United States Patent

[11] **3,549,913**

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[33] **Japan**
[31] **Nos. 42/70763, 42/70764, 42/70765, 42/70766, 42/70767 and 42/70768**

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[54] **PIEZO-ELECTRIC TRANSFORMER**
7 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **310/9.5**
[51] **Int. Cl.** **H01v 7/00**
[50] **Field of Search** 310/8.0, 8.1, 9.5, 9.8; 333/72, 30

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ABSTRACT: A piezo-electric transformer wherein an intermediate region is formed in the boundary portion between a driving portion and a power-generating portion, said intermediate portion being not polarized, polarized to only a small extent or the direction of polarization of which is gradually changed from the direction of polarization of said driving portion to that of said power-generating portion, thereby preventing the boundary portion between said driving portion and said power-generating portion from being destroyed by mechanical strength.

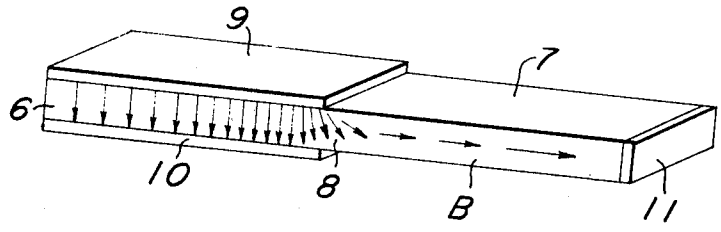


FIG. 1
PRIOR ART

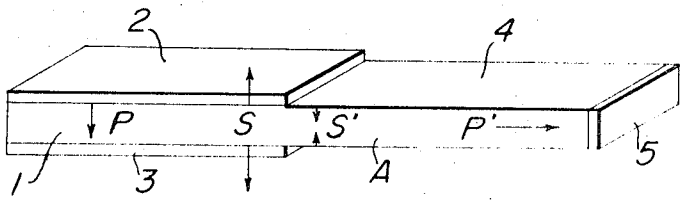


FIG. 2

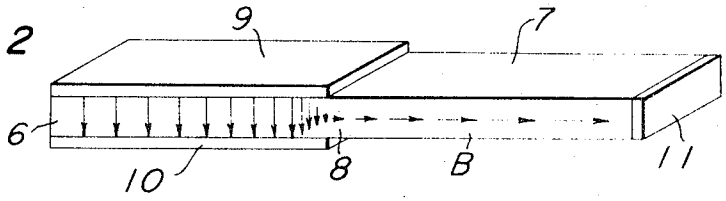


FIG. 3

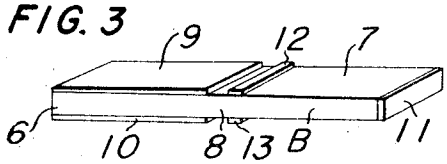


FIG. 4

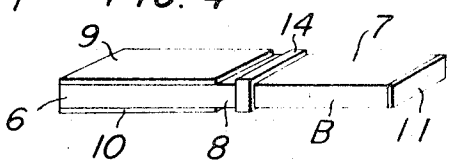


FIG. 5

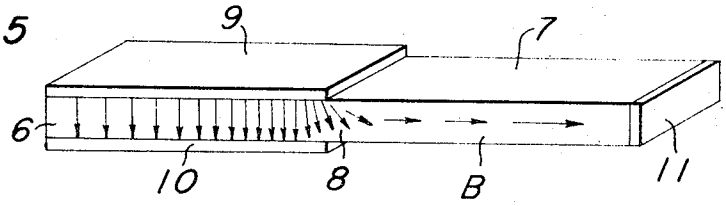


FIG. 6

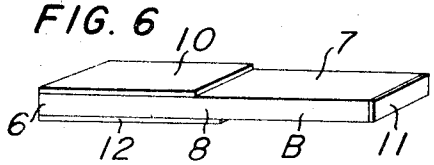
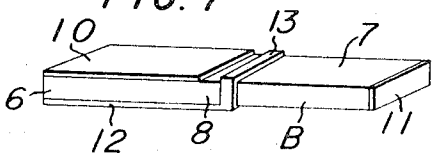


FIG. 7



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PIEZO-ELECTRIC TRANSFORMER

This invention relates to a piezo-electric transformer, and more particularly it pertains to such transformer having an intermediate region provided between a driving portion and a power-generating portion.

It is a primary object of the present invention to provide a piezo-electric transformer formed by a piezo-electric material such as barium titanate, PZT ceramic, PCM ceramic or the like, which will never be destroyed by a mechanical force resulting from polarization.

