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PIEZOELECTRIC DEVICE

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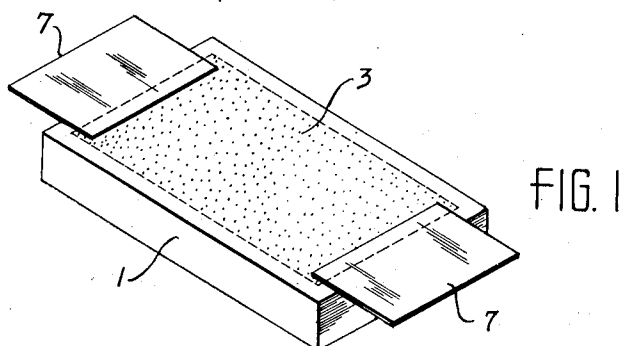


FIG. 1

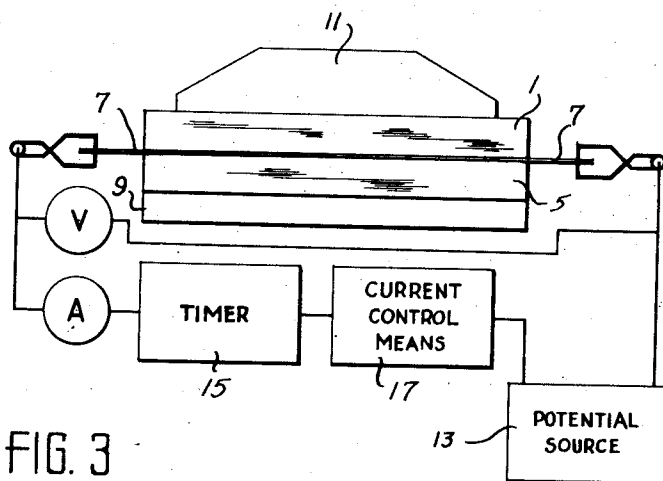
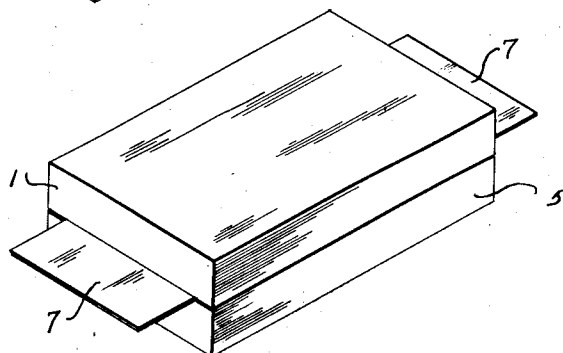


FIG. 3

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PIEZOELECTRIC DEVICE

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This invention relates primarily to piezoelectric devices and, more particularly to methods of manufacturing transducer elements of the type constituted by two or more crystal sections affixed to each other for mutual constraint and provided with suitable electrodes. The invention also relates to the joining together of fusible or thermoplastic non-conductive materials of all kinds, such, for example, as cellulose acetate, "Vinylite," or the like.

If information is desired with respect to the theory underlying the operation of transducer units of the types to which this invention primarily pertains, attention may be directed to the United States reissue patents to C. B. Sawyer, Re. 20,213, and Re. 20,680. When constituted by two sections cemented together for mutual constraint, units of the type shown in the Sawyer patents are generally known to the public under the registered trade-mark "Bimorph," and are also called "multiplate flexing elements." Previous to the cementing together of the sections constituting a multiplate flexing element, the major faces thereof are usually provided with conductive electrodes of colloidal graphite in accordance with the method disclosed in the United States patent to Alfred L. W. Williams, No. 2,106,143, to which appropriate lead extensions are affixed.

Multiplate flexing elements may also be fabricated in accordance with the teaching of the United States patent to J. H. Ream, No. 2,266,333; when so made they are considered to have advantages not attainable by the Williams' method although the electroded surfaces of the individual sections are cemented to each other in the usual manner.

The step of cementing the crystal sections together obviously involves a definite labor and material cost. Furthermore, no cement giving entire satisfaction has been discovered although many kinds, including pre-melted crystalline material itself, have been tried.

It is an object of this invention, therefore, to provide an improved piezoelectric unit that shall be devoid of cement between the opposed surfaces of the constituent crystal sections.

Another object of the invention is to provide a method of fabricating piezoelectric units of the type described.

Another object of the invention is to provide a method of fabricating piezoelectric units of the type described, whereby the individual cost thereof shall be lessened.

