June 7, 1949. R. W. TIBBETTS 2,472,179

PIEZOELECTRIC DEVICE

Filed June 11, 1947

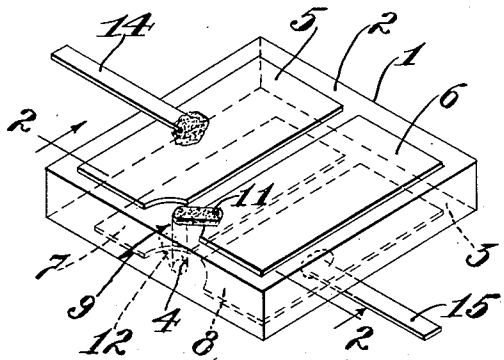


Fig. 1

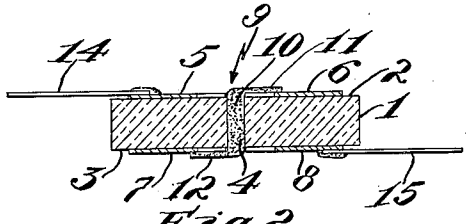


Fig. 2

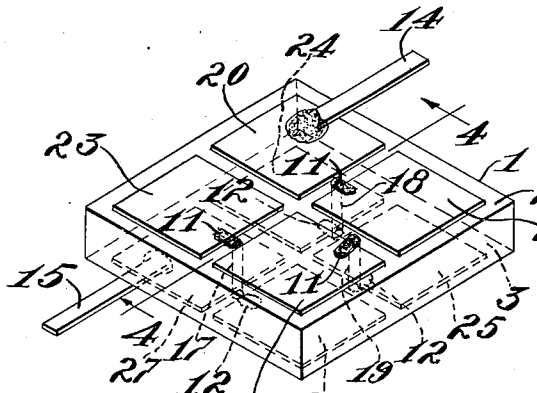


Fig. 3

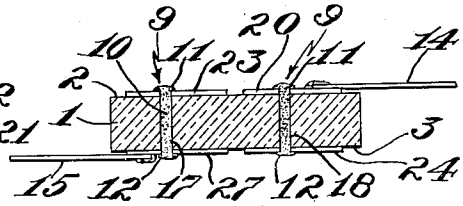


Fig. 4

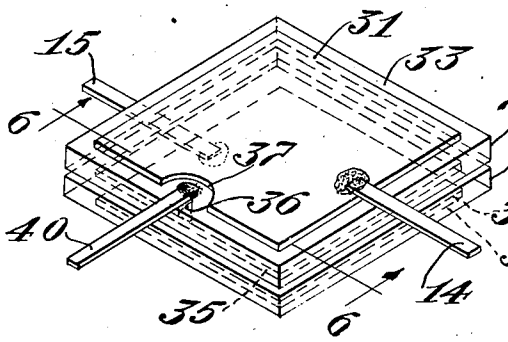


Fig. 5

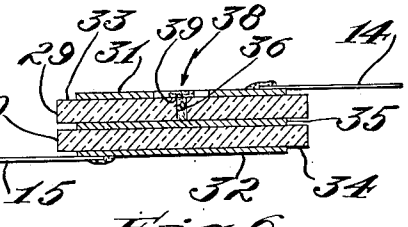


Fig. 6

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PIEZOELECTRIC DEVICE

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2 Claims. (Cl. 171—327)

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This invention relates to piezoelectric devices employing a piezoelectric element and more particularly to a piezoelectric device in which parts customarily associated in assembly with the piezoelectric element, as for example electrodes or electrodes and leads, are electrically interconnected.

In the art of making piezoelectric transducers and other devices employing piezoelectric elements, it is often necessary to provide an electrical interconnection between electrodes or between electrodes and leads in order to increase the voltage output of the device under given conditions of applied force to the device, as is described for example in the series-electroded piezoelectric element comprising one of the modifications of my United States Patent No. 2,386,279, issued October 9, 1945. Heretofore it has been attempted to accomplish this end by means of external connecting leads which have proved inefficient, expensive, and have resulted in an undesirable increase in the bulk or effective mass of the assembled piezoelectric device.

