

TITLE: "Multi-Layer Piezoelectric Transformer"

1

2 BACKGROUND OF THE INVENTION

3

4 1. Field of Invention

5

6 The present invention relates to piezoelectric ceramic
7 transformers. More particularly, the present invention
8 relates to multi-layered piezoelectric ceramic
9 transformers.

10

11

12 2. Description of the Prior Art

13

14 Wound-type electromagnetic transformers have been used
15 for generating high voltage in internal power circuits of
16 devices such as televisions or in charging devices of
17 copier machines which require high voltage. Such
18 electromagnetic transformers take the form of a conductor
19 wound onto a core made of a magnetic substance. Because
20 a large number of turns of the conductor are required to
21 realize a high transformation ratio, electromagnetic

1 transformers that are effective, yet at the same time
2 compact and slim in shape are extremely difficult to
3 produce.

4

5 To remedy this problem, piezoelectric transformers
6 utilizing the piezoelectric effect have been provided in
7 the prior art. In contrast to the general
8 electromagnetic transformer, the piezoelectric ceramic
9 transformer has a number of advantages. The size of a
10 piezoelectric transformer can be made smaller than
11 electromagnetic transformers of comparable transformation
12 ratio. Piezoelectric transformers can be made
13 nonflammable, and they produce no electromagnetically
14 induced noise.

15

16 The ceramic body employed in prior piezoelectric
17 transformers take various forms and configurations,
18 including rings, flat slabs and the like. A typical
19 example of a prior piezoelectric transformer is
20 illustrated in Fig. 1. This type of piezoelectric
21 transformer is commonly referred to as a "Rosen-type"
22 piezoelectric transformer. The basic Rosen-type
23 piezoelectric transformer was disclosed in U.S. patent
24 no. 2,830,274 to Rosen, and numerous variations of this
25 basic apparatus are well known in the prior art. The
26 typical Rosen-type piezoelectric transformer comprises a
27 flat ceramic slab 10 which is appreciably longer than it

1 is wide and substantially wider than thick. As shown in
2 Fig. 1, a piezoelectric body 10 is employed having some
3 portions polarized differently from others. In the case
4 of Fig. 1, the piezoelectric body 10 is in the form of a
5 flat slab which is considerably wider than it is thick,
6 and having greater length than width. A substantial
7 portion of the slab 10, the portion 12 to the right of
8 the center of the slab is polarized longitudinally,
9 whereas the remainder of the slab is polarized
10 transversely to the plane of the face of the slab. In
11 this case the remainder of the slab is actually divided
12 into two portions, one portion 14 being polarized
13 transversely in one direction, and the remainder of the
14 left half of the slab, the portion 16 also being
15 polarized transversely but in the direction opposite to
16 the direction of polarization in the portion 14.

17

18 In order that electrical voltages may be related to
19 mechanical stress in the slab 10, electrodes are
20 provided. If desired, there may be a common electrode
21 18, shown as grounded. For the primary connection and
22 for relating voltage at opposite faces of the
23 transversely polarized portion 14 of the slab 10, there
24 is an electrode 20 opposite the common electrode 18. For
25 relating voltages to stress generated in the longitudinal
26 direction of the slab 10, there is a secondary or high-
27 voltage electrode 22 cooperating with the common

1 electrode 18. The electrode 22 is shown as connected to
2 a terminal 24 of an output load 26 grounded at its
3 opposite end.

4

5 In the arrangement illustrated in Fig. 1, a voltage
6 applied between the electrodes 18 and 20 is stepped up to
7 a high voltage between the electrodes 18 and 22 for
8 supplying the load 26 at a much higher voltage than that
9 applied between the electrodes 18 and 20.

10

11 A problem with prior piezoelectric transformers is that
12 they are difficult to manufacture because individual
13 ceramic elements must be "poled" at least twice each, and
14 the direction of the poles must be different from each
15 other.

