

June 10, 1958

R. N. THURSTON
TORSIONAL TRANSDUCERS OF ETHYLENE DIAMINE
TARTRATE AND DIPOTASSIUM TARTRATE
Filed Aug. 15, 1955

2,838,696

FIG. 1

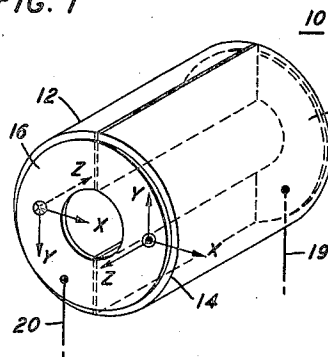


FIG. 2

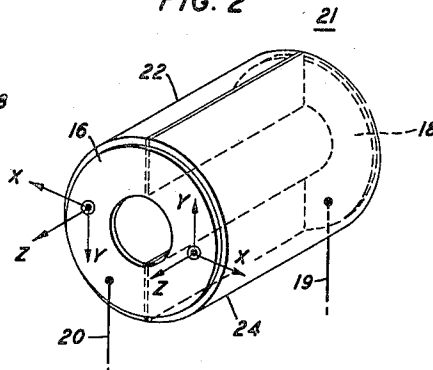


FIG. 3

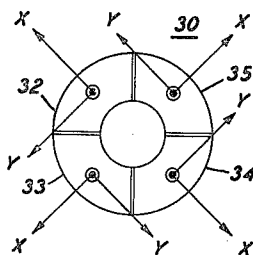


FIG. 4

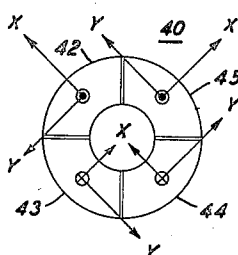


FIG. 5

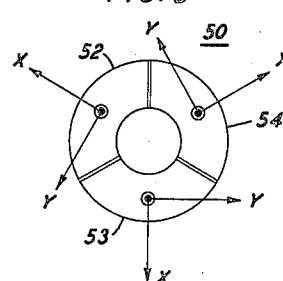


FIG. 6

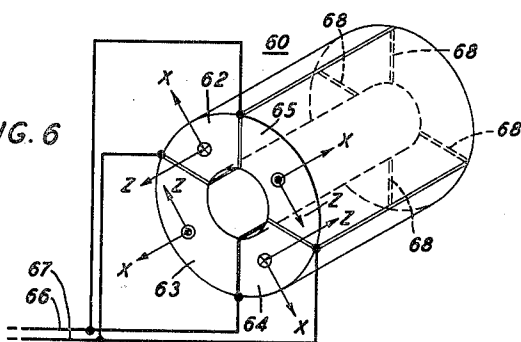


FIG. 7

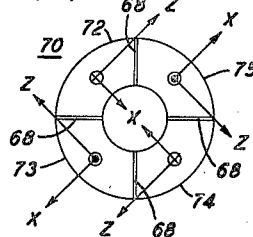


FIG. 8

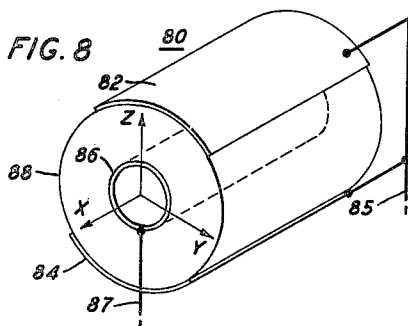
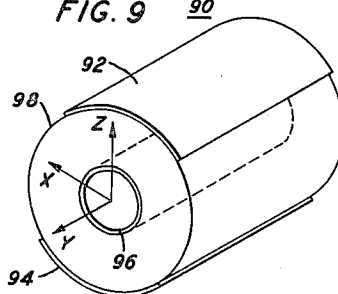


