

Jan. 20, 1953

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2,626,363

PIEZOELECTRIC CRYSTAL AND METHOD OF MAKING IT

Filed March 4, 1949

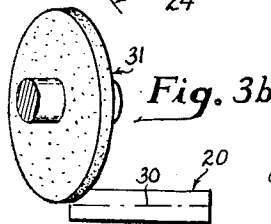
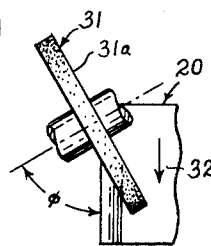
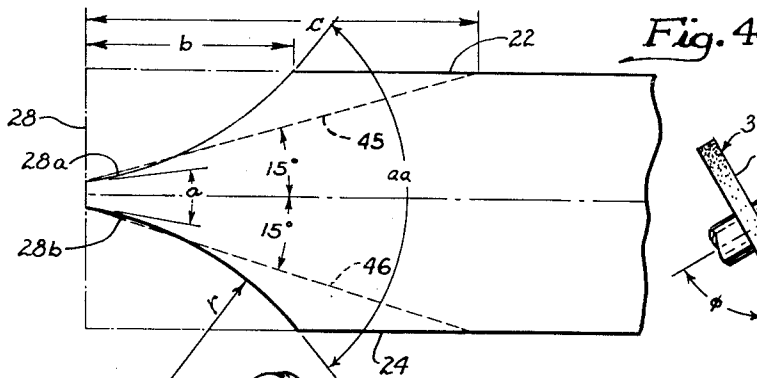
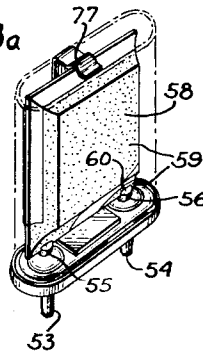
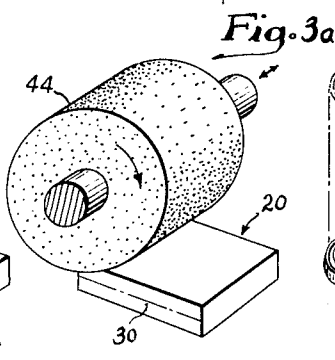
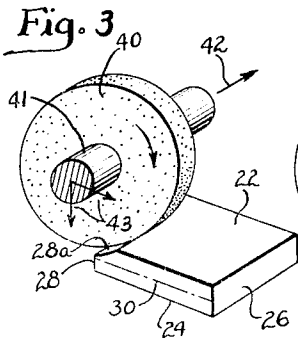
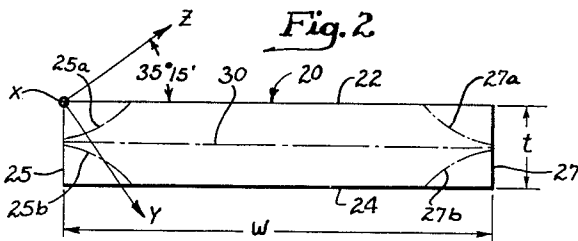
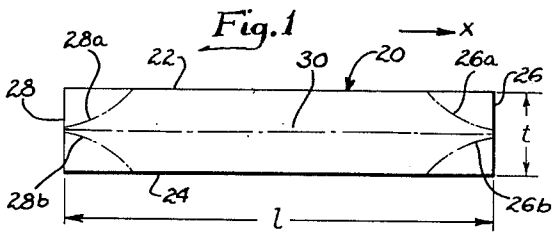


Fig. 3c
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UNITED STATES PATENT OFFICE

2,626,363

PIEZOELECTRIC CRYSTAL AND METHOD OF MAKING IT

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Application March 4, 1949, Serial No. 79,705

13 Claims. (Cl. 310—9.6)

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The present invention relates to crystals and more particularly to the manufacturing of quartz crystals beveled for mounting at the nodal plane.

In the James Knights Patent 2,505,121 which issued on April 25, 1950, there is disclosed a method of making crystals which involves first adjusting the crystal to predetermined lateral dimensions determined by the nominal or desired frequency and then beveling the edges of the crystal substantially to the central plane of symmetry which, in the case of crystals vibrating in the thickness shear mode, is the nodal plane. While crystals produced by the method disclosed therein are completely satisfactory for most all applications, nevertheless the prescribed bevel is so sharp as to reduce appreciably the flat face area. In the case of low frequency standards and other types of crystals in which the face area is small relative to the thickness, the area may be reduced to such an extent as to cut down the activity of vibration in the thickness shear mode.

