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PIEZO-ELECTRIC CRYSTAL

Filed Jan. 27, 1932

FIG. 1

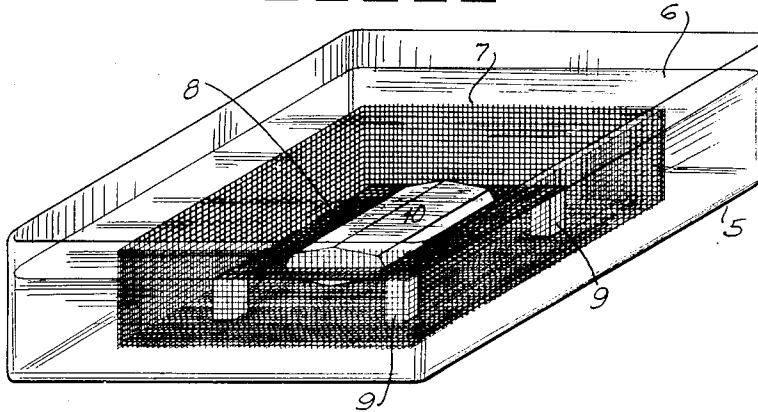


FIG. 2

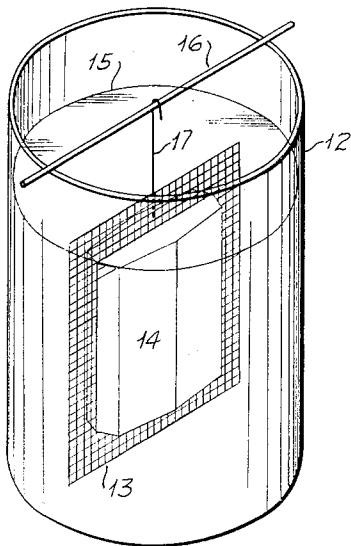


FIG. 3 FIG. 4

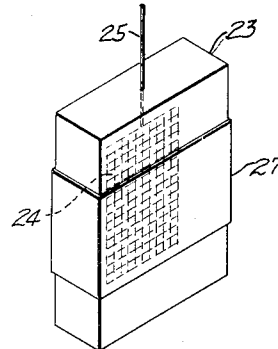
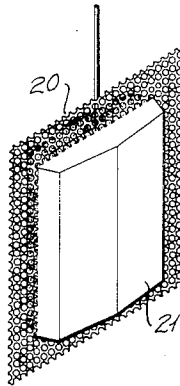


FIG. 5

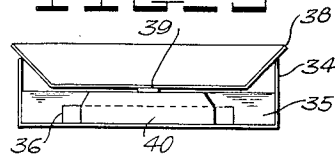


FIG. 6

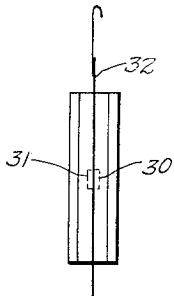
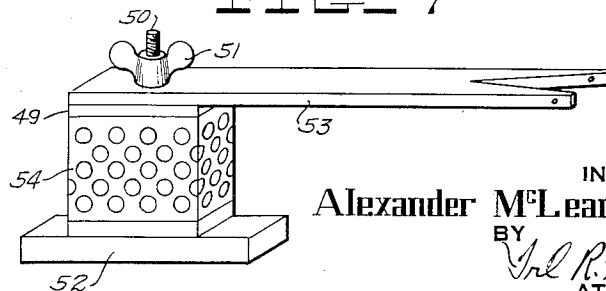


FIG. 7



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PIEZO-ELECTRIC CRYSTAL

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10 Claims. (Cl. 171—327)

This invention relates to the transformation of one form of energy into another, especially where the forms of energy are electrical current waves and sound waves.

5 An object of the invention is to efficiently transform electrical energy into mechanical or acoustic energy, or vice versa.

Another object of the invention is to produce a sensitive, efficient, simple, and durable piezo-electric crystal for transforming energy from one form to another.

10 A further object of the invention is to produce a unitary piezoelectric crystal device which after growth is complete, for connection into electrical circuits.

15 It has been known for some time that crystals of certain substances such as Rochelle salt, quartz, tourmaline and the like, produce an electromotive force if subjected to physical stress or movement, and consequently produce physical stresses or movement in response to the impression of an electromotive force upon them. Such crystals are capable of wide use and application in the electrical arts and particularly in those arts which deal with the generation, transmission, and utilization of alternating currents or potentials whether of audible frequency or of the highest radio frequency. It has been found that a crystal of Rochelle salt (sodium potassium tartrate, $\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$) has the largest piezo-electric constant, approximately 10 electrostatic units per kg. Apparently no other crystal has yet been found to approach the piezoelectric activity of Rochelle salt, particularly if the crystal is carefully chosen and specially prepared. Rochelle salt is susceptible to greatly increased piezoelectric activity to the extent that at an absolute electric charge of 200 electrostatic units per kg. potentials as high as 500 volts and alternating currents as high as 20 micro-amperes have been obtained. Acoustic tones from such a crystal may be heard at a distance of several hundred feet. To obtain such activity, however, it is necessary to make the proper contact between the crystal poles and the external circuit.

