

METHOD OF MANUFACTURING CHIP PTC THERMISTER

FIELD OF THE INVENTION

The present invention relates to a method of manufacturing a chip positive
5 temperature coefficient (hereinafter referred to as "PTC") thermister using
electrically conductive polymer having a PTC characteristic.

BACKGROUND OF THE INVENTION

A PTC thermister composed of electrically conductive polymer is used as an
10 overcurrent protective element in a variety of electronic devices. An operating
principle is such that the electrically conductive polymer having a PTC
characteristic heats up by itself when an excessive current flows in an electric
circuit, changing a resistance of its own into a high value due to a thermal
expansion of the electrically conductive polymer, thereby attenuating the current
15 into a safe minute region.

A PTC thermister of the prior art will be described hereinafter.

Japanese Patent Laid-open Publication, No. H09-503097 discloses an
example of a chip PTC thermister of the prior art. It is a chip PTC thermister
comprising a PTC element having a through-hole penetrating between a first
20 surface and a second surface, and a first and a second conductive members in a
layer form, positioned inside of the through-hole, and connected physically as well
as electrically to the first surface and the second surface of the PTC element.

Fig. 15(a) is a sectional view illustrating a chip PTC thermister of the prior
art, and Fig. 15(b) is a plan view of the same. In Fig. 15, a reference numeral 81
25 represents an electrically conductive polymer having a PCT characteristic,
reference numerals 82a, 82b, 82c, and 82d represent electrodes composed of
metallic foil, and reference numerals 83a and 83b represent through-holes.
Reference numerals 84a and 84b are conductive members formed by plating on
insides of the through-holes and over the electrodes 82a, 82b, 82c, and 82d.

Describing next will pertain to a method of manufacturing the above-described chip PTC thermister of the prior art. Fig. 16(a) through 16(d) and Fig. 17(a) through 17(c) are procedural drawings showing a method of manufacturing the chip PTC thermister of the prior art.

5 First, polyethylene and carbon as electrically conductive particles are blended, and a sheet 91 shown in Fig. 16(a) is formed. Next, the sheet 91 is sandwiched with two metallic foils 92, as shown in Fig. 16(b) and 16(c), and an integrated sheet 93 is formed by thermal-compression molding.

Next, through-holes 94 are perforated in a regularly arranged pattern on the
10 integrated sheet 93, as shown in Fig. 16(d), after it is irradiated with electron beam. A plated film 95 is then formed on insides of the through-holes 94 and on the metallic foils 92, as shown in Fig. 17(a).

Etched grooves 96 are formed next in the metallic foils 92, as shown in Fig. 17(b).

15 The laminated product is now cut into individual pieces along cutting lines 97 of a longitudinal direction and cutting lines 98 of a lateral direction as shown in Fig. 17(b), to complete manufacturing of a chip PTC thermister 99 of the prior art as shown in Fig. 17(c).

However, there has been a problem as described hereinafter with the
20 conventional method of manufacturing the chip PTC thermister, when a protective coating is formed on the plated film 95 for a purpose of preventing a short circuit and the like.

That is, formation of the protective coating needs to be carried out only after a pattern is formed by etching the metallic foil 92. Therefore, the protective
25 coating is formed by screen-printing and thermally curing a epoxy base resin, after etched grooves are formed in the metallic foil 92. The problem occurs in this process that a crack may develop in the plated film 95 formed in the through-halls 94 due to a mechanical stress generated by thermal expansion because of the heat applied when thermally curing the sheet 91.

It is conceivable to use a method wherein the etched grooves 96 are formed in the metallic foil, the protective coating is formed next, and the plated film 95 is formed thereafter, in order to prevent the crack from developing in the plated film 95. However, a problem has yet remained unresolved that the plated film 95 can not be formed uniformly on inner surfaces of the through-holes 94 in this method. It is presumed that this is because a surface of the sheet 91 loses an electric conductivity, as a result of the heat during the thermal setting of the protective coating, which causes polyethylene element in the sheet 91 to migrate toward the surface of the sheet 91 exposed on the inner surfaces of the through-holes 94.

An object of the present invention is to solve the foregoing problem of the prior art method, and to provide a method of manufacturing a chip PTC thermister having superior reliability of connection, as it does not cause a crack in the electrode connecting between an upper and a lower electrodes when the protective coating is formed on the metallic foil, and it is capable of uniformly forming a film by electrolytic plating even on a portion of the electrically conductive polymer on an inner surface of the opening when the electrode is formed.

