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H. M. BACH
METHOD AND MEANS OF FINISHING
PIEZOELECTRIC CRYSTALS
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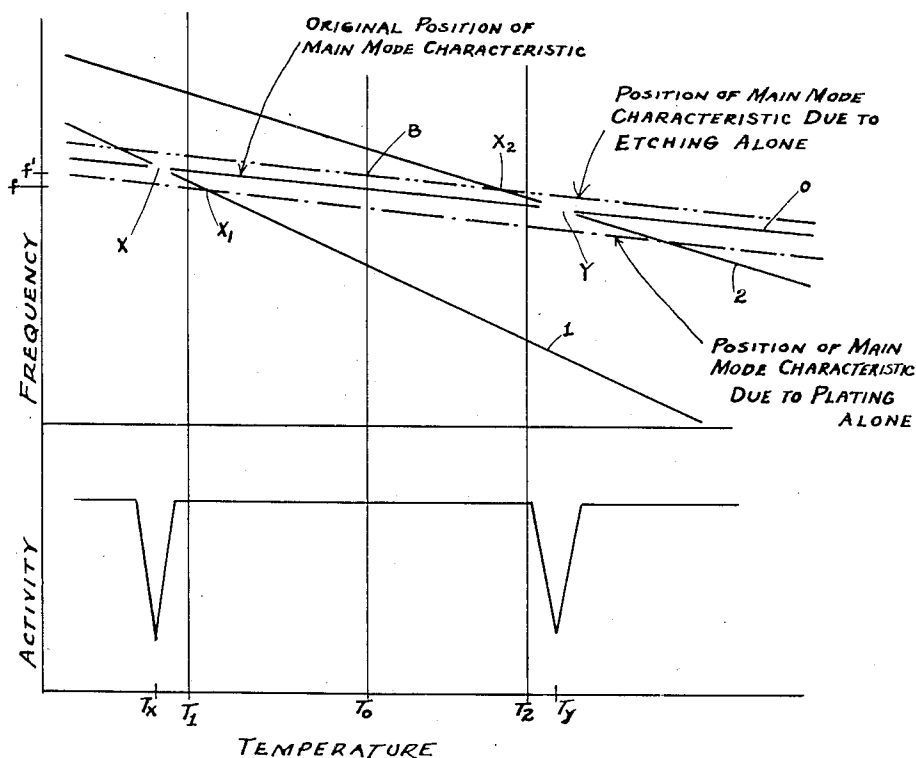


FIG. 1

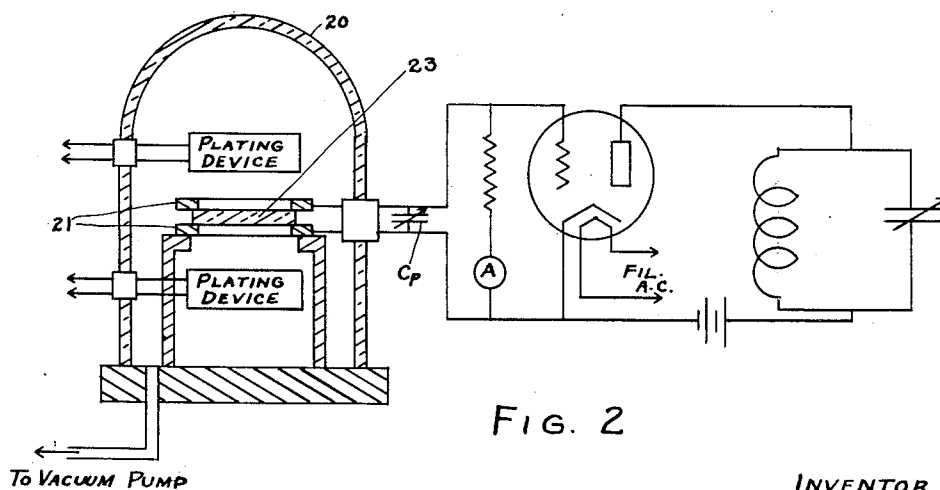


FIG. 2

INVENTOR
HENRY M. BACH

By *Herman L. Gordon*

ATTORNEY

UNITED STATES PATENT OFFICE

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METHOD AND MEANS OF FINISHING
PIEZOELECTRIC CRYSTALSHenry M. Bach, Lawrence, N. Y., assignor to
Premier Crystal Laboratories, Incorporated,
New York, N. Y.

