Aug. 23, 1949. A. L. W. WILLIAMS 2,479,987

MULTIPLATE ELECTROTRANSDUCER

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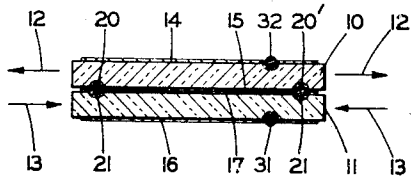


FIG. 1

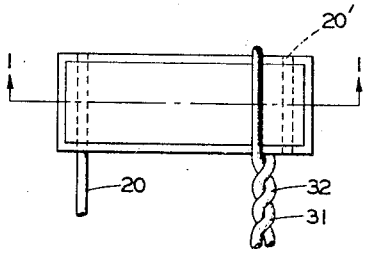


FIG. 2

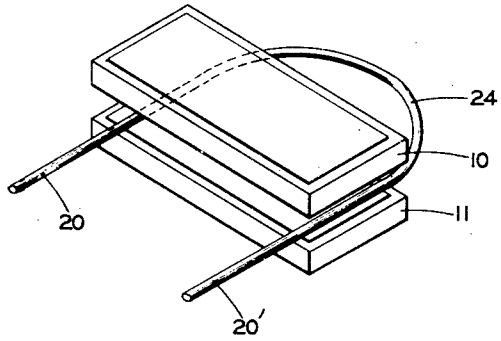


FIG. 3

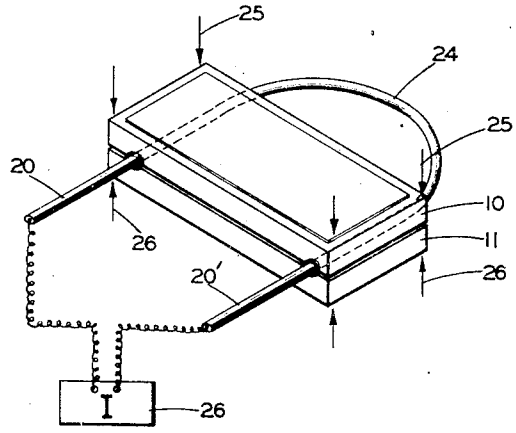


FIG. 4

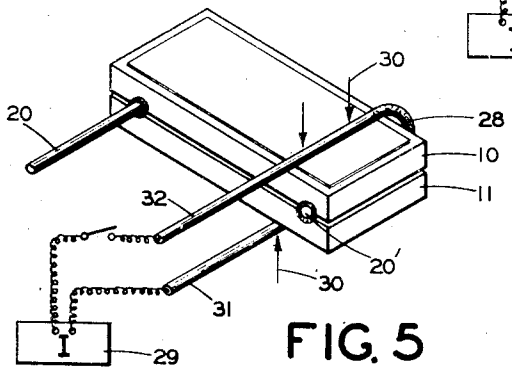


FIG. 5

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MULTIPLATE ELECTROTRANSDUCER

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11 Claims. (Cl. 171—327)

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This invention pertains to a new and novel electro-transducing element of the multi-plate type, and more particularly to a piezoelectric crystalline element.

In the prior art, multi-plate flexing type piezoelectric crystal elements have been fabricated by cementing two properly oriented plates together face-to-face with the cement substantially covering the entire area of the joined faces. It has also been proposed to connect the two plates of a bender type element together only at their ends, and to connect the two plates of a twister type element together only at their corners.

The present invention relates to a multi-plate construction wherein dowel pins are utilized to connect together localized areas of two plates, and to a method of applying the dowel pins. A somewhat similar method may also be utilized to apply leads to crystal elements of the single and multi-plate expander types, as well as to elements of the multi-plate flexing type. This method and novel articles of manufacture produced by the method are claimed in my application for United States Letters Patent Serial No. 779,268, filed concurrently herewith and assigned to the same assignee as the present invention. Application for United States Letters Patent Serial No. 779,327, filed concurrently herewith in the name of Charles K. Gravley and assigned to the same assignee as the present invention, describes and claims a crystal element and the process of making it which is similar in some respects to the present invention and to the invention of my mentioned copending application.

Theoretically, the most efficient multi-plate elements of the bender types are those wherein the two plates are connected together only at the ends, and the most efficient multi-plate twister elements are those wherein the two plates are connected together only at the corners. For a complete discussion relative to this, reference may be made to United States Letters Patent 2,373,445, issued on April 10, 1945, to Hans G. Baerwald, and assigned to the same assignee as the present invention. In the past, however, it has been somewhat impractical to manufacture these highly efficient multi-plate elements in large quantities due to the increased number of steps necessary in the process of fabricating them. The present invention greatly simplifies the manufacture of highly efficient multi-plate flexing type electro-transducers.

