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Temperature Compensation for QCMs

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Quartz crystal microbalance (QCM) technology has been used for decades to control deposition rate and thickness for the most complex processes seen in the ophthalmic, optical, display, and solar markets. INFICON has recently made a new advancement in QCM technology to address a problem seen across all of these industries related to QCM temperature effects. Thermal shock can cause QCM thickness errors which can decrease yield and increase manufacturing costs if temperature is not accounted for.

A complete QCM system consists of a thin film deposition controller, oscillator, and sensor which houses the QCM and provides the electrical connection. Quartz is a piezoelectric material, meaning when a voltage potential is applied across the two electrodes of the quartz crystal, the quartz will physically deform. With the help of an oscillator, the QCM can resonate at its fundamental frequency and be measured using a thin film deposition controller. As material is deposited onto the surface of the QCM, the mass on the crystal increases and the frequency decreases proportionally.

Temperature also impacts the frequency measurement and can create false mass readings. Thin film deposition controllers currently on the market have no good way of distinguishing frequency shifts related to mass from frequency shifts related to temperature, resulting in thickness errors and poor PID control. This can be detrimental to today's complex coating processes due to the low deposition rates and incredibly thin layers required. Thermal shocks can occur at any point in a deposition process and can cause unnecessary PID-loop correction, triggering non-uniform deposition in respect to time. This means that the quality throughout the bulk of the material is inadequate. For very thin films, the thickness termination may not be at the real intended thickness because the process time window is small compared to the time allowed for a QCM to recover from a thermal shock event.

INFICON has patented a new temperature compensation technique for SC-cut crystals to remove the effects of temperature variation on the QCM without the need for additional hardware or custom and expensive sensors. INFICON temperature compensation is also instantaneous unlike competing methods that use a thermocouple embedded inside the QCM sensor. By removing temperature from the thickness calculation, the thickness accuracy and deposition rate stability can significantly improve. Traditionally, AT-cut crystals have been used for most coating applications, however there are two additional advantages of SC-cut crystals compared to AT-cut. SC-cut crystals have 100 times reduced sensitivity to acceleration induced frequency changes compared to AT-cut. For tools that have QCM sensors mounted on robotic arms, acceleration jerks can induce a frequency change impacting the rate measurement. The second benefit to using SC-cut crystals is that SC-cut crystals have lower rate noise compared to AT-cut crystals when exposed to organic deposition material. Lower rate noise allows for better PID control with higher measurement accuracy to support technology transitions across several industries and meet the sensitivity and precision requirements of the latest product generations.

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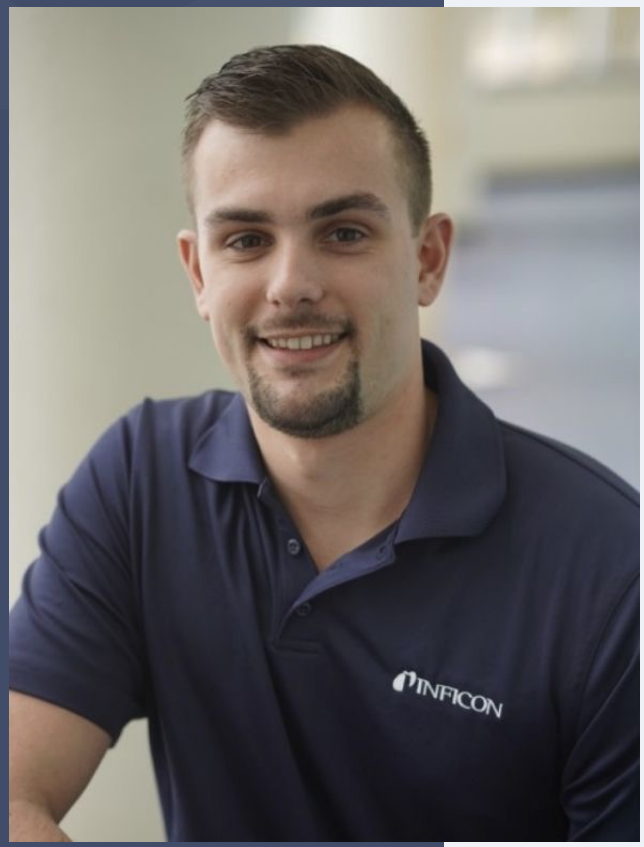
Temperature Compensation for QCMs

SVC TechCon 2024



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What Will You Learn Today?

