Nov. 18, 1947. W. F. YOUNG 2,430,969

PROCESS AND APPARATUS FOR ORIENTING CRYSTALS

Filed March 18, 1943 3 Sheets-Sheet 1

Fig. 1.

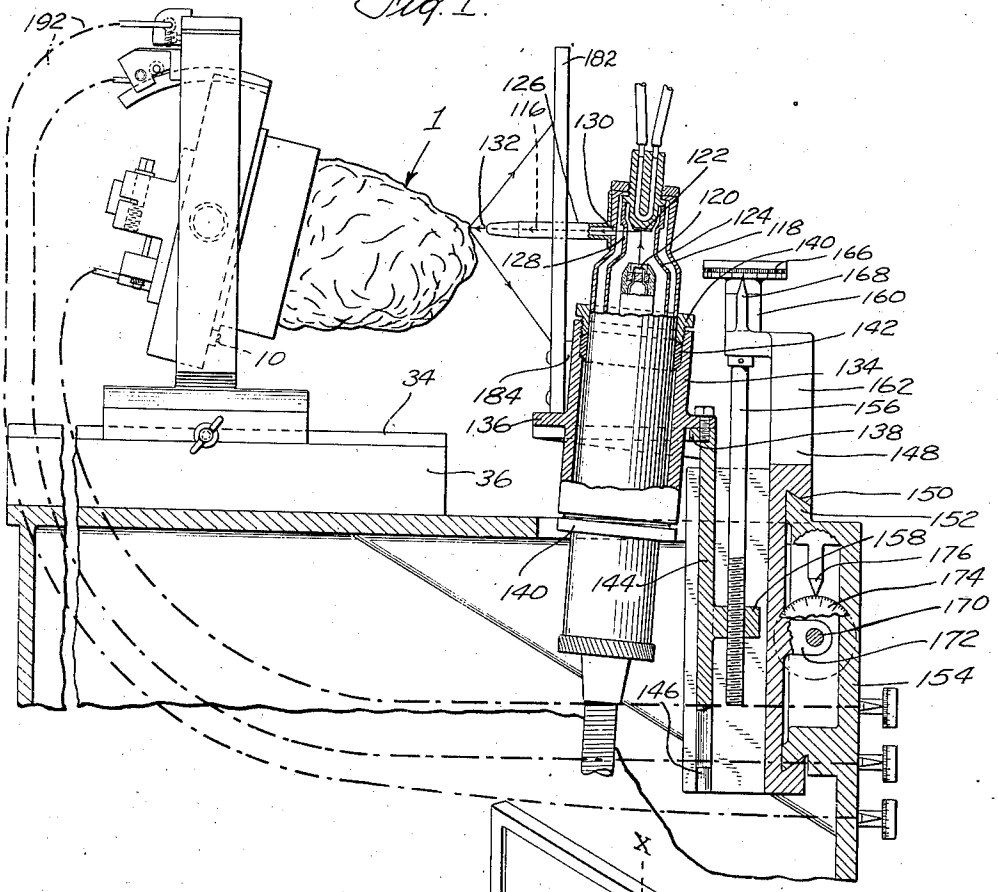
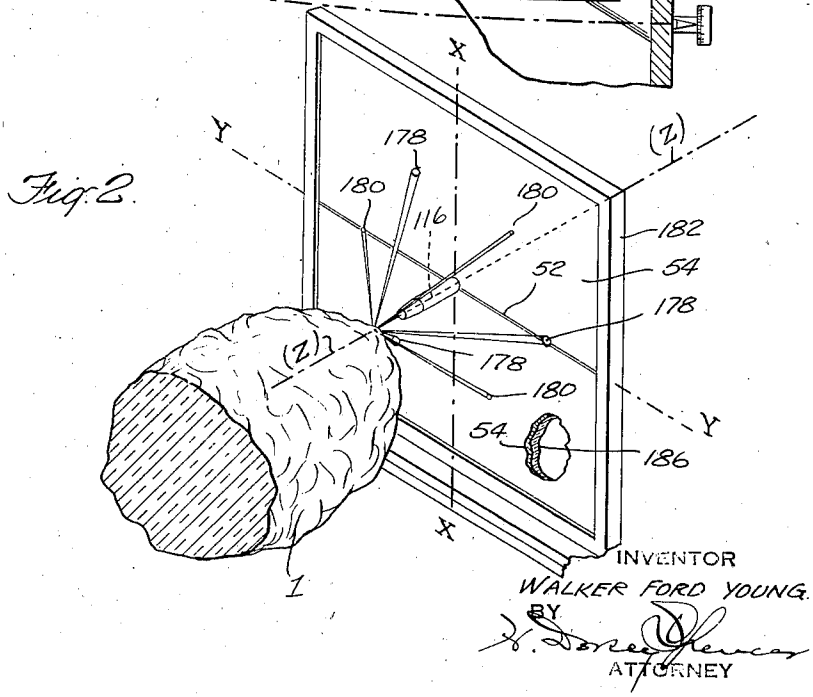


Fig. 2.



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PROCESS AND APPARATUS FOR ORIENTING CRYSTALS

Filed March 18, 1943 3 Sheets-Sheet 2

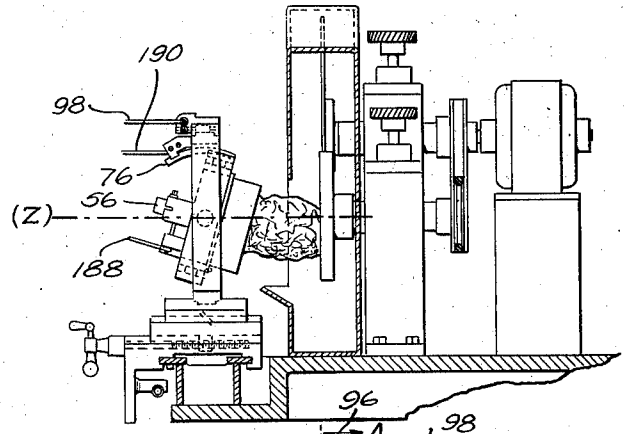


Fig. 6.

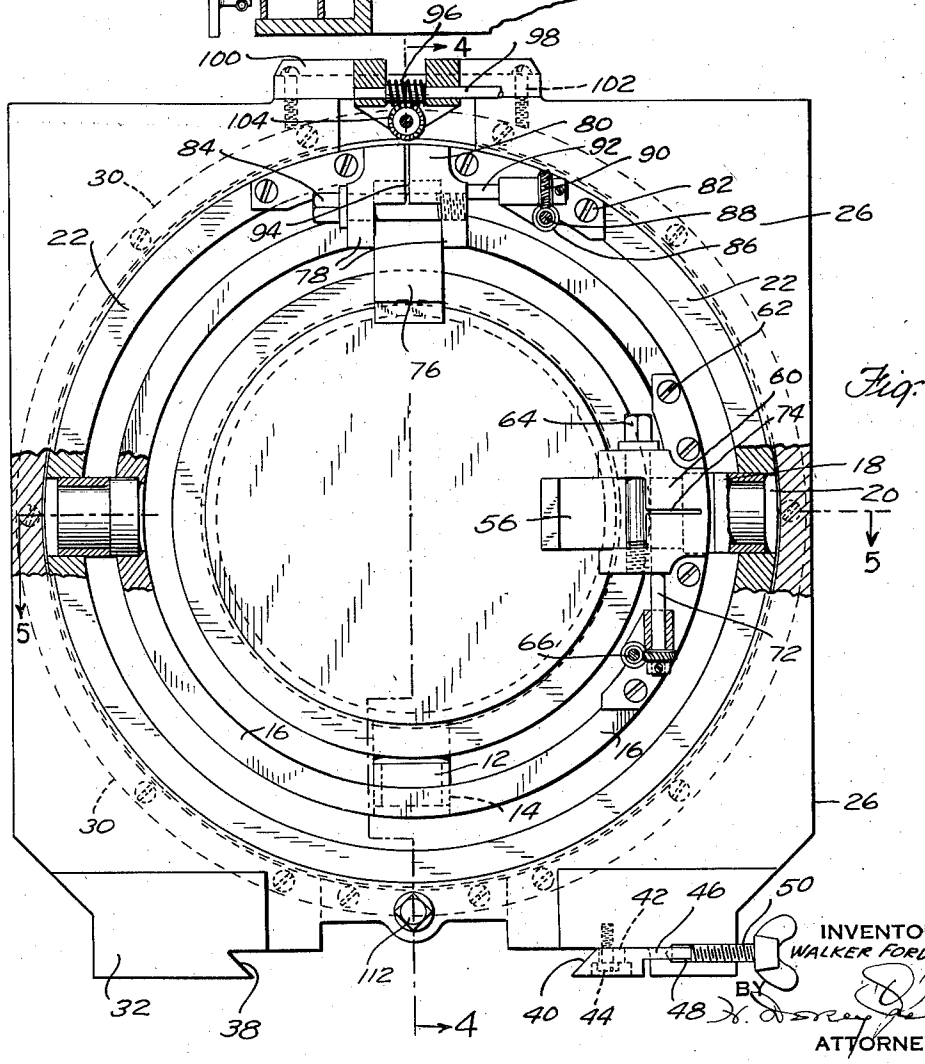


Fig. 3.

