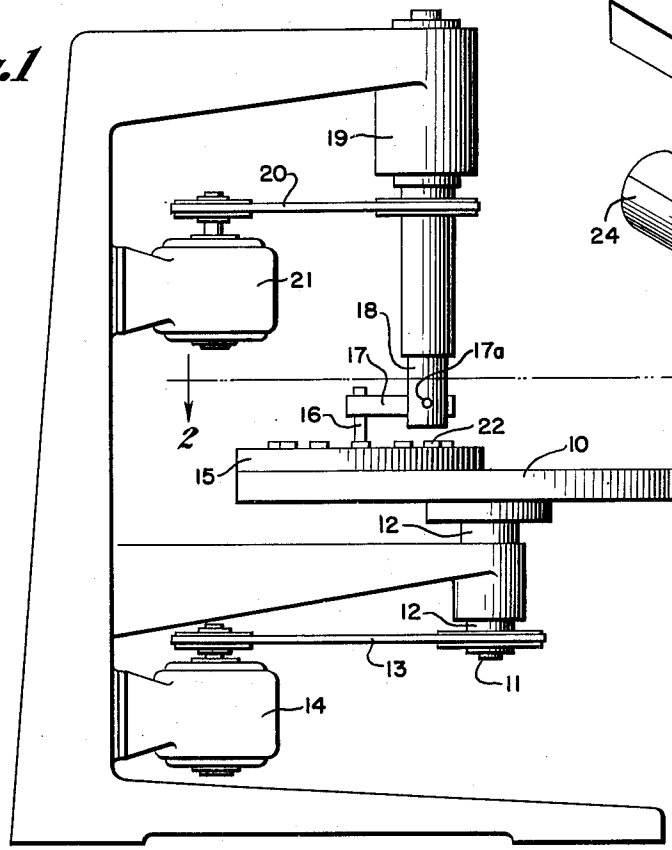
Jan. 30, 1951 J. M. WOLFSKILL 2,539,561

PIEZOELECTRIC CRYSTAL LAPPING APPARATUS

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Fig. 1



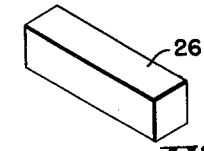


Fig. 6

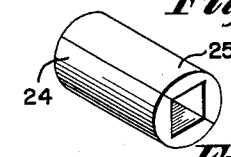
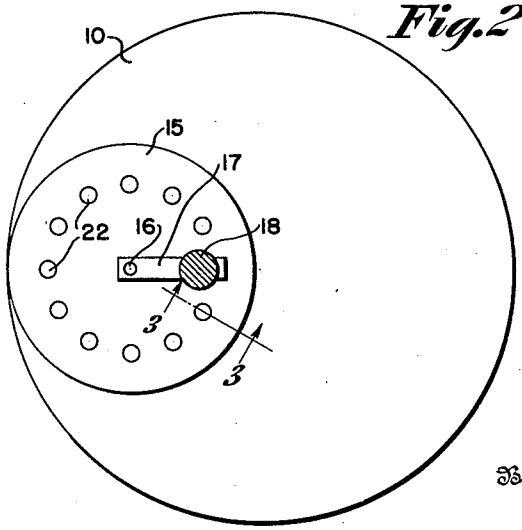


