INFICON

APPLICATION NOTE

Guide to INFICON Quartz Monitor Crystals

INTRODUCTION

The quartz monitor crystal is a crucial component of a quartz crystal based measurement and control system. The crystal enables precise and repeatable thin film depositions for a wide variety of high value end uses.

This application note describes various crystal types and package options available from INFICON®.

CHOOSING THE BEST CRYSTAL

Choosing the best INFICON crystal for an application is very important. INFICON manufactures crystals compatible with its own and all other manufacturers' equipment. All INFICON crystals are fully interchangeable within the constraints of size and frequency.

Depending on the specific application, one INFICON crystal may be better suited to the process requirements than another. The optimum crystal for a process may have a longer deposition life, show less rate noise, have a smaller rate and thickness spike when the shutter is opened, or it may have the longest shelf life. Some crystals have a fully coated electrode on both sides, others provide a very narrow starting frequency range. Whatever is important for the application, INFICON has the best crystal and package style.

Please refer to the INFICON website for a list of crystal part numbers and styles at www.inficon.com. If the type required is not shown, contact INFICON.

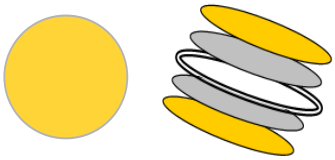
NOTE: Maxtek brand crystals, from INFICON, generally have somewhat lower performance compared to INFICON brand crystals, but are offered at lower pricing.

CRYSTAL TYPES

INFICON AT-cut, plano-convex crystals are available in:

- Two diameters (sizes)
  - 14 mm (0.550 in.)
  - 12.4 mm (0.489 in.)
- Two frequencies
  - 5 MHz
  - 6 MHz
- Three electrode materials
  - Gold
  - Silver
  - Stress-relieving Alloy
- Three different electrode patterns
  - Full Pad/Anchor Pad

  - Full Pad Both Sides



  - Single Anchor

- Four different package choices
  - Clean room compatible
  - Flat pack carousel
  - Compact box
  - 50-pack

SIZE

The first criterion for selecting a crystal for use in existing equipment is to determine the appropriate crystal size (diameter) for the sensor.

Crystals are available in two diameters:

- 14 mm (0.550 in.)
- 12.4 mm (0.489 in.)

All INFICON quartz crystal sensors are compatible with 14 mm (0.550 in.) diameter crystals, and some sensor heads can be adapted to use the 12.4 mm (0.489 in.) diameter crystal.

FREQUENCY

After choosing the crystal size, choose either a 5 MHz or 6 MHz crystal based on the crystal frequency range suitable for the instrument.

CAUTION

Make sure the frequency setting of the instrument matches the starting frequency of the crystal.

INFICON 6 MHz crystals work in all INFICON instruments and sensors as well as most other manufacturers' equipment.

Starting Frequency

In many cases, a brand new quartz crystal will not have a frequency of exactly 5 MHz or 6 MHz.

It is normal for that crystal to display a crystal life anywhere from 0 to 5% due to process variations in producing the crystal. If a new crystal indicates 5% life spent, it means that either the quartz blank is slightly thicker than normal (more mechanical robustness), or the electrode is slightly thicker than normal (better thermal and electrical properties), or both. This additional thickness causes the starting frequency to be lower than the rated value of 5 MHz or 6 MHz. Despite a lower starting frequency, its overall performance should not be adversely affected. These lower starting frequency crystals have been tested and results indicate that a brand new crystal indicating 3 to 5% life spent is just as good as, if not better than, a crystal indicating 0 to 2% life spent.

ELECTRODE MATERIALS

After choosing crystal size and frequency, choose the electrode material best suited for the application:

- Gold
- Silver
- Alloy

Gold

Gold is the most widely used electrode material. It performs well in a large variety of applications. Gold provides good adhesion, low rate noise, and good crystal life. Gold crystals have an indefinite shelf life.

Silver

Silver electrodes have high thermal conductance, enabling them to transfer heat arriving from the hot evaporation source to the water-cooled sensor body to keep the crystal from getting too hot.

Silver crystals provide good adhesion for materials used in optical coatings, delivering good crystal life and low rate noise.

Because silver tarnishes due to hydrogen sulfide present in air, the shelf life of Silver crystals is typically limited to six months after opening the package.

NOTE: INFICON ships Silver crystals in a heat-sealed external sleeve filled with inert gas to protect them against tarnishing during shipment and storage.

Alloy

The Alloy electrode provides excellent adhesion for coatings used in optics and also acts to absorb the tensile and compressive stresses common in some films, thereby maximizing crystal life and reducing rate noise.

Activity values tend to be higher for Alloy crystals compared to Gold crystals. The shelf life of INFICON Alloy crystals is typically six months.

