HOW IT WORKS: QUARTZ CRYSTAL MICROBALANCE (QCM)

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SHAW GROUP MEETING

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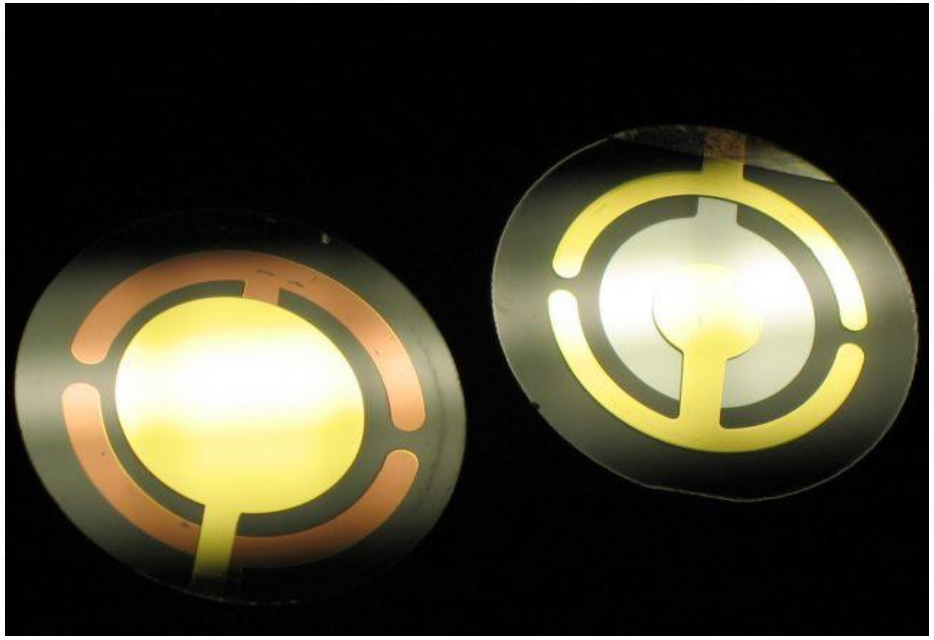
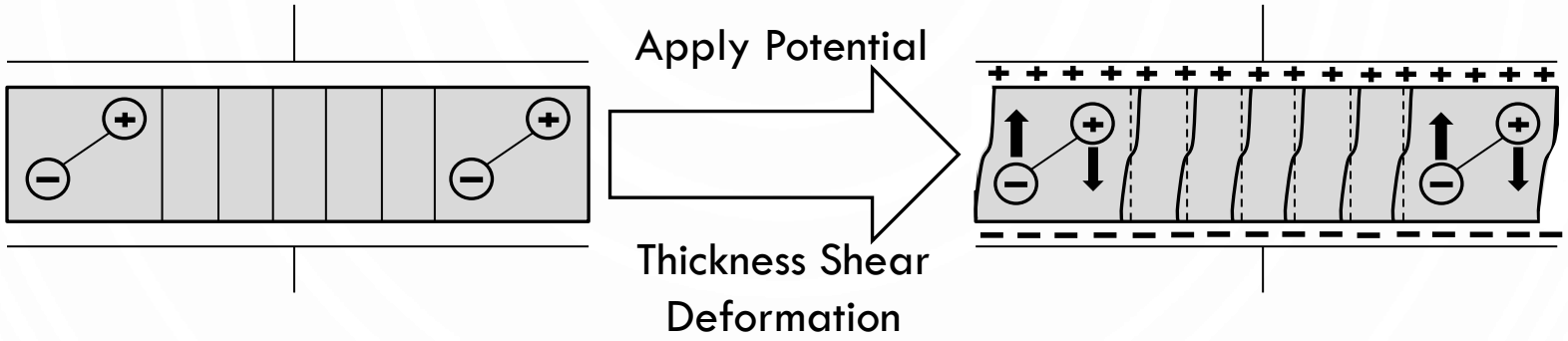


THEORY

- Piezoelectric material – Electric field forms in the presence of mechanical stress and vice versa (converse piezoelectric effect)

  Examples: Quartz crystals, sucrose, DNA, silk, tendon



- Alternating the potential (sine wave) causes the crystal to oscillate
- With a properly cut crystal and an appropriate alternating potential, a standing shear wave is formed at the resonant frequency of quartz:

$$f_0 = \frac{\sqrt{\frac{\mu_q}{\rho_q}}}{2t_q}; \mu_q = 2.947x10^{11}\,\frac{g}{cm * s^2}, \rho_q = 2.648\,\frac{g}{cm^3}, t_q = crystal\ thickness$$

$$Quality\ (Q)\ Factor = \frac{frequency}{bandwidth} = \frac{f_c}{\Delta f_{FWHM}}; Q \cong 10^6$$

Basics of a Quartz Crystal Microbalance. Gamry. www.gamry.com (accessed 3/28/14).
Deakin, M.R.; Buttry, D.A. *Anal. Chem.* **1989**, *61(20)*, 1147-1154.