16

17 Another problem with prior piezoelectric transformers is
18 that they are difficult to manufacture because it is
19 necessary to apply electrodes not only to the major faces
20 of the ceramic element, but also to at least one of the
21 minor faces of the ceramic element.

22

23 Another problem with prior piezoelectric transformers is
24 that they are difficult to manufacture because, in order
25 to electrically connect the transformer to an electric
26 circuit, it is necessary to attach (i.e. by soldering or
27 otherwise) electrical conductors (e.g. wires) to

1 electrodes on the major faces of the ceramic element as
2 well as on at least one minor face of the ceramic
3 element.

4

5 Another problem with prior piezoelectric transformers is
6 that the voltage output of the device is limited by the
7 ability of the ceramic element to undergo deformation
8 without cracking or structurally failing. It is
9 therefore desirable to provide a piezoelectric
10 transformer which is adapted to deform under high voltage
11 conditions without damaging the ceramic element of the
12 device.

13

14 SUMMARY OF THE INVENTION

15

16 The term piezoelectric transformer is here applied to a
17 passive electrical energy-transfer device employing the
18 piezoelectric properties of two co-joined materials to
19 achieve the transformation of voltage or current or
20 impedance. It is an object of the invention to provide a
21 piezoelectric transformer which is not only capable of
22 substantial transformation ratios, but in which
23 relatively high power may be transferred in relation to
24 the size of the unit.

25

26 Accordingly, it is a primary object of the present
27 invention to provide a piezoelectric transformer which

1 may be easily and inexpensively produced.

2

3 It is another object of the present invention to provide
4 a device of the character described which is capable of
5 producing high voltages and which may safely be used in
6 high voltage circuits.

7

8 It is another object of the present invention to provide
9 a piezoelectric transformer of the character described
10 comprising a pair of ceramic elements, each exhibiting
11 piezoelectric properties, which are in physical
12 (mechanical) communication with each other such that
13 deformation of one ceramic element results in
14 corresponding deformation of the other ceramic element.

15

16 It is another object of the present invention to provide
17 a piezoelectric transformer of the character described
18 which is easy to manufacture because it is sufficient to
19 pole each ceramic element only once, and wherein the
20 direction of poling for each ceramic element is constant
21 over its entire mass.

22

23 It is another object of the present invention to provide
24 a piezoelectric transformer of the character described
25 which is easy to manufacture because it is sufficient to
26 apply electrodes only to the major faces of the ceramic
27 elements, and which do not require application of

1 electrodes to minor faces of the ceramic elements.

2

3 It is another object of the present invention to provide
4 a piezoelectric transformer of the character described
5 which is easy to manufacture because it is sufficient to
6 apply electrodes only to two parallel faces of the
7 ceramic elements.

8

9 It is another object of the present invention to provide
10 a piezoelectric transformer of the character described
11 which is easy to connect or install in an electric
12 circuit, because it is sufficient to attach (i.e. by
13 soldering or otherwise) electrical conductors (e.g.
14 wires) only to electrodes on the major faces of the
15 ceramic element.

16

17 It is another object of the present invention to provide
18 a piezoelectric transformer of the character described
19 which is adapted to deform under high voltage conditions
20 without damaging the ceramic element of the device.

21

22 It is another object of the present invention to provide
23 a piezoelectric transformer of the character described
24 which is operable over wide input and output frequency
25 bandwidths.

26

27 It is another object of the present invention to provide

1 a piezoelectric transformer of the character described
2 which electrically isolates the voltage and current at
3 the input to the device from the voltage and current at
4 the output of the device.

5

6 Further objects and advantages of my invention will
7 become apparent from a consideration of the drawings and
8 ensuing description thereof.