DISCLOSURE OF THE INVENTION

A method of the present invention for manufacturing a chip PTC thermister comprises:

forming a sheet by sandwiching an upper surface and a lower surface of an electrically conductive polymer having a PTC characteristic with metallic foils, on which a pattern is formed in advance, and integrating them by thermal-compression molding;

providing an opening in the integrated sheet;

forming a protective coating, also serving as plating resist, on an upper and a lower surfaces of the sheet in which the opening is provided;

forming an electrode by electrolytic plating on the sheet on which the protective coating serving also as plating resist is formed; and

cutting the sheet, on which the electrode is formed, into individual pieces.

In addition, a material that is capable of being formed at a temperature below a melting point of the electrically conductive polymer is used for a material of the protective coating, also serving as plating resist, in the step of forming the protective coating also serving as plating resist. Furthermore, a processing temperature is maintained in such a manner as not to exceed the melting point of the electrically conductive polymer in each step of the preparatory processes from the step of providing the opening in the integrated sheet, up to the step of forming the electrode by electrolytic plating on the sheet, on which the protective coating serving also as plating resist, is formed. The manufacturing method of the present invention provides the chip PTC thermister having a superior reliability of connection, since it does not cause a crack in the electrode formed by electrolytic plating, and is capable of uniformly forming a film of the electrolytic plating even on portion of the electrically conductive polymer on the inside surface of the opening when the electrode is formed. In addition, the present invention can eliminate waste liquid that is otherwise produced if wet patterning is used for the metallic foil in the process of manufacturing the chip PTC thermister, since present method uses the metallic foil patterned in advance by die-cutting to manufacture the integrated sheet.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1(a) is a perspective view of a chip PTC thermister in a first exemplary embodiment of the present invention;

Fig. 1(b) is a sectional view taken along a line A – A' in Fig. 1(a);

25 Fig. 2(a) through 2(d) are procedural drawings showing a method of manufacturing the chip PTC thermister in the first exemplary embodiment of the present invention;

Fig. 3(a) through 3(d) are procedural drawings showing the method of manufacturing the chip PTC thermister in the first exemplary embodiment of the

present invention;

Fig. 4 is a perspective view of a chip PTC thermister illustrating an example of a defectively formed electrode;

Fig. 5(a) through 5(e) are procedural drawings showing a method of manufacturing a chip PTC thermister in a second exemplary embodiment of the present invention;

Fig. 6(a) through 6(d) are procedural drawings showing the method of manufacturing the chip PTC thermister in the second exemplary embodiment of the present invention;

Fig. 7(a) is a perspective view of a chip PTC thermister in a third exemplary embodiment of the present invention;

Fig. 7(b) is a sectional view taken along a line B – B' in Fig. 7(a);

Fig. 8(a) through 8(d) are procedural drawings showing a method of manufacturing a chip PTC thermister in the third exemplary embodiment of the present invention;

Fig. 9(a) through 9(d) are procedural drawings showing the method of manufacturing the chip PTC thermister in the third exemplary embodiment of the present invention;

Fig. 10(a) through 10(e) are procedural drawings showing a method of manufacturing a chip PTC thermister in a fourth exemplary embodiment of the present invention;

Fig. 11(a) through 11(d) are procedural drawings showing the method of manufacturing the chip PTC thermister in the fourth exemplary embodiment of the present invention;

Fig. 12(a) through 12(d) are procedural drawings showing a method of manufacturing a chip PTC thermister in a fifth exemplary embodiment of the present invention;

Fig. 13(a) through 13(d) are also procedural drawings showing the method of manufacturing the chip PTC thermister in the fifth exemplary embodiment of

the present invention;

Fig. 14(a) is a graph showing a thickness of electrode in the case a plating resist for masking is provided;

Fig. 14(b) is another graph showing a thickness of electrode when
5 manufactured without providing a plating resist for masking;

Fig. 15(a) is a sectional view of a chip PTC thermister of the prior art;

Fig. 15(b) is a plan view of the chip PTC thermister of the prior art;

Fig. 16(a) through 16(d) are procedural drawings showing a method of
manufacturing the chip PTC thermister of the prior art; and

10 Fig. 17(a) through 17(c) are procedural drawings showing a method of
manufacturing a chip PTC thermister of the prior art.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIRST EXEMPLARY EMBODIMENT

15 A chip PTC thermister and a method of manufacturing the same in a first
exemplary embodiment of this invention will be described hereinafter, by referring
to the accompanying figures.

Fig. 1(a) is a perspective view of the chip PTC thermister, and Fig. 1(b) is a
sectional view taken along a line A – A' in Fig. 1(a), in the first exemplary
20 embodiment of this invention.

