CHAPTER - 2

QUARTZ AND ITS APPLICATIONS

Quartz is one of the most common minerals on earth. It is well known as amethyst, citrine, rose, and smoky quartz. There are many other natural varieties, plus synthetic quartz that comes in every color of the rainbow. Rock crystal, colorless quartz, is rarely used as a gem.

Quartz grows primarily in pegmatite, but is hydrothermally grown in laboratories. Quartz grows very large, with cut gems in the thousands of carats. Quartz is one of the first gems to be synthetically grown on a large scale. Major development was done during World War II, to supply crystals for radios. Today, our computer industry is based on synthetic quartz. Not that there is a shortage of natural crystals, but the synthetics are always clean and are less time consuming to trim into the necessary pieces.

2.1 Type of Quartz

Although quartz (α-quartz or low quartz) is the only form of primary free silica to occur in plutonic rocks, uncombined SiO_2 is known to exist in a dozen or more structural modifications, each requiring some combination of physical conditions (**Table-2A**). About half the known forms are synthetic, without known representation in nature. All silica structures consist of silicate tetrahedral (SiO_4^{-4}) linked together on all four corners to form a framework structure, wherein every silicon ions occurs in four fold (tetrahedral) oxygen coordination and every oxygen is coordinated between two silicones. The three major polymorphs of natural SiO_2 are quartz, tridymite and cristobalite, each having a distinctive crystal structure stable over a specific temperature-pressure range, and each showing a high-temperature (β) and low temperature (α) form of closely related structure. High-temperature modifications tend to be open structure of higher symmetry. The high and low temperature (β and α) modifications of each major form represent only slightly structural adjustments (displacive) and inversion to α forms is therefore rapid. Low quartz is the most common form of uncombined silica in volcanic rocks. β-Quartz apparently crystallizes in some flows but inverts to α-quartz on cooling below 573°C, and only the α form exists at surface conditions.

Table-2A: Physical condition of quartz and its phases

α-Quartz	Stable below 573°C	Trigonal
β-Quartz	Stable from 573°C to 870°C	Hexagonal
α-Tridymite	Never stable; exists metastably from 117°C	Orthorhombic
β_1-Tridymite	Never stable; exists metastably from 117°C to 163°C	Orthorhombic
β_2-Tridymite	Stable from 867°C to 1470°C: exists metastably from 163°C to 867°C	Hexagonal

α-Quartz

Composition and Structure - Quartz is essentially pure SiO_2 without major of consistent impurities, and its optical properties are equally consistent. A few Al^{+3} ions may replace Si^{+4} ions, usually coupled with the introduction of small alkali ions (Li^+ or Na^+). This substitution is much more important in tridymite and cristobalite, where the structure is sufficiently open to allow significant introduction of interstitial ions. Germanium is a possible substitute for some silicon but is very minor in quartz analysis and is much more abundant in some silicates.

Physical Properties - In hand sample quartz is most commonly colourless and transparent, with vitreous luster and classical conchoidal fracture. Color, however, is highly variable and many varieties of coarse crystalline quartz are defined by color- Amethyst (violet), Citrine (yellow-brown), Smoky quartz (black-brown), and Rose quartz (pink).

Alteration - α-Quartz is one of the most chemically stable minerals in nature at surface conditions and is characteristically free from alteration. Under exceptional conditions, it may be partially replaced by sericite, talc, chlorite, pyrite, and magnetite and certain clays.

Occurrence - α-Quartz is probably the most abundant single mineral variety making up about 12% of the earth's crust, mainly as an essential constituent in acidic igneous rocks. Quartz is essential in alaskites, granites, adamellites, granodiorites, quartz diorites, and similar plutonic igneous rocks. Quartz is stable with high-iron olivines(fayalite) in vugs and cavities of hydrothermal or pegmatitic origin. Quartz pseudomorphs after tridymite and cristobalite are common in siliceous volcanics. Some sedimentary rocks and unconsolidated sediments are almost wholly quartz sand and quartz pebbles and detrital quartz grains are common in nearly all sediments.

β-Quartz

Composition - β-Quartz is nearly pure SiO_2 but should allow slightly more substitution of Al^{+3} and accompanying alkalis for Si^{+4} than α-quartz because of its more open structure.

Physical properties - Color of α-quartz paramorphs after β-quartz is usually opaque milky white to gray, due to extensive, minute fractures.

Occurrence - β-Quartz exists only briefly after its crystallization as phenocrysts in siliceous volcanic lava and yields its identity to the stable α form before the lava cools. Only the stubby bipyramidal habit and intense fracturing remain to tell of the existence of β-quartz.

