Welcome to the Spring 2009 QCM-D Training Workshop at The University of Kentucky

Quantifying Changes at Material Interfaces Using Dissipative Quartz Crystal Microbalance (QCM-D)

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Q-Sense
Glen Burnie, MD

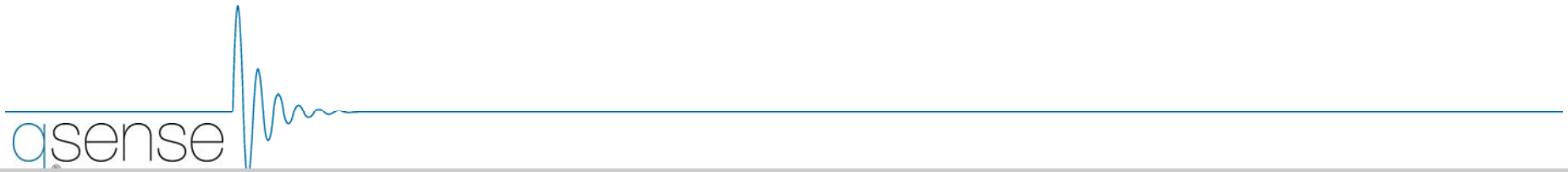
q-sense

The University of Kentucky
April 8th 2009

Outline

- Brief Q-Sense History
- The QCM with the **Dissipation** monitoring principle.
- Applications
- Discussions
- Lunch! (Approx. Noon)
- Demonstration

Note: Quartz Crystal Microbalance = QCM



Who, What and Where?


THICKNESS
Degradation - measuring swelling
and desorption rates
Lipid film
TIME

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Brief Q-Sense History

- **1995:** QCM-D patented
- **1996:** Q-Sense AB founded
- **1999:** Product development, prototype sales
- **2000:** Commercial focus, 1st generation product launched (D300)
- **2001:** US Subsidiary, Newport Beach, CA
- **2005:** Application Research Labs Established in MD.
- **2005:** 2nd Generation product launch, Q-Sense E4
- **2007:** E1 Product Launch, Module Launches (4)
- **2008:** >500 Technical publications using QCM-D
- **2009:** Systems in 28 countries (~150 in North America)

Who uses QCM-D?

Academic/Government

- University of Illinois
- MIT
- EPA
- University of Kentucky
- USDA / EPA
- Georgia Tech
- Purdue University
- Lawrence Berkeley National Labs
- Virginia Tech (2)
- Max-Planck Institute

Industrial

- 3M
- Genentech
- BASF
- Kimberly Clark
- Medtronic
- Procter and Gamble (4)
- Rohm and Haas (2)
- Boston Scientific
- Amgen
- Unilever
- SC Johnson

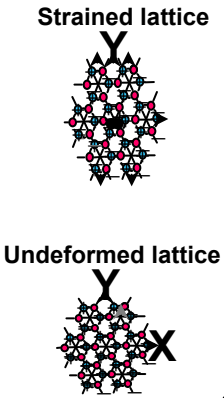
Quartz

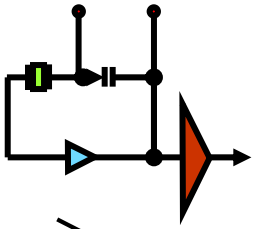
Quartz is the only material known that possesses the following combination of properties:

- Piezoelectric ("pressure-electric"; piezein = to press, in Greek)
- Zero temperature coefficient cuts exist
- Stress compensated cut exists
- Low loss (i.e., high Q)
- Easy to process; low solubility in everything, under "normal" conditions, except the fluoride etchants; hard but not brittle
- Abundant in nature; easy to grow in large quantities, at low cost, and with relatively high purity and perfection. Of the man-grown single crystals, quartz, at ~3,000 tons per year, is second only to silicon in quantity grown (3 to 4 times as much Si is grown annually, as of 1997).

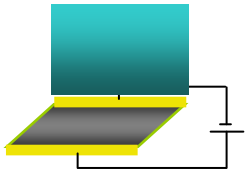
Jiri Janata, *Principles Of Chemical Sensors.* ***1989***.

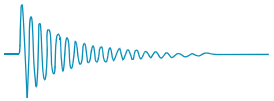
QCM Timeline





$$\Delta m = -C\frac{1}{n}\Delta f$$





Curie brothers discover piezoelectricity

First quartz crystal controlled oscillator

Sauerbrey relates frequency and mass

First QCM operating in liquid

QCM-D Patent filed

1880 1921 1959 1980 1996

Starts as research tool

Gas and vapor analysis

Liquid analysis

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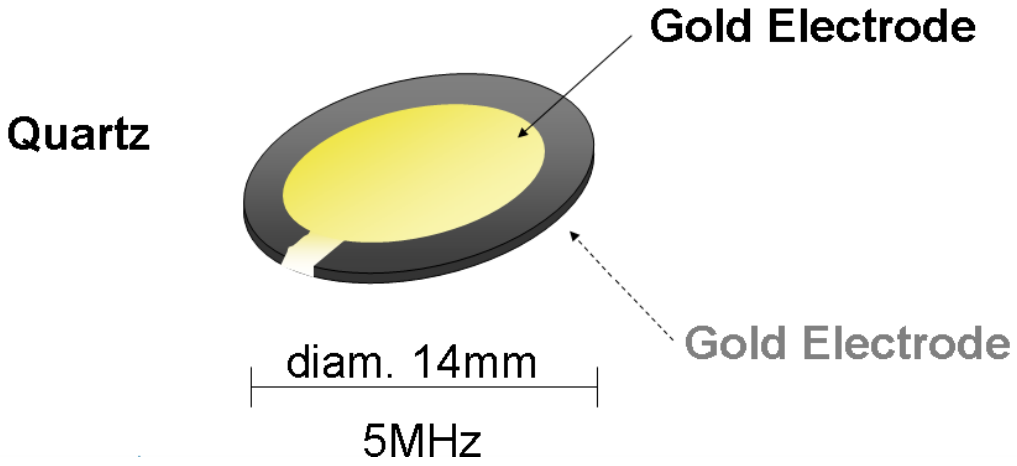
Sauerbrey, G *Z. Phys.* **155** (1959) 206.

The QCM-D sensor



	Mass Sensitivity	D-factor
in air (1 bar)	~0.2 ng/cm^2	~4×10^{-8}
in water (25 °C)	~0.9 ng/cm^2	~1×10^{-7}

- **Detection range in viscoelastic films: nm - μm**
- **Temperature Range 15-65° C; long term stability +/- 0.02˚ C**

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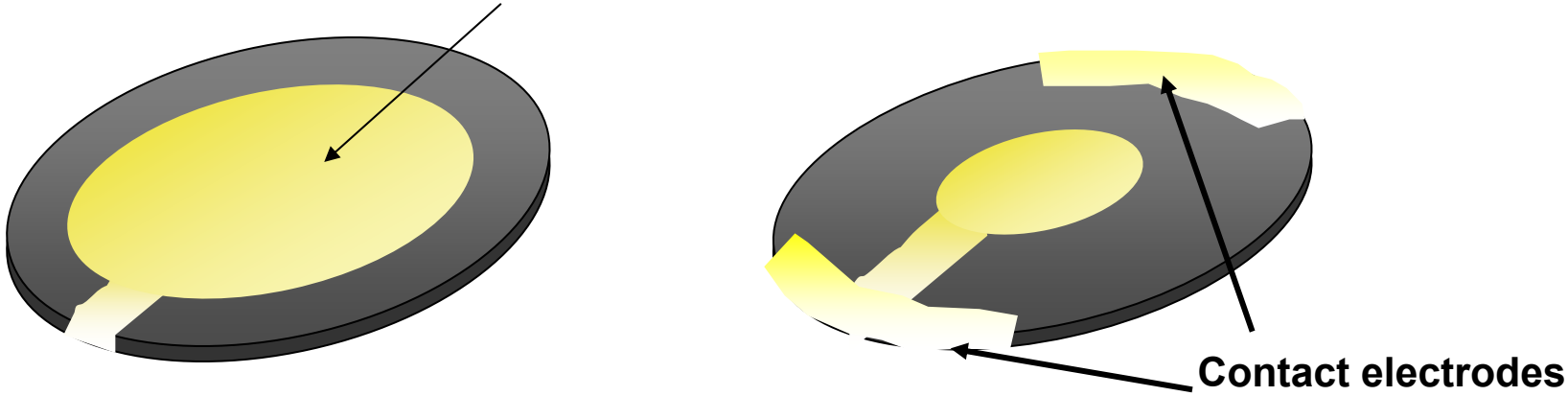
The QCM-D Sensor

Quartz

Gold Electrode



diam. 14mm

5MHz

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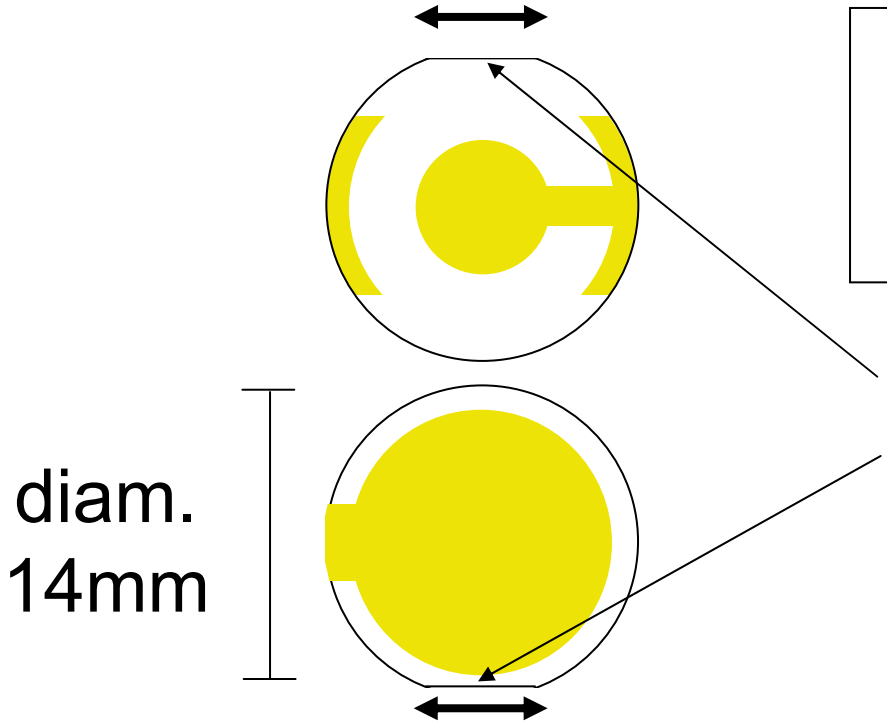
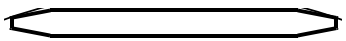
Why is There a Notch in the Quartz Crystal?





Cross section
(Plano-plano with beveled edges)

Notch Indicates
Oscillation Direction

Thickness (δ) given by 1/f
and ν_q = 3340 m/s
So for 5 MHz δ ~ 330 μm

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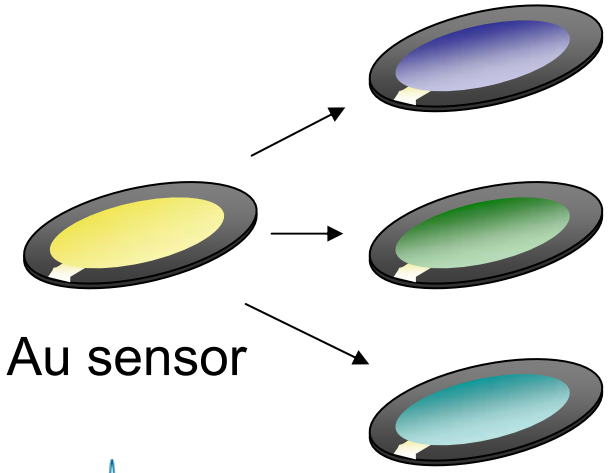
Surfaces supplied by Q-Sense

Hard Model Surfaces available from Q-Sense:

- Glass, ceramics (SiO2)
- Plastics (PE, PP, PS and PVC)
- Stainless steel

On-Request Model Surfaces can be supplied by Q-Sense:
Such as starch, grease/fat and many polymers



metals, oxides

SiO_2, Al_2O_3, Ti, Pt, Ag, W, Cu, Cr, Ir, Ta, FeC_3, TaN, CeO_2, Fe, Zn, ZnO_2, Fe_2O_3, ZnS, FeS, Stainless steel, ..., and custom made

polymers

PS, PC, PMMA, Fluoropolymer, PE, PP
Users can coat with own polymers

hydroxyapatite

nanocrystalline, RMS ~2 nm

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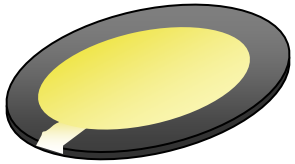
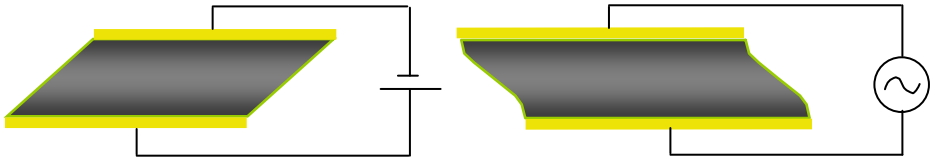
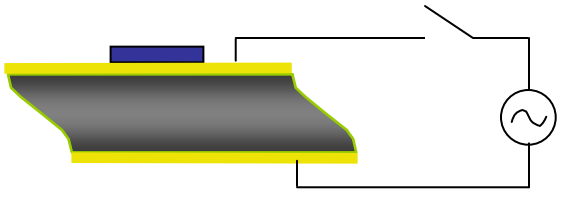
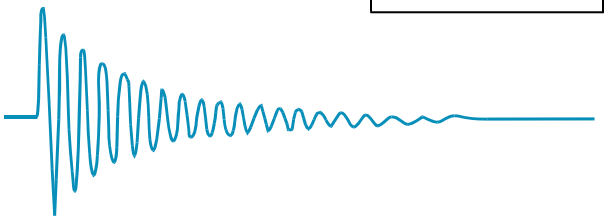
QCM-D ping principle: Teaching an Old Dog New Tricks

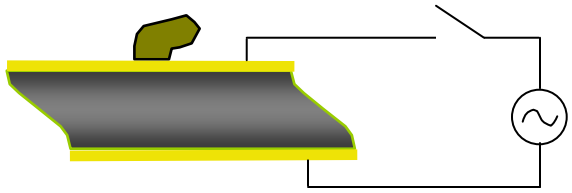








Δf **is related to the mass of the attached film (Sauerbrey relation)**

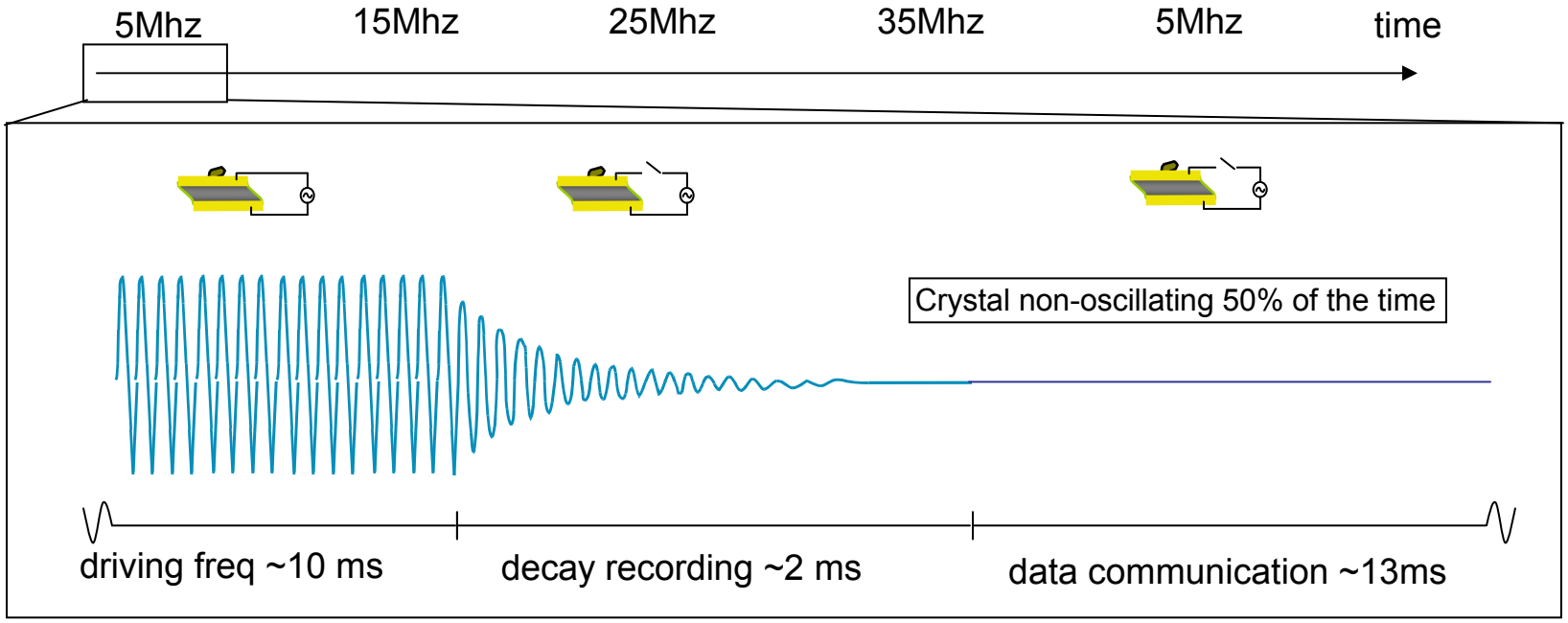


ΔD **is related to the viscoelasticity**

Instrument operation: Frequency and **Dissipation**

Features

- Sequential multi frequency measurement
- Freely oscillating crystal=true crystal frequency
- Enables multiple frequencies & viscoelastic modeling



Note: QCM-D can sample viscoelastic changes over 200 times/sec.

