

March 19, 1935.

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1,994,487

METHOD OF APPLYING ELECTRODES TO PIEZO CRYSTALS

Filed Jan. 24, 1930

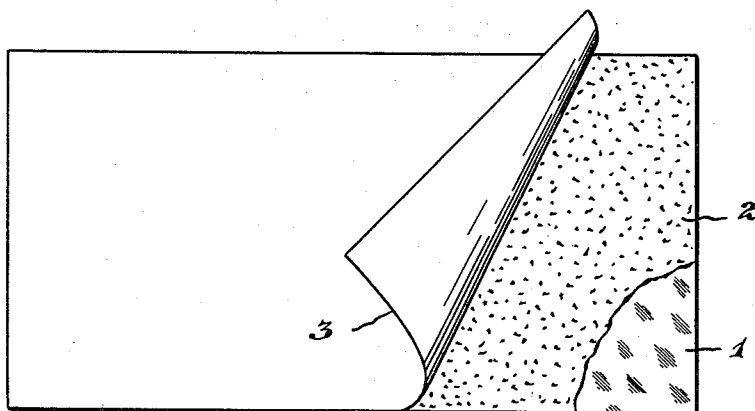


Fig. 1.

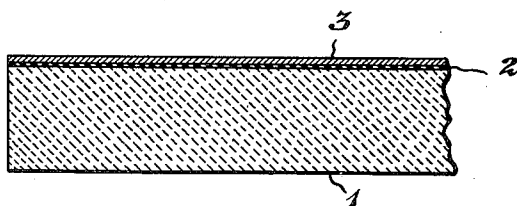


Fig. 2.

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1,994,487

METHOD OF APPLYING ELECTRODES TO
PIEZO CRYSTALS

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Application January 24, 1930, Serial No. 423,284
Renewed April 30, 1934

11 Claims. (Cl. 171—327)

This invention relates to piezo-electric apparatus for sound recording and reproduction and the translation of periodic energy impulses in general, and particularly to a new and improved method of applying electrodes to the piezo-electric crystal portions of such apparatus.

One of the objects of the present invention is to provide a new method of applying electrodes to piezo-electric crystals whereby the electrode is caused to adhere very strongly and closely to the crystal.

Another object is to provide a new method of applying electrodes to piezo-electric crystals whereby the thickness of the film of adhesive material is substantially reduced to a minimum.

Another object of this invention is to provide a method whereby the inherently high specific inductive capacity of Rochelle salt may be more fully utilized.

Another object of this invention is to provide a method of applying electrodes to the piezo-electric crystal whereby the electrodes may be situated as close to the piezo-electric surfaces as possible.

Another object is to provide a new method of applying electrodes to piezo-electric crystals whereby a close adhesion is constantly maintained, substantially unaffected by the bending, expansion, contraction or other distortions of the crystal.

A further object of this invention is to provide a method of reducing the impedance between the electrodes substantially to a minimum.

A further object is to provide a new method of applying electrodes to piezo-electric material whereby constant electrical characteristics of the unit are maintained.

With the foregoing and other objects in view which will be apparent from the detailed description to follow and the appended claims, the present invention consists in certain novel methods and steps of procedure which will be readily understood by those skilled in the art to which the invention appertains.

In the drawing, Figure 1 represents a portion of a piezo-electric crystal, the electrode being partially applied; and

Fig. 2 is an exaggerated section of the device shown in Fig. 1.

In the drawing, the crystal portion, the cement and the electrode, are indicated by the numerals 1, 2 and 3, respectively.

I have observed that in prior piezo-electric devices the characteristics may vary to a considerable extent because of variations in effective elec-

trical contact between the electrodes and the crystal surface. This may be due to a loss of conductivity of intermediate substances due to drying out, etc., or to the electrodes being slightly displaced from the crystal due to the mechanical distortion or motion of the crystal. I have discovered that the apparent capacity of the units may vary to a considerable extent with the method of applying the electrodes. For example, I find that the apparent capacity of the unit is greater and the impedance lower when the electrodes have been rubbed down carefully on the crystal than when they have been poorly applied.