FIG. 9



INVENTOR
R. N. THURSTON
BY
H. O. Wright
ATTORNEY

1

2,838,696

**TORSIONAL TRANSDUCERS OF ETHYLENE
DIAMINE TARTRATE AND DIPOTASSIUM
TARTRATE**

Robert N. Thurston, Whippany, N. J., assignor to Bell
Telephone Laboratories, Incorporated, New York,
N. Y., a corporation of New York

Application August 15, 1955, Serial No. 528,462

10 Claims. (Cl. 310—8.1)

This invention relates to piezoelectric crystal torsional transducers of ethylene diamine tartrate (abbreviated EDT) or dipotassium tartrate (abbreviated DKT). More particularly, it relates primarily to torsional transducers comprising a plurality of sections cut from single crystals of one of the above materials, the sections being oriented with respect to the crystallographic axes in particular predetermined manners so that, when the sections are appropriately assembled to form a torsional transducer and provided with appropriate driving electrodes, efficient and effective torsional transducers are obtained. Two species, each comprising a single piece of one of the above materials are, however, included.

The principal object of the invention is, accordingly, to provide efficient and effective torsional transducers of ethylene diamine tartrate or dipotassium tartrate.

Other and further objects, features and advantages of the invention will become apparent during the course of the following detailed description of illustrative embodiments of the invention and from the appended claims.

Related transducers comprising assemblies of a plurality of sections cut from single quartz crystals are disclosed and claimed in applicant's copending application Serial No. 528,461, filed August 15, 1955, concurrently with the present application. Said copending application also teaches that a large number of other piezoelectric materials in addition to quartz, EDT and DKT can be similarly employed to provide torsional transducers.

The principles of the present invention will be more readily perceived from the following detailed description of a number of specific illustrative embodiments shown in the accompanying drawings in which:

Fig. 1 shows a transducer of the invention employing an annular cylindrical element comprising two hemi-cylindrical portions cemented together, each portion being cut from a single crystal of one of the materials EDT or DKT and oriented with respect to the axes of the crystal as indicated; this species employs annular or plate electrodes at each end;

Fig. 2 shows a second two-piece transducer of the invention differing from that of Fig. 1 only in the particular orientation of one of the portions with respect to the axes of the crystal from which it is cut;

Figs. 3 and 4 are two species of four-piece transducers of the invention, otherwise similar to the transducer of Fig. 1, and illustrate two additional ways in which transducers of the invention can be arranged;

Fig. 5 shows a further species of the invention similar to that of Fig. 1 but employing a three-piece assembly of portions cut from individual crystals of one of the materials EDT or DKT;

Figs. 6 and 7 show two transducers of the invention employing the four-piece construction and arranged to be driven by electrodes between the interfaces of abutting sections; and

Figs. 8 and 9 show two transducers of the invention employing a one-piece construction with cylindrical elec-

2

trodes arranged to provide a radial drive parallel to the Z axis of the transducers.

In more detail, in Fig. 1 the assembled transducer 10 includes an annular cylindrical member of ethylene diamine tartrate or of dipotassium tartrate and is comprised of the two hemi-cylindrical sections 12 and 14 cemented together along the vertical bisecting longitudinal plane of the assembly. Each section is cut from a single crystal. The arrows designated X, Y and Z, respectively, indicate for each of the sections 12 and 14, the orientation of the section with respect to rectangular axes. These rectangular axes are related to the crystallographic axes of the crystal from which the section is cut, as explained on pages 172-173 of the book entitled "Piezoelectric Crystals and Their Application to Ultrasonics" by W. P. Mason, published by D. Van Nostrand Co., Inc., New York City, 1950.

The X and Y axes of sections 12 and 14 are horizontal and vertical, respectively, the X axes being directed radially, with respect to the longitudinal axis of the complete cylinder, and in the same direction and the Y axes being at right angles to their respective X axes and oppositely directed, as shown. The Z axes of sections 12 and 14 are both parallel to the longitudinal axis of the assembly 10 but that of section 12 is directed toward the rear face and that of section 14 toward the front face.

