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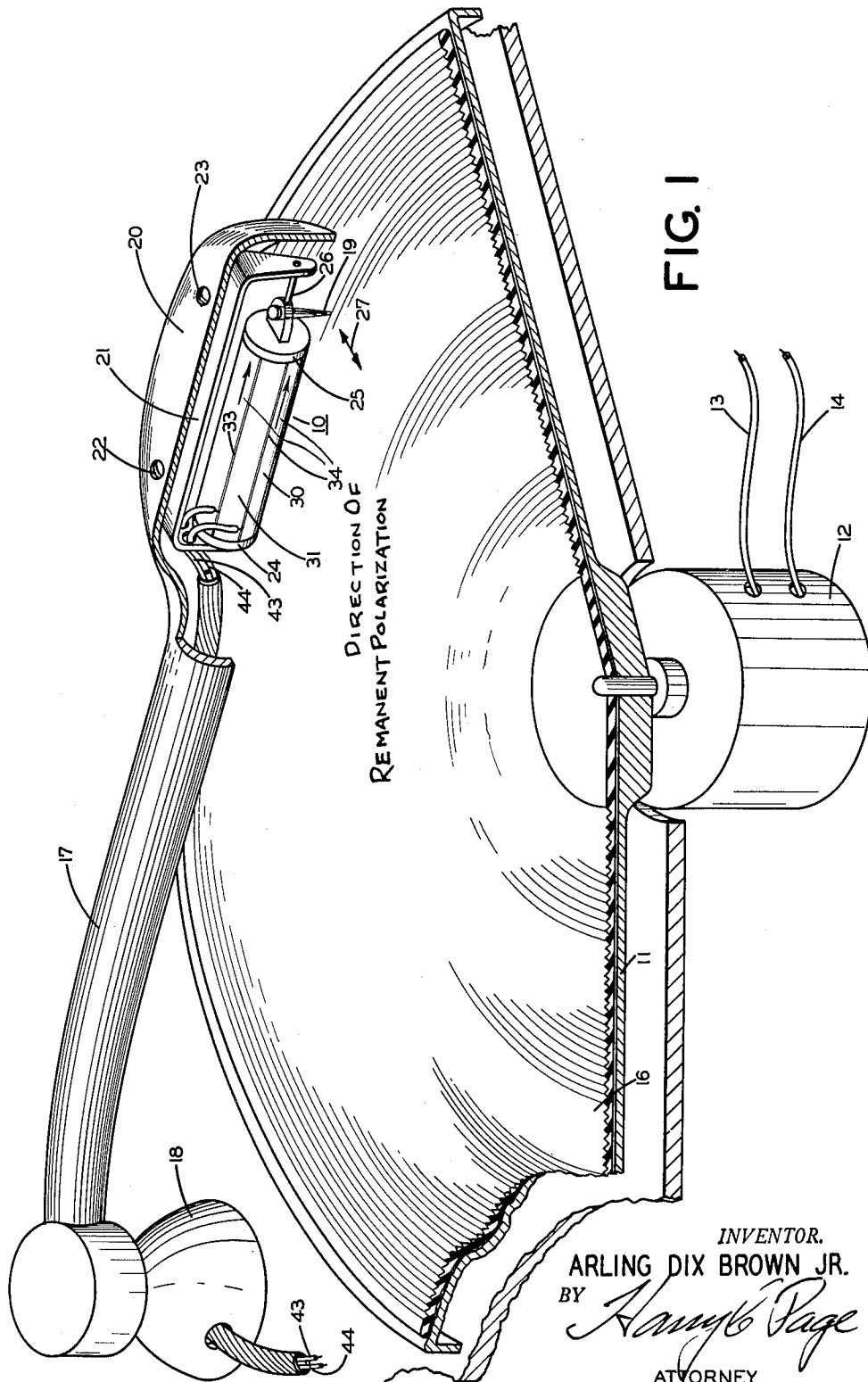
A. D. BROWN, JR