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5 Claims. (Cl. 171—327)

1

This invention relates to a new and improved method of manufacturing piezo-electric crystals.

An object of this invention is to manufacture piezo-electric crystals having desirable performance characteristics.

A further object of this invention is to provide an improved method of manufacturing pre-dimensioned plated crystals.

A still further object of this invention is to provide a method of manufacturing plated crystals wherein aging effects will be reduced to a minimum.

A still further object of this invention is to provide a method of manufacturing crystals which have been either pre-dimensioned or which have been empirically formed to give optimum performance over a specified temperature range and which have been etched to minimize aging effects.

Further objects of this invention will be apparent from the following description and claims, and from the drawings illustrative of the invention, wherein:

Figure 1 is a set of curves illustrating the performance characteristics of a typical piezo-electric crystal.

Figure 2 is a simplified diagrammatic view showing a preferred arrangement of an apparatus for practicing this invention.

For the successful fabrication of piezo-electric oscillator plates on a mass production scale it is advantageous to employ a pre-dimensioning technique. This technique has been heretofore practiced on the assumption that the oscillator plates will not be loaded or plated. By pre-dimensioning, that is, the selection of optimum values of the dimensions of the plate for a particular frequency, it is possible to produce large quantities of plates for this frequency having substantially uniform performance characteristics.

The advantages of plated crystals are well known in the art. It is also known that oscillator plates finished by conventional methods have a microscopically thin layer of disturbed quartz adhering loosely to the lapped surfaces thereof. This disturbed layer of "disoriented" material is insecurely held, and progressively detaches itself from the crystal during service, producing so-called "aging" effects, generally causing an increase in frequency over the original normal frequency. This effect is present even if the surface is plated over after lapping, if the lapping is done in the conventional manner. It can be eliminated to a substantial degree, however, by removing the disturbed layer, either by etching

2

or by very fine lapping, and then depositing plating material on the treated surface to stabilize it.

The etching (or fine lapping) and plating processes respectively affect the pre-determined performance characteristics of the pre-dimensioned oscillator plates to a measurably serious degree. To demonstrate the effects of plating, for example, on a typical pre-dimensioned unetched blank, reference is made to Figure 1, wherein the temperature characteristics of the main mode relative to the mechanically coupled modes of vibration of the blank are graphically illustrated. The main frequency characteristic of the quartz plate before plating, assuming the plate to have proper dimensions, is shown by the typical curve O in Figure 1. As shown in this figure, the dimensions have been selected so that for a particular frequency f at room temperature T_0 the frequency characteristic between the specified temperature limits T_1 and T_2 is within the points X and Y, said points representing regions of interference with mechanically coupled modes, whose frequency characteristics are represented by lines 1 and 2, respectively. The mechanically coupled modes cause activity dips at temperatures T_x and T_y which for the unplated, unetched crystal, lie outside the specified temperature range.

It may be added that the above holds true as well for plates whose dimensions have been empirically determined by a cut-and-try "edge working" technique.

When plating is applied to the crystal, the original frequency-temperature characteristic of the main mode of vibration is slightly lowered due to the loading effect of the plating. The loading effect of the plating is practically negligible as far as the temperature characteristics of the mechanically coupled modes are concerned since these secondary mode characteristics are determined mainly by the crystal dimensions. This is illustrated in Figure 1, where it is seen that the shifting of the main mode characteristic due to plating with respect to a relatively stationary secondary mode characteristic such as 1 may now cause a point of interference such as X_1 , to be included in the main mode characteristic between the specified temperature range limits T_1 and T_2 .

