Synthetic Quartz Crystal

■ Terms and Definitions

Synthetic Quartz Crystal: A single crystal grown using the hydrothermal synthesis method.

As-Grown Quartz Crystal: A synthetic quartz crystal grown naturally with no processing.

Lumbered Quartz Crystal: A synthetic quartz crystal with the X and Z surfaces processed according to specified dimensions and angles using a diamond wheel #80.

Y-bar Synthetic Quartz Crystal: A synthetic quartz crystal grown by using a bar-like seed crystal elongated in the Y-axis direction.

Z-plate Synthetic Quartz Crystal: A synthetic quartz crystal grown by using a plate-like seed crystal with a Y-axis direction length and X-axis direction width.

Inclusion: A general term for solid constituents (inclusions) that exist in synthetic quartz crystal; they can be observed when light is scattered through a liquid with a refractive index that is close to that of the synthetic quartz crystal. Main inclusions are acmite and emeleusite. They are generated by the chemical reaction of Fe within an autoclave and synthetic quartz crystal growth frame, Na from a solution, SiO_2 of a material, etc. at high temperature and under high pressure.

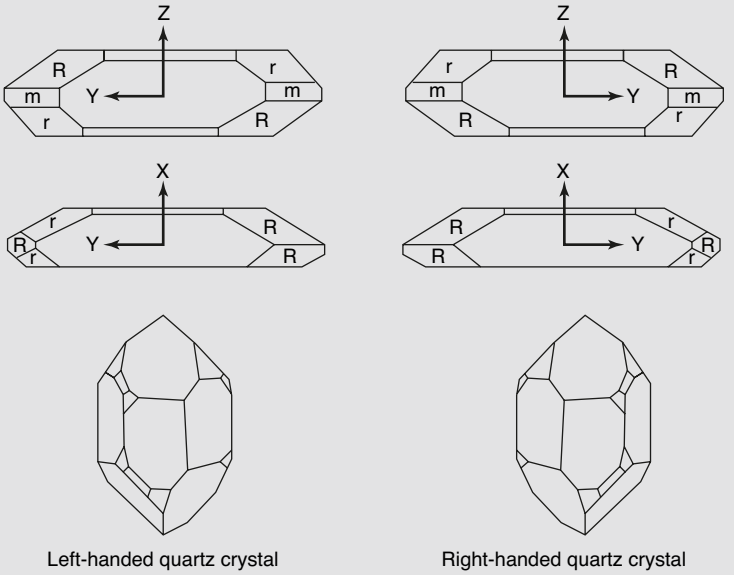
Twins: Crystallographically, taking into account specific facets or axes two or more crystals are symmetrically joined to one crystal. Almost all twin crystals that are generated as synthetic quartz crystals are electrical ones, and electrical twin crystals affect the shape of the synthetic quartz crystal. They can easily be identified visually.

Right-handed and left-handed quartz crystals: Crystals are divided into two types: right-handed and left-handed. A difference in optical rotation creates the 2 types, but their physical properties are identical. Therefore, by cutting at the correct angle, the difference does not affect the characteristics of a crystal oscillator. Generally right-handed quartz crystals are used in manufacture.

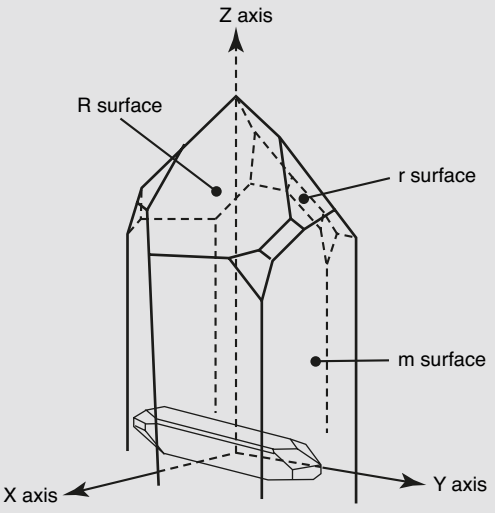
Zone: A zone with a crystal that has grown from a seed crystal at its core. There are Z, +X, -X, and S zones.

Infrared Absorption Coefficient α: This value measured with an infrared spectrophotometer is adopted as the infrared absorption coefficient α of a synthetic quartz crystal. The value is based on the absorption characteristic of the OH radical of a synthetic quartz crystal that is around 3,800 to 3,000 cm^{-1} of the infrared transmittance curve. Generally, absorption coefficients with wave numbers 3585, 3500, and 3410 cm^{-1} have been adopted. (As is usual practice, an infrared Q value is also described for reference.)

