

## GLOSSARY OF TERMS USED IN THE QUARTZ OSCILLATOR-PLATE INDUSTRY

- Activity*: A rather loose term used to describe the relative magnitude of oscillations, produced when an oscillator-plate is excited in an electronic circuit. It is generally expressed in terms of the rectified grid current measured by a milliammeter inserted in series with the grid of the vacuum tube. It can also be expressed quantitatively as the coupling between the electrical and mechanical systems which is a simple function of the piezoelectric and elastic moduli of the vibration involved and the dielectric constant of the crystal plate.
- Ageing*: The deterioration of some finished quartz oscillator-plates which initially drift upwards in frequency and downwards in activity with age. It is thought due to an unstable thin cracked and strained layer on the surface of the plate caused by abrasive action during finishing. This layer may be removed by etching to avoid deterioration of the plate.
- Air Gap*: The distance between the surface of the electrode and the oscillator-plate. It is usually necessary to avoid particular gap dimensions in which resonance damping occurs with acoustic waves generated by the oscillator-plate.
- AT Bar*: A bar cut from X sections with its long direction making an angle with Z equal to the complement of the AT angle (or  $90^\circ - 35^\circ 15' = 54^\circ 45'$ ).
- Baloney Slicing*: A name given to the process in which wafers in the approximate BT or other desired orientation are cut directly from the mother crystal, usually of prismatic habit.
- Bar*: An elongated bar-like segment of rectangular cross-section cut in a particular direction across a section. The orientation and dimensions of the bar are usually so arranged that blanks are cut perpendicularly therefrom in approximately the correct position.
- Beat Frequency Oscillator*: A device whereby the output of a variable frequency oscillator is combined with that of a fixed frequency oscillator in a rectifier or detector. The output will then contain among other constituents a current of a frequency equal to the difference in frequency of the two oscillators, i.e., a beat frequency.
- Blanks*: A term applied to quartz plates with approximately or exactly the correct edge dimensions but not yet finished to final thickness (frequency). Ordinarily applied to pieces of quartz that are in the process of being machine lapped or that are diced out but not yet lapped.

- Blue Needles*: A term applied in the grading of quartz crystals to needle-like imperfections, often definitely oriented, which show up with a bluish-white color under the carbon arc. The color is due to the selective scattering of blue light by the minute imperfections.
- BT Bar*: A bar cut from X sections with its long direction making an angle with Z equal to the complement of the BT angle (or  $90^\circ - 49^\circ 30' = 40^\circ 30'$ ).
- Candle Quartz*: A faced quartz crystal of a long prismatic and often tapering shape.
- Chamfered Edge (or Side)*: The inclined edge or narrow surface representing the Z surface remaining on blanks or wafers cut from Z sections or flat-lay cut crystals.
- Channel Sorter (or Classifier)*: An instrument, usually designed for rapid, approximate measurements, which compares the frequency of a crystal with the known frequency of a standard oscillator.
- Chuva*: A Brazilian term meaning "white rain" applied in the grading of quartz crystals to sparkling white needle-like inclusions outlined by minute bubbles or cavities. *Fine chuva* is the same thing on a small scale. Also termed "white lines."
- Combined Twinning*: A term applied to a rare type of twinning in which the twin operation can be described as composing a rotation of  $180^\circ$  around Z with reflection over  $\{11\bar{2}0\}$ .
- Comparator, Comparison Oscillator*: An instrument used to measure the frequency deviation of an unknown crystal from a standard signal, this frequency difference usually being indicated visually and having a maximum magnitude of the order of 50–100 Kc per second. A device is incorporated to indicate whether the unknown is of higher or lower frequency than the standard. Synonymous with *Duplicator*.
- Complementary Bar*: A rectangular bar cut at the complement of the AT or BT angle in X sections.
- Conoscope*: A type of polariscope employing convergent polarized light. The conoscopes presently used in the industry are fitted with a tank containing liquid with  $n = 1.54$  in which the quartz is immersed during examination and the angular deviation of the Z axis measured.
- Crystal*: This term is used in the radio industry to denote the finished piece of quartz used as a control in oscillating circuits, and is then synonymous with the terms *quartz oscillator-plate*, *piezoid*, and *plate*. The term *quartz oscillator-plate* is preferred.
- Curie Cut*: A piezoelectric oscillator-plate with its edges parallel to X, Y and Z, flattened perpendicular to X and somewhat elongated parallel to Y. The original piezoelectric cut devised by Jacques and Pierre Curie in 1880. Synonymous with X-cut.