Other objects, features and advantages of the present invention will be readily apparent from the following description of certain preferred embodiments taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic perspective view showing an example of conventional piezo-electric transformer;

FIG. 2 is a view useful for explaining a first principle of the present invention;

FIGS. 3 and 4 are schematic perspective views showing the piezo-electric transformers constructed in accordance with the first principle of the present invention, respectively;

FIG. 5 is a view useful for explaining a second principle of the present invention; and

FIGS. 6 and 7 are schematic perspective views showing the piezo-electric transformers constructed in accordance with the second principle of the present invention.

In order to provide a better understanding of the present invention, description will first be given of an example of a conventional piezo-electric transformer with reference to FIG. 1, wherein use is made of a rectangular parallelepiped rod-like piezo-electric material body A of which the left half 1 serves as driving portion having input electrodes 2 and 3 attached to the top and bottom surfaces thereof. The right half 4 of the piezo-electric material body A serves as power-generating portion having an output electrode 5 attached to the right end surface thereof and the rod-like body A may be constituted by barium, titanate, PZT ceramic, PCM ceramic or the like. In order to achieve the function of a transformer by utilizing the electro-strictive effect or piezo-electric effect, the driving portion 1 is polarized in the direction of the thickness thereof as indicated by an arrow P, and the power-generating portion 4 is polarized in the direction of the length thereof as indicated by an arrow P'.

In a common method for such polarization of a piezo-electric transformer, the input terminals 2 and 3 are short-circuited, a DC electric field is applied between the short-circuited input electrodes 2 and 3 and the output electrode 5 to thereby polarize the Power-generating portion in the direction of the length thereof, thereafter the input terminals 2 and 3 are disconnected, and a DC electric field is applied therebetween to thereby polarize the driving portion 1 in the direction of the thickness thereof. Consequently, the directions of polarization are a made to cross each other at the boundary plane between the driving portion 1 and the power-generating portion 4.

It is well known that a piezo-electric material has such a property that it expands in the direction of polarization and contracts in a direction perpendicular to the direction of polarization. With the conventional piezo-electric transformer shown in FIG. 1, therefore, an outward stress as shown by an arrow S is imparted to the driving portion 1 at a position in the vicinity of the boundary plane, and an inward stress as shown by an arrow S' is applied to the power-generating portion 4 at a position in the neighborhood of the boundary plane, so that a concentrated shearing distortion occurs in those positions to decrease the mechanical strength of those portions in the neighborhood of the boundary plane. Thus, the conventional device has a very poor reliability since it very often tends to be destroyed during the polarization or operation. To make matters worse, the more remarkable the destruction, the more perfectly effected the polarization.

The present invention intends to remove the foregoing drawbacks of the conventional piezo-electric transformer,

FIG. 2 illustrates the first principle of the present invention, wherein an intermediate region 8 which is not polarized or polarized to only a small extent is formed between the left half of a parallelepiped piezo-electric material body B serving as driving portion 6 and the right half thereof serving as power-generating portion 7.

In FIG. 2, the direction and length of each arrow correspond to the direction and degree of polarization, respectively. From this, it will be seen that the driving portion 6 is polarized in the direction of the thickness thereof, and the extent of the polarization become less toward the intermediate surface 8. By doing so, it is possible to decrease the aforementioned locally concentrated shearing distortion occurring in the neighborhood of the boundary plane so as to increase the mechanical strength of the driving portion 6 and power-generating portion 7 at positions in the vicinity of the boundary plane. Thus, the possibility of destruction tending to occur during the polarization or operation is greatly reduced, resulting in a very high reliability. The reference numerals 9 and 10 represent input electrodes respectively, and 11 an output electrode.

Although a variety of methods may be adopted to form such intermediate surface 8, several of them will be described hereinbelow.

Referring to FIG. 3, polarizing electrodes 12 and 13 are provided on the upper and lower surfaces of the power-generating portion 7 in predetermined spaced relationship to the driving portion 6. The power-generating portion 7 is polarized in the direction of the length thereof by applying a DC electric field between the electrodes 12 and 13 and the output electrode 11, with the electrodes 12 and 13 being short-circuited. Subsequently, the driving portion 6 is polarized in the direction of the thickness thereof by applying a DC electric field between the electrodes 9 and 10. In this way, the intermediate region 8 which is not polarized or polarized to only a small extent can be formed. Thus, it is possible to substantially realize the condition as shown in FIG. 2.

Another method of polarization to form such intermediate region 8 will be described with reference to FIG. 4.

In accordance with this method, a ring-like electrode 14 encircling the material body is provided thereon in the neighborhood of the boundary plane between the driving portion 6 and the power-generating portion 7. The power-generating portion 7 is polarized in the direction of the length thereof by applying a DC electric field between the ring-like electrode 14 and the output electrode 11 provided on the end surface of the power-generating portion 7. Subsequently, the driving portion 6 is polarized in the direction of the thickness thereof by applying a DC electric field between the input electrodes 9 and 10 provided on the top and bottom surfaces of the driving portion 6. In this way, an intermediate region which is not polarized or polarized to only a small extent can be formed. Thus, it is possible to substantially realize the condition as shown in FIG. 2.