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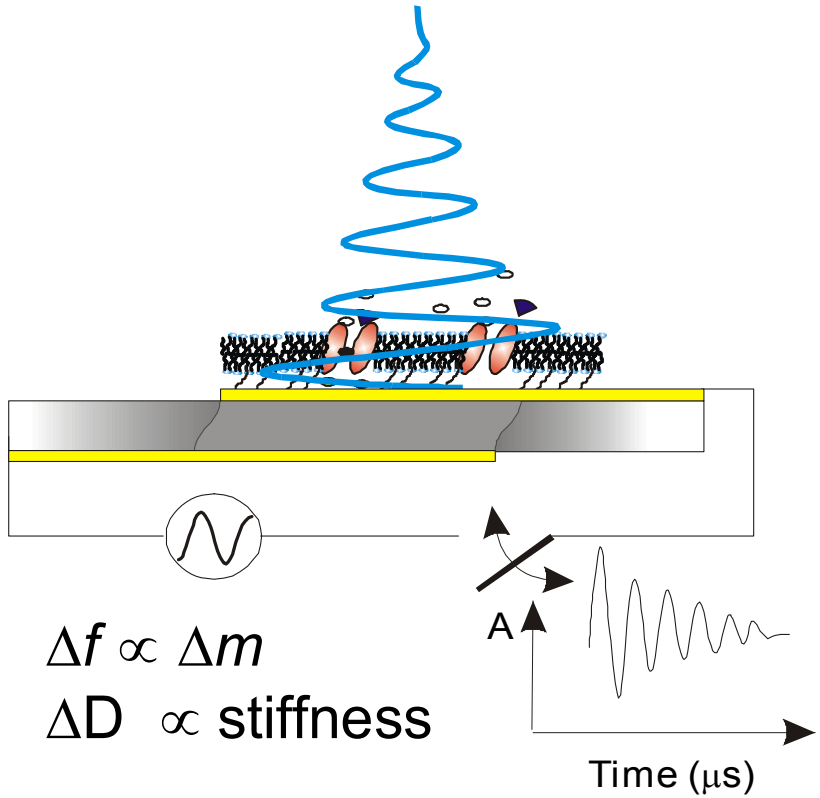
The Quartz Crystal Microbalance with Dissipation monitoring (QCM-D) technique



$\Delta f \propto \Delta m$

$\Delta D \propto$ stiffness

Mathematical representation of the decay curve

$$A(t)=A_0 \cdot \exp(-t/\tau) \cdot \sin(2\pi f t+\phi)$$

$$D=1/\pi f \tau$$

Frequency change (Δf):

⇨ adsorbed amount: $\Delta m=-C \cdot \Delta f$
(Sauerbrey equation)

Energy Dissipation (ΔD):

⇨ rigidity

Multiple frequency modeling:

⇨ shear viscosity and elasticity

Voinova et al., *Physica Scripta* **59** (1999) 391

The Q-Sense E4 System

www.q-sense.com

- ***4 Sensors (simultaneous studies)***
- ***Peltier Thermal Control***
- ***2 Weeks Learning time***
- ***Flow / stagnant mode***
- ***Wide range of chip coatings***
- ***Parallel Modules***

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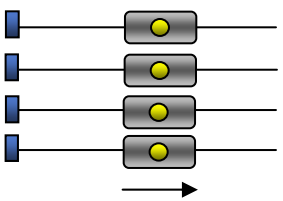
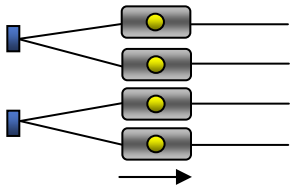
The E4 Measurement Chamber

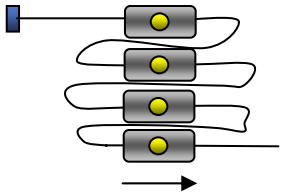
Examples of Experimental Design



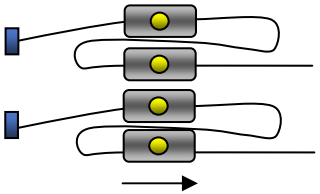
parallel



2 by 2 parallel



serial



2 by 2 serial

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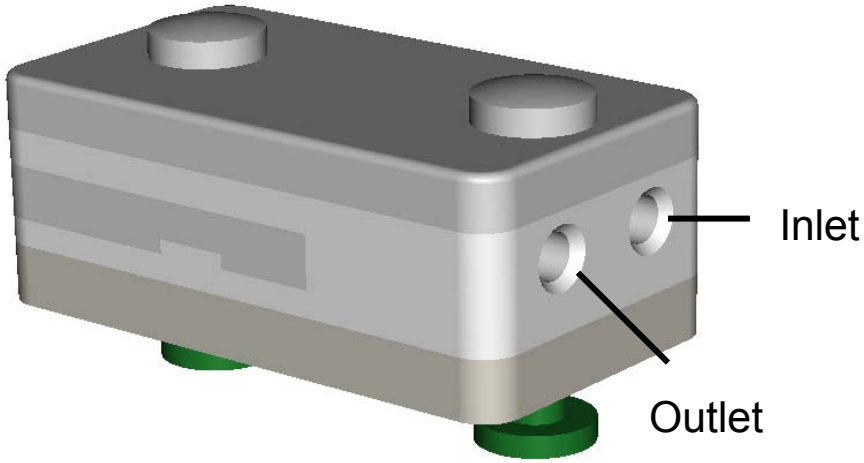
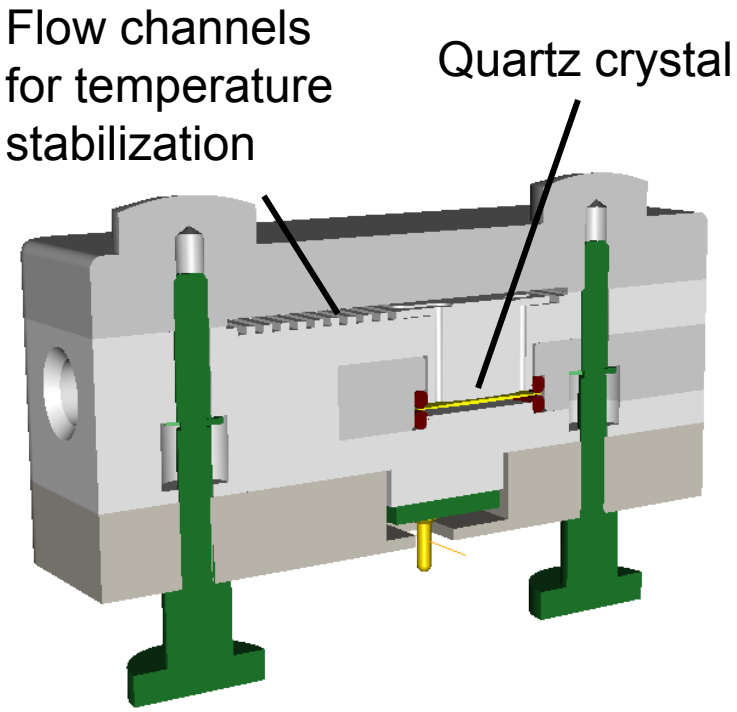
4 Removable Flow Modules





Cross section of flow module

- Volume above sensor – 40 μL
- Minimum sample volume – 200 μL
- Temperature – 15-65 °C (± 0.02 °C)
- Programmable temperature ramping
- Easy access for cleaning

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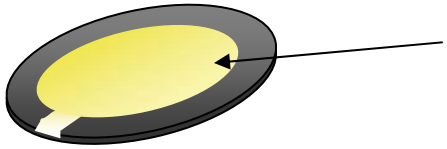
The Q-Sense E-Series Modules

- Standard Flow Module
- Electrochemistry Cell
- Window Module
- Humidity Module
- Open Module

QCM-D Technology Overview

Surfaces

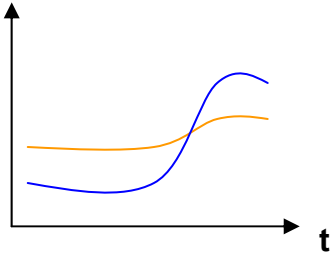


14 mm diam.
5 MHz

Wide Range of Crystal Surfaces

Metals
Metal Oxides
Reactive Surfaces
Polymers/Lipids
Hydroxyapatite
Custom Surfaces

Data

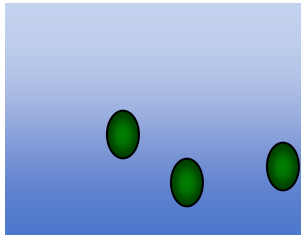


Real Time Measurement of Δf and ΔD

Mass
Thickness
Density
Viscosity/Rheology
Shear modulus

Measured Simultaneously

Samples



Wide Range of Sample Possibilities

SAMS, surfactants, detergents
Peptides, lipids, membranes
Proteins/DNA, antibodies, enzymes
Polymers, polyelectrolytes
Viruses, phage display, biofilms
Bacteria, yeast
Mammalian Cells

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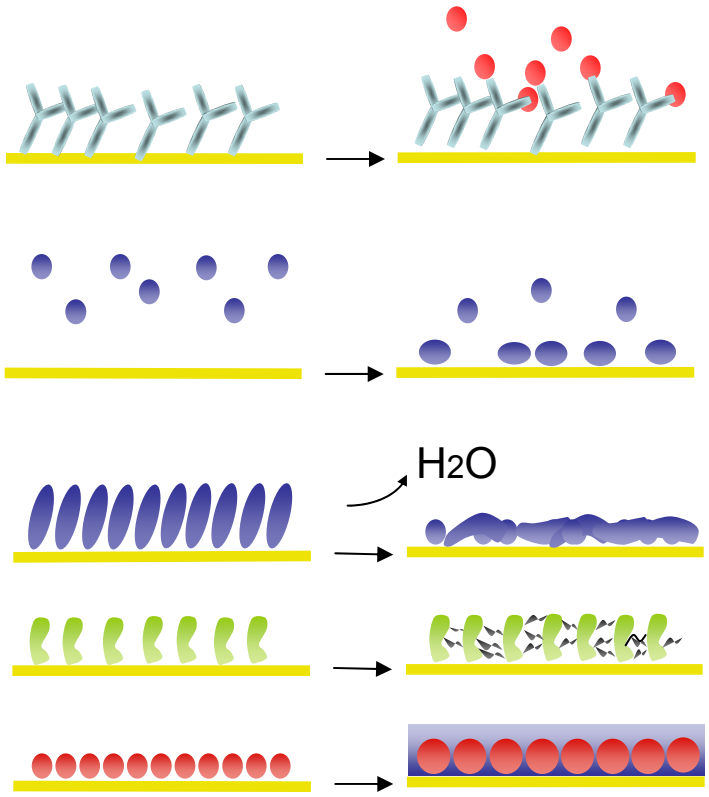
Application Areas



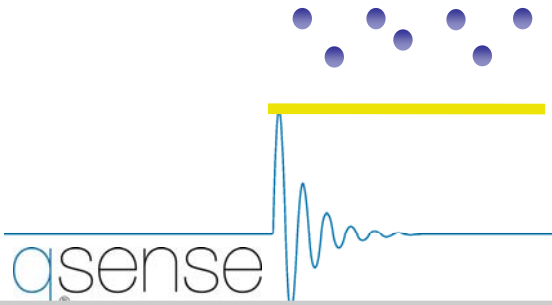
Interactions

Molecule-molecule and molecule-surface

- **Small molecule-surface interactions**
- Polyelectrolyte multilayer buildup
- **Biomolecular interactions (Biofilm growth)**
- Protein deposition or fouling

Reactions or Structural Changes

- Crosslinking events (polymers)
- **Structural properties of materials/thin films**
- **Detergent activity**
- Conformation changes (receptor conformation)
- Hydration/Swelling (polymers and other thin films)
- **Degradation/Dissolution kinetics**



Bulk Characterisation

- Viscoelastic properties of fluids (protein solutions, surfactants etc...)

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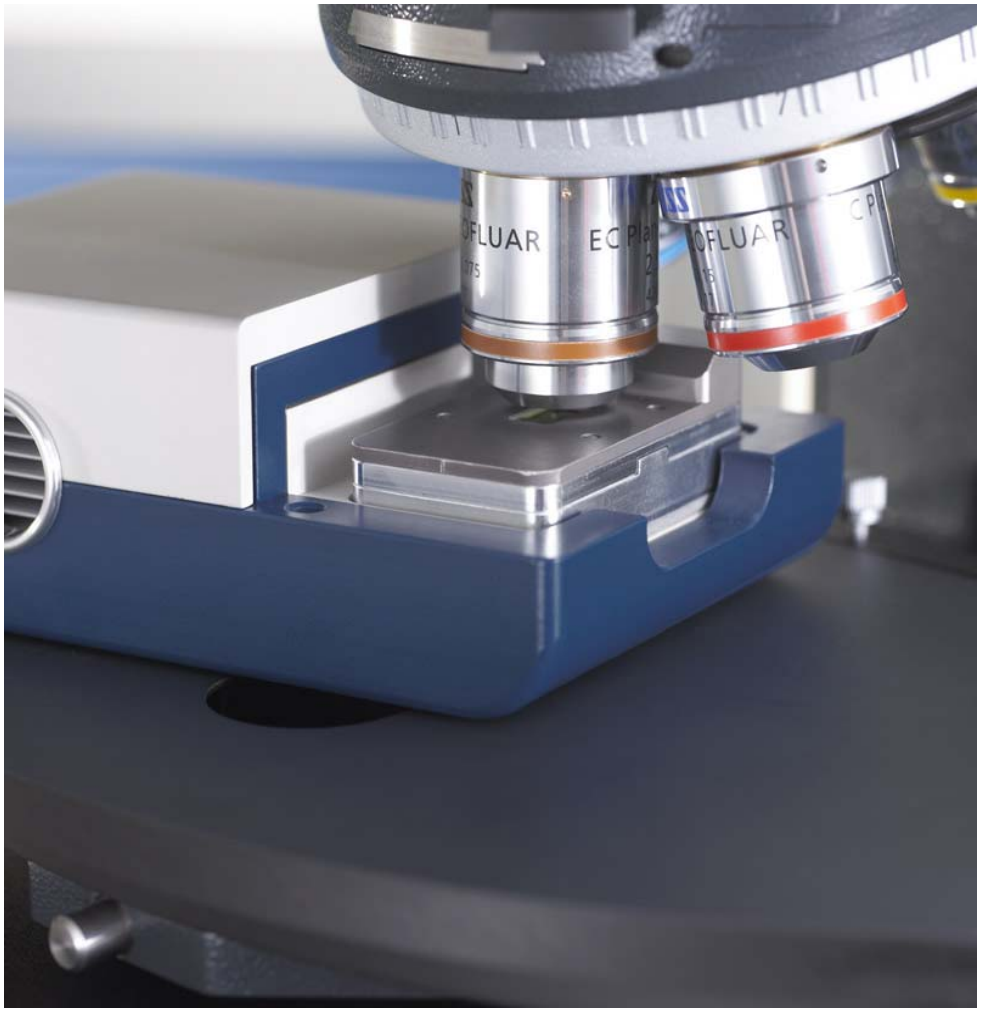
Combined QCM-D and microscopy

- New window module fits under microscope
- Examples of applications: fluorescence, light or irradiation sensitive processes



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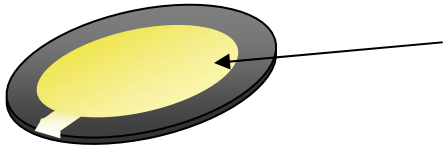
QCM-D Technology Overview

Surfaces

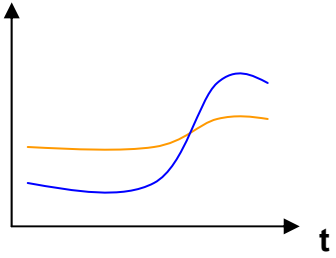


14 mm diam.
5 MHz

Wide Range of Crystal Surfaces

Metals	Polymers/Lipids
Metal Oxides	Hydroxyapatite
Reactive Surfaces	Custom Surfaces

Data

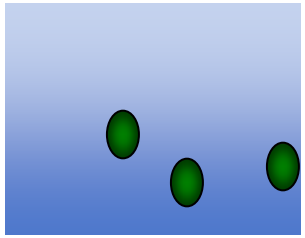


Real Time Measurement of Δf and ΔD

- Mass
- Thickness
- Density
- Viscosity/Rheology
- Shear modulus

→ Measured Simultaneously

Samples



Wide Range of Sample Possibilities

Nanoparticles, self-assembling molecules, polymers,
surfactants, detergents, Peptides, lipids, membranes
Proteins/DNA, antibodies, enzymes
Viruses, phage display
Bacteria, yeast
Mammalian Cells

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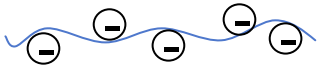
So, What can QCM-D Measure?

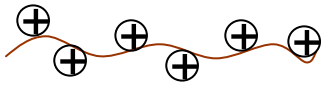
Materials

Polyelectrolyte Multilayers

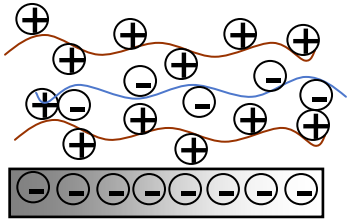
[(POD-PSS)c] and oppositely charged (PAH)



A – Negative charge

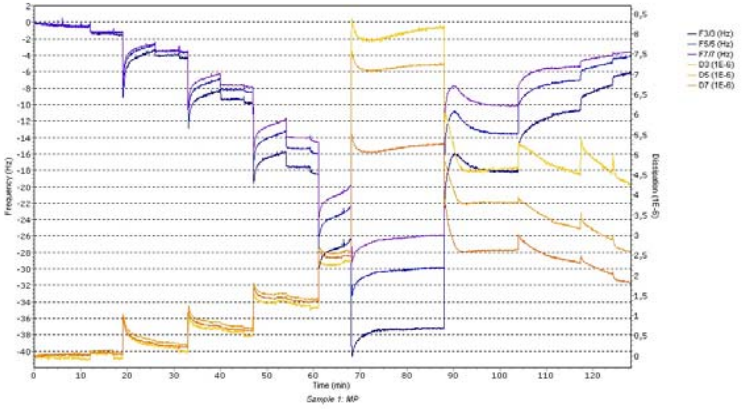


B – Positive charge

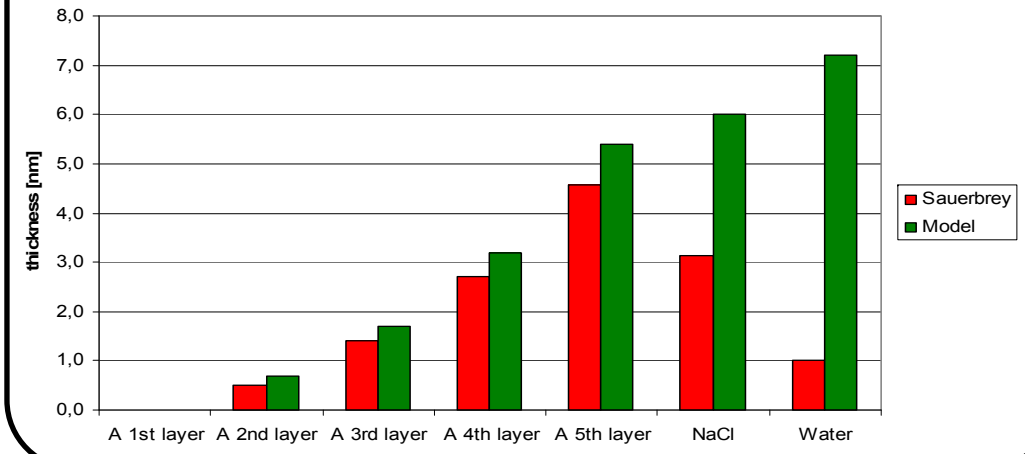


SiO_2

Raw data indicate mass loss



Modeling reveals swelling



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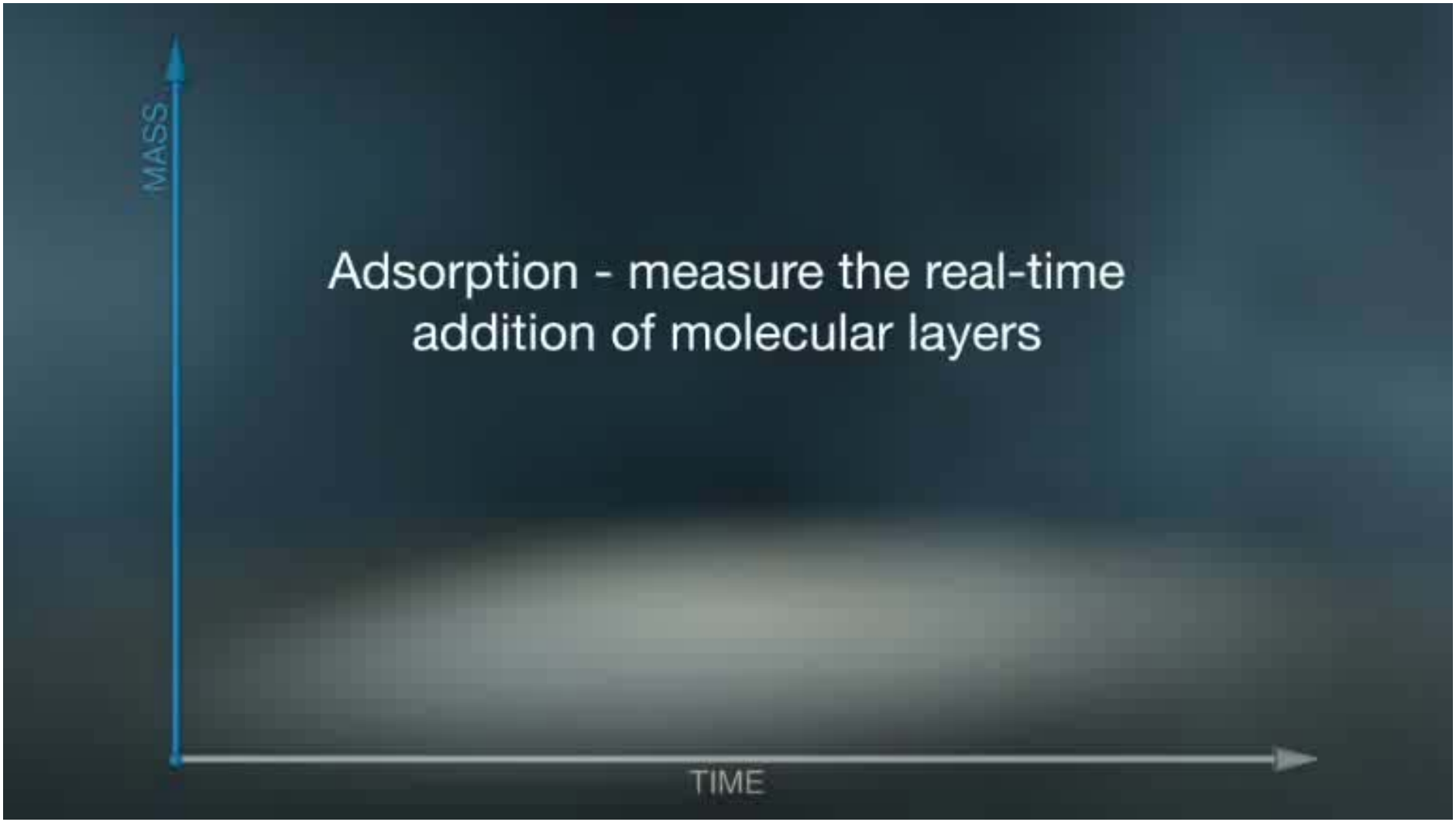
Caruso *et al. Chem. Mater.* **2005**, 17, 171-175