An object of the invention is to provide a multi-plate flexing type electro-transducer which does

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not exhibit one or more of the disadvantages of prior art transducer devices.

Another object of the invention is to provide a method of manufacturing multi-plate flexing type electro-transducers which is more economical than previous methods of manufacturing somewhat similar transducers.

An object of the invention is to provide a new and novel multi-plate flexing type electro-mechanical transducer.

Still another object of the invention is the provision of a new and novel transducer of the multi-plate flexing type which is more readily manufactured by automatic machining.

In accordance with a feature of the invention an electro-transducer comprises first and second plates of electro-transducing material, and a relatively rigid elongated member locally fused into the plates to maintain a portion of the plates at the rigid members relatively immovable when said material is used as an electro-transducer.

In accordance with another feature of the invention the method of fabricating a multi-plate piezoelectric crystal element comprises electroding both major faces of each of two expander plates of piezoelectric crystalline material, and laying two relatively rigid elongated members across the electroded face of the first of said plates with the direction of elongation substantially perpendicular to the direction of expansion of the plate. The second plate is then laid in substantial registration on the first plate with the elongated member therebetween and in contact with the electroded face of each of the plates. The elongated members are then heated to a temperature above the melting temperature of the crystalline material and the two plates are pressed together to cause crystalline material in the immediate vicinity of the elongated members to melt and to be embedded into each of said two plates. Thereafter the elongated members and the melted crystalline material are cooled.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

The single sheet of the drawing shows in Fig. 1 a cross-sectional view taken along line 1—1 of Fig. 2 of a multi-plate crystal element embodying the invention; Fig. 2 is a face view of the element shown in Fig. 1; Fig. 3 is an exploded isometric view showing one step in the construction of the element shown in Figs. 1 and 2; Fig.

4 is an isometric view showing another step in the process of constructing the element shown in Figs. 1 and 2; and Fig. 5 shows still a further step in the construction.

Referring to Fig. 1 of the drawing, there is shown an electro-transducer element comprising two plates of fusible piezoelectric crystalline material 10 and 11, such as Rochelle salt, primary ammonium phosphate, or the like, connected together to form a multi-plate flexing element of the general type disclosed in the United States Letters Patent Re. 20,680, granted to Charles B. Sawyer on March 29, 1938, and assigned to the same assignee as the present invention. While the invention is herein illustrated as applied to a flexing type of crystal element, it is to be understood that it is equally applicable to other types of electro-transducers such as single plate transducers and multi-plate expander transducers.

The element shown in Fig. 1 is known as a "bender multi-plate crystal unit" because the plate 10, upon being subjected to a given electrostatic field, is adapted to expand in the direction of the arrows 12, 12, and the plate 11, upon being subjected to an electrostatic field, is adapted simultaneously to contract in the direction of the arrows 13, 13, thereby causing a bending action of the interconnected plates 10, 11.

The piezoelectric plate 10 carries electrodes 14 and 15 on its opposite major faces, and the plate 11 carries electrodes 16 and 17 on its opposite major faces for applying the electrostatic field to the transducer plates 10, 11. As is well known to the art the plates 10, 11 may be connected in parallel or in series, depending upon the requirements which the element must fulfill. In the drawing the two plates 10 and 11 are shown connected in parallel. Their major faces are in juxtaposed face-to-face relationship with the electrode 15 of plate 10 in electrical contact with electrode 17 of plate 11, and with a lead 20 in contact with the inner electrode means 15, 17 and with a lead 32, 31 in contact with the outer electrode means 14, 16.

One or more rods 20, 20' are positioned between the two transducer plates 10, 11 and are connected thereto by means of fused solidified crystalline material 21 which substantially surrounds each of the rods. Preferably two rods are utilized which extend in a direction parallel to the plane of the plates 10, 11 and perpendicular to the directions 12, 13 of expansion and contraction of the plates. Each of the rods is located near one end of the multi-plate element and each is relatively rigid so that it serves as a dowel pin to prevent the two plates from sliding with respect to each other.