Fig. 5

Fig. 2



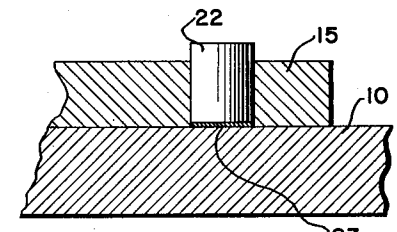


Fig. 3

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Fig.7

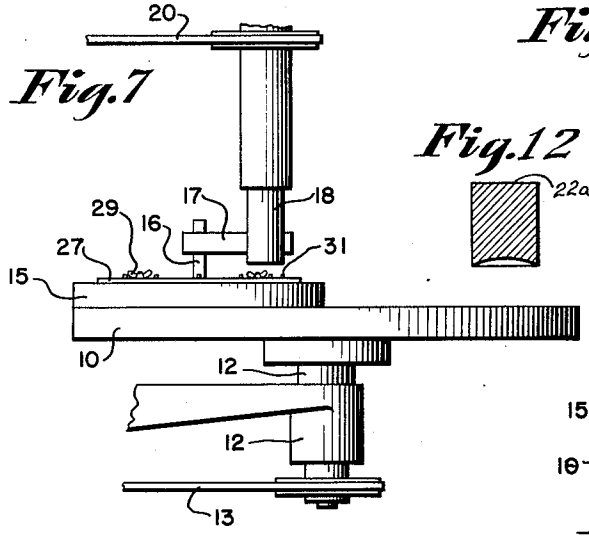


Fig.10

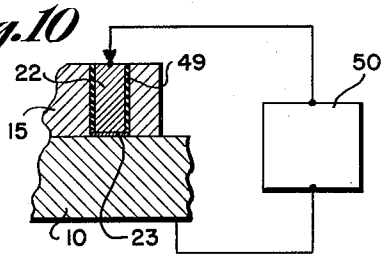


Fig.12

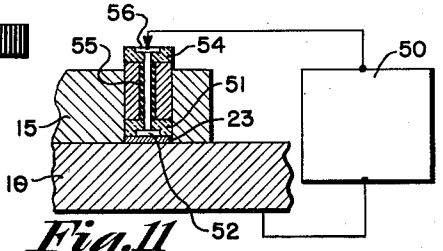


Fig.11

Fig.13

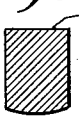


Fig.8

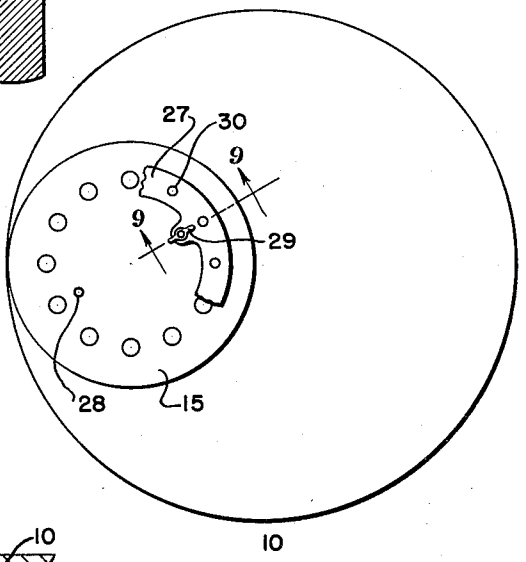
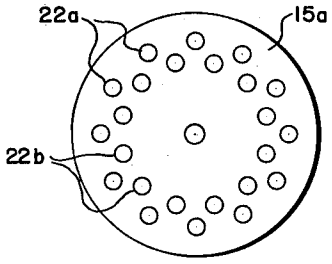


Fig.4



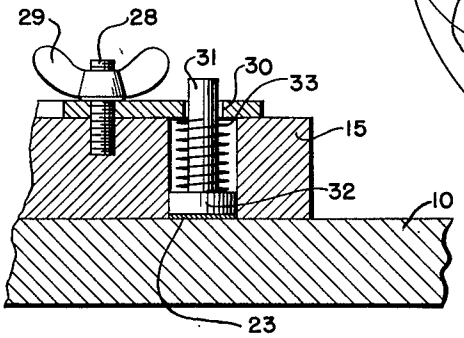


Fig.9

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UNITED STATES PATENT OFFICE

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PIEZOELECTRIC CRYSTAL LAPPING APPARATUS

John M. Wolfskill, Erie, Pa.

Application December 13, 1946, Serial No. 716,068

5 Claims. (Cl. 51—133)

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This invention relates to apparatus and method for grinding and lapping parts or pieces of material either irregular or regular in shape to relatively thin dimensions particularly to the grinding and lapping of various shaped piezoelectric quartz crystals and electrodes therefor.

An object of this invention is to provide an apparatus for lapping piezoelectric crystals to extremely thin dimensions and close tolerances.