In Fig. 1(a) and 1(b), a reference numeral 11 represents an electrically
conductive polymer (melting point: approx. 135°C) in a cuboidal shape having a
PTC characteristic, comprising a compound of high density polyethylene (melting
point: approx. 135°C), i.e. crystalline polymer, and carbon black, i.e. electrically
25 conductive particles. A reference numeral 12a represents a first main electrode
located on a first surface of the electrically conductive polymer 11. A reference
numeral 12b represents a first sub-electrode located on the same surface as the
first main electrode 12a, but independently from the first main electrode 12a. A
reference numeral 12c is a second main electrode located on a second surface

opposite to the first surface of the electrically conductive polymer 11, and a reference numeral 12d is a second sub-electrode located on the same surface as the second main electrode 12c, but independently from the second main electrode 12c. Each of the electrodes consists of a metallic foil such as electrolytic copper foil.

5 A first side electrode 13a consisting of a layer of electrolytically plated nickel, is disposed in such a manner as to surround over an entire side surface of the electrically conductive polymer 11, an edge portion of the first main electrode 12a and the second sub-electrode 12d, and to electrically connect the first main electrode 12a and the second sub-electrode 12d.

10 A second side electrode 13b consisting of a layer of electrolytically plated nickel, is also disposed in such a manner as to surround over an entire surface of another side opposite to the first side electrode 13a of the electrically conductive polymer 11, an edge portion of the second main electrode 12c and the first sub-electrode 12b, and to electrically connect the second main electrode 12c and the
15 first sub-electrode 12b.

Reference numerals 14a and 14b are a first protective coating and a second protective coating in green color, both serving also as plating resist, composed of polyester-based resin provided on outermost layers of the first surface and the second surface of the electrically conductive polymer 11. Incidentally, the first
20 side electrode 13a and the second side electrode 13b correspond to "electrode" defined in the claims, and they may take any forms that can be provided on portions of the side surfaces of the PTC thermister, or on inside of the through-holes of the prior art structure.

A method of the first exemplary embodiment of this invention for
25 manufacturing the chip PTC thermister will now be described by referring to the accompanying figures.

Fig. 2(a) through 2(d) and Fig. 3(a) through 3(d) are procedural drawings showing the method of manufacturing the chip PTC thermister in the first exemplary embodiment of this invention.

First, a 42 weight % of high density polyethylene (melting point: approx. 135°C) having a crystallinity of 70 to 90 % , a 57 weight % carbon black having a mean particle diameter of 58 nm and a specific surface area of 38 m²/g, manufactured by furnace method, and a 1 weight % of antioxidant were kneaded
5 for about 20 minutes with two-roll mill heated to approximately 170°C. The kneaded substance in a sheet-form was taken out from the two-roll mill, and an electrically conductive polymer 21 (melting point: approx. 135°C) shown in Fig. 2(a), in a sheet-form having a thickness of approximately 0.16 mm was produced.

Next, a metallic foil 22 shown in Fig. 2(b) was made from electrolytic
10 copper foil of approx. 80 μm by pattern forming with a press forming.

Next, a sheet 23 integrated as shown in Fig. 2(d) was produced by overlaying one each of the metallic foil 22 on top and bottom of the sheet-formed electrically conductive polymer 21, as shown in Fig. 2(c), and subjecting them to a compression molding for approx. 1 minute under a condition of 140°C to 150°C in
15 temperature , approx. 20 torr in degree of vacuum, and approx. 50 kg/cm² in surface pressure.

After the integrated sheet 23 was thermally treated (approx. 20 minutes at 100°C to 115°C), it was irradiated with approx. 40 Mrad of electron beam in an electron beam irradiating apparatus to complete cross-linking of the high density
20 polyethylene.

Long slit openings 24 were then formed at regular intervals in the integrated sheet 23, as shown in Fig. 3(a), by using a dicing machine, a milling machine, or the like, while cooling it with water. In the process of forming the openings 24, certain desired portions were left uncut in a longitudinal direction of the openings
25 24. In a process of rinsing and drying after the openings 24 were cut, the work was carried out at such a temperature that a temperature of the electrically conductive polymer 21 does not rise beyond the melting point (135°C) of the electrically conductive polymer 21.

Next, an upper surface and a lower surface of the sheet 23 provided with the

openings 24 was screen-printed with green colored paste of polyester based thermo-setting resin , except for an area surrounding the opening 24, as shown in Fig. 3(b), and a protective coating 25 also serving as plating resist was formed by curing it (at 125°C to 130°C for approx. 10 minutes) in a curing oven.

5 Then, a side electrode 26 was formed, as shown in Fig. 3(c), on a portion of the integrated sheet 23, where the protective coating 25 also serving as plating resist is not formed, and on inner surfaces of the openings 24. The side electrode 26 was formed by electrolytic nickel plating in a thickness of approx. 15 μm in a sulfamic acid nickel bath under a condition of an electric current density of 4
10 A/dm^2 , for about 30 minutes

The sheet 23 of Fig. 3(c) was divided , thereafter, into individual pieces with a dicing machine to complete a chip PTC thermister 27 shown in Fig. 3(d).

