

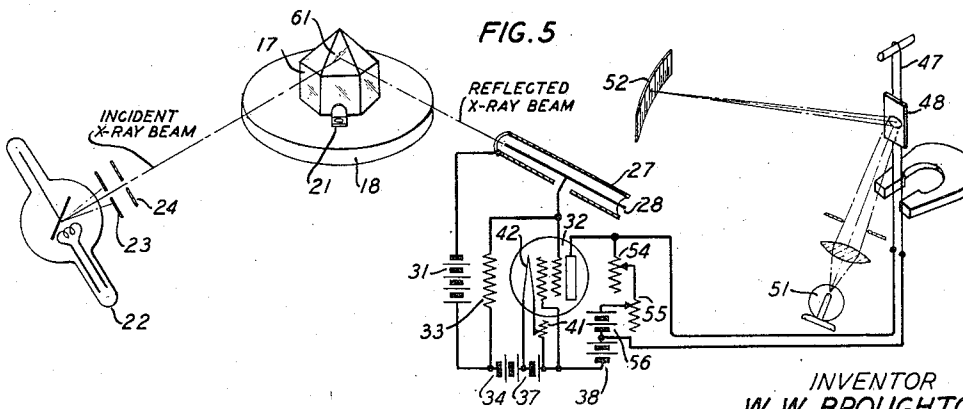
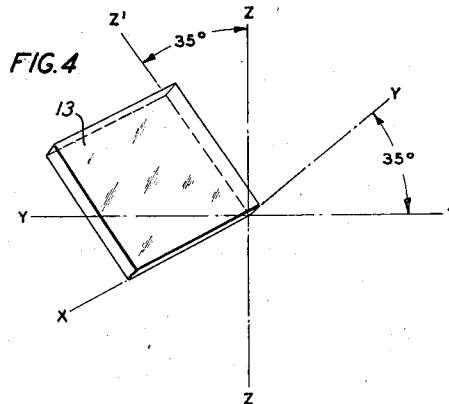
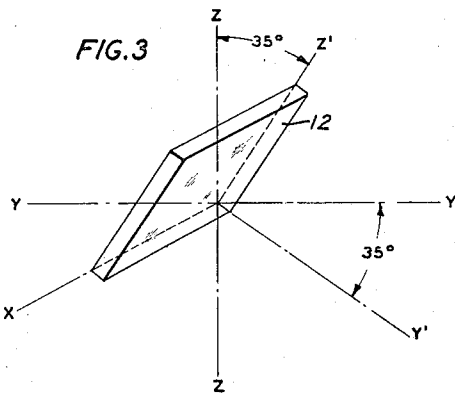
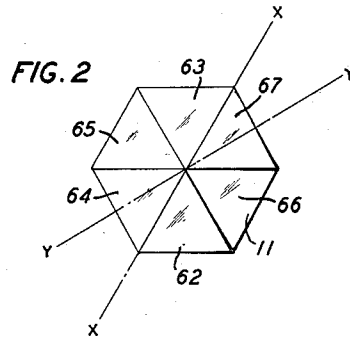
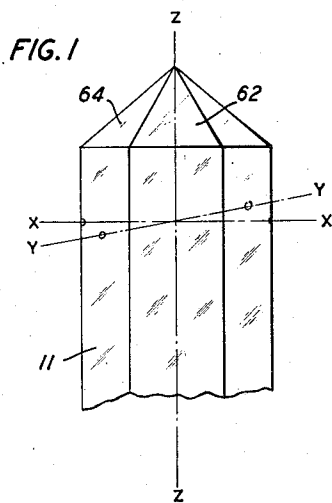
March 28, 1939.

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2,151,736

PIEZOELECTRIC APPARATUS

Filed Sept. 23, 1936



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2,151,736

PIEZOELECTRIC APPARATUS

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Application September 23, 1936, Serial No. 102,126

8 Claims. (Cl. 171-327)

This invention relates to piezoelectric apparatus and particularly to piezoelectric plates of the type cut from material having crystallographic axes such for example as quartz.

An object of the invention is to facilitate the preparation of piezoelectric plates.

Another object of the invention is to indicate the proper orientation of the plate about one of the crystallographic axes of the mother crystal from which it is to be cut.