*Dicing*: The process in which a wafer is marked out and sawed into blanks.

*Dimensioning*: The process of adjusting the edge dimensions of a plate, by grinding or lapping, to achieve maximum activity and freedom from erratic activity and frequency changes over a given range of temperature. In AT and BT plates these effects depend on the extent of coupling between high harmonics of the flexural mode and the fundamental shear frequency, as determined by the edge dimensions. In ordinary practice all plates are arbitrarily cut to fixed dimensions and the operator individually "hand tailors" each plate during the finishing process to achieve optimum results; in *predimensioning* the optimum dimensions are first found experimentally and are effected *en masse* during manufacture before the finishing operation.

*Electrical Twinning*: A type of twinning in quartz in which the two or more intergrown parts are related as by a rotation of  $180^\circ$  about the common  $Z=c$ -axis. The separate individuals of the twin are either all right-handed or all left-handed. Electrical twinning cannot be detected by optical tests but can be recognized by etching, x-ray study, pyroelectric tests or by the distribution of the  $x$  (5161) or  $s$  (1121) faces. Electrical twinning is also known as *Dauphiné twinning*, *orientational twinning* and  $180^\circ$  twinning.

*Electrometer*: An instrument for measuring small quantities of electricity. Used to determine the position and polarity of the X axes in blanks, etc., by measurement of the electric charges released by slight pressure. Also known as "squeeze meter," and polarity indicator or piezometer.

*Equivalent Circuit*: An electrical network whose frequency response is identical to that of a quartz oscillator-plate (cf., Van Dyke, K. S., *Proc. Inst. Radio Eng.*, **16**, 742, 1928).

*Etching to Frequency*: A process in which a lapped oscillator-plate is exactly adjusted to final frequency, or thickness, by etching.

*Faced Crystal*: Applied in the trade to a natural mass of quartz bounded by one or more of the original crystal growth-faces.

*Finishing Tolerance*: The number of cycles to which a crystal is finished under or over nominal frequency at room temperature in order to stay within frequency tolerance over the temperature test range.

*Focussing Plate*: A concave-convex X-cut plate of uniform thickness used to focus ultrasonic radiation. Usually made with radii two or three inches or more in length and diameters up to two or so inches.

*Force or Drive Oscillator*: An instrument to determine the resonant frequency of a crystal. A slowly varying frequency is applied to the crystal from a signal generator and the RF voltage developed across the crystal is measured with a vacuum tube voltmeter.

- Frequency-Thickness Constant*: A numerical constant expressing the relation between the frequency determining dimension of an oscillator plate and the frequency. Thus, for the fundamental shear frequency in AT or BT plates,  $F = K/T$ , where  $T$  is the thickness in thousandths of an inch, and  $K = 66$  for AT plates and 100 for BT plates.
- Frequency Tolerance*: The percentage of deviation from nominal frequency over a given temperature range permitted by the specifications.
- Hand, Handedness*: Terms used to describe the direction of rotation of the plane of polarization in quartz. The convention used by crystallographers, originally used by Biot, in which the observer looks toward the source of light is now generally accepted. In this convention the right positive trigonal trapezohedral faces in optically right-handed quartz appear at the upper right corner of the prism-rhombohedron edge. The rotation of the plane of polarization is clockwise. In the opposite convention, originally used by Herschel, the observer looks from the source of light in the direction of transmission and the apparent sense of rotation is reversed. This convention was formerly used by some chemists and radio engineers and in Bell Telephone Laboratories publications, but has now been largely abandoned.
- Hard Needles (or Inclusions)*: A term applied in the grading of quartz crystals to fairly large needle-like inclusions or imperfections which have the appearance of being hard.
- Harmonic Crystal*: A crystal designed to oscillate at an integral multiple of its fundamental frequency.
- Hunt-Hoffman Lap*: See *planetary lap*.
- Inspection Bath, Inspectoroscope*: An immersion tank containing index oil approximately  $n = 1.544$ , fitted to examine quartz in polarized light and in an arc light.
- "Lasca"*: Brazilian term for pieces of quartz up to about 100 grams in weight and without crystal faces. Used for fusing, cheap jewelry, etc.
- Light Figure*: A name given to the geometrical visible figure observed when an etched flat surface of quartz is placed over a pin-hole focussed light source.
- Loaf*: A series of blanks cemented together in parallel position for edge lapping. Also known as a stack.
- Major Face*: A term used in widely different senses in different manufacturing plants, whose meaning depends on the special process of cutting used. Thus, the faces of the major  $r$  ( $10\bar{1}1$ ) rhombohedron are spoken of as the major face when BT wafers are cut directly from a faced mother crystal. Also applied to the three prism faces which terminate in the faces of the major rhombohedron, etc.