Etch Channel: Tubular cavities generated along linear defects in a crystal when the crystal is etched. When the processing of a crystal piece for manufacturing a tuning fork-type crystal oscillator or a reversed mesa-type involves etching, a synthetic quartz crystal with a low etch channel density is particularly suitable.



Synthetic and natural right-handed and left-handed quartz crystals



Relationship between synthetic and natural quartz crystals

Synthetic Quartz Crystal

■ Properties of Quartz Crystal

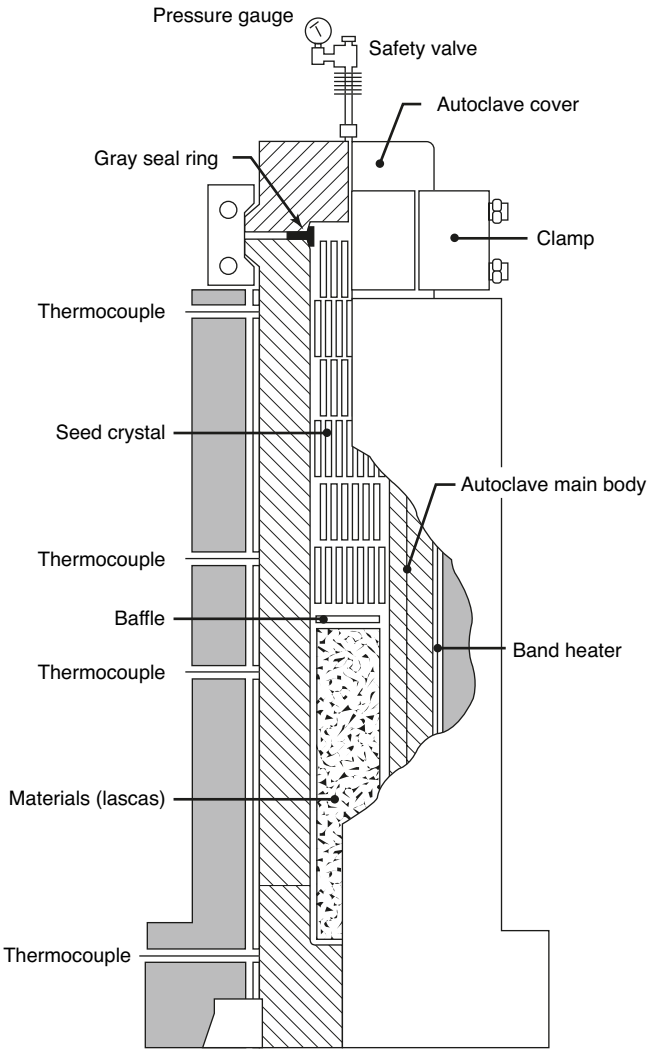
Constituent: SiO_2
Crystal system: Trigonal system
Crystallographic group: $D_3(32)$
Lattice constant: $a = 4.9027 + 70\times10^{-6}$ (T–18) kX
$c = 5.3934 + 47\times10^{-6}$ (T–18) kX
1kX = 1.002063±0.000007Å
Density: 2.649 g/cm^3
α–β phase transition temperature: 573 °C

■ Precautions for Use

Make sure to read the following carefully before using synthetic quartz crystals:
Crystal quartz changes from α crystal to β quartz crystal at a temperature of 573 °C because of phase transition. This phase transition is reversible, but transition from β quartz crystal to α crystal does not take place homogeneously, and twins are created. Therefore, careful attention must be paid to never allow the temperature to rise above 573 °C.

■ How to Manufacture Synthetic Quartz Crystal

Synthetic quartz crystal is manufactured in a vertical-type autoclave (high-temperature and high-pressure oven) using the hydrothermal synthesis method. An autoclave is partitioned by a baffle into two compartments: an upper and lower. Seed crystals are placed in the upper compartment (growth zone) and materials (lascas) in the lower (dissolution zone).A dilute alkaline solution is then poured into the remaining 60 to 80 percent of free space and, after being covered the autoclave is heated with a heater.
When the temperatures of the upper and lower compartments of the autoclave reach between 300 to 320 °C and 380 to 400 °C, respectively, the alkaline solution expands and is compressed; the pressure inside reaches 130 to 145 MPa.
Under these high temperatures and pressures the materials in the lower compartment of the autoclave dissolve in the alkaline solution to become an SiO_2 saturated solution. This saturated solution rises due to the convection caused by the temperature difference between the upper and lower compartments of the autoclave. When the solution reaches the upper compartment of the autoclave, it becomes supersaturated because of the lower temperature of the compartment, and according to the degree of the temperature difference SiO_2 is crystallized on the seed crystal. The solution then returns to the lower compartment of the autoclave and dissolves the materials, thereby becoming an SiO_2 saturated solution, and due to convection it rises and the cycle repeats. The repetition of this process leads to the successive growth of synthetic quartz crystals.



