

UNITED STATES PATENT OFFICE

ALEXANDER McLEAN NICOLSON, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO FEDERAL TELEGRAPH COMPANY, A CORPORATION OF CALIFORNIA

COMPOSITE PIEZO-ELECTRIC CRYSTAL DEVICE

Application filed December 20, 1926. Serial No. 155,898.

This invention relates to a piezo-electric device, adapted and arranged to be utilized in connection with electric circuits, and to a method of producing the same. It has been known for some time that crystals of certain substances such as Rochelle salt, quartz, tourmaline, and the like, produce an electro-motive force if subjected to physical stress or movement, and conversely, produce physical stresses or movement in response to the impression of an electro-motive 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. Many of such uses are particularly pointed out in patent No. 1,495,429 granted to me on May 27, 1924.

In the past, difficulties have been encountered in the use of comparatively large crystals, and crystals of unusual shape whether natural or grown. It has been found comparatively difficult to obtain and maintain large crystals in the case of crystals made by growth from a solution of the mother liquor, such as Rochelle salt crystals. The large crystals require more time to grow than the small ones, and moreover, they seem to be considerably more fragile and tend to develop cracks and flaws even before the crystals have been effectively cured and hardened.

In the case of natural crystals such as quartz and tourmaline, etc., it is clear that the difficulty and expense of preparing crystals increases greatly with the size, and the liability of accidental injury in the use of the crystal is much greater.

It is an object of this invention to provide a piezo-electric element and a method of fabricating the same whereby the element may be given any desired size, shape, and natural frequency, by utilizing fragments of crystals, small crystals, nuclei, and the like secured together to form a single entity so that the piezo-electric effect of the components may be integrated.

It is a further object of this invention to provide a composite piezo-electric crystal and

a method of fabricating the same, whereby a piezo-electric crystal of comparatively large size or of unusual dimensions or proportions may be produced, without the delay incident to the growth and curing of such crystals, and without the time, expense, and wastage involved in cutting and grinding natural crystals; which fabricated crystals may be of the most efficient ratio of length/depth consistent with mechanical strength of the resultant structure.

It is a further object of this invention to provide a crystal and a method of producing the same which shall be relatively strong and rugged and not easily subject to breakage if handled roughly.

It is a still further object of this invention to provide a crystal and method of producing the same from fragments and waste pieces incident to the handling of crystals. Still other objects of my invention will be apparent from the specification.

The features of novelty which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its fundamental principles and as to its practical embodiments, will best be understood by reference to the specification, and accompanying drawing, in which:

Fig. 1 is a view of a composite piezo-electric crystal in process of construction according to my invention,

Fig. 2 is a view of the same after completion,

Fig. 3 is a diagrammatic view showing the principles to be followed in assembling a composite crystal according to my invention,

Fig. 4 is a diagrammatic view of a composite crystal fabricated according to my invention, showing the method of arranging electrodes, and Fig. 5 is a diagrammatic view similar to Fig. 4, but showing a modified arrangement of electrodes.

In accordance with my invention, I provide a crystal of any desired size and shape, and of any desired natural frequency, and adapted to one, two, or three modes of vibration; that is, longitudinal, transverse, or torsional, by fabricating it from crystal frag-

ments, units, or nuclei, by properly choosing the fragments, units or nuclei, and by assembling them in a manner to be hereinafter explained, and securing them firmly in the desired position, as for example by clamping, or by setting the crystals into, or arranging upon them, a matrix or binder of the proper nature to hold the crystals firmly, and having the same elastic properties as the crystals so that stress waves are transmitted there-through and impressed upon each of the crystal components.

In addition, I provide mechanical or electrical connections between the crystals, and also provide the necessary electrodes arranged in the proper manner so that the piezo-electric effects of the various crystals may be integrated and utilized. For example, in the case of Rochelle salt crystals, the crystals are arranged with their A, B and C axes respectively parallel. It is understood, however, in the case of crystals which are found in "right-handed" and "left-handed" crystals, which may be distinguished from each other as is known in the art, it is necessary in fabricating a crystal according to my invention, to utilize all of one species of crystal.