QCM System Overview

- QCM basics
- What makes up a QCM system

Temperature Compensation

- Thermal shock and thickness errors related to temperature
- Temperature compensation technology overview

Compatible Temperature Compensation Thin Film Products

- ModeLock XIU advantage
- Benefits of SC-cut crystals

Conclusions and Questions

QCM System Overview

What is a QCM?

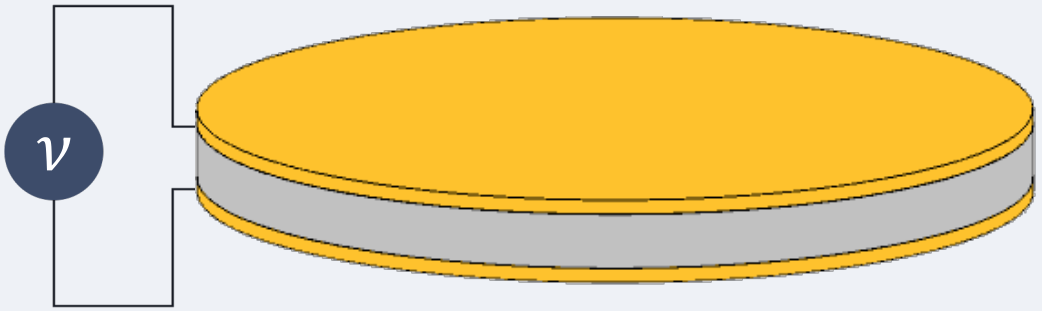
QCM stands for Quartz Crystal Microbalance

- A quartz crystal is piezoelectric and oscillates at its fundamental resonance frequency of 6 MHz (typical)
- QCMs are incredibly sensitive to changes in mass of films on the crystal surface (Nanograms and Sub-Monolayer)

QCM – How It Works

INITIAL STATE 01

When voltage is applied to the quartz crystal, it oscillates at some frequency based on how thick the crystal is and how much material is on the crystal's surface.