In all devices disclosed in the present application the electrical drive will be substantially parallel to the Z axis of each section of the complete cylinder.

In the drawings accompanying this application a small circle enclosing an x on the front surface of a transducer will be used to indicate a crystallographic axis directed toward the rear face and parallel to the longitudinal axis of the transducer, while a small circle with a dot in the center will be used to indicate an axis directed in the opposite direction, i. e., outwardly from the plane of the paper. In general two axes lying in a plane parallel with that of the front face will be designated by arrows labeled X, Y or Z, as the case may be, the third axis being understood to be that represented by the small circle enclosing a dot or a cross. For example, if the X and Y axes are indicated by arrows so labeled, the Z axis will be understood to be the one represented by the small circle enclosing a dot or a cross. In Figs. 1, 2, 8 and 9, the third axis is also represented by a labeled arrow but in the remaining figures the third arrow will be omitted to simplify the figures.

In Fig. 2, assembly 21 can be substantially identical with assembly 10 of Fig. 1, except that the left hemi-cylindrical section 22 of Fig. 2 is cut from a single crystal (EDT or DKT) with the orientation indicated by arrows X, Y and Z associated with section 22 in Fig. 2. Section 24 of Fig. 2 is cut with the same orientation as section 14 of Fig. 1, as shown by its associated arrows X, Y and Z. The leads 19, 20 and electrodes 16, 18 of Fig. 2 can be the same as the corresponding numbered items as described in connection with Fig. 1.

In Figs. 2 through 5 and 7, plain front views only are shown, since the devices of Figs. 2 through 5 are the same as that of Fig. 1 and the device of Fig. 7 is the same as that of Fig. 6 except for the orientations of the crystallographic axes as specifically shown in the respective figures.

In Fig. 3, a front view only of a four-section transducer of the invention is shown. Electrodes, leads and other details of the transducer can be substantially as shown in Figs. 1 and 2 and described in detail above. Each of the four 90 degree sections is cut from a single crystal (EDT or DKT) with the orientation indicated by the arrows X and Y and the small circles enclosing a dot or a cross associated with it as shown in Fig. 3. In this case, the X axis of each of the sections 32 through

3

35 is radial (as viewed from the center of each section) and directed outwardly from the center of the transducer and the Y axis is at an angle of 90 degrees counterclockwise to the X axis. As indicated by the small circles, each having a dot in the center, the Z axis for each of the four sections is perpendicular to both the X and Y axes and is directed outwardly with respect to the plane of the paper. In the transducer of Fig. 3, the X axis of each section is at an angle of 90 degrees with respect to the X axes of adjacent sections and at an angle of 180 degrees with respect to the X axis of the diametrically opposite section. The same general relations exist for the Y axis of each section, as indicated in Fig. 3.

In Fig. 4 an alternative arrangement to that of Fig. 3 is illustrated in that the assembly 40 comprises four 90 degree sections 42 through 45, inclusive, but in sections 43 and 44 the directions of both the X and the Z axes have been reversed with respect to the corresponding axes of sections 33 and 34, respectively, of Fig. 3.

In Fig. 5 a three-section type of transducer 50 is shown comprising the three 120 degree sections 52, 53 and 54. In Fig. 3 the X axis of each section is directed radially and outwardly and the Y axis of each section is at an angle of 90 degrees counterclockwise with respect to its X axis. The Z axes of all three sections are directed perpendicularly and outwardly with respect to the plane of the paper as indicated by the small circles with a central dot in each.

As in the case of the transducer of Fig. 3, the electrodes, leads and other details of the transducers of Figs. 4 and 5 can be substantially identical with the corresponding features of the transducers of Figs. 1 and 2, as described in detail above.