Objects of the present invention are to provide a device of the character described which eliminates the above disadvantages, which appreciably diminishes to a desired compact and convenient size the bulk or effective mass of the assembled piezoelectric device, and which insures an efficient electrical interconnection between the electrodes or the electrodes and leads. Further objects of the invention are to provide a device of the character described which is of simple and durable construction and which is easy and inexpensive to produce.

In one aspect, the invention involves a piezoelectric device comprising a plate of piezoelectric material having a hole extending therethrough, electrodes mounted on opposite faces of the plate, the edge of an electrode on one side of the plate being offset from the edge of the hole, and a conductor extending through said hole and into electrical contact with an electrode on the other side of the plate. The conductor is formed of a plastic mixture of electrically conductive material.

In another aspect the conductor extends through said hole with one end in electrical contact with an electrode on the other side of the plate, and a lead on the one side of the plate is in electrical contact with the opposite end of the conductor.

In a more specific aspect the piezoelectric device comprises a pair of superposed plates of piezoelectric material, one of said plates having

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a hole extending therethrough, outer electrodes mounted on the outer faces of each plate, and an intermediate electrode mounted between the inner faces of said plates, the edge of an outer electrode on the one plate being offset from the edge of the hole, and a conductor extending through said hole with one end in electrical contact with the intermediate electrode, and a lead on the outer face of the one plate in electrical contact with the opposite end of the conductor.

In still another aspect the invention involves a piezoelectric device comprising a plate of piezoelectric material having a hole extending therethrough, electrodes mounted on opposite faces of the plate, the edges of the electrodes being offset from the edges of the hole, and a conductor for electrically interconnecting an electrode on one face of the plate with an electrode on the opposite face of the plate, the conductor comprising a plug of conducting material filling the hole and integral portions of conducting material interconnecting the ends of the plug with said electrodes. The conductor is formed of a plastic mixture of electrically conductive material and comprises a plug filling the hole and integral portions interconnecting the ends of the plug with said electrodes.

For the purpose of illustration, typical embodiments are shown in the accompanying drawings, in which

Fig. 1 is an isometric view of a typical embodiment of the invention;

Fig. 2 is a section along the line 2—2 of Fig. 1;

Fig. 3 is an isometric view of a modified embodiment of the invention;

Fig. 4 is a section along the line 4—4 of Fig. 3;

Fig. 5 is an isometric view of still another modified embodiment of the invention; and

Fig. 6 is a section along the lines 6—6 of Fig. 5.

In Figs. 1 and 2 of the drawings, 1 designates a plate or slab of piezoelectric material as for example Rochelle salt crystal, the plate having opposed faces 2 and 3 and having a hole 4 extending through the plate from the face 2 to the opposite face 3. Spaced metal plates or electrodes 5 and 6 and 7 and 8 are mounted on the opposed faces 2 and 3 respectively, the edges of said electrodes adjacent the hole 4 being cut away thereby to off-set the electrodes from the edge of the hole.

A conductor 9 for electrically interconnecting the electrodes 6 and 7 on opposite faces of the plate comprises a body portion or plug 10 extending through and filling the hole 4 and integral extensions 11 and 12 extending from the ends

of the plug over the opposed faces of the plate and thence over and into electrical connection with the electrodes 6 and 7 respectively.

The conductor 9 is formed of a plastic mixture of electrically conductive material as here specified, by way of example, preferably as a colloidal suspension of graphite in alcoholic, aqueous or other suitable liquid, a colloidal suspension of silver in a suitable cement, or, if gold electrodes are not used, an amalgam of suitable metal such as tin or silver. The plastic mixture is of sufficient viscosity to permit of controlled flow, that is, one which will not allow the material to capillary over a greater surface than that to which it is originally applied.

In applying the conductor the plastic mixture of electrically conductive material is preferably poured through a suitable nozzle, under controlled flow, into the hole until the hole is substantially filled, after which the material is allower to flow in a controlled direction onto the opposite faces of the plate and thence onto the surface of the electrodes 6 and 7 as shown in Fig. 1. The material is then allowed to dry and the efficient and durable electrical interconnection of the electrodes is complete.