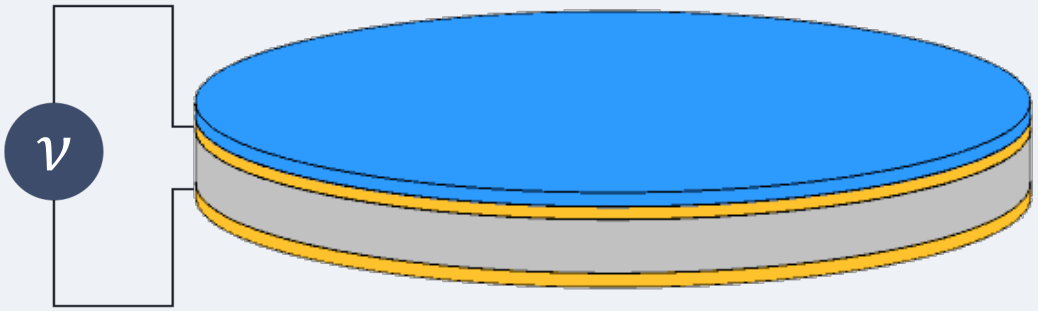


Piezoelectric effect

QCM – How It Works

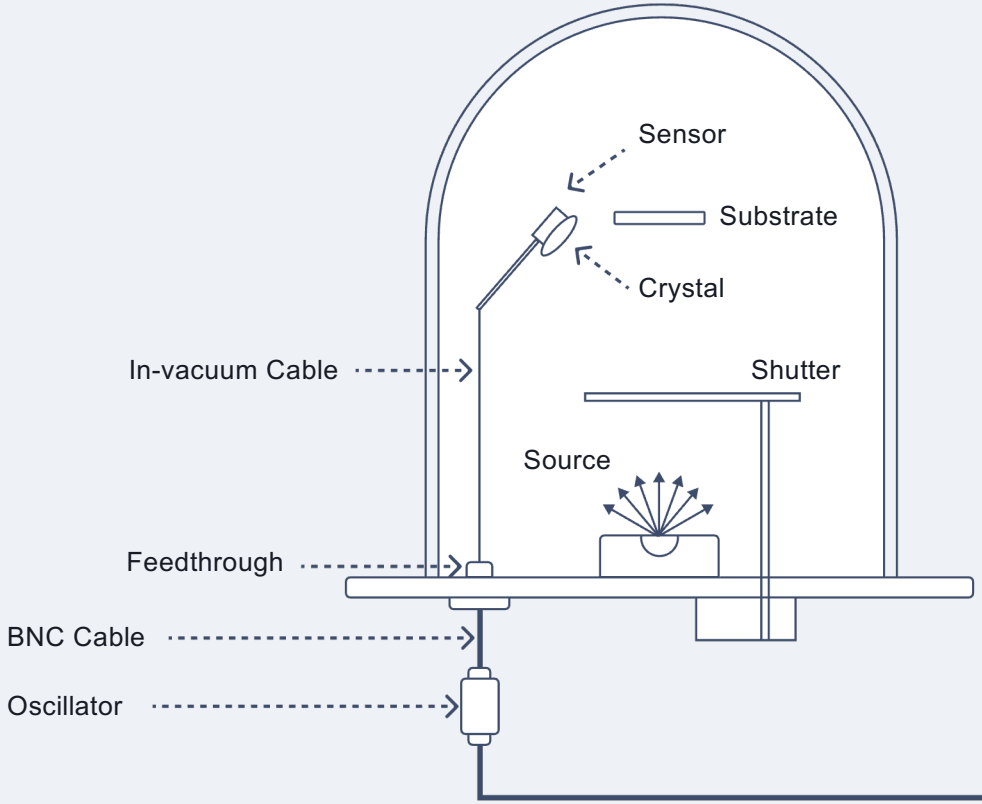
DEPOSITION 02

When material is deposited on the quartz crystal, the frequency of the oscillations decreases in proportion to the amount of material deposited onto the crystal's surface. This is known as "mass loading."