In Fig. 6 an annular cylindrical transducer 60 of EDT or DKT comprising the four 90 degree cylindrical sections 62 through 65, inclusive, is shown. In this transducer the Y axis of each section is parallel to the longitudinal axis of the assembled cylindrical element. In sections 62 and 64 the Y axis is directed toward the rear end of the assembly, while in sections 63 and 65 it is directed in the opposite direction. The X axis of each section is directed radially outward and the Z axis of each section is at a right angle with respect to the X axis of the section, the direction of the Z axis from the X axis being counterclockwise for sections 62 and 64 and clockwise for sections 63 and 65, as shown.

The transducer of Fig. 6 differs from those of Figs. 1 through 5 in that the four electrodes 68 are interposed between the interfaces of each pair of 90 degree sections, diametrically opposite electrodes being electrically interconnected, the two vertical electrodes being in turn connected to lead 66 and the two horizontal electrodes being electrically connected to lead 67. The required interfacial electrodes can conveniently be provided by cementing the four sections of the assembly together by a conducting or metallized cement. The resulting layers of cement can then perform both as electrodes and to mechanically unite the sections.

The transducer of Fig. 7 shows an alternative arrangement 70 to that of Fig. 6 and comprises four 90 degree sections 72 through 75, inclusive. The arrangement of Fig. 7 differs from that of Fig. 6 only in that the directions of the X and Z axes of sections 72 and 74 are reversed with respect to the directions of the corresponding axes of the corresponding sections 62 and 64, respectively, of Fig. 6.

In Fig. 8 a third general form of transducer 80 of the invention is shown. It includes a one-piece, annular, cylindrical, element 88 which is cut from a single crystal of EDT or DKT and oriented as indicated by the rectangular axes labeled X, Y and Z, respectively. As shown, the X axis is parallel to the longitudinal axis of the cylindrical member 88 and is directed outwardly. The Z axis is perpendicular and directed radially up-

4

wardly. The Y axis is horizontal and at a right angle in a clockwise direction from the Z axis.

The electrodes 82 and 84, which should cover an angular arc of substantially 90 degrees, are placed on the outer surface of element 88 symmetrically with respect to the plane of the Z axis (vertical bisecting plane in Fig. 8). They are connected electrically together and to lead 85, as shown.

Electrode 86 may cover the entire internal surface of element 88, as shown, and is electrically connected to lead 87.

In Fig. 9 an alternative form of transducer 90 to that of Fig. 8 is shown. It differs from that of Fig. 8 only in that the element 98 is cut from a single crystal of EDT or DKT so that its longitudinal axis is parallel to the Y crystallographic axis and its X axis is at a right angle counterclockwise with respect to the Z axis. The Z axis is vertical as for element 88 of Fig. 8. Electrodes and leads, not shown, should be applied as shown in Fig. 8 and described in detail above.

The electrodes for the devices of Figs. 8 and 9 may be conductive paint or metal foil cemented to the appropriate surfaces or deposited layers of metal, as convenience may dictate. They may be applied and connected to leads in accordance with any of the accepted practices well known to those skilled in the art.

All of the transducers of the invention can be loaded to reduce their respective frequencies of resonance under torsional vibration by cementing discs, which, for example, may be of steel, to each end of the transducer. The use of such discs can eliminate the necessity for cementing the interfaces of adjacent sections together in Figs. 1 through 5, and losses resulting from cement between the interfaces can thus be eliminated, thereby increasing the efficiency of the transducers.

All transducers of the invention when equipped with appropriate electrodes as described in detail above will respond efficiently as torsionally vibrating transducers when a signal voltage is impressed across the proper electrodes. Alternatively, torsional vibration imparted to the transducers will result in the generation of corresponding electrical output voltages at the leads connected to the appropriate electrodes as described in detail above.

Calculations show that ethylene diamine tartrate should have a slightly higher coefficient of electromechanical coupling than dipotassium tartrate in the arrangement of Figs. 1 through 7. In the arrangements of Figs. 8 and 9, DKT will have the higher coupling.

Numerous and varied other arrangements within the spirit and scope of the invention will readily occur to those skilled in the art. Accordingly, the above described embodiments are to be understood as being illustrative of the application of the principles of the invention.