Accordingly, whether the composite crystal is desired for a transmitter or receiver, that is, for generator or motor operation, groups or clusters of crystals of any or differing time constant, electrical or mechanical, may be connected electrically or mechanically together, all their girdles being electrically integrated in association with their electrically connected basal planes at one or both ends; any volumetric crystal structure may be mechanically grouped, preferably in part cemented or clamped together or both, in any configuration, of a plurality or multiplicity of crystal fragments, units, or nuclei, or crystals of such size as to be inconvenient for mounting and use by methods heretofore known in the art. The cement, binder, or matrix may be a suitable fluid medium which may be poured around the component parts, and permitted to solidify, such as hard wax, and which will not destroy the crystal fragments, or it may be a piezo-electrically active medium, such for example as Rochelle salt cement, comprising Rochelle salt from which about one fourth of the water has been removed by heating. Care should be taken in selecting the cement, binder, or matrix to choose one having correct longitudinal and other elastic properties for the necessary transmission of stress waves to all the assembled crystal units.

The crystal fragments, units, or nuclei from which the composite crystal is to be fabricated may for example be properly selected with reference to constitution, and properly arranged and oriented within a mold of the shape of the crystal desired to be pro-

duced. Provision is made for the connection of electrodes, which will preferably be molded in place upon the individual crystals, and likewise provision is made for terminals to or from which the charges may be led from or to the individual crystals.

After the various component crystals have been properly arranged in the mold as described, the binder may be poured upon the crystals and allowed to congeal, thereby securing the assembly of component crystals into one single physical entity, which may be handled as a single crystal. It will be clear that such composite crystals may be built up to possess, as a monolithic structure, any desired natural frequency. Likewise, they may be built up or finished in any shape suited to one or two or three modes of vibration, longitudinal, transverse, and torsional. Also, the electrodes, as will be understood, may be applied externally, even insulated from the crystals, or may, as already stated, be found within the structure.

The binder or matrix, as already stated, may be piezo-electrically inactive, such for instance as hard wax, in which case the space in the mold will be filled as far as possible with crystal fragments, or it may be piezo-electrically active, such as Rochelle salt "melt," comprising Rochelle salt which has been heated to a temperature controlled according to the amount of water of crystallization which it is desired to retain in the "melt," in which case the binder molecules themselves may largely constitute the crystal, being oriented and integrated, as for instance by the provision of a relatively small number of crystals, used as "seeds," in contact with the liquid mass of Rochelle salt "melt" while the latter is solidifying. It is obvious that the method of using "seed" crystals for orienting the particles of piezo-electrically active substances during solidification may be applied to other such substances besides Rochelle salt.

Referring now to Fig. 1, 3 designates a mold within which the composite crystal is to be prepared, and as already stated, it may be of any desired shape and size, although herein shown as rectangular. A stream of binder 2 is poured from a suitable container 1 into the mold 3 around, about and over crystal 4, having electrodes 5 and 6 affixed thereon on opposite sides, crystal 10, having electrodes 11 and 12, preferably of wire mesh or metal foil, on opposite sides thereof, and crystal 16 having electrodes 17 and 18 on opposite sides thereof. Electrodes 5 and 6 are provided with conductors 7 and 8 connected thereto, electrodes 11 and 12 with conductors 13 and 14, and electrodes 17 and 18 with conductors 19 and 20. Leads 7, 13, and 19 may be connected together, as also leads 8, 14, and 20, whereby the piezo-electric action of the various components is integrated.

After the binder has "set," the composite crystal may be removed from the mold and will present the appearance of Fig. 2. It will be apparent that it may be handled just as if it were a single crystal. In fact, in the case of large or odd shaped crystals, it is clear that my composite crystal is physically very much stronger than a corresponding single crystal and may be handled with much less care, since it is less expensive and easier to reproduce.

Referring now to Fig. 3, I have shown diagrammatically the proper grouping of a number of crystal fragments, units, or nuclei, wherein reference character x designates the analogous poles and y the antilogous poles of the individual portions constituting a composite element. The crystal units are selected having opposite poles by which the crystal units are oriented to the relationship designated in Fig. 3. The crystal units are positively secured in the selected relationship illustrated in Fig. 3 while the binder is being poured around the elements and until the binder has commenced to congeal at which time the securing means may be withdrawn without dislocation of the crystal elements.