Another object of this invention is to provide an apparatus for lapping piezoelectric crystals to thicknesses of less than $\frac{1}{1000}$ of an inch and close tolerances.

Another object of this invention is to provide means whereby a crystal or other part or piece of material may be lapped to a thickness which is not dependent on the thickness of any carrier, holding, or driving means surrounding the crystal or other part or piece of material being lapped.

Another object of this invention is to provide a lapping apparatus in which the articles being lapped are made to move in a number of different paths across a lapping surface the movement of which is independent of the movement of the article carrier.

A further object of this invention is to provide a method of lapping quartz crystals or similar pieces to thicknesses approaching the thickness of the abrasive particles employed.

It is another object of this invention to provide a means of accommodating all different shapes and sizes of quartz crystals or other parts to be lapped.

Still another object of this invention is to provide apparatus whereby parts may be lapped to difficult and exacting tolerances such as are required in the grinding and lapping of piezoelectric quartz crystals to high frequencies.

A further object of this invention is to provide means for lapping piezoelectric crystals and electrodes therefor or other devices to the required degree of surface finish encountered in high frequency operation.

It is still another object of this invention to provide a means of regulating the speed of lapping the surfaces of piezoelectric crystals and/or electrodes therefor by controlling the weight thereof.

A still further object of this invention is to provide a means of controlling the shape of the lapped surface or its contour to within extremely close tolerance by regulating the throw on the lapping plates or regulating the weight and shape of the plate in contact with the piece being lapped.

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It is another object to provide a means for lapping large quantities of pieces to extremely close tolerance without resorting to painstaking individualized operations.

Still another object of this invention is to provide a lap for lapping piezoelectric crystals, said lap having a lap plate provided with holes for receiving the piezoelectric crystals and weights in said holes for applying pressure to the crystals during the lapping operation.

Still another object of this invention is to provide lapping apparatus for producing extremely thin and accurate crystals, said apparatus having a lap plate provided with holes for receiving piezoelectric crystal blanks and guiding said blanks during the lapping operation.

Still another object of this invention is to provide a lap for lapping piezoelectric crystals, said lap having a lap plate provided with holes for receiving the piezoelectric crystals and insulated weights in said holes for applying pressure to the crystals during the lapping operation and for contacting said crystals for the purpose of measuring the frequency thereof.

Other and further objects of this invention will be apparent to those skilled in the art to which it relates from the following specification, drawing and claims.

In the prior art of lapping quartz crystals or other surfaces the piece being lapped is generally handled in one of two ways. Either the piece is cemented to a flat work holder by means of paraffin or similar wax or other pitch, either individually or in large quantities depending on the size of the pieces, and the entire work holder is moved about over another flat surface with an abrasive and vehicle between the aforesaid flat surface and surfaces being lapped.

Another method commonly used in the piezoelectric crystal lapping art is that in which the pieces being lapped are caused to move about between two flat surfaces by means of work holders which encircle the pieces being lapped, either closely or loosely enough to enable the pieces themselves to rotate in a space provided in the work holder.

These methods in the prior art are unduly limited insofar as the minimum thickness to which the piece or pieces may be lapped. The minimum thickness obtained by the method in which the pieces are fixed or cemented to the carrier is limited because of the distortion caused by the cementing or waxing medium on very thin pieces. The distortion takes place when the quartz crystal or other material is cemented to

the work holder. The resulting lapped surfaces of the quartz or metal piece may be exceptionally flat prior to the removal thereof from the work holder but this surface may have been originally distorted in the cementing operation. Upon removal of the quartz crystal or other material from the work holder after lapping distortions introduced therein in the course of the cementing operation are relieved and the quartz crystal or other material springs back to its naturally free condition so that the surface lapped onto it, either concave or convex, may or may not be regular. In addition, the thickness of the cementing medium between the pieces being lapped and the work holder may vary to such an extent that it is impossible to lap them to any specific thickness because the fastening medium varies and furthermore there is no telling what contour the work pieces have, until after removal thereof from the work holder.