α-Tridymite

Composition and Structure - In contrast to the quartz structure the very open structure of tridymite allow introduction of large ions, and Al^{+3} may replace appreciable Si^{+4} with the introduction of alkalis (Na^+ and K^+) or calcium into interstitial positions maintaining electrostatic neutrality. Inversion temperatures of high-low forms are significantly affected by ionic substitution, and interstitial ions may well tend to stabilize open structures.

Physical Properties - In hand sample tridymite is transparent, colorless to white, very brittle and has vitreous luster.

Alteration - Being an unstable form of silica, tridymite tends to invert to fine-grained α-quartz, particularly in older volcanic.

Occurrence - The most typical occurrence of tridymite is as relatively coarse crystals in vuges, vesicles, lithophysae and other cavities in fine-grained silicie and intermediate volcanic rocks such as obsidian, acid tuff, rhyolite, trachyte, deltenite, dacite and andesite (less commonly in basalts) where it has been deposited by late, hot gases. Tridymite may also occur as tiny, disseminated grains in the groundmass of these rocks and occasionally as distinct phenocrysts. Tridymite may occupy a cavity alone or in association with cristobalite, sanidine, quartz, chalcedony, specular hematite, fayalite, augite, hornblend, topaz or cassiterite. Tridymite is rather common in stony meteorites. Industrial silica bricks contain synthetic tridymite as their major constituent, with cristobalite, quartz and pseudowollastonite.[1]

2.2 Structure

SiO_2 (silica) makes up 12.6% by weight of the Earth's crust as crystalline and amorphous silica. It occurs in 14 forms depending on the temperature and pressure of formation. The most common form is trigonal alpha-quartz which is composed exclusively if $[SiO_4^{-4}]$ tetrahedral with all oxygens joined together in a three dimensional network. The trigonal low-temperature quartz (alpha-quartz) transforms enantiotropically at 575°C under normal pressure into hexagonal high-temperature quartz (beta-quartz). The conversion occurs by changes in the bonding angle of the oxygen rings accompanied by an enlargement of the crystal lattice **Fig-2A**. The reverse process takes place in magnetic processes, where high-quartz transform into low-quartz during cooling.[2]

Quartz and its polymorphs, tridymite and cristobalite, occur naturally in the temperature ranges < 870°C, 870°C-1470°C and >1470°C, respectively. Both tridymite and cristobalite are metastable at ambient temperatures and both occur as natural minerals. All three minerals have alpha and beta modification- alpha quartz being stable below 573°C and beta quartz being stable between 573°C and 870°C. The alpha-beta transition is a displacive phase changes, involving small adjustments in atomic positions without bond rearrangement, and is reversible.

The alpha form is rhombohedral and beta form has a hexagonal structure. In both form, the oxygen atoms are tetrahedrally shared between those of silicon. Two of the Si-O bonds in alpha make an angle of 66° with the optic axis (c-channel) whilst the two others (of slightly longer length, viz 1.616Å compared to 1.598Å) make an angle of 44°. Thus, the oxygens occur in two equivalent pairs.

The nature of the Si-O bond is SiO_2 is described as being ~40% ionic and ~60% covalent. The covalent component gives the material a rigid structure such that microscopic diffusion of lattice atoms is prevented. Dislocation and intrinsic defects exist, but have complex structures and rather poorly defined. Misplaced lattice atoms tend to be located near impurities. The mixed ionic and covalent nature of the SiO_2 lattice has resulted in two basic mechanism of damage by radiation- namely, Si-O bond rupture (requiring only ionizing radiation) and direct "knock-on" collision resulting in vacancy and interstitial creation. This second mechanism requires energetic nuclear particle radiation.