As has been pointed out in detail in United States Letters Patent 2,373,445, granted April 10, 1945 on the application of Hans G. Baerwald and assigned to the same assignee as the present invention, a very efficient multi-plate flexing element may be fabricated by rigidly interconnecting the two plates only at their ends, in the case of a bender, and only at their corners, in the case of a twister. Slippage between the plates in the region between the points of rigid connection tends to increase the efficiency of the unit. The dowel pins of the present construction are ideally suited for such a construction as they may be tightly bonded to the crystalline material in their immediate vicinity, thus maintaining a portion of each of the plates relatively immovable when the element is used as a transducer, yet permitting efficient multi-plate flexing action.

A convenient way to connect the two plates 10 and 11 together is to fabricate the electroded plates 10 and 11 and thereafter to lay the two rods 20, 20' across the face of the plate 11 in engagement with the upper electrode 17. Preferably the two rods 20, 20' comprise a single length of fine wire with the closed loop end 24 of the wire extending beyond the edge faces of the crystal element, as is shown in Fig. 3. The electroded plate 10 is thereafter laid across the wire and, as is shown in Fig. 4, a current source 26 is connected across the open ends of the loop of wire 24 to cause the wire, by conduction of electric current, to become heated to a temperature above the melting point of the crystalline material. The plate 10 is then pushed downward, as indicated by the arrows 25, 25, toward the plate 11 which is supported from underneath, as indicated by the arrows 26, 26. As the hot wire 20, 20' melts the material in its immediate vicinity, the wire 20, 20', due to the squeezing action, is embedded substantially equally into both of the plates 10 and 11 and good electrical contact is made between the wire and the two inner electrodes 15 and 17 of the plates 10 and 11. After plate 10 has been pushed until it is in firm contact with plate 11, heating of the wire 20, 20' is terminated and the wire and the melted crystalline material are allowed to cool, whereupon the melted crystalline material solidifies and causes the wire to adhere to the crystal plates 10 and 11.

The loop 24 is removed by clipping the wires close to the edge faces of the crystal elements. One of the free ends of the wire, for example 20', is removed by clipping it close to the crystal element. The other free end 20 of the wire is retained as the lead extension for the inner electrode of the multi-plate crystal element.

As a further step in the production of this crystal element the lead to the outside electrodes 14, 16 may also be fused into the top and bottom surfaces of the plates 10 and 11 in substantially the aforedescribed manner. Fig. 5 illustrates such a step wherein a loop of wire 28 extends around the multi-plate crystal element 10, 11. The loop 28 is heated by electric current from a source 29 and, after it reaches a temperature above the melting point of the crystal material, pressure is applied in the direction of the arrows 30, 30 to cause the wire to come in close mechanical contact with the top and bottom surfaces of the multi-plate element. Due to its temperature, the wire melts the crystalline material in its immediate vicinity and, due to the pressure applied, it becomes embedded in the crystal plates. The heating of the wire 28 is thereafter terminated, and the wire and the melted crystalline material are permitted to cool. The back portion of the loop 28 which extends beyond the edge face of the multi-plate element is then clipped off and the two wires 31, 32 are twisted together to form a common lead for the outer electrodes 14, 16 of the multi-plate element.

In the drawing it has been necessary, in order clearly to show the invention, to exaggerate certain dimensions of the transducer with respect to other dimensions. The invention has been successfully carried out utilizing single plates of crystalline material, which are about .03 inch thick, and utilizing solid wire about .003 inch in diameter. Three strands of .001 inch diameter wire twisted together have also been successfully used.

In the practical mass production of multi-plate units, it has been found desirable to start with crystalline plates which are considerably thicker than the aforementioned .03 inch. After the two plates have been connected together with the dowel pins 20, 20' in place and prior to fusing the lead 31, 32 into the crystalline material, the outside surfaces of the plates 10, 11 may be milled or abraded until they are considerably thinner. The outside electrodes and leads may then be applied to form a very thin multi-plate element. Thus considerable breakage, due to rapidly fabricating thin fragile crystal plates, is greatly reduced.

A further advantage of the invention lies in the fact that two interconnected plates of crystalline material can be parallel to each other even though a lead of appreciable thickness is positioned between them at one end of the assembly. Such an advantage is most appreciated in an assembly of many expander plates. For example, 16 or 18 plates may be connected together fact-to-face with a lead between each two plates extending out from one end of the assembly. The lead usually extends between the plates for only such a distance as to enable it to make good electrical contact with an electrode therebetween. This causes the plates in the assembly to be non-parallel. By fusing the lead wires into the crystalline material the non-parallelism of the plates can be obviated.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. An electro-transducer element comprising, first and second plates of electro-transducing material, and relatively rigid elongated member means locally fused into said plates with the length dimension of said elongated means extending only in one direction substantially perpendicular to the direction of major expansion and contraction of said plates to maintain a portion of said plates at said rigid member relatively immovable when said material is used as an electro-transducer.