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PROCESS AND APPARATUS FOR ORIENTING CRYSTALS

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Fig. 4.

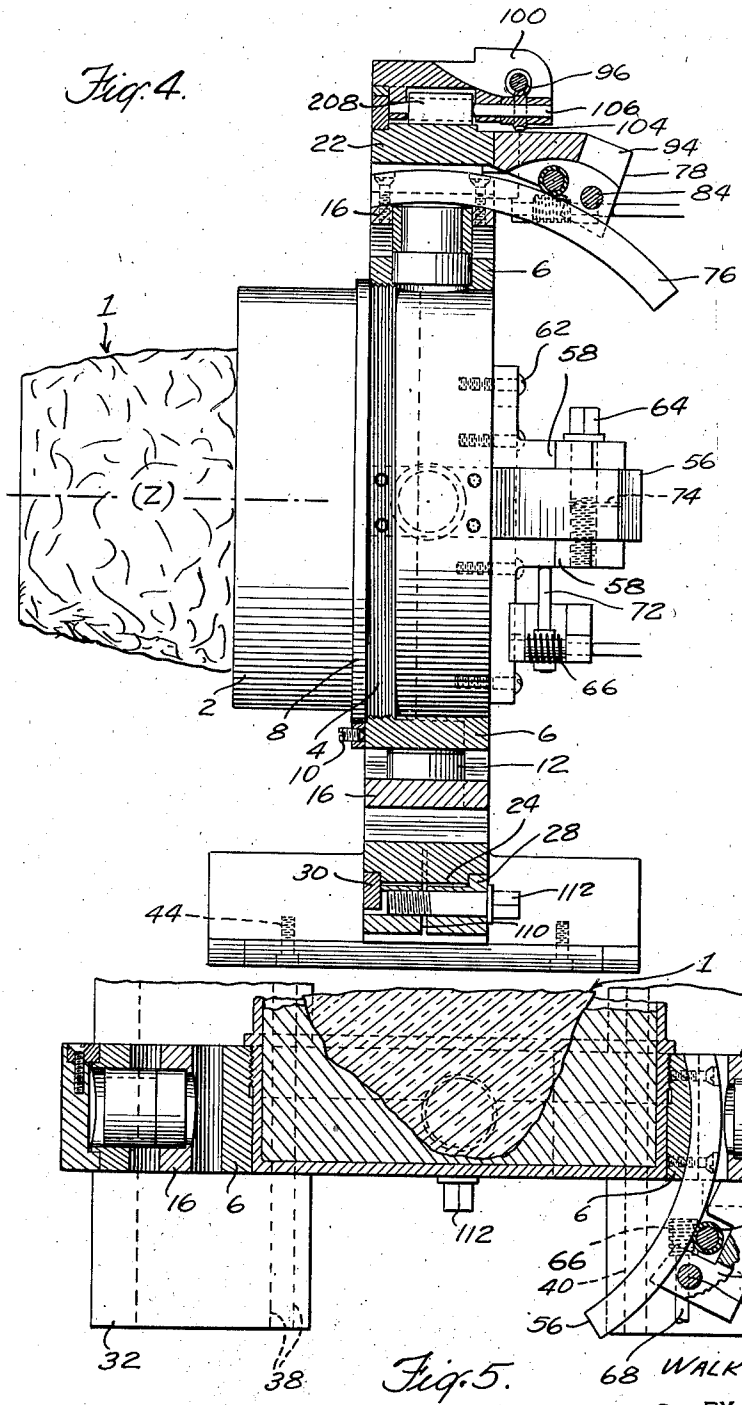


Fig. 5.

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UNITED STATES PATENT OFFICE

2,430,969

PROCESS AND APPARATUS FOR ORIENTING CRYSTALS

Walker Ford Young, Bogota, Columbia, assignor of eighteen and three-fourths per cent to Albert Ramsay, eighteen and three-fourths per cent to Eric G. Ramsay, eighteen and three-fourths per cent to Marcus Ramsay, and twenty-five per cent to H. Dorsey Spencer, all of New York, N. Y.

Application March 18, 1943, Serial No. 479,609

26 Claims. (Cl. 250—53)

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This invention relates to the orientation of crystals and particularly to the orientation of crystals of the class which exhibit the phenomenom of piezo-electricity, such as quartz, Rochelle salt and tourmaline, the invention being herein described as applied particularly to the orientation of either face or rough quartz. A general object of the invention is to provide an improved process and improved apparatus for effecting orientation of crystals of the aforementioned class quickly and accurately.

In the growth of crystals, the substance of which the crystal is formed, such, for example, as the silicon dioxide of which the anhydrous crystals of quartz are formed, tends to arrange itself in planes commonly referred to as "atomic planes," these planes being formed by the arrangement of the atoms of the substance of which the crystal is composed. Some of these planes are in or parallel to the major and minor apex faces of the crystal and others of the planes lie at other angles to the optical (Z) axis of the crystal, probably representing other possible faces that might have been formed in a crystal of that particular substance.

In the case of quartz, which crystallizes in the rhombohedral division of the hexagonal crystal system, there are atomic planes of the above defined character which are inclined at various degrees to the optical axis of the crystal but which otherwise are symmetrically arranged about the optical (Z) axis of the crystal in the same manner as the outer faces of a typical quartz crystal. In other words, these atomic planes are located in the same sectors about the optical (Z) axis of the crystal as are the faces of the crystal, and all intersections of planes perpendicular to the optical (Z) axis with both face planes and atomic planes in any one face sector form parallel lines. Advantage is taken of this fact by the present invention to provide simple and easily operated means and methods for effecting the location of the optical (Z), electrical (X) and mechanical (Y) axes of such crystals, and also in the location of the major and minor apex faces of the crystal, preparatory to cutting plates to other forms therefrom for use as piezo-electric resonators and oscillators. The invention makes possible also the determination by the same means and methods of the polarity of the electrical (X) axes, where desired and also the detection of electrical twinning.

As is well known, the frequency of vibration of a quartz plate which is to be used as a resonator or oscillator is governed almost entirely by its

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dimensions, by the type of vibration and by the orientation of the plate in the original quartz crystal. In order, therefore, to be able to cut from a quartz crystal a plate having a predetermined frequency of vibration and particularly to cut plates for portable radio transmitters, where it is important that the plates have substantially a zero thermal coefficient of frequency, it is very important to know the location of the optical (Z) axis, the electrical (X) axes and the mechanical (Y) axes of the quartz. Not only is it important to know the locations of these axes but it is also important to determine the relative positions of the major and minor apex faces of the crystal, and also any electrically twinned areas that are to be avoided.

Because of the exceptional demand at the present time for quartz crystals suitable for making oscillators for portable radio transmission sets, it is particularly important that any process and apparatus for orienting the quartz not only do this work accurately but also as quickly as possible. Most of the processes and apparatus heretofore employed for this purpose have been complicated in operation, have required special skills and special tables of computations or templates for their successful practice and many of them, even with all their complications, have failed to secure accurate orientation. As a result of the failure to secure such accurate orientation, it has been necessary to effect extensive and expensive corrections of the blanks cut from the crystal before they could be used in oscillators or resonators, all of which involves, besides, a considerable waste of material. This has been particularly true when the rough crystal has had none of its original faces left from which the orientation could be started.

By the present invention the difficulties heretofore encountered in orienting accurately either face or rough crystals have been overcome and the complications of the prior processes and apparatus have been so much eliminated that a most accurate orientation can be obtained by direct readings within a few seconds after the crystal has been mounted in the orienting apparatus. This important result has been accomplished in the illustrated preferred embodiment of the invention by causing an X-ray beam of selected wave lengths to be reflected (diffracted) from atomic planes, so selected and so responding to the wave lengths, that these reflections (diffractions) are of sufficient intensity and compactness of the direction to be viewed on a fluorescent screen of relatively small dimensions

and so located that the proper orientation may be determined by direct observation of the locations of the reflections (diffractions) on the screen.