APPLICATIONS TO SURFACE SCIENCE

- Resonant frequency of quartz can be precisely determined
- Small amounts of matter (ng/cm^2) placed on the crystal surface can be quantified by measuring the change in resonating frequency (Sauerbrey equation)

$$\Delta f = -\frac{2nf_0^2}{\sqrt{\rho_q \mu_q}} \frac{\Delta m}{A}; \; T_f = \frac{\Delta m}{A\rho_f}$$

- Assumes the deposited film is uniform and rigid (and $\Delta f/f < 2\%$)
- If $\Delta f/f > 2\%$, Sauerbrey eqn. is expanded to incorporate film elasticity
- Can be applied to liquid contact measurements

$$\Delta f = -{f_0}^{3/2} \sqrt{\frac{\eta_l \rho_l}{\pi \rho_q \mu_q}}$$

Quartz Crystal Microbalance Theory and Calibration. Stanford Research Systems. www.thinksrs.com (accessed 3/31/14).

ELECTROCHEMICAL QCM (EQCM)

- Integrated QCM and potentiostat
- Impedance and mass analysis
- Mass change versus time, charge, potential
- Using EQCM, the current efficiency (ratio of mass deposited at the electrode surface during an electrochemical reaction to the total charge passed through the electrode) can be determined
- Applications in electrodeposition, corrosion studies, self-assembled monolayers

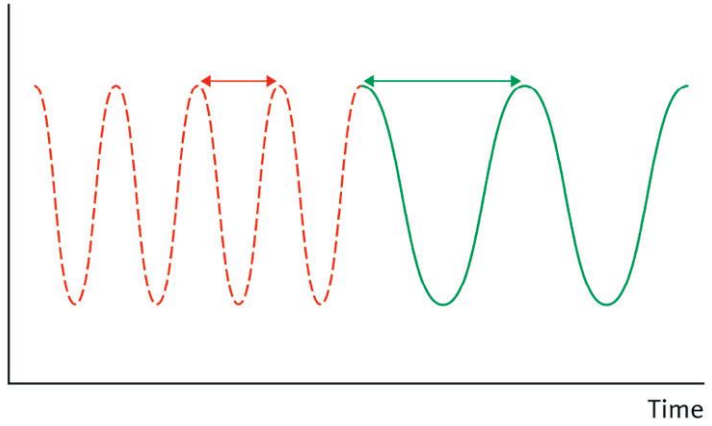
Buttry, D.A.; Ward, M.D. *Chem. Rev.* **1992**, *92*, 1355-1379.
EQCM Instrument. Gamry. www.gamry.com (accessed 3/31/14).

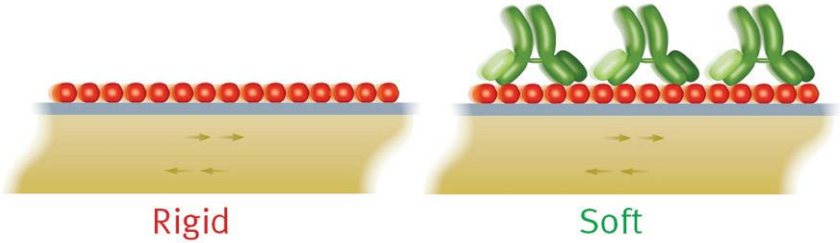
QCM WITH DISSIPATION MONITORING (QCM-D)

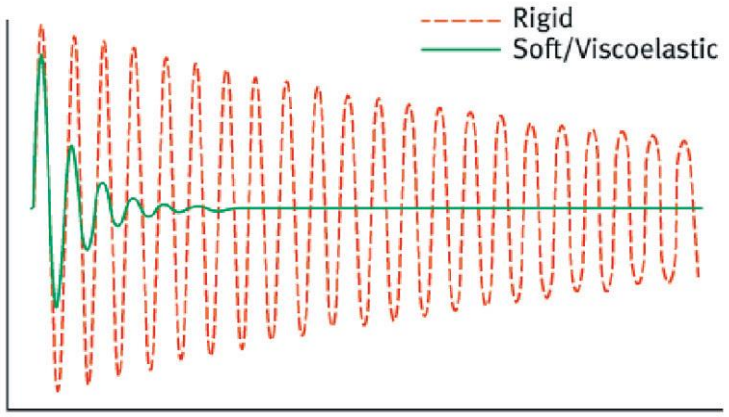
- Provides structural (viscoelastic) thin film analysis as well as mass analysis
- Dissipation (damping) is significant when the adsorbed film is not rigid (i.e. film and crystal oscillations not fully coupled)

$$D = \frac{E_{lost}}{2\pi E_{stored}}$$

- The potential is shut off, and the time required for oscillation to cease quantifies the "softness" (viscoelasticity) of the adsorbed film
- Visualization







QCM-D Technology. Q-Sense. http://www.q-sense.com/qcm-d-technology (accessed 3/31/14).