Hereinafter an advantage of the foregoing processes will be explained , wherein a temperature of the electrically conductive polymer 21 is so maintained
15 as not to exceed the melting point (135°C) of the electrically conductive polymer 21 during the preparatory processes which include the steps from the forming of the openings 24 shown in Fig. 3(a) to the forming of the side electrode 26 shown in Fig. 3(c), by adopting the protective coating, also serving as plating resist, capable of being formed at a temperature equal to or lower than the melting point
20 135°C of the electrically conductive polymer.

In comparison , a protective coating 25, also serving as plating resist, was formed by screen-printing a resin paste of the ordinary epoxy based thermo-setting resin and curing it (at 140°C to 150°C for approx. 10 minutes) in a oven , in the step of forming the protective coating 25, also serving as plating resist, shown in
25 Fig. 3(b). The following problem arose in this case, in the step of forming the side electrode 26.

First of all, Fig. 4 shows an example of defects developed when the side electrode 13a and 13b of the chip PTC thermister were formed.

In Fig. 4, a reference numeral 15 represents a defective portion formed in the

side electrodes 13a and 13b. Although nickel plating is properly formed on the main electrodes 12a, 12c, and the sub-electrodes 12b and 12d, the same nickel plating is formed only partially on the electrically conductive polymer 11. Therefore, the main electrodes 12a and 12c, and the sub-electrodes 12b and 12d has not connected both electrically and physically. This is caused by a fact that the electrically conductive polymer 11 is unable to keep an electrical conductivity in its surface, while the main electrodes 12a and 12c as well as the sub-electrodes 12b and 12d, as being metal parts, keep high electrical conductivity. It is presumed that the surface of the electrically conductive polymer 11 is unable to maintain the electrical conductivity, because the electrically conductive polymer 11 is heated beyond the melting point of 135°C under the processing temperature of 140°C to 150°C for 10 minutes, which causes the polyethylene element within the electrically conductive polymer 11 to migrate toward its surface. Naturally, a film of the electrolytic plating is not formed on the portion where electrical conductivity is lost, thereby giving rise to a trouble of defective formation of the side electrodes 13a and 13b.

There are two important points described below in order to avoid the foregoing trouble, and to ensure reliability of connection by successfully forming the side electrode 26.

The first one is to use a protective coating 25 serving as plating resist that can be formed at a temperature equal to or less than the melting point of 135°C of the electrically conductive polymer 21.

The second one is to prevent temperature of the electrically conductive polymer 21 being heated up to the melting point (135°C) or higher during the steps from the forming of the openings 24 through the completing the formation of the side electrode 26.

It is therefore necessary to prevent the temperature of the electrically conductive polymer 21 from being heated to the melting point (135°C) or higher even with a processing temperature in any step other than the step of forming the

protective coating 25 , also serving as plating resist, such as a processing temperature when rinsing and drying it, and so on, after the dicing, for the same reason as described above.

Because of the above reason, the first exemplary embodiment of this invention does not cause a crack in the side electrode 26 composed of a layer of electrolytically plated nickel , even if the protective coating 25, also serving as plating resist, is formed upon consideration of a short circuiting due to deviation in a position of soldering on a printed circuit board.

This exemplary embodiment can also provide the chip PTC thermister having superior reliability of connection, as it does not cause such a trouble as not forming the side electrode 26 uniformly on the inner surface of the opening 24.

An advantage of the first exemplary embodiment of this invention for forming the side electrode 26 with the layer of electrolytically plated nickel will be described hereinafter.

First of all, it requires approx. 30 minutes with an electric current density of about 4.0 A/dm^2 in order to form the side electrode 26 in a thickness of $15 \text{ }\mu\text{m}$ in the case of electrolytic nickel plating in the step of forming the side electrode. On the contrary, it requires more than twice as longer time to approx. 80 minutes with an electric current density of approx. 1.5 A/dm^2 in the case of electrolytic copper plating. Defects such as yellowing, abnormal deposition, and the like of the plating occur if the electric current density for the electrolytic copper plating is increased to about 4.0 A/dm^2 for the purpose of forming the plated film within a short period of time. In the case of the electrolytic copper plating, therefore, it is difficult to form a plated film of the same thickness as the electrolytic nickel plating in a short period of time.

