QCM - AMPLITUDE OF MOTION

Amplitude of Motion

The amplitude of lateral displacement rarely exceeds a nanometer. More specifically one has

$$u_0 = \frac{4}{(n\pi)^2} dQU_{\mathrm{el}}$$

with u_0 the amplitude of lateral displacement, n the overtone order, d the piezoelectric strain coefficient, Q the quality factor, and U_{el} the amplitude of electrical driving. The piezoelectric strain coefficient is given as $d = 3.1 \cdot 10^{-12}$ m/V for AT-cut quartz crystals. Due to the small amplitude, stress and strain usually are proportional to each other. The QCM operates in the range of linear acoustics.

Effects of Temperature and Stress

The resonance frequency of acoustic resonators depends on temperature, pressure, and bending stress.

Temperature-frequency coupling is minimized by employing special crystal cuts.

A widely used temperature-compensated cut of quartz is the AT-cut. Careful control of temperature and stress is essential in the operation of the QCM.

AT-cut crystals are singularly rotated Y-axis cuts in which the top and bottom half of the crystal move in opposite directions (thickness shear vibration) during oscillation. The AT-cut crystal is easily manufactured. However, it has limitations at high and low temperature, as it is easily disrupted by internal stresses caused by temperature gradients in these temperature extremes (relative to room temperature, ~25 °C). These internal stress points produce undesirable frequency shifts in the crystal, decreasing its accuracy. The relationship between temperature and frequency is cubic. The cubic relationship has an inflection point near room temperature. As a consequence the AT-cut quartz crystal is most effective when operating at or near room temperature. For applications which are above room temperature, water cooling is often helpful.

Stress-compensated (SC) crystals are available with a doubly-rotated cut that minimizes the frequency changes due to temperature gradients when the system is operating at high temperatures, and reduces the reliance on water cooling. SC-cut crystals have an inflection point of ~92 °C.

In addition to their high temperature inflection point, they also have a smoother cubic relationship and are less affected by temperature deviations from the inflection point. However, due to the more difficult manufacturing process, they are more expensive and are not widely commercially available.

Electrochemical QCM

The QCM can be combined with other surface-analytical instruments. The electrochemical QCM (EQCM) is particularly advanced. Using the EQCM, one determines the ratio of mass deposited at the electrode surface during an electrochemical reaction to the total charge passed through the electrode. This ratio is called the current efficiency.

Source: http://www.juliantrubin.com/encyclopedia/electronics/qcm.html