Piezoelectric effect

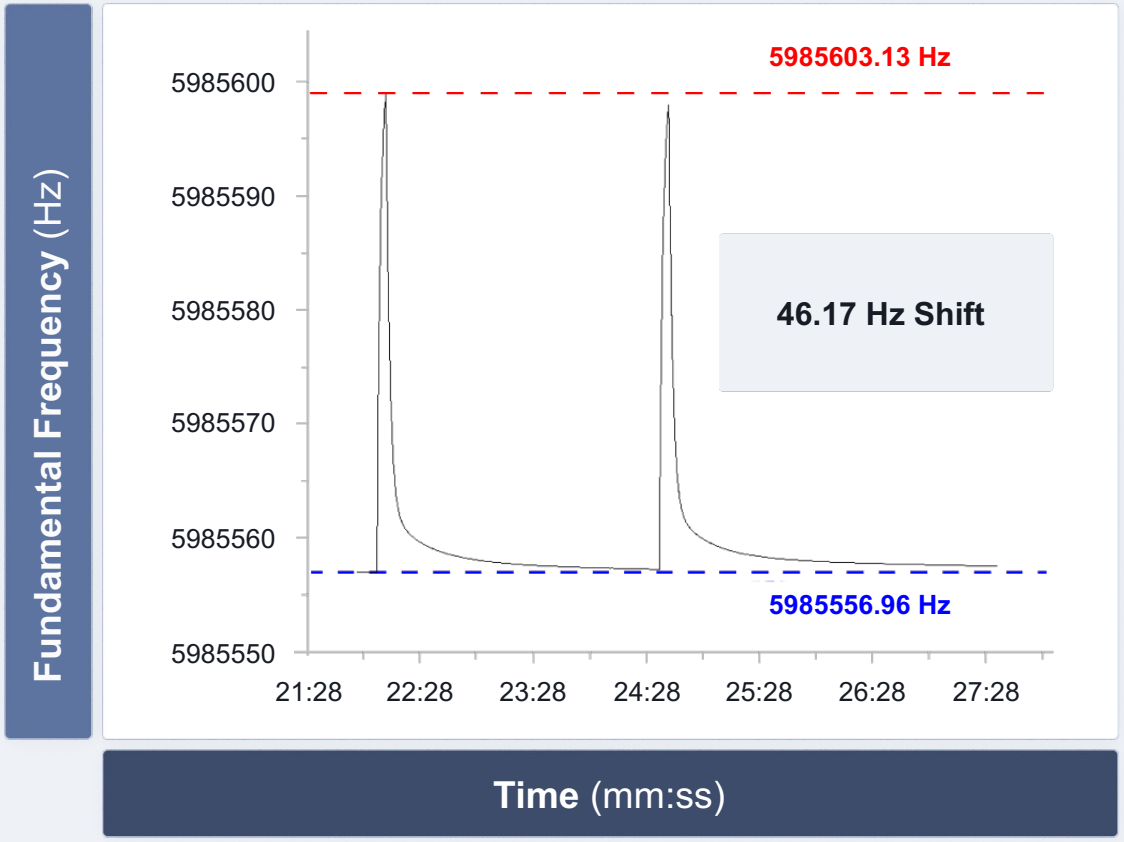
What Components Make Up A Complete QCM System?