As just suggested, an important feature of the invention is the selection, for the reflection (diffraction) of the X-ray beam employed, which has its radiation confined to a definite predetermined wave band, of certain inner atomic planes of the crystal which have such an angular relation to the optical (Z) axis of the crystal and which have such inter-atomic planar distances that from these planes reflections (diffractions) of sufficient intensity may be made upon a translucent fluorescent screen of compact dimensions as to permit direct viewing of these reflections (diffractions) and therefore direct determination, not only of the correct location of the optical (Z) axis, but also at the same time of the definite location of the electrical (X) axes, the definite location and the positive and negative ends of the mechanical (Y) axes, and the relative positions of the major and minor apex faces of the crystal, all from a single reading of the reflections (diffractions) on the fluorescent screen as viewed therethrough.

A further important feature of the invention is the employment of a specially constructed and supported universally mounted holder for the crystal to be oriented in which the crystal is so mounted and located in respect to the X-ray beam that, by manipulation of said holder, the reflections (diffractions) from the six aforementioned planes can quickly be brought into view upon a fluorescent screen located in a plane perpendicular to and extending about the X-ray beam and at the same time these reflections (diffractions) may be brought into definite relations to an indicator on said screen by which the location of the major and minor faces of the apex part of the crystal as well as the location of the electrical (X) and mechanical (Y) axes and of the optical (Z) axis can immediately be determined. The universal holder of the present invention is so constructed and so supported in the orienting apparatus that, when the crystal, rigidly secured therein, has been oriented the universal can be locked firmly in the adjusted relation of its parts necessary to effect the orientation and the holder and its support can then be bodily transferred to a cutting machine in which the holder serves to hold the crystal in proper relation to the cutting tool for effecting the initial cutting of the crystal, as, for example, when the crystal is to be cut into sections having their faces in planes at a definite angle, usually perpendicular, to the optical (Z) axis, now accurately located. It will be obvious that this holder can serve equally well to present the crystal in properly oriented relation to a saw by which it is to be cut into wafers.

As hereinabove suggested, the novel process and apparatus of the present invention can be utilized also for detecting electrical twinning in the crystal being oriented and an important feature of the invention is the provision for relative adjustments of the X-ray collimator and the crystal holder to facilitate such detection. As is well known, in electrical twinning one part of the crystal has been rotated through an angle of 180° in respect to the adjoining part, so that the pattern of the reflections from the selected atomic planes will be reversed when a reflection is taken from first one side and then the other side of the boundary plane between the twinned portions of the crystal. Since in this type of twinning the

optical (Z) axes of the two twinned parts of the crystal are parallel and since a characteristic of the present invention is that the X-ray beam is directed upon the reflecting atomic planes in a direction parallel to the optical (Z) axis, it will be apparent that if provision is made for effecting a relative movement of the crystal holder and the collimator tube without disturbing this parallelism, so that a reflection is taken first on one side and then on the other side of the boundary plane between electrically twinned parts of the crystal, the observer, by simply noting the sudden reversal of the pattern, can detect readily not only any electrical twinning but also the approximate location of the boundary plane between the electrically twinned portions.

Having regard, therefore, to the foregoing possibilities presented in connection with the practice of the novel process of the present invention, the invention contemplates further such a construction and arrangement of the apparatus employed to practice the novel process that, when the crystal has been so oriented that the optical (Z) axis is parallel to the X-ray beam and that, preferably, either the mechanical (Y) axis or the electrical (X) axis, or both, bear a definite relation to the path of travel of the holder in the cutting machine, as hereinafter more fully set forth, a relative movement of the crystal holder and of the collimator tube may be effected, both horizontally and vertically, without disturbing the parallelism of the X-ray beam to the optical (Z) axis of the crystal and thus the beam may be caused to travel across any boundary planes between electrically twinned portions of the crystal, if there be such. Not only does this constitute an important novel step of the process of the present invention but the means for practicing this step herein shown constitute an important novel feature of the illustrated apparatus in which the apparatus features of the invention are embodied.

Other objects and important features of the invention will appear in the following description when considered in connection with the accompanying drawings, in which

Figure 1 is a side elevation, partly in section, of orienting apparatus suitable for carrying out the novel process of the present invention and embodying the novel apparatus features of the present invention;

Figure 2 is a perspective detail showing the reflections from the six atomic planes utilized in carrying out the novel process of the present invention;

Figure 3 is a rear elevation of the universal holder in which the prism to be oriented is held both during the orienting operation and during at least the first of the subsequent cutting operations;

Figure 4 is a vertical section on the line 4—4 of Figure 3;

Figure 5 is a section on the line 5—5 of Figure 3, and

Figure 6 is a vertical section through a machine designed to cut the oriented prism either into sections or into wafers, this view illustrating the manner of mounting the universal holder in the cutting machine to hold the prism in its proper oriented relation to the cutting and resurfacing tools.

In carrying out the novel process of the present invention with the novel apparatus herein shown, it is preferable first to determine approximately the location of the optical (Z) axis of the quartz

lump, block or boulder to be oriented. Of course, if the lump or block to be oriented is a substantially perfect crystal having the majority of its faces, particularly its apex faces, or even some readily identifiable faces, still intact, not much difficulty is experienced in locating the optical (Z) axis. In fact, in such a case the location of the optical (Z) axis could usually be approximated sufficiently, by mere inspection of the crystal, to permit mounting the crystal in the universal holder of the orienting apparatus hereinafter to be described.

If, however, the lump, block or boulder of quartz to be oriented does not still have any of its original crystal faces or if it has lost the major part of its faces, the approximate location of the optical (Z) axis in the original crystal is then more difficult. In such a case, any of the well known optical means, such as conoscopes, or polariscopes for locating the optical (Z) axis of the crystal may be employed for the initial approximate location.

The optical (Z) axis of the lump or block of quartz 1 having been approximately located in the above-described manner, the quartz is then placed in a removable part of a universal holder comprising a sleeve-like member 2 having threads 4 adapted to be received in the inner ring 6 of the universal holder hereinafter to be more fully described. In locating the quartz lump or other crystal in the ring 6 preparatory to effecting the accurate orientation thereof, it is, of course, desirable that the approximately located optical (Z) axis of the quartz lump or other crystal be substantially aligned with the axis of the member 2 in order that it may be presented with this optical (Z) axis substantially in parallelism with the X-ray to be used in the orientation, as will hereinafter more fully appear. The lump or block of quartz or other crystal 1 is secured in the cylindrical member 2 in its aforementioned relation thereto by means of any suitable cement such, for example, as a thermoplastic cement of sufficient holding strength, when set, to hold the quartz for the later cutting operations.

After the lump or block of quartz or other crystal 1 to be oriented has been aligned up in the sleeve-like member 2 of the universal holder in the manner just described and secured therein by the setting of the cement, the sleeve is then screwed into the threaded opening in the inner ring 6 of the universal holder. As herein shown, the sleeve-like member 2 is provided with a flange 8 which abuts the front edge of the inner ring 6 of the universal holder so that when the threaded part 4 of the member 2 is screwed in until the flange 8 abuts the ring 6 it will ordinarily be held securely enough without other securing means. If desired, however, a set screw 10 may be provided for holding the member 2 against turning in the ring 6 in the subsequent operations.

As herein shown, the universal holder comprises the inner ring 6 in which the sleeve-like member 2 is carried, this ring 6 being provided with trunnions 12 which are received in bearings 14 in an intermediate ring 16 which is itself provided with trunnions 18 received in bearings 20 in the outermost ring 22. The outermost ring 22 has upon its periphery a rib 24 arranged to turn in a guideway in the frame 26 of the universal holder, this guideway comprising an annular recess in the frame 26 providing a fixed stop portion 28 against which one shoulder of the rib 24 bears and a removable stop portion 30 in the form

of a removable ring against which the other shoulder of the rib 24 bears.

The frame 26 in which the movable parts of the universal holder are movably mounted, as just described, has a base 32 extending some distance to either side of the upright portion of the frame 26 to provide a rigid support for the universal holder and to insure maintenance of the orientation when the holder is transferred from the orienting machine to the cutting machine.

As shown in Figure 1, the base 32 of the universal holder is adapted to be received on a carefully machined dovetail guide 34 on a fixed support 36 in the orienting apparatus shown in Figure 1, the base 32 being provided with one fixed side 38 of a dove tail groove and an adjustable side 40 so that the base may be quickly placed in position on the guide 34 and then secured by adjustment of the movable side 40 of the dove tail groove in the base rigidly and definitely in its proper relation to the guide 34. As herein shown, the movable side 40 of the groove has therein a slot 42 providing for movement of the side 40 over the shank of the machine screw 44 by which it is secured in position. A stem 46 extending into the threaded opening 48 is engaged by a set screw 50 which serves to force the movable side 40 of the dovetail groove into its locking engagement to the fixed dovetail guide 34.

