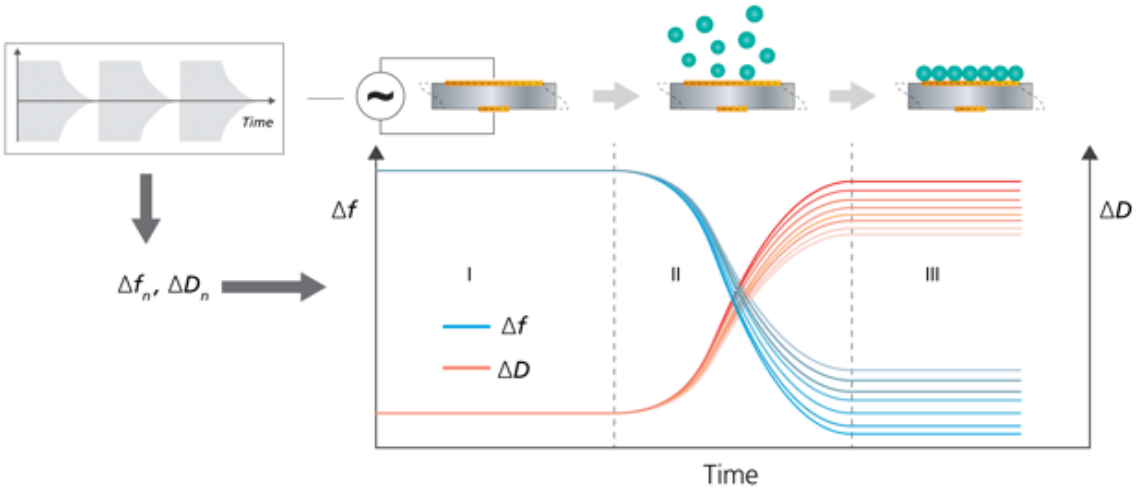
Quartz Crystal Microbalance with Dissipation (QCM-D)

Quartz Crystal Microbalance (QCM) and extended versions, such as Quartz Crystal Microbalance with Dissipation monitoring (QCM-D) are surface sensitive, real-time technologies that detect mass changes at the sensor surface with nanoscale resolution. Essentially, these instruments are balances for very small masses and the molecule-surface interactions are detected as changes in mass, i.e. mass uptake or mass loss, as molecules adsorb or desorb.
The relation between frequency and mass, which enables the detection of molecule-surface interactions, was first identified by Günther Sauerbrey in 1959 and resulted in the so-called Sauerbrey relation.
The equation states that there is a linear relation between frequency change and mass change according to

$$\Delta m = -C \cdot \frac{\Delta f}{n} \qquad (1)$$

where *C,* the so-called mass sensitivity constant, is a constant related to the properties of quartz and *n=1, 3, 5…* is the number of the harmonic used. C = 17.7 ng Hz^{-1} cm^{-2}
QCM-D measures changes of both frequency, *f*, and dissipation, *D*. The *D*-value gives information about the energy loss in the system, and reveals how soft, or viscoelastic the layer at the surface is.



MSI has QSense Analyzer (E4) from Biolin Scientific

- > 500 µl minimum sample volume
- 25-150 µl/min applicable for QSense setup (peristaltic pump settable to 0-1 ml/min)
- LOD: 1.34 ng/cm^2
- Minimum noise: frequency 0.03 Hz, mass 0.5 ng/cm^2, dissipation 12 x 10^{-9}
- Sensor diameter: 14 mm
- Sensor thickness: 100 nm