Quartz, a material from which piezoelectric plates are commonly cut has, as is well known, three principal crystallographic axes commonly designed as the X or electric axis, the Y or mechanical axis, and the Z or optic axis. Now, it has been discovered previously that plates cut from quartz at certain definite orientations with respect to one or more of the principal axes have certain definite desirable characteristics. For example, two such plates are described in the copending application of Messrs. Lack, Willard and Fair, Serial No. 728,640, filed June 2, 1934, the plates therein described being rotated about the X-axis of the mother crystal until in the instance of one plate, an angle of approximately +35 degrees with respect to the Z-axis is attained and in the instance of the other plate an angle of -49 degrees with respect to the Z-axis is attained.

Quartz occurs, as is well known, in two forms, namely right-hand and left-hand. These conventional terms are used in different senses by different authors and scientists. In accordance with the teachings of one group of authorities the term right-hand is applied to that type of quartz crystal which rotates the plane of polarization of plane polarized light traveling along the optic or Z-axis in a left-hand direction when facing in the direction of the propagation of the light and the term left-hand is applied to the type of quartz crystal which rotates the plane of polarization to the right. For the purpose of convenient description the terms will be used in this sense in the following description.

If a compressional stress be applied to the ends of the electric axis of a quartz body and not removed, a charge will be developed which is positive at the positive end of the electric axis and negative at the negative end of the axis for either right-hand or left-hand crystals.

It is usual when describing piezoelectric plates which are cut from a mother crystal to designate them by the magnitude of their angle of orientation together with a sign (- or +) indicating the direction of their rotation (hence the +35

degrees and the -49 degrees designations referred to above). However, such a designation must be interpreted differently for right-hand crystals than for left-hand crystals and the polarity of the X-axis must also be considered. It is necessary, therefore, or more strictly speaking it was necessary before applicant's invention, in order to determine the correct orientation of plates of the nature referred to, first to determine the handedness, that is right-hand or left-hand, of the mother crystal and second to determine the polarity of the electric or X-axis. For example, if the quartz be right-handed and the positive end of the X-axis be up, that is pointed towards the observer, a plus angle of rotation is to be taken to mean clockwise rotation of the plate about the Z-axis while if the positive end of the X-axis be down, that is pointed away from the observer (still dealing with the right-hand quartz) the plus angle of rotation should be taken to mean counter-clockwise rotation of the plate. In the two examples cited had the quartz been left-handed the opposite directions of rotation would be indicated. While determination of the factors referred to, that is the handedness of the quartz and the polarity of the X-axis, may be had by following well established laboratory practices, such determination does, of course, take considerable time and involves some expense. Further, determination of the handedness of the quartz usually requires a preliminary cutting of the crystal which, of course, results in waste of the material.

In accordance with the features of applicant's invention it is not necessary to determine the handedness of the mother crystal nor the polarity of the X-axis thereof in order to determine the correct orientation of the plate to be cut, it is merely necessary to utilize X-rays in the simple manner invented by applicant in order to obtain an indication of the proper orientation of the plates.

In accordance with a specific embodiment of the invention a plane is selected from the group of planes of the mother crystal having the property of reflecting X-rays while their image planes with respect to the Z or optic axis do not reflect X-rays, or do so only slightly. X-rays are then projected to the selected plane and observance of whether or not the projected X-rays are reflected indicates the correct orientation of the desired plate with respect to the Z-axis, i. e., whether for example a + angle of rotation of the plate should be taken to mean clockwise ro-

tation about the X-axis or counter-clockwise rotation thereabout.

A complete understanding of the method contemplated by the invention as well as an appreciation of the various desirable features thereof may be gained from a consideration of the following detailed description and the attached drawing in which:

Fig. 1 shows a quartz mother crystal of the type from which piezoelectric plates are commonly cut;

Fig. 2 is a top view of the crystal shown in Fig. 1;

Fig. 3 shows a piezoelectric plate having an orientation produced by rotation about the X or electric axis in a clockwise direction with respect to the Z or optic axis, the positive end of the X-axis being pointed toward the observer;

Fig. 4 shows a piezoelectric plate having an orientation produced by rotation about the X or electric axis in a counter-clockwise direction with respect to the Z or optic axis, the positive end of the X-axis being pointed toward the observer;

Fig. 5 shows schematically the apparatus utilized in observing a crystal in accordance with the features of the invention.