MASS
Adsorption - measure the real-time
addition of molecular layers
TIME

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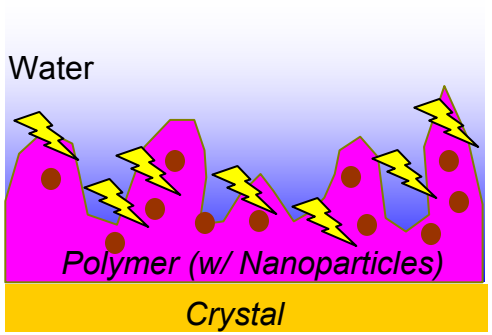
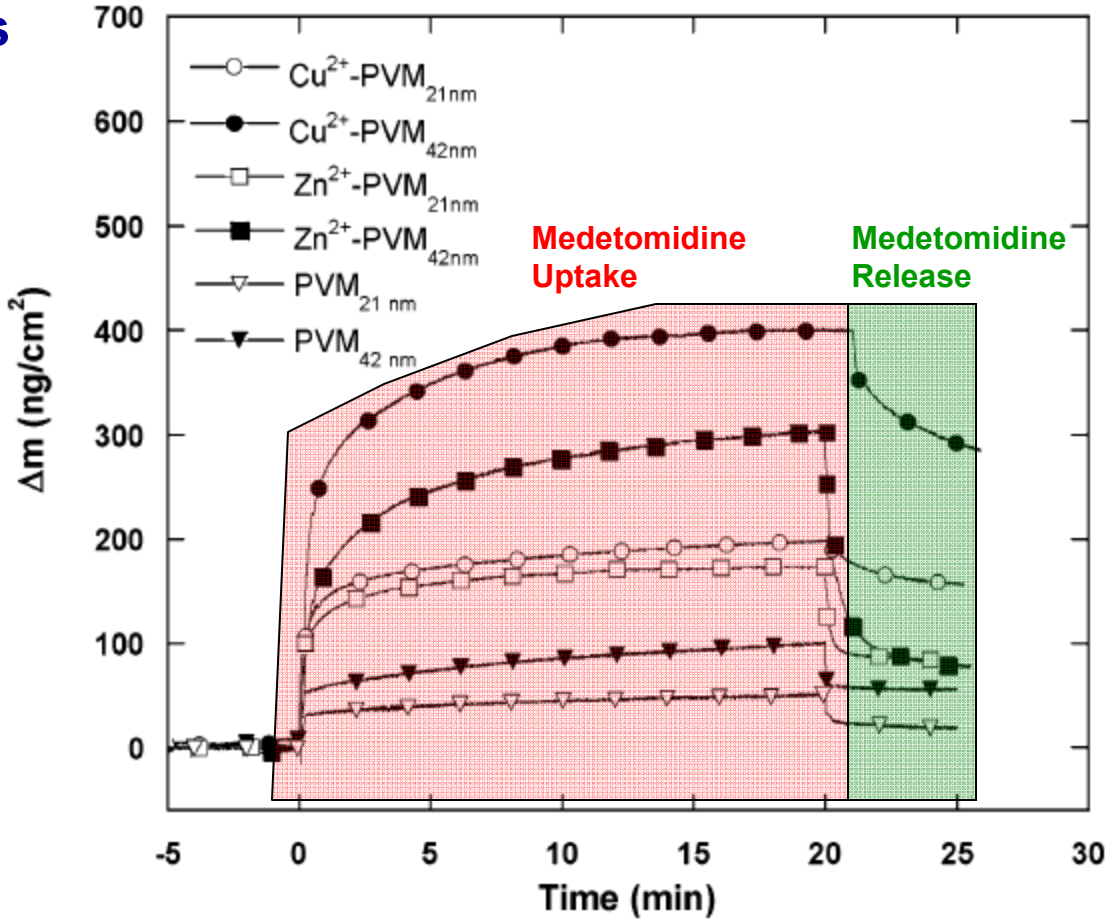
Anti-fouling Development

Developing tailored materials

- **controlled uptake**
- **controlled release**



= Medetomidine



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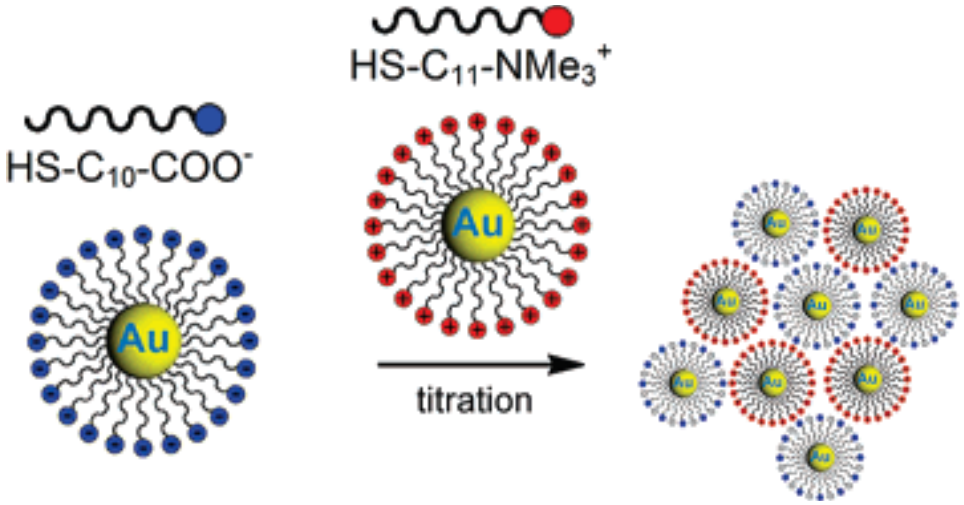
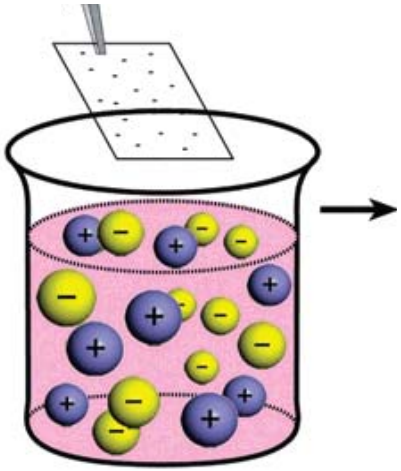
Fant et al. *J. Phys. Chem B.* (**2006**).

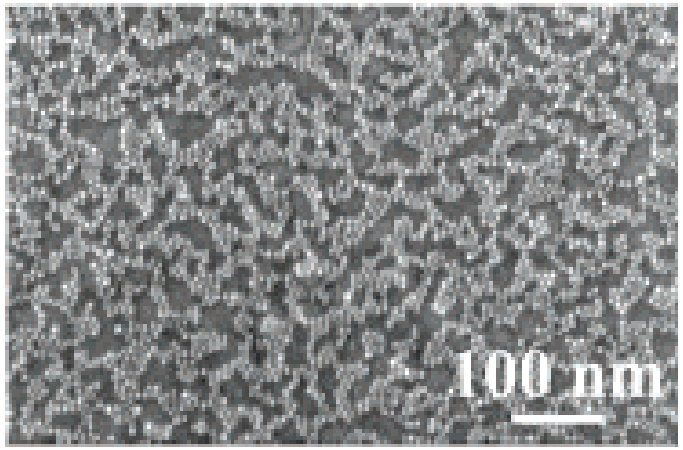
Cooperative Adsorption of Functionalized Nanoparticles onto Silica



- Single functionalized particle-type will NOT assemble.

- When functionalized NPs are mixed with oppositely charged functionalized NPs… assembly DOES occur!





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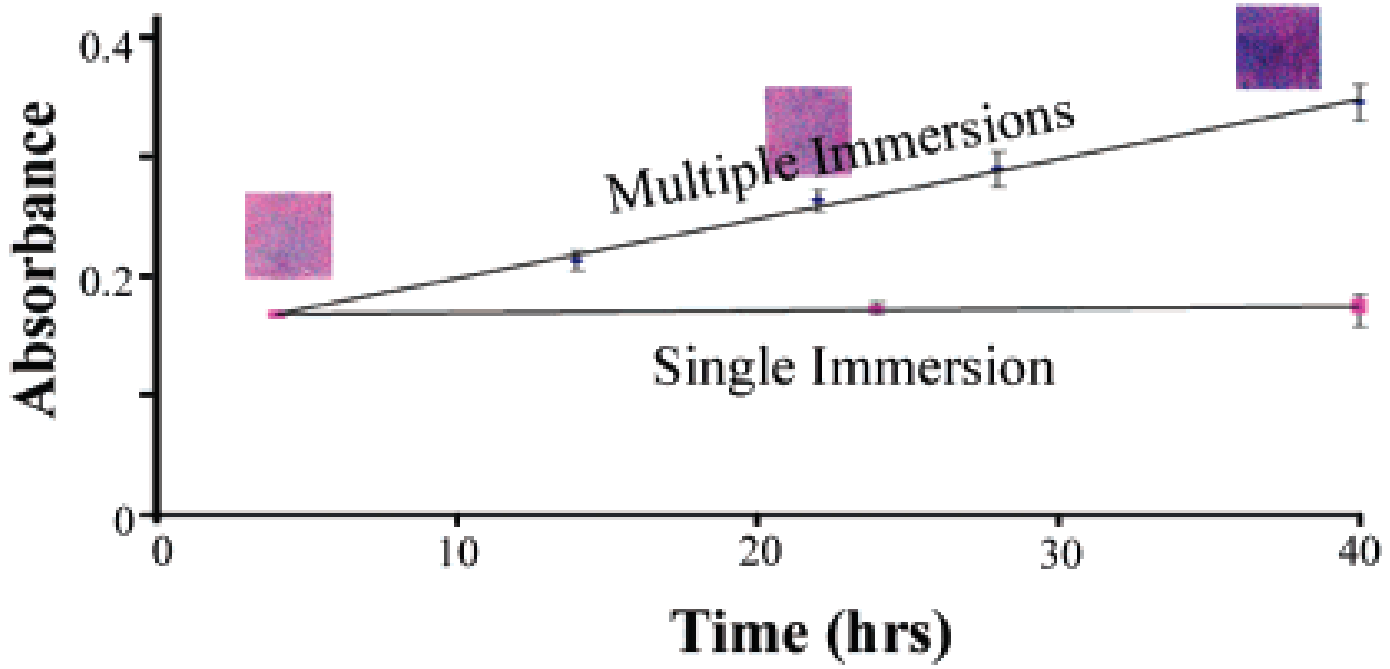
S. Smoukov et al., *J. AM. CHEM. SOC.* 2007, 129, 15623-15630 (**2007**)

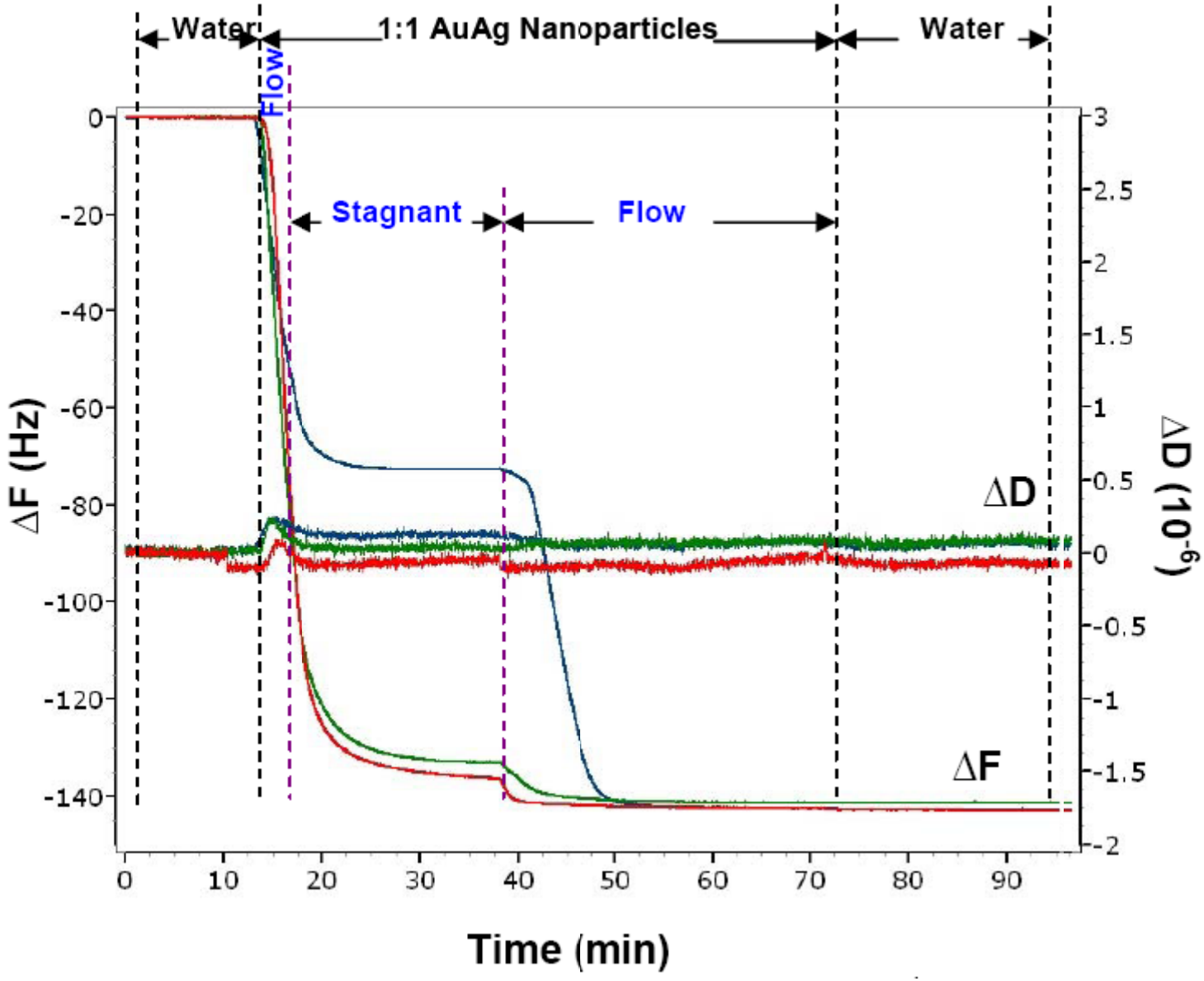
Adsorption of Functionalized Nanoparticles onto Silica (cont)



Coating density impacted by immersion?

S. Smoukov et al., *J. AM. CHEM. SOC.* 2007, 129, 15623-15630 (**2007**)

Using QCM-D to Follow the Adsorption of Functionalized Nanoparticles onto Silica



Adsorption Rate of Deposition as Determined with QCM-D

Concentration of 1:1 AuAg nanoparticles	Adsorption rate (Hz/min) (ng cm^{-2} min^{-1})			
	Initial flow mode	Stagnant mode	Average rate for first saturation	Flow over the adsorbed layer
50 µg/ml	(14.2) (251)	(1.4) (25)	(2.57) (45.5)	(3.7) (62)
150 µg/ml	(23.5) (416)	(2.1) (37)	(3.7) (65)	(0.4) (7.1)
400 µg/ml	(23) (407)	(2.2) (39)	(3.7) (65)	(0.3) (5.3)

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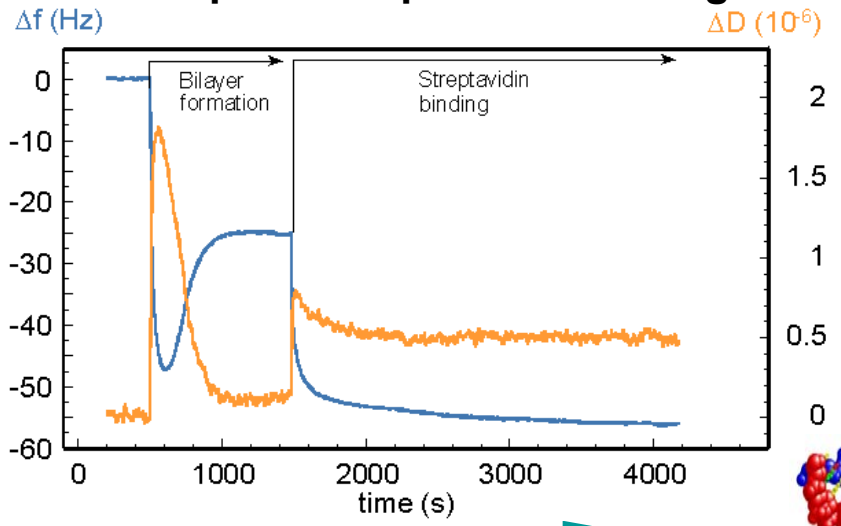
M.A. Poggi et. al, *J. Phys. Chem. C.* submitted (**2008**)

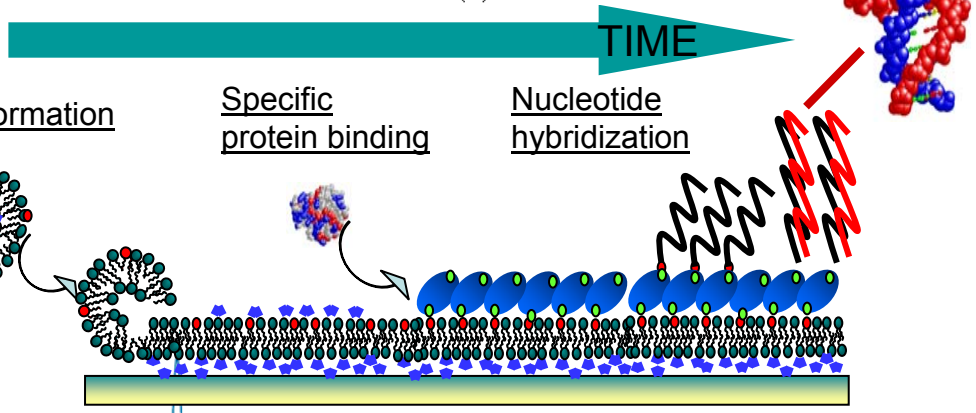
So, What can QCM-D Measure?

Biological

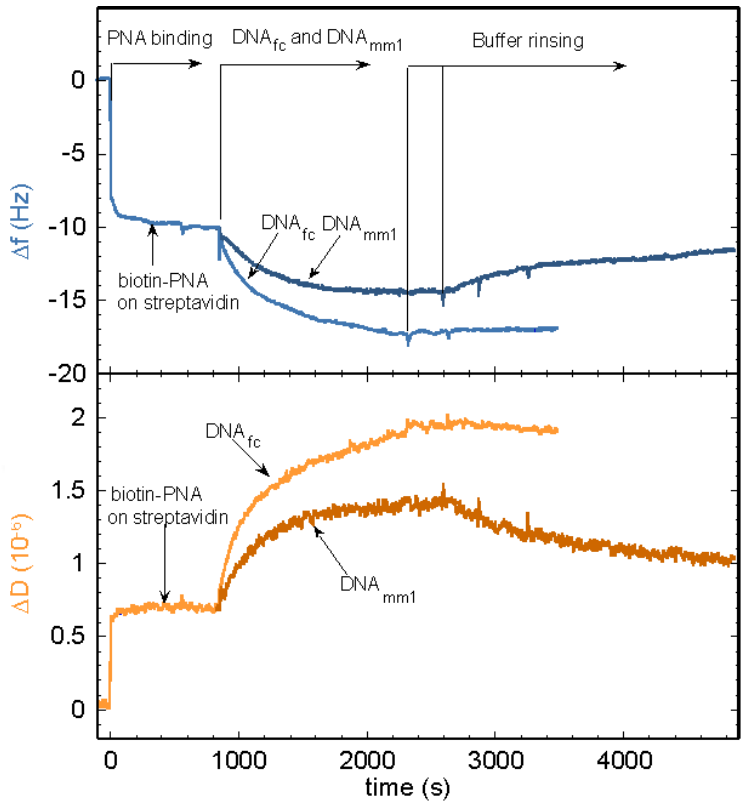
Single Mismatch Detection During PNA (15-mer) and DNA (15-mer) Hybridization

Biotinylated bilayer and subsequent streptavidin binding





Single mismatch detection during hybridization



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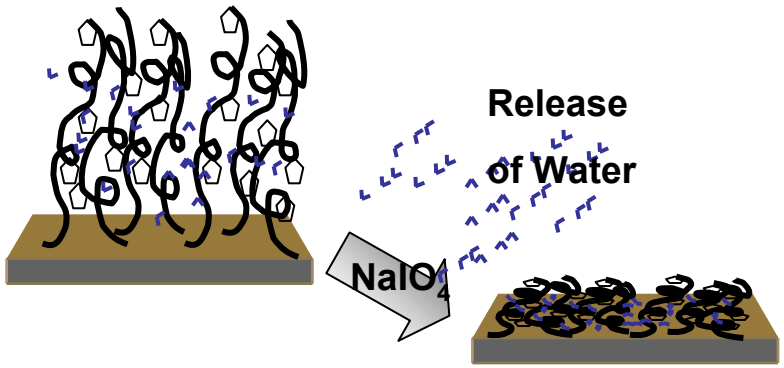
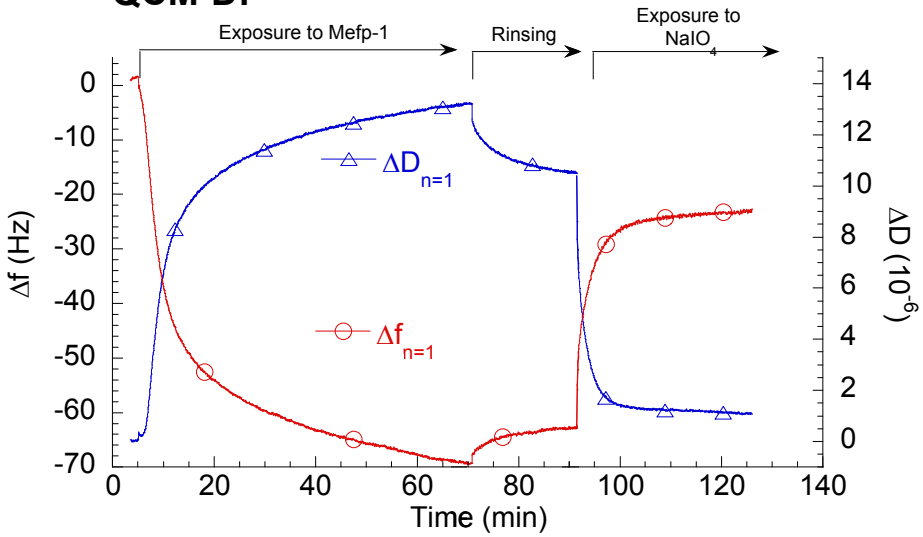
Höök, F. et al. Langmuir 2001, 17, 8305-8312