20 In an article published in the "Proceedings of the Institute of Electrical Engineers", November 1919, I described the various methods of preparing Rochelle salt crystals having the above sensitivity and pointed out that each crystal has two end poles, or poles of like sign, the basal plane being perpendicular to the principal axis and an equatorial or girdle pole of the opposite sign orthogonal thereto comprising the remaining faces of the crystal. I have also disclosed meth-

ods of, and means for attaching electrodes to these poles, such as by gluing or wrapping strips of tinfoil about the crystal to form loops or bands, and by inserting mercury within the crystal and sealing up the opening.

60 The present invention contemplates an improved method of, and means for making connections between the poles of the above described crystals and electrical elements in a circuit in which the crystal is placed. In brief, the desired crystals are produced by growing them from seed crystals placed in a solution of mother liquor similarly to that disclosed in my United States Patent No. 1,590,311 of June 29, 1926, while the electrodes to be used with each crystal are placed in the mother liquor in such a position that when the crystal grows by the cooling of the liquor the electrodes are embedded therein making intimate contact with the crystal. This may be accomplished in several ways to be fully described hereinafter, such as by positioning electrodes of screen mesh or punched material supported within the liquor, or by attaching seed crystals upon such electrodes and suspending them in a solution of the mother liquor. By thus growing a crystal the electrodes thereof become an integral part of the crystal element being interlaced therethrough providing an electrical generator of maximum efficiency, if the crystal is so used. When the crystal is used as the transformer of energy from the mechanical state to the electrical form, the crystal will also function at its highest efficiency as the perfect contact between the crystal and external circuit prevents the usual electrode losses.

70 The invention will be more fully understood both as to its fundamental principles and to its practical application by reference to the following description taken in conjunction with the accompanying drawing, in which:

75 Figs. 1 and 2 show two methods of growing crystals with embedded electrodes.

Figs. 3 and 4 show mesh structures and how they are embedded in the crystals by the method shown in Fig. 2.

80 Fig. 5 shows another method of growing a crystal from seed.

Fig. 6 is a view of an embedded electrode showing the seeds or seedlings from which the crystals were grown; and

85 Fig. 7 shows a mounted crystal.

Referring now to Fig. 1, a suitable container such as a glass crystallizing dish 5 contains the mother liquor 6 in which are submerged two electrode screens 7 and 8. Electrode screen 8 is

shown supported from the bottom of the dish 5 by means of posts or beads 9 which may rest upon the bottom of the electrode 7, the latter being shown in the form of a box similar to the shape of the dish 5, but which may be solely a flat plate similar to the electrode 8. The electrode 7 may also have a cover similar to the bottom thereof to form a complete closure and a girdle electrode. A crystal 10 is shown partially grown with the electrode 8 embedded through the center thereof. The crystal eventually increases in size until the bottom of the electrode 7 is also embedded in its lower surface in the same manner as electrode 8 thereby forming electrodes for the crystal poles. When the electrode 7 has an upper surface this portion will also be interlaced through the face of the crystal in the same manner as electrode 8. After the crystal has reached a stage of growth where it rests upon the bottom electrode the posts 9 may be removed and the crystal growth continued to the sides of the electrode 7. However, if any particular size is desired the crystal may be removed from the mother liquor at the time this growth is reached. By adding new liquor to that in the container 5 the crystal embeds both electrodes, the crystal appearing substantially in the shape of crystal 10, but larger. As described in the above mentioned patent, the crystal in dish 5 is formed with its *b* and *c* axes in a horizontal position, the growth along these axes being dominant while development along the vertical *a* axis is suppressed by the surface of the liquor and the bottom of the dish. The taper effect is produced by the gradation in density of the solution of the mother liquor. The proper orientation is obtained by positioning a seed crystal, which is usually a cropping of a crystal, with the axes as described, the dimensions being a function of the density and head of the liquor. A single seed may be placed on top of the electrode 8 and the crystal grown therethrough, or two seeds, one on either side of the electrode can be used.

Referring to Fig. 2, a crystallizing dish 12 has suspended therein a grid like electrode 13 with a partially grown crystal 14 attached, the crystal having substantially equal portions on either side of the electrode. This crystal of course may be used as shown with a second other electrode being attached to the opposite faces, or growth may be continued until it entirely encloses the electrode 13. The crystal 14 is grown from a seed or seeds attached to the screen in the same manner as discussed above in Fig. 1, the *a* axis now being horizontal, the crystal having a tendency to take more of a square form. The grid 13 is supported on a crossbar 16 suspended from the hook 17, this hook being used afterwards as a conductor.

