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CHIP PTC THERMISTOR
AND METHOD FOR MANUFACTURING THE SAME

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TECHNICAL FIELD

The present invention relates to the chip PTC thermistor which uses a conductive polymer having a positive temperature coefficient (hereinafter referred to as "PTC"), and methods for manufacturing the same.

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BACKGROUND ART

PTC thermistors have been used as the components to protect a device against an overcurrent. Exposure to an overcurrent in an electric circuit causes the conductive polymer having the PTC characteristics used in a PTC thermistor to heat up and expand by self heating. The thermal expansion increases resistance of the conductive polymer sheet in the PTC thermistor, and thus reduces the current to a safer level.

A conventional chip PTC thermistor is described below.

One known chip PTC thermistor is disclosed in the Japanese Laid-open Patent No. H9-503097. The chip PTC thermistor is formed of a resistive material having the PTC characteristics, the chip thermistor having a first surface and a second surface. The chip thermistor comprises a PTC resistor element that specifies a space between the first surface and the second surface, a lateral conductive member provided within said space through the first surface and the second surface of PTC element, which conductive member being fixed to said PTC element, and a first layered conductive member connected physically and electrically to the lateral conductive member. FIG. 14A shows a cross sectional view of the conventional chip PTC thermistor, FIG. 14B is the plan view. In FIG.s 14A and B, a resistor body 61 is formed of a conductive polymer having the PTC

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characteristics, electrodes 62a, 62b, 62c, 62d are formed of a metal foil, conductive members 64a, 64b are formed inside the openings 63a, 63b by plating, and electrically couple the electrode 62a with 62d, and the electrode 62b with 62c respectively.

5 A method for manufacturing the conventional chip PTC thermistor is described below. FIGs. 15A-15D, and FIGs. 16A-16C illustrate the process steps for manufacturing the conventional chip PTC thermistor.

 Polyethylene and conductive carbon particles are mixed to form a sheet 71 shown in FIG. 15A. The sheet 71 is sandwiched by two sheets of a metal foil 72, as shown in FIG. 15B, and these are heat pressed together to be integrated into a sheet 73 as shown in FIG. 15C. After undergoing electron beam irradiation, the integrated sheet 73 is provided with through holes 74 in a regular pattern arrangement as shown in FIG. 15D, and then a metal film 75 is formed by plating to cover the inner surface of the through hole 74 and the metal foil 72, as shown in FIG. 16A. Then, as shown in FIG. 16B, an etched slit 76 is formed in the metal foil through a photo-lithographic process. And then, it is cut off along a longitudinal cut line 77 and a lateral cut line 78 to be separated into piece chips to obtain the conventional chip PTC thermistor 79 as shown in FIG. 16C.

20 In the conventional chip PTC thermistor of the above configuration, however, the two electrodes 62a and 62b, or 62c and 62d, which are to be connected with a printed circuit board when the chip thermistors are mounted thereon, are disposed on only one surface of the chip thermistor (ref. FIG. 14(a)). As a result, when the chip thermistors are mounted on a printed circuit board and reflow-soldered, solder fillets formed by the soldering are not visible from the above because they are shadowed by the chip thermistors. Therefore, it is difficult to make sure of the state of soldering by visually inspecting the soldered portion. Furthermore, because the electrodes of the chip thermistors are not disposed at their sides, flow soldering process is not applicable.

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Furthermore, in the above described conventional manufacturing method, dislocation of the cut lines in relation to the location of through hole is not avoidable because of dispersions in the accuracy of the sheet aligning and the cutting operations. This readily leads to a variation in the area of coupling between the conductive member formed within the through hole and the top/bottom electrodes. FIG. 17A shows a state where no dislocation exists between the through hole and the cut line, while FIG. 17B shows a state where there is a dislocation. In FIGs. 17A and 17B, numeral 81 denotes a through hole, 82 is a cut line, 83 is an electrode, 84 is an etched slit. In a case where a part of one through hole 81, among the through holes locating at both sides of a cut line, is cut as a result of the above described dislocation, as shown in FIG. 17B, area at a contact section 85 making contact between the conductive member disposed within the through hole and the top/bottom electrodes becomes smaller, as compared with a case where there is no such dislocation. The case caused by a dislocated cut line is illustrated in FIG. 17C. A problem with the reduced contact area between the conductive member and the top/bottom electrodes is that the junction between the conductive member and the top/bottom electrodes easily gets cracks due to a stress caused thereon by repetitive expansion and shrinkage of the conductive polymer.

The present invention addresses the above problems and aims to provide a chip PTC thermistor, as well as a method of manufacturing the same, with which the soldered portion can be inspected easily visually after the chip thermistors are mounted on a printed circuit board, and the chip PTC thermistor can be soldered by flow soldering; furthermore, the coupling between the conductive member and the electrodes has only a small dispersion in the strength of connection against the stress that will be caused as a result of expansion and shrinkage of the conductive polymer.

DISCLOSURE OF THE INVENTION

A chip PTC thermistor of the present invention comprises:

A cuboidal form conductive polymer having the PTC characteristics;
a first main electrode disposed on a first surface of the conductive polymer;

5 a first sub electrode disposed on the same surface as the main electrode, yet being independent from the first main electrode;

a second main electrode disposed on a second surface opposing to the first surface of the conductive polymer;

a second sub electrode disposed on the same surface as the second main electrode, yet being independent from the second main electrode;

10 a first side electrode disposed covering at least the entire surface of one of side surfaces of the conductive polymer, which side electrode being electrically connected with the first main electrode and the second sub electrode; and

a second side electrode disposed covering at least the entire surface of
15 the other side surface opposing to the one side surface of the conductive polymer, which side electrode being electrically connected with the first sub electrode and the second main electrode.

In a method for manufacturing the chip PTC thermistors of the present invention , a conductive polymer having the PTC characteristics is
20 sandwiched from the top and the bottom by a patterned metal foil and these are integrated by heat pressing into a sheet form, the integrated sheet is provided with openings, the integrated sheet having the openings is coated on the top and the bottom surfaces with a protective coating, a side electrode is formed at the side of the sheet having the protective coating and the openings,
25 and the sheet provided with the side electrodes and the openings is divided into pieces.

With the chip PTC thermistors as configured above, solder fillet can be formed at the side of thermistor chips mounted on a printed circuit board because the side electrode is provided covering at least the entire side surface
30 of the two side surfaces of the conductive polymer. Thus the chip PTC

thermistors provides an advantage that the state of soldering of the soldered portions can be confirmed easily by visual inspecting after the chip thermistors are mounted on a printed circuit board. Further advantage of the chip PTC thermistor is that they can be used in a flow soldering process.

5 In a method for manufacturing the chip PTC thermistors , where the conductive polymer having the PTC characteristics and the patterned metal foils are heat-pressed to be integrated into a sheet form and the sheet is provided with openings and then the side electrode is formed thereon by plating or other means, shape of the end surfaces of the openings does not
10 vary even if there was a slight displacement in the location of opening relative to the pattern of metal foil due to a tolerance in the accuracy during the process for forming the openings; the shape remains straight lined.

 Therefore , the side electrode formed on the end face by plating, or the like method, always have a certain stable junction area with the first and the
15 second main electrodes; so, the strength of coupling at the junction area between the side electrode and the first or the second main electrode against stress due to the expansion and shrinkage of conductive polymer will have only small dispersion.

20 BRIEF DESCRIPTION OF THE DRAWINGS

 FIG. 1A is a perspective view of a chip PTC thermistor in accordance with a first exemplary embodiment of the present invention.

 FIG. 1B is a sectional view of the chip PTC thermistor along the line 200 - 200 of FIG. 1A.

25 FIG. 1C is a sectional view of the chip PTC thermistor being mounted on a printed circuit board.

 FIGs. 2A -2C illustrate a process for manufacturing the chip PTC thermistor of embodiment 1.

 FIGs. 3(a) - (e) illustrate a process for manufacturing the chip PTC
30 thermistor of embodiment 1.

FIGs. 4A and B show examples of a strip form and a comb shape.

FIG. 5 is a sectional view of a chip PTC thermistor in accordance with a second exemplary embodiment of the present invention.

FIGs. 6A -6C illustrate a process for manufacturing the chip PTC thermistor of embodiment 2.

FIG. 7 illustrates a process for manufacturing the chip PTC thermistor of embodiment 2.

FIG. 8 is a sectional view of a chip PTC thermistor in accordance with a third exemplary embodiment of the present invention.

FIGs. 9A -9D illustrate a process for manufacturing the chip PTC thermistor of embodiment 3.

FIGs. 10A and 10B illustrate a process for manufacturing the chip PTC thermistor of embodiment 3.

FIG. 11 is a sectional view of a chip PTC thermistor in accordance with a fourth exemplary embodiment of the present invention.