- Sensor frequency: 4.95 MHz

Flow Modules

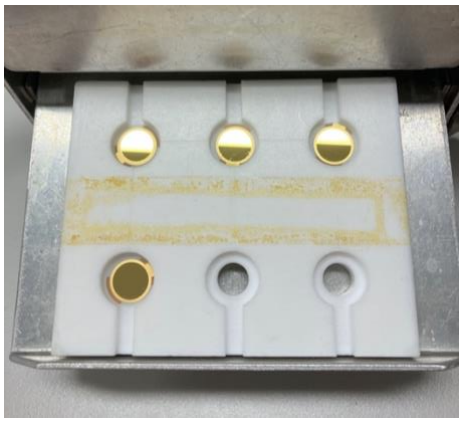
- The E4 Chamber Platform holds 4 flow modules. They can be set up in any combination - all four serially, all four parallel, one module alone, etc, depending on how they are interconnected by the tubing.
    - Flow modules are set up in parallel. Speak with the staff at MSI if you want to change the flow module setup.
- Place the flow module with the spring-loaded electrode pins pointing downwards, so that they contact the plates on the heat block of the chamber platform. Close the latch.
- Line the tubing in the Teflon slits on the sides of the chamber. Close the lid.
- Between measurements (or at the end of experiment), rotate the flow module upside down for stable handling during crystal loading etc.
- MSI also has other modules. Talk to MSI staff if you require these modules.
    - Electrochemistry module for simultaneous QCM-D and electrochemistry measurements on the same surface.
    - Window module allowing optical access to the sensor surface through a sapphire window.

Clean crystals before use

Basic Piranha solution cleaning

- Applicable for Au and Pt sensors.
- Efficient removal of organic and biological material using oxidation.
- Everything need to kept in the fume hood. Piranha solution is highly corrosive and should be handled with care.
- UV/Ozone cleaning for 10 min before basic piranha solution treatment.
- Put the water bath in fume hood. Add water to the mark level. Heat it up to 75℃.
- Freshly prepared a piranha solution in 15 ml beaker, 7 ml MQ water, 1.4 ml of 25% ammonia, 1.4 ml of 30% hydrogen peroxide.
- Place sensor on the holder, into the 15 ml beaker, into the water bath. Heat the solution for 5 min at 75℃
- Rinse with MQ water (make sure the sensor surfaces are kept wet after piranha solution treatment until they are rinsed with waters).
- Dry with N_2 gas.
    - For the Pt sensor, rinse the sensor surface with 99% ethanol. And try with N_2 gas again.
- UV/Ozone cleaning for 10 min following the step below.

UV/Ozone cleaning



- Applicable for all sensors, except for Ag and and low MW hydrocarbon samples
- A minimum of 12 mW/cm2 at 1 inch from a 185/254 nm lamp is recommended
- Install the UV/Ozone chamber in fume hood.
- Place the sensor surface in UV/Ozone chamber, approximate 5 mm from the lamp on a white holder.
- Turn on the UV/lamp for 10 min.

SDS cleaning

- Applicable for SiO_2 sensors
- UV/Ozone cleaning for 10 min.
- Immerse the sensor surface in 2% (w/v) sodium dodecyl sulphate (SDS) solution for 30 min at room temperature.
- Rinse with MQ water (make sure the sensor surface are kept wet after SDS immersion until they are rinsed with water).
- Dry with N2 gas.
- UV/Ozone treatment for 10 min.

Startup

- Ensure the controlling computer is on and logged in before switching on the other equipment
- Turn on all equipment
    - Electronics unit: large silver button on the front
    - Pump: black switch on the back

Mounting the Sensor Crystal

- Lift the lid of the module Q-sense analyzer
- Unscrew the flow module. For stability, the flow module can be placed in its holder while unscrewing.
- The inlet and outlet to the chamber void will then be visible, inside the o-ring. **Important! Make sure that the o-ring is lying flat in its bed.**
- Place the sensor crystal with its active side down, resting on the o-ring. The arrow-shaped electrode should then point as shown to the left (also indicated on the module).

- A correctly mounted sensor crystal, with its backside upwards and the active side towards the flow system. Check that the crystal is lying parallel to the lowering of the housing, and as centred as possible.
- Screw the contact block back onto the flow module.

- Gently slide the module securing clip to the left to lock it.
- Close the lid. Keep tubes clear of the hinge.

Qsoft 401

- Open QSoft 401.
- Set module temperature by choosing Acquisition – Setup measurement (or ctrl + F) and choose Temperature tab.
- Enter desired set temp in value box. For protein samples, this should be 37°C (set at 37.1°C for closest response).
- Allow for the temperature to stabilise before beginning any experimental work. This should take approximately 10 minutes. To view a time history of the temperature, select Tools – Show preacquisition form (or ctrl + shift + P).
- Click back to the Setup measurement window and select the Sensors tab.
- Included sensors heading: Check a number of sensors that will be used, any combination 1, 2, 3 and 4.
- Ensure that All sensors have the same fundamental frequency is selected.
- Included resonances heading: Check several resonances to be used in measurements.
- Select the checkbox for All sensors that have the same included resonances as the first sensor.
- Unless specific resonances are being tested for, it is recommended that all resonances (1st – 13th) are selected.
- Resonance optimisation heading: For normal measurements select the Automatic optimisation box.
- Find all resonances heading: Check Quick check found resonances box.
- Click Find All to find resonances.
- If there are problems in finding resonances: Check surface of the crystal is clean. Check crystal is facing down and sits flat on the O-ring. Ensure pads line up with electrodes. Run Find all again. If a minimal number of resonances are unfound use Find specific resonance to find them individually. If issues are still found, swap out the offending crystals.