- Mechanical Axis*: A name given to the Y axis of quartz. Perpendicular to the  $m$  ( $10\bar{1}0$ ) prism faces.
- Mother Crystal, Mother*: A name given to the mass of raw quartz, either faced or rough, as found in nature.
- Muck Saw*: A type of saw using an uncharged blade, usually steel, which runs in a bath or stream of carborundum abrasive.
- Natural Face*: A name given to the X direction as pencilled on Z sections of unfaced quartz and whose position is determined by x-ray measurements or etching. The name also is given to the artificial prism face (parallel to  $(11\bar{2}0)$ ) thus located and produced by sawing the section in the YZ plane. Also applied to the natural growth faces on faced raw quartz crystals.
- Node*: A point, line or plane of no motion in a vibrating plate.
- Optical Twinning*: A type of twinning in quartz in which the parts of the twin are alternately left- and right-handed. Optical twinning is also known as *Brazil twinning* and *chiral twinning*. So-called because it can be recognized by optical tests in distinction to Dauphiné (electrical) twinning. Optical twinning as ordinarily applied includes all twin laws in quartz with the exception of the Dauphiné.
- Oriascope*: An instrument used to determine orientation by directed reflection or by pin-hole transmission from sawn and etched sections of quartz. Developed by G. W. Willard of the Bell Telephone Laboratories (*Bell Syst. Techn. J.*, **23**, 11 (1944)).
- Oscillator Quartz*: Used in reference to raw quartz which is of sufficiently high quality to be used in the manufacture of oscillator-plates.
- Parallel Cut*: Synonymous with Y section and Y-cut.
- Perpendicular Cut*: Synonymous with X section and X-cut.
- Pierce oscillator*: An oscillator circuit in which the crystal is inserted in the feedback path and controls the frequency of oscillation.
- Piezoelectricity*: A name given to the interconversion of mechanical and electrical energy, in which electric charges are produced as the result of properly directed mechanical stress on a crystal (direct piezoelectricity); also given to the reverse effect, in which a mechanical strain is produced in a crystal by an applied electric field (indirect piezoelectricity). Compression along an X= $a$ -axis produces negative charges on that end of the axis terminated by the trigonal trapezohedral faces and positive charges on the opposite unmodified end; tension reverses the charges. These phenomena are known as the "direct longitudinal effect." Compression along a Y axis (at right angles to both X and Z= $c$ ) produces charges on the ends of the X axis identical with those produced by tension along X; and tension along Y reverses the effect. These phenomena are known as the "direct trans-