2. A multi-plate piezoelectric crystal element for use as a transducer comprising, first and second plates of piezoelectric crystalline material, and relatively rigid elongated member means locally fused into said plates with the length dimension of said elongated means extending only in one direction substantially perpendicular to the direction of major expansion and contraction of said plates to maintain a portion of said plates adjacent said rigid member relatively immovable when said element is used as a transducer.

3. A multi-plate piezoelectric crystal element for use as a transducer comprising, first and second plates of piezoelectric crystalline material, and relatively rigid elongated member means locally fused into said plates with the length dimension of said elongated means extending only in one direction substantially perpendicular to the direction of major expansion and contraction of said plates to connect said plates together and to maintain a portion of said plates adjacent said rigid member means relatively immovable when said element is used as a transducer, and electrode means on said plates, one of said plates being adapted to expand and the other to contract in a given direction upon being subjected to a given electrostatic field.

4. A multi-plate piezoelectric crystal element for use as a transducer as set forth in claim 3 in which the length direction of said rigid member means is substantially parallel to the planes of said plates.

5. A multi-plate piezoelectric crystal element for use as a transducer as set forth in claim 4 in which said rigid member means is wire.

6. The method of fabricating a multi-plate piezoelectric crystal element comprising the steps of: electroding one major face of each of the two expander plates of piezoelectric crystalline material, laying two relatively rigid elongated members across the electroded face of the first of said plates with the direction of elongation thereof substantially perpendicular to the direction of expansion of said plate, laying the second plate in substantial registration on said first plate with said elongated members therebetween and in contact with the electroded face of each of said plates, heating said elongated members to a temperature above the melting temperature of said crystalline material, pressing said two plates together to cause crystalline material in the immediate vicinity of said elongated members to melt and to be embedded into each of said two plates, and cooling said elongated members and the melted crystalline material.

7. The method of fabricating a multi-plate piezoelectric crystal element comprising the steps of: electroding one major face of each of two plates of piezoelectric crystalline material, laying both legs of a substantially U-shaped loop of electrically conductive lead material across the electroded face of the first of said plates with the closed portion of the loop extending beyond the edge of the plate, laying the second plate in substantial registration on said first plate with said lead material therebetween and in contact with the electroded face of each of said plates, heating said loop of material to a temperature above the melting temperature of said crystalline material, pressing said two plates together to cause crystalline material in the immediate vicinity of said heated loop of material to melt and the material to be embedded into each of said two plates, cooling said loop of material and the melted crystalline material, and removing that closed portion of said loop of material which extends beyond the edge of said plate.

8. The method of fabricating a multi-plate piezoelectric crystal element comprising the steps of: electroding both major faces of each of two plates of piezoelectric crystalline material, laying both legs of a first substantially U-shaped loop of electrically conductive lead material across one electroded face of the first of said plates with the closed portion of said loop extending beyond the edge of said plate, laying the second plate in substantial registration on said first plate with said lead material therebetween, placing the registering plates between the legs of a second substantially U-shaped loop of electrically conductive lead material, heating said first and second loops of material to a temperature above the melting temperature of said crystalline material, pressing said two plates together and pressing said second loop of material into said first and second plates to cause crystalline material in the vicinity of said heated lead material to melt and the two leads

to be embedded into each of said two plates, cooling said leads and the melted crystalline material, and removing that closed portion of said first loop which extends beyond the edge of said plate.

9. The method of fabricating a multi-plate piezoelectric crystal element as set forth in claim 8 further characterized by maintaining the two legs of said U-shaped loop substantially parallel.

10. A multi-plate piezoelectric crystal element for use as a transducer comprising, first and second expander plates of piezoelectric crystalline material, means connecting said plates together in face-to-face relationship to form a bender element adapted to alternately expand and contract in a given direction, said means comprising rigid elongated member means locally fused into both of said plates, said rigid elongated member

means having an extension only in a direction substantially perpendicular to said direction of expansion and contraction.

11. A multi-plate piezoelectric crystal element as set forth in claim 10, further characterized by said rigid elongated member means comprising two rods each positioned near one end of said multi-plate element.

ALFRED L. W. WILLIAMS.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,388,242	Arndt	Nov. 6, 1945