The present invention contemplates a new method of applying electrodes to piezo-electric crystals, whereby a very close adhesion between the crystal and electrodes is obtained, which is substantially unaffected by the extensive mechanical motions of the crystal when subjected to alternating electromotive forces. It is also contemplated to provide such a method of applying electrodes to piezo-electric crystals that the electrical impedance between electrodes will be substantially reduced to a minimum. An explanation of this result is that the dielectric constant of the crystal is far greater than that of the material used to hold the electrodes to the crystal.

As an illustration, it has been found that a thickness of cementing material of one-thousandth of an inch will reduce the apparent capacity of a crystal of three-sixteenths of an inch in thickness by several hundred percent. It will be apparent from the method which will now be described that applicant can obtain layers of cementing material of minute thickness which greatly assist in obtaining the desired apparent capacity and impedance in a piezo-electric unit.

When use is made of the piezo-electric properties of Rochelle salt for acoustic purposes, the apparatus preferably comprises a slab or portion of Rochelle salt, or its equivalent, situated between conducting electrodes. This, in normal operation, acts as a condenser and provides a capacitive load for the circuit supplying a current thereto. The impedance therefore increases as the frequency decreases and becomes high in the lower register. In order to reproduce a low frequency well, it is desirable to keep this impedance as low as possible, and a very desirable way to do this is to make the most efficient use of the high dielectric constant of the salt.

Air has a dielectric constant of 1; waxes, paraffins, and other similar dielectrics have a constant from 2 to 4. The constant of glass, mica,

and the like will range from 4 to 10; and so far as known no chemical compound outside of Rochelle salt has a dielectric constant of over 100. The dielectric constant of Rochelle salt is from 10,000 to 20,000 under ordinary conditions of frequency, saturation and temperature, and may in some cases have an instantaneous value over 150,000.

When dealing with a dielectric of such enormous specific inductive capacity a space between the dielectric and the electrode, small enough to give highly efficient results with ordinary dielectrics, raises the impedance of the apparatus to a comparatively large value when used in conjunction with a dielectric of such large specific inductive capacity.

The deleterious effect of even a minute thickness of material of low dielectric capacity between the electrodes and the Rochelle salt dielectric can best be made apparent by an actual example.

The capacity of a condenser having the space between the electrodes filled with layers of two dielectrics having different thicknesses and different dielectric constants is given by the following formula:

$$C = 0.2245S \frac{K_1 K_2}{K_2 t_1 + K_1 t_2}$$

Where:

C equals the capacity in micromicrofarads.

S equals the surface area of one side of one electrode in square inches.

K₁ equals the dielectric constant of one material.

K₂ equals the dielectric constant of the other material.

t₁ equals the total thickness of one material.

t₂ equals the total thickness of the other material.

Suppose the dielectric to consist of a piece of glass 0.15" thick and having an area of

$$S = \frac{1}{0.2245}$$

sq. in. and having a dielectric constant or specific inductive capacity of say 6. The electrodes are supposed to be fastened on with a cement having a thickness of 0.0001" between the electrode and the plate, and a dielectric constant of 2.

Then we have

K₁ equals 6

K₂ equals 2

t₁ equals 0.15

t₂ equals 0.0001" + 0.0001" equals 0.0002"

and

$$C = 0.2245 \times \frac{1}{0.2245} \times \frac{6 \times 2}{(2 \times 0.15) + (6 \times 0.0002)} = \frac{12}{0.3012}$$

equals 39.8074 micromicrofarads.

Now if the thickness of cement is reduced to zero we have

K₁ equals 6

K₂ equals 2

t₁ equals 0.15

t₂ equals 0

and C equals

$$0.2245 \times \frac{1}{0.2245} \times \frac{6 \times 2}{(2 \times 0.15) + (6 \times 0)} = \frac{12}{0.30} =$$

40 micromicrofarads.

The increase is 40.0 - 39.8074 = 0.1926 micromicrofarads =

$$\frac{0.1926 \times 100}{39.8074}$$

equals 0.459 percent.

If a Rochelle salt slab be substituted for the glass, however, all other factors remaining the same, we have

K₁ equals 10,000

K₂ equals 2

t₁ equals 0.15

t₂ equals 0.0002

and the capacity of the condenser is

$$\frac{10000 \times 2}{(2 \times 0.15) + (10000 \times 0.0002)}$$

equals

$$\frac{20000}{2.3}$$

equals 8695.6 micromicrofarads.