Schematic depiction of synthetic quartz crystal growth

Synthetic Quartz Crystal

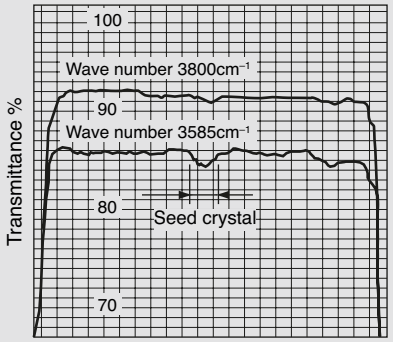
■ Characteristics of NDK Synthetic Quartz Crystal

● Product Variety and Wide Selection

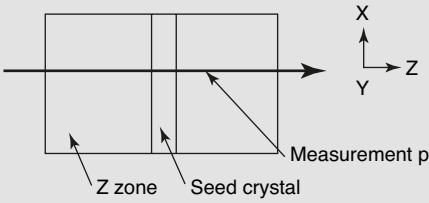
To ensure a high yield when wafer cutting, according to the end purpose the dimensions and directions of Y-bar synthetic quartz crystals to large-size synthetic quartz crystals can be freely selected.

● High Quality

- Synthetic quartz crystals have fewer internal defects that affect electrical and optical characteristics
- The infrared absorption coefficient α is measured by the infrared ray absorption method and the standard α_{3585} comes guaranteed as being 0.069 or less (the infrared Q value is 1.8 million or more). Homogeneous quality has been achieved because the inhomogeneousness of the infrared absorption coefficient α, that depends on the positions inside the crystal, is stable.
- Because the surfaces of the lumbered synthetic quartz crystal have been processed to a high degree of precision, good precision wafer cutting is possible.
- Because the synthetic quartz crystals have been grown in mass-production facilities based on a practical design, inhomogeneousness in quality is minimized.



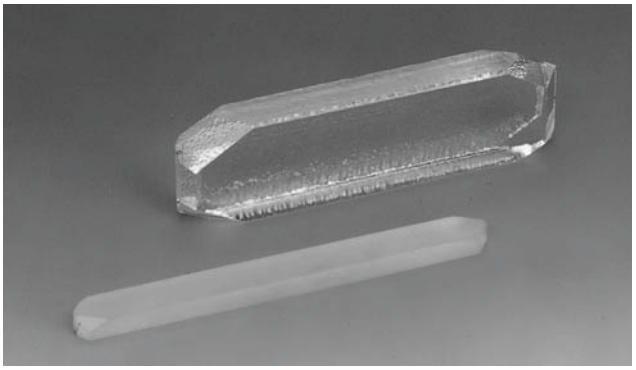
Distribution of infrared transmittance inside a crystal



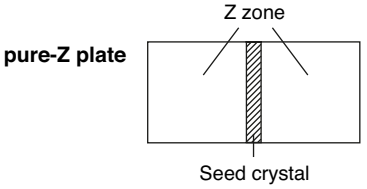
Cross section of lumbered synthetic quartz crystal (Pure-Z)

■ Product Types

● Synthetic Quartz Crystal for AT-cut



Features: This is the most general synthetic quartz crystal for AT-cut crystal oscillators.
The shape and dimensions of the crystal have been optimized, and a high yield can be obtained from wafer cutting. Therefore, it is suitable for mass-production. Types and dimensions can be selected according to the types of wafers to be cut.



● Synthetic Quartz Crystal for Optical Components

Features: This is an optical synthetic quartz crystal best suitable for optical low-pass filter, wavelength plates, etc. They are grown so that the densities of striae and inclusions that affect optical characteristics are low.
In addition, excluding the seed dimensions, large-size optical synthetic quartz crystals with a Z size in excess of 50 mm and an X size of more than 80 mm are available.

● High-purity Synthetic Quartz Crystal

Features: High-purity synthetic quartz crystals, in which the densities of impurities (aluminum, alkaline metal, etc.), linear defects, and inclusions have been kept to a low level, are available.
Because high-purity synthetic quartz crystals have high laser resistance, they are most suitable for optical components for high-power/short-wavelength lasers.
In addition, this crystal contains an extremely small amount of alkaline metals that affect the frequency change of a crystal oscillator in a radiation environment. Therefore, it is best suited for highly stable crystal oscillators used in radiation environments, such as outer space.
It can also be used in a variety of experiments.