FIGs. 12A -12C illustrate a process for manufacturing the chip PTC thermistor of embodiment 4.

FIGs. 13A-13C illustrate a process for manufacturing the chip PTC thermistor of embodiment 4.

FIG. 14(a) is a sectional view of a prior art chip PTC thermistor.

FIG. 14(b) is a plan view of the prior art chip PTC thermistor.

FIGs. 15A-15D illustrate a process for manufacturing the conventional chip PTC thermistor.

FIGs. 16A-16C illustrate a process for manufacturing the prior art chip PTC thermistor.

FIGs. 17A-17C illustrate location of the through holes relative to cut line, in the prior art chip PTC thermistor.

BEST MODE FOR CARRYING OUT THE INVENTION

(Embodiment 1)

A chip PTC thermistor in a first exemplary embodiment of the present invention is described with reference to the drawings.

FIG. 1A is a perspective view of the chip PTC thermistor in the first exemplary embodiment of the present invention. FIG. 1B is a sectional view
5 taken along the line A-A of FIG. 1.

In FIGs. 1A and 1B, a cuboidal form conductive polymer 11 having the PTC characteristics is made of a mixed compound of high density polyethylene, i.e. a crystalline polymer, and carbon black, i.e. conductive particles.

First main electrode 12a is disposed on a first surface of the conductive
10 polymer 11. First sub electrode 12b is disposed on the same surface as the first main electrode 12a, yet being independent from the first main electrode 12a.

Second main electrode 12c is disposed on a second surface, which is opposing to the first surface, of the conductive polymer 11. Second sub
15 electrode 12d is disposed on the same surface as the second main electrode 12c, yet being independent from the second main electrode 12c.

Each of these main and sub electrodes is made of electrolytic copper foil.

First side electrode 13a is formed of a plated nickel covering the entire
20 surface of one of the side ends of the conductive polymer 11, and is electrically connected with the first main electrode 12a and the second sub electrode 12d.

Second side electrode 13b is formed of a plated nickel covering the entire surface of the other side end opposing to the first side electrode 13a of the conductive polymer 11, and is electrically connected with the second main
25 electrode 12c and the first sub electrode 12b.

First and second protective layers 14a , 14b are formed of an epoxy-modified acrylic resin.

When a side electrode is formed by plating , since adhesion between the conductive polymer and a plated layer is not sufficiently strong, the side
30 electrode is liable to peel off from the conductive polymer. So, the sub

electrode , together with the main electrode, are expected to function as the supporting body for the plated side electrode, for ensuring a good adhesion of the side electrode onto the conductive polymer.

Next, a method for manufacturing a chip PTC thermistor in a first
5 exemplary embodiment as configured above is described with reference to the drawings.

FIGs. 2A-2C and FIGs. 3(a) - (e) illustrate process of a method of manufacturing the chip PTC thermistors in accordance with embodiment 1.

In the first place , 49 wt.% of high density polyethylene of 70-90%
10 crystallinity, 50 wt.% of furnace black having average particle diameter of 58 nm and specific surface area of $38 \text{ m}^2/\text{g}$, and 1 wt.% of antioxidant are mixed and kneaded for about 20 minutes using two roll mills heated about 150°C , to fabricate a conductive polymer sheet 21 of about 0.3 mm thick, as shown in FIG. 2A.

Then, as shown in FIG. 2B, an electrolytic copper foil is patterned to
15 have comb shape slits using a die press to provide electrode 22. A Slit 26 is made for forming a gap between a main electrode and a sub electrode after a sheet is divided into pieces in a later process step. A slit 27 is provided for reducing cut area of the electrolytic copper foil in the process of dividing a
20 sheet into pieces.

The slit 27 contributes to eliminate generation of burr of the electrolytic copper foil at the dividing process step, as well as to eliminate exposure of the cut face of the electrolytic copper foil in the side surface of a divided chip PTC thermistor. The exposure of cut face may invite oxidation of
25 the electrolytic copper foil, and short-circuiting by solder when the chip PTC thermistor is mounted on a printed circuit board.

And , then, as shown in FIG. 2C and FIG. 3(a) , the conductive polymer sheet 21 is sandwiched from the top and the bottom by the electrode 22, and these are heat pressed at about 175°C , in a vacuum of about 20 torr,
30 and under the pressure of about $50 \text{ kg}/\text{cm}^2$ for about 1 minute using a vacuum

heat press to make an integrated sheet 23. Then, an about 40 Mrad electron beam is irradiated to the sheet in an electron beam irradiation equipment to crosslink the high density polyethylene.

As shown in FIG. 3(b), oblong openings 24 (slits) are provided at a regular interval so that a space corresponding to the length of a certain chip PTC thermistor is left preserved, using a die press or a dicing machine.

Process of providing the opening may either be the formation of strips or the formation into a comb shape, as shown in FIGs. 4A and 4B.

Protective coating 25 is formed, as shown in FIG. 3(c), on the top and the bottom surfaces of the sheet 23 having the openings 24, except the area at the vicinity of the openings 24, by screen printing an acrylic, or an epoxy-modified acrylic UV curing resin, followed by a curing in an UV curing oven.

Then, as shown in FIG. 3(d), 10 - 20 μm thick nickel film 28 is plated on the sheet 23 in an area on which there is no protective coating 25, including the inner wall surface of the opening 24, in the Watts nickel bath for about 30 minutes at a current density of about $4\text{A}/\text{dm}^2$.

The sheet 23 is divided into pieces by a die press or a dicing machine to obtain a chip PTC thermistor 29 of the present invention as shown in FIG. 3(e). The chip PTC thermistors of the same configuration may be obtained also by first integrating unpatterned metal foil with conductive polymer sheet through heat-pressing and then patterning the metal foil using the photolithography and etching process.

Now in the following, embodiment 1 of the present invention is described further in detail with respect to the structure.

After chip-type electronic components are mounted on a printed circuit board by reflow soldering, it is a common practice to inspect the soldered portion visually; since uneven printing of cream solder or an insufficient solder quantity invites a poor contact, or deteriorates the reliability of solder during the heat cycles.

With the chip PTC thermistors of the present invention, the solder

fillet is formed at the side of chip thermistors soldered on a printed circuit board; namely, the solder fillet is positioned outside of a chip thermistor. Therefore, the soldered portion can be easily inspected.

FIG. 1C is a sectional view of the chip PTC thermistor being mounted on a printed circuit board. Numerals 16a, 16b denote the lands of the printed circuit board. As indicated with an arrow mark in FIG. 1C, the fillets 15a, 15b can easily be observed from the above.

Further, it has been confirmed that the chip PTC thermistors of the present invention can be used in the flow soldering process.

In general, the adhesion between the plated film forming the side electrode and the conductive polymer is weak. In embodiment 1 of the present invention, however, the plated film is supported by the main electrode and the sub electrode formed respectively on the top and bottom surfaces of the conductive polymer. Thus the side electrode, which has been formed by plating, is well secured with respect to adhesion to the conductive polymer. The above described structure of the present invention is effective enough to avoid peeling of the side electrode off the conductive polymer.

In the prior art manufacturing method, a cut line dislocated relative to the location of through hole may result in a reduced area of coupling between the conductor within the through hole and the top/bottom electrodes.

However, in the manufacturing method of embodiment 1, where a conductive polymer having the PTC characteristics and metal foils are integrated into a sheet form by heat-pressing and the sheet is provided with openings and then a conductive film is formed therein by plating, the area of coupling between the plated film and the top/bottom electrodes remains unchanged and constant despite a possible dislocation. Namely, the strength of coupling between the plated film and the top/bottom electrodes is not reduced; and cracks will not be generated at the coupling portion by the stress due to repetitive expansion and shrinkage of the conductive polymer.

Furthermore, in the present process of embodiment 1, only the cutting

in lateral direction completes the dividing into chip thermistor pieces; there is no need of longitudinal cutting operation for the dividing.

In the prior art manufacturing method, where plated layer is formed within through holes provided by drilling or other method, number of the
5 through holes to be drilled is at least more than number of chip thermistor pieces yielded out of a sheet. Thus it needs a long time to drill all the through holes. In addition, the heat generated due to friction during drilling causes melting of the conductive polymer, which results in a rough wall surface of the through holes; consequently, a layer plated thereon becomes uneven.

10 Under the manufacturing method in accordance with embodiment 1, however, the openings are provided at once in a strip shape using a die press, dicing machine, etc. This contributes to a higher productivity. Furthermore, since there is no melting in the conductive polymer, the wall surfaces of the openings are relatively smooth; which contributes to provide a plated layer of
15 even thickness.

Furthermore, in the conventional manufacturing method, plating solution can not circulate well inside the through holes, and concentration of metal ions in the plating liquid becomes unstable; this disturbs formation of a plated layer in even thickness. If a plated layer is formed in uneven thickness,
20 the concentration of stress due to repetitive expansion and shrinkage of the conductive polymer responding to overcurrent in a chip thermistor at work will lead to a breakage of the plated layer.