A still further object is to provide a method

of joining together structural elements or sections of a fusible, electrically non-conducting material such as cellulose acetate, "Vinylite," "Styron," and the like.

For convenience in describing and claiming the invention, Rochelle salt and piezoelectric crystalline mixtures isomorphous therewith will be designated "R-type" material; primary phosphates, primary arsenates and piezoelectric crystalline mixtures isomorphous therewith will be designated "P-type" material. Inasmuch as the invention has achieved marked success in connection with Rochelle salt and with primary ammonium phosphate those compounds will be referred to particularly hereinafter in disclosing the invention, but the reference thereto is not to be construed as a limitation because the invention is applicable equally as well to all other fusible piezoelectric materials.

The term "section," as employed hereinafter, is to be construed as meaning either a plate cut from a crystal of fusible piezoelectric material or as defining a structural element of any fusible or thermoplastic material that is substantially a non-conductor of electricity, such, for example, as the materials enumerated above.

The improved method, as practiced in the fabrication of a multiplate flexing element from two R-type crystal sections, or from two sections of P-type material, having planar faces, preferably comprises four steps, namely:

1. Depositing a colloidal graphite electrode on one face of one section or on one face of each section.

2. Positioning the said planar faces in contact with each other so that the graphitic material is disposed between them, and providing conductive lead-ins at opposite ends of the said material.

3. Pressing said electroded surfaces together while passing an electric current through the graphite layer by way of the lead extensions, the duration of current-flow and the amplitude of the current being just sufficient to cause melting of the crystal sections adjacent to the electroded surfaces.

4. Discontinuing the application of potential and thereafter maintaining pressure on the sections until they have cooled.

The novel features considered characteristic of the invention are set forth with particularity in the appended claims. The method itself, however, together with further objects and advantages of the resulting product, will best be understood from a consideration of the following de-

scription thereof, when read in connection with the accompanying drawing, in which:

Figure 1 is a view in perspective of a crystal section, having a colloidal graphite electrode to the opposite ends of which a lead extension has been applied;

Figure 2 is a view in perspective of a partially completed piezoelectric unit that has been constructed according to this invention, and

Figure 3 is a diagrammatic, conventionalized view exemplifying the method of the invention.

In all figures of the drawing, identical elements are similarly designated.

Referring now to Figures 1 and 2, in fabricating a multiplate flexing element according to the invention one face of a section 1 of piezoelectric material, either R-type, such as Rochelle salt, or P-type, such as primary ammonium phosphate, is provided with a restricted surface coating 3 of colloidal graphite or the like, preferably by following the method outlined in the Williams' patent. A similarly dimensioned section 5 of crystalline material is then selected, which may or may not be provided with a similar graphitic coating, depending upon whether a high or a low electrode resistance is desired in the finished product.

After thoroughly drying the coating or coatings the sections are placed together in face-to-face relation, with the surfaces to be joined in contact with each other and in registry, to form a stack as shown in Figure 2. At the time the stack is formed the unit may be provided with two lead extensions 7 of metallic foil, the inner ends of which, respectively, are disposed in conductive contact with the opposite ends of the graphitic material. Alternatively, as illustrated in Figure 1, the lead extensions may be affixed to one of the electroded sections in advance of forming the stack. If cement of any sort is utilized for holding the extensions in place it should be confined to the uncoated margin of the crystal face and not be interposed between the extension and the graphite layer.

Referring now to Figure 3, after the stack has been formed, it is placed upon a smooth supporting surface 9, preferably heat conductive, and the electroded faces of the sections are urged toward each other by appropriate means, such, for example, as a metallic weight 11. Thereafter, the lead extensions are connected to a suitable source of potential 13, alternating or unidirectional, and electric current is caused to flow through the graphitic material for the purpose of generating heat sufficient to fuse the crystal substance directly adjacent thereto. An automatic timer 15 and a potential regulating device 17, such as a rheostat or the like, may be interposed in the heating circuit for so limiting the current and the duration thereof that damage is not done to the sections.

It is substantially impossible to give specific values of current necessary for satisfactory operation, or to state the length of time that the current should flow in all instances. These factors can be determined only by experiment, inasmuch as they depend upon the resistance of the graphite layer, the dimensions of the crystal sections and the particular piezoelectric material employed.

It may be stated in general, however, that it is preferable to maintain a relatively high temperature over as short a time interval as possible, directly at the electroded surfaces, rather than to heat the electrodes to a lower temperature over a longer time period. The cooling of the unit, after

the welding operation is finished, also should be carefully controlled, if the sections are thin, in order to avoid cracking.