In addition, a thermal-shock test (between -40°C for 30 minutes and $+125^\circ\text{C}$ for 30 minutes) was performed on samples having a side electrode of the same thickness prepared with a layer of the electrolytically plated nickel, and a layer of the electrolytically plated copper. No defect such as a crack, etc. occurred on any

of the electrode samples formed with the layer of electrolytically plated nickel, upon observation of polished sections after completion of a 100-cycle and a 250-cycle thermal shock tests. In the case of the samples formed with the layer of electrolytically plated copper, however, a crack occurred, as was observed on polished sections after a completion of the 100-cycle thermal shock test. Moreover, it was observed that some of the samples show a complete disconnection due to cracks after the 250-cycle thermal shock test.

The above results suffice it to note that the side electrode 26 formed with the layer of electrolytically plated nickel has such effects as shortening a manufacturing time and improving reliability of connection.

SECOND EXEMPLARY EMBODIMENT

A method of manufacturing a chip PTC thermister in a second exemplary embodiment of the present invention will be described next by referring to Fig. 5 and 6.

Fig. 5(a) through 5(e) and Fig. 6(a) through 6(d) are procedural drawings showing the method of manufacturing the chip PTC thermister in the second exemplary embodiment of this invention.

An electrically conductive polymer 31 (melting point: approx. 135°C) shown in Fig. 5(a), in a sheet-form having a thickness of approximately 0.16 mm was produced in the same manner as in the first exemplary embodiment.

Next, an integrated sheet 33 shown in Fig. 5(d) was produced by overlaying a metallic foil 32 shown in Fig. 5(b) composed of an electrolytic copper foil of approx. 80 μm on top and bottom of the electrically conductive polymer 31, as shown in Fig. 5(c), and subjecting them to a thermal-compression molding for approx. 1 minute at 140°C to 150°C in temperature, approx. 40 torr in degree of vacuum, and approx. 50 kg/cm^2 in surface pressure.

The metallic foils 32 on the top and the bottom surfaces of the integrated sheet 33 were etched by the photolithographic process to form a pattern as shown

in Fig. 5(e).

The sheet 33, formed with the pattern, was thermally treated (at 100°C to 115°C for approx. 20 minutes), and it was irradiated with approx. 40 Mrad of electron beam in an electron beam irradiating apparatus to complete cross-linking of the high density polyethylene. A chip PTC thermister 37 shown in Fig. 6(d) was obtained by taking manufacturing steps thereafter, as shown in Fig. 6(a) through 6(d), in the same manner as the first exemplary embodiment of this invention.

The chip PTC thermister 37 manufactured in the manner as described above has similar effects as those of the first exemplary embodiment of this invention. That is, this exemplary embodiment can provide for the chip PTC thermister having superior reliability of connection, as it does not cause such a trouble as having a crack in a side electrode 36 composed of a layer of electrolytically plated nickel, and a defect in formation of the side electrode 36, even if a protective coating 35, also serving as plating resist, is formed upon consideration of a short circuiting due to deviation in a position of soldering on a printed wiring board.

THIRD EXEMPLARY EMBODIMENT

A chip PTC thermister and a method of manufacturing the same in a third exemplary embodiment of this invention will be described next by referring to the accompanying figures. Fig. 7(a) is a perspective view of the chip PTC thermister, and Fig. 7(b) is a sectional view taken along a line B - B' in Fig. 7(a), in the third exemplary embodiment of this invention.

A structure of the chip PTC thermister shown in Fig. 7(a) and 7(b) is the same in principle with that of the first exemplary embodiment. This exemplary embodiment differs from the first exemplary embodiment, in that a first and a second protective coatings 44a and 44b, also serving as plating resist of green color, provided on outermost layers of a first surface and a second surface of an electrically conductive polymer 41 are composed of epoxy based resin.

The method of the third exemplary embodiment of this invention for manufacturing the chip PTC thermister will be described next by referring to Fig. 8(a) through 8(d) and Fig. 9(a) through 9(d).

Manufacturing processes of this exemplary embodiment are same as those of the first exemplary embodiment, up to the step for irradiating the electron beam on an integrated sheet.

Next, an upper surface and a lower surface of an integrated composite sheet 53 was screen-printed with green colored paste of epoxy base thermo-setting resin, and a protective coating 54, also serving as plating resist, was formed by curing it (at 145°C to 150°C for approx. 10 minutes) in a curing oven, as shown in Fig. 9(a).

Long slit openings 55 were then formed at regular intervals in the integrated sheet 53, as shown in Fig. 9(b), by using a dicing machine, a milling machine, or the like, while cooling it with water. In the process of forming the openings 55, predetermined portions were left uncut in a longitudinal direction of the openings 55. In the case of rinsing and drying it after the openings 55 were cut, the work was carried out at such a temperature that a temperature of an electrically conductive polymer 51 does not rise beyond the melting point (135°C) of the electrically conductive polymer 51.