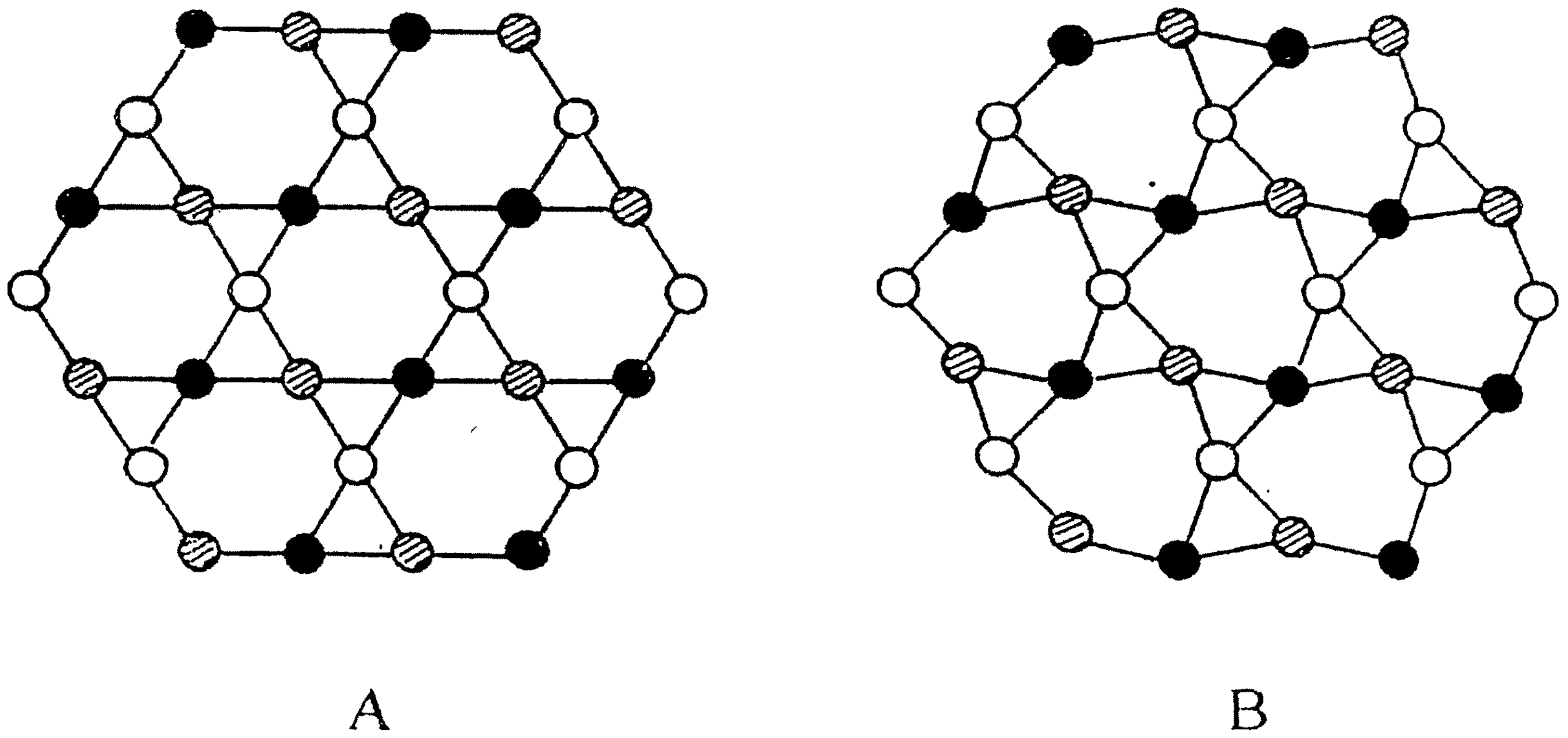

Fig-2A: The Crystal Structure of Quartz - Circle - Si at 0, Dotted Circle - Si at 1/3, Dark Circle - Si at 2/3

(A) Alpha Quartz (B) Beta Quartz

Most of the defects caused by ionizing radiation appear to occur at pre-existing imperfections-predominantly impurities. The trapped electron and hole populations, which results give rise to several optical absorption, luminescence, magnetic and electrical phenomena.[3]

2.3 Defects

The following are the center types in natural and synthetic quartz

(1) Impurity centers

Electron Center (Titanium, Germanium and in general $M^{+4} + e^-$)

Hole Centers (Aluminum, with iron and in general with M^{+3}, M^{+2} ions, as well as atomic Hydrogen)

(2) Vacancy Centers

Electron Centers (with oxygen vacancies)

Hole Centers (silicon vacancies)

According to the precursor, type the electron (e^-) and hole (e^+) centers in quartz can be grouped as follow

e^- : Ti, Ge, V_0, and H_0

e^+ : Al, Fe and V_{si}

Each one of these types has subtypes and varieties, depending on the kind of the ion-charge compensator in structural channels (H^+, Li^+, Na^+) as well as on the position of the compensator. There are also geometrically nonequivalent positions, i.e., some positions of the same center related to one another through the symmetry elements exist. The electron centers Ti^{+3} and Ge^{+3} are stable in the presence of the compensators M^+ and one not stable without them. On the contrary, the hole centers O^--Al are stable without an ion compensator near the center, and form unstable varieties in the presence of M^+. Other impurities can be inserted into synthetic quartz crystals (W, Co, Ga and others), and the similar center types can be formed with these impurities. Most widely distributed centers in natural quartz are O^--Al, Ti^{+3} and O_2^{-3}.