Movement of the members of the universal holder to effect the desired movement of the block or lump of quartz 1 or other crystal to bring its optical (Z) axis into exact parallelism to, or coincidence with, the X-ray beam employed in effecting the orientation and also to bring either its mechanical (Y) axis or its electrical (X) axis into definite oriented relation to an indicator or reference line 52 on the fluorescent screen 54, hereinafter to be more fully described, may be brought about in any suitable manner. As herein shown, the inner ring 6 of the universal holder is provided with a segmental arm 56 extending rearwardly therefrom and being concentric with the axis of rotation of the trunnions 12. This segmental arm 56 is guided in a guideway formed by the fork members 58 of a split casting 60 secured in any suitable manner, as, for example, by machine screws 62, to the intermediate ring 16 of the universal holder. A clamp screw 64 extending through one of the fork members 58 and threaded into the other serves to clamp the segment arm 56 of the inner ring 6 in any adjusted relation to the intermediate ring 16.

Gradual adjustment of the ring 6 in relation to the ring 16 can be brought about during the orienting operation by means of a worm 66 on a shaft 68, the worm 66 engaging the worm wheel 70 on a shaft 72 having its bearings in the casting 60 and carrying, between the fork members 58, a rubber-surfaced drive roller 74 frictionally engaging the outer face of the segment 56 to effect the movement thereof and thereby effect the movement of the inner ring 6, about the axis of its trunnions 12, in respect to the intermediate ring 16.

Similarly, the intermediate ring 16 may be provided with a segment arm 76 concentric with the axis of rotation of its trunnions 18, this segment being guided between the fork members 78 of a split casting 80 secured by screws 82 to the outermost ring 22. A clamp screw 84 operates in the same manner as the clamp screw 64 to squeeze the fork members 78 into engagement with the segment arm 76 of the interme-

diate ring 16 and thus lock this ring in its adjusted relation to the outermost ring 22.

Gradual turning of the intermediate ring 16 about the axis of its trunnions 18 is brought about substantially in the same manner as the turning of the innermost ring 6 about the axis of its trunnions 12. As herein shown, a worm 86 on a shaft 88 engages a worm wheel 90 on a shaft 92 having, between the fork members 78, a rubber-surfaced roller 94 frictionally engaging the outer face of the segment arm 76.

Gradual turning of the outermost ring 22 in its annular guideway may likewise be brought about in a manner somewhat similar to that of the movements of the other rings. As herein shown, a worm 96 carried on a worm shaft 98 mounted in bearings in a removable casting 100 attached to the top of the frame 26 in any suitable manner, as by machine screws 102, engages a worm wheel 104 on a shaft 106 mounted in cross bearings in the casting 100. The shaft 106 carries a rubber-surfaced drive roller 108 frictionally engaging the peripheral face of the rib 24 of the ring 22 and thus serving to rotate it. By providing a split 110 in the lower part of the upright portion of the frame 26 of the universal holder and a clamp screw 112, it will be apparent that the fixed shoulder 28 and the removable shoulder 30 of the guide for the rib 24 may be squeezed more tightly into engagement with the side faces of the rib 24 and thus lock the outermost ring 22 in any of its positions of rotary adjustment.

From the foregoing description of the universal holder for the lump or block of quartz 1 or other crystal to be oriented, it will be seen that movement of the mounted block or lump of quartz or other crystal into any angular relation to the X-ray beam employed in the orienting operation can be brought about. As particularly shown in Figure 1 of the drawings, when the universal holder is mounted upon the dovetail guide 34, the guideway for the rib 24 of the outermost ring 22 of the universal holder will lie in a plane perpendicular to the X-ray beam projected through the collimator tube 126 of the X-ray apparatus and will preferably present this guideway with its center lying in the X-ray beam 116. By so arranging the guideway for the rib 24 of the ring 22, after the optical (Z) axis has been definitely located so that the optical (Z) axis coincides substantially with the X-ray beam, then the universal can be rotated about the optical (Z) axis to bring a mechanical (Y) axis into register with the index line 52 which coincides with a diameter of the circle, in the circumference of which the reflections hereinafter to be more fully described are located.

Referring now to Figure 1 of the drawings, the X-ray tube 118 may be of any suitable construction, as, for example, one comprising a heated filament 120 and a cold target 122 of a suitable material to produce an X-ray beam of the desired wave length range to secure substantially the maximum reflection (diffraction) of the beam from the selected atomic planes used in orienting the crystal. In the case of quartz, which crystallizes in the rhombohedral division of the hexagonal crystal system, the atomic planes employed are preferably those making an angle of 68¼° to the optical (Z) axis, there being six of these planes arranged symmetrically about the optical axis in the same trigonal symmetry as the original crystal faces, that is, there are the same number of atomic planes about the

optical (Z) axis as there were original crystal faces and these planes therefore correspond respectively to the major and minor apex faces.

It has been found that for orienting quartz a suitable material for the target 122 is either chromium, cobalt, copper, iron or nickel, copper being the target material most commonly employed.

As shown in Figure 1, the X-ray tube 118 is mounted within an impervious shield 124 which is provided with a collimator tube 126, also of impervious material, such as lead, this collimator tube 126 receiving the X-ray beam 116 produced by the target 122 through the windows 128 and 130 respectively of the tube and shield. The tip 132 of the collimator tube 126 may be provided with any suitable diaphragm or stop to confine the X-ray beam to a definite cross section such, for example, as a circular cross section.

The X-ray tube 118 and its shield 124 are mounted in a tubular holder 134 which has a flange 136 so inclined to the axis of the holder that when mounted upon its support 138 it will so incline the X-ray tube that the beam 116 projected through the collimator tube 126 will be projected substantially horizontally or, in other words, substantially parallel to the dovetail guide 34 and perpendicular to the vertical plane in which the guideway for the rib 24 of the outermost ring 22 lies. The purpose of this is to make more convenient the transfer of the universal holder with its oriented crystal to the machine in which the first cutting operation is to take place. The X-ray tube and its sheath 124 may be secured and centered in the tubular holder 134 in any suitable manner as, for example, by glands 140 engaging packing rings 142.

To provide for adjustments of the X-ray tube, during the orienting operation, transverse to the optical (Z) axis of the quartz, both vertically and horizontally, without disturbing the parallelism of the X-ray beam 116 to the optical (Z) axis of the quartz, for the purpose of detecting and locating electrical twinning, as hereinafter more fully set forth, the tubular holder 134 is carried on a vertical slide 144, travelling in lateral guides 146 in a supporting frame 148, which itself is provided with a dovetail-shaped groove 150 travelling on a horizontal dovetail guide 152 formed on the supporting table 154 on which the entire orienting apparatus is mounted. Vertical adjustment of the X-ray tube may be effected by the turning of a shaft 156 threaded through a lug 158 on the slide 144, this shaft turning in a bearing 160 provided in an upright 162 on the table 154. If desired, the head 166, by which the shaft 156 is turned, may be provided with graduations movable past an indicator 168. Similarly, the horizontal movement of the X-ray tube required to detect and determine the location of electrical twinning in the crystal may be effected by means of a threaded shaft 170 threaded through a lug 172 on the horizontal slide 148, said shaft 170 also having its bearings in the table 154, and, if desired, being provided with graduations on the head 174, by which it is turned, which may be read with respect to an indicator 176.

From the foregoing description it will be seen that, when the optical (Z) axis of the lump or block of quartz or other crystal to be oriented has been approximately located by means of the conoscope or polariscope or other optical means and its ends have been marked on the lump or block,

if the lump or block 1 is then rigidly secured in the member 2 by means of a suitable cement, this member 2, when it is placed in the inner ring 6 of the universal holder, the rings 6, 16, and 22 being initially all nested, will present the lump or block to the collimator tube 126 in such manner that the thus approximately located optical (Z) axis is approximately parallel to the X-ray beam 116. It will thus be seen that not much adjustment of the universal holder will then be required to bring the optical (Z) axis exactly into parallelism or coincidence with the X-ray beam 116.