Then, a side electrode 56 comprising a layer of electrolytically plated nickel in a thickness of approx. 15 μm was formed, as shown in Fig. 9(c), on a portion of the sheet 53, where the protective coating 54, also serving as plating resist, is not formed, and on inner walls of the openings 55 by nickel plating in a sulfamic acid nickel bath under a condition of an electric current density of 4 A/dm², for about 30 minutes.

The sheet 53 of Fig. 9(c) was divided, thereafter, into individual pieces with a dicing machine to complete a chip PTC thermister 57 shown in Fig. 9(d).

An effect of the manufacturing method shown in this third exemplary embodiment of the present invention will be described hereinafter.

First, there is a necessity, for the same reason as what has been described in the first exemplary embodiment of this invention, that temperature of the electrically conductive polymer 51 is maintained so as not to exceed the melting point (135°C) of the electrically conductive polymer 51 during the preparatory processes from the step of forming the openings 55 shown in Fig. 9(b) to the step of forming a side electrode 56 shown in Fig. 9(c). The purpose of this is to properly form the side electrode 56 that is an essential point to assure reliability of connection.

Next, an advantage of forming the protective coating 54, also serving as plating resist, shown in Fig. 9(a), before cutting the openings 55 shown in Fig. 9(b), will be described.

It becomes unnecessary to restrict material used for forming the protective coating 54, also serving as plating resist, to such a material that can be formed at a temperature below the melting point (135°C) of the electrically conductive polymer 51, when the protective coating 54 serving as plating resist is formed before cutting the openings 55. Therefore, this gives an advantage that material can be selected freely among a variety of general resin materials that can be formed at about 150°C, according to characteristics necessary in respect of adhesiveness, mechanical strength, and so on. Furthermore, it can give such an effect as to shorten a curing time and to improve adhesion by increasing a curing temperature to approx. 150°C for a material that can be formed at the curing temperature of 130°C or below,.

FOURTH EXEMPLARY EMBODIMENT

A method of a fourth exemplary embodiment of this invention for manufacturing a chip PTC thermister will be described next by referring to Fig. 10(a) through 10(e) and Fig. 11(a) through 11(d). Manufacturing processes of this exemplary embodiment are same as those of the second exemplary embodiment, up to the step for irradiating electron beam on an integrated sheet.

A chip PTC thermister 67 shown in Fig. 11(d) was obtained by taking the manufacturing steps shown in Fig. 11(a) through 11(d) in the same manner as those of the third exemplary embodiment of this invention.

The chip PTC thermister 67 manufactured in the manner as described above
5 has similar effects as those of the third exemplary embodiment of this invention. That is, this exemplary embodiment can provide a chip PTC thermister having superior reliability of connection, as it does not cause such a trouble as having a crack in a side electrode 66 composed of a layer of electrolytically plated nickel, and a defective formation of the side electrode, in that the side electrode 36 can
10 not be formed uniformly over an inner surface of openings 65, even if a protective coating, also serving as plating resist, is formed upon consideration of a short circuiting, etc. due to deviation in a position of soldering on a printed wiring board.

In addition, it becomes unnecessary to restrict material used for forming the
15 protective coating 64, also serving as plating resist, to such a material that can be formed at a temperature below the melting point (135°C) of an electrically conductive polymer 51, when the protective coating 64 also serving as plating resist is formed before cutting the openings 65. Therefore, this gives an advantage that material can be selected freely among a variety of general resin
20 materials that can be formed at about 150°C , according to characteristics necessary in respect of adhesion, mechanical strength, and so on. Furthermore, it can give such an effect as to shorten a curing time and to improve adhesion by increasing a curing temperature to approx. 150°C for a material that can be formed at the curing temperature of 130°C or below.

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FIFTH EXEMPLARY EMBODIMENT

A method of a fifth exemplary embodiment of this invention for manufacturing a chip PTC thermister will be described next by referring to Fig. 12(a) through 12(d) and Fig. 13(a) through 13(d). Manufacturing processes of

this exemplary embodiment are the same as those of the first exemplary embodiment, up to the step for forming an opening 74.

Next, a protective coating 75, also serving as plating resist, and another plating resist 76 for masking purpose were formed at the same time with same
5 material by screen-printing green colored paste of polyester base thermo-setting resin on an upper surface and a lower surface of a sheet 73 provided with the openings 74 , and by curing it (at 125°C to 130°C for approx. 10 minutes) in a curing oven, as shown in Fig. 13(b).

During this process , the protective coating 75, also serving as plating resist,
10 was formed on a product part except for an area surrounding the openings 74, and the plating resist 76 for masking was formed on a area not usable for the product part of the sheet 73 with a contact point 79 for plating left intact.