Accordingly, it is an object of the present invention to provide a piezoelectric crystal and method of making it particularly suited for thick crystals which avoids vibration in unwanted modes while making available substantial face area for stable vibration in the thickness shear mode.

It is another object of the invention to provide an improved crystal in which a relatively sharp edge is presented for gripping at the nodal plane and which at the same time resists chipping and other damage as a result of shock and mechanical vibration.

It is a further object to provide a method of making piezoelectric crystals in which a concave bevel is applied to the crystal edge and which is suitable for rapid and economical manufacture of crystals in a production line setup. It is a related object to provide a procedure for applying a concave bevel to crystals which enables the use of an abrasive wheel having a radius which exceeds the radius of curvature of the bevel and in which wear on the wheel is reduced to a minimum.

Other objects and advantages of the invention will be apparent from the following detailed description taken in connection with the accompanying drawing, in which:

Figure 1 is an edge view of a crystal blank of AT cut taken along the X axis to which the present invention is especially applicable.

Fig. 2 is an edge view of a crystal blank taken at right angles to that shown in Fig. 1.

Fig. 3 shows a grinding wheel in contrast with the crystal edge for cutting the bevel.

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Fig. 3a discloses an alternative form of grinding wheel arrangement.

Fig. 3b is a view in elevation showing a production setup in which the shaft of the grinding wheel is skewed relative to the edge being ground.

Fig. 3c is a plan view of the arrangement shown in Fig. 3a.

Fig. 4 is an enlarged fragmentary view of one edge of a crystal in which the concave bevel is compared with a form of prior art bevel.

Fig. 5 shows a finished crystal having electrodes deposited thereon of wrap-around type and mounted in a holder.

Fig. 6 is a more detailed showing of the manner in which the crystal is gripped in the holder of Fig. 5.

While the invention is susceptible of various modifications I have shown in the drawing and will herein describe in detail only the preferred embodiments of the invention. It is understood, however, that I do not intend to limit the invention by such disclosure but aim to cover all modifications and alternatives falling within the spirit and scope of the invention as expressed in the appended claims.

Referring now to Figs. 1 and 2 there is shown a blank 20 of conventional AT cut. This blank has faces 22, 24 of length l and a width w respectively. The four edges of the crystal blank are designated 25-28. It will be assumed that the crystal blank has been adjusted to a thickness t to produce a desired nominal frequency of vibration when vibrating in the thickness shear mode. As fully described in the above-mentioned patent, such vibration takes place about a central plane of symmetry or nodal plane 30.

In accordance with the present invention the edges of the crystal are given a concave bevel extending from the crystal faces inwardly toward the nodal plane. This is accomplished by means of a grinding or abrasive wheel which rotates about an axis which may be parallel or at an angle to the edge being ground.

Referring to Fig. 3 there is shown a setup in which the abrasive wheel 40 is rotated by a power driven shaft 41 oriented parallel to the edge of the crystal blank and spaced diagonally from the blank. In applying the bevel the wheel is rotated at high speed, for example, clockwise as indicated in Fig. 3, and simultaneously advanced relative to the edge of the crystal in the direction of the arrow 42. In order to simplify the showing as much as possible no specific means is set forth for rotating the wheel or for causing relative movement between the wheel and the crystal. The specific mounting of the wheel is a matter

which is well within the capabilities of one skilled in the art. It will be apparent that any desired calibrated or micrometer type adjusting means may be used for advancing the shaft either horizontally or vertically in the direction of arrows 43 to adjust the depth of cut, and the crystal may be movably mounted as on a sliding table.

With this arrangement many crystals may be ground on a production line basis without any necessity for "contouring" the wheel or for replacing it. The wheel must inherently remain circular and therefore may be considered as "self-contouring." While it is true that the wheel will wear slightly after many operations, this may be compensated for by lateral take-up in the direction of the arrows 43. However, considerable wear must take place before the curvature is sufficiently "off" to warrant discarding the wheel in favor of a new one. Diamond wheels have been found to have a long life which more than offsets their greater cost.