Adsorption and Cross-linking of Polymers

Mefp-1



QCM-D:



	Measured parameter	Prior to cross-linking	After cross-linking
QCM-D	Δm, sauerbrey, n=3 (ng / cm^2)	1168	730
	Thickness, sauerbrey n=3 (nm)	11.3	6.9
	Thickness, modelling (nm)	22.4	7.3
	Viscosity (e-3 N s m^{-2})	1.8	6
	Elasticity (e4 N m^{-2})	6.6	30
ELM	Δm (ng / cm^2)	135	130
	Thickness (nm)	21	5
	Refractive index	1.35	1.40

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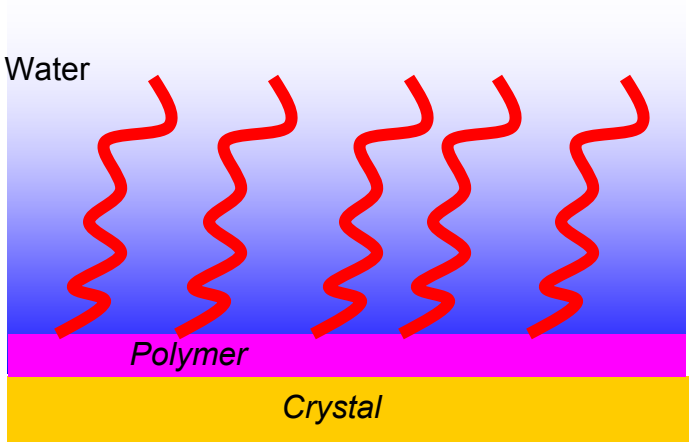
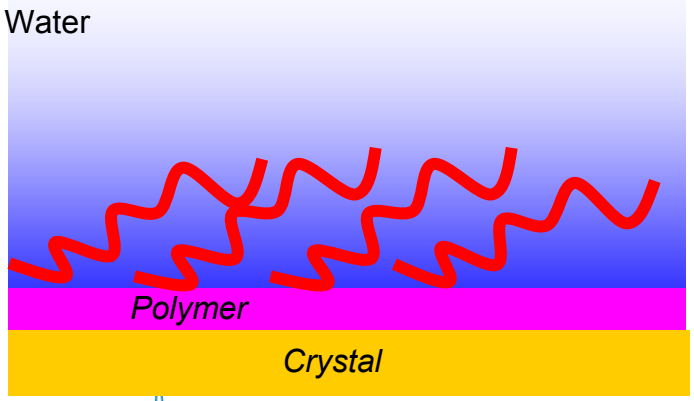
Fant, C & Höök, F; Anal. Chem. **(2001)**, 73, 5796-5804

Fibrinogen Adsorbed to the Surface of Biopolymers





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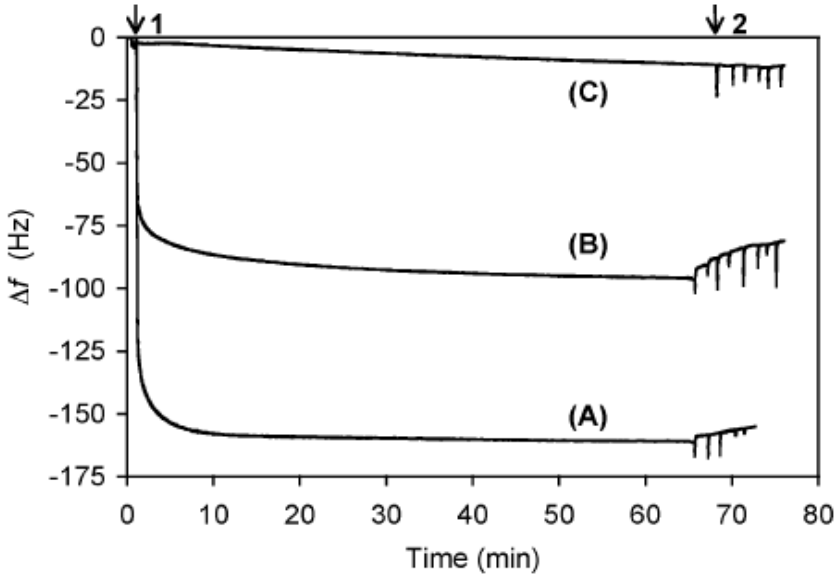
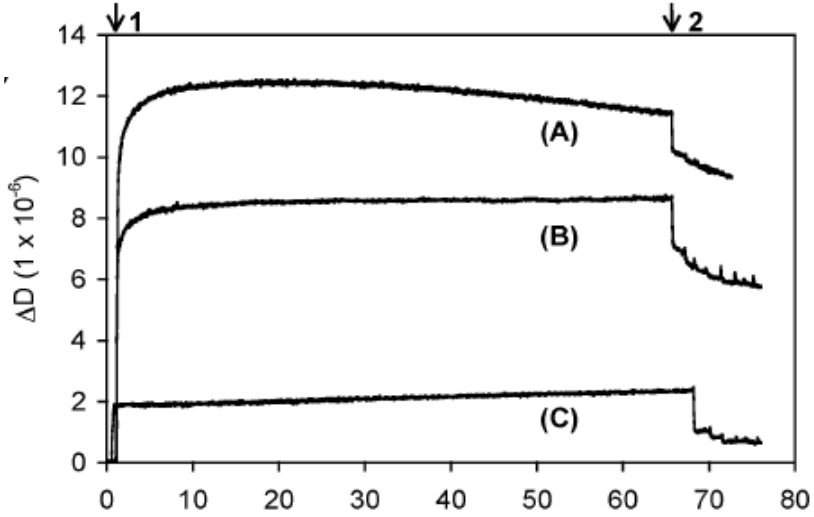
Weber et al. *Langmuir* **2007**, 23, 3298-3304

Fibrinogen adsorption (cont.)

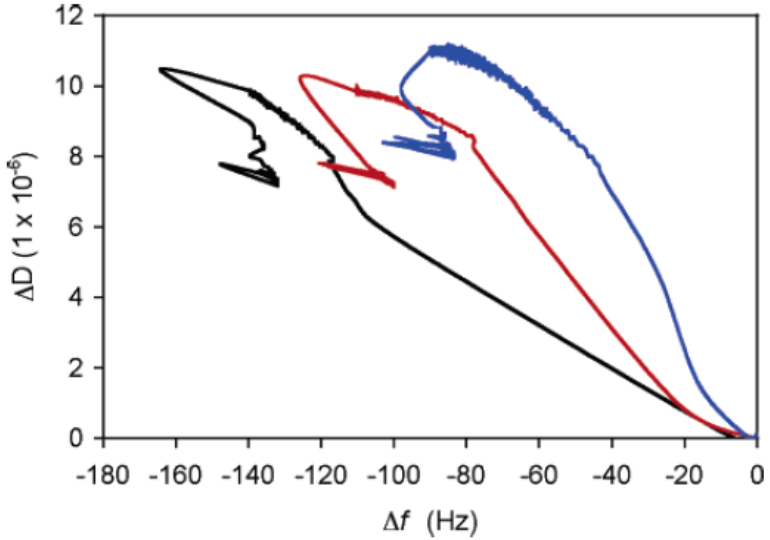




A = PLLA

B = Steel

C = poly(PEG) graft



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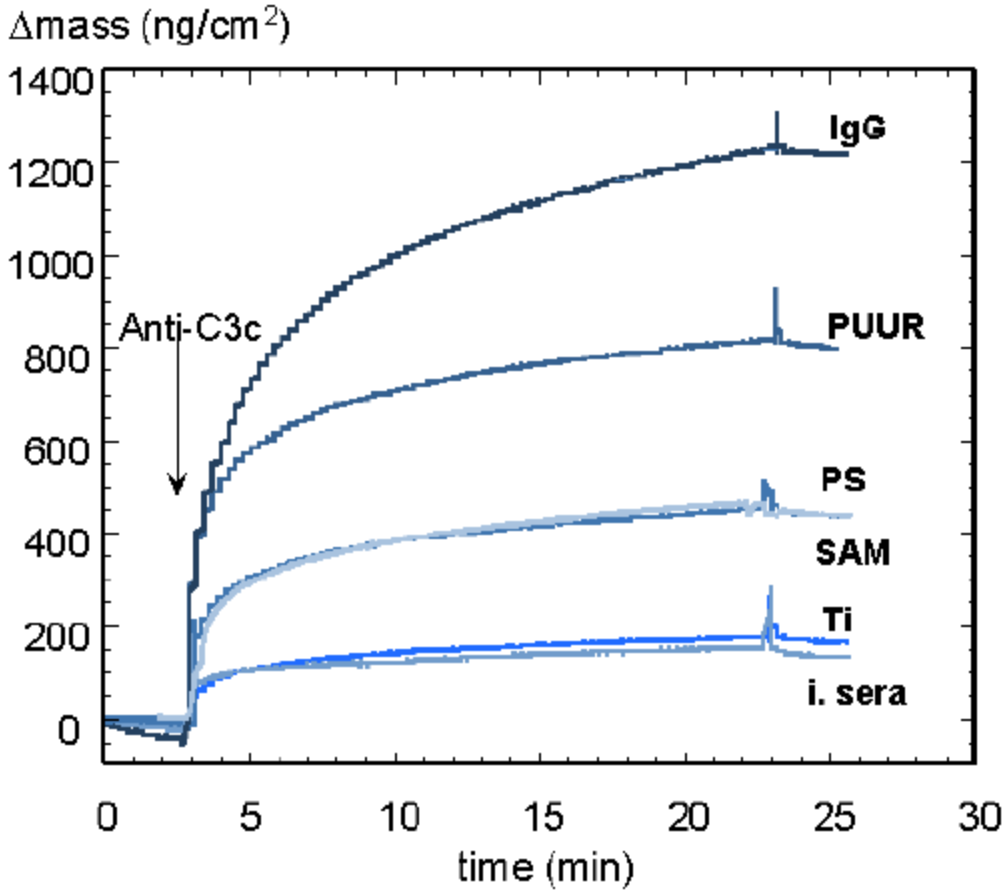
Weber et al. *Langmuir* **2007**, 23, 3298-3304

Rapid Screening of Protein Adsorption onto Different Surface Chemistries



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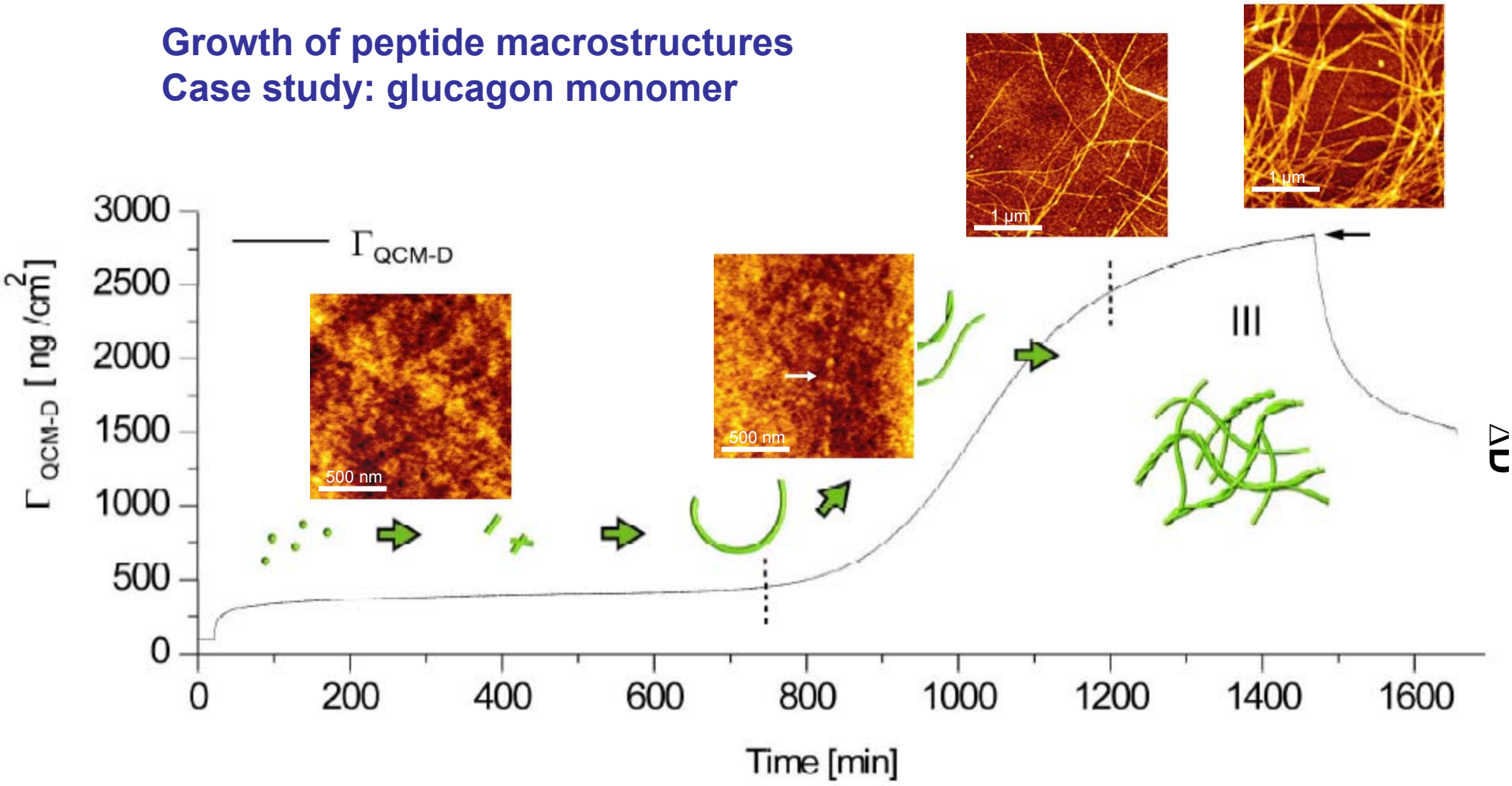
Growth of peptide macrostructures
Case study: glucagon monomer



Surface mass density quantified at different stages of fibrillation.

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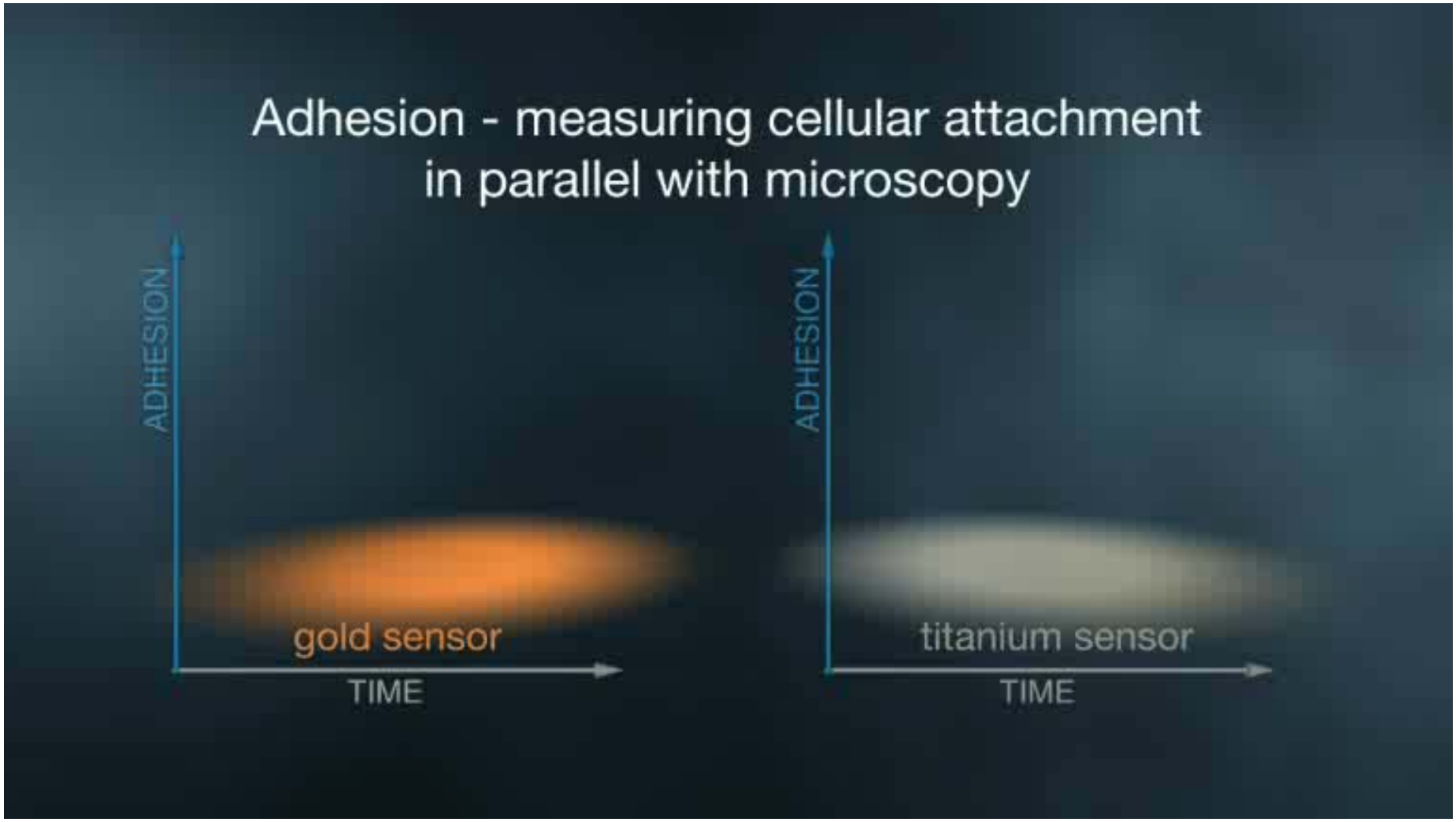
Hovgaard et al. *Biophysical Journal*, 93, 2162-2169, **2007**

T.P.J. Knowles et al. *PNAS*, 104, 10016-10021, **2007**


Adhesion - measuring cellular attachment
in parallel with microscopy
ADHESION
gold sensor
TIME
ADHESION
titanium sensor
TIME

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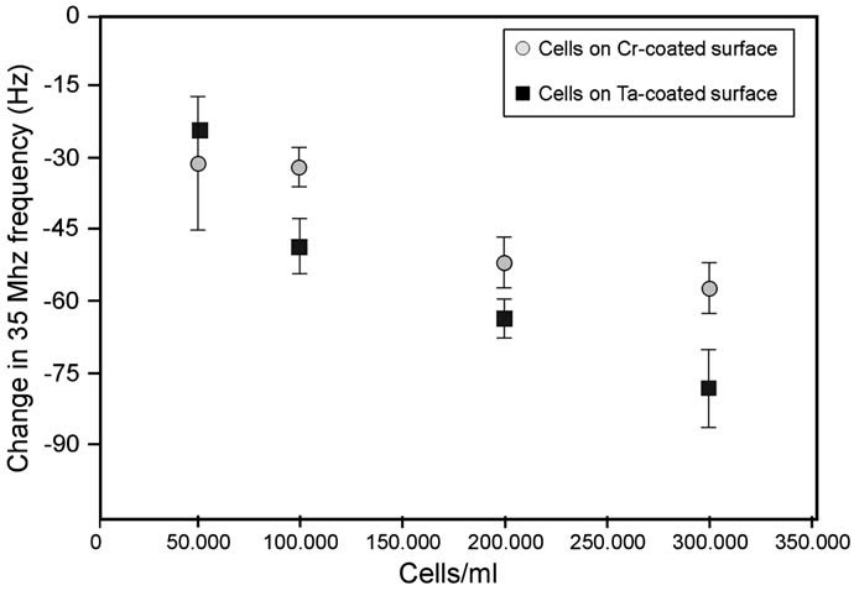
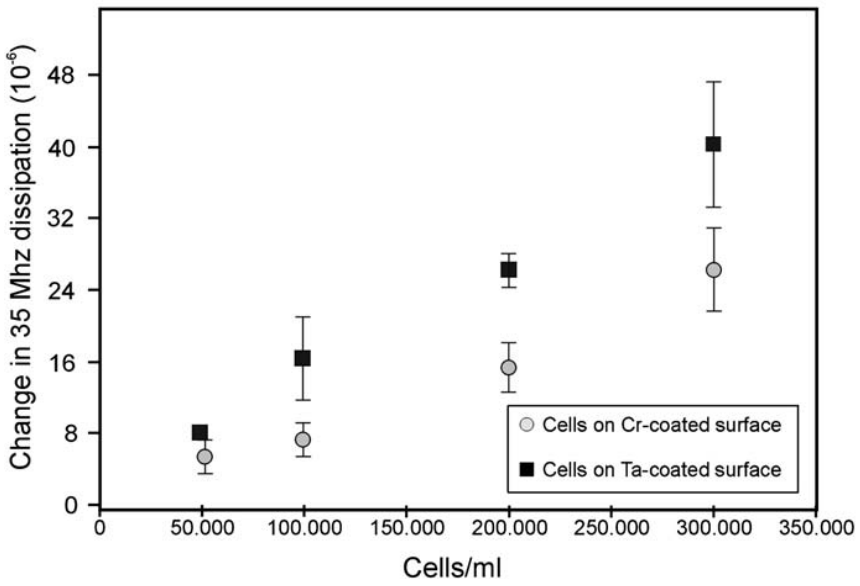
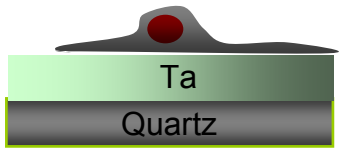
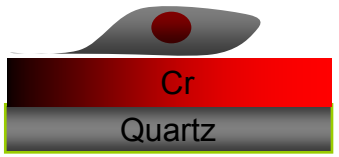
Bone Stem Cells on Ta & Cr Surfaces