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CYLINDRICAL TWISTER-TYPE ELECTROMECHANICAL DEVICE

Filed May 22, 1951

2 Sheets-Sheet 1



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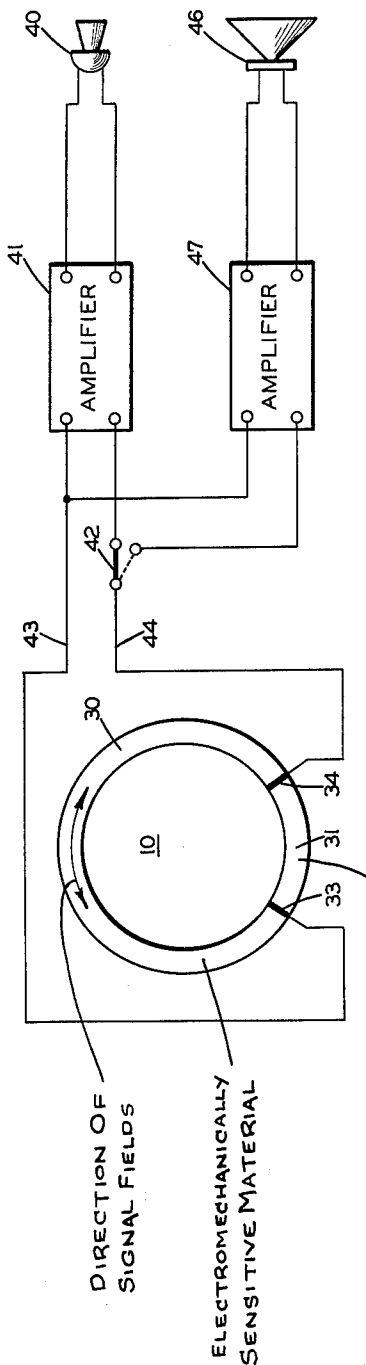
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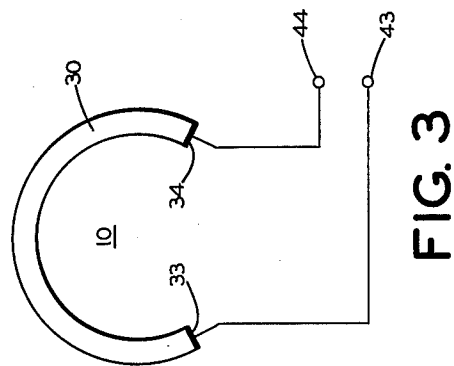
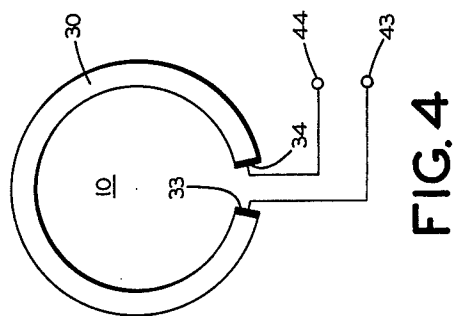
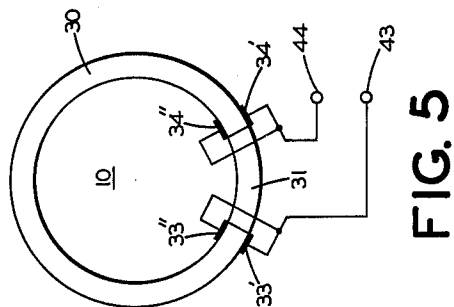
CYLINDRICAL TWISTER-TYPE ELECTROMECHANICAL DEVICE

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2 Sheets-Sheet 2



MATERIAL OF  
RELATIVELY LOW DIELECTRIC  
CONSTANT



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2,719,929

## CYLINDRICAL TWISTER-TYPE ELECTRO-MECHANICAL DEVICE

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Application May 22, 1951, Serial No. 227,712

7 Claims. (Cl. 310—8.1)

The present invention relates to cylindrical twister-type electromechanical devices and, specifically, to a device which, when twisted, mechanically will generate electrical energy or, when electrical energy is applied thereto, will twist mechanically.