Referring now to Figs. 1 and 2, a quartz mother crystal 11 of the type from which piezoelectric plates are commonly cut is shown, the X (electric), Y (mechanical) and Z (optic) axes being indicated.

Piezoelectric plates may be cut from the mother crystal 11 at an orientation, for example, of 35 degrees with respect to the Z axis, this orientation being produced as illustrated by plate 12 (Fig. 3) by clockwise rotation about the X-axis or, as illustrated by plate 13 (Fig. 4) by counter-clockwise rotation about the X-axis, the positive end of the X-axis being pointed toward the observer in each instance. As stated above the present invention provides a method of readily determining whether, having been given a particular angular value such as +35 degrees, rotation of the plate about the X-axis should be in a clockwise direction (Fig. 3) or in a counter-clockwise direction (Fig. 4).

Referring now to Fig. 5 the apparatus utilized in carrying out the invention is illustrated in a more or less schematic fashion. A quartz mother crystal 17 from which it is desired to cut piezoelectric plates is shown mounted on a support 18. A stop 21 serves to locate and hold crystal 17 in proper position on the support. An X-ray tube 22 of ordinary type (provided with the usual shielding and mounting appliances and a source of power, which it does not appear necessary to disclose or describe specifically) is provided together with shields 23 and 24, apertures being provided in the latter through which an X-ray beam may be directed to the desired surface of crystal 17. An ionization chamber 27 (shown in section in Fig. 5) is provided, being set with its axis parallel to the reflected X-ray beam and so positioned that the beam will enter the chamber. Collector plate 28 of the ionization chamber is connected in series with battery 31 and the input resistance of vacuum tube 32, which may be of a type commonly referred to as the "General Electric Co. Pilotron F. P. 54". A relatively high resistance 33 is included in the input circuit of the vacuum tube while the usual voltage sources 34, 37 and 38 are connected in the conventional manner, a rheostat 41 being provided for controlling the energization of cathode 42. The vibrating ribbon 47 of a galvanometer (shown

schematically in Fig. 5) is connected across the output of vacuum tube 32. A mirror 48 vibrated by ribbon 47 is adapted to reflect a beam of light onto scale 52, the light being projected onto the mirror from light source 51. By means of rheostats 54 and 55 which are connected in series with battery 56 across the output circuit of the tube, the galvanometer circuit may be so balanced that normally no current will pass through the ribbon 47 and the beam of light reflected by mirror 48 will be stationary on scale 52. When an X-ray beam enters ionization chamber 27 however and strikes collector plate 28, a current is produced along plate 28 and a potential is formed across the input circuit of vacuum tube 32. As a result the plate resistance of the vacuum tube is changed and the output circuit is unbalanced, causing a current to flow through galvanometer ribbon 47 which results in rotation of mirror 48. This, of course, causes movement of the light beam along scale 52. The arrangement, therefore, provides a simple method of readily observing whether or not the X-ray beam projected on crystal 17 is reflected therefrom.

Let us assume, to fully explain the invention, that the operator be handed a quartz mother crystal and be instructed to cut therefrom a +35 degrees plate, i. e., a plate rotated about the axes of the mother crystal until an angle of 35 degrees from the Z axis is attained. Now as pointed out above, the operator, lacking the teachings of applicant's invention, would first have to determine whether crystal 17 is left-hand or right-hand and would next have to determine the polarity of the X-axis, these steps being necessary to obtain an indication of the proper direction of rotation of the plate. Acting in accordance with the teachings of the present invention, however, he need not do either of these things; instead he need only proceed as follows:

The mother crystal 17 is placed on support 18 and so positioned against stop 21 that it will be in the path of the incident X-ray beam projected from X-ray tube 22. By means of rheostats 54 and 55 the galvanometer circuit is so balanced that ribbon 47 does not vibrate and the reflected light beam is stationary on scale 52. Now X-ray tube 22 is set into operation and apertured shields 23 and 24 are so adjusted that the incident X-ray beam is projected to one of a selected group of planes in the quartz which have the property of reflecting X-rays while their "mirror image" planes with respect to the Z-axis do not reflect X-rays or do so only feebly. (That groups of planes having such properties do exist in quartz is well known and has been commented upon by various authors. See for example "Introduction to Crystal Analyses" by Sir William Bragg, published by D. Van Nostrand Co. or "Structure of Alpha Quartz" by R. E. Gibbs, Proceedings of Royal Society of London, vol. 110 (1926) page 443.) We will assume, for purposes of description, that a plane substantially parallel to cap face 61 of the crystal is selected. The "mirror image" plane of the plane selected will then of course be parallel to that cap face which is opposite to face 61. Going back for a moment to Fig. 2 for explanation of this, if we were to select a plane which is parallel to cap face 62 the "mirror image" plane of that selected plane with respect to the Z-axis would be parallel to cap face 63 and if we were to select a plane parallel to cap face 64 the "mirror image" plane would be parallel to cap face 67 and so on.