As hereinabove suggested, the exact orientation is brought about by so relatively turning the rings 6, 16 and 22 of the universal holder that the X-ray beam, when reflected (diffracted) from selected atomic planes of the crystal (in the illustrative case, quartz) will make a symmetrical pattern of reflections about the optical axis and about the X-ray beam itself. This will only occur when the X-ray beam and the optical axis are in absolute parallelism, or, it might be said, when they coincide, there being, of course, an infinite number of parallel optical (Z) axes, at least one of which will coincide with the X-ray beam when parallelism has been attained. I have found that extremely satisfactory results are obtained by the use of a copper target 122 and that when the copper target is used and the parts are arranged as shown in Figure 1, the atomic planes in the quartz which, by reason of the interatomic planar distances produce the maximum reflection (diffraction) of the X-ray beam, are those which are inclined to the optical (Z) axis at an angle of about 68¼°. These are recognized atomic planes existing in the quartz crystal, namely (1013).

These 68¼° atomic planes, which have the same trigonal symmetry in the original quartz crystal as the original faces of the crystal, may for this reason obviously be utilized to determine the positions of the original faces and thus determine the locations of both the electrical (X) axes and of the mechanical (Y) axes and also the relative positions of the major and minor apex faces of the original crystals.

In order that the operator who is doing the orienting and who sits behind the X-ray tube, that is at the right hand side of the table 154 as viewed in Figure 1, may directly view the reflections (diffractions) of the X-ray beam 116 from the six 68¼° atomic planes, which, as above stated, are located in those sectors about the optical axis in which the six apex faces of the original crystal were located, and that he may thus, from the grouping of these reflections (diffractions), bring about an adjustment of the crystal into a position in which the optical (Z) axis of the crystal is absolutely parallel to the exploratory X-ray beam 116, the fluorescent screen 54, hereinabove referred to, is so arranged that the reflections (diffractions) of the beam 116 from the said six 68¼° atomic planes will strike this screen. As will be obvious, the screen must necessarily be located at a point in front of the quartz lump or block 1 to be oriented and must necessarily extend about all sides of the optical (Z) axis. I have found that the most convenient arrangement of this screen 54 is to locate it in a vertical plane with the collimator tube 126 extending through it near or at its center. The tube 126 being of comparatively small diameter does not interfere to any extent with the viewing of the reflections of the beam 116 which, as shown in Figure 2, appear on the screen 54 in the form of small but comparatively bright spots 178 and 180.

Spots 178, which, as hereinafter pointed out, represent reflections from atomic planes corresponding to major apex faces, are somewhat larger and brighter than the spots 180, which represent reflections from atomic planes corresponding to the minor apex faces. When accurate orientation has been obtained, these spots 178 and 180 will be located on the circumference of a circle through the center of which both the X-ray beam and the then coincident optical (Z) axis pass.

As shown in Figure 1, the fluorescent screen 54 is carried in a frame 182 which is fastened to a boss 184 on the tubular holder 162 so that the screen will move with the holder, this boss having its abutting face so inclined to the axis of the tube that the fluorescent screen 54 will lie in a vertical plane perpendicular to the X-ray beam 116. To protect the operator, a sheet of lead glass 186 is carried in the frame 182 and is interposed between the fluorescent screen 54 and the operator to prevent any reflections of the X-ray beam 116 from striking the operator. It will be obvious that the fluorescent screen may be formed by coating the face of the sheet of lead glass 186 which is nearest the quartz lump 1 with fluorescent material.

Having regard to the foregoing description of the arrangement of the parts of the apparatus, it will be seen that when the sleeve-like member 2, containing the lump or block 1 of quartz to be oriented, has been placed in the inner ring 6 of the universal holder, with the optical (Z) axis of the quartz or other crystal, as approximately theretofore located, in substantial parallelism with the X-ray beam 116, if the X-ray beam is then directed onto the quartz it will be reflected back from the six 68¼° atomic planes hereinabove referred to. If the approximate location of the optical (Z) axis of the quartz by optical means has been fairly close, it may be that the operator will at once see all six of the spots 178 and 180 but with not all of either the group 178 or the group 180 showing equal intensity and with not all symmetrically positioned about the center of the circle through which the X-ray beam 116 passes. If the original approximate location of the optical (Z) axis has not been very close the operator may see only one or two of the aforementioned spots on the fluorescent screen 54. It only requires, however, a fairly approximate location to bring at least one or two of the spots into view on the screen 54.

Having observed one or more or all of the reflected spots, the operator then starts to adjust the universal holder, either to bring more of the spots into view or to get the spots symmetrically located about the center of the circle through which the X-ray beam passes. This can readily be done, since, if only one or two spots are in view, only the slightest motion in the wrong direction will cause them to disappear. This immediately gives the operator the clue to the direction in which to effect his first adjustment. These adjustments, as hereinabove pointed out, can be made by means of the worm shafts 68 and 88 which are preferably connected to flexible shafts 188 and 190, respectively, so that the operating ends of the shafts may be brought around in front of the table 154 and in front of the screen 54 out of the range of stray X-rays. In a similar manner the worm shaft 98, which effects the adjustment of the outermost ring 22 can be connected to a flexible shaft 192, the operating end of which

may also be brought around in front of both the table 154 and the screen 54.

By effecting slight angular adjustments of the block or lump 1 of quartz, when the quartz is being oriented, in the manner described, the operator can quickly bring it into a position where it will produce a pattern on the fluorescent screen 54 such as shown in Figure 2 of the drawings. This pattern will first comprise six alternating and substantially uniformly spaced bright and less bright spots 178 and 180, there being three bright spots 178 and three less bright spots 180 arranged in trigonal symmetry about the optical (Z) axis and about the X-ray beam 116. As they first appear upon the screen in this trigonal symmetry, the spots will not necessarily be arranged about the center as shown in Figure 2, but may all be off the indicator line 52. The indicator line 52 is a horizontal diameter of the spot circle, as shown, in respect to which indicator it is usually desirable to orient the mechanical (Y) axis. Each two diametrically opposite spots 178 and 180 represent respectively the positive end and the negative end of a mechanical (Y) axis. The reason that this is so is that the brighter spots 178 are reflections from planes in the major apex face sectors of the prism and the less bright spots 180 are reflections from planes in the minor apex face sectors. Since the positive end of the mechanical (Y) axis lies in a major face and the negative end lies in a minor face, the spot 178 will necessarily indicate the positive end of a mechanical (Y) axis and the diametrically opposite spot 180 the negative end of the same axis. Therefore, by arranging the pattern so that a spot 178 is intersected by the reference or indicator line 52 and the diammetrically opposite less bright spot 180 is also intersected by the reference or indicator line 52, we have one of the mechanical (Y) axes coinciding with this reference line and also extending in a horizontal direction.

As above suggested, if the initial orientation of the optical (Z) axis of the quartz has not been comparatively accurate, all six of the reflections 178 and 180 may not appear at once upon the fluorescent screen. Moreover, if the voltage and amperage of the X-ray unit are sufficient and the specimen has not been approximately accurately oriented in respect to the optical (Z) axis in the optical means used in the preliminary location of this axis, other spots than the spots 178 and 180, representing other atomic planes, will also appear on the screen. These spots, however, will be less intense and will not lie on a circle and should, therefore, cause no confusion. Moreover, the six more intense spots 178 and 180, that is, the spots caused by the reflections (diffractions) from the aforementioned 68¼° planes, when a copper target is used in the X-ray tube, exhibit a slightly concavo-convex form, with their concave surfaces directed toward the center of the circle upon which they lie, this center being the position of the optical (Z) axis. This simplifies the orientation procedure by indicating the direction in which a spot appearing upon the screen should be moved to bring it into its correct symmetrical relation to the optical (Z) axis.

Since, as above pointed out, the appearance of the spots 178 and 180 is governed by the wave length of the X-rays used, by the interatomic planar distances of the reflecting (diffracting) atomic planes and by their reflecting (diffracting) power, and also by the angle of incidence of the X-ray beam on the atomic planes, it follows that a variation of any of these factors will cause a spot to change in intensity and finally to disappear. Since the wave length of the X-rays is limited by the fact that the characteristic radiation of the target is used and since the interatomic planar distances and their reflecting (diffracting) powers are fixed quantities, then only the angle of incidence of the X-ray beam on the reflecting (diffracting) atomic planes may be varied. This, as above pointed out, can be brought about by operating the adjusting means for the respective rings 6, 16 and 22 of the universal holder through operating handles arranged within convenient reach of the orienting operator. This adjustment is carried out until the six alternating bright and less bright spots 178 and 180, above referred to, group themselves symmetrically about the center of the circle in which they lie, as hereinabove pointed out. The required adjustments necessary to effect such a symmetrical positioning of the spots are quickly learned after a few trials and the entire orientation in the apparatus shown in Figure 1 is usually a matter of seconds, and, at most, only a matter of minutes.