In this same manner, if a correctly dimensioned plate is lightly etched to remove quartz dust and disoriented surface material to thereby minimize its tendency to "age," the frequency-temperature characteristic of the main mode

of the plate is slightly raised, and since the dimensions which produce mechanically coupled modes are affected only to a negligible degree, this may cause a point of interference X_2 between the main mode characteristic and a secondary mode characteristic 2, to be included in the main mode characteristic between the specified temperature range limits T_1 and T_2 .

Activity dips within the specified temperature range may therefore be caused by either plating or etching an originally correctly dimensioned plate.

In the prior art it has been recognized that plating the crystal causes a reduction in frequency, and therefore a crystal which is to be subsequently plated is first ground slightly higher in frequency than the final desired ultimate frequency. By plating the over-ground crystal its frequency is reduced to the desired value.

The prior art has also recognized the necessity of making allowance for etching by finishing the blank a little low in frequency prior to etching. Both in the case of the first above-described method of finishing crystals, i. e., by plating to frequency, and in the case of the second above-described method of finishing crystals, i. e., by etching to frequency, no provision has been made for maintaining the relationship of the temperature characteristic curve for the desired mode constant with respect to the characteristics of the coupled modes so as to prevent the movement into the specified temperature range of activity dips caused by shifting of the main mode frequency-temperature characteristic.

In the present invention it is desired to take advantage of the opposite shifting of the main mode frequency-temperature characteristic caused respectively by the etching and plating of a correctly dimensioned crystal blank to restore the original room temperature frequency and to maintain the original relationship of the frequency-temperature characteristic of the desired mode of vibration of the plate with respect to the temperature characteristics of the mechanically coupled modes.

It has been found by experiment by etching and subsequently plating as disclosed herein, that very stable operating conditions of the plate can be achieved and that the plate will have very satisfactory freedom from aging effects together with substantially the same effective geometry as the initially correctly dimensioned blank.

In a preferred embodiment of this invention a quartz blank 23 is finished to optimum activity (by edge work or by pre-dimensioning, for example) at the desired frequency f . It is then placed in a bell jar, such as 20 in Figure 2, containing plating devices of the evaporation type, and the pressure in the bell jar is reduced to plating pressure although the plating devices are kept inactive. Standard electrodes with raised corners as shown in applicant's U. S. Patent No. 2,329,321 are disposed in working relationship to the blank 23 and said electrodes are connected to an external conventional tuned-plate oscillator having a rectified D. C. grid current ammeter connected so as to measure the "activity" of the crystal. An external variable capacitor C_p is connected in parallel with the crystal and capacitance thereof is adjusted to bring the crystal back to frequency f from the value resulting from the evacuation of the bell jar to plating pressure. The adjustment of C_p at this point is noted. Also noted are the adjustment values of C_p at which activity dips are observed. (These

values correspond to points along the temperature characteristic at which mechanically coupled modes cause activity dips. A correctly dimensioned blank will exhibit activity dips only at adjustment values corresponding to temperatures outside the specified working range.) The blank 23 is then removed from bell jar 20 and etched the desired amount to remove the layer of disturbed quartz which might tend to cause "aging" of the blank. The etched blank 23 is then replaced in bell jar 20. Frame-shaped electrodes 21, such as disclosed in applicant's U. S. Patent No. 2,327,487 are disposed in working relationship to the blank 23, the blank faces are each lightly plated, and said electrodes are connected to the external conventional tuned-plate oscillator having a rectified D. C. grid current ammeter connected so as to measure the "activity" of the crystal. The frame-shaped electrodes 21 are of such external length and width as to extend beyond the edges of the blank 23 in a manner to prevent plating material from being deposited on the edges of the blank. Plating is deposited thereon until the original adjustment values of C_p are duplicated.

Conventional means of accurately measuring the output frequency of the oscillator at any time are employed in the above procedure.