Returning now to consideration of Fig. 5 and 75

keeping in mind that the galvanometer circuit is in its normal balanced condition, the X-ray beam is projected as shown to a plane substantially parallel to cap face 61. Now if the X-ray be reflected, the reflected ray will, as described, produce a current in ionization chamber 27 thereby producing a potential across the input of tube 32, causing a change in the plate resistance of the tube and changing its output current, all of which results in the unbalancing of the galvanometer circuit and a movement of the light beam reflected from mirror 48 along scale 52. In order to determine whether or not the X-ray beam is reflected from the selected plane, therefore, the operator has but to observe scale 52.

Assuming now that the X-ray beam was reflected by the plane selected (as indicated by movement of the light beam along scale 52), applicant has discovered that this fact indicates that a + angle of rotation should be interrupted to denote a rotation about the X-axis in a clockwise direction with respect to the Z-axis and that a - angle of rotation should be taken as indication of rotation in a counter-clockwise direction, the positive end of the X-axis being pointed toward the observer in each instance. The operator above referred to having been given an angle of +35 degrees would therefore rotate the plate as shown in Fig. 3 about the X-axis parallel to the lower boundary of faces 62 and 63 with the upper end of the plate inclined toward the side of cap face 62 and away from the side of cap face 63. While it is necessary in the description of Fig. 3 to state from which end of the X-axis, i. e., the negative end or the positive end, the plate is observed in order that the direction designation will be definite, it will be understood that the operator when orientating the plate is not concerned with this fact. He knows, from previous instructions, that if the plane reflects he is to cut the plate at one orientation and if the plane does not reflect he is to cut the plate at the other orientation. In this specific instance he knows from previous instruction that if the plane reflects the plate is to be cut substantially at right angles thereto while if the plane does not reflect the plate is to be cut substantially parallel to the plane. This is in accordance with that which is brought out in the first two sentences of the paragraph; the angle of the cap face is approximately 38 degrees so that a plate rotated as in Fig. 3 would be substantially at right angles thereto while a plate rotated as in Fig. 4 would be substantially parallel thereto.

Now had it been found that the selected plane did not reflect the X-ray beam this would indicate, according to applicant's discovery, that a +angle of rotation should be taken as indication of rotation in a counter-clockwise direction, i. e., the operator in order to produce his +35 degrees plate had he observed no reflection of the X-ray beam would rotate the plate as shown in Fig. 4.

In view of the type of planes selected (i. e. those whose "mirror image" planes do not reflect) it will be known that if a plane parallel to cap face 62 (referring to Fig. 2) reflects, planes parallel to cap faces 65 and 67 will also reflect while planes parallel to cap faces 64, 63 and 66 will not reflect. According to applicant's invention, therefore, it is necessary only to test one of the planes, the characteristics thereof will indicate the proper direction of rotation of plates cut from any of the other planes.

It is believed that it will be apparent that applicant's invention provides a simple, efficient

method of determining from the angular designation of a desired piezoelectric plate the proper relationship of the plate to the axes of the mother crystal. Two major steps heretofore considered necessary in the preparation of piezoelectric plates have been eliminated thereby effecting a saving in time and equipment.

While certain specific embodiments of the invention have been selected for detailed description, the invention is not of course limited in its application to the embodiments described. For example, planes other than those parallel to the "cap faces" of the mother crystal may be tested, it is only necessary that the plane be one of a selected group of planes which have the property of reflecting X-rays while the "mirror image" planes with respect to the Z-axis do not reflect X-rays. The embodiments described should be taken as illustrative of the invention rather than as restrictive thereof.