Under the manufacturing method in embodiment 1, however, the portion on which a plated layer is to be formed is exposed to an open space,
25 and plating solution can circulate freely; therefore the concentration of metal ion can be maintained stable. This contributes to formation of a layer in even thickness.

Still further, in the conventional manufacturing method, foreign items contained in the plating solution may sneak into the through holes, or burr, if
30 the through hole has been provided by drilling, may easily catch such foreign

items. This may create a void in the plating film.

However, under the manufacturing method in embodiment 1, the portion on which the side electrode is to be formed is exposed to a sufficiently open space, so such foreign items, if any, contained in plating solution may not
5 be staying on the portion. The side electrodes of the present invention are disposed open to the outside and is easily inspected from outside. The plating current is sufficiently lower than a level for the conductive polymer to start its PTC operation, so the conductive polymer will never be put into operation.

Furthermore, in the manufacturing method of embodiment 1, an
10 integrated sheet provided with the openings is plated for formation of the side electrodes, and then the sheet is divided into pieces. Therefore, other two side faces of the thermistor than the two side surfaces on which the side electrode has been formed can not have a plated layer. In other manufacturing methods, where, for example, completed chips are barrel-plated after the dividing
15 process step, the conductive polymer, which having a conductive side face, will have a chance to be plated in all of the four side-faces. This of course leads to short circuiting between the first main electrode and the second main electrode.

(Embodiment 2)

20 A chip PTC thermistor in a second exemplary embodiment of the present invention is described with referring to the drawings.

FIG. 5 is a sectional view of the chip PTC thermistor of the second exemplary embodiment.

In FIG. 5, a cuboidal form conductive polymer 41 having the PTC
25 characteristics is made of a mixed compound of high density polyethylene, i.e. a crystalline polymer, and carbon black, i.e. conductive particles.

First main electrode 42a is disposed on a first surface of the conductive polymer 41. First sub electrode 42b is disposed on the same surface as the first main electrode 42a, yet being independent from the first main electrode 42a.
30 Second main electrode 42c is disposed on a second surface, which is opposing

to the first surface of the conductive polymer 41. Second sub electrode 42d is disposed on the same surface as the second main electrode 42c, yet being independent from the second main electrode 42c.

Each of these main and sub electrodes is made of electrolytic copper foil.

First side electrode 43a is formed by nickel plating covering the entire surface of one of the side ends of the conductive polymer 41, and is electrically connected with the first main electrode 42a and the second main electrode 42c.

Second side electrode 43b is formed by nickel plating covering the entire surface of the other side end opposing to the first side electrode 43a of the conductive polymer 41, and is electrically connected with the first sub electrode 42b and the second sub electrode 42d.

First and second protective coating layers 44a, 44b are made of an epoxy-modified acrylic resin.

Inner main electrode 45a is disposed within the conductive polymer 41, in parallel with the first main electrode 42a and the second main electrode 42c, and is electrically connected with the second side electrode 43b. Inner sub electrode 45b is disposed at the same plane as the inner main electrode 45a, yet being independent from said inner main electrode 45a, and is electrically connected with the first side electrode 43a.

A method for manufacturing the chip PTC thermistors in a second exemplary embodiment is described next with reference to the drawings.

FIGs. 6A-6C and FIG. 7 illustrate process of a method of manufacturing the chip PTC thermistors in embodiment 2 of the present invention. In the same way as in embodiment 1, a conductive polymer sheet 51 as shown in FIG. 6A, is provided, and an electrolytic copper foil is patterned by die press to provide electrode 52 as shown in FIG. 6B.

Thickness of the electrolytic copper foil for forming the inner electrode should be not less than 35 μm , preferably thicker than 70 μm , so as it is not

broken by expansion of the conductive polymer during formation of a laminated body, to be described later, by heat pressing.

Next, as shown in FIG. 6C, the conductive polymer 51 and the electrode 52 are alternately stacked to be integrated into a sheet 53 of FIG. 7 by heat pressing. The three sheets of electrode 52, shown in FIG. 6C, may have a same pattern, which means that these sheets may be provided using only one die pattern. This is an economical advantage.

Thereafter, the same manufacturing process steps as the embodiment 1 have been followed to provide the chip PTC thermistor in embodiment 2 of the present invention.

A laminated body may also be formed using unpatterned metal foils for the outermost layers, while other foils are those patterned by die pressing, and integrating these metal foils and conductive polymer together by heat pressing, and then patterning the outermost metal foils using the photolithography and etching process. A chip PTC thermistor of the same configuration may be produced out of the laminated body thus produced, by following the same process steps as those in embodiment 1.

In the PTC thermistor chips of embodiment 2, the overlapping area of opposing electrodes has been increased by alternately laminating the layers of conductive polymer and metal foil, without making the overall dimensions of the thermistor greater. This configuration enables to lower the internal resistance of a chip thermistor; as a result, a chip PTC thermistor that allows a greater current in a compact body is obtained.

In a practical example ; a chip PTC thermistor of single layered conductive polymer, dimensions 3.2 mm x 4.5 mm, has an overlapping area between the first and the second main electrodes (area of the opposing electrodes) of 9 mm², resistance of approximately 150 m Ω ; whereas that of the double layered exhibited a low resistance of approximately 80 m Ω with the area of opposing electrodes 18 mm², while maintaining the same plane dimensions of 3.2 mm x 4.5 mm. In the following, more exemplary

embodiment of the present invention is described, in which the resistance is further reduced.

(Embodiment 3)

FIG. 8 illustrates a sectional view of a chip PTC thermistor in a third
5 exemplary embodiment of the present invention.

In FIG. 8, a cuboidal form conductive polymer 1 having the PTC characteristics is made of a mixed compound of high density polyethylene, i.e. a crystalline polymer, and carbon black, i.e. conductive particles.

First main electrode 2a is disposed on a first surface of the conductive
10 polymer 1. First sub electrode 2b is disposed on the same surface as the first main electrode 2a, yet being independent from the first main electrode 2a.

Second main electrode 2c is disposed on a second surface, which is opposing to the first surface, of the conductive polymer 1. Second sub electrode 2d is disposed on the same surface as the second main electrode 2c, yet being
15 independent from the second main electrode 2c.

Each of these main and sub electrodes is made of electrolytic copper foil.

First side electrode 3a is formed by nickel plating covering the entire surface of one of the side ends of the conductive polymer 1, and is electrically
20 connected with the first main electrode 2a and the second sub electrode 2d.

Second side electrode 3b is formed by nickel plating covering the entire surface of the other side end opposing to the first side electrode 3a of the conductive polymer 1, and is electrically connected with the first sub electrode 2b and the second main electrode 2c.

25 First and second protective coating layers 4a, 4b are made of an epoxy-modified acrylic resin.

First inner main electrode 5a is disposed within the conductive polymer 1, in parallel with the first main electrode 2a and the second main electrode 2c, and is electrically connected with the second side electrode 3b.
30 First inner sub electrode 5b is disposed at the same plane as the first inner

main electrode 5a, yet being independent from the first inner main electrode 5a, and is electrically connected with the first side electrode 3a.

Second inner main electrode 5c is disposed within the conductive polymer 1, in parallel with the first main electrode 2a and the second main electrode 2c, and is electrically connected with the first side electrode 3a. Second inner sub electrode 5d is disposed at the same plane as the second inner main electrode 5c, yet being independent from the second inner main electrode 5c, and is electrically connected with the second side electrode 3b.

In the chip PTC thermistor configured as above, where the conductive polymer 1 of 3.2 mm x 4.5 mm size has been stacked in three layers and the resistances between the first main electrode 2a and the first inner main electrode 5a, that between the first inner main electrode 5a and the second inner main electrode 5c and that between the second inner main electrode 5c and the second main electrode 2c have been connected in parallel, the overlapping area of opposing electrodes reached 27 mm² in real terms and the resistance has been reduced to as low as approximately 50 m Ω . Thus a extremely low resistance chip PTC thermistor was obtained.

A method for manufacturing the chip PTC thermistors in a third exemplary embodiment is described next with reference to the drawings.

FIGs. 9A-9D and FIGs. 10A and 10B illustrate a method of manufacturing the chip thermistors having three conductive polymer layers.

In the same way as in embodiment 1, a conductive polymer sheet 31, shown in FIG. 9A, is provided. An electrolytic copper foil is patterned by die press to provide electrode 32 as shown in FIG. 9B. Like in the case of the chip thermistor having two conductive polymer layers, thickness of the electrolytic copper foil for the inner electrode should be not less than 35 μ m, preferably thicker than 70 μ m, so as it is not broken by expansion of the conductive polymer during formation of a laminated body by heat pressing.