Electromechanical transducers, per se, are well known in the art and have found many uses in microphones, phonograph pickups, etc. Some of these devices comprise a piezo-electric material, and the expansion properties thereof, when a voltage is applied to electrodes on the device, are utilized. Others of the devices utilize some arrangement to stress the material mechanically so that the expansion properties of the material cause a voltage to be generated. However, for most purposes, it has been found desirable to utilize a sandwich of two such elements to provide, for example, a bending action under an applied voltage or to generate a voltage in response to a bending action. Still others of such devices operate to provide a voltage in response to a twisting action or to provide a twisting action in response to a voltage. These twisting devices are generally comprised of a sandwich of two electromechanically responsive plates in which the mechanical action involved is a shear in a face of each of the plates. When a sandwich of two such plates is utilized with a shear action of opposite sense in each of the plates, a so-called twister device is provided in a manner which, per se, is well understood by those skilled in the art.

However, in recent years, ceramic electromechanical transducers have come into an extensive amount of use. Such transducers are generally comprised of a fired ceramic material which is comprised mainly of barium titanate, although in some cases the material may have added thereto a few weight percent of some metal oxide in order to provide some particular operating characteristic. Generally speaking, there are always fractional percentages of other materials present as impurities in the barium titanate which is used to make such transducers. Transducers which are made of such ceramic materials are effective to change mechanical energy into electrical energy or to change electrical energy into mechanical energy, or both. They also have found a considerable amount of use as the transducing devices in microphones, phonograph pickups, devices for introducing sound energy into a liquid medium, devices for producing electrical energy from sound energy in a medium, etc. Several such ceramic transducers are described and claimed in United States Patent 2,486,560, granted on November 1, 1949, on an application filed September 20, 1946, by Robert B. Gray.

While ceramic transducers of the type here under consideration have found some use in devices where a continuous unidirectional bias voltage is applied while the transducer is in operation, it is the general practice to cause the material of such transducers to have a remanent polarization which renders the provision of a continuous unidirectional bias voltage during the operation of the device unnecessary. The ceramic materials of the type

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here under consideration are caused to have a remanent polarization by subjecting the material to a high intensity electric field at some time during the manufacturing process of the device. This polarizing process is done after the material has been fired and is usually done after suitable electrodes have been applied to the surfaces of the material. It is usually necessary or desirable to apply a polarizing field of the order of 75,000 volts per inch to the material at ambient room temperatures, although it is possible to reduce this voltage gradient requirement by about half if the material being polarized is maintained at a temperature near, and preferably just below, its Curie point. The Curie point of barium titanate is around 120° C.

Many of the barium titanate ceramic materials here under consideration have a relatively strong mutual coupling action between an electric signal field at right angles to the direction of remanent polarization and a mechanical shear in a plane which includes the direction of polarization and the direction of the electric signal field. Specifically, if an electric signal field is applied to the material in a direction normal to the direction of polarization, the ceramic material will be subjected to a mechanical shear and, conversely, if the material is subjected to a mechanical shear of the proper orientation, an electric signal field will result in the material, which signal field can be utilized to derive electrical energy from the material. The mutual coupling coefficient here under consideration has a value of about 0.4 for a properly polarized ceramic material of barium titanate.

It has been proposed that two shear plates of such ceramic material be bonded together in such a way as to provide what is effectively a sandwich element of two oppositely acting shear plates, thus to provide a twister action of the type mentioned above. However, when this is done, it is either necessary that the two plates of the sandwich be polarized in opposite directions or that the signal fields in the two plates be applied with opposite directions. Either of these requirements may be very difficult or inconvenient to provide in certain applications.

It has also been proposed that two half cylinders of such ceramic material be bonded together to provide a twister device in which each half of the cylinder is oppositely polarized and in which the signal fields of the two half cylinders are in opposite directions circumferentially in the material. Here again these requirements are impossible or very difficult to provide in many applications.

