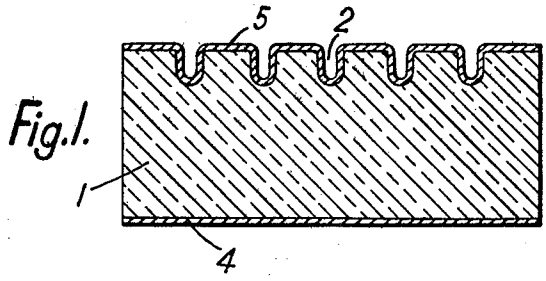
XR 3,059,130 CROSS REFERENCE SEARCH ROOM

Oct. 16, 1962 R. H. ROBINS 3,059,130

ELECTROMECHANICAL TRANSDUCERS

Filed Sept. 9, 1958

Fig.1.



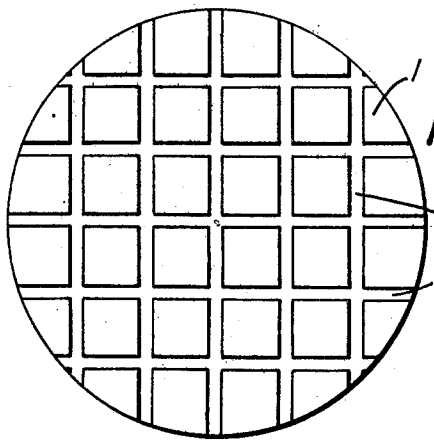


Fig.2.

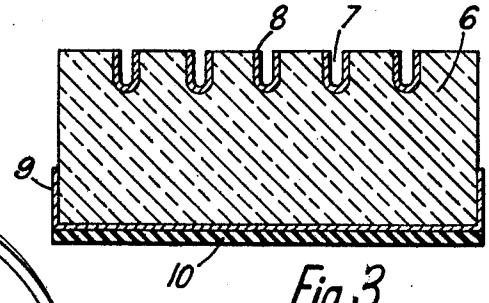
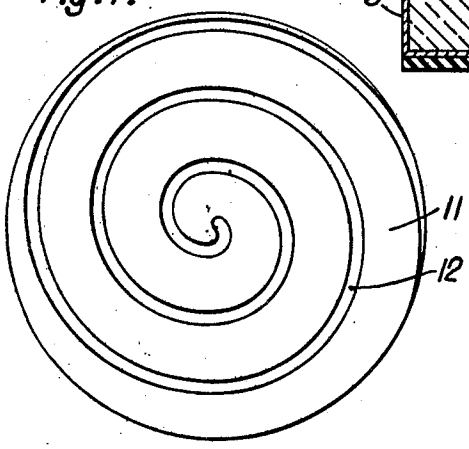


Fig.3.

Fig.4.



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ELECTROMECHANICAL TRANSDUCERS

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This invention relates to electromechanical transducers of the kind comprising a body of a piezo-electric material, or of a material or composition which has an effective piezo-electric response, carrying two or more electrodes, at least two of the electrodes being so arranged on opposed surfaces of the body that it functions wholly or in part as a thickness mode transducer. Transducers of this kind can be used to convert mechanical into electrical energy, or vice versa, and can also be used as filters, oscillators and for other purposes.

The invention is more particularly, but not exclusively, concerned with transducers based on ceramic bodies, having for an example an alkaline earth metal titanate as a principal constituent, but is also applicable to transducers based on bodies of other composition whether of hetero-crystalline or of single crystal form. For convenience bodies in which dimensional variation is so related to applied potential that they are suitable for use in electromechanical transducers will hereinafter be referred to as "piezo-electric" bodies whether or not they exhibit a true piezo-electric effect.

Objects of the invention are to provide methods of adjusting the resonant frequency of an electromechanical transducer, after adherent electrodes have been applied to the piezo-electric body of the transducer, and to provide electro-mechanical transducers which can readily be adjusted to increase their resonant frequency.