What is claimed is:

1. A piezoelectric crystal torsional transducer comprising a plurality of cylindrical sections of crystal, the crystal, for all sections of the transducer, being one of the pair named ethylene diamine tartrate and dipotassium tartrate, respectively, said plurality of sections being assembled to form a complete crystal cylinder, each section being cut from a single crystal with a predetermined orientation with respect to the crystallographic axes thereof, said sections being assembled to form the complete cylinder, each section having its X axis radially directed and two of the three crystallographic axes at an angle of at least 90 degrees with respect to the corresponding crystallographic axes of each of the other sections, all sections having the same crystallographic axis parallel to the longitudinal axis of the complete cylinder, and means for applying signal voltage to said cylinder substantially parallel to the Z axis of said cylindrical sections to induce torsional vibration of said cylinder.

5

2. A transducer in accordance with claim 1, the cylindrical element thereof comprising two hemi-cylindrical sections.

3. A transducer in accordance with claim 2, said means for applying signal voltage comprising a pair of electrodes, each electrode consisting of a layer of conductive material substantially coextensive with and adhering to an end of the cylindrical element of said transducer.

4. A transducer in accordance with claim 1, the cylindrical element thereof comprising three 120 degree cylindrical sections.

5. A transducer in accordance with claim 1, the cylindrical element thereof comprising four 90 degree cylindrical sections.

6. A transducer in accordance with claim 5, said means for applying signal voltage comprising a pair of electrodes, each electrode consisting of a layer of conductive material substantially coextensive with and adhering to an end of the cylindrical element of said transducer.

7. A transducer in accordance with claim 5, said means for applying signal voltage comprising conductive electrodes interposed between the interfaces of adjacent 90 degree cylindrical sections of the cylindrical element of said transducer, diametrically opposite electrodes being electrically interconnected.

8. A transducer comprising a cylindrical element of one of the substances ethylene diamine tartrate and dipotassium tartrate, said element consisting of two hemi-cylindrical sections, each section being cut from a single crystal of the substance, the Z crystallographic axes of both sections being parallel to the longitudinal axis of said element, the X and Y crystallographic axes of one section being parallel to the corresponding axes of the other section, two of the crystallographic axes of one section being oppositely directed with respect to the corresponding axes of the other section, the X axis of each section being radially directed with respect to the longitudinal axis of said transducer, and means for applying a signal voltage substantially parallel to the Z axes of both sections.

6

9. A transducer comprising a cylindrical element of one of the substances ethylene diamine tartrate and dipotassium tartrate, said element consisting of four 90 degree cylindrical sections, each section being cut from a single crystal of the substance, the Z crystallographic axes of all four sections being parallel to the longitudinal axis of said cylindrical element, the X axis of each section being radially directed with respect to said cylindrical axis, two of the three crystallographic axes of each section being oppositely directed with respect to the corresponding axes of the diametrically opposite section of said cylindrical element, and means for applying a signal voltage in the direction of the longitudinal axis of said transducer.

10. A transducer comprising a cylindrical element of one of the substances ethylene diamine tartrate and dipotassium tartrate, said element consisting of 90 degree cylindrical sections, each section being cut from a single crystal of the substance, the Y crystallographic axis of all four sections being parallel to the longitudinal axis of said cylindrical element, the X axis of each section being radially directed with respect to the cylindrical axis, two of the three crystallographic axes of each section being oppositely directed with respect to the corresponding axes of the diametrically opposite section of said cylindrical element, and means for applying a signal voltage substantially parallel to the Z axis of each section.

References Cited in the file of this patent

UNITED STATES PATENTS

2,439,499	Williams et al.	Apr. 13, 1948
2,507,636	Kistler	May 16, 1950

FOREIGN PATENTS

756,697	Germany	Dec. 22, 1952
---------	---------------	---------------

OTHER REFERENCES

Mason, "Piezoelectric Crystals and Their Application to Ultrasonics," p. 165, D. Van Nostrand Company, Inc., New York, 1950.