Since the same portion of the wheel touches each point along the edge of the crystal, absolute uniformity of edge contour is assured. However, if greater production speed is desired, the wheel may be made of a width equal to or greater than the crystal dimension. Such a wheel is indicated at 44 in Fig. 3a. Any tendency for the wheel to wear more at one spot than another along its axis may be minimized by reciprocating the shaft through a small amplitude in the axial direction.

In accordance with one of the aspects of the invention an abrasive wheel may be employed which has a radius considerably greater than that of the bevel which it produces. This is accomplished by arranging the axis of the wheel at an angle to the edge of the crystal so that the profile of the wheel when looking along the edge of the crystal appears as an ellipse. The angling is adjusted so that the narrow end portions of the ellipse have a degree of curvature which will produce the desired concavity in the bevel. The crystal is then moved by means of a compound or the like into contact with the selected portion of the wheel profile. One possible wheel orientation obtained by the above procedure is shown in Figs. 3b and 3c. Here the shaft of the wheel 31 has been rotated about an angle ϕ in a plane which is parallel to the plane of the crystal, the angle in the present example being on the order of 60 degrees. This produces an elliptical contour in which the end portions of the ellipse are of a relatively small effective radius. The portion of the wheel profile having the small effective radius is then brought into contact with the edge of the crystal and the crystal is moved parallel to the engaged edge. The same contour is thus applied all along the edge with a high degree of uniformity. The relative crystal movement may be obtained by mounting the crystal on a slide capable of motion in the direction of the arrow 32 in Fig. 3c.

One of the primary advantages of this arrangement is that an abrasive wheel may be used which is of a larger size more readily obtainable. Equally important, however, is the fact that a wheel having a large radius has more working abrasive surface and consequently wear will be considerably reduced. The leading "corner" of the wheel will, as might be expected, round off in time but such wear has no substantial effect on the concavity of the bevel. It may be shown from purely geometrical considerations that a given amount of wear on the wheel pe-

riphery has a smaller effect, expressed in percent, on the degree of concavity than when using smaller wheels oriented with its shaft parallel to the edge being ground.

As a still further advantage of using a large radius wheel arranged as in Fig. 3b, an efficient cutting speed may be achieved with a lower shaft speed. This greatly simplifies the driving requirements and enables conventional motors and bearings to be used.

While the contour of the bevel will not be exactly circular when using on a wheel which is angled or skewed with respect to the crystal edge, it will be apparent that the effective radius of curvature is quite uniform. Thus the bevel contour will not depart appreciably from an arc of a circle having the same average effective radius.

Preferably, the entire periphery of the crystal blank including all eight of the corner edges are treated as indicated in the drawing. It will be apparent, however, that the invention is not limited to the use of one wheel, but would also include setups in which wheels are applied simultaneously to two or more edges. If desired a second wheel may be arranged symmetrically at the other side of the crystal blank for grinding both sides of the V at the same time.

While the radius of curvature of the concave bevel and the depth of beveling may vary over quite wide limits without departing from the present invention and without adversely affecting the operation of the crystal, nevertheless I have found it advisable to keep the radius within reasonable limits. The preferred range will be explained with reference to the detailed view of Fig. 4. Here the concave bevel may be compared with the flat bevel produced by the procedure disclosed in the above-mentioned patent of James Knights. The surfaces resulting from the use of a flat bevel are at an angle of 15 degrees to the nodal plane as indicated by the dotted lines 45, 46 respectively. The angle between the surfaces 45, 46 is, under such circumstances, 30 degrees. In practicing the present invention in its more detailed aspects it has been found desirable to keep the apex angle α to approximately 30 degrees or less as shown. This produces a sharp and well defined edge for gripping in the crystal holder and also permits maximum movement of the face portions of the crystal in the thickness shear mode.

As a second criterion for concave beveling it is desirable that the inward extent of the bevel indicated at b be approximately half the inward extent c obtained using the flat 14 degree bevel. This determines the range of effective radius r of the abrasive wheel which may be employed. In the example given in Fig. 4 the radius of the bevel is roughly one and one-half times as great as the thickness of the crystal. A range of from one to about three times the crystal thickness has been found to give satisfactory results. Another measure of the degree of curvature which may be conveniently used is the included angle $\alpha\alpha$ at the base of the bevel. This angle is preferably on the order of 90 degrees or somewhat greater. This corresponds to a maximum angle of beveling of approximately 45 degrees. This angle is about three times as abrupt as the recommended flat bevel while producing a gripping edge which is as sharp or sharper than that obtained using the flat bevel.