The other method in the prior art has the definite disadvantage in that the thickness to which the quartz crystals or other material being lapped may be lapped is the thickness of the carrier or work holder which must be of a thickness and strength to move the work pieces, that is, the quartz crystals or other material, between the laps without tearing, fracturing or buckling. Regardless of what material such carriers or work holders are made, or regardless of the pressure on the lapping surface or between laps and work piece this disadvantage remains. There appears to be a practical limit to the thickness or thinness of the work holders of about .004" or .005" where the work holders tear, fracture and/or buckle.

It is the purpose of this invention to disclose a method of lapping to extremely thin dimensions with the limits in minimum thickness fixed only by the precision to which the lapping plates are made, and to the maximum size of the abrasive grain used.

Briefly, this apparatus comprises a top lap that is rotated over a bottom lap such that the top lap makes several rotations for each rotation of the bottom lap. The ratio of five to one or six to one has been used in this development but this can be varied over wide limits. The top lap is moved by a central pivot arm in such a manner that the abrasive action on the bottom lap remains consistent over its entire surface. The radius of the top lap movement can be varied as well as the center of the top lap movement to obtain uniform wear on the bottom lap. A plurality of holes are drilled either radially or in any configuration desired through the top lap and the work pieces placed in these holes. The work pieces themselves can be of any shape laterally and a freely floating cylinder is placed on top of each of the work pieces or piezoelectric crystals to provide pressure against the bottom lap. The holes drilled in the top lap confine the work piece and the bottom ends of the freely floating cylinders press on the work pieces. The bottom surfaces of these cylinders may be flat to produce flat work piece or crystal surfaces or they can be made convex, for instance so that most of the pressure will be in the central area of the work piece and this will produce a concave surface if it is desired. For instance, to lap a quartz crystal concave this method would be used. If it is desired to lap one face of the crystal convex, the end of the cylinder pressing against the crystal could be made concave in which case the pressure would be around the periphery of the crystal and this portion would be lapped down faster than the center area. In thin work pieces, such as encountered in piezoelectric crystals, a similar effect can be produced by hand operation in which case the finger or a pencil point can provide pressure at different points over the crystal surface as it is being hand lapped. In producing extremely flat surfaces the cylinder faces themselves must be flat so that the pressure is uniformly distributed over the crystals or work piece surfaces. Such a flat surface on the cylinder face is easily established by lapping the entire top lap with its complement of cylinders without the work pieces inserted. This can be carried on prior to loading of the top lap with piezoelectric crystal blanks.

Round as well as square crystals can be lapped in this apparatus. However, if a square or rectangular shaped crystal or work piece is lapped, the sideways or lateral pressure on the corners may become excessive if the square or rectangular crystals are positioned in the round holes of the top lap. If the crystal is extremely thin, the pressure may be sufficient to fracture the corners. In such instances, the top lap may be further modified either by using a square hole originally in the top lap, which is difficult to machine, or by introducing a free cylinder with a square hole, through it and in which a free floating square or rectangular weight can be placed. In order to get around the difficulty of machining a square hole through a cylinder the original round cylinder may be split into two parts or may even consist of three or four parts. If it is split the two similar cylinders can be milled in the center so as to form any desired shape internally to accommodate the square or rectangular work pieces.

Further details of this invention will be apparent to those skilled in the art to which it relates from the following specification, claims and drawing in which briefly:

Fig. 1 is a view of an embodiment of this apparatus;

Fig. 2 is a top view of the top lap plate showing the piezoelectric crystal receiving holes;

Fig. 3 is a fragmentary sectional view taken along the line 3—3 of Fig. 2;

Fig. 4 is a top view of a modified form of top plate with two circular rows of piezoelectric crystal receiving holes formed therein;

Fig. 5 is a view of a circular plug with a rectangular hole formed therein to be employed in the crystal receiving holes of the plates shown in Figs. 1, 2, 3 and 4 for adapting the top plates of this apparatus for rectangular crystal blanks;

Fig. 6 is a weight of bar like configuration having a rectangular cross section to fit into the rectangular holes of the elements shown in Fig. 5 for the purpose of pressing on the rectangular crystal blanks;

Fig. 7 is a modified form of this apparatus;