Table 1 Electrode materials table

Electrode Material	Advantages	Disadvantages
Gold (Standard Type)	***1*** Does not oxidize ***2*** Indefinite shelf life ***3*** Most widely used, good for a large number of applications	***1*** Crystal life may be shorter than Silver or Alloy in some applications (materials used in optical coatings)
Silver (Sputtering Type)	***1*** Best transfer of heat arriving at crystal to cooled sensor body (high thermal conductance)	***1*** Shelf life depends on oxidation and exposure to sulfur content in air (tarnishing effect) ***2*** Not widely used
Alloy (High Stress Coatings)	***1*** Longest life (2x) for materials used in Optical films or for high stress semiconductor materials ***2*** Higher Activity values compared to Gold and Silver	***1*** Alloy electrode will oxidize, shorter shelf life compared to Gold ***2*** No added benefit when depositing “normal” stress materials (non-high stress metals)

ELECTRODE PATTERNS

INFICON crystals are available with three different electrode patterns:

- Full Pad/Anchor Pad (double anchor)
- Full Pad/Anchor Pad (single anchor)
- Full Pad Both Sides

Full Pad/Anchor Pad

Double Anchor Single Anchor

Full Pad/Anchor Pad crystals have a full-pad electrode pattern on one side and a single or double-anchor electrode pattern on the other side. The double-anchor pattern provides a more reliable electrical connection and is recommended. The crystal must be oriented with the fully-coated side facing the deposition source. The anchor electrode pattern focuses the excitation energy into the center area of the crystal to help avoid unwanted vibrational modes which reduce crystal life and increase rate noise. This design maximizes crystal stability and life by minimizing the opportunity to couple unwanted modes of oscillation.

The excitation area on the anchor electrode pattern side is sized to focus energy at the center of the crystal. This ensures the physical connections made at the perimeter of the crystal have no detrimental effect on its operation.

The Full Pad/Anchor Pad electrode pattern will provide the best performance in crystal life and rate noise and is recommended as standard.

NOTE: The Full Pad/Anchor Pad crystal must be installed with the fully coated side facing the deposition source.

Full Pad Both Sides

Full Pad Both Sides crystals have a fully-coated electrode on each side. These crystals do not require a specific orientation when installed. Full Pad Both Sides crystals are suitable for high volume production applications where maximum crystal life is not required. The Full Pad Both Sides design results in somewhat shorter crystal life and possible coupling of unwanted modes of oscillation. These unwanted modes can cause rate noise to appear earlier in crystal life.

Table 2 Electrode pattern

Electrode Pattern	Advantage	Disadvantage
Double Anchor	***1*** Traps energy in the center of the crystal ***2*** Maximizes crystal stability and life by minimizing opportunity to couple unwanted modes of oscillation	***1*** Crystal can be put into crystal holder upside down
Single Anchor	***1*** Traps energy in the center of the crystal ***2*** Maximizes crystal stability and life by minimizing opportunity to couple unwanted mode of oscillation	***1*** Crystal can be put into crystal holder upside down ***2*** May not be compatible with all sensor head types (depends on placement of sensor electrical contacts)
Double Full Face (dual pad, no anchor pattern)	***1*** No orientation dependency when placing crystal into holder (crystal cannot be put in upside down)	***1*** Expect shorter life, and coupling of unwanted modes of oscillation (crystal can be noisy, earlier in life)

APPLICATIONS - OPTICAL COATINGS

Standard Optical Coatings

Standard Optical Coatings typically have fewer than eight layers controlled by the crystal. They include ophthalmic and simple camera lenses as well as basic anti-reflective display coatings. This application typically uses Gold crystals.

Precision Optical Coatings

Precision optical coating applications typically require multi-layer stacks of dielectric materials.

The applications include bandpass optical filters with a sharp cutoff for dense wave division multiplexing and other fiber-communication applications, high-quality, anti-reflectance optics for cameras, telescopes, rifle scopes, microscopes, medical instruments, binoculars, night vision optics devices and semiconductor photolithography.

Dielectric materials include aluminum oxide (Al_2O_3), calcium fluoride (CaF_2), magnesium fluoride (MgF_2), tantalum pentoxide (Ta_2O_5), titanium dioxide (TiO_2), thorium fluoride (ThF_4), silicon monoxide (SiO), silicon dioxide (SiO_2), zirconium dioxide (ZrO_2), and many more. These materials cause a higher level of stress to the crystal and an Alloy crystal is recommended.

For some applications, when the source or sensor shutter opens, there is a large increase in the amount of heat arriving at the crystal, resulting in a sudden jump in crystal temperature and film stress. Both of which cause a spike in rate and thickness. For these applications, Low Thermal Shock Gold crystals are recommended.

Very Thin Optical Coatings Under 50 nm Thick

These applications are susceptible to an initial rate and thickness spike when the shutter is opened, due to the large increase in heat arriving at the crystal. This spike may cause incorrect thickness termination and possible control loop instability. Low Thermal Shock Gold crystals are recommended.

NOTE: Low Thermal Shock Gold crystals are designed to reduce the rate and thickness spike induced by the thermal shock created when the source or sensor shutter opens. Compared to standard Gold crystals, lifetime is slightly reduced.

APPLICATIONS - METAL COATINGS

High Heat Load Applications

High heat load is often present in diode sputtering from large sources when evaporating very high melting point materials such as molybdenum (Mo), tantalum (Ta), and tungsten (W), or when the substrates are heated above 300°C.