As also above pointed out, when the spots 178 and 180 are brought into their proper symmetrical position on a circle which lies in a plane perpendicular to the optical (Z) axis and through the center of which this axis passes, there will be two groups of three spots each, the spots 178 of one group alternating with the spots 180 of the other group, the spots 178 being considerably brighter than the spots 180. As also suggested hereinabove, this difference in brightness is explained as follows:

Since quartz crystallizes in the rhombohedral division of the hexagonal crystal system it exhibits a trigonal rather than a hexagonal symmetry. As also pointed out above, this effect is used in determining the positive and negative ends of the mechanical (Y) axes, the three spots due to the major (positive) planes of the 68¼° reflecting rhombohedron having been found to be more intense than those due to the minor (negative) planes of the 68¼° rhombohedron. Since the reflecting (diffracting) planes which are responsive to the wave length of the X-ray beam selected, by reason of their interatomic planar distances, lie in the same zones or sectors as the rhombohedral faces (major and minor apex faces) usually present on quartz crystals, it is possible, from the arrangement of the spots hereinabove referred to, to identify the position of each major rhombohedral face (major apex face) and thus the proper direction for angular cuts in the manufacture of piezoelectric crystal blanks.

Observation has shown that, only when the angles of incidence of the X-ray beam on the six reflecting (diffracting) atomic planes (in this case, with the copper target, the 68¼° planes) are equal, will the spots comprise two groups of three spots each, the spots in each group being of equal intensity. From this fact it may be seen that by moving the specimen by means of the universal holder, as hereinabove described, it is possible to vary the angle of incidence and thus vary the intensity of the spots in respect to each other and also their absolute intensity. It should here be noted that, although a single spot may remain visible throughout a relatively large angle of rotation of a quartz lump or block, once all six spots have appeared upon the fluorescent screen a rotation of less than 1° of arc will cause at least

one spot to disappear completely. This results in a marked simplification of the orientation procedure in that, when starting the orientation, one or two spots may be located, even though an error of several degrees may exist in the original approximate orientation of the optical (Z) axis by the optical means preliminarily employed. These one or two spots will be nearer the center of the circle than they should be when the other spots are visible and, therefore, when one or two spots have thus been located, the universal holder may readily be manipulated in such a way that these spots are moved away from the center of the circle, whereupon the remaining spots will appear. As above stated, once all six spots are visible a movement of only a few minutes of arc will cause a very noticeable change in the intensity of certain of the spots.

Since, as above pointed out, the six 63¼° atomic planes from which the X-ray beam has been reflected (diffracted) to produce the spots 178 and 180, all make equal angles with the optical (Z) axis, it follows that if the spots are brought into a circle where they make two groups, with the spots in each group of equal intensity, necessarily the optical (Z) axis must be exactly parallel to the X-ray beam 116. In other words, one of the optical (Z) axes then coincides with the X-ray beam. Likewise, since these six atomic planes are tangential to the circle on which the six spots 178 and 180 are located (these points of tangency, as above suggested, being located respectively at the positive and negative ends of the mechanical (Y) axes), it follows that a line drawn between two diametrically opposite spots will necessarily give the exact direction of one of the mechanical (Y) axes. This is the reason for providing the reference or indicator line 52 on the fluorescent screen 54. In order that this reference line may readily be viewable in the dark room in which the orientation must take place with the form of the invention herein shown, the line 52 is preferably formed of phosphorescent material, which is self-luminous. It may also be formed as a slit in the phosphorescent coating, in which case the diametrically opposite spots 178 and 180 would disappear wholly or partly when brought into coincidence therewith.

It will be obvious that, when one of the mechanical (Y) axes has been brought into coincidence with the reference line 52, that is, into a horizontal position, then, for reasons which will appear more fully hereinafter, the direction of one of the electrical (X) axes will also have been ascertained, since this axis will be perpendicular to the mechanical (Y) axis thus definitely located. In other words, any line drawn perpendicular to the mechanical (Y) axis thus located on the crystal will correspond to an electrical axis. Since the mechanical (Y) axis has been brought into a horizontal position, then any vertical line in the same plane, that is, in the plane perpendicular to the optical Z axis which has thus been determined, will also correspond with an electrical (X) axis.

From the foregoing it will be seen that it is possible quickly to locate the direction of all three mechanical (Y) axes and therefrom the directions of all three electrical (X) axes from direct observation. However, the location of one only of the mechanical (Y) axes is usually necessary, if the subsequent cutting operations are to proceed in the manner hereinafter set forth and as more fully disclosed in the copending application of Marcus Ramsay, Serial No. 483,906, filed April 21, 1943.

After the orientation just described has been effected, that is, after the optical (Z) axis has been made to coincide with the direction of the X-ray beam and the spot pattern shown in Figure 2 has been produced, it is usually desirable to determine whether or not there is any electrical twinning in the quartz. Since, as above pointed out, in electrical twinning one part of the crystal has been rotated through an angle of 180° in respect to the adjoining part, the pattern of the reflections from the selected atomic planes will be reversed when a reflection is taken first from one side and then from the other side of the boundary plane between the twinned portions of the crystal. However, the optical (Z) axes of the twinned parts of the crystal are parallel.

In order, therefore, to detect whether or not any portions of the crystal are electically twinned, all that it is necessary to do, after any optical (Z) axis of the crystal has been caused to coincide with the X-ray beam 116, is to effect a relative movement of the X-ray beam and the crystal while maintaining the parallelism of the X-ray beam and the optical (Z) axis, so that the X-ray beam 116 can be moved from one side to the other of the boundary plane or planes between any twinned portions of the crystal. This can readily be done by effecting such relative movement through the vertical and horizontal adjusting screws 156 and 170. This will cause the collimator tube 126 to move either in a vertical or in a horizontal direction while maintaining the parallelism of the optical (Z) axis and the X-ray beam 116.

As the X-ray beam 116 moves from one side to the other of any boundary plane between twin portions, after the pattern shown in Figure 2 has been determined, the bright spot 178 and the less bright spot 180 on the reference line 52 will reverse their positions, thus indicating that a boundary plane has been crossed. Substantially the exact location of this boundary plane can thus be determined and the twinned portions marked either for immediate removal, if sufficiently large to be useful, or to be left for future consideration, depending somewhat upon the type of cutting to which the quartz is to be subjected.

In order that the oriented quartz block 1 may maintain its oriented position in the subsequent cutting operations, after the pattern shown in Figure 2 has been obtained and also before effecting the adjustments to detect electrical twining, the three rings 6, 16 and 22 of the universal holder should be locked in their adjusted positions by the respective clamping screws 64, 84 and 112. This locking of the universal holder enables the operator who is to perform the succeeding cutting operations, for example the cutting into sections or the cutting into wafers, to present the crystal to the cutting tool in such manner that its optical (Z) axis is located at a definite angle to the plane of the cut. If the first cutting operation be one in which the lump or block of quartz or other crystal is to be cut into sections, from which bars and then blanks are later to be cut, the parts will be locked as shown in Figure 1 so that the lump or block of quartz or other crystal will be presented to the section cutting saw with the optical axis perpendicular to the plane in which the cutting edge of the saw normally travels, at least when idling. Furthermore, it will be seen that when the orienting has been caused to produce the pattern shown in Figure 2, the lump or block

of crystal will be presented to the cutting saw with one of its mechanical (Y) axes extending in a horizontal direction in the plane of the cut, that is, in the said plane perpendicular to the optical (Z) axis.

All that is necessary, therefore, to be able to insure cutting of the sections with their faces perpendicular to the optical axis, is to provide on the carriage of the cutting machine a dovetail guide similar to the guide 34 in Figure 1 on which the universal holder can be mounted, this guide extending horizontally at right angles to the plane of the saw, and the movement of the carriage itself being a horizontal movement.

As more fully disclosed in the co-pending application of Marcus Ramsay, Serial No. 483,906, filed April 21, 1943, after each cut the face of the quartz lump or block, from which the section has been cut, is passed over a surface grinder having its abrading face in a plane perpendicular to the optical (Z) axis of the lump so that any irregularities in the face of the quartz, which may have been left by wandering of the saw, can be removed and the face thus brought into a plane absolutely perpendicular to the optical axis. After this is done a scratch mark is placed on this face to indicate either the direction of the aforemention horizontal mechanical (Y) axis or that of the electrical (X) axis perpendicular thereto. If the direction of the electrical (X) axis is to be indicated, this may be done, as more fully shown in said co-pending application of Marcus Ramsay, by swinging a vertical marking guide into position against the crystal face along which guide the diamond can travel over the then resurfaced face of the quartz lump or block and thus scratch a mark that will correspond with that electrical (X) axis which is perpendicular to that mechanical (Y) axis that has been definitely determined by the orientation. Usually also a scratch mark is placed to indicate the direction toward a major face.