Titanium Center - Ti^{+3}, i.e. $Ti^{+4} + e^-$ substituting silicon; the existence of their varieties is caused by the presence of H^+, Li^+, or Na^+ ions in channels near some or other edge of the silicon-oxygen tetrahedron.

Germanium Centers - $Ge^{+3}(Ge^{+4} + e^-)$ have the same type of orientation and the same varieties as Ti^{+3}.

Aluminum Centers - O^--Al, or AlO_4^{-4} is the particular case of hole O^- center with all its characteristics. There are six nonequivalent positions of the center. The substitution of aluminum for silicon ($Si^{+4} \rightarrow Al^{+3}$) is accompanied by charge compensation though incorporation of H^+, Li^+ and Na^+ ions in the channels near the Al tetrahedron. Irradiation causes formation of the O^--Al center with simultaneous diffusion of the ion compensators. The center is stable up to 300°C, and after heating can be restored by the X-ray or gamma irradiation. The O^--Al/H^+, O^--Al/Na^+ and O^--Al/Li^+ centers are unstable at room temperature, but the O^--Al/Li, H center (with simultaneous presence in the channels near O^--Al of both Li and H compensators) is stable up to ~180°C; one of the radiation citrine colour corresponds to this variety.

Centers with Oxygen Vacancies - As in other structure with tetrahedron oxyanions these are oxygen vacancies in the SiO_4^{-4} radical, which have trapped, an electron that is being distributed over the whole of the radical forming electron centers SiO_3^{-3} (or $SiO_3V_oe^-$, or Si^{+3} in the tetrahedron with oxygen vacancy). The fact that quartz has a framework polymeric crystal structure and each oxygen here is a bridging one, i.e., it belongs simultaneously to two SiO_4 tetrahedra, dose not essentially complicate the center model because the electron tapped by the vacancy is drawn off towards one of the tetrahedral. SiO_3V_o.

Centers with Silicon Vacancies - In the quartz crystal structure the existence of the silicon vacancy leads to hole trapping by two oxygen ions with formation of an O_2^{-3} center (i.e., $O^{-2} + O^{-} \rightarrow O_2^{-3}$), which can only form on two of the four O-O edges of the SiO_4 tetrahedron. As perfect crystal structures do not exist, the properties of quartz are determined by its real, or "defect", structure. The type and frequency of lattice defects are influenced by the thermodynamic condition during minerolization. The lattice defects can be classified according to their structure and size as follow: point defects (most important for luminescence studies), translations, and inclusions of paramagnetic minerals and gas/liquid inclusions. New formation on structure of defect centers in quartz has been obtained from studies using Electron Spin Resonance (ESR) alone or in combination with other spectroscopic methods such as thermoluminescence, infrared spectroscopy or absorption measurements.

Generally, about 20 different types of paramagnetic defect center can be observed. Which are subdivided into two main types: defects caused by foreign ions (foreign ion centers and interstitial defects), and centers associated with empty oxygen or silicon positions (**Table-2B**).

Table-2B: Common paramagnetic centers in quartz

	Foreign ion centers Si^{+4} substitution	Interstitial	Oxygen vacancies	Vacancies Si vacancies
Metastable Electron Centers ($+e^-$)	$[TiO_4]$, $[TiO_4/M^+]^\circ$, $[GeO_4]^-$, $[GeO_4/M^+]^\circ$	$M^+ = H^+, Li^+$	E' centers: $[SiO_3^{-3}]$	
Defect electron centers ($-e^-$)	$[AlO_4]^\circ$,$[FeO_4]^\circ$			O^- centers: O^-, O_2^{-3} O_2^{-3} - M^+
Stable (paramagnetic without trapped charge)	$[FeO_4/M^+]^\circ$, ?$[FeO_4]^-$, (precursor for $[FeO_4]^\circ$)	$M^+ = Na^+, Li^+, Fe^{+3}$		

Additionally, several types of nonparamagnetic precursor of the paramagnetic defects have been observed.