Then, a side electrode 77 was formed, as shown in Fig. 13(c), on a portion of the sheet 73, where the protective coating 75, also serving as plating resist, and the
15 plating resist 76 for masking are not formed, and on inner walls of the openings 74 by plating with nickel in a thickness of approx. 15 μm . The nickel plating was made in a sulfamic acid nickel bath under a condition of an electric current density of 4 A/dm², for about 30 minutes.

The sheet 73 of Fig. 13(c) was divided, thereafter, into individual pieces with
20 a dicing machine to complete a chip PTC thermister 78 shown in Fig. 13(d).

Described hereinafter is an effect of the plating resist 76 for masking.

Two kinds of samples were prepared for comparison purpose , wherein the side electrode 77 was formed after forming the plating resist 76 for masking on the area not usable for the product part of the sheet 73, for one case, and the side
25 electrode 77 was formed without forming the plating resist 76 for masking in another case. 50 samples were taken for each of the groups, and thickness of the side electrodes 77 were measured by observing their sections. The results are shown in Fig. 14(a) and 14(b). As it is obvious from Fig. 14(a) and 14(b), the case where the plating resist 76 for masking was formed shows a smaller deviation

in thickness of the side electrode 77. The reason of this is that a presence of the plating resist 76 for masking makes the electric current density uniform around an area of the side electrode 77 during the plating process.

Accordingly, the fifth exemplary embodiment of this invention can provide
5 the chip PTC thermister exhibiting stable reliability of connection, since it can reduce the deviation in thickness of the side electrode 77, in addition to the effects provided by the first to the fourth exemplary embodiments.

The protective coating 75, also serving as plating resist, and the plating resist 76 for masking may be formed individually with different materials. However, a
10 positional relation can be established firmly between the protective coating 75, also serving as plating resist, and the plating resist 76 for masking, if they are formed at the same time with the same material as in the case of this fifth exemplary embodiment of the invention. This method can therefore offer an effect of uniformizing thickness of the side electrode further as compared to the
15 case in which they are formed individually. Moreover, it also provides with an effect of a cost reduction by reducing the manufacturing steps, etc., since the protective coating 75 and the plating resist 76 for masking can be formed with a single step of printing.

Besides, although the polyester base thermo-setting resin was used for the
20 protective coating 75, also serving as plating resist, and the plating resist 76 for masking, in the present exemplary embodiment, any other kind of epoxy based resin may also be used, as it is superior in its properties of heat resistance, chemical resistance, and adhesion, as described in the foregoing third and the fourth exemplary embodiments.

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As has been described, the method of the present invention for manufacturing the chip PTC thermister comprises the steps of :

forming a sheet by sandwiching an upper surface and a lower surface of an electrically conductive polymer having a PTC characteristic with metallic foils, on

which a pattern is formed, and integrating them by thermal-compression molding;
providing an opening in the integrated sheet;

forming a protective coating, also serving as plating resist, on an upper and a lower surfaces of the sheet in which the opening is provided;

5 forming an electrode by electrolytic plating on the sheet on which the protective coating serving also as plating resist is formed; and

dividing the sheet, on which the electrode is formed, into individual pieces.

In addition, a material that can be formed at a temperature below a melting point of the electrically conductive polymer is used for a material of the protective
10 coating, serving also as plating resist.

Furthermore, a processing temperature is maintained in such a manner as not to exceed the melting point of the electrically conductive polymer in each step of the preparatory processes from the step of providing the opening in the integrated sheet , up to the step of forming the electrode by electrolytic plating on the sheet,
15 on which the protective coating serving also as plating resist, is formed.

This manufacturing method does not cause a crack in the electrode due to an effect of heat during formation of the protective coating, serving also as plating resist, since the electrode is formed by plating only after the protective coating serving also as plating resist is formed.

20 Moreover, this method is able to form the electrode uniformly , since it maintains an electrical conductivity on a surface of the electrically conductive polymer, by way of controlling the processing temperature in such a manner as to prevent polymer in the electrically conductive polymer from migrating toward a surface of the electrically conductive polymer exposed on an inner surface of the
25 opening. As a result, an effect capable of manufacturing the chip PTC thermister having a superior reliability of connection can be obtained.

INDUSTRIAL APPLICABILITY

As has been described, a method of the present invention for manufacturing

a chip PTC thermister provides an effect of providing a manufacturing method of the chip PTC thermister having superior reliability in connection, at low cost with excellent mass-productivity. Accordingly, the chip PTC thermister can be used effectively as an over-current protective element in a variety of electronic devices.