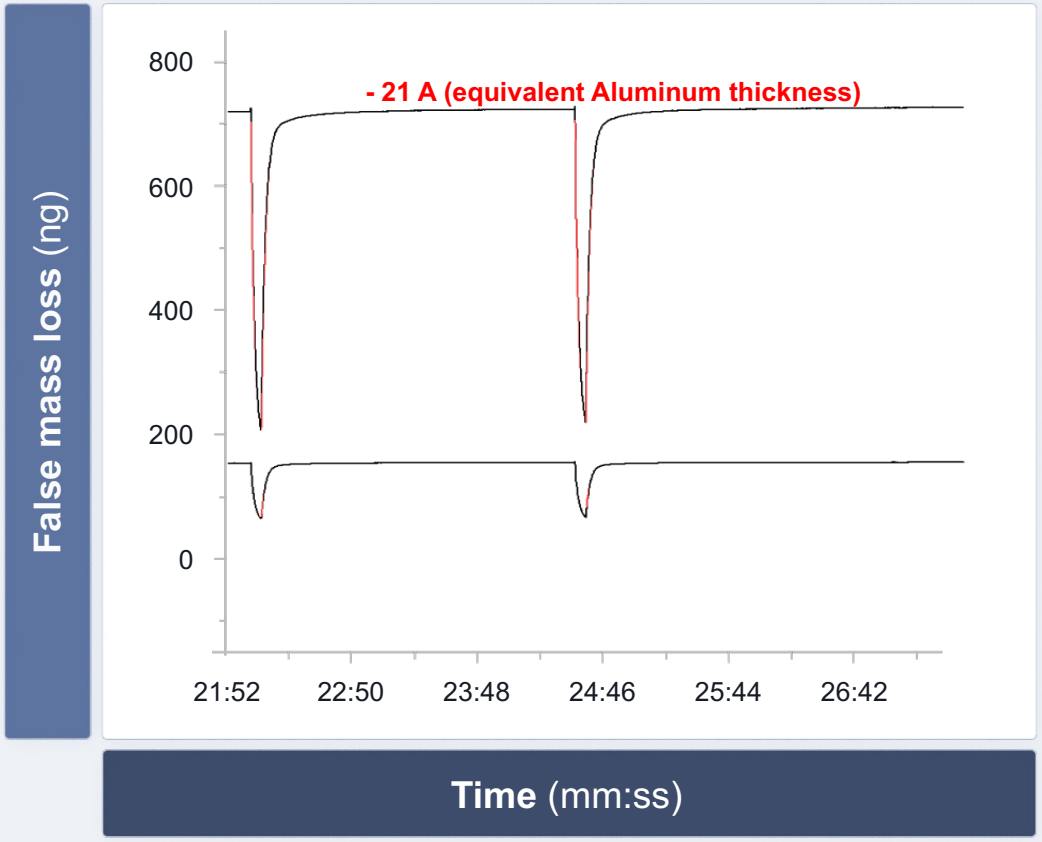
Interconnect Cable

Temperature Compensation

Thermal Shock: Without Temperature Compensation



Thermal Shock: Without Temperature Compensation



Eliminate Thickness Errors with Temperature Compensation

Temperature Compensation is a patent pending:

- system and a method to resolve the true mass frequency from the temperature-affected total frequency

