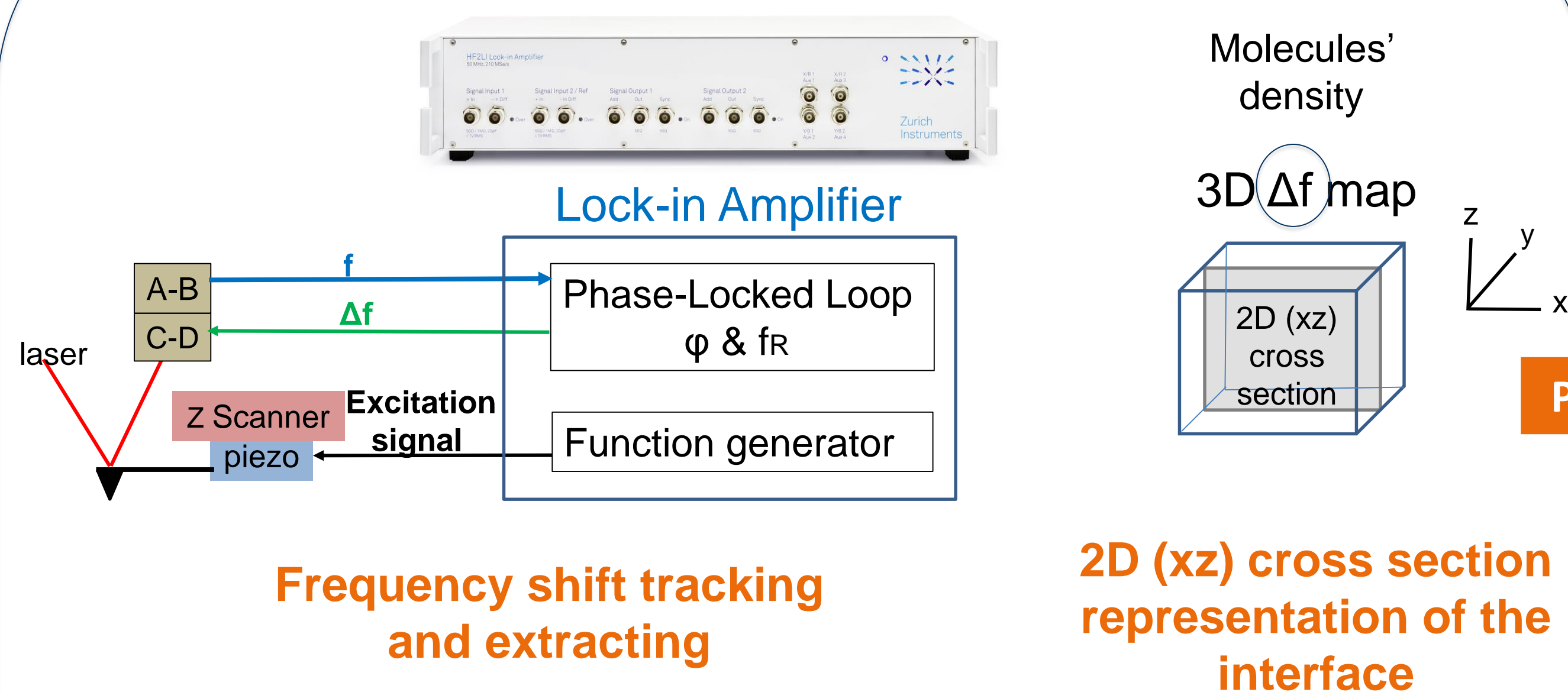
Force curves in pure water



### Different adhesion forces:

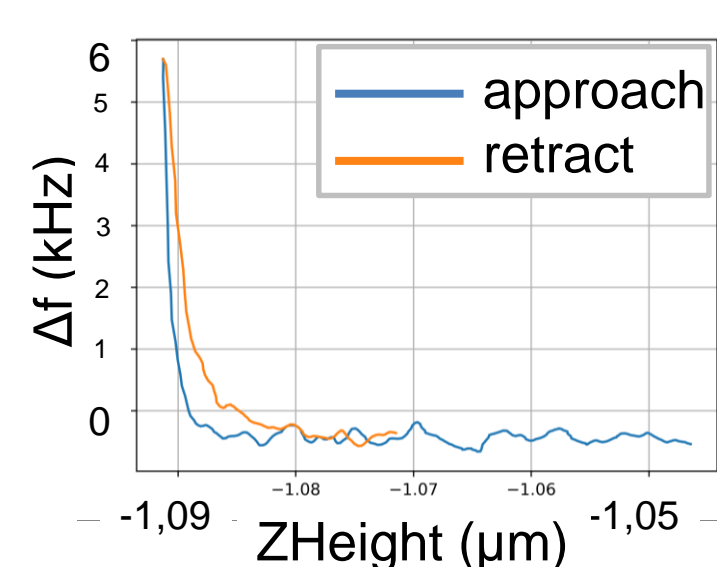
- adhesion on gold: 1 – 1.5nN
- adhesion on PAA: 0.7 – 1nN
- adhesion on PEO: 0.1 – 0.5nN
- both PAA and PEO behaviors on PAA/PEO