If now the thickness of the cement be reduced to zero, t₂ equals 0 and the capacity of the condenser is

$$\frac{10000 \times 2}{(2 \times 0.15) + (10000 \times 0)}$$

equals

$$\frac{20000}{0.3}$$

equals 66666.6 micromicrofarads.

The increase in capacity is 66666.66 - 8695.6 equals 57970 micromicrofarads, and the percent increase is

$$\frac{57970 \times 100}{8695.6}$$

equals 666%.

We thus see that a thickness of cement which will affect the apparent capacity between the electrodes by an unappreciable amount (less than one percent) with ordinary dielectrics may cause a variation of several hundred percent when a material of high dielectric capacity, such as Rochelle salt, is used.

These effects are especially noticeable in acoustic devices, and it has been found experimentally that certain methods of attaching the electrode which are apparently best adapted to reduce the film of adhesive material between the electrodes and the Rochelle salt dielectric to the minimum of thickness give very superior results in acoustic devices, especially in the bass register.

One very effective method of accomplishing this result which I have devised, is as follows:

It is desirable to use an extremely light electrode material which is very flexible and which will not constrain the mechanical movement of the crystal when subjected to alternating electromotive forces. A preferred electrode material is a good grade of tinfoil, preferably of about five ten-thousandths of an inch thickness.

A solution of dry Canada balsam dissolved in approximately five times its weight of xylol is preferably employed as the cementing material. However, other suitable cementing substances may be used if desired, such as, Japanese size, or other resinous solutions.

The solution of dry Canada balsam and xylol is spread over the surface of the crystal portion to which it is desired to secure the tinfoil electrode. The solution is allowed to attain a tacky consistency, and the tinfoil is then applied and rubbed down with a hard cloth to provide an even layer of the cementing solution and to produce a burnishing effect on the electrode.

The unit is then placed in an oven having a

constant temperature of between thirty and fifty-five degrees centigrade for a sufficient period to evaporate the xylol from the solution, but the unit is removed before the balsam hardens. The length of time that the unit remains in the oven depends somewhat on the size of the crystal portion and the electrode area. A crystal portion having a surface area of about six square inches is preferably left in the oven for approximately one hour to drive off the xylol to the desired extent; however, due to varying conditions, such as the nature of the electrode, the amount of oven ventilation, temperature, etc., a shorter or longer period may be required. The unit is removed from the oven at the desired time and, as soon as the xylol has sufficiently evaporated, is positioned on a heated surface which is preferably about the same temperature as the oven.

While the unit is on the heated surface the tinfoil electrode is again rubbed down by a hard cloth, a sponge rubber pad, or other suitable material. It is preferable to heat the rubbing pad and to dust it with talc or some such material, which will prevent the rubbing pad from sticking to the electrode. By rubbing the heated unit with a warm pad the tacky balsam which has not yet hardened, is gradually smoothed down to a very thin layer and securely attaches the electrode to the crystal face with the desired small effective separation between them.

The term "effective separation" is utilized to define the mean separation between the crystal and the electrode. Because of the necessary unevenness and departure of the surface of the dielectric from a perfect plane, the separation of the electrode and the crystal is different in different places. It may be in actual contact at some points of the surface of the dielectric but separated at other points. This, however, can all be expressed as the equivalent or effective separation; that is, the uniform separation which would produce the same effect if both surfaces were perfectly plane.

The unit, after it has been rubbed down sufficiently, is removed from the heated surface and allowed to cool to room temperature.

Comparative capacity measurements on plates of crystalline Rochelle salts indicate that the effective thickness of film obtained is less than half of one ten-thousandth of an inch.

It is clear that by rubbing the electrode while the unit is warm, the cementing material is reduced to a minimum thickness, whereby the electrode is worked into very intimate contact with every portion of the crystal surface.

Furthermore, it is obvious that by reducing the cementing material to a minimum thickness in the manner described, the apparent capacity of the unit is materially increased so as to provide a very efficient unit.

It is further obvious that the characteristics of a unit having its electrodes firmly secured thereto in the manner described will remain substantially constant when subjected to alternating electromotive forces.