It would be very desirable, therefore, to provide a cylindrical twister device of the general nature here under consideration in which the electromechanically sensitive material involved can be polarized in the same direction lengthwise of the cylinder throughout the material and in which the electric signal fields in the material can be in the same direction circumferentially in the material at all points.

It is an object of the invention to provide an improved electromechanical twister device.

It is still another object of the invention to provide a twister electromechanical device which effectively comprises the major portion of a cylindrical element and which can be polarized in the same direction throughout the electromechanically sensitive material.

It is still another object of the invention to provide a twister-type electromechanically sensitive device which is easy to manufacture, using ceramic materials, in that all of the ceramic materials involved may be fired together as one unit.

It is still another object of the invention to provide an improved electromechanical twister device which has a very high coupling efficiency in its desired mode of action.

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In accordance with the invention, a twister-type electromechanical device comprises an element including an electromechanically sensitive material of high dielectric constant in the form of a major portion of a cylinder, this portion having substantial remanent electrostatic polarization in the same lengthwise direction of the cylinder throughout and the material having a coupling action as between an electric signal field circumferentially in the cylinder and mechanical shear in planes normal to the radii of the above-mentioned cylinder portion. The device also comprises electrodes, adjacent the circumferentially spaced edges of the above-mentioned cylinder portion, which provide a low impedance throughout the above-mentioned cylinder portion and a relatively high impedance between the electrodes through any other path. The device also includes a means for effectively providing during operation of the device potentials at the above-mentioned electrodes which correspond to signal fields in the above-mentioned cylinder portion having at any given time the same circumferential direction throughout the cylinder portion. By this arrangement, a twisting action of the element can be converted into electrical energy or vice versa.

As used in this specification, the term "high dielectric constant" is intended to mean a dielectric constant which is many times that of air, and the term "relatively low dielectric constant" is intended to refer to a dielectric constant which is many times less than the material herein referred to as having a high dielectric constant. This difference in magnitude of the dielectric constants should be at least 10 and should preferably be 100 or more.

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.

In the drawings, Fig. 1 illustrates an embodiment of the invention utilized as the electromechanical device of a phonograph pickup or record cutter; Fig. 2 illustrates certain additional features of the device of Fig. 1; and Figs. 3, 4, and 5 illustrate various modifications of the Fig. 1 device.

Referring now more particularly to Fig. 1, there is there shown a twister-type electromechanical device in accordance with the invention which has been indicated generally by the reference numeral 10. A preferred embodiment of the invention involves the use of the device 10 as the electromechanically sensitive element of a phonograph pickup or as the electromechanically sensitive element of a phonograph record cutter, and the device of Fig. 1 can be used for either purpose. For the moment, however, the illustration of Fig. 1 will be considered to apply to a phonograph pickup device.

Thus Fig. 1 comprises a turntable 11 driven by an electric motor 12 having electrical leads 13 and 14. A phonograph record 16 is shown in place on the turntable 11, which is adapted to be rotated by the motor 12. The device also includes an arm 17 which is pivoted within the structure 18 in order to allow a needle 19 to follow grooves in the phonograph record 16 in a manner which is well understood, per se, by those skilled in the art.

The electromechanical device 10 is held within a housing 20 in the arm 17 by means of a bracket 21 which is affixed to the housing 20 by means of screws 22 and 23. One end of the device 10 is rigidly clamped or otherwise fixedly held to one arm of the bracket 21 by means of clamp 24. To the other end of the device 10 is also attached a clamp 25 to which is affixed a pivot 26 which operates in a bearing in the bracket 21. The needle 19 is rigidly fastened to the structure including the clamp 25 and the pivot 26 so that to-and-fro motions of the needle in directions illustrated by the double-headed arrow 27, which are caused by the record member 16, are effective to provide a twisting action of the electromechanical device 10. Clamps 24 and 25 are of a non-

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conducting material in order that they will not interfere with the electrical characteristics of device 10 in a manner which will be apparent from the detailed description of the device to be given hereinafter.