Next, as shown in FIGs. 9C and 9D, the conductive polymer sheet 31 is sandwiched by two electrodes 32 to be integrated into a first sheet 33, shown

in FIG. 9D, by heat pressing. And, then, as shown in FIG. 10A, two conductive polymer sheets 31 and two electrodes 32 are stacked on both surfaces of the first sheet 33, so that respective electrodes 32 are placed on the outermost surface, which are to be integrated into a second sheet 34 of FIG. 10B by heat pressing.

Thereafter, the same manufacturing process steps as in embodiment 1 are followed to obtain the chip PTC thermistors having three conductive polymer layers.

The reason why the heat-pressing operation has been conducted separately in two steps is for avoiding unevenness in the thickness of conductive polymer sheets. If the heat-pressing is conducted in one step for integrating all the layers together, the low heat transmittance to the inner polymer sheet creates uneven temperature distribution between the inner polymer sheet and the outer polymer sheets, which results in the formation of conductive polymer sheets of uneven thickness.

Also in the present embodiment, a laminated body may be formed using unpatterned metal foils for the outermost layers, while other foils are those patterned by die pressing, integrating these metal foils and conductive polymer sheets together by heat pressing, and then patterning the outermost metal foils using the photolithography and etching process.

A chip PTC thermistor of the same configuration may be produced out of the laminated body thus produced, by following the same process steps as those in embodiment 1.

A chip PTC thermistor containing the five or more odd number layers of the conductive polymer is obtainable, by repeating the cycle of stacking and heat-pressing of additional conductive polymer sheet and additional patterned electrode on the outer surfaces of the second sheet. Also in this example, the outermost layers may be formed of unpatterned metal foils, and patterning the foils in a later stage by etching.

(Embodiment 4)

FIG. 11 is a sectional view of a chip PTC thermistor in a fourth exemplary embodiment of the present invention.

In FIG. 11, a cuboidal form conductive polymer 91 having the PTC characteristics is made of a mixed compound of high density polyethylene, i.e. a crystalline polymer, and carbon black, i.e. conductive particles.

First main electrode 92a is formed on a first surface of the conductive polymer 91. First sub electrode 92b is disposed on the same surface as the first main electrode 92a, yet being independent from said first main electrode 92a.

Second main electrode 92c is formed on a second surface, which is opposing to the first surface of the conductive polymer 91. Second sub electrode 92d is disposed on the same surface as the second main electrode 92c, yet being independent from the second main electrode 92c.

Each of these main and sub electrodes is made of electrolytic copper foil.

First side electrode 93a is formed by nickel plating covering the entire surface of one of the side ends of the conductive polymer 91, and is electrically connected with the first main electrode 92a and the second main electrode 92c.

Second side electrode 93b is formed by nickel plating covering the entire surface of the other side end opposing to the first side electrode 93a of the conductive polymer 91, and is electrically connected with the first sub electrode 92b and the second sub electrode 92d. First and second protective coating layers 94a, 94b are made of an epoxy-modified acrylic resin.

First inner main electrode 95a is disposed within the conductive polymer 91, in parallel with the first main electrode 92a and the second main electrode 92c, and is electrically connected with the second side electrode 93b. First inner sub electrode 95b is disposed at the same plane as the first inner main electrode 95a, yet being independent from the first inner main electrode 95a, and is electrically connected with the first side electrode 93a.

Second inner main electrode 95c is disposed within the conductive

polymer 91, in parallel with the first main electrode 92a and the second main electrode 92c, and is electrically connected with the first side electrode 93a. Second inner sub electrode 95d is disposed at the same plane as the second inner main electrode 95c, yet being independent from the second inner main electrode 95c, and is electrically connected with the second side electrode 93b.

Third inner main electrode 95e is disposed within the conductive polymer 91, in parallel with the first main electrode 92a and the second main electrode 92c, and is electrically connected with the second side electrode 93b. Third inner sub electrode 95f is disposed at the same plane as the third inner main electrode 95e, yet being independent from the third inner main electrode 95e, and is electrically connected with the first side electrode 93a.

A method of manufacturing the chip PTC thermistor in a fourth exemplary embodiment is described next with reference to the drawings.

FIGs. 12A-12C and FIGs. 13A-13C illustrate a method of manufacturing the chip thermistor having four conductive polymer layers.

In the same way as in embodiment 1, a conductive polymer sheet 101, shown in FIG. 12A, is provided. An electrolytic copper foil is patterned by die press to provide electrode 102 as shown in FIG. 12B. Like in the case of the chip thermistor having two conductive polymer layers, thickness of the electrolytic copper foil for the inner electrode should be not less than 35 μm , preferably thicker than 70 μm , so as it is not broken by expansion of the conductive polymer during formation of a laminated body by heat pressing.

Next, as shown in FIG. 12C, three sheets of the electrode 102 and two sheets of the conductive polymer sheet 101 are stacked alternately to be integrated by heat pressing into a first sheet 103, shown in FIG. 13(a), with the electrode 102 on the outermost surface.

And then, as shown in FIG. 13B, the first sheet 103 is sandwiched from the top and the bottom by two conductive polymer sheets 101 and two electrodes 102, so that respective electrodes 102 are placed on the outermost surface, which are heat pressed to be integrated into a second sheet 104 of FIG.

13C.

Thereafter, the same manufacturing process steps as in embodiment 1 are followed to obtain the chip PTC thermistor having four conductive polymer layers. Also in the present embodiment, a laminated body may be formed using unpatterned metal foils for the outermost layers, while other foils are those patterned by die pressing, integrating these metal foils and conductive polymer sheets together by heat pressing, and then patterning the outermost metal foils using the photolithography and etching process. Chip PTC thermistor of the same configuration may be obtained out of the laminated body thus produced, by following the same process steps as those of embodiment 1.

A chip PTC thermistor containing the six or more even number conductive polymer layers is obtainable, by repeating the cycle of stacking and heat-pressing of additional conductive polymer sheet and additional patterned electrode on the outer surfaces of the second sheet. Also in this embodiment, the outermost layers may be formed of unpatterned metal foils, and patterning the foils in a later stage by etching.

Number of layers of the conductive polymer may be increased through the processes as described above. However, the stress due to repetitive expansion and shrinkage of the conductive polymer caused by exposure to an overcurrent also adds up along with the increasing number of layers. So, it is important to address the problem of reliability of the coupling between the side electrodes and the main electrodes.

In the chip thermistor in accordance with exemplary embodiments of the present invention, however, side electrodes are provided covering the entire surface of the side end. With such a structure of the present invention, the stress is well dispersed and the reliability in the coupling is sufficiently assured despite the increased number of layers stacked.

Also, the inner sub electrode is effective to prevent increase of the amount of expansion of the conductive polymer sheet, because it prevents to

increase the total thickness of the conductive polymer sheet at the vicinity of side electrode.

Thus the stress caused by the expansion and shrinkage of the conductive polymer sheet effecting to the side electrode can be alleviated, and
5 the reliability is further improved.

The use of nickel, as exhibited in the present invention, for the side electrode has been verified to be more effective for improving the above reliability, as compared with side electrode of copper, copper alloy, etc.

As for comparing, the chip thermistor having side electrode formed of
10 nickel plated layer in accordance with the manufacturing method of embodiment 1 of the present invention was prepared. And those having copper plated side electrodes have been prepared under the following conditions.

A 20 μm thick copper layer is formed by plating on the side surface of a
15 strip-shaped sheet provided through the process of embodiment 1 in the copper sulfate plating bath for about 60 minutes at a current density of about 1.5 A/dm², and then the strip-shaped sheet was divided into pieces.

In order to confirm the reliability of the side electrodes against heat cycle, 30 pieces each of the chip PTC thermistor with the side electrodes of
20 nickel plated layer and those with the side electrodes of copper plated layer were soldered on printed circuit board for cycle test.

In the test, a 12 V DC power was connected, and an overcurrent of 40 A was supplied for operating (trip) the conductive polymer; the current supply continued for one minute, and then stopped for 5 minutes. After 100 cycles,
25 200 cycles, and 1,000 cycles of the trip cycle test, 10 pieces were sampled from each type, and observed by cross-sectional observation for the presence of any cracks in the side electrode layer. No cracks were observed after the 1,000 cycles among samples having the side electrode layers formed by nickel plating. However, in all the 10 samples among 10 of the thermistor having
30 copper side electrode layer, cracks were found at the junction corner between

the side electrode and the upper electrode, before end of the 100 cycles.