Fig. 3 shows a crystal grown in the manner just described but in which an electrode 20 is of punched material such as aluminum, platinum, copper, silver, and the like, these materials being chosen for their inactive properties when in contact with the sodium potassium tartrate, copper however, being the most active of those mentioned above but which is a satisfactory material. The mesh electrodes of Figs. 1 and 2 are preferably of these materials. The crystal 21 may be used at the size in the drawing or may have its growth continued until it is entirely embedded in the crystal as shown in Fig. 4.

In Fig. 4 a crystal 23 entirely surrounds a mesh electrode 24 connection therewith being made through a conductor 25 which may have constituted its support in the mother liquor. The girdle pole is contacted with by means of an electrode 27

which surrounds the crystal, and which may have been placed thereon after complete growth, or which may have been suspended in the mother liquor along with the electrode 24, the crystal grown within the electrode.

In Fig. 6 a side view of the crystals in Figs. 2, 3, 4, shows two seed crystals 30 and 31 positioned on electrode 32 and from which the crystals were grown. By the proper orientation of these seeds, the grown crystal structure will exhibit comparatively large stresses and deformations per unit of applied voltage.

Referring now to Fig. 5 another method of growing crystals with embedded electrodes is shown. The crystallizing dish 34 has therein a quantity of mother liquid 35 and an immersed electrode 36. A V shaped dish 38 has fastened to its underside by any suitable means a properly oriented seed crystal 39 which may be positioned above the mother liquor but in contact therewith. From this seed 39 a crystal 40 will result which emerges through the mesh and continues its growth to the bottom of the dish 34. By maintaining the saturation and level of the liquor constant a substantial square crystal may be obtained such as shown in Fig. 4. A girdling electrode may be placed around the crystal 40 after growth as shown in Fig. 4.

The structure in which any of the crystals grown by any of the above methods may be used is shown in Fig. 7. In this figure a crystal 49 has its internal pole connected to an external circuit (not shown) through a bolt 50 which contacts with the embedded electrode. This bolt passes through the crystal and by the aid of a thumbnut 51 serves as a clamping support for the structure which includes a base plate 52 and a mechanical transmission lever 53. The connection to the external pole of the crystal is through an electrode 54 of punched material encircling the crystal as shown in Fig. 4, the crystal having been grown within the electrode. In such a crystal structure torsion produced therein will be transmitted along the bar 53 to a working element such as a diaphragm which may be attached to one prong of the fork by a screw through the holes. Conversely mechanical movements of the bar 53 will be transferred to the crystal to generate potential differences which will be produced between the electrodes 50 and 54.

Although only a few specific embodiments of the invention have been disclosed above, it is to be understood that there are other methods of producing piezoelectric crystals with electrodes integral therewith in accordance with the principles set forth above which will occur to those skilled in the art.

The scope of the invention, however, is defined by the appended claims.

What is claimed is:

1. A piezoelectric crystal having a plurality of embedded electrodes positioned at the electric poles of said crystal and integral therewith, said crystal having been grown in a solution immersing said electrodes.

2. A piezoelectric crystal having a principal axis, an electrode positioned along said axis, said electrode having a mesh formation the interstices of which have been filled with said crystal by growth.

3. A piezoelectric crystal having a principal axis, a mesh electrode positioned along said axis the interstices of which have been filled with said crystal by the growth thereof, and a second mesh electrode near the outer surface of said crystal

the interstices of which have been filled with said crystal by the growth thereof.

4. The method of growing a piezoelectric crystal with embedded electrodes comprising placing one of said electrodes near the bottom of a vessel, supporting a second electrode upon said first electrode, and bringing a seed crystal in contact with said second electrode.

5. The method of growing piezoelectric crystals with electrodes integral therewith comprising supporting said electrodes in a saturated solution of mother liquor in the positions desired for the finished crystal, and beginning the growth of said crystals by attaching a seed crystal to at least one of said electrodes.

6. The method of constructing a piezoelectric crystal having electrodes integral therewith comprising positioning perforated metallic electrodes in a solution of concentrated mother liquor and beginning the growth of said crystal by attaching a seedling to at least one of said electrodes.

7. A piezoelectric crystal grown from a solution of sodium potassium tartrate having a plurality of electrodes integral therewith and positioned at the poles of said crystal.

8. In a piezoelectric crystal having a rectangular configuration, an electrode embedded near the central portion of said crystal having interstices through which the crystal has grown, and a second electrode positioned in the outer portion of said crystal, said electrodes being positioned at the electric poles of said crystal.

9. In a piezoelectric crystal having a principal axis, a mesh electrode positioned along said axis through which the crystal has grown and a second electrode having a mesh formation located in the outer portion of said crystal, said crystal having been grown through said second electrode.

10. A piezoelectric crystal having a principal axis, a mesh electrode positioned along said axis the interstices of which have been filled by said crystal growing therethrough, and a second mesh electrode on the outer surface of said crystal, the interstices of which have been filled by said crystal growing therethrough, said electrodes being at the electrical poles of said crystal.

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