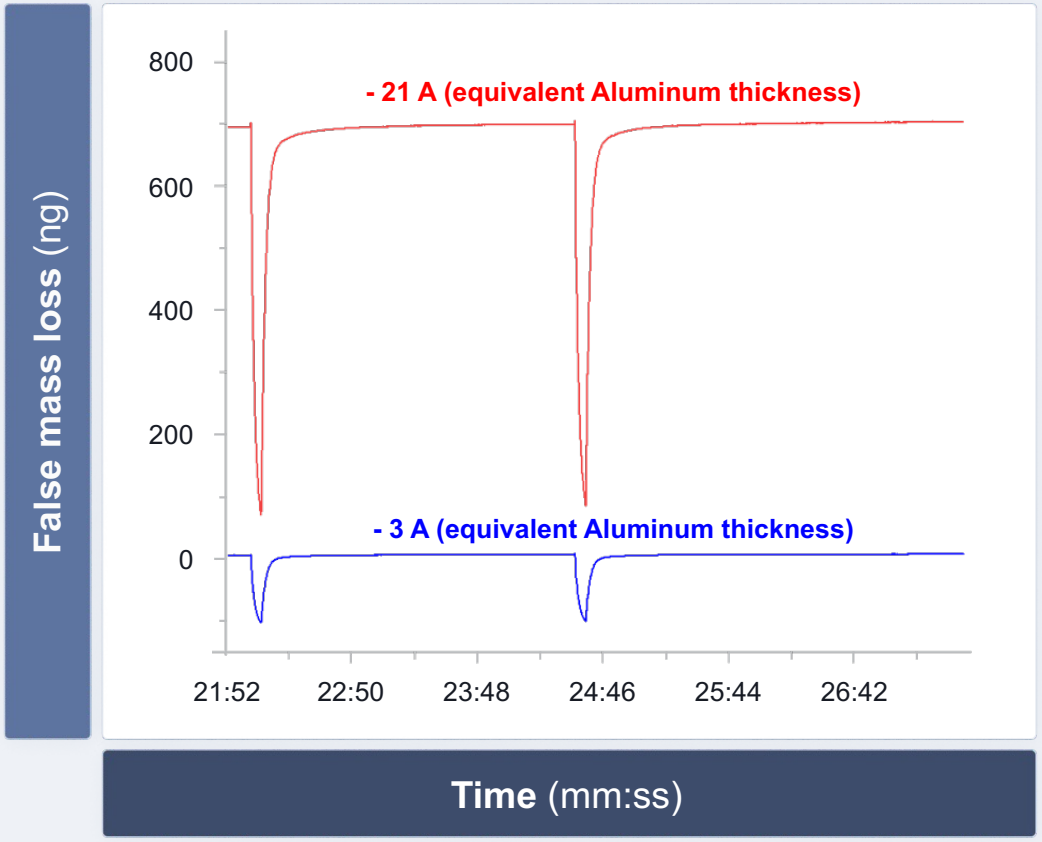
01

The system retrieves information from the QCM for analysis

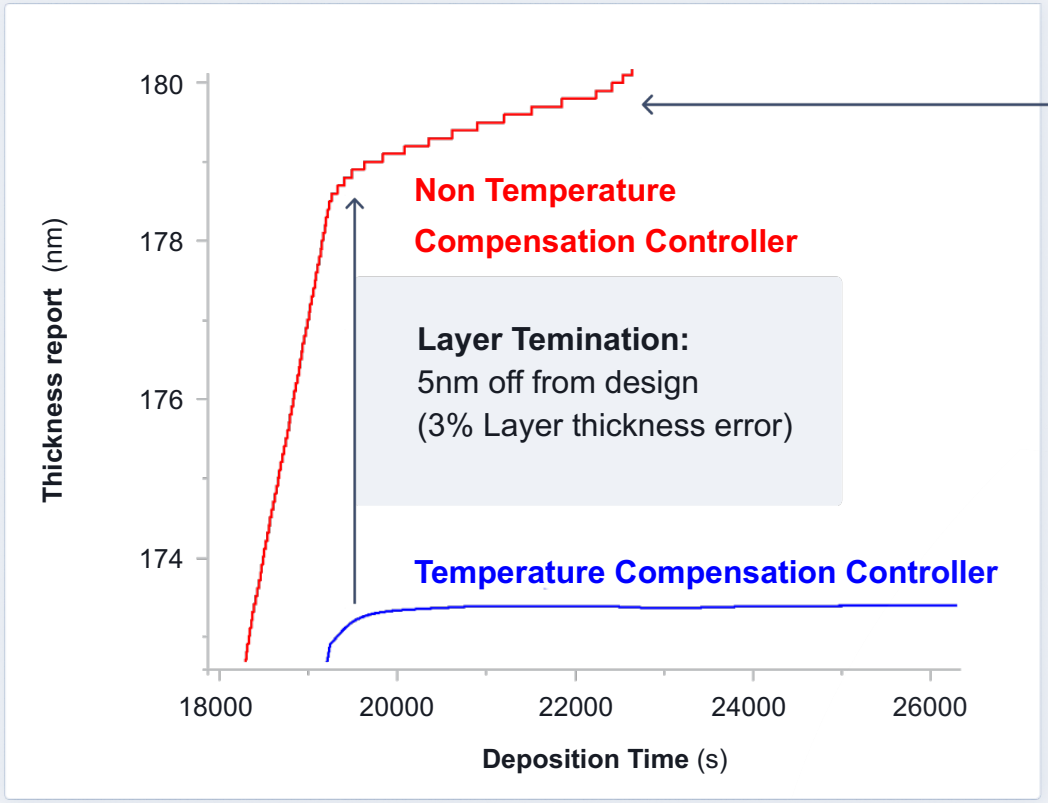
02

Temperature-compensated mass is reported every 100ms

Thermal Shock: With Temperature Compensation



Layer Thickness Error Due to Temperature



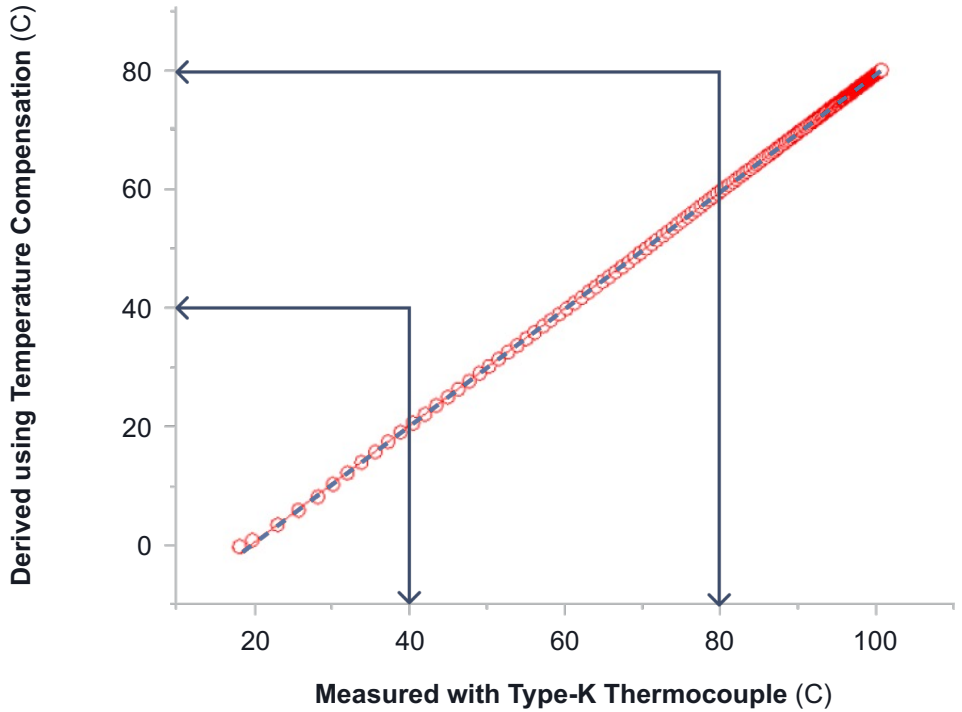
QCM cooling effect from Source Power OFF event

Temperature Compensation vs Thermocouple

Temperature Compensation is offset from room temperature

(Slope = 0.99)

1:1 Correlation



Compatible Temperature Compensation Thin Film Products

ModeLock XIU Advantage

Maximize reproducibility and uniformity with the highest thickness accuracy, best resolution, and lowest rate noise using the ModeLock measurement system

Maximize yield with pre-process crystal verification

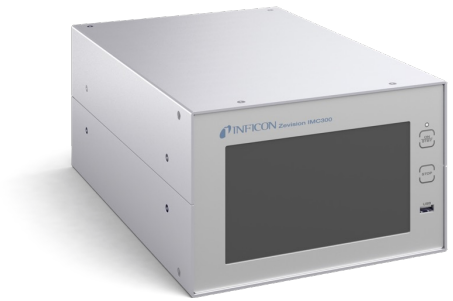
Maximize uptime and throughput with ModeLock (longest useable crystal life)

Flexible system integration

Compatible Temperature Compensation Thin Film Products

CONTROLLERS

Zevision® IMC300



Temperature Compensation for Optical Market (In Development)

MONITORS

IMM-200

Temperature Compensation for Semi Market in 2024

CRYSTALS

SC-cut

Temperature Compensation for All Coating Markets

Benefits of SC-cut Crystal

Different crystal cuts

Two advantages of SC-cut crystals

- SC-cut crystals have 100 times reduced sensitivity to acceleration-induced frequency changes
  - Reduces frequency changes induced by acceleration shock
  - **Improved performance** for QCMs mounted on robotic arms

- SC-cut crystals have lower rate noise compared to AT-cut
  - Higher measurement accuracy for organics
  - **Superior** PID control

Conclusions

01

Thermal shock and temperature instability causes thickness errors impacting product quality and yield

02

Temperature Compensation removes unwanted temperature induced frequency changes from the thickness calculation

03

Temperature Compensation will be implemented in monitors (IMM-200) and controllers (IMC300) in the near future

04

SC-cut crystals provide low rate deviation and 100 times reduced sensitivity to acceleration induced frequency changes