As a step preliminary to beveling, the crystal blank is preferably adjusted to a length and width such that coupling with undesired modes

of vibration is a maximum. Thus the length is adjusted so as to cause the crystal to vibrate in the X flexural mode with an even high order vibration at the same nominal frequency in which the crystal is intended to vibrate in the thickness shear mode. Preferably, too, the width is adjusted so that the crystal vibrates at the above-mentioned nominal frequency in the Z shear mode. The subsequent beveling then causes a departure from these undesirable conditions of coupling without actually changing the lateral dimensions of the crystal. The use of a flat bevel of 15 degrees more or less to the nodal plane to accomplish this is fully discussed in the above copending application.

It has been found that reducing the inward extent to substantially less than the distance *b* illustrated in Fig. 4 is disadvantageous since the beveling operation may not bring the effective dimension of the crystal, particularly in the X direction, far enough away from the length corresponding to the even order flexural vibration at nominal crystal frequency. This would raise the possibility that undesired coupling might be set up between the thickness shear mode of vibration and the flexural mode of vibration. On the other hand, extending the bevel distance *b* inwardly along the face of the crystal to a substantially greater extent than that shown serves only to cut down the effective face area of the crystal and to adversely affect its ability to vibrate stably in the thickness mode. This is particularly true in the case of thicker than average crystals.

Crystals produced as disclosed herein are ideally suited for mounting in a holder which grips the crystal in compression in the Z dimension and at the nodal plane. A preferred form of cooperating holder will be seen in Figs. 5 and 6, the finished crystal being indicated at 50. The holder 51 includes a base 52 having prong terminals 53, 54 making contact with a pair of insulated crystal supports 55, 56. The latter are notched as shown in Fig. 6 and the crystal is pressed into the notches by a spring finger 57 which may be fastened to the base by any desired means. The faces of the crystal are coated to form electrodes 58, 59 which are "wrapped around" the lower edge of the crystal and separated from one another by a diagonal clear strip 60 for contact with the respective supports 55, 56. A suitable conductive cement is preferably applied in the grooves. Such a mount effectively damps many of the lesser extraneous modes of vibration while leaving the faces of the crystal free to vibrate in a desired thickness shear mode. The soldering of wires to the crystal faces required in other types of holders and the attendant manufacturing problems are completely avoided.

Crystals manufactured in accordance with the disclosed method have been found to be extremely resistant to all types of damage from shock, mechanical vibration, overload and the like, particularly chipping. This is in spite of the fact that the edges engaged by the holder are relatively sharp, with an included angle which may be substantially less than 30 degrees. While the invention is particularly applicable to crystals of AT cut, the beveling techniques disclosed may be used in the case of other specific cuts to produce strong, easily mounted crystals of stable electrical characteristics.

I claim as my invention:

1. The process of producing a quartz crystal

for vibration in the thickness shear mode which includes the steps of adjusting the crystal blank to predetermined thickness so that it vibrates in the shear mode at a corresponding desired frequency, adjusting the lateral dimensions of said blank so that the crystal would tend to vibrate at said frequency in other modes of vibration which are capable of causing coupling with the vibration in the desired shear mode, and then applying a concave bevel to the edges of the crystal to inhibit vibration in said other modes.

2. In the production of quartz crystals for vibration in the thickness shear mode, the step which comprises cutting a bevel in the periphery of the crystal to produce relatively sharp edges which enable the crystal to be gripped at the nodal plane, said bevel being concave and having a radius of curvature of from one to approximately three times the thickness of the crystal.

3. In the manufacture of quartz crystals the steps which comprise arranging a grinding wheel with its axis spaced from an edge of the crystal blank and offset from one of the faces thereof, said wheel being of such a radius as to produce in said crystal a bevel of generally circular contour which makes an angle with the plane of the crystal blank varying from about 15 degrees at the apex of the bevel to about 45 degrees at the base portion thereof, and then advancing said crystal relatively to the wheel to cause the bevel to be cut inwardly to substantially the central plane of symmetry of the crystal vibratory mode.

4. In the manufacture of quartz crystals the method of finishing the crystal which comprises orienting a crystal blank with respect to a grinding wheel so that the axis of rotation of the latter is parallel to an edge of the crystal blank but spaced outwardly from both said edge and from an adjoining face, and then advancing said grinding wheel axially along said crystal to produce a circular concave bevel of uniform contour extending substantially to the nodal plane.