Cell attachment stronger and more spread on Ta surface then Cr

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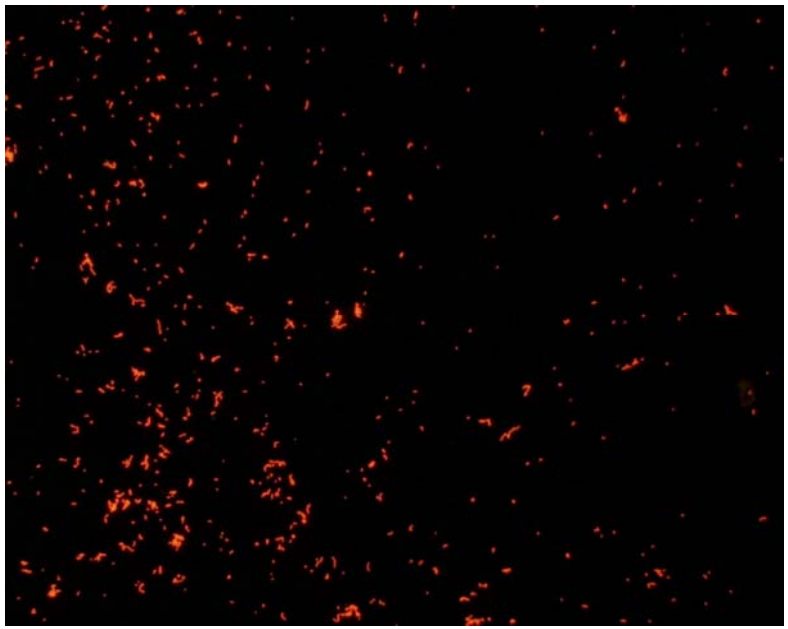
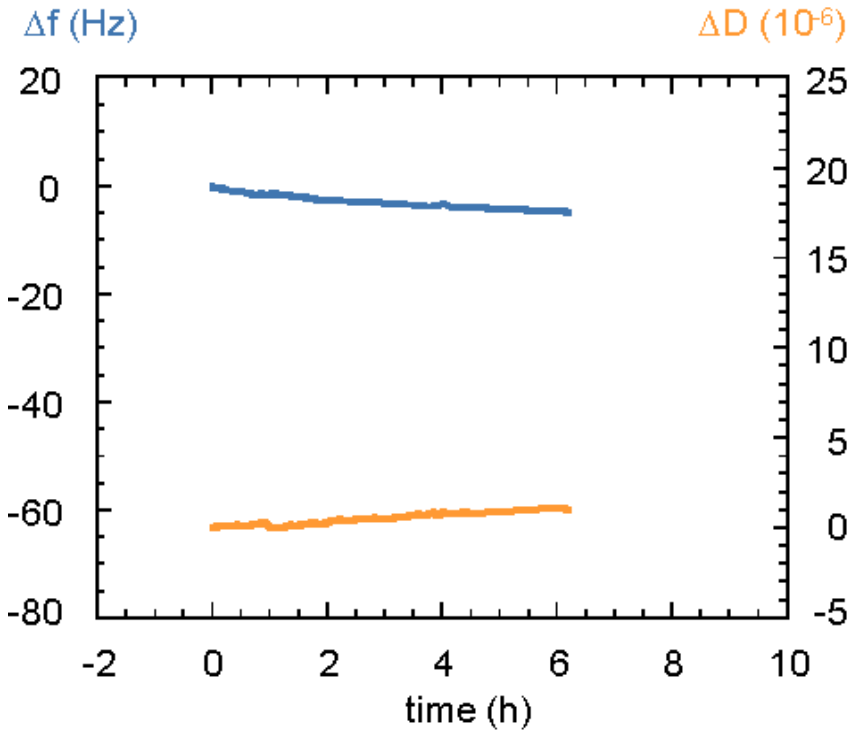
Modin et al. *Biomaterials* 27 (**2006**) 1346–1354

Monitoring/Quantifying the Formation of Biofilms (cont.)

Fluorescence Microscopy



QCM-D



Bacteria: Leuconostoc mesenteroides

Surface: Steel

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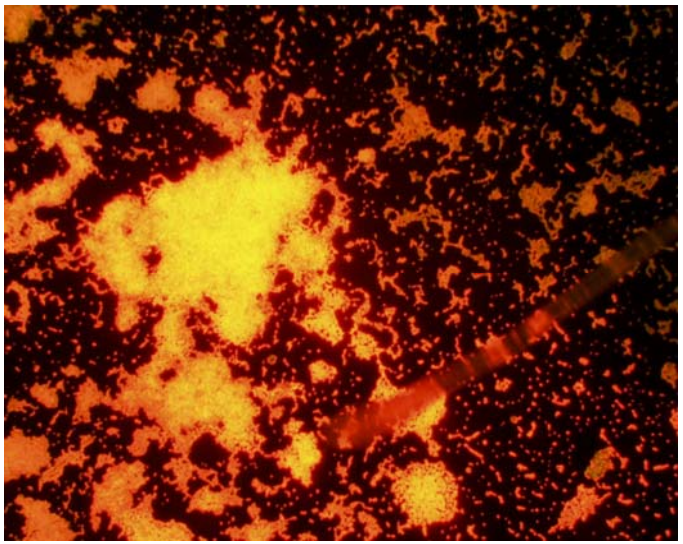
H. Green Q-Sense AB. **2004**.

Monitoring/Quantifying the Formation of Biofilms (cont.)

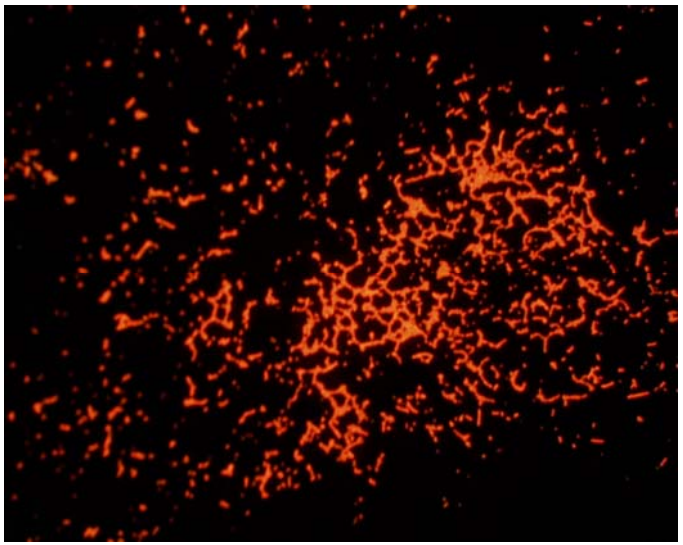
Time

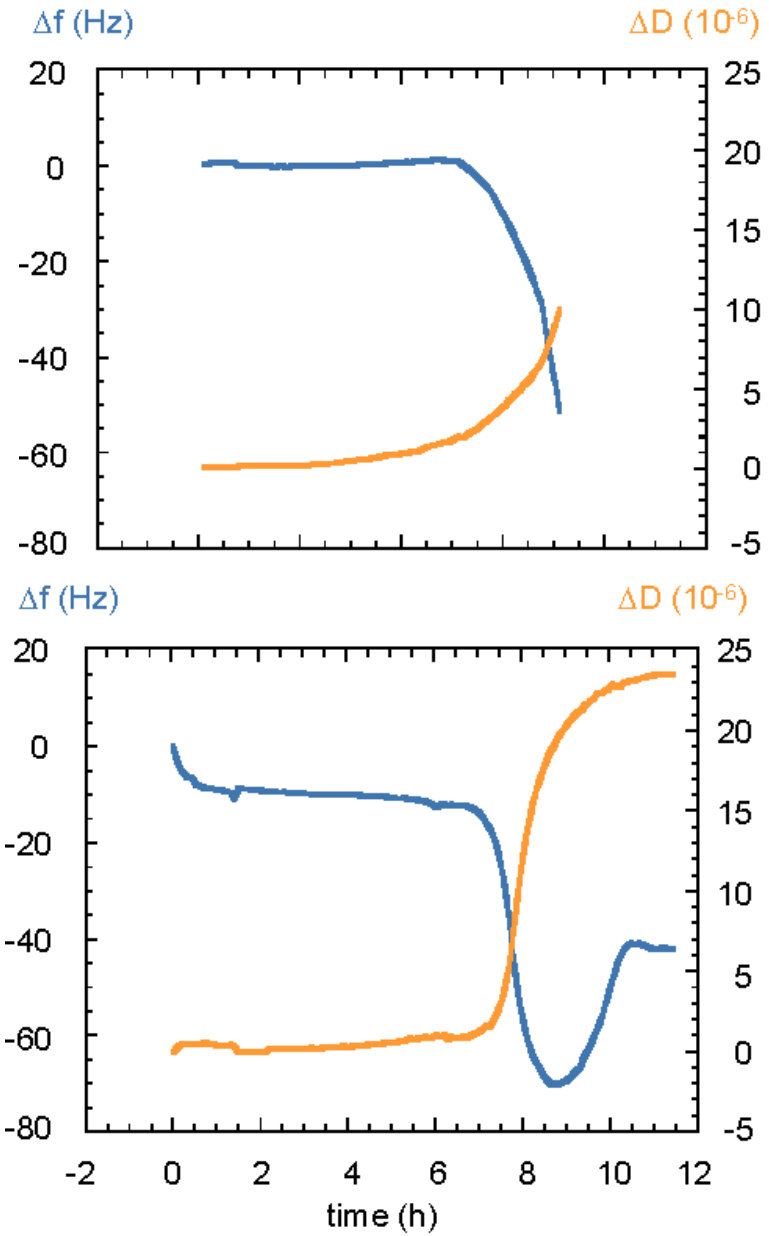
6 hr



Time

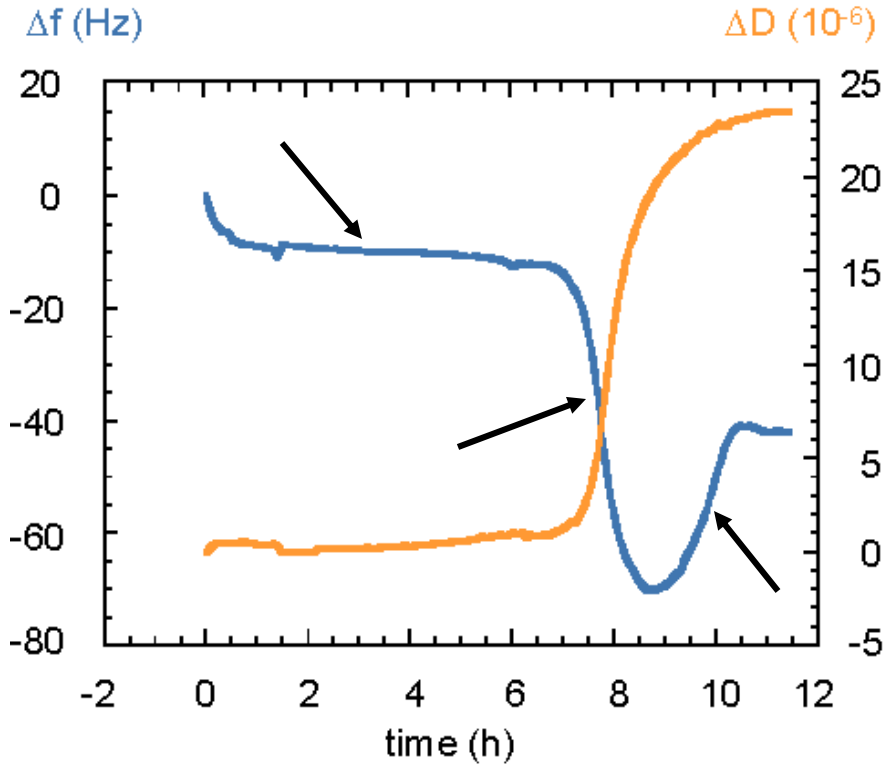
12 hr

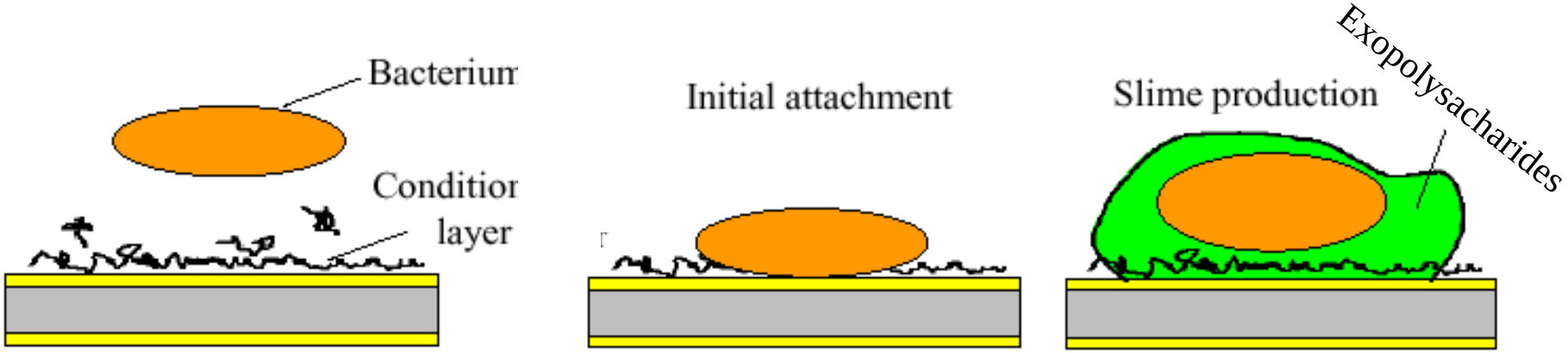




H. Green Q-Sense AB. **2004**.

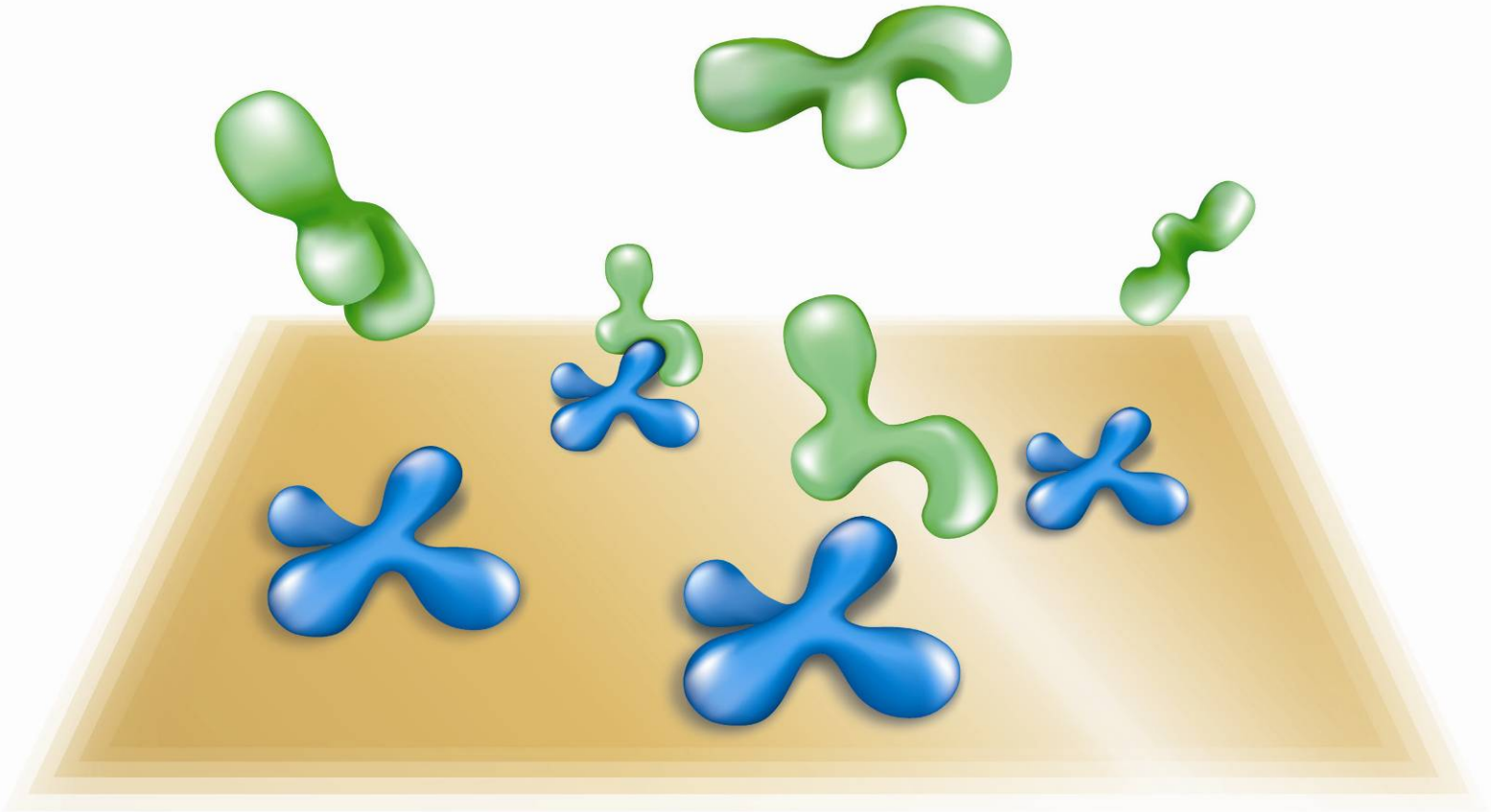
Monitoring/Quantifying the Formation of Biofilms (cont.)





H. Green Q-Sense AB. **2004**.

Experimental Planning and Methods



QCM-D Fundamental Training

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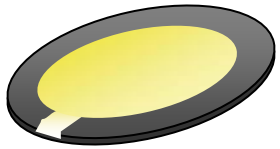
Outline

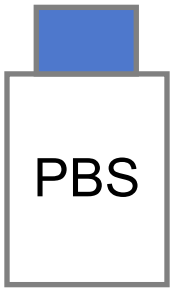
- Measurement requirements
- Surfaces
- Cleaning protocols
- Sample preparation
- Tech Tips

QCM-D Experiment Planning
S.S.I



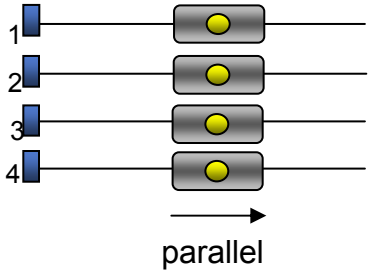
Surface

What type of surface?
How will I clean/prepare the surface?



Samples

What buffer (solvent)?
Which concentration(s)?
What Temperature?
Do I need to degas my samples?



Instrument

How do I cleaning/prepare the instrument?
What liquid path am I going to use?
What about solvent compatibility?
Flow rate/Batch mode?