Fig. 8 is a view of the top plate of the apparatus shown in Fig. 7 in which the pressure plate is shown in fragmentary detail;

Fig. 9 is a fragmentary sectional view taken along the line 9—9 of Fig. 8;

Fig. 10 is a view similar to Fig. 3 showing insulated weight plugs connected to frequency measuring apparatus;

Fig. 11 is another view similar to Fig. 3 showing insulated electrodes on the weight plugs connected to frequency measuring apparatus;

Fig. 12 is a sectional view of a weight having a concave bottom for resting on the top of a

crystal to produce a crystal lapped with a convex face and Fig. 13 is a sectional view of a weight having a convex bottom for resting on the top of a crystal to produce a crystal lapped with a concave face.

Referring to Fig. 1 in detail, there is illustrated an embodiment of this apparatus employing a bottom lap plate 10 adapted to be supported and rotated by the shaft 11 which is mounted in bearings 12. Appropriate belt or gear drive means 13 is employed between the shaft 11 and the motor 14 for rotating the bottom plate 10. The lap plate 15 is arranged to move over the top surface of the lap 10 and is driven by the pin 16 of hardened steel and eccentric 17 which is attached to the lower end of the shaft 18. The shaft 18 is provided with a bearing 19 and is driven by the motor 21 through the belt or gear arrangement 20. It is obvious that one motor may be employed in place of the motors 14 and 21 for driving both of the shafts 11 and 18 through suitable belt or gear arrangements. It is however desirable to rotate the eccentric crank 17 at a speed bearing a ratio of a prime number such as 5, 7, and 11, etc., with respect to the speed of the bottom lap 10. The purpose of this being that a point on the top lap 15 will describe a large number of epicycloidal paths on the bottom lap 10 before that point travels over the same course on the bottom lap 10 again. These ratios however are not necessary for the production of thin crystals although employing one of the aforesaid prime number ratios will maintain flatness or a particular contour of the bottom lap 10 over a greater period of time. Furthermore the top lap 15 is rotated over the bottom lap 10 such that the top lap makes several rotations for each rotation of the bottom lap. A ratio of 5 to 1 or 6 to 1, that is, either 5 revolutions of the top lap 15 to one revolution of the bottom lap 10 or 6 revolutions of the top lap 15 to one revolution of the bottom lap 10 was employed in this apparatus. However, it will be appreciated that this ratio may be varied over wide limits and that it is not necessary to employ the aforesaid 5 to 1 or 6 to 1 ratios. Also the radius of the swing of the top lap 15 may be varied by lengthening or shortening the arm of the eccentric 17 and this may be done readily by loosening the set screw 17*a* which retains the eccentric 17 in a hole provided therefor at the lower end of the shaft 18. Thus the length of the eccentric 17 may be varied periodically so that the radius of swing of the top lap 15 is varied and produces substantially uniform wear on the bottom lap 10.

The lap 15 is provided with a plurality of holes for receiving the plugs 22 therein. The plugs 22 function as weights for pressing the work pieces 23, which in this case are the quartz piezoelectric crystal blanks, against the top lap 10 as shown in Fig. 3. The plugs 22 are fitted into the holes so that substantially all of the weight of each individual plug is uniformly distributed upon the respective piezoelectric crystal face associated therewith. However these plugs must not be so loose that they wobble in the holes inasmuch as such a loose fit would produce distorted lapping of the piezoelectric crystal since the weight of the plugs would not be uniformly distributed over the surfaces of the corresponding crystals.

In the embodiment shown in Figs. 1 and 2 only one circular row of piezoelectric crystal receiving holes is provided to the lap plate 15. However it is obvious that several circular rows of holes may be provided as shown in Fig. 4.