- verse effect." The sign and distribution of the electrical charges produced by cooling are the same as those produced by compression along X; heating reverses the effect.
- Pin-Hole Box*: An instrument used to illuminate etched sections of quartz from below through a small hole for the purpose of obtaining light figures.
- Planetary Lap*: A type of machine lap employing a number of geared workholders which rotate with an epicyclic motion between two stationary lapping plates. The crystals, when contained in pentagonal holes in the workholder, have an imposed rotatory motion. Also known as the Hunt-Hoffman, Hoffman, or Bendix lap.
- Plate*: A term variously used, but most commonly to designate the finished quartz body used in an oscillating circuit. See *crystal*.
- Plated Crystal*: A crystal with a conductive surface film of gold, silver, aluminum or other metal produced by cathode sputtering, evaporation or chemical methods. The films, to which lead wires may be soldered, take the place of the conventional clamped metal electrodes.
- Predimensioning*: See dimensioning.
- Pryamids*: A trade term often used for quartz crystals with well-defined rhombohedral crystal faces.
- River Quartz*: A name given to rounded, waterworn masses of quartz found in stream gravels. See also *unfaced quartz*.
- Rodometer*: An instrument devised by Professor W. G. Cady of Wesleyan University to find the hand and piezoelectric axes of quartz by focusing a beam of light upon an etched Z or other section.
- Section*: Used with the prefix X, Y or Z to denote broad pieces of quartz sawed from the mother-crystal perpendicular to the X-axis (X-sections), Y-axis (Y-sections) or Z-axis (Z-sections). Also used loosely to refer to any saw cut or sawed-out piece through a mother-crystal.
- Soft Inclusions*: A term applied in the grading of quartz crystals to feathery or fern-like types of foreign inclusions, which look soft (no implication of physical hardness).
- Spurious Frequencies*: The response of a crystal at frequencies other than the nominal one, commonly due to interfering coupled modes of oscillation. In predimensioning this is reduced by edge dimensioning.
- Straubel Plate*: An X-cut quartz plate so shaped laterally that its radius vector is proportional to the square root of the elastic modulus in that particular direction.
- TC*: Abbreviation for temperature coefficient of frequency.

*Temperature Coefficient:* The change in frequency caused by a change in temperature of the oscillator-plate. The TC is usually expressed in cycles per megacycle per degree C. between two temperature limits. The frequency-temperature graphs may be linear (as in X and Y cuts) or parabolic (as in the so-called inclined or zero-coefficient cuts: AT, BT, CT, etc.) Only the GT cut has an essentially zero coefficient over an extended range of temperature.

*Third Axis:* A name sometimes given to denote the Y or mechanical axis of quartz.

*Turning Point:* The particular temperature at which the sign of the temperature-coefficient curve changes. The turning point is determined by minor adjustment of the ZZ' cutting angle which shifts the parabolic temperature coefficient of frequency curve to higher or lower temperatures.

*Twinoriascope:* A type of oriascope used to detect and mark twinning and determine the sense of orientation in etched sections.

*Twinoscope:* An instrument employing a directed beam of light used to examine etched wafers for twinning.

*Unfaced Quartz:* A name given to defaced masses of raw quartz.

*V Cut:* A type of oscillator cut used by RCA of specified ZZ' and XX' angles which approximate in orientation to conventional cuts (XX' = 0°). The V<sub>1</sub> cut is approximately an AT and the V<sub>2</sub> approximately a BT orientation.

*Veil:* A term applied to white cloud- or veil-like aggregates of minute bubbles in raw quartz crystals.

*Wafers:* A name given to the rough slice obtained by sawing directly from a mother crystal or section. The process of manufacturing wafers is variously known as wafering, wafering from the crystal or slab, wafering from the mother crystal, and baloney slicing.

*White Lines:* See *chuva*.

*Workholders:* A thin circular holder of zinc or bakelite impregnated linen and perforated with square or pentagonal-shaped holes which contain and hold the quartz blanks between the upper and lower laps in the machine lapping process. Also known as crystal holder, nest or carrier.

*X-Bar:* A rectangular bar, usually cut from a Z section, elongated parallel to X and with its edges parallel to X, Y, and Z.

*X-Cut:* A type of oscillator-plate cut with its major plane surface perpendicular to X and with the edges either parallel to Y and Z or rotated in the ZY plane; often cut as discs. Also known as the Curie, zero-angle, perpendicular, normal, or ultrasonic cut.

*Y-Bar*: A bar cut in Z sections with its long direction parallel to Y.

*Y-Cut*: A type of oscillator-plate cut with its edges parallel to X, Y and Z and with its major plane surface perpendicular to Y. Also known as the 30-degree or parallel cut.

*Z-Bar*: A rectangular bar, usually cut from X-sections, elongated parallel to Z.

*Zero-beat*: When comparing two or more frequencies, zero-beat is the point of absolute coincidence. Usually done by comparing an unknown fixed frequency with a known variable frequency.