Simultaneous AFM and QCM measurements of biological and electrochemical processes

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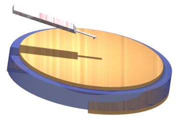

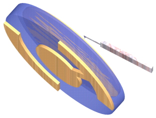

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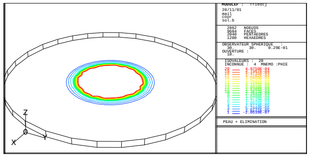
Development of a novel platform for bioanalytical investigations

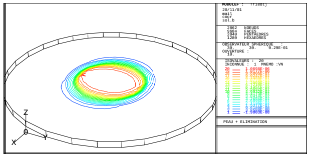
- Understanding the oscillation properties of the quartz resonator under viscous load (liquid medium)
- Monitoring of processes at the cm^2 (QCM) and nm^2 (AFM) scales

→ analysis of the interactions of the two techniques:

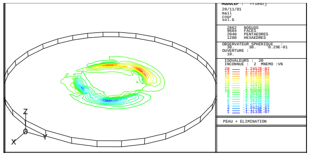
- static finite element analysis: out of plane displacement is 0.1 pm
- dynamic displacement=static displacement×Q ⇒ out of plane displacement is 0.3 nm ($Q \simeq 3000$)
- in plane displacement is at most 3 nm, smaller than AFM pixel size
- standing wave pattern between QCM and cantilever holder only disturbs the resonance frequency during approach
- fundamental resonance frequency (5 MHz) is unstable and overtones of the QCM must be used



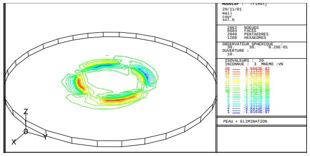
DC potential (0.5 V)



In-plane displacement (1 pm)

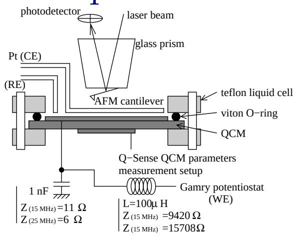


In-plane displacement (0.1 pm)



Out-of-plane displacements (0.1 pm)

Experimental setup



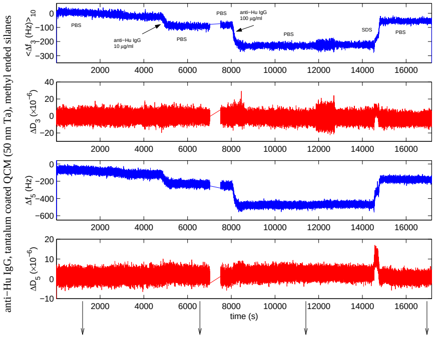
Use of commercial instruments:

- QSense-AB QCM monitoring electronics (frequency overtones and damping)

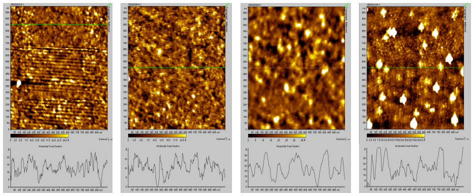
→ continuous monitoring of the 3rd, 5th and 7th overtones+quality factor

- Molecular Imaging AFM (moving scanner, fixed sample holder)
- Gamry potentiostat for electrochemistry applications

Application to biological processes

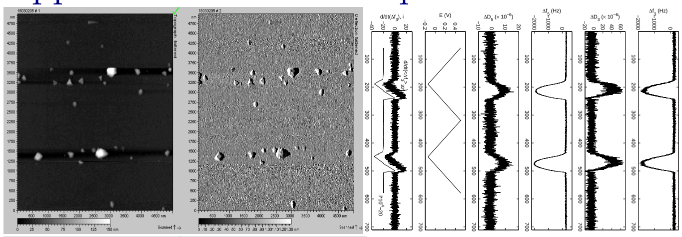


Data obtained by W. Laureyn

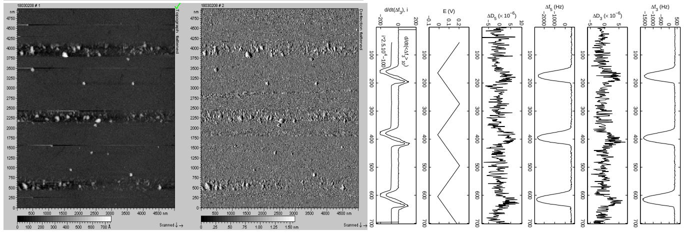


Cu and Ag electrodeposition display different crystal structures ⇒ rougher surfaces interact more with the viscous layer of surrounding liquid. Biological layers behave as viscous or rigid layers depending on the binding mechanism.

Application to electrodeposition monitoring



Cu



Ag

Rigid layer ⇒ $\Delta f_n/n \propto \Delta m_{layer}$ (low damping) with n: overtone number

Viscous layer ⇒ $\Delta f_n/\sqrt{n} \propto \{\Delta m_{liquid}, \Delta m_{layer}\}$ (large damping)