Substitution of silicon atoms in the lattice is rare because of the small ion radius of Si^{+4} (0.42Å), and the high valence. So far Al^{+3}(0.51Å), Ga^{+3}(0.62Å), Fe^{+3}(0.64Å), Ge^{+4}(0.53Å), Ti^{+4}(0.64Å), and P^{+5}(0.35Å) have been detected as substitutes. Researchers reported a hydrogenic trapped hole-center with four hydrogen atoms on a silicon lattice position. Al is the most frequent trace element in quartz (up to a few hundred ppm). Its diadochic incorporation into quartz is explained by the common occurrence in the Earth's crust and by the similar ionic radii of Al^{+3} and Si^{+4}. Since, in the case of some elements, compensation of the electric charge is necessary, additional cations such as H^+, Li^+, Na^+, K^+, Cu^+ and Ag^+ can be incorporated on inter lattice locations in conjunction with structural channels.

The second type of defect is attributed to the group with E' and O^- centers, the best known of which is the E_1' center, an oxygen vacancy center. The oxygen tetrahedral is transformed into a planar arrangement of three oxygen ions. The center can exist in three different stages E_1^o, E_1' and E_1'' corresponding to its thermal stability and to the reactivity with respect to irradiation (capture of one or two electrons possible). O^- centers represent different types of defect associated with electrons on O^{-2} in tetrahedra with a silicon vacancy.

The peroxy radical (≡Si-O-O) is an oxygen-associated hole center, consisting of an O^{-2} bonded to a single silicon on three oxygen atoms. Nonbridging oxygen hole centers (≡Si-O) are described as a hole trapped in a pure 2pπ orbital of a single oxygen bonded to a single silicon on three oxygen atoms in the SiO_2 structure. The defect structure of SiO_2 is extremely sensitive to ionizing radiation. For instance, ionizing radiation can cause irradiation colors of quartz due to the presence of paramagnetic centers and the transformation of nonparamegnetic precursors **(Fig-2B).**[4]