Alternatively, the device just described may be considered to be a record cutter in which the to-and-fro movements of the needle 19 are effective to cut a record into the member 16 in a manner which, per se, is well understood by those skilled in the art. However, the proportioning of the device 10 must in general be somewhat different for these two types of operation.

The device 10 of Fig. 1 is a twister-type electromechanical device which includes an element of electromechanically sensitive material of high dielectric constant in the form of a major circumferential portion 30 of a cylinder. The device 10 also includes a second cylinder portion 31 comprised of a material of relatively low dielectric constant and which effectively completes the remainder of the cylinder. The material of the cylinder portion 30 is prepolarized so that it has substantial remanent electrostatic polarization in the same lengthwise direction of the cylinder throughout and has a mutual coupling action as between an electric signal field circumferentially in the cylinder and mechanical shear in planes normal to the radii of the major cylinder portion 30. The materials of cylinder portions 30 and 31 should have moduli of elasticity which are related to provide an effectively mechanically integral cylinder. In other words, the two portions effectively provide a complete cylinder which is a unitary structure mechanically insofar as the operational stresses and strains in the device are concerned. Electrodes 33 and 34 are provided adjacent the circumferentially spaced edges of the major cylinder portion 30. A low impedance is thus provided between electrodes 33 and 34 through the cylinder portion 30, due to the relatively high dielectric constant of the material of portion 30. Also, a relatively high impedance is provided between the electrodes 33 and 34 through the material of portion 31, due to the relatively low dielectric constant of the material of portion 31.

Reference is now made to Fig. 2 where an end view of the device 10 of Fig. 1 is illustrated and similar circuit elements have identical reference numerals in the two figures. The cylinder portion 30 is preferably comprised of any of the barium titanate materials mentioned above which have a strong mutual coupling action as between an electric field normal to the direction of polarization and mechanical shear in planes which include the direction of polarization and the direction of the electric signal field. Such material also has a high dielectric constant.

The cylinder portion 31 is provided in order to provide a cylinder which is complete mechanically, although, since the cylinder portion 31 is of a low dielectric constant material and need not be electromechanically sensitive, the cylinder portions 30 and 31 are considerably different electrically.

The cylinder portion 30 can be polarized in the length direction by means of electrodes applied to the end surfaces thereof before the cylinder portion 31 is inserted and before the electrodes 33 and 34 are affixed thereto. Alternatively, it is sometimes desirable to polarize the cylinder portion 30 without affixing electrodes thereto and this can be done by providing any suitable arrangement by which an intimate electrical contact can be made to the ends of cylinder portion 30 and thus effectively provide temporary electrodes for polarizing purposes. If polarizing electrodes are actually applied to the ends of cylinder portion 30, it is necessary that they be removed thereafter because otherwise they would have the effect of short-circuiting the signal field electrodes 33 and 34 during operation of the device 10. Cylinder portion 31 can be cemented in place after portion 30 has been suitably polarized and after electrodes 33 and 34 have been applied to the edges of cylinder portion 30.

The remaining portion of Fig. 2 is provided for the

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purpose of illustrating, in conjunction with Fig. 1, the use of element 10 either as a phonograph pickup device or as a record cutter. Thus, Fig. 2 includes a microphone 40 which is adapted to be coupled through an amplifier 41, a switch 42, and leads 43 and 44 to the electrodes 33 and 34 of device 10. Specifically, lead 43 is connected to electrode 33 and lead 44 is connected to the electrode 34. Alternatively, the leads 43 and 44 may be connected to a loudspeaker 46, through an amplifier 47 and switch 42, when the switch 42 is in the dotted position as shown in Fig. 2.