5. In the manufacture of quartz crystals capable of vibrating in the thickness shear mode and having a nodal plane parallel to the crystal faces, the beveling steps which include orienting a crystal blank with respect to a cylindrical grinding wheel so that the axis of rotation of the latter is parallel to an edge of the crystal blank but spaced outwardly from said edge and from an adjoining face, said grinding wheel having a length which is at least as great as the length of the edge to be beveled and then gradually moving the grinding wheel perpendicular to its axis into engagement with said crystal blank while said grinding wheel is rotating until the depth of bevel at the crystal edge closely approaches the nodal plane.

6. In the manufacture of quartz crystals the method of finishing which comprises orienting a grinding wheel laterally offset from one of the crystal edges with its shaft parallel to the plane of the crystal but angled with respect to said edge, bringing the wheel into contact with said edge, and then imparting relative movement to the crystal in the direction of said edge to produce an elliptical bevel therein which is of small effective radius as compared to the radius of the wheel.

7. A quartz crystal for mounting in a holder capable of gripping the crystal at its nodal plane, said crystal having the gripped edges concavely beveled forming a relatively sharp edge at the nodal plane, said bevel extending inwardly along the face of the crystal by an amount which is

approximately half the inward extent of a 15 degree bevel.

8. A quartz crystal for mounting in a holder capable of gripping the crystal at its nodal plane, said crystal having the gripped edges concavely beveled forming a relatively sharp edge at the nodal plane, said bevel extending inwardly along the face of the crystal by an amount which is approximately half the inward extent of a 15 degree bevel and the included angle at the sharp edge being less than approximately 30 degrees.

9. As an article of manufacture a quartz crystal of orientation such that the crystal vibrates in the thickness shear mode about a nodal plane, said crystal having edges concavely beveled to a relatively sharp edge at the nodal plane, the included angle of the beveled portion varying from about 30 degrees at the apex of the bevel to about 90 degrees at the base.

10. The process of making quartz crystals for vibration in the thickness shear mode which includes the steps of adjusting the crystal blank to predetermined thickness so that it vibrates in the X shear mode at a corresponding desired frequency, adjusting the dimension of said blank along the X axis so that the crystal would tend to vibrate at said frequency in the X flexure mode at an even high order of vibration, and then applying a concave bevel to the edges of the crystal perpendicular to the X axis to inhibit vibration in the flexural mode.

11. In the method of beveling the edges of a crystal with a concave bevel the steps which comprise orienting an abrasive wheel so that its profile when viewed along one edge of the crystal is an ellipse having end portions of small effective radius, bringing one of said end portions into contact with the edge of the crystal, and then moving the crystal relative to the abrasive wheel in a direction parallel to the engaged edge so that a concave bevel is formed along the entire length of said edge which is of an effective radius less than the radius of said wheel.

12. As an article of manufacture a quartz crystal capable of vibrating in the thickness shear

mode about a nodal plane, at least two oppositely facing edges of said crystal being beveled at each face so that the edge is of V-formation, each of the bevels being concavely formed and extending inwardly along the crystal edge substantially to said nodal plane and extending inwardly along the faces adjacent thereto an amount which is no greater than would be produced by a flat V bevel having an included angle of 30 degrees.

13. As an article of manufacture a quartz crystal having a central plane lying midway between the crystal faces and parallel thereto, at least two oppositely facing edges of said crystal being beveled at each face so that the edge is of V-formation, each of the bevels being concavely formed and extending inwardly along the crystal edge substantially to said central plane and having an included angle at the apex of the V of approximately 30 degrees, said bevels each extending inwardly along the faces adjacent thereto an amount which is substantially less than that which would be produced by a flat V-bevel of 30 degrees included angle.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
749,551	Goehring	Jan. 12, 1904
1,918,668	Reusser	July 18, 1933
1,969,339	Usselman	Aug. 7, 1934
2,443,700	Sylvester et al.	June 22, 1948
2,454,777	Cronan	Nov. 30, 1948
2,486,916	Bottom	Nov. 1, 1949
2,497,275	Samuelson	Feb. 14, 1950
2,505,121	Knights	Apr. 25, 1950

FOREIGN PATENTS

Number	Country	Date
667,387	France	June 10, 1929
108,484	Australia	Mar. 7, 1940