As compared with the method described above in connection with FIG. 3, the method just described is disadvantageous in that the manufacturing labor is increased since an electrode material must be applied also to the side surfaces of the piezo-electric transformer, but it can be effectively applied to a piezo-electric transformer with a great thickness since the formation of the intermediate region can be more perfectly effected.

FIG. 5 illustrates the second principle of the present invention, according to which destruction is prevented from occurring in the neighborhood of the boundary plane between the driving portion and the power-generating portion of the piezo-electric transformer. In FIG. 5, arrows indicate the directions of polarization. From this, it will be seen that the driving portion 6 is polarized in the direction of the thickness thereof, that the direction of the polarization is gradually changed to the direction of the length of the device then approaching the intermediate region 8, and that beyond the intermediate region, the polarization is effected completely lengthwise. With

such arrangement, the aforementioned locally concentrated shearing distortion occurring in the vicinity of the boundary plane is decreased so that the mechanical strength of the driving portion 6 and power-generating portion 7 at positions adjacent to the boundary plane is increased. Thus, the possibility of destruction tending to occur during the polarization or operation of the device is greatly reduced, thus resulting in a very high reliability.

Various methods of gradually changing the direction of polarization in the vicinity of the boundary plane between the driving portion 6 and the power-generating portion 7 may be conceivable. An example of such methods is illustrated in FIG. 6.

The piezo-electric transformer shown in FIG. 6 is characterized in that the length of the one input electrode 12 is made different from or longer than that of the other input electrode 10, the excess portion of said electrode 12 extending toward and onto the power-generating portion. By polarizing such piezo-electric transformer in the same manner as described above in connection with FIG. 1, it is possible to substantially realize the condition as shown in FIG. 5.

Referring to FIG. 7, there is shown a piezo-electric transformer including a third input electrode 13 which is integrally provided at the power-generating portion 7 side end of the longer electrode 12 in such a manner as to encircle the material body. Namely, the new electrode 12, 13 has such a shape that said longer electrode 12 and said ring-like electrode 14 are integrally formed. The power-generating portion 7 is first polarized in the direction of the length thereof by applying a DC electric field between the input electrode 12 and the output electrode 11, and then the driving portion 6 is polarized in the direction of thickness thereof by applying a DC electric field between the input electrodes 10 and 12. Thus, it is possible to substantially realize the condition as shown in FIG. 5.

As described above, in accordance with the present invention, it is possible to greatly reduce concentrated distortion tending to occur in the neighborhood of the boundary plane between the driving portion and the power generating portion, so that the reliability of a Piezo-electric transformer can be remarkably increased. Thus, the piezo-electric transformer of the present invention can be effectively utilized as transformer adapted especially for high-amplitude operation such as a high voltage transformer for television.

We claim:

1. A piezo-electric transformer comprising a piezo-electric element in the form of a rectangular parallelepiped rod-like body made of a piezo-electric material of which a first portion serves as driving portion having first and second input electrodes attached to top and bottom surfaces thereof, said driving portion being polarized in the direction of the thickness thereof, of which a second portion serves as power-generating portion having an output electrode attached to a right end surface thereof, said power-generating portion being polarized in the direction of the length thereof, and which rod-like body has an intermediate portion lying in the boundary region between said driving and power-generating portions, the direction of polarization of said intermediate portion being different from those of said driving and power-generating portions.

2. A piezo-electric transformer as claimed in claim 1, wherein said intermediate portion has such a property that the polarization thereof does not take place or that the degree of the polarization thereof is very slight.

3. A piezo-electric transformer as claimed in claim 2, further including polarizing electrodes provided on said upper and lower surfaces of said power-generating portion in a predetermined spaced relationship to said driving portion and adapted to cause said power-generating portion to be polarized in the direction of the length thereof.

4. A piezo-electric transformer as claimed in claim 2, further including a ring-like electrode encircling said power-generating portion and disposed in a predetermined spaced relationship to said driving portion and adapted to cause said power-generating portion to be polarized in the direction of the length thereof.

5. A piezo-electric transformer as claimed in claim 1, wherein the direction of polarization in said intermediate portion is of a phase transitive from that in said driving portion to that in said power-generating portion.

6. A piezo-electric transformer as claimed in claim 5, wherein the length of one of said input electrodes is different from that of the other of said input electrodes.

7. A piezo-electric transformer as claimed in claim 5, wherein said first input electrode is longer than said second input electrode, said first electrode having integrally formed therewith a ring-like electrode encircling said power-generating portion and disposed in a predetermined spaced relationship to said driving portion and adapted to cause said power-generating portion to be polarized in the direction of the length thereof.