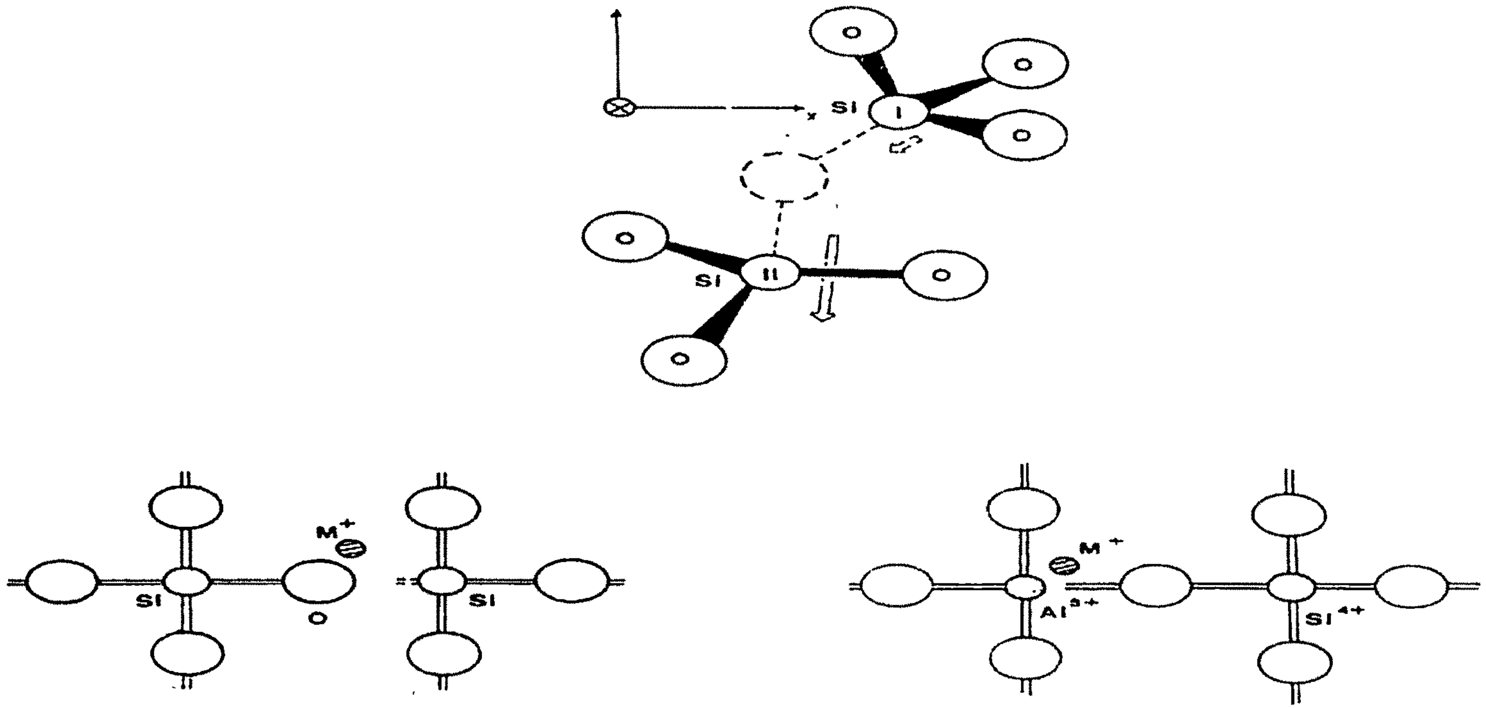

Fig-2B: Upper Model - The E_1'-Center in quartz - Consisting of an oxygen vacancy (dotted circle) with an unpaired electron located at the Si (I) site. The arrows indicate that the asymmetric relaxation of the Si atoms from their normal lattice positions.

Lower LHS Model - Non-bridging oxygen formed as a result of the incorporation of an alkali ion M^+ into the SiO_2 lattice.

Lower RHS Model - The Al-alkali center.

2.4 Method of preparation of Synthetic Quartz (S.Q.)

Natural quartz typically has inclusions such as groups of tiny prismatic crystals, flecks of various impurities, and so on. The primary question for most individuals involved in healing and meditation work is "why use synthetic quartz?" The tendency is that most natural quartz has a twinned or "confused" spiraling of its molecular matrix. This means that the pattern of rotation of the molecules is not just to the left or to the right, but a hodge-podge of both. In the experience of some practitioners this slows down the movement of energy through the crystal. Synthetic quartz does not have this condition unless it was intentionally grown with source material from twinned crystals. This is why the quartz used in the electronics industry is laboratory-grown material.

Earth grown crystal will always have the imprint of the environment in which it grew. This is a plus for most people. It is a connection to the earth and a relationship to whatever coding may have been installed in the crystal either intentionally or through the natural process of its long history of growth. Synthetic crystal does not have this history. Those who use such crystals use them for just this reason. They want a crystal that is devoid of any prior programming and has a purer matrix than that, possible in nature.

The Synthetic Quartz Crystals dates back to 1845 when C.E. Schafhautl succeeded in creating a tiny quartz crystal first in the world. In Japan Yamanashi University first started research on synthetic quartz crystal in 1953. Effort of applying synthetic quartz crystals to the industrial field was launched in 1959 even though the first production quality was only 7kg(1lot). Since then, technology for creating synthetic quartz crystal has been developed to allow mass production with the same quality as that of natural quartz at last. Full-scale mass production was achieved thanks to the development of autoclave in 1973.

2.5 Preparation of S.Q. at Central Glass and Ceramic Research Institute (C.G.C.R.I.)

The manufacturing of synthetic quartz on commercial scale began in 1958 and in 1971 the use of laboratory grown crystals overlook the use of natural quartz in the production of electronic components. The technology of growing high quality crystals was developed on laboratory scale in Central Glass and Ceramic Research Institute in 1972, and demonstrated on semi-commercial scale in 1989.

The Growth of Synthetic Quartz single crystals at C.G.C.R.I.

Basically, the growth of quartz crystals involves dissolving small crystalline quartz chips, called nutrient quartz, in an aqueous alkaline medium and allowing them to grow on single crystal seed rods or plates. Dissolution of nutrient quartz and growth on seed rods take place at high temperatures (typically at about 355°C) and pressures (typically at about 800 $Kg.cm^{-2}$), and hence the nutrient quartz, the aqueous alkaline solvent medium and the seed rods have to be confined in a high-pressure autoclave. The autoclave is a vertical cylinder comprised of an upper and a lower chamber separated by a baffle plate with holes in it. Small pure polycrystalline quartz chips are placed in a perforated basket and lowered into the lower portion of the autoclave. In the upper portion, the single crystal seed rods and plates are arranged and it is around these seeds that the synthetic quartz single crystals develop.