The operation of the device of Figs. 1 and 2 will first be explained as a record cutter, which requires that the switch 42 be in the full-line position illustrated in Fig. 2. Under these conditions, it is assumed that the motor 12 is effective to drive a blank record disk 16 and that the arm 17 is suitably tracked over a spiral record path on the face of the record blank by some suitable means (not shown). The sounds to be recorded are picked up by the microphone 40 (Fig. 2), and amplified by the amplifier 41 and applied to the electrodes of the device 10. These signal voltages cause a twisting action of device 10 (Fig. 1) which, since one end of the device is clamped by the member 24, is effective to move the needle 19 to and fro in the direction generally indicated by the double arrow 27 and in a manner corresponding to the signals to be recorded. These to-and-fro movements of the needle 19 actually cut corresponding portions of the member 16 to provide a permanent record of the sound signals at microphone 40.

In considering the operation of the device of Figs. 1 and 2 as a phonograph pickup device, it will be assumed that a record 16 to be reproduced is placed on the turntable 11 and that it is driven by the motor 12. It will also be assumed that the switch 42 of Fig. 2 is in its dotted position. Under these conditions, the recording in the record grooves is effective to cause a to-and-fro motion of the needle 19, again as generally represented by the arrow 27. These motions of the needle apply twisting motions to the device 10 and are effective to provide at the electrodes of device 10 signal voltages corresponding to the record being reproduced. These signal voltages are transmitted by means of leads 43 and 44 (Fig. 2) through the switch 42 to the amplifier 47 wherein they are amplified and after which they are reproduced by the loudspeaker 46.

During the operation of the device 10 either as a phonograph pickup or as a record cutter, potential differences at electrodes 33 and 34, corresponding to signal fields in cylindrical portion 30, are provided. These signal field directions have at any given time the same circumferential direction throughout the cylinder portion 30. Specifically, when the device of Figs. 1 and 2 is operated as a record cutter, voltages are applied between electrodes 33 and 34 and these voltages in turn produce signal fields in cylinder portion 30 which, at any given time, have the same circumferential direction in cylinder portion 30. The coupling action between these signal fields in cylinder portion 30 and a mechanical twisting motion of the cylinder portion in turn causes the needle 19 to respond as desired. Alternatively, when the electrode 10 is utilized as a phonograph pickup, it will be apparent that to-and-fro movements of the needle 19 cause twisting actions to be applied to element 10. These twisting actions provide signal fields in cylinder portion 30 which have, at any given time, the same direction throughout cylinder portion 30.

It will be apparent that, during either of the operations described above, the requirements for potential differences between electrodes 33 and 34 are such that circumferential signal fields are also provided in cylinder portion 31. However, these fields are undesired and, in general, have a deleterious effect upon the operation of the device and therefore should be kept as low as possible. It is for this reason that the material of cylinder portion 31 is prefer-

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ably of a material having a very low dielectric constant, although since it is desirable that the cylindrical device 10 operate mechanically as a unitary cylinder, it is also desirable that cylinder portion 30 and cylinder portion 31 should have moduli of elasticity which are substantially equal and, in any event, which are not sufficiently different as to prevent the complete cylindrical arrangement from operating effectively as a mechanically integral cylinder.

In Fig. 3, there is shown a device which is generally similar to that illustrated in Figs. 1 and 2 and similar circuit elements have identical reference numerals. Thus the device 10 of Fig. 3 has a portion 30 which effectively comprises the major portion of a cylindrical element and the portion 31, which was provided in the Figs. 1 and 2 embodiment, has been omitted. Aside from this fact, the operation of the Fig. 3 embodiment is essentially like that of the embodiment of Figs. 1 and 2. Since the cylinder portion 31 has been omitted in the Fig. 3 embodiment, the impedance between electrodes 33 and 34 through the material of cylinder portion 30 is very much lower than that of any other path between the electrodes.

In the Fig. 4 embodiment the cylinder portion 30 has the form of a substantially complete circumferential portion of the cylinder and the remaining portion of the cylinder, which effectively comprises a small air gap between electrodes 33 and 34, can be made very small due to the fact that the high dielectric constant of material 30 is very much higher than that of air.

Fig. 5 also is generally similar to the embodiment of the invention illustrated in Figs. 1 and 2, and like elements bear identical reference numerals while similar electrodes bear identical reference numerals primed.