In Figs. 5 and 6 is illustrated a fixture consisting of a cylindrical insert made in two sections 24 and 25 of such size as to fit snugly into the piezoelectric crystal receiving holes of the laps 15 of 15*a* for adapting these holes for receiving rectangular piezoelectric crystal wafers or blanks. The holes formed in the laps 15 and 15*a* are of circular configuration as shown for the purpose of receiving circular piezoelectric crystal wafers. However when it is desired to lap rectangular crystal wafers the insert shown in Fig. 5 having an outside circular configuration and a rectangular hole therethrough is snugly fitted into each of the crystal receiving holes on the laps 15 and 15*a* and the rectangular bar 26 shown in Fig. 6 is placed into the axial hole of the insert 24, 25 to function as a weight distributed uniformly on the top of the crystal blank being lapped. The insert is made in two sections 24 and 25 inasmuch as this facilitates the manufacture thereof since it is quite difficult to cut a rectangular hole axially through an elongated rod.

It is of course obvious that the lap 15 may be employed for lapping both circular crystal wafers and rectangular crystal wafers in the different crystal receiving apertures thereof at the same time. Furthermore crystal wafers of different thicknesses may be lapped in different holes of the laps 15 and 15*a* simultaneously.

Also the weights 22 may have the cylindrical sides thereof coated with insulating material and function as electrodes on the top faces of the crystal blanks 23 being lapped so that the frequencies of these crystal blanks may be checked on suitable frequency measuring apparatus 50 (shown in Fig. 10) simply by connecting the bottom lap 10 to one side of the input of the frequency measuring apparatus by means of a suitable brush or wiping contact or through the bearing of the lap 10 and the other side of the input of this apparatus may be connected selectively to the different weights 22. Likewise the inserts shown in Fig. 5 may be made of insulating material or the elongated sides of the weight 26 may be coated with insulation instead so that the weight 26 shown in Fig. 6 may be used as an electrode on the top surface of the rectangular crystal wafer being lapped. In this way, the frequencies of the crystal wafers may be checked without removing the crystal wafers from the lap. If desired the bottom portion of each of the weights 22 and 26 may be made of insulation material 51 and a small button electrode 52 supported on this insulation material for the purpose of making frequency measurements of the crystal wafer 23, as shown in Fig. 11. In this case the button electrodes each must of course be connected to a suitably insulated segment 54 on the top of the weights 22 and 26 by a piece of insulated wire 55.

It is of course necessary to have the bottom of the weights 22 and 26 flat if flat piezoelectric crystal blanks are to be produced in this lapping apparatus and likewise the electrode 52 and insulation 51 must have the bottom surface thereof lapped flat for producing flat crystals.

Where it is desired to produce crystal blanks 23, each having a convex face or faces, the

weights 22a, each having a concave face as shown in Fig. 12, are employed in rotatable laps 15 and 15a. On the other hand, if it is desired to produce crystal blanks, each having a concave face or faces, then the weight member 22b, having a bottom surface that is convex as shown in Fig. 13, is employed in each of the holes of the laps 15 or 15a.

In Figs. 7, 8 and 9 as illustrated a modified form of this invention in which an annular pressure plate 27 is attached to the top of the lap 15 by suitable studs 28 and wing nuts 29. This pressure plate is provided with a plurality of holes 30 for receiving the tops of the rods 31. These rods 31 are encircled by helical springs 33, the tops of which engage the bottom of the pressure plate 27 and the bottoms of which engage the discs 32 which are attached to the bottom ends of the rods 31. The discs 32 rest upon the top surfaces of the piezoelectric crystal wafers 23 that are being lapped and apply the spring pressure uniformly to said crystal blanks. The holes in the pressure plate are large enough so that they do not touch the shafts of the rods 31 otherwise these rods would be pushed out of their free positions and the plugs 32 would not rest uniformly on the crystal wafers resulting in a cone being generated on the crystal wafer face even though the bottom surface of disc 32 is flat.

In the operation of this apparatus the crystal blanks desired to be lapped are inserted into the holes provided therefor in the lap 15 together with a small amount of abrasive and abrasive vehicle. The laps 10 and 15 may be set into motion either simultaneously or the lap 15 may be started prior to or after the lap 10 is started.

It will be appreciated that modifications of this apparatus may be made without departing from the spirit and scope thereof and therefore it is not desired to limit this invention to the exact embodiment illustrated and described except insofar as this may be defined by the claims.