When the nutrient quartz material and single crystal seed quartz are in position, a 0.5M solution of sodium carbonate/ hydroxide with 0.05M-dopant level lithium nitrite is poured into the autoclave so that approximately 75 percent of the internal free space of the autoclave becomes filled up (**Table-2C**). The autoclave is then sealed to withstand the high pressure (700-900 $Kg.cm^{-2}$) that would subsequently be generated, and heat is applied by means of electric heating elements (band heaters strapped around the autoclave body) are arranged and controlled in such a manner that a temperature difference in the range of 5°-15° C can be maintained between the upper growth zone and the lower nutrient zone, the upper growth zone temperature always being lower than the lower nutrient zone temperature. When the desired temperature (350°-360°C) and pressures (700-900Kg.cm^{-2}) and temperature difference are attained, the nutrient polycrystalline quartz chips dissolve in the aqueous alkaline medium as silica and are transported to the cooler growth zone where the single crystal quartz seed rods and plates are located. The silica-bearing aqueous alkaline medium becomes supersaturated here because of lower temperature, and silica precipitates out of the solution on to single quartz seed surfaces. The cool solution then sinks to the lower nutrient zone, is heated up there, and again takes up polycrystalline quartz in solution; the supersaturated solution is again transported to the upper cooler growth zone and the whole cycle is repeated continuously. Thus the synthetic quartz single crystals are gradually built up slowly on the seed rods and plates, and to attain the proper size of the crystals the process has to be continued for typically about 35-45 days. Any attempt to hasten the process by unduly increasing the temperature difference, temperature or pressure will result in growth of crystals, which would not be suitable for the electronic industry.[5]

Table-2C: Demonstration run for growing synthetic quartz at C.G.C.R.I.

1. Run particulars

Duration : 35 days (in 1989)

Growth temperature : 356°C

Temperature difference : 9°C

Pressure : 760 Kg.cm^{-2}

Solvent : 0.5M Na_2CO_3 + 0.05 M $LiNO_2$

Number and size ranges of single crystal quartz seeds placed inside autoclave:

Rods (Y-bar) in the size range:

110-210 mm along Y............................... 523 nos.

Z-Plates (in X-Y plane) in the size range:

length 180-205 mm, breadth 45-50 mm............. 4 nos.

Run conducted at about 75% of full capacity

2. Total yield: 39.0 Kg

	Yield		
Crystal Perfection	by weight	by percent	
(a) Flawless			
(i) Y-bar crystals	35.5	91	
			95
(ii) Z-plate crystals	1.5	4	
(b) Flawed	2.0		5

2.6 Quality rating of Synthetic Quartz

The Synthetic Quartz Crystals may have defects or include impurities depending on growing rate, additives, raw material and other factors. Growing rate particularly affects alpha value and frequency temperature characteristics which both are essential characteristics of S.Q. crystals. High growing rate increases alpha value to cause variation in frequency temperature characteristics. Q value (Energy stored over a cycle/Energy lost over a cycle) of quartz oscillator was used as an index of quality of synthetic quartz crystals at the earliest stage.

The high-grade cultured quartz is produced by most modern facilities and tight quality control and used for quartz crystal products such as crystal units, crystal filters, SAW devices, optical filters and others.

2.7 World Production: Synthetic Quartz crystals.

Pure synthetic crystals is a product made by fusing Lasca and growing a seed quartz crystal under high temperature and high pressure condition (at 350°C and 1,000 atmospheric pressure) in a container called synthetic crystal growing furnace (Autoclave) filled with alkaline solution. It usually requires 30 to 90 days to grow synthetic crystal it can be a pure quartz crystal.

1959 Daiwa Shinku Kogyosho founded by Kazuo Hasegawa in Kobe City for the processing of electronic parts.

1965 Opened Kakogawa Plant for mass production of quartz crystal resonator parts.

1974 Built Ichikawa Japan Plant for highest possible mass production of synthetic quartz crystal in the world.

1976 Opened Miyazaki Plant for production of tuning fork type crystal units.

1977 Established DAISHINKU (AMERICA) corp. (former Daiwa Crystal).

Started supply of quartz crystal units to U. S. market.

1978 Developed quartz microphone.

1980 Opened Tottori Plant for production increase of quartz crystal units. Started production of quartz crystal filters and production of crystals oscillators for clock.

1981 Established DAISHINKU (HK) LTD (former Daiwa Crystal Hong Kong) started supply of tuning fork type crystal units to Hong-Kong and China market.

1984 Opened Tokushima Plant as a base of operations for consistent production of synthetic quartz crystal, resonator parts and quartz crystal devices. Started mass production of Optical Low Pass Filters. Developed crystal pressure sensors and small-sized crystal oscillators.

