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(54) PCT Thermistorelement

(57) A PTC thermistor element (1) has resistance of 0.2 Ω or less at 25°C and includes a planar thermistor body (2) made of a barium titanate ceramic material, a pair of electrodes (2c, 2d) on the main surfaces of the thermistor body (2), a pair of lead wires (3, 4) each bonded to a corresponding one of the pair of electrodes (2c, 2d), and an electrically insulating resin layer (7) covering the thermistor body (2), the electrodes (2c, 2d) and the lead wires (3, 4) entirely except where the lead wires (3, 4) are pulled. The thermistor body (2) has a thickness 0.1 - 0.3mm and each of its mutually oppositely facing main surfaces has an area of 25 - 121 mm^2. Cu wires or Fe wires having a diameter less than 0.65 mm and covered with a solder are preferably used as the lead wires (3, 4), at least one of them having a kinked portion where it is pulled out of the is thermistor body for absorbing an external force applied at its tip so as to prevent it from reaching the thermistor body (2). The resin layer (7) has a thickness 0.4 - 0.8 mm over the thermistor body (2) and preferably is made of a resin material such as silicone resin materials and epoxy resin materials having bending strength according to JIS K6911 of not less than 10 Mpa and not greater than 50 Mpa.

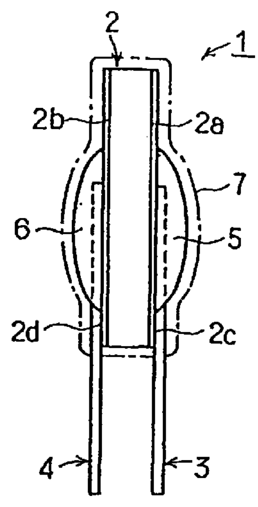

FIG.1B

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Description

Background of the Invention

[0001] This invention relates to a positive temperature coefficient (PTC) thermistor element. More particularly, this invention relates to a PTC thermistor element which can be made thinner such that its resistance is reduced.

[0002] PTC thermistors are used as over-current protection elements or heat-detecting elements. Recently, PTC thermistor elements with even more reduced resistance values are being required. In general, a PTC thermistor element is of a structure having electrodes formed on both of the main surfaces of a planar thermistor body. Its resistance can be reduced, therefore, by using a thinner thermistor body and by increasing the areas of the electrodes which are formed on the mutually oppositely facing main surfaces of the thermistor body. If it is desired to reduce the resistance value of a thermistor element without increasing the size of the main surfaces of the thermistor body such that its external dimensions does not have to be increased, the thickness of the thermistor body must be reduced even further. If this is done, however, the strength of the thermistor body against breaking is significantly reduced.

[0003] Explained more in detail, if the force applied to a PTC thermistor body is Pm and its resistance against breaking is given by τ, they are related by the following formula:

$$Pm = (2/3)\tau Wt^2/L$$

where W is the width of the thermistor body, t is its thickness and L is the distance perpendicular to the direction of its width between the supporting points on which it is placed when a force is applied to measure its resistance. In other words, the force which the thermistor body can withstand is proportional to the square of its thickness. If the size of its main surfaces is increased, furthermore, it means that the distance L between the supporting points increases effectively and hence that the maximum strength which the thermistor body can withstand is reduced. Thus, there is a limit to how thin the thermistor body can reasonably be made and how large its surface area can be made since it is not desirable to make it too weak and too easy to break.

[0004] In the case of PTC thermistor elements using a thermistor body mainly comprising barium titanate ceramics and having a thickness less than 0.4mm, the maximum force which can be withstood thereby is about 600gf if the distance L between the supporting points is 6mm. When PTC thermistor elements are produced with lead wires bonded thereonto, however, the force applied to the thermistor body at the time of the bonding is about 600gf and hence the thermistor bodies have a very high probability of breaking. In other words, it has been very difficult to mass-produce PTC thermistor elements with thermistor bodies of barium titanate ceramics thinner than 0.4mm and having lead wires attached to them. Even after such PTC thermistor elements are produced, furthermore, there is an additional danger that they may break by the force applied thereon at the time of mounting them on a printed circuit board.