9

1

2 **BRIEF DESCRIPTION OF THE DRAWINGS**

3

4 Fig. 1 is a perspective view showing the construction of
5 a Rosen-type piezoelectric transformer of the prior art;

6

7 Fig. 2 is a perspective view showing the preferred
8 embodiment of a piezoelectric transformer constructed in
9 accordance with the present invention;

10

11 Fig. 3 is a cross-sectional elevational view showing
12 details of the construction of the laminate layers of the
13 invention;

14

15 Fig. 4 is a perspective view of a modified embodiment of
16 the invention;

17

18 Fig. 5 is a perspective view of a modified embodiment of
19 the invention;

20

21 and Fig. 6 is a perspective view of a modified embodiment
22 of the invention.

1

2 **DESCRIPTION OF THE PREFERRED EMBODIMENT**

3

4 In the preferred embodiment of the invention, a
5 piezoelectric transformer (generally designated 1) is
6 manufactured by stacking and bonding together a number of
7 laminate layers as illustrated in Fig. 2 and as will be
8 more fully described below.

9

10 A first piezoelectric ceramic wafer 30 is preferably in
11 the form of a slab having two substantially parallel
12 major faces which are each electroplated 32 and 38.

13

14 A second piezoelectric ceramic wafer 48 is preferably in
15 the form of a slab having two substantially parallel
16 major faces which are each electroplated 46 and 50.

17

18 A first pre-stress layer 36 is positioned adjacent one
19 electroplated surface 32 of the first piezoelectric
20 ceramic wafer 30. An adhesive layer 34 is disposed
21 between the first pre-stress layer 36 and the adjacent
22 electroplated surface 32 of the first piezoelectric
23 ceramic wafer 30 for purposes of bonding the two members
24 (i.e. the first pre-stress layer 36 and the first
25 piezoelectric ceramic wafer 30) together. The first pre-
26 stress layer 36 is preferably a conductive material
27 (preferably metal) having a coefficient of thermal

1 expansion/contraction which is greater than that of the
2 material of the first ceramic wafer 30.

3

4

5 A second pre-stress layer 42 is positioned adjacent the
6 other electroplated surface 38 of the first piezoelectric
7 ceramic wafer 30. An adhesive layer 40 is disposed
8 between the second pre-stress layer 42 and the adjacent
9 electroplated surface 38 of the first piezoelectric
10 ceramic wafer 30 for purposes of bonding the two members
11 (i.e. the second pre-stress layer 42 and the first
12 piezoelectric ceramic wafer 30) together. The second
13 pre-stress layer 42 is preferably a conductive material
14 (preferably metal) having a coefficient of thermal
15 expansion/contraction which is greater than that of the
16 material of the first ceramic wafer 30.

17

18 An electroplated surface 46 of the second piezoelectric
19 ceramic wafer 48 is positioned adjacent the second pre-
20 stress layer 42, such that the second pre-stress layer 42
21 is between the two ceramic wafers 30 and 48, as shown in
22 Fig. 2. An adhesive layer 44 is disposed between the
23 second pre-stress layer 42 and the adjacent electroplated
24 surface 46 of the second piezoelectric ceramic wafer 48
25 for purposes of bonding the two members (i.e. the second
26 pre-stress layer 42 and the second piezoelectric ceramic
27 wafer 48) together. The first pre-stress layer 36 is

1 preferably has a coefficient of thermal
2 expansion/contraction which is greater than that of the
3 material of the second ceramic wafer 48.

4

5 A third pre-stress layer 54 is positioned adjacent the
6 other electroplated surface 50 of the second
7 piezoelectric ceramic wafer 48. An adhesive layer 52 is
8 disposed between the third pre-stress layer 54 and the
9 adjacent electroplated surface 50 of the second
10 piezoelectric ceramic wafer 48 for purposes of bonding
11 the two members (i.e. the third pre-stress layer 54 and
12 the second piezoelectric ceramic wafer 48) together. The
13 third pre-stress layer 54 is preferably a conductive
14 material (preferably metal) having a coefficient of
15 thermal expansion/contraction which is greater than that
16 of the material of the second ceramic wafer 48.