With the PTC thermistor chips in exemplary embodiment 1 of the present invention , which comprises a cuboidal form conductive polymer 11 having the PTC characteristics, a first main electrode 12a disposed on a first surface of the conductive polymer 11, a first sub electrode 12b disposed on the same surface as the first main electrode 12a, yet being independent from the first main electrode 12a, a second main electrode 12c disposed on a second surface, which is opposing to the first surface of the conductive polymer 11, a second sub electrode 12d disposed on the same surface as the second main electrode 12c, yet being independent from the second main electrode 12c, a first side electrode 13a covering at least the entire surface of one of the side ends of the conductive polymer 11, which side electrode being electrically connected with the first main electrode 12a and the second sub electrode 12d, and a second side electrode 13b covering at least the entire surface of the other side end opposing to the first side electrode 13a of the conductive polymer 11, which side electrode being electrically connected with the first sub electrode 12b and the second main electrode 12c; the solder fillet is formed at the sides of a chip thermistor mounted on a printed circuit board because the side electrodes 13a, 13b have been provided covering at least the entire surface of two side end surfaces of the conductive polymer 11. As a result, the soldered portions can be easily inspected visually. Furthermore, the chip thermistor of the present invention can be used in the flow soldering process.

With the chip PTC thermistors in exemplary embodiments 2 and 4 of the present invention , which comprise cuboidal form conductive polymers 41, 91 having the PTC characteristics, first main electrodes 42a, 92a formed on the first surface of the conductive polymers 41, 91, first sub electrodes 42b, 92b disposed on the same surface as the first main electrodes 42a, 92a, yet being independent from the first main electrodes 42a, 92a, second main electrodes 42c, 92c formed on the second surface, which is opposing to the first

surface of the conductive polymers 41, 91, second sub electrodes 42d, 92d
 disposed on the same surface as the second main electrodes 42c, 92c, yet being
 independent from the second main electrodes 42c, 92c, first side electrodes
 43a, 93a covering at least the entire surface of one of the side ends of the
 5 conductive polymer 41, 91, which side electrode being electrically connected
 with the first main electrodes 42a, 92a and the second main electrodes 42c,
 92c, second side electrodes 43b, 93b covering at least the entire surface of the
 other side end opposing to the first side electrodes 43a, 93a of the conductive
 polymers 41, 91, which side electrode being electrically connected with the
 10 first sub electrodes 42b, 92b and the second sub electrodes 42d, 92d, odd
 number inner main electrodes 45a, 95a, 95c, 95e disposed within the
 conductive polymer 41, 91, in parallel with the first main electrodes 42a, 92a
 and the second main electrodes 42c, 92c, odd number inner sub electrodes 45b,
 95b, 95d, 95f disposed at the same plane as the inner main electrodes 45a, 95a,
 15 95c, 95e yet being independent from the inner main electrodes 45a, 95a, 95c,
 95e, the inner main electrode 45a, 95a, 95e immediately opposing to the first
 main electrodes 42a, 92a being electrically connected with the second side
 electrodes 43b, 93b, the inner sub electrodes 45b, 95b disposed at the same
 plane as the inner main electrodes 45a, 95a immediately opposing to the first
 20 main electrodes 42a, 92a being electrically connected with the first side
 electrodes 43a, 93a, the inner main electrodes 95c and 95e as well as inner sub
 electrodes 95f and 95d disposed next to each other being electrically connected
 alternately with the first side electrode 93a and the second side electrode 93b,
 respectively; the resistance of a chip thermistor has been reduced without
 25 making the area of main electrodes greater, because the overall resistance of a
 chip thermistor is represented by a resistance formed of two parallel-
 connected resistances, in an exemplary case where there is one inner main
 electrode, of the conductive polymer disposed between first main electrode and
 inner main electrode and the conductive polymer between second main
 30 electrode and inner main electrode. This structure enables to lower the

resistance of a chip thermistor without increasing the overall dimensions.

With the chip PTC thermistor in exemplary embodiment 3 of the present invention, which comprises a cuboidal form conductive polymer 1 having the PTC characteristics, a first main electrode 2a formed on a first surface of the conductive polymer 1, a first sub electrode 2b disposed on the same surface as the first main electrode 2a, yet being independent from the first main electrode 2a, a second main electrode 2c formed on a second surface, which is opposing to the first surface of the conductive polymer 1, a second sub electrode 2d disposed on the same surface as the second main electrode 2c, yet being independent from the second main electrode 2c, a first side electrode 3a covering at least the entire surface of one of the side ends of the conductive polymer 1, which side electrode being electrically connected with the first main electrode 2a and the second sub electrode 2d, a second side electrode 3b covering at least the entire surface of the other side end opposing to the first side electrode 3a of the conductive polymer 1, which side electrode being electrically connected with the first sub electrode 2b and the second main electrode 2c, even number inner main electrodes 5a, 5c disposed within the conductive polymer 1, in parallel with the first main electrode 2a and the second main electrode 2c, and even number inner sub electrodes 5b, 5d disposed at the same plane as the inner main electrode 5a, 5c, yet being independent from the inner main electrode 5a, 5c, the inner main electrode 5a immediately opposing to the first main electrode 2a being electrically connected with the second side electrode 3b, the inner sub electrode 5b disposed on the same plane as the inner main electrode 5a immediately opposing to the first main electrode 2a being electrically connected with the first side electrode 3a, the inner main electrode 5c and inner sub electrode 5d disposed next to each other being electrically connected with the first side electrode 3a and the second side electrode 3b, respectively; the overall resistance of a chip thermistor has been reduced without making the area of main electrodes greater, because the overall resistance of a chip thermistor is

represented by a resistance formed of parallel-connected resistances, in an exemplary case where there are two inner main electrodes, of the conductive polymer disposed between first main electrode and first inner main electrode, the conductive polymer between second main electrode and second inner main electrode, and the conductive polymer between first inner main electrode and second inner main electrode. This structure enables to lower the resistance of a chip thermistor without increasing the overall dimensions.

Furthermore, since the side electrodes in embodiments 1 through 4 of the present invention have been formed of nickel, or nickel alloy, which has a relatively strong withstanding capability against repetitive stress, which stress caused by the repetitive expansion and shrinkage of the conductive polymer, tends to concentrate at the junction corner between the side electrode and the main electrode, the reliability in the coupling of the side electrodes with the first and the second main electrodes has been improved.

Under a method of manufacturing the chip PTC thermistor in exemplary embodiment 1 of the present invention, which comprises the steps of sandwiching conductive polymer having the PTC characteristics from the top and the bottom with patterned metal foil and integrating these into a sheet 23 by heat pressing, providing the integrated sheet 23 with openings 24 (slits), providing a protective coating 25 on the top and the bottom surfaces of the sheet 23 having the openings 24, forming side electrodes 13a, 13b in the sheet 23 that has been provided with the protective coating 25 and the openings 24, and dividing the sheet 23 having the side electrodes 13a, 13b and the openings 24 into piece chip thermistor; shape of the end face of the opening 24, which shape being formed of straight lines, will have least variation even if there is a slight displacement in the location of the opening 24 relative to the pattern of metal foil due to a tolerance in the processing accuracy during formation of the opening 24.

Accordingly, the side electrodes 13a, 13b formed on the side face of the opening 24 by plating or the like method is provided with a certain stable

junction area with the first and the second main electrodes 12a, 12c; so, the strength of coupling between the side electrodes 13a, 13b and the first and second electrodes 12a, 12c against the stress due to expansion and shrinkage of the conductive polymer will have only small dispersion.

5 Under another method for manufacturing the chip PTC thermistor in exemplary embodiment 1 of the present invention, which comprises the steps of sandwiching conductive polymer having the PTC characteristics from the top and the bottom with metal foil and integrating these into a sheet 23 by heat pressing, patterning the metal foil at the top and the bottom of the
10 integrated sheet 23 by etching, providing the integrated sheet 23 with openings 24 (slits), providing a protective coating 25 on the top and the bottom surfaces of the sheet 23 having the openings 24, forming side electrodes 13a, 13b in the sheet 23 having the protective coating 25 and the openings 24, and dividing the sheet 23 having side electrodes 13a, 13b and the openings 24 into
15 piece chip thermistor; shape of the end face of the opening 24, which shape being formed of straight lines, will have least variation even if there is a slight displacement in the location of the opening 24 due to a tolerance in the processing accuracy during formation of the opening 24.

 Accordingly, the side electrodes 13a, 13b formed on the side face of the
20 opening 24 by plating or the like method is provided with a certain stable junction area with the first and the second main electrodes 12a, 12c; so, the strength of coupling between the side electrode 13a, 13b and the first and second electrodes 12a, 12c against the stress due to expansion and shrinkage of the conductive polymer will have only small dispersion.

25 Furthermore, because the pattern is formed on the metal foil by etching after the heat-pressing process, the pattern is disposed at highly accurate location on the top and the bottom metal foils; namely, the overlapping area formed of the first main electrode 12a and the second main electrode 12c, which overlapping area being relevant to resistance of a chip
30 thermistor, will have only small dispersion. This contributes to a reduced

dispersion in the resistance among the thermistor chips.