[0005] Japanese Patent Publication Tokkai 8-138906 has disclosed a PTC thermistor device using a thermistor body with thickness less than 0.4mm. The thermistor body is provided with electrodes on both its main surfaces and is mounted to a supporting substrate which serves to add strength to it such that a reinforced PTC thermistor device with resistance less than 20Ω can be obtained. With a PTC thermistor device thus structured, however, since the electrode formed on the side of the thermistor body which is attached to the supporting substrate becomes hidden thereby, an extra electrode must be provided in order to make a connection possible to this hidden electrode from a side surface of the layered structure of the thermistor body and the supporting substrate. Moreover, it is difficult to attach a lead wire to such a hidden electrode. In other words, with the main surface of one of the electrodes having entirely attached to the supporting substrate for providing strength, it has become very difficult to present it as an electronic component of an ordinary type with lead wires attached to both its surfaces.

Summary of the Invention

[0006] It is therefore an object of this invention to eliminate this disadvantage of the prior art technology and to provide an improved PTC thermistor element which can be produced with a thin thermistor body such that a low resistance value can be obtained but is not easily breakable and hence can be made into an electronic component of an ordinary type with lead wires attached to both its main surfaces without requiring the presence of any extra electrode.

[0007] A PTC thermistor element embodying this invention, with which the above and other objects can be accomplished, may be characterized as having resistance of 0.2Ω or less at 25°C and comprising a planar thermistor body made of a bariun titanate ceramic material, a pair of electrodes on the main surfaces of the thermistor body, a pair of lead wires each bonded to a corresponding one of the pair of electrodes, and an electrically insulating resin layer covering the thermistor body, the electrodes and the lead wires entirely except where the lead wires are pulled out of the PTC thermistor element. The thermistor body has a thickness 0.1-0.3mm and each of its mutually oppositely facing main surfaces has an area of 25-121mm^2.

[0008] According to a preferred embodiment of the invention, Cu wires or Fe wires having a diameter less than 0.65mm and covered with a solder are used as the lead wires and at least one of them has a kinked portion where it is pulled out of the thermistor body for absorbing an external force applied at its tip so as to prevent it from reaching the thermistor body. The resin layer has a thickness 0.4-0.8mm over the thermistor body and preferably comprises a resin material such as silicone resin materials and epoxy resin materials having bending strength according to JIS K6911 of not less than 10Mpa and not greater than 50Mpa.

Brief Description of the Drawings:

[0009] The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings:

Figs. 1A and 1B are respectively a front view and a schematic side view of a PTC thermistor element embodying this invention;
Figs. 2A and 2B are respectively a front view and a schematic side view of the PTC thermistor element of Figs. 1A and 1B with its resin layer removed; and
Fig. 3 is a graph for showing the relationship between the surface size and the breaking strength of PTC thermistor elements embodying and not embodying this invention.