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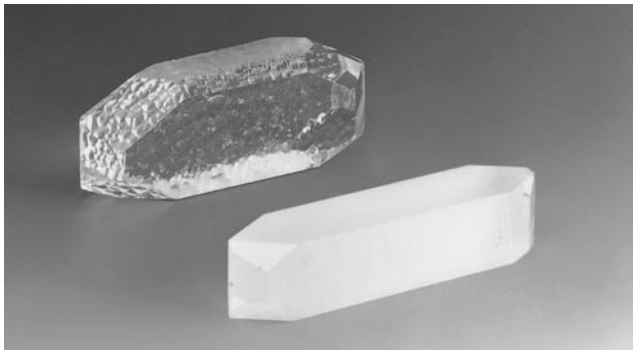
Crystal Bridge to the Future

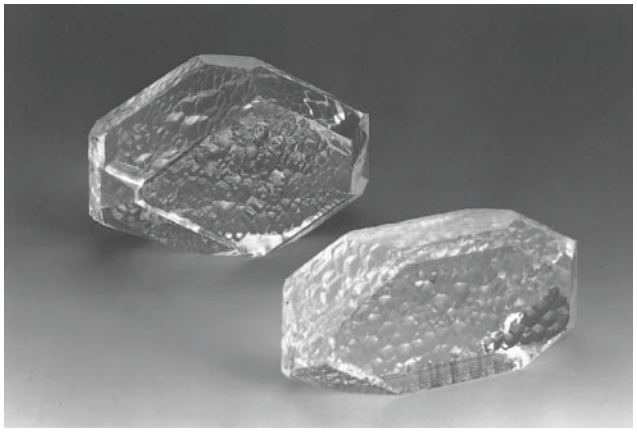
■ Product Types

● Wrist Watch Synthetic Quartz Crystal



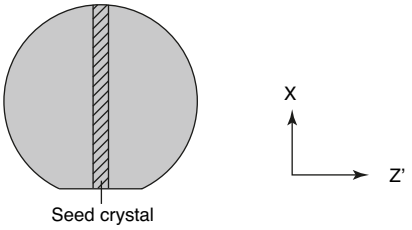
Features: A seed crystal cut with a tilt angle of one to two degrees in the Y-axis direction on the Z surface is suitable for ultra-compact oscillators. Because the etch channel density of the seed has been controlled, ores with a low etch channel density for photolithographic processing that meet your specifications are available.

● Synthetic Quartz Crystal for SAW Devices



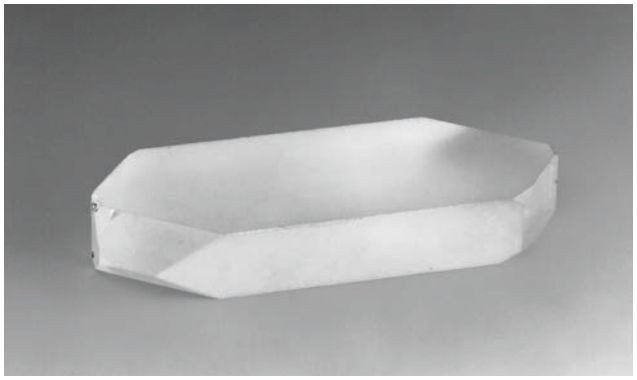
Features: A large-size synthetic quartz crystal grown for a long period of time with an X-size large seed.
Suitable for 3- to 4-inch large-size wafers for ST-cut.

ST-cut wafer

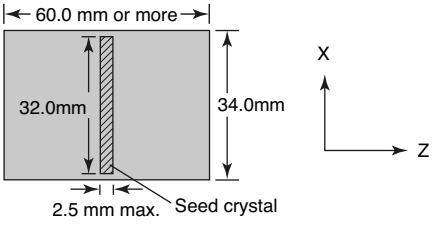


* Although the central part of the wafer contains a seed crystal, a seed with a low etch channel density is used, and, in addition, processing ensures the prevention of pinholes from being created in the seed part. All these factors ensure a crystal that can be used with confidence.

● High-Q Synthetic Quartz Crystal



Features: This crystal has been grown slowly over a long period of time and its growth speed has been kept constant. In all the areas of the Z zone, the infrared absorption coefficient α_{3585} is 0.024 or less (the infrared Q value is 3 million or more) constantly. This crystal is especially ideal for crystal units used in highly stable crystal oscillators.



Infrared transmittance curve