17

18 During manufacture of the transformer 1 the entire stack
19 of laminate layers (i.e. the two ceramic wafers 30 and
20 48, the three pre-stress layers 36, 42 and 54, and the
21 four adhesive layers 34, 40, 44 and 52) are arranged as
22 described herein above and as illustrated in Fig. 2, and
23 simultaneously heated to a temperature above the melting
24 point of the adhesive materials 34, 40, 44 and 52. In
25 the preferred embodiment of the invention the adhesive
26 material used in the four adhesive layers 34, 40, 44 and
27 52 is LaRC-SI_{TM} adhesive, as developed by NASA-Langley

1 Research Center and commercially marketed by IMITEC, Inc.
2 of Schenectady, New York. LaRC-SI_{TM} adhesive, which has a
3 melting point above 300 deg. C, is a very strong adhesive
4 and has a coefficient of thermal contraction which is
5 greater than that of most ceramics (and, in particular,
6 is preferably greater than that of the materials of the
7 two ceramic wafers 30 and 48). While LaRC-SI_{TM} adhesive
8 is used in the preferred embodiment of the invention, it
9 is within the scope of the present invention to use other
10 adhesives, provided they have a melting point below that
11 of the other laminate layers of the transformer (i.e. the
12 two ceramic wafers 30 and 48, and the three pre-stress
13 layers 36, 42 and 54), are capable of hardening to apply
14 a bond between the respective pre-stress layers 36, 42
15 and 54 and the ceramic wafers 30 and 48 sufficient to
16 transfer longitudinal stresses between adjacent layers of
17 the transformer 1.

18

19 After the entire stack of laminate layers (i.e. the two
20 ceramic wafers 30 and 48, the three pre-stress layers 36,
21 42 and 54, and the four adhesive layers 34, 40, 44 and
22 52) have been heated to a temperature above the melting
23 point of the adhesive materials 34, 40, 44 and 52, the
24 entire stack of laminate layers (i.e. the two ceramic
25 wafers 30 and 48, the three pre-stress layers 36, 42 and
26 54, and the four adhesive layers 34, 40, 44 and 52) are
27 then permitted to cool to ambient temperature. As the

1 temperature of the laminate layers (i.e. the two ceramic
2 wafers 30 and 48, the three pre-stress layers 36, 42 and
3 54, and the four adhesive layers 34, 40, 44 and 52) falls
4 below the melting temperature of the adhesive materials
5 34, 40, 44 and 52, the four adhesive layers 34, 40, 44
6 and 52 solidify, bonding them to the adjacent layers.
7 During the cooling process the ceramic wafers 30 and 48
8 become compressively stressed along their longitudinal
9 axes due to the relatively higher coefficients of thermal
10 contraction of the materials of construction of the pre-
11 stress layers 36, 42 and 54.

12

13 It will be understood that a piezoelectric transducer 1
14 constructed in accordance with the preceding description
15 comprises a pair of longitudinally pre-stressed (i.e.
16 compressed) piezoelectric ceramic wafers which are
17 intimately bonded to each other (albeit separated by
18 laminated adhesive and pre-stress layers) along one of
19 their major faces.

20

21 As discussed above, in the preferred embodiment of the
22 invention the four adhesive layers 34, 40, 44 and 52)
23 preferably comprise LaRC-SI_{TM} adhesive. LaRC-SI_{TM} adhesive
24 is a dielectric. Therefore, in the preferred embodiment
25 of the invention it is desirable to roughen the surfaces
26 of the three pre-stress layers 36, 42 and 54 which are in
27 contact with the four adhesive layers 34, 40, 44 and 52

1 (as illustrated in Fig. 3), so that the pre-stress layers
2 36, 42 and 54 may electrically conduct to the
3 corresponding electroplated surfaces 32, 38, 46 and 50 of
4 the respective ceramic wafers 30 and 48.