In the method in accordance with the invention of manufacturing and adjusting electromechanical transducers, a surface of a piezo-electric body, to which is to be applied an electrode which will function in conjunction with another electrode applied to the body as an electrode of a thickness mode transducer is, before the application to it of the electrode, formed with a groove or grooves, preferably of substantially uniform depth; the electrode is then applied to the grooved surface, either wholly or partly in the groove or grooves. Preferably two groups of grooves at an angle to each other are cut in such a way as to form a regular mesh pattern, preferably a square mesh, but any pattern formed from a single groove (e.g. a spiral) or from a number of grooves can be used, provided that the electrode material applied to the groove or grooves will cover a sufficient area and be sufficiently evenly distributed to function effectively as one electrode of the transducer and provided that, where more than one groove is used, the layers of electrode material in the various grooves are electrically interconnected, as by interlinking the grooves, or otherwise. The electrode can be applied by any process which will provide a sufficiently adherent layer of metal for example a conventional silvering process. After the electrode has been applied to the groove surface of the body and a complementary electrode has been applied to an opposed surface, the frequency of the thickness mode transducer thus formed can be adjusted if required by removing part of the body from the lands projecting between the

grooves, or between the parts of the single groove, as by grinding or lapping the grooved surface.

The electrode applied to the grooved surface is conveniently formed by depositing metal over the whole of that surface, i.e. covering the bottom and sides of the groove or grooves and the lands between the grooves or between the parts of the single groove. The removal of the metallic deposit from the lands during the first grinding or lapping has surprisingly little effect on the characteristics of the transducer.

When it is desired to provide for the possibility of obtaining a greater range of adjustment than would be possible if one electrode were applied to a grooved surface, both electrodes may be formed in this way. Alternatively one electrode may be applied to a grooved surface, as described above, and the other electrode may have an adherent layer of a glaze applied to it so that the frequency of the transducer can be increased by reducing the thickness of the glaze layer, for example by grinding, lapping or polishing.

The method of manufacture and adjustment in accordance with the invention has the advantage that the electrodes can be applied in their final form and location before the frequency adjustment is effected, thus enabling frequent or continuous monitoring of the frequency adjustment.

Two transducers in accordance with the invention and methods of adjusting the resonant frequency of these transducers will hereinafter be described by way of example with reference to the accompanying drawing in which

FIGURE 1 is an elevation in cross-section of the first transducer before its frequency has been adjusted;

FIGURE 2 is a plan of the first transducer,

FIGURE 3 is an elevation in cross-section of the second form of transducer after its frequency has been adjusted, and

FIGURE 4 is a plan of a modified form of the first transducer.

Referring to FIGURES 1 and 2, the first transducer was made in the following way.

A disc 1 of ceramic material was made by firing together ingredients which form a barium titanate ceramic containing 5% of calcium titanate and 0.5% of cobalt oxide (both percentages being based on the total weight of the barium titanate and calcium titanate), and both plane surfaces of the disc were ground flat giving the disc a thickness of approximately 12.7 mm. and a diameter of approximately 32 mm. Parallel grooves 2 and 3 were cut in one surface of the disc as shown in FIGURE 2, the depth of the grooves being approximately 1.7 mm. and their width approximately 0.8 mm. The opposed surfaces of the disc were then silvered by a standard method to give a continuous metallic deposit 4 on the smooth surface and a continuous metallic deposit 5 on the grooved surface, after which the ceramic material was polarised.

Measurements of the piezo-electrical properties and other properties of the transducer were made by the normal radio frequency bridge technique and the thickness of the transducer was then reduced progressively by lapping the grooved surface, first to remove the metal coating from the lands between the grooves and then to remove the ceramic material from the lands.

The results of the electrical measurements are set out in the table below:

	Thickness in mm.	Thickness resonant frequency Kc./s.	Coupling coefficient (thickness mode)	Capacitance @ 1Kc./s. in pF	Tan $\delta \times 10^{-4}$ @ 1Kc./s.	Ambient temp. ° C.
(a)	12.76	206	25	644	81	20.5
(b)	12.71	206.89	25	642	82	18.8
(c)	12.50	209.78	26			20.0
(d)	12.23	212.16	29	633	82	21.0
(e)	12.00	216.26	30	631	93	21.7
(f)	11.70	220.41	31	624	81	22.0
(g)	11.46	224.86	27	615	81	22.5

The first measurements (*a*) were made before the first reduction in thickness and the remaining readings (*b*)–(*g*) were taken as the thickness was progressively reduced. From a comparison of measurements (*a*) and (*b*) it will be seen that removal of the metal coating from the lands between the grooves has very little effect on the electromechanical properties of the transducer. The results show how the resonant frequency of the transducer can readily be adjusted simply by lapping the grooved face of the transducer.