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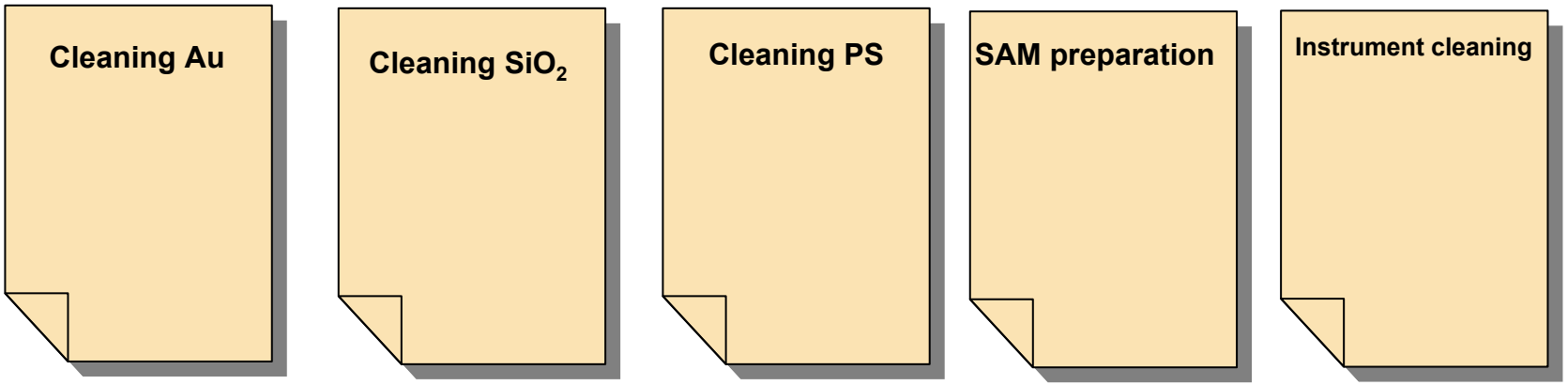
Methods & Protocols



Collection of preparation and cleaning methods for surfaces and instrument

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Wide Range of Crystal Surfaces

Metals & Metal Oxides

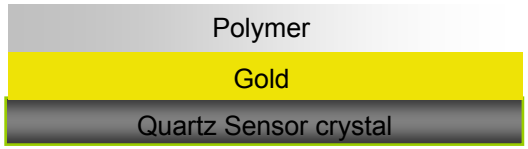
- Au, SiO_2, Al_2O_3, Ti, Stainless steel, Pt
- Ag, W, Cu, Cr, Ir, Ta, FeC_3, TaN, CeO_2, Fe, Zn, ZrO_2, SiOC, Iron oxide, Si_3N_4 etc
- Other coatings can be made on request

Unique Inorganic Coating

- Hydroxyapatite (nanocrystalline, RMS roughness ~2-3 nm)

Spin Coated Polymers

- In stock: Polystyrene
- Other polymers on request Examples: PC, PMMA, PP, PE, PVC
- Users can coat sensors with their own polymers/materials



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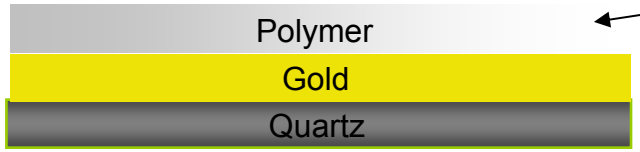
Surfaces - Polymeric

Spin coated polymers

Many polymers can be spin coated:
PS, PC, PMMA

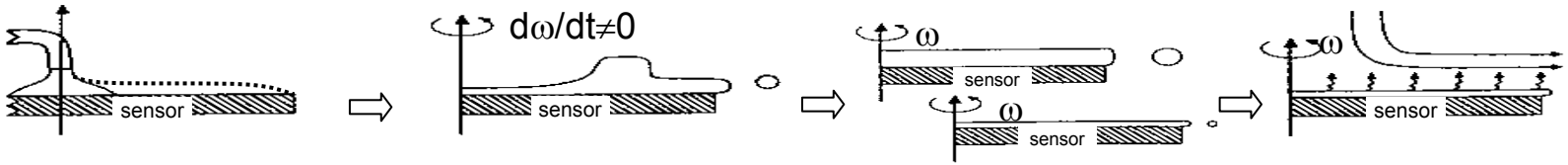


Thickness range:
100nm-1µm

Other methods

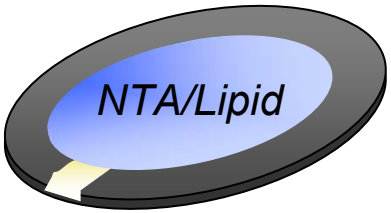
•Surface attached polymerization

Spin coating

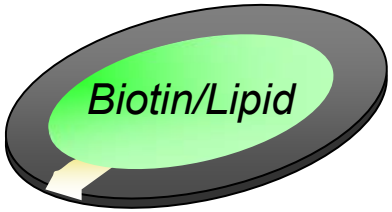


Deposition (full coverage) | Acceleration | Fluid thinning | Evaporation

Surfaces – Specific Chemistry



•SLB NTA modified surface for His linkeage Protocol



•Biotin immobilization surface Protocol

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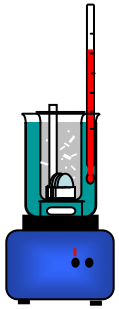
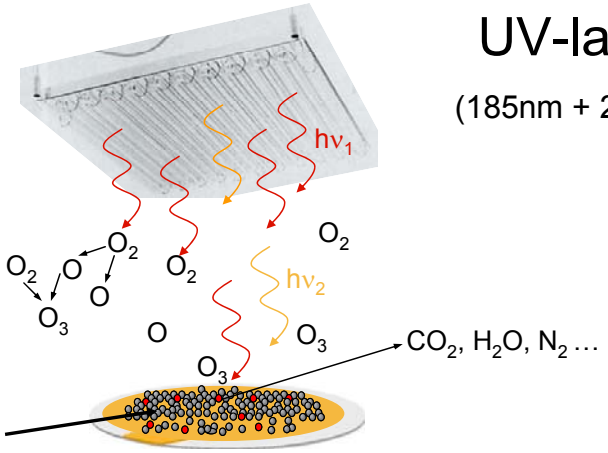
Clean Sensor (and tweezers)

Gold



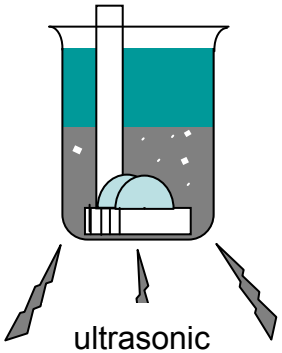


Amonia, Peroxide Mix (TL1, Piranha) + UV/Ozone

SiO_2

SDS + UV/Ozone

Thick films/
Heavy contaminated



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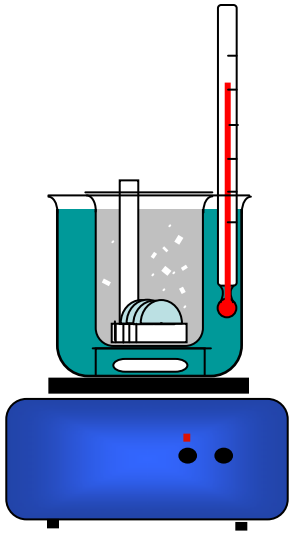
Chemical Treatment, APM, TL1



- Surface: gold
- Deposits: lipids, thiols, proteins in molecular layers
- Method:
  - UVO-treatment (10 min)
  - Heat 5:1:1-mixture of mQ-water, ammonia (25%) and hydrogen peroxide (30%) to 75°C
  - Immerse sensors in solution using a cleaning holder (5 min)
  - Clean tweezer in the same beaker
  - Rinse in mQ-water, dry with N_2
  - UVO-treatment (10 min)

W. Kern et al., *RCA Review* **31** (1970) 187

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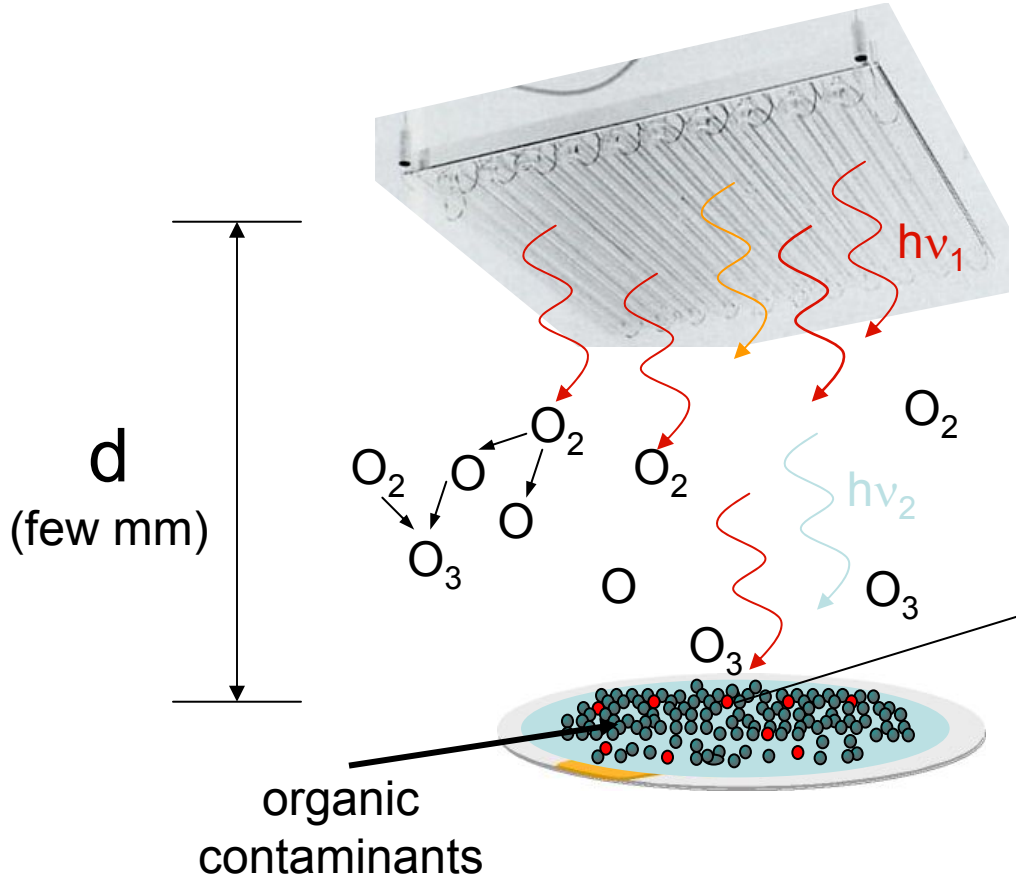
Cleaning Surfaces – UVO-Treatment



- effective in air
- exposure time: 5..10 min

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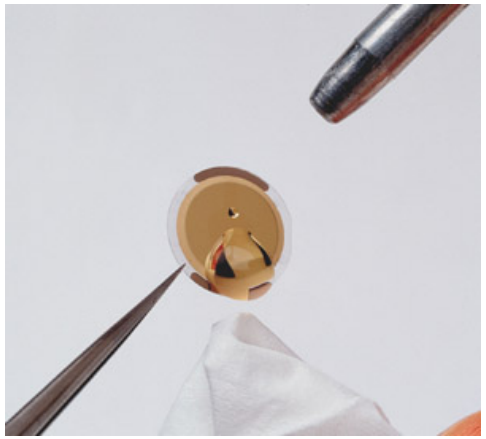
Sensors Dry and Dust Free

Rinse washing solution off

Keep tweezer below sensor

Dry with a clean gas



N_2
Ar_2
CO_2

Never use compressed air!

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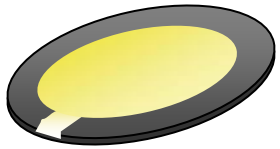
QCM-D Experiment Planning

S.S.I

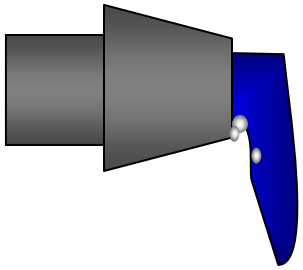


Surface ✓

What type of surface?
How will I clean it?

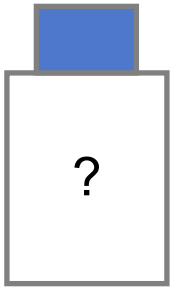
Pure Samples

Water:
18,3 MΩ MilliQ



sterile≠clean

Buffers:
Prepare your own buffers, do not trust the ”kitchen”!



? – Water, PBS, HEPES, MES, ACETAT, ...

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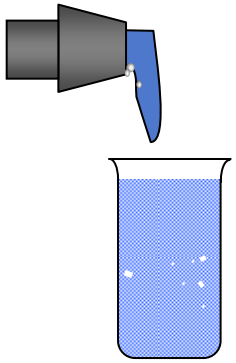
Concentrations

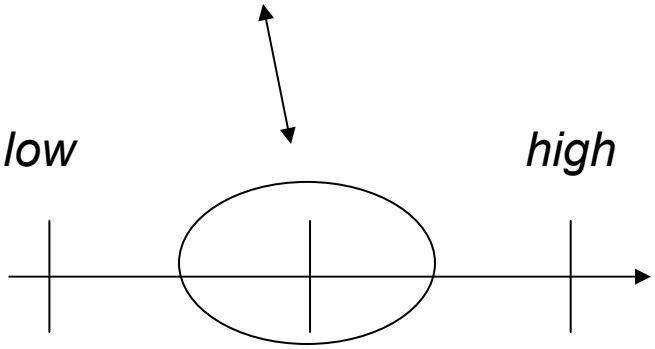


0.1-100 ug/ml

<u>Typical Concetrations</u>

Protein	0.1-100 µg/ml
Antibody	0.01-10 µg/ml
Cells	10^4 - 10^6 CFU/ml
DNA	pmol-nmol

Optimal concentration region



No/slow response
Diffusion / Depletion

Bulk effect
Too rapid kinetics
Costly

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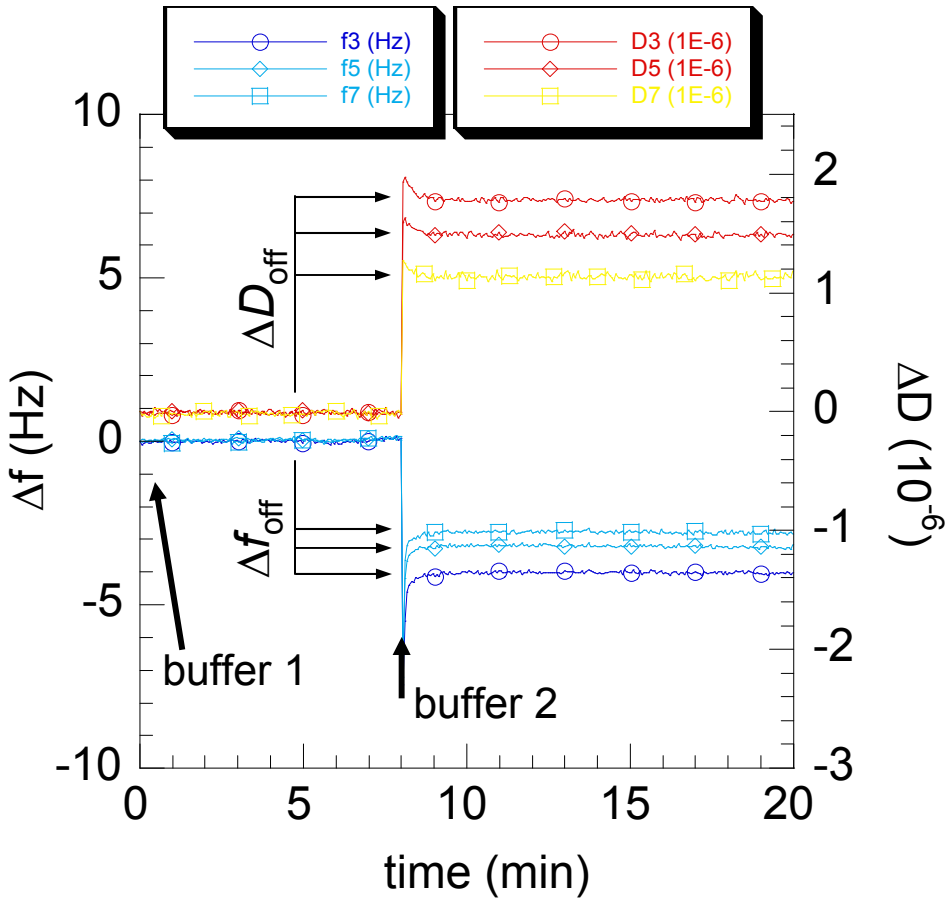
Bulk effects – “Buffer step”



- Effect:

  offset in baseline of *f* and *D* when changing solution

- Cause:

  bulk properties

  - *density* & *viscosity* -

  influence *f* and *D*

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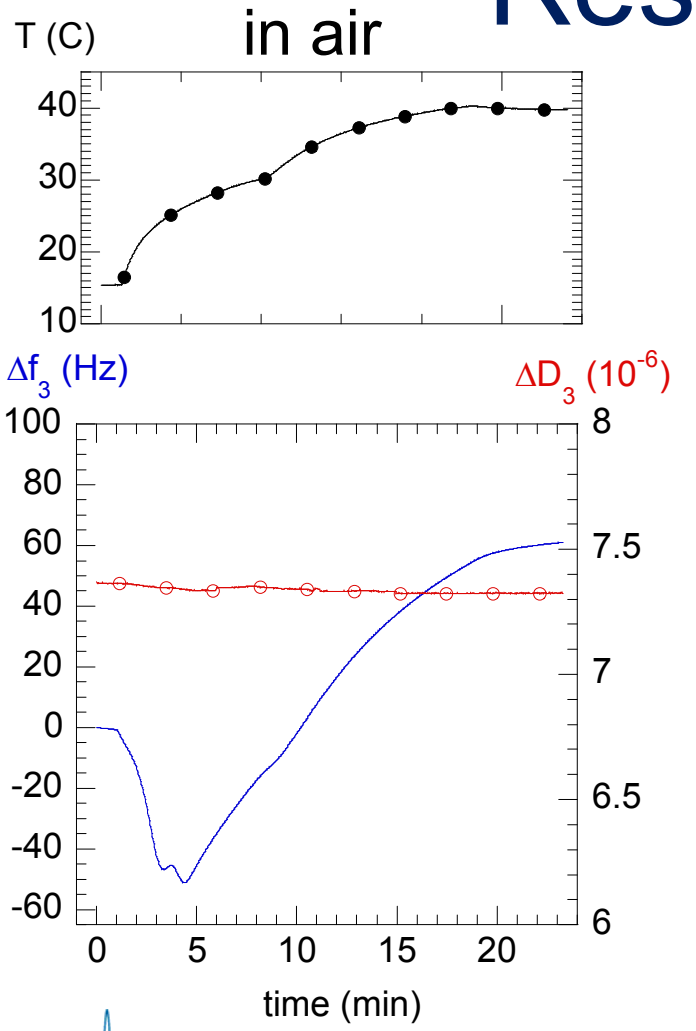
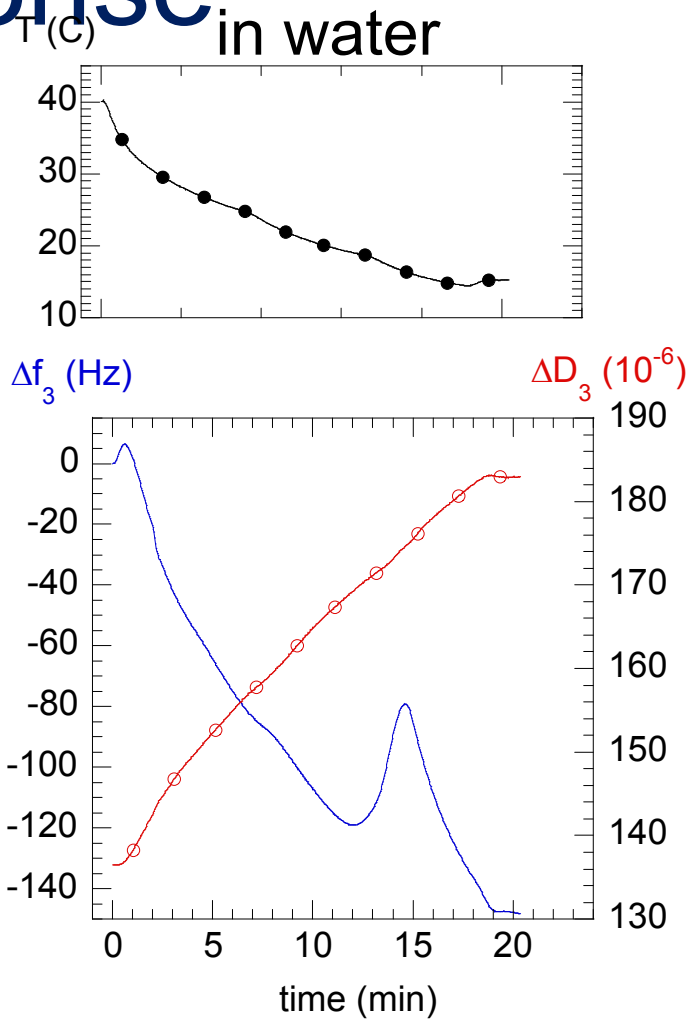
QCM-D Temperature Response





(clean sensor with thin rigid coating)

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T Response of Our QCM-D

$$\Delta f = -C_T f_0 \Delta T$$

C_T = constant depending on design and manufacturing of crystal
~ 4×10^{-7} deg^{-1} (for crystal with radius 5 mm and thickness 0.2 mm)
f_0 = fundamental frequency

For a 5 MHz crystal with ΔT = 1 °C Δf = - 2 Hz

- E4 has T control +/- 0.02 °C
- D300 has T control +/- 0.03 °C

Zelenka, J. Piezoelectric Resonators and their Applications; Elsevier: Amsterdam-Oxford-New York-Tokyo, **1986;** Chapter 6.