5
6 In the preferred embodiment of the invention the pre-
7 stress layers 36, 42 and 54, and the four adhesive layers
8 34, 40, 44 and 52 are longer than the two ceramic wafers
9 30 and 48 and, accordingly, protrude beyond the ends of
10 the ceramic members. Electric terminals 56, 58 and 60
11 are connected (e.g. by wire and solder, or other common
12 means) to an exposed surface of the pre-stress layers
13 54, 42 and 36, respectively.

14
15 In the preferred embodiment of the invention the three
16 pre-stress layers 36, 42 and 54, and the four adhesive
17 layers 34, 40, 44 and 52 each compressively stress the
18 two ceramic members 30 and 48. By compressive stressing
19 the two ceramic members 30 and 48, the ceramic members 30
20 and 48 are less susceptible to damage (i.e. cracking and
21 breaking).

22
23 FIGURE 4 illustrates the construction of a modified
24 piezoelectric transformer 2 which is similar to that of
25 the preferred embodiment of the invention (Fig. 2), less
26 the two outboard pre-stress layers 36 and 54 and adhesive
27 layers 34 and 52.

1

2 FIGURE 5 illustrates the construction of another modified
3 piezoelectric transformer 3. In this modified
4 piezoelectric transformer 3 two piezoelectric wafers 30
5 and 48, having parallel electroplated surfaces 32, 38, 46
6 and 50 are bound together at two adjacent major faces of
7 the wafers.

8

9 In the preferred embodiment of the piezoelectric
10 transformer 1 and the two modified piezoelectric
11 transformer 2 and 3, each of the ceramic wafers 30 and 48
12 is poled in one direction. More specifically, in the
13 preferred embodiment of the piezoelectric transformer 1
14 and the two modified piezoelectric transformer 2 and 3,
15 each of the ceramic wafers 48 and 30 is poled such that
16 when a voltage potential is applied across the
17 corresponding electrodes 46 and 50, or 32 and 38 on its
18 respective major faces, the wafer will longitudinally
19 strain. Conversely, in the preferred embodiment of the
20 piezoelectric transformer 1 and the two modified
21 piezoelectric transformer 2 and 3, each of the ceramic
22 wafers 48 and 30 is poled such that when either of the
23 ceramic wafers 30 is longitudinally strained a voltage
24 potential is generated between the corresponding
25 electrodes 46 and 50, or 32 and 38, on its respective
26 major faces.

27

1 **OPERATION**

2 Referring now to Figure 2: When a primary (i.e. input)
3 voltage V1 is applied across terminals 58 and 60
4 connected to the electrodes 32 and 38 of the first
5 ceramic wafer 30, the first ceramic wafer 30 will
6 piezoelectrically generate an extensional stress
7 commensurate with the magnitude of the input voltage V1,
8 the piezoelectric properties of the wafer 30 material,
9 the size and geometry of the wafer 30 material, and the
10 elasticity of the other materials of the other laminate
11 layers (i.e. the ceramic wafer 48, the three pre-stress
12 layers 36, 42 and 54, and the four adhesive layers 34,
13 40, 44 and 52) which are bonded to the first wafer 30.
14 The extensional stress which is generated by the input
15 voltage V1 causes the first ceramic wafer 30 to be
16 longitudinally strained, (for example as indicated by
17 arrow 64).

18
19 Because the first ceramic wafer 30 is securely bonded to
20 the second ceramic wafer 48 (i.e. by adhesive layers 40
21 and 44), any longitudinal strain 64 of the first ceramic
22 wafer 30 will result in a longitudinal strain (of the
23 same magnitude and direction) in the second ceramic wafer
24 48 (as indicated by arrow 65). The longitudinal strain
25 65 of the second piezoelectric ceramic wafer 48 generates
26 a voltage potential V2 across the two electroplated
27 surfaces 46 and 50 of the second ceramic wafer 48. The

1 electric terminals 58 and 56 may be electrically
2 connected to corresponding electroplated surfaces 46 and
3 50 of the second ceramic wafer 48. The magnitude of the
4 piezoelectrically generated voltage V2 between the two
5 electrodes 46 and 50 of the second ceramic wafer 48
6 depends upon the piezoelectric properties of the wafer 48
7 material, the size, geometry and poling of the wafer 48
8 material.