Under a method of manufacturing the chip PTC thermistor in exemplary embodiment 2 of the present invention, which comprises the steps of forming an integrated sheet 53 by sandwiching a patterned metal foil from the top and the bottom surfaces with conductive polymer having the PTC characteristics, further stacking patterned metal foil on both surfaces and integrating these into sheet 53 by heat-pressing, providing the integrated sheet 53 with openings, forming a protective coating on the top and the bottom surfaces of sheet 53 having the openings, forming side electrodes 43a, 43b in the sheet 53 having the protective coating and the openings, and dividing the sheet 53 having side electrodes 43a, 43b and the openings into piece chip thermistor; a laminated body containing two sheets of the conductive polymer and three sheets of patterned metal foil alternately stacked therein can be provided through one heat-pressing operation.

Under another method for manufacturing the chip PTC thermistor in exemplary embodiment 2 of the present invention, which comprises the steps of forming an integrated sheet 53 by sandwiching a patterned metal foil from the top and the bottom surfaces with conductive polymer having the PTC characteristics, further stacking metal foil on both surfaces and integrating these into sheet 53 by heat-pressing, patterning the metal foils on the top and the bottom surfaces of the integrated sheet 53 by etching, providing the integrated sheet 53 with openings, forming a protective coating on the top and the bottom surfaces of the sheet 53 having the openings, forming side electrodes 43a, 43b in the sheet 53 having the protective coating and the openings, and dividing the sheet 53 having side electrodes 43a, 43b and the openings into piece chip thermistor; the pattern is disposed at highly accurate location on the outermost metal foils, since the pattern is formed by etching the outermost metal foils after a laminated body containing two sheets of conductive polymer, one sheet of patterned metal foil and two sheets of the outermost metal foil alternately stacked therein is formed by one heat-

pressing operation. Namely, the overlapping area formed of the first main electrode 42a, the second main electrode 42c and the inner main electrode 45a, which overlapping area being relevant to resistance of a chip thermistor, will have only small dispersion. This contributes to a reduced dispersion in the resistance among the chip thermistor.

Under a method for manufacturing the chip PTC thermistor in exemplary embodiment 3 of the present invention, which comprises the steps of forming a first sheet 33 by sandwiching the conductive polymer having the PTC characteristics from the top and the bottom with patterned metal foil and integrating these by heat pressing, forming a second sheet 34 by sandwiching the first sheet 33 from the top and the bottom with conductive polymer having the PTC characteristics, further stacking patterned metal foil on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these into a laminated body by heat pressing, the cycle of heat pressing for integration may be repeated twice or for more cycles, providing the integrated second sheet 34 with openings, providing protective coating on the top and the bottom surfaces of the sheet 34 having the openings, forming side electrodes 3a, 3b in the second sheet 34 having the protective coating and the openings, and dividing the second sheet 34 having the side electrodes 3a, 3b and the openings into piece chip thermistor; thickness of the conductive polymer layers will have only small variation among those locating in the middle strata of the laminated body and those in the outer strata.

The reason for the small variation of the layer thickness is that a laminated body has been formed starting from the inner portion by repeating stacking and heat-pressing step after step towards outer strata; forming a laminated body by first integrating one sheet of the conductive polymer and two sheets of patterned metal foil into one sheet form by heat pressing, and then repeating the cycle of further stacking the conductive polymer for two or more even number layers and patterned metal foil for two or more even number layers to be integrated by heat pressing, eventually forming a

laminated body containing the conductive polymer for three or more odd number layers and patterned metal sheets alternately therein.

Under other method for manufacturing the PTC thermistor chips in exemplary embodiment 3 of the present invention , which comprises the steps

5 of forming a first sheet 33 by sandwiching the conductive polymer having the PTC characteristics from the top and the bottom with patterned metal foil and integrating these by heat pressing, forming a second sheet 34 by sandwiching the integrated first sheet 33 from the top and the bottom with conductive polymer having the PTC characteristics and further stacking metal foil on the

10 top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these into a laminated body by heat pressing, patterning the metal foil on both surfaces of the integrated second sheet 34 by etching, providing said integrated second sheet 34 with openings, providing a protective coating on the top and the bottom surfaces of the second sheet 34

15 having the openings, forming side electrodes 3a, 3b in the second sheet 34 having the protective coating and the openings, and dividing the second sheet 34 having side electrodes 3a, 3b and the openings into piece chip thermistor; the pattern is disposed at highly accurate location on the outermost metal foils, since the pattern is formed by etching the outermost metal foils after a

20 laminated body containing one sheet of conductive polymer and two sheets of patterned metal foil are integrated into one sheet form by heat pressing, further stacking thereon the conductive polymer for two sheets and unpatterned metal foil for the outermost layers for two sheets to be integrated by heat pressing. Namely, the overlapping area formed of the first main

25 electrode 2a, the second main electrode 2c and the inner main electrode 5a, which overlapping area being relevant to resistance of a chip thermistor, will have only small dispersion. This contributes to a reduced dispersion in the resistance among the chip thermistor.

Under a still other method for manufacturing the PTC thermistor

30 chips in exemplary embodiment 3 of the present invention , which comprises

the steps of forming a first sheet 33 by sandwiching the conductive polymer having the PTC characteristics from the top and the bottom with patterned metal foils and integrating these by heat pressing, forming a second sheet 34 by sandwiching the integrated first sheet 33 from the top and the bottom with
5 conductive polymer having the PTC characteristics, further stacking patterned metal foil on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these into a laminated body by heat pressing, the cycle of heat pressing for integration may be repeated twice or for more cycles, forming a third sheet by
10 sandwiching the integrated second sheet 34 from the top and the bottom with the conductive polymer having the PTC characteristics, further stacking metal foil on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these into a laminated body by heat pressing, patterning the metal foil on the top and the bottom surfaces of said
15 integrated third sheet by etching, providing said integrated third sheet with openings, providing a protective coating on the top and the bottom surfaces of the integrated third sheet having the openings, forming side electrodes 3a, 3b in the third sheet having the protective coating and the openings, and dividing the third sheet having said side electrodes 3a, 3b and the openings into piece
20 chip thermistor; the pattern is disposed at highly accurate location on the outermost metal foils, since the pattern is formed by etching the outermost metal foils after a laminated body containing one sheet of conductive polymer and two sheets of patterned metal foil are integrated into one sheet form by heat pressing, further stacking thereon the conductive polymer for two or
25 more even number layers and patterned metal foil for two or more even number layers alternately to be integrated through repeated heat-pressing cycles, and providing unpatterned metal foil for the outermost layers to be integrated by heat pressing, eventually forming a laminated body containing the conductive polymer for five or more odd number layers, patterned metal
30 foils and the unpatterned metal foils for the outermost layers disposed

alternately. Namely, the overlapping area formed of the first main electrode 2a, the second main electrode 2c and the inner main electrode 5a, which overlapping area being relevant to resistance of a chip thermistor, will have only small dispersion. This contributes to a reduced dispersion in the resistance among the chip thermistor.

Under a method for manufacturing the chip PTC thermistor in exemplary embodiment 4 of the present invention, which comprises the steps of forming a first sheet 103 by sandwiching a patterned metal foil from the top and the bottom with conductive polymer having the PTC characteristics and further stacking patterned metal foil on the top and the bottom surfaces, and integrating these into a laminated body by heat pressing, forming a second sheet 104 by sandwiching the integrated first sheet 103 from the top and the bottom with conductive polymer having the PTC characteristics and further stacking patterned metal foil on the top and the bottom surfaces of the conductive polymer having the PTC characteristics, and integrating these into a laminated body by heat pressing, the cycle of stacking and heat-pressing for integration may be repeated twice or more cycles, providing the integrated second sheet 104 with openings, forming a protective coating on the top and the bottom surfaces of the second sheet 104 having the openings, forming side electrodes 93a, 93b in the second sheet 104 having the protective coating and the openings, and dividing the second sheet 104 having the side electrodes 93a, 93b and the openings into piece chips; thickness of the conductive polymer layers will have only small variation among those locating in the middle strata of the laminated body and those in the outer strata. The reason for the small variation of the layer thickness is that a laminated body has been formed starting from the inner strata by repeating stacking and heat-pressing step after step towards outer strata; by first integrating two sheets of conductive polymer and three sheets of patterned metal foil into one sheet form by heat pressing, and then further stacking the conductive polymer for two or more even number layers and the patterned metal foil for two or more

even number layers alternately to be integrated through repeated cycles of the heat pressing process, eventually forming a laminated body containing the conductive polymer for four or more even number layers and the patterned metal foils alternately therein.