P Response of Our QCM-D

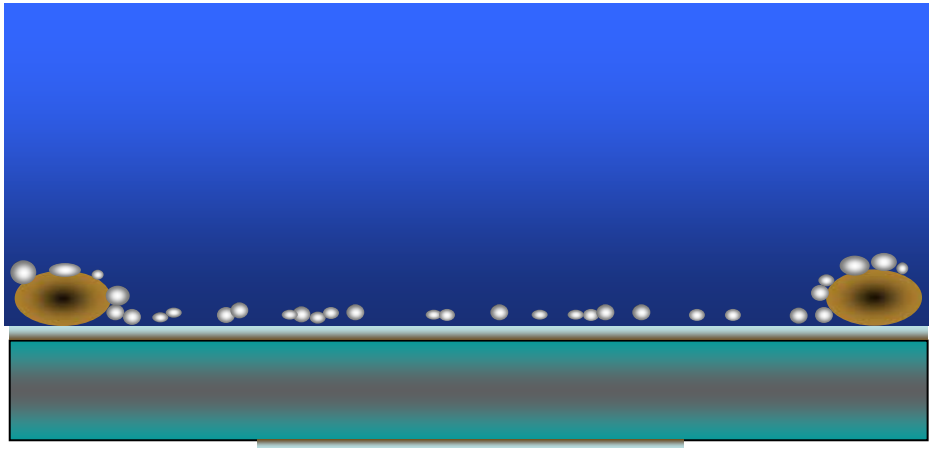
$$\Delta f = -C_P \Delta P$$

C_P = constant independent of nature of gas in torr
= $1 \times 10^{-9} * f_0$
f_0 = fundamental frequency

For a 5 MHz crystal with ΔP = 760 torr Δf = - 3.8 Hz

Stockbridge, C. D. In *Vacuum Microbalance Techniques;* Behmdt, K. H., Ed.; Plenum Press: New York, **1966**; Vol. 5, p 147.

Degas Samples



Origin
- Buffer

Hydrophobic surfaces more problematic!

Degassing samples
- Sonicator
- Heat ($T_{sample} > T_{instrument}$)

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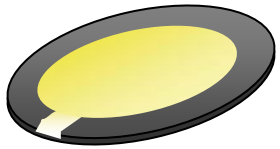
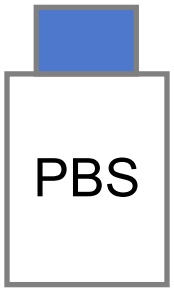
QCM-D Experiment Planning

S.S.I



Surface ✓

What type of surface?
How will I clean it?



Samples ✓

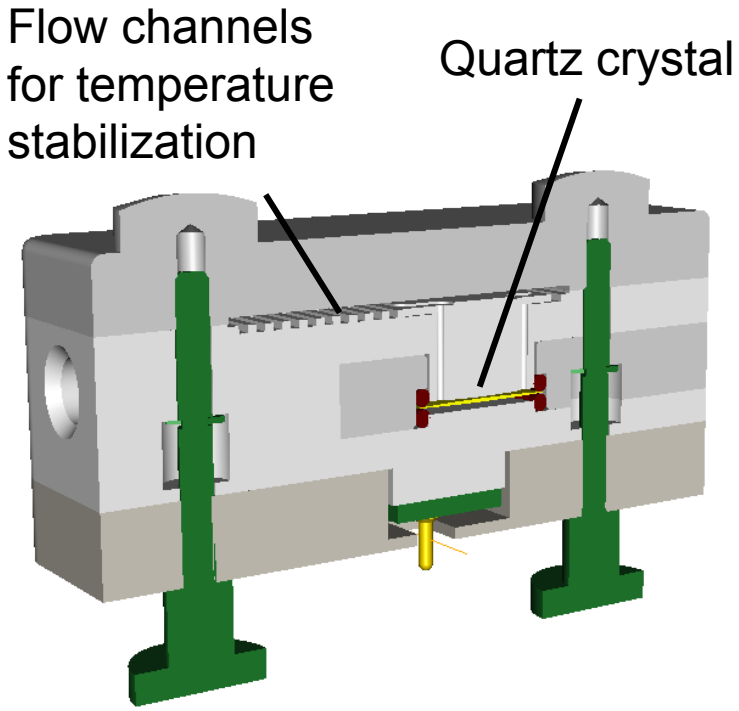
What buffer (solvent)?
Which concentration(s)?
Temperature?
Degassing

Instrument Cleaning

Cleaning solutions:
Hellmanex II
SDS 2%
Roche cleaner

Always end with a water rinse and store chamber dry!

Replace rubber parts when worn out or every year.



Cross section of flow module

Clean the instrument before and after every experiment !!

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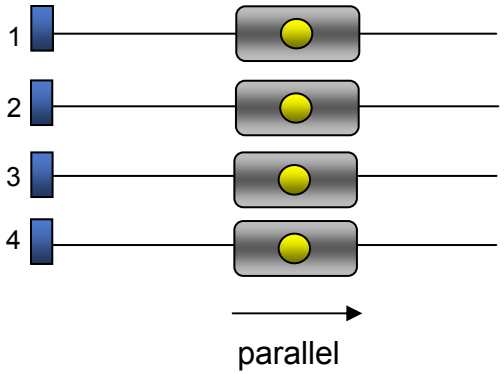
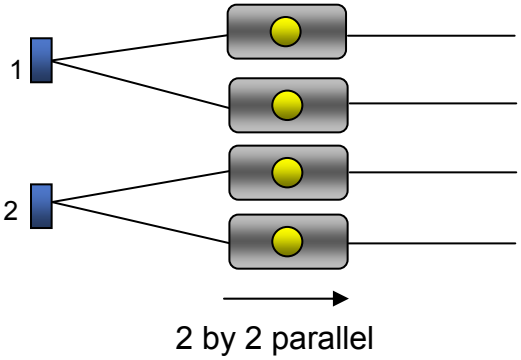
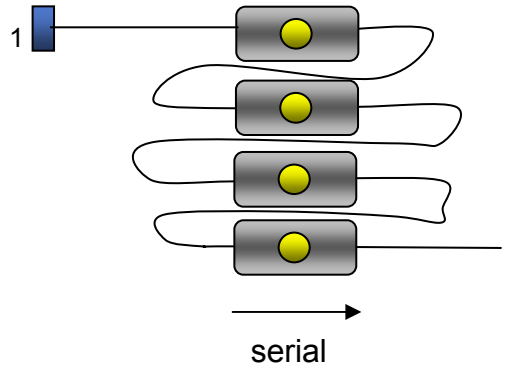
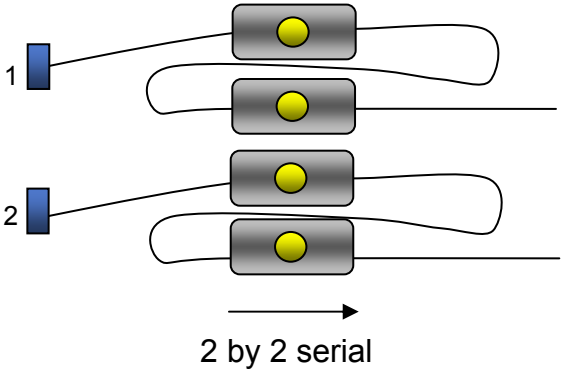
Liquid Path (E4)









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Solvent Combatibility

	E4	Ismatc Peristaltic pump
		
Liquid interfacing materials - *(standard configuration)*	Titanium oxide Viton PTFE	Tygon

Check Appendix – Chemical Compatibility Chart!

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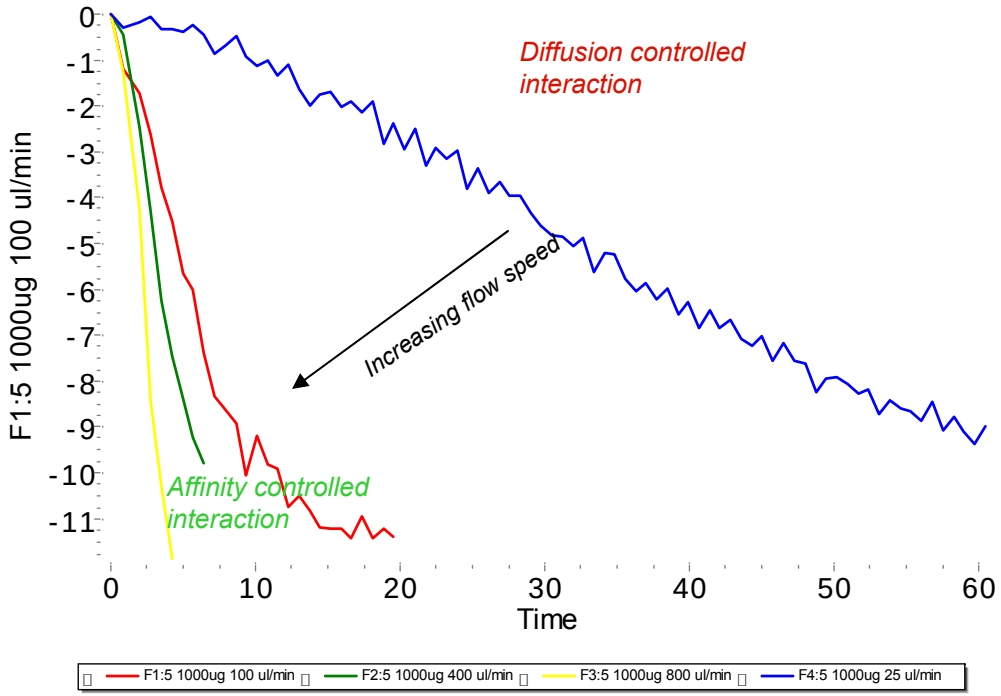
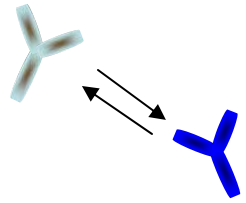
Mass Transport Limitations

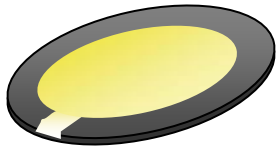




Antibody interaction

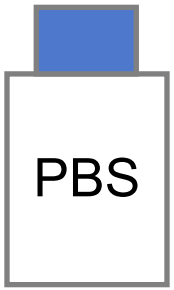
25 µl/min
100 µl/min
400 µl/min
800 µl/min

Summary



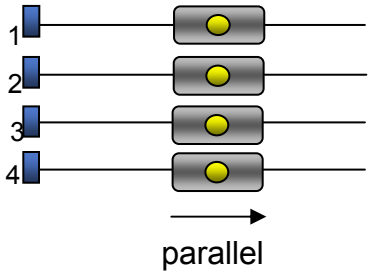
Surface

What type of surface?
How will I clean it?



Samples

What buffer (solvent)?
Which concentration(s)?
Temperature?
Degassing



Instrument

Cleaning
Liquid path
Solvent compatibility
Flow rate

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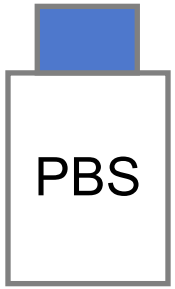
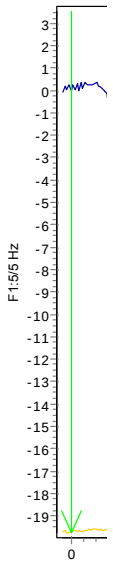
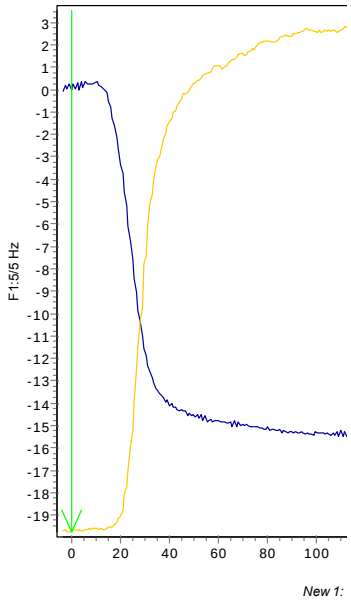
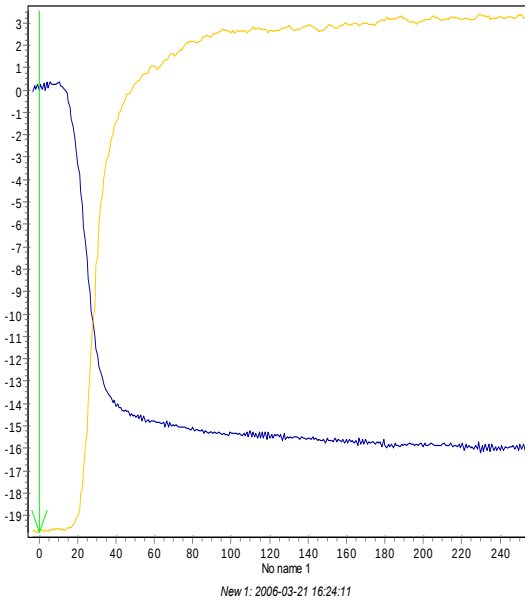
Measurement Time Line

- Surface
- Sample
- Instrument









1) S.S. I.)

2) Establish base line in blank (buffer)

3) Introduce sample

4) Rinse with blank (buffer)

5) Save file and clean instrument

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Tech Tips

- Always start in blank (buffer, water etc)
- Avoid difference in bulk properties
- Bubble = trouble
- Do your own sample preparation!

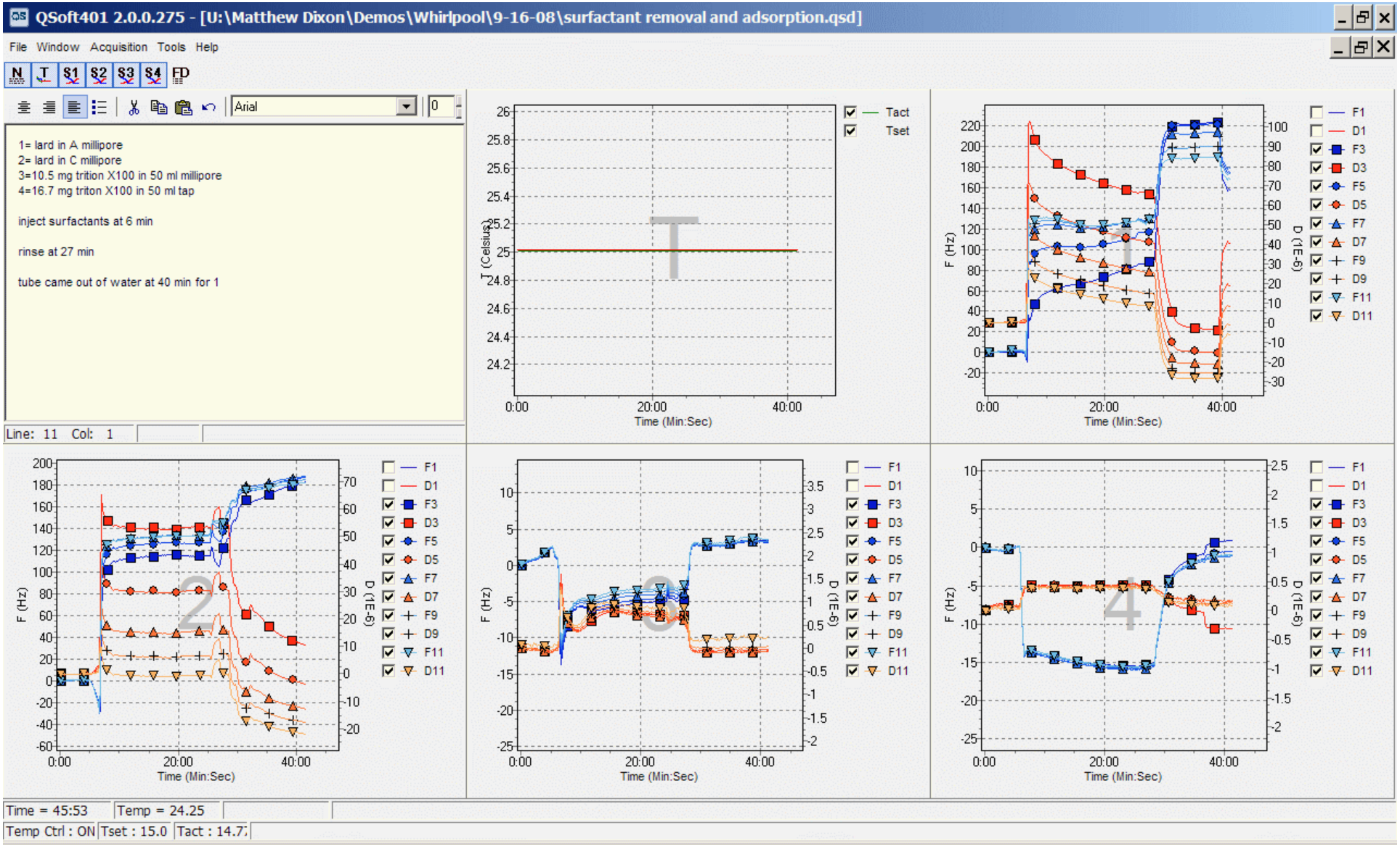
Thank you for your attention!

Software Primer

Raw Data of Demo experiments

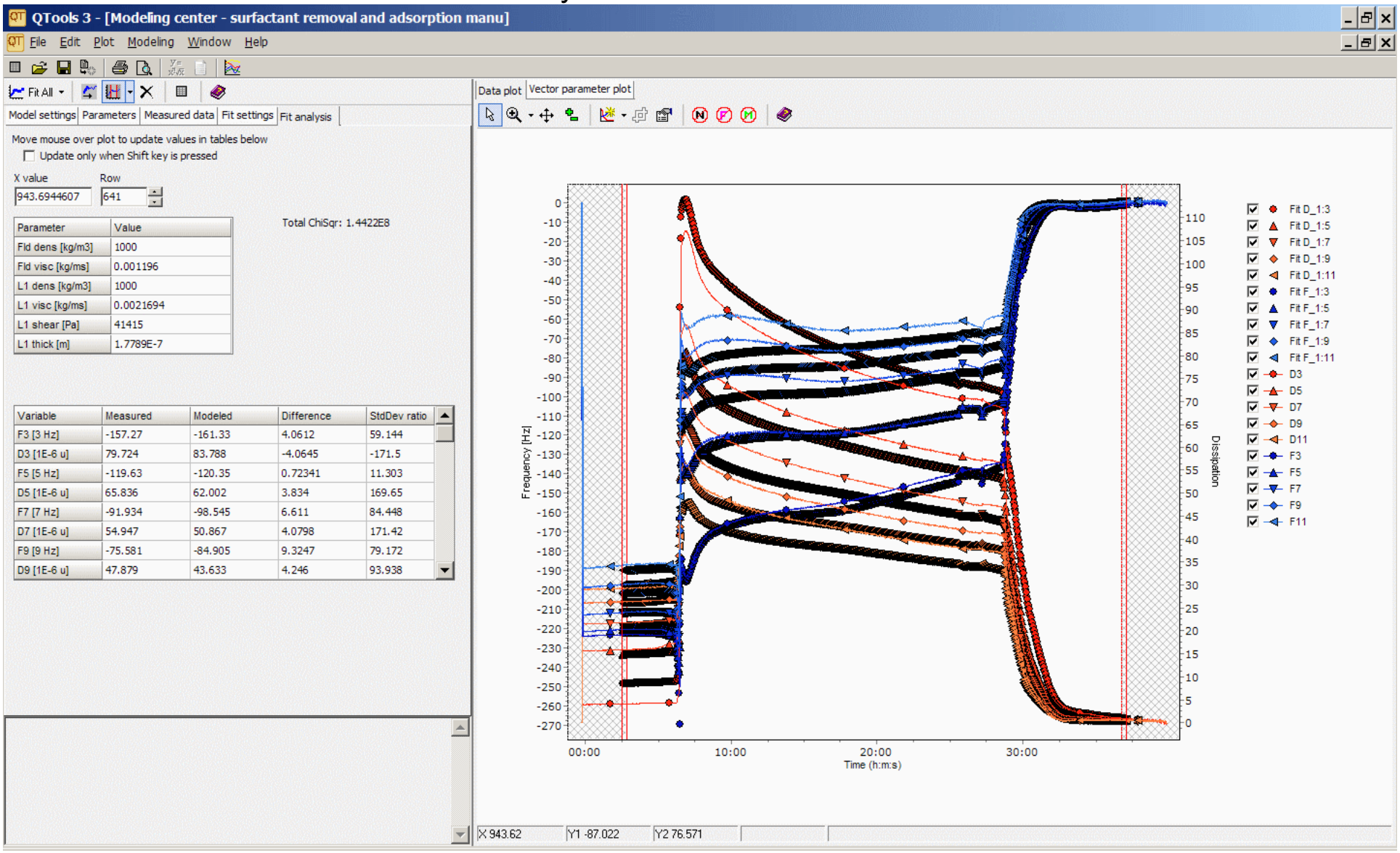
Modules 1 and 2: lard removal by two different commercially available surfactants