From the foregoing it will be seen that the process and apparatus of the present invention permit not only quick and accurate orientation of the crystal to insure positive maintenance of this orientation through at least the first cutting operation, as more fully pointed out in the co-pending application of Marcus Ramsay hereinabove identified, but the orientation can also be maintained easily throughout the succeeding cutting operations by reason of the fact that in each step a true oriented face is provided which can be used for locating the section or bar for the succeeding cutting operations.

It will further be seen from the foregoing description that the hereinabove described novel process and apparatus for orienting either face or rough crystals, and which has been herein described in its application particularly to the orientation of rough quartz, has the following advantages over existing processes and apparatus:

1. It makes provision for the quick and accurate orientation of quartz lumps which have no crystal faces.

2. By providing a holder in which the quartz can be first oriented and then locked in its oriented position in definite relations to the mechanism employed in cutting it up, the process makes possible positive holding of the original orienation throughout at least the first slitting step.

3. Both the process and the apparatus are so simple that all steps may be performed by unskilled labor.

4. It is equally applicable to the orientation and to the maintenance in its original oriented position of a quartz lump, whether the lump is subsequently to be cut first into sections and then into bars and blanks or whether it is first to be cut into obliquely oriented wafers and then into blanks.

5. Both the process and the apparatus can be employed to orient quartz lumps of any of the commercial sizes and has the advantage over many of the existing processes in that it does not require that a portion of the quartz lump be removed, oriented and then replaced.

6. The system used in the orientation is extremely stable and is not affected by such temperature changes as it would ordinarily be subjected to. In other words, it employs no unstable units such as ionization chambers, Geiger Mueller Counters or photoelectric tubes with amplification circuits, all of which are likely to fluctuate due to outside influences.

As hereinabove pointed out, the appearance of the spots on the fluorescent screen is governed by only one variable, that of the angle of incidence of the X-ray beam on the reflecting (diffracting) atomic planes. Thus, only when the specimen is properly oriented with respect to all of its axes, will the desired effect, that is, the symmetrical arrangement about the optical (Z) axis and the relative intensities of the two groups of spots and their uniform intensity in each group be noted.

7. No preliminary grinding of a face or etching of the crystal is necessary to prepare it for orienting. The crystal as it is received in its crude state can be oriented without any preliminary operation whatever upon it.

8. The specimen need not be at any definite distance from the fluorescent screen in order to obtain the desired figure effect. This leads to simplification of manipulation, particularly when dealing with quartz lumps of varying sizes.

9. With the arrangement of parts hereinabove described, it will be seen that the operator is completely shielded from any direct or any scattered or vagrant X-ray radiation.

10. By connecting the X-ray tube to a flexible lead, as herein shown, the tube may be adjusted to a position such that its characteristic radiation leaves the tube in a horizontal plane. This obviates the necessity for supporting the specimen to be oriented at some angle to the horizontal in order to insure that the X-ray beam strike the specimen in a direction parallel to the optical (Z) axis of the specimen.

11. By using a flexible lead to the X-ray tube it is possible to place the bulky generating unit at some point where it will not interfere with the orientation procedure.

12. By making the first accurate slit in the specimen while it is locked in its oriented relation to the slitting tool in the holder in which it has been oriented, there isn't the usual danger of loss of orientation which occurs in existing practices in transferring the specimen from one holder to another. As hereinabove pointed out, not only are the first sections cut from the lump while the lump is positively held in its oriented position in the universal holder, with the optical (Z) axis perpendicular to the plane of the cut, but the holder also holds it in this same relation for the succeeding surface grinding operation by which a true face is formed upon each succeeding section before it is severed from the lump. This facilitates maintaining the orientation in the

subsequent operations which involve mounting the sections in new holders.

What is claimed as new is:

1. The process of orienting either face or rough quartz to locate accurately the positions of the optical (Z) axis, the electrical (X) axes, the mechanical (Y) axes, and the relative positions of the major and minor apex faces, which consists in first effecting an approximate location of the optical (Z) axis by any suitable optical means, then directing onto the quartz, in substantial parallelism to the optical (Z) axis, an X-ray beam of defined cross section and also having its radiation confined within a definite wave band, whereby reflections (diffractions) are obtained from six atomic planes symmetrically arranged about the optical (Z) axis and which, by reason of their interatomic planar distances, effect substantially a maximum reflection (diffraction) of the said wave band, interposing a translucent fluorescent screen in the paths of said reflections (diffractions) and manipulating the quartz until six intense spots may be seen through said fluorescent screen, in symmetrical arrangement about a common center and divided into two groups, each group comprising three spots of equal intensity but the spots of one group being more intense than those of the other.

2. A process according to claim 20 in which the means responsive to energization is so interposed in the paths of the reflections (diffractions) that the reflection intercepting parts thereof lie substantially in a plane perpendicular to the direction of the X-ray beam.

3. A process according to claim 21 in which, after orientation about the optical (Z) axis has been effected, relative vertical and horizontal movements of the quartz and X-ray beam are effected without disturbing the parallelism of said X-ray beam to the optical (Z) axis, in order to detect and locate any electrically twinned portions of the quartz.

4. A process according to claim 21 in which, in the initial approximate location of the optical (Z) axis the right-handedness or left-handedness of the quartz is noted, whereby the polarity of the electrical axes may also be observed during the orientation.

5. A process according to claim 21 in which the wave band of the X-ray beam is utilized which has the characteristic radiation of a target formed from one of a group of metals comprising chromium, cobalt, copper, iron and nickel.

6. A process according to claim 21 in which the wave band of the X-ray beam is utilized which has the characteristic radiation of a copper target whereby atomic planes of the quartz may be employed for the reflections (diffractions) which are inclined to the optical (Z) axis of the crystal at approximately 68¼°.

7. A process according to claim 1 in which an indicator is provided upon the fluorescent screen in such position that it coincides with a diameter of a circle having the X-ray beam at its center.

8. A process according to claim 21 in which the quartz is mounted in a universal holder permitting locking thereof in its oriented relation to the X-ray beam for succeeding cutting operations.

9. A process according to claim 1 in which, to facilitate succeeding operations on the quartz, the X-ray beam is directed in a horizontal direction, the fluorescent screen is located in a vertical plane and a universal holder for the quartz is carried on a slide member also movable in a horizontal direction parallel to that of the X-ray beam.

10. The process of orienting crystals which consists in first effecting an approximate location of an optical (Z) axis of the crystal by any suitable optical means, then directing onto the crystal in a predetermined relation to the optical (Z) axis thereof an X-ray beam of defined cross section and also having its radiation confined within a definite wave band, whereby reflections (diffractions) are obtained from atomic planes arranged in sectors corresponding to those in which certain faces of the crystal are located and which, by reason of their interatomic planar distances, effect substantially a maximum reflection (diffraction) of the said wave band, interposing a translucent fluorescent screen in the path of said reflections (diffractions) and in a plane perpendicular to the direction of the X-ray beam and manipulating the crystal until intense spots may be seen through said fluorescent screen in an arrangement about a common center corresponding to the arrangement of the faces in the crystal and providing on said screen a reference line in respect to which a face of the crystal may be oriented.

11. Apparatus for orienting crystals comprising, in combination, an X-ray tube having a target capable of producing an X-ray beam within a selected wave band, a collimator tube for defining the cross section of said beam and directing it, a universal holder for the crystal to be oriented, comprising relatively movable members, one of which is constructed to receive the crystal and have it fixed therein in approximately preoriented relation thereto so far as the optical (Z) axis only of said crystal is concerned, a support upon which said universal holder may be removably mounted, said support being so arranged that when the universal holder is mounted thereon it will present the crystal with its approximately preoriented (Z) axis in approximately the desired predetermined relation to the X-ray beam which is required to secure reflections (diffractions) from selected atomic planes of the crystal, a translucent fluorescent screen so located in the path of the reflections (diffractions) from said selected atomic planes that the reflections (diffractions) from all said selected atomic planes may be seen through said screen when the optical (Z) axis of the crystal has been brought definitely into the aforementioned desired predetermined relation to the X-ray beam, said universal holder being provided with means for rigidly holding the relatively movable parts thereof in their adjusted relation when the aforementioned predetermined relation has been established.

12. Apparatus according to claim 22 in which the removable holder and its support are provided with cooperating locating means by which they may be definitely and positively located in predetermined relation to each other and whereby like location of said universal holder on a like support on a cutting machine is facilitated.

13. Apparatus according to claim 22 in which the holder comprises three relatively movable members each movable about an axis perpendicular to the other two axes, one of said members being provided with a removable part in which the crystal may be cemented in fixed preoriented relation to said member.