Detailed Description of the Invention

[0010] The invention is described next by way of an example. Figs. 1A and 1B are respectively a front view and a schematic side view of a PTC thermistor element 1 embodying this invention, comprising a thermistor body 2 and lead wires 3 and 4. Figs. 2A and 2B show how these lead wires 3 and 4 are attached to the thermistor body 2.
[0011] The thermistor body 2 is of a rectangular shape, comprising a barium titanate ceramic material. Its thickness is within the range of 0.1-0.3mm, and the area of the pair of its mutually oppositely facing main surfaces 2a and 2b is within the range of 25-121mm^2. Another way of limiting the surface size of the thermistor body 2, if it is rectangular, is to say that its longer side is within the range of 6-17mm. If the thickness of the thermistor body is less than 0.1mm, its mechanical strength becomes too low and the work for its manufacture becomes impossible. If the thickness exceeds 0.3mm, on the other hand, its resistance becomes too large and its area would have to be intolerably large in order to obtain a low enough resistance value. If the area of the main surfaces 2a and 2b exceeds 121mm^2, or if the longer side of its rectangular surface exceeds 17mm, the thermistor body 2 becomes too easily breakable by the heat shock when the lead wires 3 and 4 are attached because its thickness is small. If the surface area is less than 25mm^2, or if the longer side of its rectangular surface is less than 6mm, on the other hand, it becomes difficult to produce a product with a sufficiently low resistance value.
[0012] Each of the pair of electrodes 2c and 2d formed on the main surfaces 2a and 2b of the thermistor body 2 has a layered structure with a Cr layer, a Ni-Cu layer and a Ag layer stacked one on top of another.
[0013] The lead wires 3 and 4 are each bonded at one of its ends respectively to the electrodes 2c and 2d through a solder 5 and 6. The lead wires 3 and 4 have kinked portions 3a and 4a where they extend from the thermistor body 2. By the kinked portion will be herein meant a portion of the lead wire bent so as to protrude transversely to the direction in which the wire generally extends. These kinked portions 3a and 4a are provided so as to absorb the effect of any force applied to a portion of the wires 3 and 4 closer to the tip, preventing it to reach the thermistor body 2 itself and thereby protecting the bonds between the thermistor body 2 and the lead wires 3 and 4 through the solder 5 and 6. Although each of the lead wires 3 and 4 is shown as having only one kinked portion, two or more kinks may be formed in each of the lead wires 3 and 4.
[0014] The lead wires 3 and 4 may be a Cu wire of cross-sectional diameter 0.65mm so as to be relatively soft and flexible such that external forces applied thereto are not likely to propagate therethrough to the thermistor body 2 or the junctions between the thermistor body 2 and the lead wires 3 and 4. Instead of a Cu wire, a wire of another relatively soft metallic material such as Fe may be used.
[0015] It is preferable that the cross-sectional diameter of the lead wires 3 and 4 be 0.65mm or less. If the diameter exceeds 0.65mm, the wire becomes too rigid and external forces applied thereto become likely to be propagated to the thermistor body 2.
[0016] As shown in Figs. 1A and 1B, the PTC thermistor element 1 is nearly entirely covered by an electrically insulating resin layer 7 except the portions from which the lead wires 3 and 4 are pulled out. In other words, the resin layer 7 covers the thermistor body 2, the electrodes 2c and 2d and the lead wires 3 and 4 nearly entirely. This resin layer 7 serves to increase the mechanical strength of the PTC thermistor element 1 since its thermistor body 2 is relatively thin, as well as to more reliably protect it against the environmental conditions such as moisture.

[0017] A resin material with bending strength not less than 10Mpa and not greater than 50Mpa according to JIS K6911 is preferably used for the resin layer 7. If a resin material with bending strength less than 10Mpa is used, the effect of reinforcing the thermistor body 2 is not sufficient and the resultant PTC thermistor element 1 with a thermistor body as thin as required above may not be as strong as desired. As for the maximum bending strength, it must be remembered that resin materials with a large bending strength tend to have a large reaction shrinkage, causing a large force to be experienced by the thermistor body 2 after the hardening of the resin. In order to prevent breakage of PTC thermistor elements as thin as required according to the present invention, a reasonable maximum bending strength is 50Mpa.

[0018] The thickness of the resin layer 7 over the thermistor body 2 is preferably within the range of 0.4-0.8mm. If the thickness is less than 0.4mm, a sufficient reinforcing effect on the thermistor body 2 may not be obtained. If the thickness exceeds 0.8mm, the thermal capacity of the resin becomes excessively large and the temperature response becomes adversely affected when the thermistor element is generating heat.

[0019] The invention does not impose any particular limitation as to the kind of the insulating material for the resin layer 7 as long as the aforementioned requirement on the bending strength is satisfied. Epoxy resins and phenol resins which are mechanically strong may be used. Even some resin materials which are not known for a strong mechanical strength such as silicone resins may be used by adding an inorganic filler such as silica to increase the strength.

[0020] Since the PTC thermistor element 1 is a heat-generating component, it is desirable to use a resin material which is high in thermal resistance to form the insulating resin layer 7. Epoxy resins and silicone resins with increased mechanical strength having an inorganic filler may be used because of their superior resistance against heat.