5 Under other method for manufacturing the chip PTC thermistor in exemplary embodiment 4 of the present invention, which comprises the steps of forming a first sheet 103 by sandwiching a patterned metal foil from the top and the bottom with conductive polymer having the PTC characteristics, further stacking patterned metal foil on the top and the bottom surfaces and
10 integrating these by heat pressing into a laminated body, forming a second sheet 104 by sandwiching the integrated first sheet 103 from the top and the bottom with conductive polymer having the PTC characteristics, further stacking metal foil on the top and the bottom surfaces of the conductive polymer having the PTC characteristics, and integrating these into a
15 laminated body by heat pressing, patterning the metal foil provided on the top and the bottom surfaces of the integrated second sheet 104 by etching, providing the integrated second sheet 104 with openings, forming a protective coating on the top and the bottom surfaces of the second sheet 104 having the openings, forming side electrodes 93a, 93b in the second sheet 104 having the
20 protective coating and the openings, and dividing the second sheet 104 having side electrodes 93a, 93b and the openings into piece chip thermistor; the pattern is disposed at highly accurate location on the outermost metal foils, since the pattern is formed by etching the outermost metal foils after a laminated body containing two sheets of conductive polymer and three sheets
25 of patterned metal foil are integrated into one sheet form by heat pressing, further stacking thereon the conductive polymer for two layers and unpatterned metal foil for the outermost layer for two layers alternately to be integrated into a laminated body by heat pressing. Namely, the overlapping area formed of the first main electrode 92a, the second main electrode 92c and
30 the inner main electrodes 95a, 95c, 95e, which overlapping area being

relevant to resistance of a chip thermistor, will have only small dispersion. This contributes to a reduced dispersion in the resistance among the chip thermistor.

Under a still other method for manufacturing the PTC thermistor chips in exemplary embodiment 4 of the present invention, which comprises the steps of forming a first sheet 103 by sandwiching a patterned metal foil from the top and the bottom with conductive polymer having the PTC characteristics, further stacking patterned metal foil on the both surfaces and integrating these into a laminated body by press heating, forming a second sheet 104 by sandwiching the integrated first sheet 103 from the top and the bottom with conductive polymer having the PTC characteristics, further stacking patterned metal foil on the both surfaces and integrating these into a laminated body by heat pressing, the cycle of heat pressing for integration may be repeated twice or for more cycles, forming a third sheet by sandwiching the integrated second sheet 104 from the top and the bottom with conductive polymer having the PTC characteristics, further stacking metal foil on the both surfaces and integrating these into a laminated body by heat pressing, patterning the metal foil on both surfaces of the integrated third sheet by etching, providing the integrated third sheet with openings, providing a protective coating on the top and the bottom surfaces of the third sheet having the openings, forming side electrodes 93a, 93b in the third sheet having the protective coating and the openings, and dividing the third sheet having the side electrodes 93a, 93b and the openings into piece chip thermistor; the pattern is disposed at highly accurate location on the outermost metal foils, since the pattern is formed by etching the outermost metal foils after a laminated body containing two sheets of conductive polymer and three sheets of patterned metal foil are integrated into one sheet form by heat pressing, further stacking thereon the conductive polymer for two or more layers in counts and patterned metal foil for two or more even number layers alternately to be integrated into one sheet form through repeated cycle

of the heat-pressing process, further providing unpatterned metal foil for the outermost layers to be integrated, eventually forming a laminated body containing the conductive polymer for six or more even number layers and the patterned metal foils alternately therein. Namely, the overlapping area
5 formed of the first main electrode 92a, the second main electrode 92c and the inner main electrodes 95a, 95c, 95e, which overlapping area being relevant to resistance of a chip thermistor, will have only small dispersion. This contributes to a reduced dispersion in the resistance among the chip thermistor.

10 Furthermore , under a method for manufacturing the chip PTC thermistor in exemplary embodiment 1 of the present invention, where the opening 24 (slits) is formed in a strip shape, or a comb shape, and the end face of the opening is formed of straight lines; form of the end face of the opening will have least variation even if location of the end face is slightly dislocated
15 relative to the pattern of metal foil due to tolerance in the processing accuracy allowed during formation of the strip shape, or the comb shape. Accordingly , the side electrodes 13a, 13b formed on the end face by plating or the like method will have a certain stable junction area with the first main electrode 12a and the second main electrode 12c; so, strength in the coupling at the
20 junction between the side electrodes 13a, 13b and the first main electrode 12a and the second main electrode 12c against the stress caused by expansion and shrinkage of the conductive polymer will have a smaller dispersion.

Still further, under a method for manufacturing the chip PTC thermistor in exemplary embodiment 1 of the present invention, the metal foil
25 is patterned into a comb shape at the opening 24 (slit). Therefore, in a later process step of dividing into piece chip thermistor, the metal foil is incised at a portion corresponding to the comb tooth. Thus the incised portion is smaller as compared with a metal foil having no comb opening. This reduces quantity of burr generation with the metal foil at the dividing step , also reduces the
30 exposure of the cut end of metal foil to the side surface of a chip thermistor,

which is advantageous in avoiding oxidation of the exposed surface and in preventing the occurrence of short-circuiting by solder when mounting the chip thermistor on a circuit board.

5 INDUSTRIAL APPLICABILITY

The PTC thermistor chips of the present invention are formed of a cuboidal form conductive polymer having the PTC characteristics , a first main electrode disposed on a first surface of the conductive polymer, a first sub electrode disposed on the same surface as the main electrode, yet being independent from the first main electrode, a second main electrode disposed on a second surface opposing to the first surface of the conductive polymer, a second sub electrode disposed on the same surface as the second main electrode, yet being independent from said second main electrode, a first side electrode covering at least the entire surface of one of the side surfaces of the conductive polymer, which side electrode being electrically connected with the first main electrode and the second sub electrode, and a second side electrode covering at least the entire surface of the other side surface opposing to the one side surface of the conductive polymer, which side electrode being electrically connected with the first sub electrode and the second main electrode.

Under the structure as configured above, since the side electrode is provided covering at least the entire side surface of the two side surfaces of the conductive polymer, solder fillet can be formed at the side of the chip thermistor mounted on a printed circuit board. It is the advantage of the chip PTC thermistor of the present invention that the soldered portion can be easily inspected visually after the chip thermistor are mounted on a printed circuit board; furthermore, the chip PTC thermistor can be used in the flow soldering process.



CLAIMS:

1. A chip PTC thermistor comprising:

a cuboidal form conductive polymer having the PTC characteristics;

5 a first main electrode disposed on a first surface of said conductive polymer;

a first sub electrode disposed on the same surface as said main electrode, yet being independent from said first main electrode;

a second main electrode disposed on a second surface opposing to said first surface of said conductive polymer;

10 a second sub electrode disposed on the same surface as said second main electrode, yet being independent from said second main electrode;

a first side electrode covering at least the entire surface of one of side surfaces of said conductive polymer, which side electrode being electrically connected with said first main electrode and said second sub electrode; and

15 a second side electrode covering at least the entire surface of the other side surface opposing to the one side surface of said conductive polymer, which side electrode being electrically connected with said first sub electrode and said second main electrode.

20 2. A chip PTC thermistor comprising:

a cuboidal form conductive polymer having the PTC characteristics;

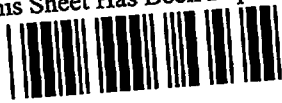
a first main electrode disposed on a first surface of said conductive polymer;

25 a first sub electrode disposed on the same surface as said main electrode, yet being independent from said first main electrode;

a second main electrode disposed on a second surface opposing to said first surface of said conductive polymer;

a second sub electrode disposed on the same surface as said second main electrode, yet being independent from said second main electrode;

30 a first side electrode covering at least the entire surface of one of side



surfaces of said conductive polymer, which side electrode being electrically connected with said first main electrode and said second sub electrode;

a second side electrode covering at least the entire surface of the other side surface opposing to the one side surface of said conductive polymer, which side electrode being electrically connected with said first sub electrode and said second main electrode;

odd number inner main electrode or inner main electrodes disposed within said conductive polymer in parallel with said first and second main electrodes;

odd number inner sub electrode or inner sub electrodes disposed at the same plane as said inner main electrode or inner main electrodes, yet being independent from said inner main electrode or inner main electrodes; wherein

said inner main electrode immediately opposing to said first main electrode is electrically connected with said second side electrode, while said inner sub electrode disposed at the same plane as said inner main electrode immediately opposing to said first main electrode is electrically connected with said first side electrode; further, said inner main electrode and inner sub electrode disposed adjacent to each other are electrically connected, alternately, with said first side electrode and said second side electrode.

