LECETURE 6

Piezoelectric sensor

Part 3

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One of the practical applications of quartz oscillators is sensing to detect mass.
This type of measurement is QCM, which measure the mass from the resonant frequency of the quartz oscillator, which depends on the mass adsorbed on the surface of the quartz.
The QCM is a simple, cost effective, high-resolution mass sensing technique, based upon the piezoelectric effect.
an applied mechanical force

the internal generation of electrical charge

the internal generation of a mechanical strain

Direct piezoelectric effect

Reverse piezoelectric effect

an applied electrical field
The **high sensitivity** and the **real-time monitoring** of mass changes on the sensor crystal make QCM a very attractive technique for a large range of applications.
QCM technique has been recognized as a standard tool that is able to provide both qualitative and quantitative information about their target materials.
Photograph of typical quartz crystal resonators as used for QCM, metallized with gold electrodes (left: front electrode, right: back electrode) by vapor deposition.
The **core** of the QCM technique is **the piezoelectric AT-cut quartz crystal sandwiched between a pair of electrodes.**
Quartz crystal structure

Silicon dioxide
chemical formula: \( \text{SiO}_2 \)

Melting point: 1750 °C
Density: 2.65g/cm³
Shear modulus, hardness…
Z axis, Optical axis

X axis, Electric axis

Y axis, Mechanical axis

Distribution of crystal axis of natural quartz crystal
1. Quartz crystal
2. Electrode material

\[ \Delta F = -2 F_0^2 \Delta M / A \left( \mu_q \rho_q \right)^{1/2} \]

\( \Delta F \): Frequency Change of Quartz Crystal;
\( \Delta M \): Mass Change of the Substance on Electrode
Gold film electrodes as the substrate for adsorption studies. The resonance frequency of the crystal was determined by using the crystal as the frequency-determining element of an electronic oscillator.
The QCM is an **ultrasensitive weighing device**, consisting of a thin disk of single crystal quartz, with metal electrodes deposited on each side of the disk. The crystal can be made to oscillate at its resonant frequency, when connected to an external driving oscillator circuit.
Figure 1. (A) Photograph of typical quartz crystal resonators as used for QCM, metallised with gold electrodes, (B) Equivalent circuit model for determining frequency change of the quartz crystal, and (C) the proposed designed of QCM system.
\[ \Delta f = -\left( \frac{2f_0^2}{\sqrt{\rho_Q \mu_Q}} \right)m \]

\[ \Delta F = -2.26 \times 10^6 x f_0^2 x \frac{\Delta m}{A} \]

Where \( \Delta f \) is the measured frequency shift due to the added mass in hertz, \( f_0 \) is the fundamental oscillation frequency of the dry crystal, \( \Delta m/A \) (\( m' \)) the mass per unit area, \( \rho_Q \) the quartz density has the value (2.649 g/cm\(^3\)) and \( \mu_Q \) the shear modulus has the value (2.947 \times 10^11 \text{ dyne/cm}^2).
The time-dependent frequency responses and $m^\prime$ of the QCM.
A great deal of attention was paid to the deposition of a thin layer on various surfaces.
In-situ Route for Adsorption Process

Mechanism for In-situ adsorption routes of target into QCM surface
Indirect Route for Adsorption Process

Mechanism for indirect adsorption routes of target into QCM surface
In-situ and indirect routes for QCM surface for the adsorption process of various materials.
QCM are classified according to the way the wafer is cut relative to the natural crystallographic orientation of quartz.
Polished grade, 5 MHz (8 MHz , 10 MHz...), AT cut quartz crystal was employed for this study.
QCM sensor’s surface can be functionalized with organic and inorganic materials to improve its sensitive and selective efficiency.
Thin films with desired properties and functionalities have been synthesized by various available methods.

chemical oxidation, electrochemical synthesis, spin-coating, dip-coating, drop-coating, thermal evaporation, Langmuir–Blodgett and self-assembly techniques
Homework （Materials for the Seminar course）

• Please describe a kind of preparation method and application of functionalized film for QCM.

• You need to report them in the seminar course.
THANK YOU!