[0021] As explained above, the PTC thermistor element 1 according to this invention includes a thermistor element comprising a barium titanate ceramic material with thickness less than 0.3mm, the area of its main surfaces 25-121mm^2 (and the longer side of its main surfaces 6-17mm if they are rectangular). Thus, the resistance between the electrodes on the main surfaces can be as low as 0.2Ω or less at 25°C. Although use is made of an extremely thin thermistor element, the mechanical strength is sufficient because of the resin coating which completely covers the thermistor element and the electrodes except where the lead wires are connected. Because the lead wires are made of a flexible material and include kinks, propagation of externally applied forces to the thermistor element and the junctions between the thermistor element and the lead wires can be effectively suppressed. As a result, the outer surface of the resin coating can be marked by a contact process. Because of the reinforced nature, many such PTC thermistors can be placed randomly inside a bag for shipment, like the prior art PTC thermistor elements with larger resistance values having lead wires. Another advantage of PTC thermistor elements according to this invention is that they do not break easily when forces are applied to their lead wires when they are being mounted to a printed circuit board.

[0022] Although the invention was described above with reference to only one example, this example is not intended to limit the scope of the invention. Many modifications and variations are possible within the scope of the invention, and the disclosure is intended to be interpreted broadly. For example, the thermistor body 2 need not be rectangular but may be a circular or take upon a different shape, although such different examples are not separately illustrated. If the thermistor element of a circular shape is employed, its diameter should be in the range of 6-17mm. If the thermistor element is a square, its sides should be 6-17mm.

[0023] Next, advantageous effects of the invention is described by way of results of measurements carried out both on samples according to this invention and prior art thermistor elements. For this purpose, various thermistor elements as shown in Table 1 below were prepared by using a PTC thermistor material comprising mainly barium titanate ceramics. They were all made in a square shape and hence their "length" in Table 1 means the length of each side of their square shape.

[0024] For making prior art samples ("comparison" in Fig. 3), use was made of various thermistor bodies with thickness 0.5mm and length in the range of 4-25mm. Their measured breaking strengths are shown both in Table 1 and Fig. 3. Electrodes were formed entirely on both main surfaces of these thermistor bodies by sputtering Cr, Ni-Cu and Ag in this order, and Cu wires of diameter 0.6mm were attached to these electrodes by soldering. Thereafter, a silicone resin material was used to cover them to a thickness of 0.5mm except the portions where the lead wires are pulled out. The bending strength of the resin material according to JIS K6911 was 10Mpa. The measured bending strengths of the comparison sample PTC thermistors thus prepared are shown in Table 1 and Fig. 3.

[0025] The same thermistor material used to produce these comparison samples was used again to produce planar square thermistor bodies with thickness 0.2mm and length 4-14mm. For each of these thermistor bodies, the bending strength was measured as above. The results are also shown in Table 1 and Fig. 3. Electrodes were formed similarly as described above on these thermistor bodies, and Cu wires of diameter 0.5mm were attached to these electrodes by soldering. Thereafter, the same silicone resin material with bending strength 10Mpa was used to cover them to a thickness of 0.6, 0.7 and 0.8mm to obtain test examples 1, 2 and 3 of PTC thermistor elements embodying this invention. The measured bending strengths of these test sample PTC thermistors thus prepared are also shown in Table 1 and Fig. 3.

Table 1

Breaking Strength (g • f)						
	Comparison Examples		Test Examples			
	Thermistor body *	PTC Element **	Thermistor Body *	Sample #1 **	Sample #2 **	Sample #3 **
Strength	--	10Mpa	--	10Mpa	10Mpa	10Mpa
Thermistor Thickness	0.5mm	0.5mm	0.2mm	0.2mm	0.2mm	0.2mm
Resin Thickness	0mm	0.5mm	0mm	0.6mm	0.7mm	0.8mm
Thermistor Length						
20mm	555.6	691.6				
18mm	638.9	790.1				
16mm	736.1	906.2				
14mm	803.6	997.9	128.6			626.1
12mm	937.7	1164.5	150.0		594.5	730.5
10mm	1027.5	1299.6	164.4	556.2	697.7	861
8mm	1094.7	1434.8	175.1	664.9	841.8	1045.9
6mm	1259.5	1713	201.5	854.6	1090.4	1362.5
4mm	1676.8	2357	268.3	1247.9	1601.6	2009.8