Crystals for these applications must have high thermal conductance to transfer heat, arriving from the hot evaporation source, to the water-cooled sensor body which maintains crystal temperature.

For long crystal life and low rate noise, crystals used in high heat load applications must have good adhesion for the materials used in optical coatings. INFICON Silver crystals (known as Sputtering Type) are well-suited for this application.

NOTE: High heat load applications refer to those applications, such as sputtering, that use water to cool the crystal. For ALD applications, High Temperature crystals are recommended, see Applications - ALD.

Low stress coatings such as aluminum, gold and silver

Low stress coatings are often used for electrical contacts and in “Cold Mirrors” to reflect the heat and light from light sources used in projection equipment and other lighting applications, such as store display lighting systems, automotive lights, flashlight reflectors and LEDs. These applications typically use Gold crystals.

High Stress Material Coating

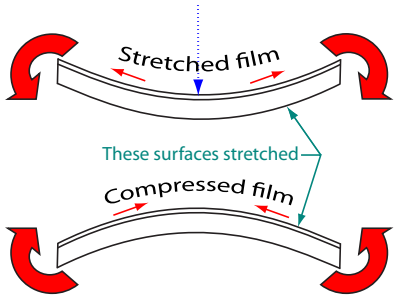


Illustration provided by Felix Lu,
Applied Quantum Technologies / Duke University

High stress materials include those used in semiconductor processes: chromium (Cr), germanium (Ge), molybdenum (Mo), nichrome, nickel (Ni), tantalum (Ta), titanium (Ti), silicon oxycarbide (SiOC), zirconium (Zr), as well as the dielectric materials listed above under Precision Optical Coatings. For these applications, Alloy crystals usually perform the best. However, Silver crystals are also suitable.

APPLICATIONS - OLED

OLED materials have a granular amorphous structure which does not bond firmly to the crystal electrode. This structure dissipates motional energy, which results in short crystal life. Low Thermal Shock Gold crystals are recommended.

Some OLED materials are deposited at extremely low rates. Maximizing rate stability and minimizing rate noise are very important. Alloy crystals will provide the best rate stability and minimum noise.

APPLICATIONS - ALD

ALD uses two precursors that react to deposit material (metals or metal oxides) one atomic monolayer at a time. Most ALD reactions are temperature dependent, and the crystal must remain at the reaction temperature.

Water cooling cannot be used during an ALD process to cool the crystal and maintain the optimal temperature for standard INFICON crystals. High Temperature ALD crystals are recommended for ALD applications for this reason.

High Temperature crystals are 6 MHz, gold-coated crystals that are optimized at 120, 240, or 285°C. These crystals have a smaller range of temperatures that deliver stable and accurate thickness readings. See Figure 1.

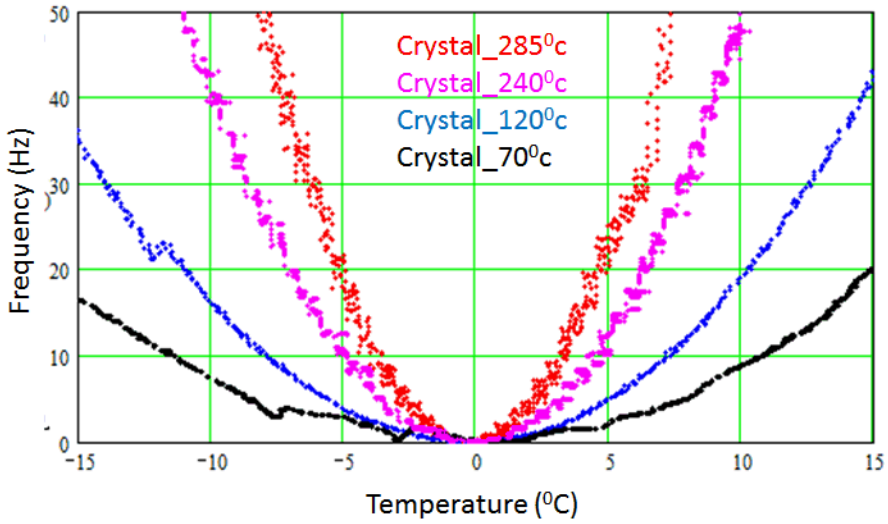
NOTE: Crystals optimized to additional temperatures are available upon request. Please contact INFICON for custom crystals.

The graph represents the temperature change from the optimal crystal temperature and the resulting frequency error due to temperature.

NOTE: The optimization temperatures of the High Temperature crystals (120, 240, or 285°C) as well as standard INFICON crystals (70°C) have been normalized to zero to be able to compare the temperature range of all offerings on one graph.

- 70°C crystals display a stable frequency operating in a temperature range of 59 to 81°C.
- 120°C crystals display a stable frequency operating in a temperature range of 112 to 128°C.
- 240°C crystals display a stable frequency operating in a temperature range of 235 to 245°C.
- 285°C crystals display a stable frequency operating in a temperature range of 281 to 289°C.

Figure 1 High temperature crystal frequency error



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