What is claimed is:

1. In the preparation of a piezoelectric device by cutting a plate from a crystalline material of the type having crystallographic axes and, when in perfect natural state, apex faces, the method of determining the correct orientation of the plate about one of the crystallographic axes of the crystalline material which comprises selecting a plane from the group of atomic planes in the crystalline material having the property of reflecting X-rays projected thereon while the mirror image planes of the group do not reflect such X-rays, projecting X-rays to the selected plane and observing whether the projected X-rays are reflected said selected plane being substantially parallel to the plane of one of said apex faces.

2. In the preparation of a piezoelectric device by cutting a plate from a crystalline material of the type having crystallographic axes and, when in perfect natural state, apex faces, the method of determining the correct orientation of the plate about the electric or X-axis of the crystalline material which comprises, selecting a plane from the group of atomic planes in the crystalline material having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the Z or optic axis of the crystalline material do not reflect such X-rays, projecting X-rays to the selected plane, and observing whether the projected X-rays are reflected said selected plane being substantially parallel to the plane of one of said apex faces.

3. In the preparation of a piezoelectric device by cutting a plate from a crystalline material of the type having crystallographic axes and, when in perfect natural state, apex faces, the steps comprising selecting a plane from the group of atomic planes in the crystalline material having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the optic or Z-axis of the crystalline material do not reflect such X-rays, projecting X-rays to the selected plane, observing whether the projected X-rays are reflected, and cutting the plate oriented in one direction about the X-axis of the crystalline material if the X-rays are reflected and in the opposite direction about the X-axis if the X-rays are not reflected said selected plane being substantially parallel to the plane of one of said apex faces.

4. In the preparation of a piezoelectric device by cutting a plate from a crystalline material of the type having crystallographic axes and, when in perfect natural state, apex faces, the steps

comprising selecting a plane from the group of atomic planes in the crystalline material having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the optic or Z-axis of the crystalline material do not reflect such X-rays, projecting X-rays to the selected plane, observing whether the projected X-rays are reflected, and cutting the plate oriented in one direction with respect to the selected plane if the X-rays are reflected and oriented in another direction with respect to the selected plane if the X-rays are not reflected said selected plane being substantially parallel to the plane of one of said apex faces.

5. In the preparation of a piezoelectric device by cutting a plate from quartz, the method of determining the correct orientation of the plate about the electric or X-axis of the quartz which comprises selecting a plane from the group of atomic planes in the quartz having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the Z or optic axis of the quartz do not reflect such X-rays, projecting X-rays to the selected plane, and observing whether the projected X-rays are reflected, said selected plane being substantially parallel to the plane of one of the apex faces of the quartz.

6. In the preparation of a piezoelectric device by cutting a plate from a quartz body having crystallographic axes and, when in perfect natural state, apex faces, the steps comprising selecting a plane from the group of atomic planes in the quartz having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the optic or Z-axis of the quartz body do not reflect such X-rays, projecting X-rays to the selected atomic plane of the quartz, observing whether or not the projected X-rays are reflected from the selected plane, and cutting the plate oriented in one direction about the X-axis if the X-rays are

reflected and in the opposite direction if the X-rays are not reflected, said selected plane being substantially parallel to the plane of one of the apex faces of the quartz.

7. In the preparation of a piezoelectric device by cutting a plate from a quartz body having crystallographic axes and, when in perfect natural state, apex faces, the steps comprising selecting a plane from the group of atomic planes in the quartz having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the optic or Z-axis of the quartz body do not reflect such X-rays, projecting X-rays to the selected atomic plane of the quartz, observing whether or not the projected X-rays are reflected from the selected plane, and cutting the plate oriented in one direction with respect to the selected plane if the X-rays are reflected and oriented in another direction with respect to the selected plane if the X-rays are not reflected, said selected plane being substantially parallel to the plane of one of the apex faces of the quartz.

8. In the preparation of a piezoelectric device by cutting a plate from a crystalline material of the type having crystallographic axes, and, when in perfect natural state, apex faces, the steps comprising selecting a plane from the group of atomic planes in the crystalline material having the property of reflecting X-rays projected thereon while the mirror image planes of the group with respect to the optic or Z-axis of the crystalline material do not reflect such X-rays, projecting X-rays to the selected plane, observing whether the projected X-rays are reflected, and cutting the plate oriented in one direction about the X-axis of the crystalline material if the X-rays are reflected and in the opposite direction about the X-axis if the X-rays are not reflected, said selected plane being inclined with respect to said optic or Z-axis.

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