* bare type PTC
** coated PTC

[0026] Fig. 3 shows that the bending strength for the prior art thermistor body is 555.6gf if the body length is 200mm. Since the limit obtainable by the prior art methods is 600gf, this means that the bending strength in this situation is below the limit value. After lead lines are bonded and insulating resin layers are formed to make a PTC thermistor element, its bending strength is 691.6gf, which is above the limit value. In other words, a bending strength above the limit is obtained in the case of this prior art PTC thermistor element because its thermistor body is as thick as 0.5mm. With the test examples embodying this invention, by contrast, the bending strength is very small, say, less than 268.3gf if the length of the thermistor body is in the range of 4-14mm, being below the prior art limit value. After lead wires are bonded and insulating resin layers are formed on them to produce PTC thermistor elements, however, their bending strength is above the prior art limit value even where the thermistor body is as thin as 0.2mm. In summary, the present invention can provide PTC thermistor elements having a bending strength above the prior art limit even if a very thin thermistor body is used. In other words, small PTC thermistor elements with low resistance can be provided according to this invention.

Claims

1. A PTC thermistor element (1) with resistance 0.2 Ω less at 25°C, comprising:

a planar thermistor body (2) made of a barium titanate ceramic material, said thermistor body (2) having thickness 0.1 - 0.3 mm and mutually oppositely facing main surfaces with area 25 - 121 mm^2;

a pair of electrodes (2c, 2d) each on a different one of said main surfaces of said thermistor body (2);

a pair of lead wires (3, 4) each bonded to a corresponding one of said pair of electrodes (2c, 2d); and an electrically insulating resin layer (7) covering said thermistor body (2), said electrodes (2c, 2d) and said lead wires (3, 4) entirely except where said lead wires (3, 4) are pulled out of said PTC thermistor element (1).

2. The PTC thermistor element (1) of claim 1 wherein said lead wires (3, 4) each have a diameter less than 0.65 mm and comprise a metal wire selected from the group consisting of a Cu wire and a Fe wire, said metal wire being covered with a solder material.

3. The PTC thermistor element (1) of claim 1 or 2 wherein at least one of said lead wires (3, 4) has a kinked portion (3a, 4a) where said one lead wire is pulled out of said thermistor body.

4. The PTC thermistor element of one of claims 1 to 3 wherein said resin layer (7) has a thickness 0.4 - 0.8 mm over said thermistor body (2) and comprises a resin material having bending strength according to JIS K6911 of not less than 10 Mpa and not greater than 50 Mpa.

5. The PTC thermistor element (1) of one of claims 1 to 4 wherein said resin layer (7) consists of a material selected from a group consisting of silicone resin materials and epoxy resin materials.

6. The PTC thermistor element (1) of one of claims 1 to 5 wherein said thermistor body (2) is circular with diameter 6 - 17 mm.

7. The PTC thermistor element (1) of one of claims 1 to 5 wherein said thermistor body (2) is a square with each side 6 - 17 mm.