14. Apparatus according to claim 11 in which the fluorescent screen surrounds the collimator tube.

15. Apparatus according to claim 11 in which the fluorescent screen is provided with a reference mark in respect to which one of the axes

transverse to the optical (Z) axis may be definitely oriented.

16. Apparatus according to claim 22 in which provision is made for relative adjustment of the crystal holder and the collimator tube in directions transverse to the X-ray beam, without disturbing the orientation, in order to detect electrical twinning.

17. Crystal orienting apparatus comprising, in combination, means for directing an X-ray beam, of defined cross section and having its radiation confined in a definite wave band, onto a crystal to be oriented, means, comprising a holder constructed for adjustment of the crystal, in relation to its optical (Z) axis, angularly in all directions and in which the crystal may be rigidly held, for presenting the crystal in reflecting (diffracting) relation to said X-ray beam with the optical (Z) axis of the crystal initially in approximately parallel relation to said X-ray beam, a translucent fluorescent screen lying in a plane perpendicular to said X-ray beam and interposed in the path of the reflections (diffractions) of said X-ray beam from atomic planes of said crystal which are preselected by reason of the wave band used and through which translucent screen said reflections (diffractions) may be viewed by the operator, said fluorescent screen extending about all sides of said X-ray beam, and means for locking said holder against further adjustment when said crystal has been brought, by adjustment of said holder, into the position in which it produces reflections from said atomic planes symmetrically arranged upon said fluorescent screen about said X-ray beam.

18. Crystal orienting apparatus according to claim 17 in which the fluorescent screen is provided with an indicator line, viewable under operating conditions, which coincides with the diameter of a circle through the center of which said X-ray beam extends.

19. Crystal orienting apparatus according to claim 17 in which provision is made for relative adjustment of the crystal holder and the X-ray beam in directions transverse to the X-ray beam, without disturbing the orientation, in order to detect electrical twinning.

20. The process of orienting crystals which consists in first effecting an approximate location of an optical (Z) axis of the crystal to be oriented by any suitable optical means, then directing onto the crystal, in a predetermined relation to the optical (Z) axis thereof, an X-ray beam of defined cross section and also having its radiation confined substantially within a definite wave band, whereby reflections (diffractions) are obtained from atomic planes arranged in sectors corresponding to those in which certain faces of the crystal are located and which, by reason of their interatomic planar distances effect substantially a maximum reflection (diffraction) of the said wave band, interposing in the paths of said reflections (diffractions) means responsive to energization by said reflections and capable of presenting visible evidence of the relative positions and intensities of the separate fields of energization produced by the respective reflections (diffractions) and manipulating the crystal until fields of intense energization corresponding to the reflections (diffractions) from said atomic planes have been brought into an arrangement about a common center which corresponds to the arrangement of the aforementioned faces of the crystal about the optical (Z) axis thereof.

21. The process of orienting either face or rough quartz to locate accurately the positions of the optical (Z) axis, the electrical (X) axes and the mechanical (Y) axes, which consists in first effecting an approximate location of the optical (Z) axis by any suitable optical means, then directing onto the quartz, in substantial parallelism to the optical (Z) axis, an X-ray beam of defined cross section and also having its radiation confined substantially within a definite wave band, whereby reflections (diffractions) are obtained from six atomic planes symmetrically arranged about the optical (Z) axis and which, by reason of their interatomic planar distances effect substantially a maximum reflection (diffraction) of the said wave band, interposing in the paths of said reflections means responsive to energization by said reflections (diffractions) and capable of presenting visible evidence of the relative positions and intensities of the separate fields of energization produced by the respective reflections (diffractions) and manipulating the quartz until fields of intense energization corresponding to the reflections (diffractions) from said atomic planes have been brought into symmetrical arrangement about a common center in two groups, each group comprising three fields of equal intensity but the fields of one group being more intense than those of the other.

22. Apparatus for orienting crystals comprising, in combination, an X-ray tube having a target capable of producing an X-ray beam within a selected wave band, a collimator tube for defining the cross-section of said beam and directing it, a holder for the crystal to be oriented comprising a member constructed to receive the crystal and have it fixed therein in approximately preoriented relation thereto so far as the optical (Z) axis only of said crystal is concerned, a support upon which said holder may be removably mounted, said support being so arranged that when the holder is mounted thereon it will present the crystal with its approximately preoriented (Z) axis in approximately the desired predetermined relation to the X-ray beam which is required to secure reflections (diffractions) from selected atomic planes of the crystal, said holder and collimator tube being also so relatively movable that the crystal and the X-ray beam may be brought accurately into the desired predetermined relation to each other, means responsive to energization by said atomic plane reflections (diffractions) and capable of presenting visible evidence of the relative positions and intensities of the separate fields of energization produced by the respective reflections (diffractions), said means being so located in the paths of the reflections (diffractions) from said atomic planes that the relative intensities and positions of the fields of energization produced by the reflections (diffractions) from said selected atomic planes may be visibly evident when the optical (Z) axis of the crystal has been brought definitely into the aforementioned desired predetermined relation to the X-ray beam.

23. In apparatus for manufacturing quartz oscillator plates, in which an electrical axis of the crystal is located by passing X-rays into and deflecting them from the crystal, the improvement comprising an X-ray machine, means associated with the X-ray machine for emitting X-rays in a predetermined direction, a guide support in adjustable relationship with the X-ray machine, a removable holder adapted to engage the guide support in a predetermined position,

means associated with the holder for supporting a crystal thereon with its optical axis in fixed predetermined relationship with a given part of the holder, and further means associated with the holder for tilting the crystal about its optical axis while in the path of the X-rays to locate and to place one of its electrical axes in fixed predetermined relationship with said given part of the holder while the optical axis remains in fixed relationship with said given part of the holder.

24. In apparatus for manufacturing quartz oscillator plates, in which an electrical axis of the crystal is located by passing X-rays onto and deflecting them from the crystal, the improvement comprising an X-ray machine, means associated with the X-ray machine for emitting X-rays in a predetermined direction, a guide support in adjustable relationship with the X-ray machine, the guide support being pivotally supported and provided with adjustable means to swivel it laterally about its pivot support, a holder provided with a reference base having a part adapted to engage the guide support in parallel alignment with X-rays passed into the crystal, an intermediate support mounted pivotally on the base and tiltable at right angles to the optical axis, a second intermediate support mounted pivotally on the first intermediate support and tiltable in parallel alignment with the optical axis, a rotatable base carried by the second intermediate support on which to mount the crystal, said rotatable base and second intermediate support being adjustable with respect to one another and to the first intermediate support to locate the optical axis of the crystal and to fix the optical axis in parallel alignment with said reference base part and to lock the crystal, rotatable base, second intermediate support and first intermediate support as a unit in their adjusted positions, said first intermediate support being adjustable with respect to the reference base part to fix an electrical axis of the crystal at right angles to the reference base part while the optical axis remains in fixed parallel alignment with the reference base part, and a fluorescent screen located at a suitable distance from and at a suitable angle to the holder so that X-rays deflected from the crystal supported thereon may impinge on the screen for visual inspection.

25. In the method of manufacturing quartz oscillator plates, the improvement which comprises passing a stream of X-rays against a quartz

crystal in a predetermined direction with respect to a given reference line removed from the crystal, the optical axis of the crystal being fixed in predetermined relationship with said reference line, moving the crystal in said stream of X-rays while maintaining the optical axis in fixed relationship with the reference line to bring an electrical axis of the crystal into predetermined relationship with the reference line, said movement of the crystal in the stream of X-rays being continued until X-ray beams reflected onto a fluorescent screen cause characteristic spots to be visually discernible, and fixing the crystal so that both the optical axis and the electrical axis of the crystal are maintained in fixed relationship to the reference line.

26. In the method of manufacturing quartz oscillator plates, the improvement which comprises mounting a quartz crystal upon a holder, placing a given part of the holder in predetermined relationship with the direction of travel of a stream of X-rays, passing the stream of X-rays against the quartz crystal in a predetermined direction with respect to the given part of the holder, the optical axis of the crystal being in fixed relationship with said given part of the holder, adjusting the holder and crystal while moving the crystal about an axis parallel to the optical axis in said stream of X-rays to bring an electrical axis of the crystal into predetermined relationship with said part of the holder while maintaining the optical axis in its fixed relationship with said part of the holder, said movement of the crystal in the stream of X-rays being continued until X-ray beams reflected onto a fluorescent screen cause characteristic spots to be visually discernible, locking the holder and crystal in their adjusted position to fix the relationship between said electrical axis of the crystal and said part of the holder so that both the optical axis and said electrical axis of the crystal are maintained in fixed relationship to said part of the holder.

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