The initial adjustment value of C_p corresponds to T_0 in Figure 1, and the adjustment values for activity dips correspond to T_x and T_y respectively, in Figure 1. The etched blank in the bell jar 20 before plating will have a frequency f' corresponding to point B in Figure 1, at the T_0 adjustment of C_p . As plating is applied, the frequency will decrease and the plating is continued until the original frequency f is reached. To test for determining that the original effective geometry has been restored, C_p is varied to locate activity dips. The activity dips should appear approximately at the adjustment values of C_p obtained with the unetched blank.

In mass production, following the teachings of this invention, a quantity of quartz plates are adjusted to the desired ultimate frequency by individual etching. The plates are then mass etched (in an agitated etching solution in which the temperature, concentration, and other parameters determining the etching vs. time relationship are carefully controlled) for a predetermined period of time corresponding to a depth of etch necessary to remove all disoriented particles. It has been accurately determined exactly what frequency increase will be caused by this mass etch. The plates, after this etch, are then mass plated in a controlled plating apparatus until a predetermined mass of plating has been deposited on each plate. The predetermined mass is the mass required to lower the vibrating frequency by the same amount that the mass etching increased the frequency.

While the above specific arrangement and procedure has been described as a preferred embodiment of this invention it should be understood that the invention can be practiced in many different ways and is not limited to an etching and plating sequence of operations. Any method of removing the disturbed layer of material other than by etching, such as by fine lapping, for example, can be used, and any method of loading back the crystal to restore its original effective geometry other than by plating, such as by X-ray irradiation, for example, can be used as the means of reducing frequency.

This method also contemplates locating the ac-

tivity dips by other methods than by the above described method of varying a shunt capacitance; any method of varying the crystal input capacitance may be used. Furthermore, for greater accuracy in locating activity dips, conventional temperature runs may be made instead of relying on the variable input capacitance method.

Also contemplated within this invention are repeated cycles of unloading and loading the crystal to produce the desired effective geometry, that is, an overplated crystal may be unloaded, as by etching or grinding, to restore the desired effective geometry. In this procedure if it should happen that too much material is unloaded, the desired effective geometry can be achieved by again depositing plating on the crystal. This method thereby provides a means of obtaining the desired effective geometry of any substantially completed crystal without edge work thereon.

Numerous modifications will be apparent to those skilled in the art. This invention is therefore not to be limited except insofar as is necessitated by the prior art or by the scope of the appended claims.

What is claimed is:

1. A method of processing a piezo-electric plate comprising the steps of varying the input reactance across the plate until a value of reactance is obtained causing the plate to have an activity dip, etching the plate to remove surface material therefrom, and then loading the plate until the activity dip of the plate occurs at substantially the same value of input reactance as that at which the activity dip was originally obtained.

2. A method of processing a piezo-electric plate comprising the steps of varying the shunt capacitance across the plate until a value of shunt capacitance is obtained causing the plate to have an activity dip, etching the plate to remove surface material therefrom, and then loading the plate until the activity dip of the plate occurs at substantially the same value of shunt capacitance as that at which the activity dip was originally obtained.

3. A method of processing a piezo-electric plate

comprising the steps of varying the shunt capacitance across the plate until a value of shunt capacitance is obtained causing the plate to have an activity dip, etching the plate to remove surface material therefrom, and then depositing plating material on the etched surface until the activity dip of the plate occurs at substantially the same value of shunt capacitance as that at which the activity dip was originally obtained.

4. A method of processing a piezo-electric plate comprising the steps of varying the shunt capacitance across the plate until a value of shunt capacitance is obtained causing the plate to have an activity dip, etching the plate to remove surface material therefrom, and then irradiating the plate with X-ray radiation until the activity dip of the plate occurs at substantially the same value of shunt capacitance as that at which the activity dip was originally obtained.

5. A method of processing a piezo-electric plate comprising the steps of varying the input reactance across the plate until a value of reactance is obtained causing the plate to have an activity dip, removing surface material from the plate, and then loading the plate until the activity dip of the plate occurs at substantially the same value of input reactance as that at which the activity dip was originally obtained.

HENRY M. BACH.

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