## 3D-AFM implementation



Frequency shift tracking and extracting

2D (xz) cross section representation of the interface

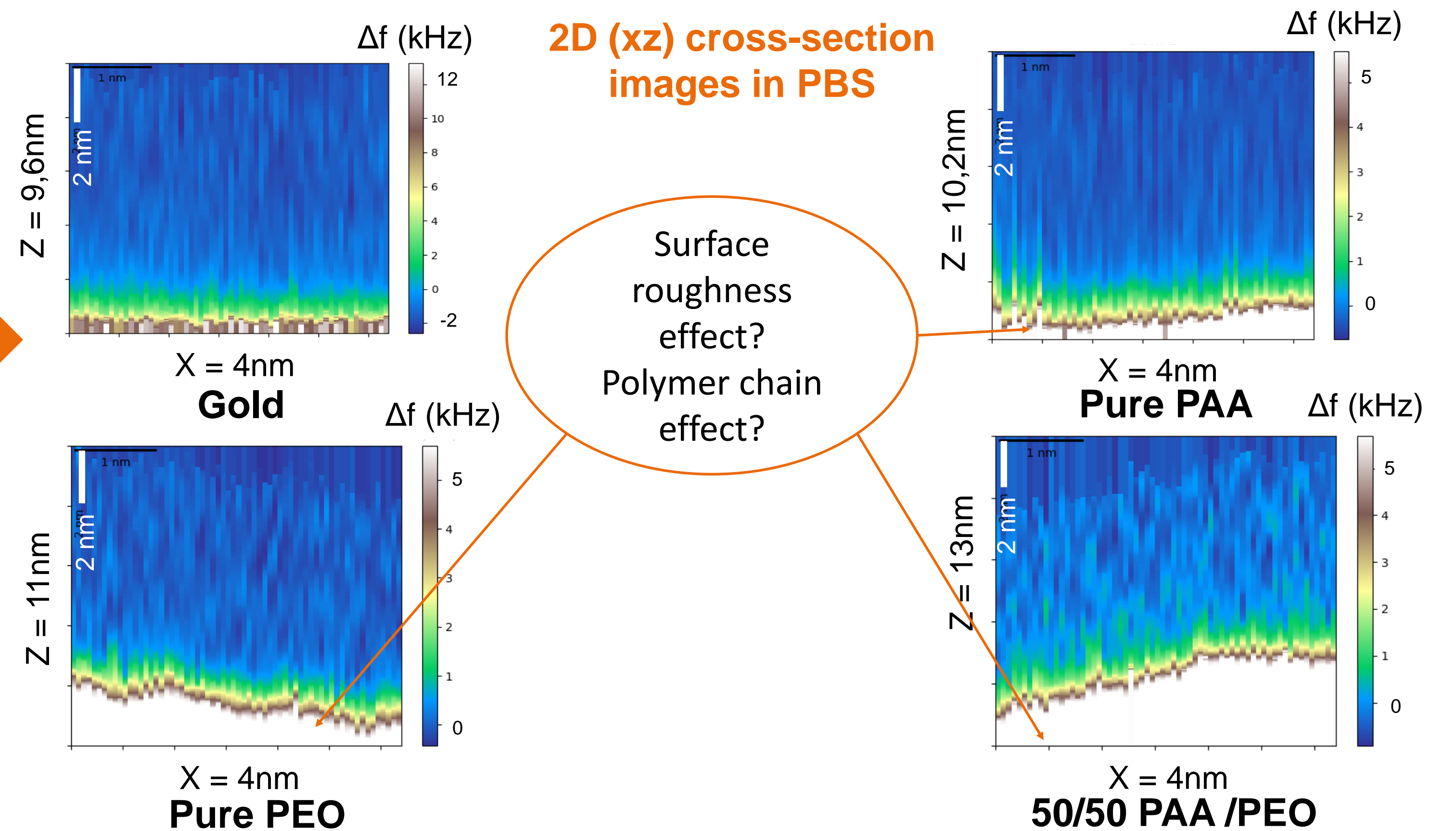


$\Delta f \rightarrow \Delta F \rightarrow$  3D force maps

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

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

## 3D-AFM Measurements



- 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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