In Fig. 5 electrodes 33' and 33'' are provided on the inside and outside faces of the cylinder adjacent one edge of cylinder portion 30. Similarly, electrodes 34' and 34'' are provided adjacent the other circumferential edge portion of cylinder portion 30. This construction has the advantage that the complete cylinder, including cylinder portion 30 and cylinder portion 31, may be fired together providing a ceramic bond between the portions so that a complete element of ceramic material is provided. Here again the material of portion 30 can be any of those mentioned above while the material of portion 31 can be of some other ceramic material which bonds well to the material used in portion 30 but which has a relatively low dielectric constant and the proper mechanical properties as set forth above. The fact that the electrodes in this case are on the outside and inside surfaces of the cylinder will not unduly interfere with the desired field pattern in the cylinder and all portions of the signal field will be substantially in the circumferential direction in cylinder portion 30. As a matter of fact, if desired, either the inside or outside set of electrodes may be omitted and the operation will be substantially as desired utilizing only the remaining two electrodes.

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.

What is claimed is:

1. A twister-type electromechanical device, comprising: an element including an electromechanically sensitive material of high dielectric constant in the form of a major circumferential portion, generally C-shaped in cross section, of a hollow cylinder, said material of said portion having substantial remanent electrostatic polarization in the same axial direction throughout said cylinder portion and having a mutual coupling action as between an electric signal field circumferentially in said cylinder portion and mechanical shears in planes normal to the radii of said portion; axially extensive electrodes closely adjacent in-

dividually to the circumferentially spaced edges of said cylinder portion so that potential differences across said electrodes correspond to signal fields in said portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said portion but a relatively high impedance between said electrodes through any other path; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said mechanical shears in said planes normal to the radii; whereby any application of said potential differences across said electrodes causes said motion associated with said twisting action while any movement of said mechanical coupling means to provide said twisting action causes development of said potential differences across said electrodes.

2. A twister-type electromechanical device, comprising: an element including an electromechanically sensitive barium titanate material of high dielectric constant in the form of a major circumferential portion, generally C-shaped in cross section, of a hollow cylinder, said material of said portion having substantial remanent electrostatic polarization in the same axial direction throughout said cylinder portion and having a mutual coupling action as between an electric signal field circumferentially in said cylinder portion and mechanical shears in planes normal to the radii of said portion; axially extensive electrodes closely adjacent individually to the circumferentially spaced edges of said cylinder portion so that potential differences across said electrodes correspond to signal fields in said portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said portion but a relatively high impedance between said electrodes through any other path; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said mechanical shears in said planes normal to the radii; whereby any application of said potential differences across said electrodes causes said motion associated with said twisting action while any movement of said mechanical coupling means to provide said twisting action causes development of said potential differences across said electrodes.

3. A twister-type electromechanical device for converting electrical energy into mechanical energy, comprising: an element including an electromechanically sensitive material of high dielectric constant in the form of a major circumferential portion, generally C-shaped in cross section, of a hollow cylinder, said material of said portion having substantial remanent electrostatic polarization in the same axial direction throughout said cylinder portion and being effective under the influence of an electric signal field circumferentially in said cylinder portion to develop mechanical shears in planes normal to the radii of said portion; axially extensive electrodes closely adjacent individually to the circumferentially spaced edges of said cylinder portion so that potential differences across said electrodes correspond to signal fields in said portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said portion but a relatively high impedance between said electrodes through any other path; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said mechanical shears in said planes normal to the radii; and means for applying electrical energy to said electrodes to provide said potential differences thereacross, whereby such applied electrical energy is converted into said twisting action of said element, resulting in said associated motion of said mechanical coupling means.