1985 Opened Tokushima 2nd Plant. Started production of ceramic products.

1987 Started production of voltage controlled crystal oscillators and temperature compensated crystal oscillators.

1989 P. T. KDS INDONESIA to start overseas production of quartz crystal units.

1990 Developed surface mount type crystal units.

1992 Developed SAW filters.

1993 Established TIANJIN KDS CORP start overseas production of tuning fork type crystal units.

1998 Started production of quartz crystal units, smallest class in the world. Developed crystal oscillators, smallest class in the world.

1999 Started mass production of crystal filters.

2000 Started mass production of surface mount tuning fork type crystal units

2001 Expanded production floor size of TIANJIN KDS CORP

2002 Acquired technical Specification by International Organization for Standardization.

2003 Established SHANGHAI DAISHINKU INTERNATIONAL TRADING Co., LTD. to strengthen sales in China.[6]

2.8 Properties

Electrical and Magnetic Properties

Electricity and magnetism are two expressions of a single force, called "electromagnetism". Two electrical properties that have important industrial and electronic applications are piezoelectricity and pyroelectricity, although these properties are not typically used in mineral identification. Certain classes of minerals or synthetic crystalline materials that lack a center of symmetry show these properties. Magnetism is an important diagnostic tool for a few minerals.

Radioactivity or the spontaneous decay or disintegration of an unstable atomic nucleus accompanied by the emission of electromagnetic energy, can be detected in some minerals with a Geiger counter and for these minerals, it is a diagnostic property.

Chemical Properties

Clear Quartz is pure, or nearly pure, made of Silicon and Oxygen, the Earth's most common elements. Any impurities are generally trace elements of Aluminum, Lithium, Potassium or Sodium. Quartz has also been found in meteorites and moon rooks.

Optical properties of synthetic quartz

Explorations and researches on a variety of crystal materials, such as nonlinear optical crystals, infrared crystals, laser crystals, photo refractive crystals, piezoelectric quartz crystal, electro-optical crystals, scintillating crystals, acoustic-optic crystals and magneto-optic crystals have been carried out.

2.9 Applications

Piezoelectricity

Crystallographers recognize 32 classed of crystals of which 20 exhibit the piezoelectric effect. It is apparent that piezoelectricity is not a particularly rare phenomenon. Although many crystals exhibit the piezoelectric effect, very few are useful, and quartz alone provides the necessary combination of mechanical, electrical, chemical, and thermal properties required for making piezoelectric elements for communication devices. Piezoelectricity literally means, "Pressure electricity" and may be defined as the electric polarization produced by a mechanical strain in crystals (that belong to certain classes of crystals).

Piezoelectric Transducer

An important point needs to be made about the role of piezoelectricity in the design of an acoustic quartz resonator. It is best to think of the piezoelectric effect as the "hammer" that causes the bell to ring. The quartz unit structure and shape (the bell) will determine the frequency and the majority of the resonator's characteristics. The piezoelectric effect is a convenient, built in transducer that converts mechanical movement to electrical signals and visa versa. The piezoelectric effect simply provides a way of connecting an electrical circuit to the resonant system.

Uses and Mining of Deposits

Clear, colorless, untwined quartz crystals had important uses as oscillators in radio equipment and in periscopes, gun sights, and other optical equipment, particularly during World War II. More recently, quartz has been mined for use in electronics, fiber optics, and as the source of silica in the production of synthetic quartz crystals.

Crystals as Electronic Parts

A crystal is a single crystal of silicon dioxide (quartz), and it is used for mobile and optical communication devices and projection equipment as optical product, and as electronic component for personal computers and other digital equipment.

Synthetic Quartz Glass

Quartz glass is especially superior in its optical characteristics, such as its light transmittance characteristics. Also, quartz glass is of high purity, at the same time it also provides high heat-resistance and radiation-resistance characteristics. Thus, quartz glass is an extremely pure optical material.

On the solid foundation of its advanced research and development system, Shin-Etsu Quartz Products Co., Ltd. (SQP) manufactures and markets the "SUPRASIL-P" series of ultra-pure, highly homogeneous synthetic quartz glass. Such series of glass is chiefly used as lens material for the exposure devices employed in the semiconductor manufacturing process, but it is also suitable as an optical material for prisms, glass, lenses, mirrors and so on.

Typical Applications

The various forms of synthetic quartz are also used as gemstones, because it is a primary ingredient in sand. It is also used to make glass and laboratory ware silica brick, cement, and mortar. Further, it is used as an abrasive in stonecutting, sandblasting, and glass grinding. Powdered quartz is used in making porcelain, scouring soaps, sandpaper, and wood fillers. Recent uses are with solar panels. Quartz also rotates the plane of polarized light and is used in polarizing microscope.[6]

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