9
10 It will therefore be appreciated that by applying a first
11 voltage V1 across the electroplated 32 and 38 major
12 surfaces of the first ceramic wafer 30, the first ceramic
13 wafer 30 is caused to longitudinally strain 64, which, in
14 turn, causes the second ceramic wafer 48 to
15 longitudinally strain 65 a like amount, which, in turn
16 produces a second voltage potential V2 between the
17 electroplated 46 and 50 major surfaces of the second
18 ceramic wafer 48.

19
20 It will be understood that ratio of the first voltage V1
21 to the second voltage V2 is a function of the
22 piezoelectric properties of the wafer 30 and 48, the size
23 and geometry of the wafers 30 and 48 material, the
24 elasticity of the other materials of the other laminate
25 layers (i.e. the ceramic wafers 30 48, the three pre-
26 stress layers 36, 42 and 54, and the four adhesive layers
27 34, 40, 44 and 52), and the poling characteristics of the

1 two ceramic wafers 30 and 48. It will also be understood
2 that the first voltage V1 may alternatively be either an
3 "input" voltage or an "output" voltage, and the second
4 voltage V2 may respectively be either an "output" voltage
5 or an "input" voltage.

6
7 In the preferred embodiment of the invention the
8 corresponding facing electroplated surfaces 38 and 46 of
9 the first ceramic wafer 30 and second ceramic wafer 48,
10 respectively, are electrically connected to a common
11 electric terminal 58. In an alternative embodiment of
12 the transformer 4 (as shown in Fig. 6), the corresponding
13 facing electroplated surfaces 38 and 46 of two ceramic
14 wafers 30 and 48 are electrically insulated from each
15 other, (for example by a dielectric adhesive layer 62a),
16 and connected to corresponding terminals 69 and 68. It
17 will be appreciated that in this modified embodiment of
18 the transformer 4 the two piezoelectric ceramic wafers 30
19 and 48 are completely electrically isolated from each
20 other. Thus it will be understood that a transformer 4
21 constructed in accordance with this modification of the
22 invention may be used in an electric circuit to
23 electrically protect electrical components "downstream"
24 from the transformer 4 from damage from high current
25 discontinuities "upstream" of the transformer 4.

26

27 While the above description contains many specificities,

1 these should not be construed as limitations on the scope
2 of the invention, but rather as an exemplification of one
3 preferred embodiment thereof. Many other variations are
4 possible, for example:

5

6 The various laminate layers (i.e. the ceramic wafers 30
7 and 48, the pre-stress layers 36, 42 and 54, and the
8 adhesive layers 34, 40, 44 and 52) may be bonded to each
9 other without sequentially heating and cooling so as to
10 pre-stress the ceramic members;

11

12 The two ceramic wafers 30 and 48 may be constructed of
13 either similar or dissimilar piezoelectric materials
14 which may either have identical or dissimilar
15 piezoelectric coefficients;

16

17 The two ceramic wafers 30 and 48 may either be of equal
18 or unequal thicknesses; and

19

20

21 The adhesive layers (34, 40, 44, 52) may either be
22 electrically conductive or non-conductive.

23

1

2 Accordingly, the scope of the invention should be
3 determined not by the embodiment illustrated, but by the
4 appended claims and their legal equivalents.