Merely by way of example, in manufacturing a multiplate flexing element approximately one inch square, the graphite layer had a thickness of approximately .0005", and was substantially co-extensive with the section faces in contact with each other. The resistance of the layer, from end to end, before the heating current was caused to flow therethrough, was of the order of 2,000 ohms and it required 45 milliamperes for several seconds to produce a satisfactory joint.

As a result of the heat and pressure, the fused layers of the sections coalesce, the graphitic material is permanently bonded to the lead extensions, and contact between the graphite and the crystal mass per se is improved. Also, quite contrary to expectation, the resistance of the graphite electrode may be kept at a satisfactory value although it is probable that the coalescing of the fused material interrupts the continuity of the layer to some extent.

Insofar as the character of the bond between the cooled sections is concerned, it is a matter of interest to note that the weld actually is stronger than the remainder of the crystalline mass and that it resists shearing stresses many times greater than the cements, heretofore employed, are capable of withstanding.

Instead of passing current directly through the graphite by conductively connecting it to a source of potential, it may be heated inductively by momentarily exposing the unit to an alternating electromagnetic field having the requisite frequency and density. Such alternative, being reasonably obvious in view of Gravley Serial Number 576,561, Arndt Serial Number 471,968, and Arndt Patent Number 2,388,242, has not been illustrated. Also, it is believed obvious that granular materials other than graphite may be utilized, if desired, and that the material may be dry or wet.

Outer electrodes may be applied to the unit either by following the method described in the Williams' patent, the method disclosed by Ream or by any other well-known method and the unit, thereafter, may be waterproofed as is customary.

From a consideration of the foregoing, it will be evident that the new method of joining crystal sections and of providing the unit with a central electrode is a decided improvement over methods heretofore known. Not only does it enable a substantial reduction to be made in the cost of labor and material, but the units produced thereby are very uniform and are appreciably more efficient and durable than those produced by previously known methods, such as those referred to hereinbefore.

As pointed out earlier in this specification the new method is not limited to the fabrication of crystalline multiplate flexing elements but it may also be employed for joining together plates or other structural elements, large or small, of other fusible materials that are substantially non-conducting. It thus lends itself, for example, to the production of laminated sheets of cellulose acetate if transparency is not required, or to the joining together of thermoplastic materials for which no satisfactory cement is available.

The inventor is fully aware of the fact that numerous modifications of the disclosed method will be apparent to those skilled in the art to which the invention pertains. The invention, therefore, is not to be limited except insofar as it

necessitated by the prior art and by the spirit of the appended claims.

What is claimed is:

1. The steps in a method of electroding the surface of a section of fusible piezoelectric matter, that comprise positioning on said surface a layer of granular electrically conductive material, heating said layer to a temperature sufficiently high to cause incipient fusion of the piezoelectric matter immediately adjacent thereto and discontinuing the heating before damage is done to the remainder of the section, whereby said layer is intimately bonded to the section to constitute an electrode therefor.
2. The method as set forth in claim 1, characterized in that the piezoelectric matter is taken from the group hereinbefore designated R-type.
3. The method as set forth in claim 1, characterized in that the piezoelectric matter is taken from the group hereinbefore designated P-type.
4. The method as set forth in claim 1, characterized in that the piezoelectric matter is Rochelle salt.
5. The method as set forth in claim 1, characterized in that the piezoelectric matter is a primary phosphate.
6. The steps in a method of joining together two structural elements of fusible material, that comprise providing a surface of at least one of said elements with a coating of granular electrically conducting material, bringing a surface of the other element in forcible contact with the coated surface, passing an electric current through said coating at such amperage and for such time as will cause fusion of the fusible material immediately adjacent to the coating, discontinuing the flow of current, maintaining the forcible contact until the fused material has substantially solidified, and thereafter discontinuing the application of force to the joined elements.
7. The method as set forth in claim 6, characterized in that the specific electrical resistance of the structural material is high with respect to the specific electrical resistance of the conducting material.
8. The steps in a method of fabricating transducer units from at least two sections of crystalline piezoelectric matter each of which has an extended substantially planar surface, that comprise positioning on at least one of said surfaces a layer of granular electrically conducting material, urging said surfaces toward each other to exert pressure upon said layer, causing an electric current to flow through said layer at such amperage and for such period of time as will occasion the heating thereof to a degree sufficient to cause fusion of the piezoelectric matter closely adjacent thereto, stopping the flow of current before fusion has extended to the remainder of each section, and thereafter permitting the unit to cool while maintaining the pressure.
9. The method as set forth in claim 8, characterized in that the piezoelectric matter is taken from the group hereinbefore designated R-type.
10. The method as set forth in claim 8, characterized in that the piezoelectric matter is taken from the group hereinbefore designated P-type.
11. The method as set forth in claim 8, characterized in that the piezoelectric matter is Rochelle salt.
12. The method as set forth in claim 8, characterized in that the piezoelectric matter is a primary phosphate.
13. The method as set forth in claim 8, characterized in that the piezoelectric matter is primary ammonium phosphate.
14. The method as set forth in claim 8, characterized in that the granular material is graphite.
15. A transducer assembly comprising a body of fusible piezoelectric matter, an electrode constituted by a layer of granular electrically conductive material and an autogenous joint connecting said body of piezoelectric matter to said electrode.
16. A transducer assembly comprising at least two bodies of fusible piezoelectric matter, an autogenous joint connecting said two bodies together, and an electrode of granular electrically conductive material substantially coextensive in area with the joint and integrally included therein.
17. A transducer assembly comprising at least two plates of fusible piezoelectric matter disposed in face-to-face relation, granular electrically conductive material interposed between said faces, said faces being united to each other and to said conductive material through a solidified autogenous joint.
18. An assembly as defined in claim 17, characterized in that the piezoelectric matter is taken from the group hereinbefore designated R-type.
19. An assembly as defined in claim 17, characterized in that the piezoelectric matter is taken from the group hereinbefore designated P-type.
20. The steps in a method of joining together two structural elements of fusible material, that comprises providing a surface of at least one face of at least one of said elements with a coating of granular electrically conducting material extending over less than the entire area of said face, bringing a surface of the other element in forcible contact with the surface having said coating, passing an electric current through said coating at such amperage and for such time as will cause fusion of the fusible material immediately adjacent to the coating including the uncoated fusible material to the side of said coating, discontinuing the flow of current, maintaining the forcible contact until the fused material has substantially solidified, and thereafter discontinuing the application of force to the joined elements.
21. The steps in a method of joining together two structural elements of fusible piezoelectric material that comprises providing a surface of at least one of said elements with a coating of granular electrically conducting material, placing a lead of electrically conducting material in engagement with said granular material at each of two spaced points, bringing a surface of the other element in forcible contact with said leads and with the surface having said coating, passing an electric current through said leads and through said coating at such amperage and for such time as will cause fusion of the fusible material immediately adjacent to the coating, discontinuing the flow of current, maintaining the forcible contact until the fused material has substantially solidified, and thereafter discontinuing the application of force to the joined elements.
22. An assembly comprising a body of fusible piezoelectric matter, an electrode constituted by a layer of granular electrically conductive material on a face of said body, said electrode layer extending over less than the entire area of said face, and an autogenous joint between said body and said layer.
23. An assembly comprising two bodies of fusible piezoelectric matter, an electrode constituted

by a layer of granular electrically conductive material on a face of at least one of said bodies, said electrode layer extending over less than the entire area of said face, and an autogenous joint connecting said two bodies together with said layer of granular material between said two bodies and integrally included in said joint, and said joint including the unelectroded area of said electroded face.

24. An assembly comprising two bodies of fusible piezoelectric matter, an electrode constituted by a layer of granular electrically conductive material on a face of at least one of said bodies, said electrode layer extending over less than the entire area of said face with the unelectroded area of said face defining a peripheral margin, an electrically conductive lead extension in contact with said electrode layer and extending over said unelectroded margin, and an autogenous joint connecting said two bodies together with said electrode layer between said two bodies and integrally included in said joint and with one end of said conductive lead extension between said two bodies.

25. The method as set forth in claim 1, further characterized in this: that electric current is passed through said layer to cause heating thereof by the resistance of the layer to the flow of current.

26. The steps in a method of joining together two bodies of fusible material, that comprises providing a surface of at least one of said bodies with a coating of comminuted material whose electrical conductivity is high compared to the electrical conductivity of said two bodies, bringing a surface of the other body in forcible contact with the coated surface, inductively passing an electric current through said coating for such time as will cause fusion of the fusible material immediately adjacent to the coating, discontinuing the flow of current, maintaining the forcible contact until the fused material has substantially solidified, and thereafter discontinuing the application of force to the joined bodies.

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