Referring now to Fig. 4, I have shown a number of crystals 22, 23, 24 and 25, grouped to form a composite crystal, the individual crystals being provided with electrodes on opposite poles, such as 26 and 27 on crystal 22, and corresponding electrodes on the crystals 23, 24 and 25. The corresponding electrodes 26, 28, 30 and 32, are connected together through master conductor 34, and similarly electrodes 27, 29, 31 and 33 are connected together through master conductor 35. It will be seen that by impressing stress waves upon the composite crystal, each of the component crystals will be subjected to stress and the piezo-electric effects will be integrated. Similarly, by subjecting the electrodes 34 and 35 to fluctuating potentials, such potentials will be impressed upon the individual crystals, and the motional or stress effect of all the crystals will be integrated.

Referring to Fig. 5, I have shown the crystals 22, 23, 24 and 25 as before, but in this instance the crystals are provided with girdle electrodes, and have their basal planes electrically connected. For example, crystal 22 is provided with girdle electrode 36, and end electrode 37, crystal 23 with girdle electrode 38 and end electrode 39, crystal 24 with girdle electrode 40 and end electrode 41, and crystal 25 with girdle electrode 42 and end electrode 43. The girdle electrodes 36, 38, 40, and 42 are connected to master conductor 34, and the end electrodes 37, 39, 41 and 43, are connected to master conductor 35, from which it will be seen that, as before, the piezo-electric effect of the component crystals is integrated.

It is to be understood that other arrangements of crystals and electrodes are possible

in addition to those herein shown, the figures showing by way of example some of the arrangements which may be utilized in accordance with the principles herein set forth. It will be apparent that modifications and changes may be made without departing from the spirit and scope of my invention, as will be apparent to those skilled in the art. More particularly, while I have shown in the figures definite numbers of crystals, it will be understood that this is merely by way of example and that any number of component crystals of heterogeneous shape and size may be used.

It is also to be understood that while I have described in detail the assembling of component Rochelle salt crystals into the composite device, that this is by way of example, and that it is within the scope of my invention to use fragments of quartz, tourmaline and other substances, and that in each case the particular binder to be used will be chosen with respect to the crystal components with which it functions.

I claim:

1. A piezo-electric device comprising a plurality of optically similar piezo-electric crystals of heterogeneous size and shape physically secured in a single entity by means of a homogeneous binder surrounding each of said crystals and extending between the interstices with their principal axes parallel to each other, said crystals being completely embedded in said binder.

2. A composite piezo-electric crystal comprising a plurality of piezo-electric crystals of heterogeneous size and shape completely embedded in an elastic matrix, said crystals being oriented so that their corresponding principal optical axes are respectively substantially parallel each to each and being electrically connected so that the piezo-electric effects of said crystals are integrated.

3. A piezo-electric device comprising a plurality of optically similar piezo-electric crystals completely embedded in a matrix of elastic properties similar to those of said crystals, said crystals being oriented so that their corresponding principal optical axes are respectively substantially parallel each to each and being electrically connected so that piezo-electric effects of said crystals are integrated.

4. A piezo-electric device comprising a plurality of piezo-electric crystals secured in a matrix to form a single entity, said matrix completely surrounding said crystals and filling the interstices therebetween, said crystals being oriented so that their corresponding principal optical axes are substantially parallel respectively each to each, and said crystals being electrically connected so that the piezo-electric effects of said crystals are integrated.

5. A piezo-electric device comprising a plurality of piezo-electric crystals secured in a matrix to form a single entity, said matrix

being composed of piezo-electrically active material derived from materials having piezo-electric properties similar to the piezo-electric properties of said crystals, said crystals being oriented so that their corresponding principal optical axes are substantially parallel respectively each to each, and said crystals being electrically connected so that the piezo-electric effects of said crystals are integrated.

6. A piezo-electric device comprising a plurality of piezo-electric crystals secured in a matrix to form a single entity, said matrix being composed of piezo-electrically active material derived from materials having piezo-electric properties similar to the piezo-electric properties of said crystals, said matrix having its constituent particles oriented optically in substantially the same manner by contact during solidification from a liquid state with one or more seed crystals of the material from which said piezo-electrically active matrix is derived, said first mentioned crystals being oriented so that their corresponding principal optical axes are substantially parallel respectively each to each, and said crystals being electrically connected so that the piezo-electric effects of said crystals are integrated.

In testimony whereof I hereunto affix my signature.

ALEXANDER McLEAN NICOLSON.

35

40

45

50

55

60

65