3. A chip PTC thermistor comprising:

a cuboidal form conductive polymer having the PTC characteristics;

a first main electrode disposed on a first surface of said conductive polymer;

a first sub electrode disposed on the same surface as said main electrode, yet being independent from said first main electrode;

a second main electrode disposed on a second surface opposing to said first surface of said conductive polymer;

a second sub electrode disposed on the same surface as said second main electrode, yet being independent from said second main electrode;



a first side electrode covering at least the entire surface of one of side surfaces of said conductive polymer, which side electrode being electrically connected with said first main electrode and said second sub electrode;

5 a second side electrode covering at least the entire surface of the other side surface opposing to the one side surface of said conductive polymer, which side electrode being electrically connected with said first sub electrode and said second main electrode;

even number inner main electrodes disposed within said conductive polymer in parallel with said first and second main electrodes;

10 even number inner sub electrode disposed at the same plane as said inner main electrodes, yet being independent from said inner main electrodes; wherein

said inner main electrode immediately opposing to said first main electrode is electrically connected with said second side electrode, while said
15 inner sub electrode disposed at the same plane as said inner main electrode immediately opposing to said first main electrode is electrically connected with said first side electrode; further, said inner main electrodes and inner sub electrodes disposed adjacent to each other are electrically connected, alternately, with said first side electrode and said second side electrode.

20

4. The chip PTC thermistor of claim 1, claim 2 or claim 3, wherein the side electrode is formed of nickel or nickel alloy.

5. A method of manufacturing the chip PTC thermistor comprising:

25 forming a sheet by sandwiching conductive polymer having the PTC characteristics from the top and the bottom with patterned metal foils and integrating these by heat pressing,

providing said integrated sheet with openings,

30 providing protective coatings on both surfaces of the sheet having said openings,



forming a side electrode in the sheet having said protective coating and said openings, and

dividing the sheet having said side electrode and said opening into pieces.

5

6. A method of manufacturing the chip PTC thermistor comprising:

forming a sheet by sandwiching conductive polymer having the PTC characteristics from the top and the bottom with metal foils and integrating these by heat pressing,

10 patterning the metal foils on the top and the bottom surfaces of said integrated sheet by etching,

 providing said integrated sheet with openings,

 providing protective coatings on both surfaces of the sheet having said openings,

15 forming a side electrode in the sheet having said protective coatings and said openings, and

 dividing the sheet having said side electrode and said openings into pieces.

20 7. A method of manufacturing the PTC thermistor chips comprising:

 forming a sheet by sandwiching a patterned metal foil from the top and the bottom conductive polymer having the PTC characteristics, further stacking patterned metal foil on the top and the bottom surfaces and integrating these by heat pressing;

25 providing said integrated sheet with openings;

 providing protective coatings on both surfaces of the sheet having said openings;

 forming a side electrode in the sheet having said protective coatings and said openings; and

30 dividing the sheet having said side electrode and said openings into



pieces.

8. A method of manufacturing the chip PTC thermistor comprising:

forming a sheet by sandwiching a patterned metal foil from the top
5 and the bottom with conductive polymer having the PTC characteristics,
further stacking metal foils on the top and the bottom surfaces and
integrating these by heat pressing;

patterning the metal foil on the top and the bottom surfaces of said
integrated sheet by etching;

10 providing said integrated sheet with openings;

providing protective coatings on both surfaces of the sheet having said
opening;

forming a side electrode in the sheet having said protective coatings
and said openings; and

15 dividing the sheet having said side electrode and said opening into
pieces.

9. A method of manufacturing the chip PTC thermistor comprising:

forming a first sheet by sandwiching conductive polymer having the
20 PTC characteristics from the top and the bottom with patterned metal foils
and integrating these by heat pressing;

forming a second sheet by sandwiching said integrated first sheet from
the top and the bottom with conductive polymer having the PTC
characteristics, further stacking a patterned metal foil on the top and the
25 bottom surfaces the conductive polymer having the PTC characteristics and
integrating these by heat pressing, process cycle of the heat pressing for
integration be once or be repeated more than twice for forming a laminated
body;

providing said integrated second sheet with openings;

30 providing protective coatings on both surfaces of the second sheet



having said openings;

forming a side electrode in the second sheet having said protective coatings and said openings; and

dividing the second sheet having said side electrodes and said
5 openings into pieces.

10. A method of manufacturing the chip PTC thermistor comprising:

forming a first sheet by sandwiching conductive polymer having the PTC characteristics from the top and the bottom with a patterned metal foil
10 and integrating these by heat pressing;

forming a second sheet by sandwiching said integrated first sheet from the top and the bottom with conductive polymer having the PTC characteristics, further stacking metal foils on the top and the bottom surfaces and integrating these by heat pressing;

15 patterning the metal foil on both surfaces of said integrated second sheet by etching;

providing said integrated second sheet with openings;

providing protective coatings on both surfaces of the second sheet having said openings;

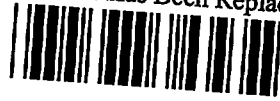
20 forming a side electrode in the second sheet having said protective coatings and said openings; and

dividing the second sheet having said side electrode and said openings into pieces.

25 11. A method of manufacturing the chip PTC thermistor comprising:

forming a first sheet by sandwiching conductive polymer having the PTC characteristics from the top and the bottom with patterned metal foils and integrating these by heat pressing;

forming a second sheet by sandwiching said integrated first sheet from
30 the top and the bottom with conductive polymer having the PTC



characteristics, further stacking patterned metal foils on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these by heat pressing, process cycle of the heat pressing for integration be once or be repeated more than twice for forming a laminated
5 body;

forming a third sheet by sandwiching said integrated second sheet from the top and the bottom with conductive polymer having the PTC characteristics, further stacking metal foils on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating
10 these by heat pressing;

patterning the metal foil on both surfaces of said integrated third sheet by etching;

providing said integrated third sheet with openings;

providing protective coatings on both surfaces of the third sheet
15 having said opening;

forming a side electrode in the third sheet having said protective coatings and said openings; and

dividing the third sheet having said side electrode and said openings into pieces.

20

12. A method of manufacturing the chip PTC thermistor comprising:

forming a first sheet by sandwiching a patterned metal foil from the top and the bottom with conductive polymer having the PTC characteristics, further stacking a patterned metal foil on the top and the bottom surfaces and
25 integrating these by heat pressing;

forming a second sheet by sandwiching said integrated first sheet from the top and the bottom with conductive polymer having the PTC characteristics, further stacking patterned metal foil on the top and the bottom surfaces and integrating these by heat pressing, process cycle of the
30 heat pressing for integration be once or be repeated more than twice for



forming a laminated body;

providing said integrated second sheet with openings;

providing protective coatings on both surfaces of the second sheet having said openings;

5 forming a side electrode in the second sheet having said protective coatings and said openings; and

dividing the second sheet having said side electrode and said openings into pieces.

10 13. A method of manufacturing the chip PTC thermistor comprising:

forming a first sheet by sandwiching a patterned metal foil from the top and the bottom with conductive polymer having the PTC characteristics, further stacking a patterned metal foil on the top and the bottom surfaces and integrating these by heat pressing;

15 forming a second sheet by sandwiching said integrated first sheet from the top and the bottom with conductive polymer having the PTC characteristics, further stacking metal foils on the top and the bottom surfaces and integrating these by heat pressing;

20 patterning the metal foils on the top and the bottom surfaces of said integrated second sheet by etching;

providing said integrated second sheet with openings;

providing protective coatings on both surfaces of the second sheet having said opening;

25 forming a side electrode in the second sheet having said protective coatings and said openings; and

dividing the second sheet having said side electrode and said opening into pieces.

14. A method of manufacturing the chip PTC thermistor comprising:

30 forming a first sheet by sandwiching a patterned metal foil from the top and the bottom with conductive polymer having the PTC characteristics,



further stacking patterned metal foils on the top and the bottom surfaces and integrating these by heat pressing;

5 forming a second sheet by sandwiching said integrated first sheet from the top and the bottom with conductive polymer having the PTC characteristics, further stacking patterned metal foils on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these by heat pressing, process cycle of the heat pressing for integration be once or be repeated more than twice for forming a laminated body;

10 forming a third sheet by sandwiching said integrated second sheet from the top and the bottom with conductive polymer having the PTC characteristics, further stacking metal foils on the top and the bottom surfaces of the conductive polymer having the PTC characteristics and integrating these by heat pressing;

15 patterning the metal foil on both surfaces of said integrated third sheet by etching;

providing said integrated third sheet with openings;

providing protective coatings on both surfaces of the third sheet having said opening;

20 forming a side electrode in the third sheet having said protective coatings and said openings; and

dividing the third sheet having said side electrode and said openings into pieces.

25 15. The method of manufacturing the chip PTC thermistor recited in one of claims 5 through 14, wherein the process for providing the openings is a process of forming the openings in a strip shape or a comb shape.

16. The method of manufacturing the chip PTC thermistor recited in one of claims 5 through 14, wherein the metal foil is processed so that it has an
30 openings of a comb shape after patterning.