Experiment setup

- Immerse desired intake tubes, extending from the chamber right, into a running buffer.
- Rest output tubes from the pump (on the left side) in an empty 25 ml beaker.
- Set the pump flow rate using up/down arrows to the right of the display.
- Press red Run/Stop to begin flow. The flow rate light should flash when the pump is running.
- In QSoft401, select Acquisition – Start Measurement (or ctrl + R) to begin collecting data (Frequency/Dissipation vs Time).

- Run the pump until the baseline stabilises. - To check whether there is any blockage, pull fluid through entire systems. Output tubes in use should have a steady drip.
- Once QSoft401 collected a minimum of 5 min of baseline data, stop the flow of the pump.
- Remove input tubes from a running buffer and dry ends with kimwipe; take care to avoid forming any air bubbles.
- Immerse input tubes in use into a test solution.
- Collect data until the changes in frequency and dissipation reach plateaus. If test samples are limited, then please test with at least 500 uL of samples. (Please make sure not to inject air or bubbles).
- Halt flow.
- Remove the input tube from a test solution, dry it with kimwipe and place it in a running buffer.
- Run flow for a minimum of 5 min.
- Halt flow.
- Stop acquisition by selecting Acquisition – Stop measurement (or ctrl + Q) and save the file.
- Close QSoft 401.

Shutdown

- Always run the cleaning process with a sensor installed in each used module

Chemical and non-sticky samples

- Set the pump flow rate to 300 – 400 µL/min and run the pump to empty running buffer.
- Insert the inlet tube into MilliQ water.
- Run the pump for 3 min.
- Remove the inlet tube from MillIQ water and insert it into 80 % (v/v) ethanol.
- Run the pump for 3 min.
- Remove the inlet tube from 80 % (v/v) ethanol and inert into MilliQ water.
- Run the pump for 3 min.
- Repeat steps 4 – 7 once more.
- Remove the inlet tube from MilliQ water (leave it in the air) and run the pump until no liquid comes out.
- Halt flow.

Protein and sticky samples

- Set the pump flow rate to 300 – 400 µL/min and run the pump to empty the running buffer.
- Insert the inlet tube into MilliQ water.
- Run the pump for 5 min.

- Remove the inlet tube from MillIQ water and insert it into 2 % (w/v) SDS (in MilliQ water).
- Run the pump for 5 min.
- Remove the inlet tube from 2 % (w/v) SDS and insert it into MilliQ water.
- Run the pump for 5 min.
- Repeat steps 4 – 7 once more.
- Insert the inlet tube into MilliQ water and run the pump for 15 minutes to clean off 2 % (w/v) SDS residue.
- Remove the inlet tube from MilliQ water (leave it in the air) and run the pump until no liquid comes out.
- Halt flow.

Cleanup

- Open the lid of the device and release the catches for modules.
- Turn modules upside down, avoiding twisting the tubes.
- Unscrew the inlet and outlet tubes from the modules.
- Remove modules from the device.
- Unscrew two bolts on top of the module.
- Lift the lid of the modules.
- Carefully lift and remove the installed crystal with tweezers.
- Remove the installed rubber o-ring.
- Dry modules with nitrogen gas.
- Blow gas through each of the holes on the side of the chamber until no further fluid is expelled.
- Dry the fluid in the central chamber with nitrogen gas.
- Repeat steps 9 and 11 to remove any lingering fluid.
- Install the rubber o-ring in each module and press until flat in depression.
- Assemble the base and the lid of the module and gently refasten the screws.
- Reattach inlet and outlet tubes, taking care to ensure that they are in the correct position.
- Install the assembled modules into the device.
- Carefully close the lid of the device.