To complete the electrical connection from the electrodes to an external circuit, leads 14 and 15 of well-known electrically conductive material are mounted by suitable means to the electrodes 5 and 8 respectively, as shown in Figs. 1 and 2, a small amount of the same plastic mixture as above described being flowed over the ends of the leads and onto the surface of the electrodes to insure an efficient electrical contact between said leads and electrodes.

The embodiment illustrated in Figs. 3 and 4 is of similar construction to the embodiment of Fig. 2 and illustrates the interconnection in series of a plurality of electrodes on opposite faces of the piezoelectric plate 1, the same reference numerals being used for identical corresponding parts. In this embodiment three holes 17, 18 and 19 are provided in the plate 1 and each hole similarly extends through the plate from the face to the opposite face 3. Spaced metal electrodes 20, 21, 22 and 23, and 24, 25, 26, and 27 are similarly mounted on the opposed faces 2 and 3 respectively, the edges of said electrodes being offset from the edges of holes 17, 18, 19 respectively. Conductors 9 of similar electrically conductive material as above described and having identical body portions or plugs 10 and integral extensions 11 and 12 are applied to the plate and electrodes in the same manner as above described thereby to electrically interconnect electrodes 24 and 21, 25 and 22, and 26 and 23 respectively, and the leads 14 and 15 are similarly mounted on electrodes 20 and 27 respectively to complete the electrical connection from the electrodes to an external circuit.

Referring to Figs. 5 and 6 a third typical embodiment of the invention comprises a pair of superposed plates or slabs 29 and 30 of similar piezoelectric material. Outer metal plates or electrodes 31 and 32 are mounted by suitable means to the outer faces 33 and 34 of the plates respectively, and an intermediate electrode 35 is mounted between the inner faces of the plates 29 and 30. The plate 29 has a hole 36 extending therethrough from its outer face 33 to its inner face and the edge of the electrode 31 adjacent to the edge of the hole is cut away as at 37 thereby to offset said electrode from the edge of the hole. Conductor 38 of similar electrically conductive

material as above described and having a body portion or plug 39 is applied to the plate 29 in the same manner as above described and extends through the hole 36 with one end in electrical contact with the intermediate electrode 35. A lead 40 extends over the outer face 33 of plate 29 and is mounted in electrical contact with the opposite end of plug 39, a small amount of the same plastic mixture as above described being flowed over the connected end of said lead and onto said opposite end of plug 39 to insure an efficient electrical contact between the lead and plug. From the foregoing it is evident that the intermediate electrode is thus electrically interconnected with the lead 40 thereby to eliminate the heretofore usual intermediate foil lead cemented in position between the plates 29 and 30 and in contact with the intermediate electrode 35. In a similar manner to that shown in the other embodiments leads 14 and 15 are similarly mounted on electrodes 31 and 32 respectively, to complete the electrical connection from the electrodes to an external circuit.

While the embodiments described above illustrate typical ways of interconnecting various opposed electrodes or electrodes and leads in accordance with my invention, it is to be understood that my invention is not to be so limited but may be used to connect or interconnect various arrangements of electrodes and electrodes and leads as specific applications may require.

Further, it should be understood that the present disclosure is for the purpose of illustration only and that the invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. A piezoelectric device comprising a plate of piezoelectric material having a hole extending therethrough, electrodes mounted on opposite faces of the plate, the edges of the electrodes being offset from the edges of the hole, and a conductor for electrically interconnecting an electrode on one face of the plate with an electrode on the opposite face of the plate, the conductor comprising a plug of conducting material filling the hole and integral portions of conducting material interconnecting the ends of the plug with said electrodes.

2. A piezoelectric device comprising a plate of piezoelectric material having a hole extending therethrough, electrodes mounted on opposite faces of the plate, the edges of the electrodes being offset from the edges of the hole, and a conductor for electrically interconnecting an electrode on one face of the plate with an electrode on the opposite face of the plate, the conductor being formed of a plastic mixture of electrically conductive material and comprising a plug filling the hole and integral portions interconnecting the ends of the plug with said electrodes.

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