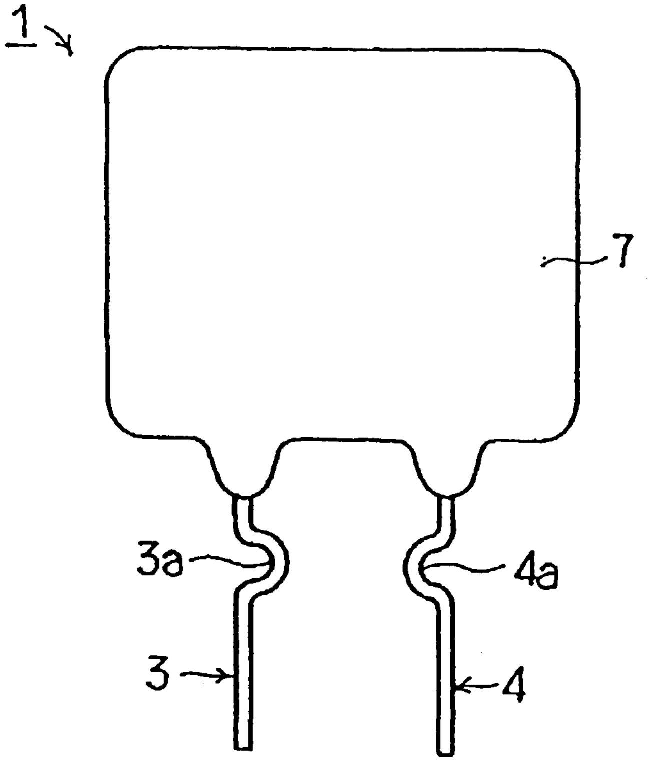


FIG.1A

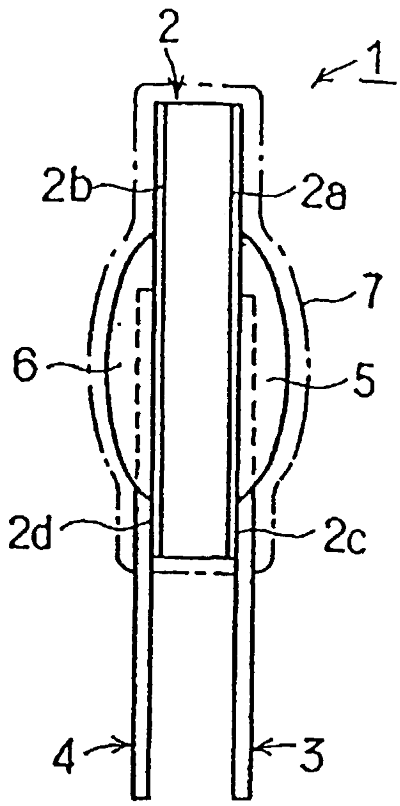


FIG.1B

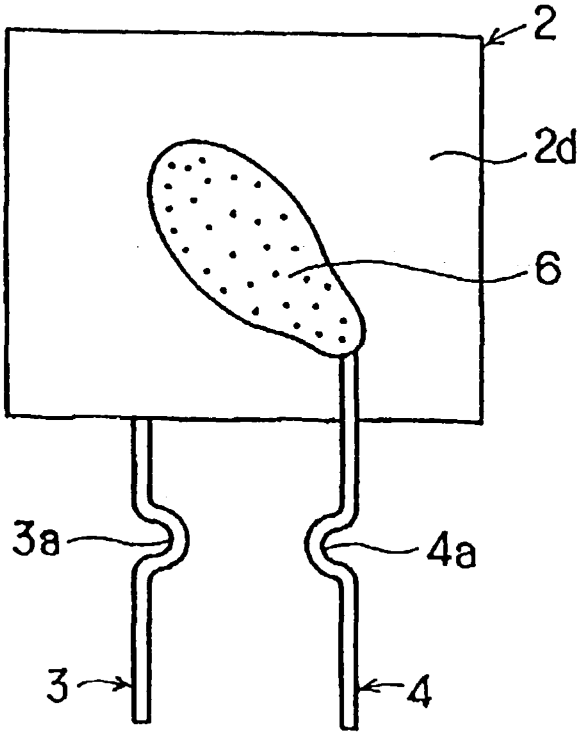


FIG.2A

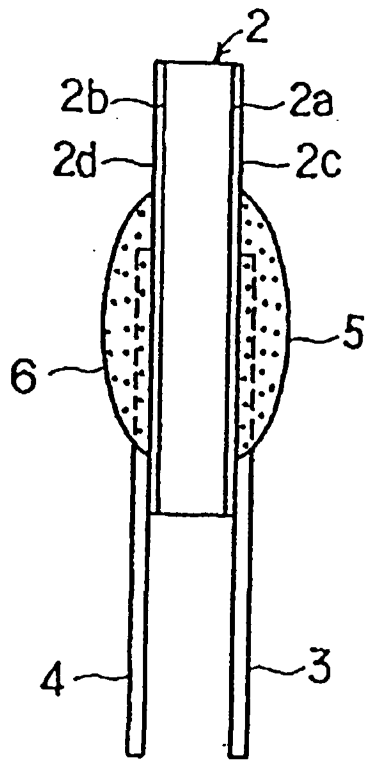
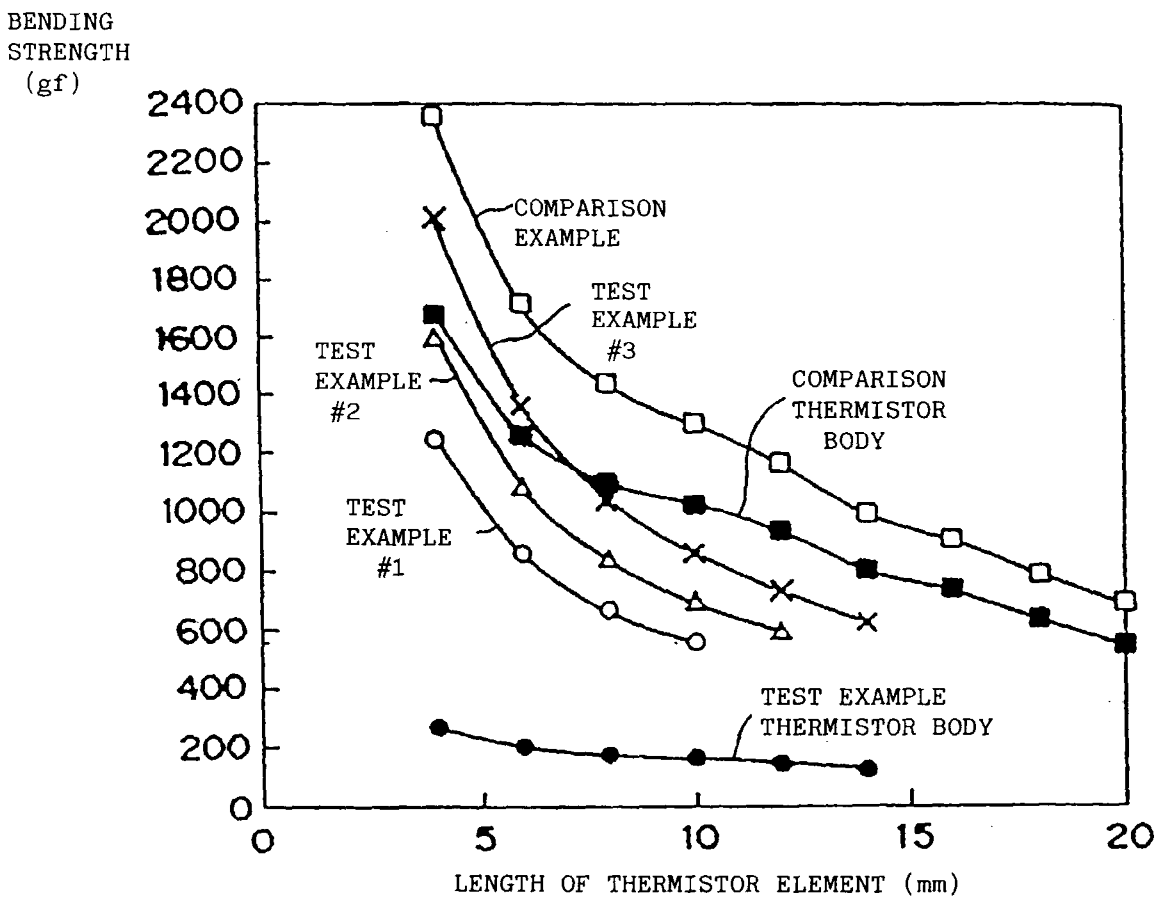


FIG.2B


BENDING
STRENGTH
(gf)
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2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
COMPARISON
EXAMPLE
TEST
EXAMPLE
#3
TEST
EXAMPLE
#2
COMPARISON
THERMISTOR
BODY
TEST
EXAMPLE
#1
TEST EXAMPLE
THERMISTOR BODY
0
5
10
15
20
LENGTH OF THERMISTOR ELEMENT (mm)

FIG.3