I claim:

1. Apparatus for lapping piezoelectric crystal blanks to relatively thin dimensions comprising a lap plate, a work holder having a face thereof in engagement with the lapping face of the lap plate, means operably connected to said work holder for moving said work holder and said lap plate with respect to each other, said work holder having a hole formed therein to receive a piezoelectric crystal blank having a pair of major faces the diameters of which are large compared to the thickness of the blank, said work holder being adapted to guide said crystal blank against the lapping surface of said lap plate, and a weight member freely positioned in said hole for applying pressure to said piezoelectric crystal blank, the face of said weight member engaging a major face of said crystal blank being convex so that the major face of said crystal blank being lapped is lapped concave.

2. Apparatus for lapping piezoelectric crystal blanks to relatively thin dimensions comprising a lap plate, a work holder having a face thereof in engagement with the lapping face of the lap plate, means operably connected to said work holder for moving said work holder and said lap plate with respect to each other, said work holder having a hole formed therein to receive a piezoelectric crystal blank having a pair of major faces the diameters of which are large compared to the thickness of the blank, said work holder being adapted to guide said crystal blank against the lapping surface of said lap plate, and a weight member freely positioned in said hole for applying pressure to said piezoelectric crystal blank, the face of said weight member engaging a major face of said crystal blank being concave so that the major face of said crystal blank being lapped is lapped convex.

3. Apparatus for lapping piezoelectric crystal blanks to relatively thin dimensions comprising a lap plate, a work holder having a face thereof in engagement with the lapping face of the lap plate, means operably connected to said work holder for moving said work holder and said lap plate with respect to each other, said work holder having a hole formed therein to receive a piezoelectric crystal blank having a pair of major faces the diameters of which are large compared to the thickness of the blank, said work holder being adapted to guide said crystal blank over the lapping surface of said lap plate, a weight member positioned in said hole to ride on said piezoelectric crystal blank for applying pressure to said piezoelectric crystal blank uniformly over one of the major faces of said blank to secure uniform lapping thereof, a resilient member positioned against said weight member and a member adjustably attached to said work holder for applying pressure to said weight member through said resilient member so that the rate of lapping of said crystal blank may be controlled to prevent fracture thereof, the face of said weight member engaging a major face of said crystal blank being convex so that the major face of said crystal blank being lapped is lapped concave.

4. Apparatus for lapping piezoelectric crystal blanks to relatively thin dimensions comprising a lap plate, a work holder having a face thereof in engagement with the lapping face of the lap plate, means operably connected to said work holder for moving said work holder and said lap plate with respect to each other, said work holder having a hole formed therein to receive a piezoelectric crystal blank having a pair of major faces the diameters of which are large compared to the thickness of the blank, said work holder being adapted to guide said crystal blank over the lapping surface of said lap plate, a weight member positioned in said hole to ride on said piezoelectric crystal blank for applying pressure to said piezoelectric crystal blank uniformly over one of the major faces of said blank to secure unifrom lapping thereof, a resilient member positioned against said weight member and a member adjustably attached to said work holder for applying pressure to said weight member through said resilient member so that the rate of lapping of said crystal blank may be controlled to prevent fracture thereof, the face of said weight member engaging a major face of said crystal blank being concave so that the major face of said crystal blank being lapped is lapped convex.

5. Apparatus for lapping a plurality of piezoelectric crystal blanks to a thinness corresponding substantially to the size of the abrasive particles used, comprising a lap plate, means operatively connected to said lap plate for rotating said lap plate, a piezoelectric crystal guiding member having a plurality of holes formed therein for receiving piezoelectric crystals of

thin wafer-like configuration, said holes having diameters corresponding substantially to the diameters of said piezoelectric crystals, means operatively connected to said piezoelectric crystal guiding member for moving said guiding member on the top of said lap plate, weight members fitting into said holes for uniformly pressing a surface of each of said piezoelectric crystals against said lap plate without distorting the shapes of said piezoelectric crystals, insulation means for electrically insulating said weight members from said guiding member, and frequency measuring apparatus connected to said insulated weight members and to said lap plate for indicating the frequency of said crystal blanks.

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