Modules 3 and 4: surfactant adsorption from Millipore (3) and tap (4) water



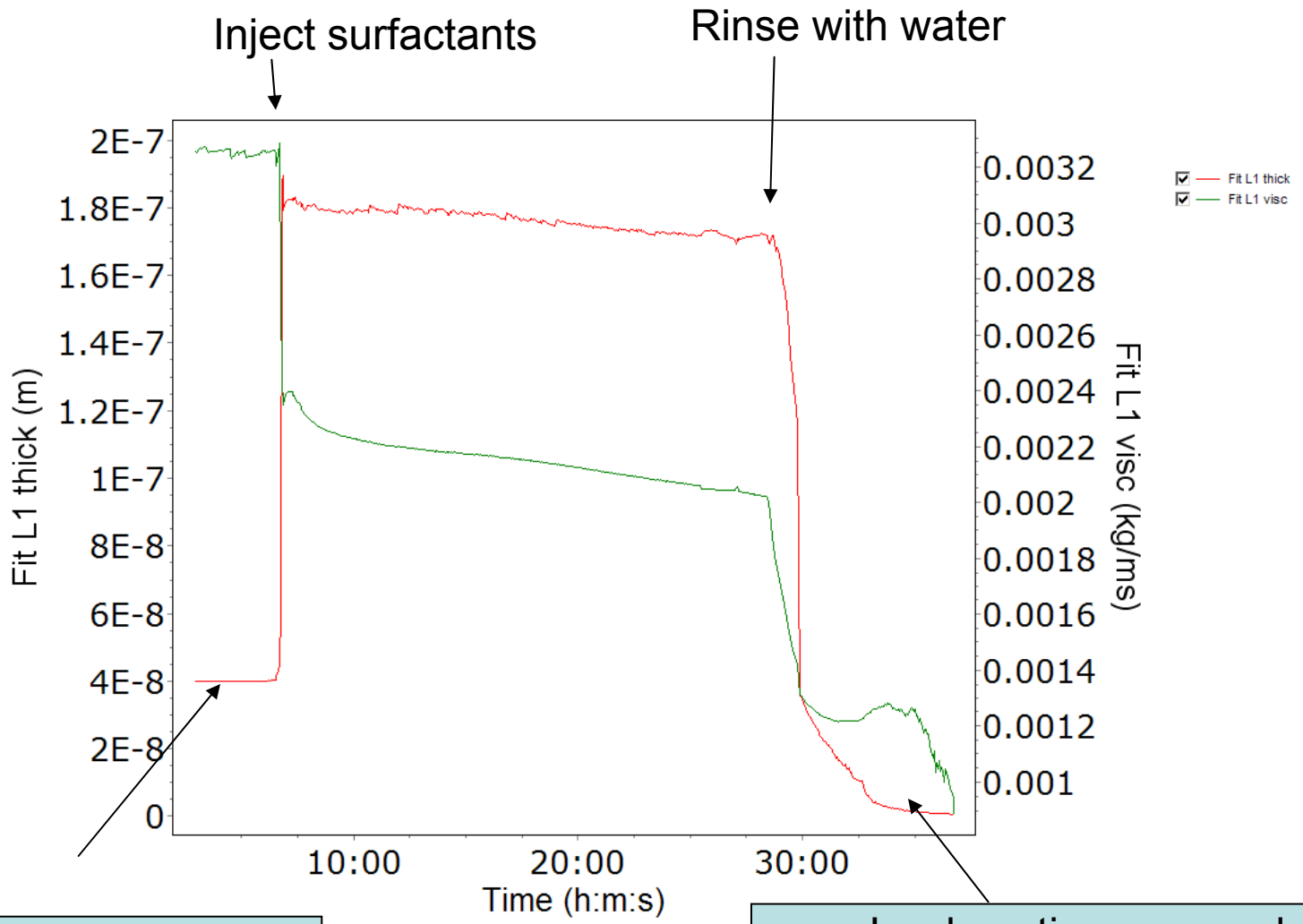
Example Modeled Data of Module 1

Blue lines = frequency
Red lines = dissipation
Black symbols are the fits



Module 1

Modeled Thickness (red) and Viscosity (green)



Lard coating in water
(note thickness is ~40 nm)

Lard coating removed
(note thickness is ~ 0
and viscosity ~ water)

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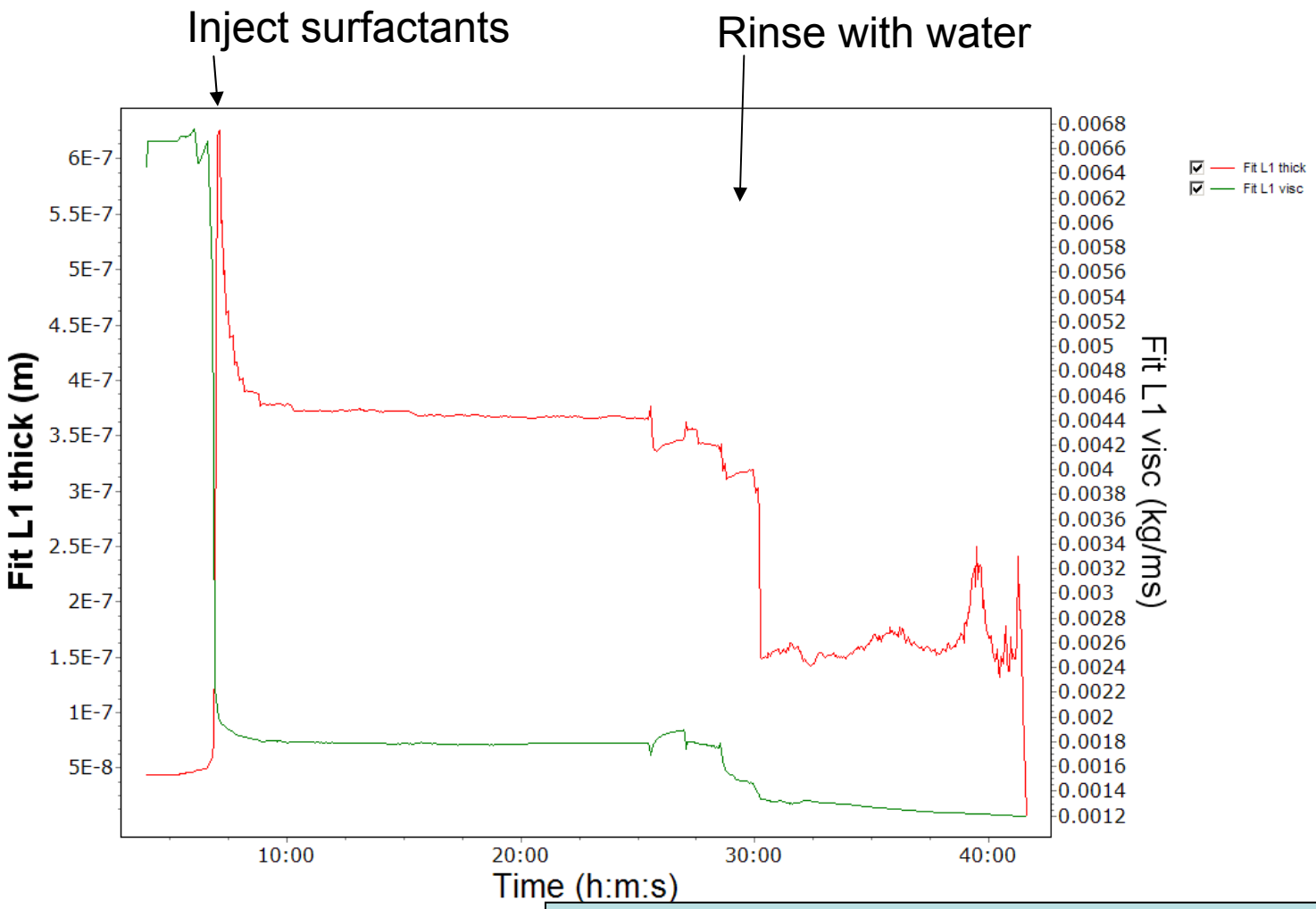
Module 2

Modeled Thickness (red) and Viscosity (green)



Lard coating in water
(note thickness is ~40 nm)

Lard coating removed towards very end of rinse
(note thickness is ~ 0
and viscosity ~ water)

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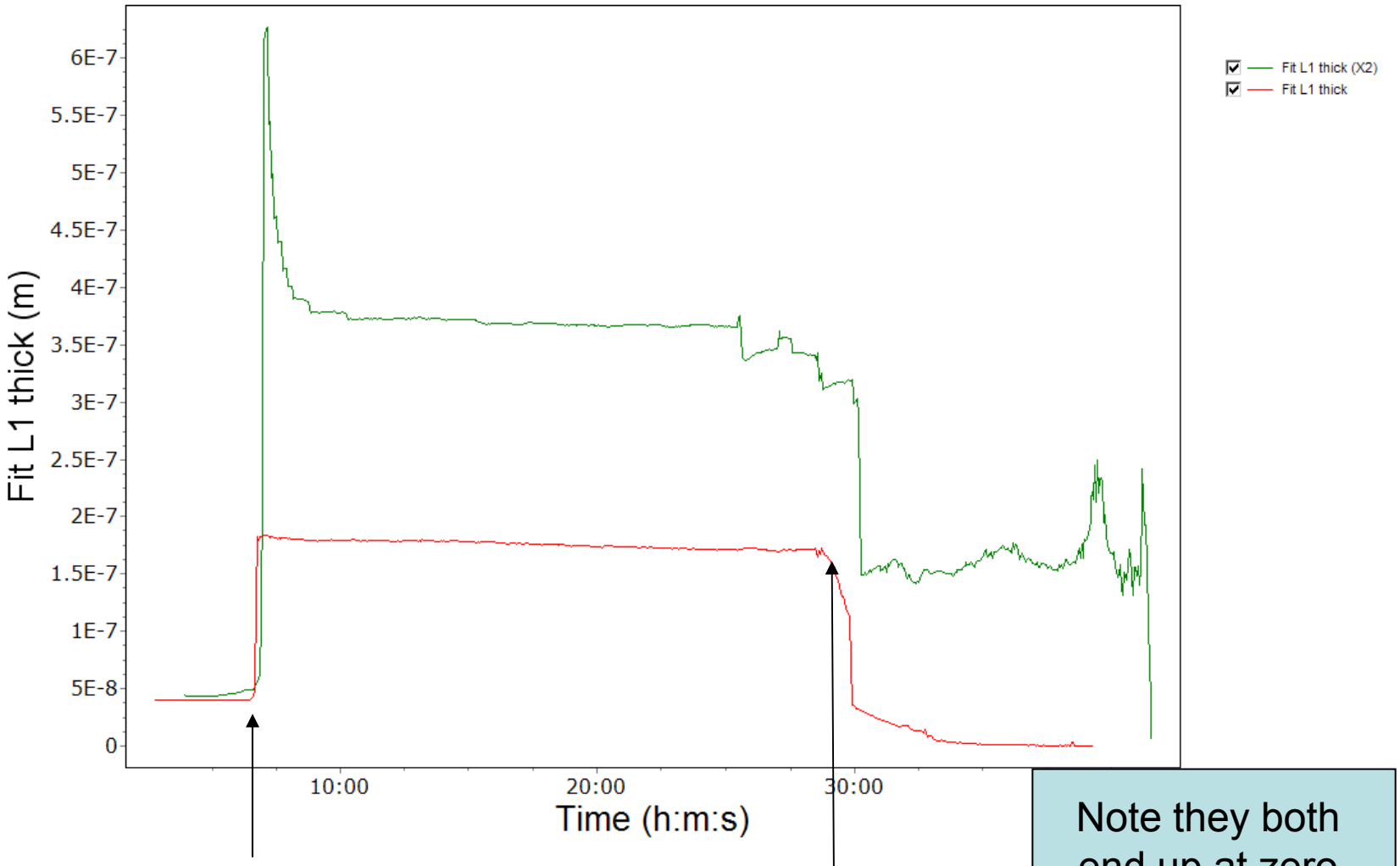
Comparing Thickness of Module 1 (red) and Module 2 (green)



Inject surfactant

rinse

Note they both end up at zero but 2 takes longer

QTools Software

- Q-Sense Adapted Graphics and Plots

  Fully exportable and customizable

- Sauerbrey – thickness δ

- Models (Voight & Maxwell) – thickness δ, shear viscosity η, and a shear elasticity μ

- Kinetics – K_{off}, K_A, and K_{on}

QTools Software

Theoretical Modeling of the QCM-D Response (Viscoelastic Modeling)

$$\Delta f = f_1(n, \eta_f, \rho_f, \mu_f, \delta_f)$$

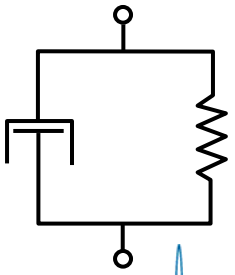
$$\Delta D = f_2(n, \eta_f, \rho_f, \mu_f, \delta_f)$$

ρ: density, (kg/m3)

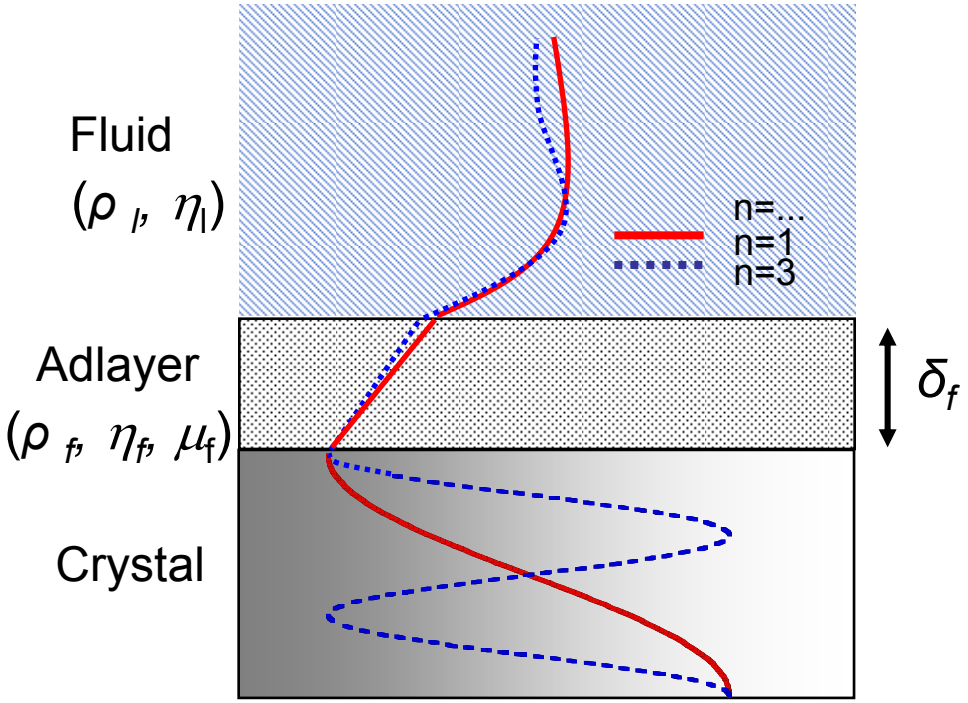
η: viscosity (G''/ω), (kg/ms)

μ: elasticity (G'), (Pa)

δ: thickness, (m)

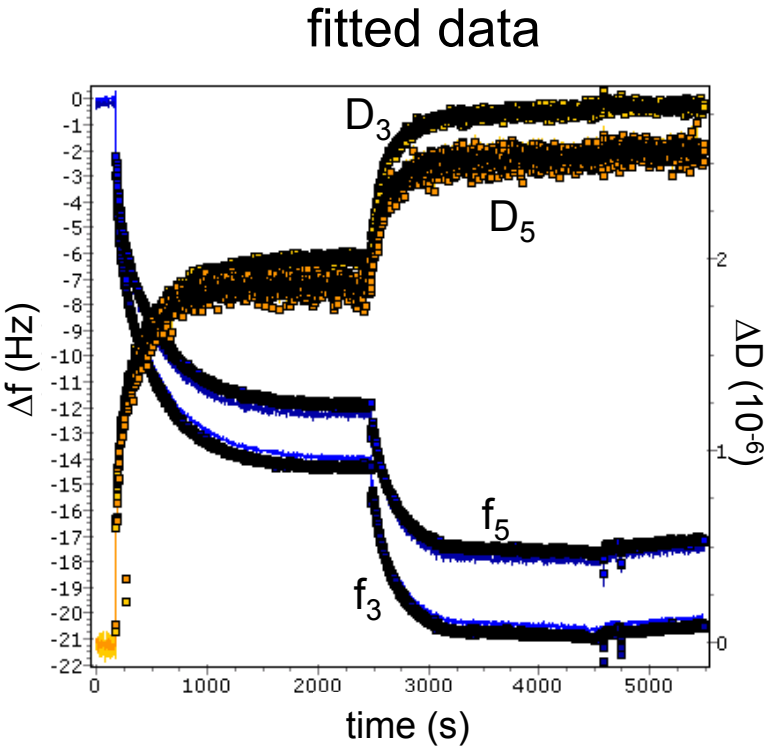


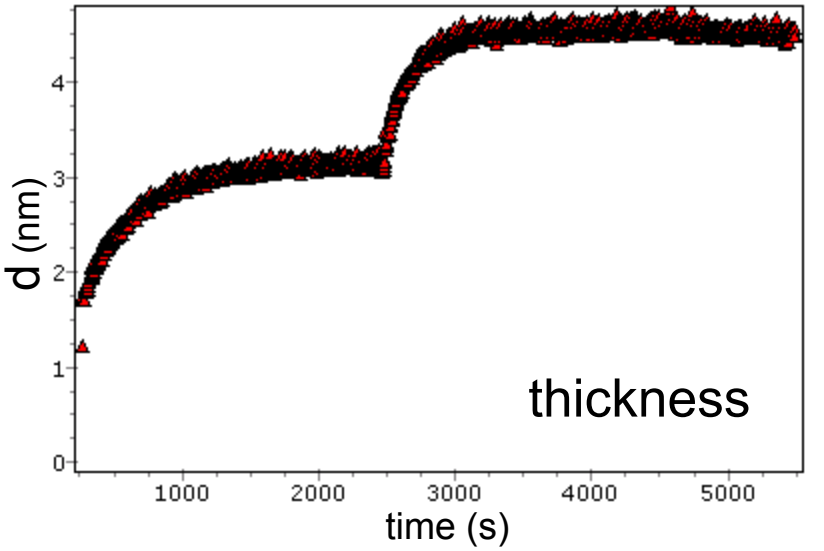
$$G = G' + jG''$$
$$= m + j2\pi f\eta$$

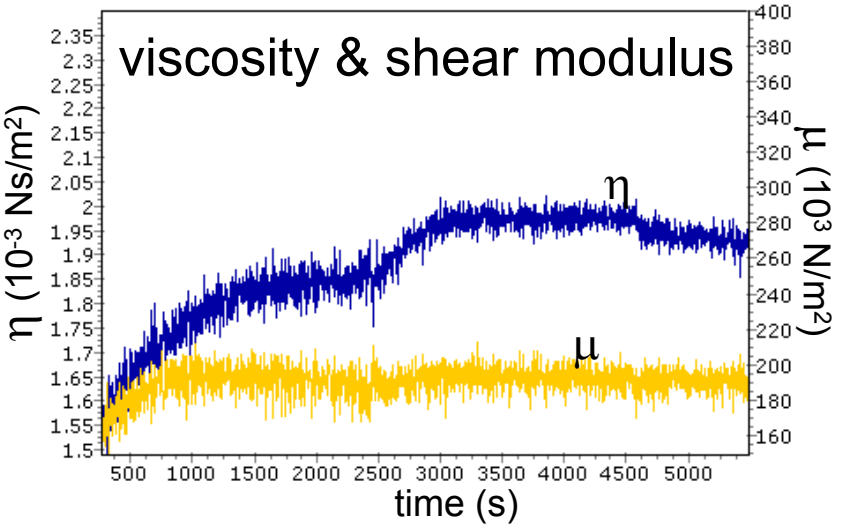


Voinova et al., *Physica Scripta* **59** (1999) 391

Information extracted from modeling (15 & 25 MHz)







input: ρ = 1050 g/dm^3
(estimated by QCM-D & SPR)

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Concluding Remarks

- QCM-D provides not only mass changes but also viscoelastic properties of chemical systems.
- Real-time, sensitive technique
- Surface interaction/reaction
- QCM-D provides the ability to quantify

The Q-Sense QCM-D Solution

Education & Training

Turn key QCM-D system

Advanced Modeling software

Q-Sense E4

Data evaluation support

User's 28 Countries

Annual User Meetings

qsense®

Thank You!

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Office #: 877-773-6730
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Demo experiment polymeric adsorption on metallic surfaces

Objective

To demonstrate adsorption of a water soluble polymer: Diethylaminoethyl-Dextran to different surfaces.

Materials

- Au, SiO_2, PS and Al_2O_3 crystals
- PBS Buffer pH 7.4 150 mM NaCl (Sigma)
- DEAE Dextran (50 µg/ml in PBS)