Similar results may be obtained by using a cement, which is a conductor when it has hardened, or by impregnating a cement with very small conducting particles such as carbon, graphite, or precipitated metal particles, and applying the electrodes in the ordinary manner to the conductive cement, since in this case the cement itself acts as a conductor and, due to its fluid nature, comes in intimate contact with the

crystalline plate. In this case both the electrode and cement are conductive and it is only necessary for the electrode to be in electrical contact with the cement, as is the case in the usual application of tinfoil electrodes.

The hereindisclosed piezo-electric units, produced by my improved method of applying electrodes to piezo-electric crystal portions, are not claimed herein since they constitute the subject of my copending application Serial No. 595,694 which constitutes a continuation in part of the present application.

It is to be clearly understood that the exact procedure of carrying out the method of the present invention as heretofore described may be varied without departing from the spirit and substance of the invention, the scope of which is commensurate with the appended claims.

What I claim is:

1. The method of attaching an electrode to a piezo-electric crystal portion, which comprises applying an adhesive substance between the crystal portion and electrode, rubbing the electrode, heating the crystal portion, and again rubbing the electrode.

2. The method of attaching an electrode to a piezo-electric crystal portion, which comprises applying a solution of resinous material to the crystal portion, drying said material to a tacky consistency, applying the electrode to the resinous material, and rubbing the electrode while applying heat to the opposite side of the crystal portion.

3. The method of attaching an electrode to a piezo-electric crystal portion, which comprises applying a solution of resinous material to the crystal portion, drying said material to a tacky consistency, applying the electrode to the resinous material, heating the unit thus formed, and then rubbing the electrode into contact with the crystal portion while maintaining the latter at a substantially constant temperature.

4. The method of attaching an electrode to a piezo-electric crystal portion, which comprises cementing the electrode to the crystal portion, rubbing the electrode to distribute evenly the cement, heating the crystal portion, and rubbing the electrode into intimate association with the crystal portion, thereby forming a film of cement of minute average thickness between the crystal portion and the electrode.

5. The method of attaching an electrode to a piezo-electric crystal portion, which comprises coating the crystal portion with an adhesive material, applying the electrode thereto, and then alternately rubbing the electrode and heating the crystal portion.

6. The method of attaching a flexible metallic electrode to a piezo-electric crystal portion, which comprises coating the crystal portion with a resinous cement, applying the electrode thereto, applying heat to the opposite side of the crystal portion and then rubbing the electrode into intimate association with the crystal portion while warm.

7. The method of applying a flexible metallic electrode to a piezo-electric crystal portion, which comprises coating the crystal portion with a resinous cement, drying said cement to a tacky consistency, applying the electrode thereto, forcing the electrode into intimate association with the crystal portion, heating the crystal portion, and rubbing the heated electrode, thereby forming a film of cement of minute average

thickness between the crystal portion and the electrode.

8. The method of applying a tinfoil electrode to a piezo-electric crystal portion, which comprises coating the crystal portion with a solution of dry Canada balsam and xylol, drying the solution to a tacky consistency, applying the electrode thereto, rubbing the electrode to uniformly distribute the solution, heating the crystal portion to evaporate the xylol, and rubbing the electrode into intimate association with the crystal portion while warm.

9. The method of attaching an electrode to a piezo-electric crystal portion, which comprises applying a solution of an adhesive to one of the surfaces, rubbing the electrode into intimate association with the crystal portion to provide an even layer of the adhesive, heating the unit thus formed for a sufficient length of time to evaporate the major portion of the solvent but for an insufficient time to harden the adhesive, and then applying an additional rubbing action to the electrode to reduce the thickness of the adhesive layer to the desired extent.

10. The method of attaching an electrode to a piezo-electric crystal portion, which comprises applying a solution of an adhesive to the surface of one of the elements, bringing the other element into contact with the coated surface of the first mentioned element, and rubbing the electrode to provide an even layer of the adhesive, heating the unit so formed to evaporate the solvent, and then applying an additional rubbing action to the electrode to reduce the thickness of the adhesive layer to the desired extent.

11. The method of attaching an electrode to a piezo-electric crystal portion, which comprises applying a solution of a resinous material to the surface of one of the elements, bringing the other element into contact with the coated surface of the first mentioned element, rubbing the electrode to provide an even layer of the adhesive material, heating the unit so formed to evaporate the solvent, and then applying an additional rubbing action to the electrode to reduce the thickness of the adhesive layer to the desired extent.

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