I Claim:

- 1 1. A transformer comprising:
2
3 a first electroactive member having two opposing major
4 faces which are disposed on the opposite sides of a first
5 longitudinal axis;
6
7 a second electroactive member having two opposing major
8 faces which are disposed on the opposite sides of a
9 second longitudinal axis;
10
11 wherein an electrode is bonded to each of said two
12 opposing major faces of said first electroactive member;
13
14 and wherein an electrode is bonded to each of said two
15 opposing major faces of said second electroactive member;
16
17 said first electroactive member being polarized
18 transversely in a thickness direction between said two
19 opposing major faces of said first electroactive member,
20 such that said first electroactive member longitudinally
21 strains when a voltage is applied across said two
22 opposing major faces of said first electroactive member;
23
24 said second electroactive member being polarized
25 transversely in a thickness direction between said two



1 opposing major faces of said second electroactive member,
2 such that said second electroactive member longitudinally
3 strains when a voltage is applied across said two
4 opposing major faces of said second electroactive member,
5 said second electroactive member being polarized in a
6 direction substantially parallel to said first
7 electroactive member;

8
9 wherein said first electroactive member is mechanically
10 bonded to said second electroactive member by a bonding
11 layer, said bonding layer being disposed between a first
12 major face of said first electroactive member and a first
13 major face of said second electroactive member.

1 2. The device according to claim 1,
2
3 wherein said first and second electroactive members
4 comprise a piezoelectric material.

1 3. The device according to claim 2,
2
3 wherein said bonding layer comprises a first electrically
4 conductive member.



1 4. The device according to claim 3,
2
3 wherein said bonding layer further comprises a second
4 electrically conductive member, and a dielectric layer,
5 wherein said dielectric layer is disposed between said
6 first and second electrically conductive members and
7 wherein said first electrically conductive member is in
8 electrical communication with said first major face of
9 said first electroactive member and said second
10 electrically conductive member is in electrical
11 communication with said first major face of said second
12 electroactive member.

1 5. The device according to claim 3,
2
3 wherein said first major face of said first electroactive
4 member is concave and a second major face of said first
5 electroactive member is convex.

1 6. The device according to claim 5,
2
3 wherein said first major face of said second
4 electroactive member is convex and a second major face of
5 said second electroactive member is concave.



1 7. The device according to claim 6,

2

3 wherein said bonding layer comprises a thermoplastic
4 copolyimide material having a melting point above 100
5 degrees Celsius.

1 8. The device according to claim 1,

2

3 wherein said bonding layer comprises pre-stressing means
4 for applying a longitudinal compressive stress to said
5 first and second electroactive members.

1 9. The device according to claim 8,

2

3 wherein said pre-stressing means comprise a thermoplastic
4 copolyimide material having a melting point above 100
5 degrees Celsius.

1 10. The device according to claim 9,

2

3 wherein said pre-stressing means further comprises a
4 first electrically conductive member.



* C L M S *

1 11. The device according to claim 10,
2
3 wherein said pre-stressing means further comprises a
4 second electrically conductive member, and a dielectric
5 layer, wherein said dielectric layer is disposed between
6 said first and second electrically conductive members and
7 wherein said first electrically conductive member is in
8 electrical communication with said first major face of
9 said first electroactive member and said second
10 electrically conductive member is in electrical
11 communication with said first major face of said second
12 electroactive member.

1 12. The device according to claim 10,
2
3 further comprising a pre-stress layer bonded to a second
4 surface of said first electroactive member, wherein said
5 pre-stress layer applies a longitudinal compressive
6 stress to said first electroactive member or wherein said
7 pre-stress layer is bonded to a second surface of said
8 second electroactive member, wherein said pre-stress
9 layer applies a longitudinal compressive stress to said
10 second electroactive member.



1 13. The device according to claim 12,
2
3 wherein said pre-stress layer comprises a thermoplastic
4 copolyimide material having a melting point above 100
5 degrees Celsius.

1 14. The device according to claim 13,
2
3 wherein said pre-stress layer further comprises a third
4 electrically conductive member.

1 15. The device according to claim 10,
2
3 wherein said first major face of said first electroactive
4 member is concave and a second major face of said first
5 electroactive member is convex.

16. The device according to claim 15,

wherein said first major face of said second
electroactive member is convex and a second major face of
said second electroactive member is concave.