4. A twister-type electromechanical device for converting mechanical energy into electrical energy, comprising:

an element including an electromechanically sensitive material of high dielectric constant in the form of a major circumferential portion, generally C-shaped in cross section, of a hollow cylinder, said material of said portion having a substantial remanent electrostatic polarization in the same axial direction throughout said cylinder portion and being effective under the influence of a mechanical deformation of said material involving a system of shears in planes normal to the radii of said cylinder portion to develop an electric signal field circumferentially in said portion; axially extensive electrodes closely adjacent individually to the circumferentially spaced edges of said cylinder portion so that potential differences across said electrodes correspond to signal fields in said portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said portion but a relatively high impedance between said electrodes through any other path; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said system of mechanical shears in said planes normal to the radii; and means for applying mechanical energy to said mechanical coupling means to provide said motion thereof with said associated twisting action, whereby such applied mechanical energy is converted into said potential differences across said electrodes.

5. A twister-type electromechanical device, comprising: an element including an electromechanically sensitive first material of relatively high dielectric constant in the form of a major circumferential portion, generally C-shaped in cross section, of a hollow cylinder and including a second material of relatively low dielectric constant completing the remainder of the generally circular cross section of said hollow cylinder, said first material having substantial remanent electrostatic polarization in the same axial direction throughout said major cylinder portion and having a mutual coupling action as between an electric signal field circumferentially in said major cylinder portion and mechanical shears in planes normal to the radii of said portion, and said two materials having moduli of elasticity which are related to provide an effectively mechanically integral cylinder; axially extensive electrodes closely adjacent individually to the circumferentially spaced edges of said major cylinder portion so that potential differences across said electrodes correspond to signal fields in said portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said first material but a relatively high impedance between said electrodes through said second material; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said mechanical shears in said planes normal to the radii; whereby any application of said potential differences across said electrodes causes said motion associated with said twisting action while any movement of said mechanical coupling means to provide said twisting action causes development of said potential differences across said electrodes.

6. A twister-type electromechanical device, comprising: an element including an electromechanically sensitive first material of relatively high dielectric constant in the form of a substantially complete circumferential portion of a hollow cylinder with an axially extensive slot therethrough and including a second material of relatively low dielectric constant in said slot completing the remaining relatively small circumferential portion of said hollow cylinder, said first material having substantial remanent electrostatic polarization in the same axial direction throughout said substantially complete cylinder portion and having a mutual coupling action as between an electric signal field circumferentially in said cylinder portion and mechanical shears in planes normal to the radii of said portion, and said two materials having moduli of elasticity which are related to provide an effectively mechanically integral cyl-

ind; axially extensive electrodes closely adjacent individually to the circumferentially spaced edges of said slot so that potential differences across said electrodes correspond to signal fields in said cylinder portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said first material but a relatively high impedance between said electrodes through said second material; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said mechanical shears in said planes normal to the radii; whereby any application of said potential differences across said electrodes causes said motion associated with said twisting action while any movement of said mechanical coupling means to provide said twisting action causes development of said potential differences across said electrodes.

7. A twister-type electromechanical device, comprising: an element including an electromechanically sensitive first material of relatively high dielectric constant in the form of a major circumferential portion, generally C-shaped in cross section, of a hollow cylinder and including a second material of relatively low dielectric constant completing the remainder of the generally circular cross section of said hollow cylinder, said first material having substantial remanent electrostatic polarization in the same axial direction throughout said major cylinder portion and having a mutual coupling action as between an electric signal field circumferentially in said major cylinder portion and mechanical shears in planes normal to the radii of said portion, and said two materials having moduli of

elasticity which are related to provide an effectively mechanically integral cylinder; axially extensive electrodes on a circumferential surface of said major cylinder portion and closely adjacent individually to the circumferentially spaced edges thereof so that potential differences across said electrodes correspond to signal fields in said portion having at any given time the same circumferential direction throughout said portion, providing a low impedance between said electrodes through said first material but a relatively high impedance between said electrodes through said second material; and, affixed to said element, mechanical coupling means motion of which is associated with an axial twisting action of said element corresponding to the resultant of said mechanical shears in said planes normal to the radii; whereby any application of said potential differences across said electrodes causes said motion associated with said twisting action while any movement of said mechanical coupling means to provide said twisting action causes development of said potential differences across said electrodes.

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