Referring now to FIGURE 3, the second transducer consists of a disc of ceramic material 6 identical with the disc 1 being formed on its upper surface with grooves 7 in the same way as the disc 1. Both surfaces of the disc 6 were silvered originally in the same way as the transducer described with reference to FIGURES 1 and 2 except that the silvering 9 on the lower surface is continued part of the way up the cylindrical surface of the disc. The flat surface of the silver coating 9 is provided with a layer of glaze 10, formed by painting on to the silver sufficient of a finely ground ceramic enamel in a suitable organic vehicle to form a layer of vitreous structure 0.3 mm. thick when the layer is fired at 650° C.

The resonant frequency of this transducer can be adjusted by lapping either or both surfaces, the frequency change obtainable by lapping the glaze alone being of the order of 5 kc./s.

As shown in the drawing the silver coating on the lands between the grooves has been removed by lapping leaving only coatings 8 in the grooves.

Referring to FIGURE 4, this figure shows the transducer of FIGURES 1 and 2 modified in that the grooved surface of the ceramic body 11 is formed with a single continuous spiral groove 12.

What I claim as my invention is:

1. A thickness mode transducer comprising a piezoelectric body having two opposed major surfaces, at least one of which is formed with a series of grooves of substantially uniform depth arranged in a regular mesh pattern, and two opposed electrodes each adhering to and substantially coextensive with one of said surfaces, the electrode on the grooved surface being located primarily in the bottom of the grooves which are sufficiently evenly distributed over said surface to ensure that the resonant frequency of the transducer can be adjusted by removing part of the body from the lands projecting between the grooves.

2. A transducer in accordance with claim 1 in which the grooves are arranged in two groups substantially at right angles to each other to form a substantially square mesh pattern.

3. A thickness mode transducer comprising a piezoelectric body, a first electrode applied at least partly in the bottom of grooves in a major surface of the body, a second electrode applied to a smooth major surface of the body opposing said grooved surface and an adherent layer of a glaze on at least the major part of the exposed surface of the second electrode, the grooving being sufficiently evenly distributed over said surface to insure that the resonant frequency of the transducer can be adjusted by removing part of the body forming the lands projecting between the grooves and by reducing the thickness of the glaze applied to the second electrode.

4. A thickness mode transducer comprising a piezoelectric body having two opposed major surfaces, one of which is grooved, and two opposed electrodes each adhering to and substantially coextensive with one of said surfaces, the electrode on the grooved surface being located primarily in the bottom of the grooves which are sufficiently evenly distributed over said surface to ensure that the resonant frequency of the transducer can be adjusted by removing part of the body from the lands projecting between the grooves.

5. A thickness mode transducer comprising a piezoelectric body having two opposed major surfaces, both of which are grooved, and two opposed electrodes each adhering to and substantially coextensive with one of said surfaces, the electrodes being located primarily in the bottom of the grooves which are sufficiently evenly distributed over said surfaces to ensure that the resonant frequency of the transducer can be adjusted by removing part of the body from the lands projecting between the grooves.

6. A thickness mode transducer comprising a piezoelectric body having two opposed major surfaces, at least one of which is formed with a single continuous groove, and two opposed electrodes each adhering to and substantially coextensive with one of said surfaces, the electrode on the grooved surface being located primarily in the bottom of the groove which is sufficiently evenly distributed over said surface to ensure that the resonant frequency of the transducer can be adjusted by removing part of the body from the lands projecting between the grooves.

7. A thickness mode transducer comprising a piezoelectric ceramic body having two opposed major surfaces, at least one of which is grooved, and two opposed electrodes each adhering to and substantially coextensive with one of said surfaces, the electrode on the grooved surface being located primarily in the bottom of the grooves which are sufficiently evenly distributed over said surface to ensure that the resonant frequency of the transducer can be adjusted by removing part of the body from the lands projecting between the grooves.

8. A method of manufacturing a thickness mode transducer which comprises forming a transducer having a resonant frequency lower than the required value by forming grooves in at least one of two opposed major surfaces of a piezo-electric body and applying two opposed adherent electrodes to said body, each substantially coextensive with one of said surfaces with the electrode on the grooved surface located primarily in the bottom of the groove, and adjusting the resonant frequency of the transducer by removing part of the body from the lands projecting between the grooves.

9. A method as claimed in claim 8 in which an electrode is applied to the grooved surface in such a way as to cover and adhere both to the bottom of the grooves and to the surfaces of the lands between the grooves.

10. A method as claimed in claim 8 in which the resonant frequency is adjusted by simultaneously grinding

away the coplanar surfaces of all of the lands between the grooves.

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