WHAT IS CLAIMED IS:

1. A method of manufacturing a chip PTC thermister comprising:

5 (1) forming a sheet by sandwiching an upper surface and a lower surface of an electrically conductive polymer having a PTC characteristic with metallic foils having a pattern formed thereon, and integrating them by thermal-compression molding;

(2) providing an opening in said integrated sheet;

10 (3) forming a protective coating, also serving as plating resist, on an upper surface and a lower surface of said sheet provided with said opening;

(4) forming an electrode by electrolytic plating on said sheet having said protective coating, serving also as plating resist, formed thereon; and

(5) dividing said sheet having said electrode formed thereon into individual pieces, wherein

15 said protective coating, serving also as plating resist, is formed with a material that can be formed at a temperature below a melting point of said electrically conductive polymer, and

a processing temperature is maintained in a manner not to exceed the melting point of said electrically conductive polymer in each step of preparatory
20 processes from the step of providing said opening in said integrated sheet, to the step of forming said electrode by electrolytic plating on said sheet having said protective coating, serving also as plating resist, formed thereon.

2. A method of manufacturing a chip PTC thermister comprising:

25 (1) forming a sheet by sandwiching an upper surface and a lower surface of an electrically conductive polymer having a PTC characteristic with metallic foils, and integrating them by thermal-compression molding;

(2) forming a pattern by etching said metallic foils on an upper surface and a lower surface of said integrated sheet;



- (3) providing an opening in said sheet having the pattern formed thereon;
- (4) forming a protective coating, also serving as plating resist, on the upper and the lower surfaces of said sheet provided with said opening;
- (5) forming an electrode by electrolytic plating on said sheet having said protective coating, serving also as plating resist, formed thereon; and
- (6) dividing said sheet having said electrode formed thereon into individual pieces, wherein
- said protective coating, serving also as plating resist, is formed with a material that can be formed at a temperature below a melting point of said electrically conductive polymer, and
- a processing temperature is maintained in a manner not to exceed the melting point of said electrically conductive polymer in each step of preparatory processes from the step of providing said opening in said integrated sheet, to the step of forming said electrode by electrolytic plating on said sheet having said protective coating, serving also as plating resist, formed thereon.

3. A method of manufacturing a chip PTC thermister comprising:

- (1) forming a sheet by sandwiching an upper surface and a lower surface of an electrically conductive polymer having a PTC characteristic with metallic foils having a pattern formed thereon, and integrating them by thermal-compression forming;
- (2) forming a protective coating, also serving as plating resist, on an upper and a lower surface of said integrated sheet;
- (3) providing an opening in said sheet having said protective coating, serving also as plating resist, formed thereon;
- (4) forming an electrode by electrolytic plating on said sheet provided with said opening; and
- (5) dividing said sheet having said electrode formed thereon into individual pieces, wherein



a processing temperature is maintained in a manner not to exceed the melting point of said electrically conductive polymer in each step of preparatory processes from the step of providing said opening in said sheet having said protective coating, serving also as plating resist, formed thereon, to the step of
5 forming said electrode by electrolytic plating.

4. A method of manufacturing a chip PTC thermister comprising the steps of:

(1) forming a sheet by sandwiching an upper surface and a lower surface
10 of an electrically conductive polymer having a PTC characteristic with metallic foils, and integrating them by thermal-compression forming;

(2) forming a pattern by etching said metallic foils on an upper surface and a lower surface of said integrated sheet;

(3) forming a protective coating, also serving as plating resist, on the
15 upper and the lower surfaces of said sheet having the pattern formed thereon;

(4) providing an opening in said sheet having said protective coating, serving also as plating resist, formed thereon;

(5) forming an electrode by electrolytic plating on said sheet provided with said opening; and

20 (6) dividing said sheet having said electrode formed thereon into individual pieces, wherein

a processing temperature is maintained in a manner not to exceed the melting point of said electrically conductive polymer in each step of preparatory processes from the step of providing said opening in said sheet having said
25 protective coating, serving also as plating resist, formed thereon, to the step of forming said electrode by electrolytic plating.

5. The method of manufacturing a chip PTC thermister according to any one of claim 1 through claim 4, wherein the step of forming said electrode by



electrolytic plating is carried out by electrolytic nickel plating.

6. The method of manufacturing a chip PTC thermister according to any one of claim 1 through claim 4 further comprising an additional step between the
5 step of forming said integrated sheet and the step of forming said electrode by electrolytic plating , said additional step for forming a plating resist for masking purpose on the upper and the lower surfaces of said sheet in a portion not usable for a product.

10 7. The method of manufacturing a chip PTC thermister according to claim 5 further comprising an additional step between the step of forming said integrated sheet and the step of forming said electrode by electrolytic plating , said additional step for forming a plating resist for masking purpose on the upper and the lower surfaces of said sheet in a portion not usable for a product.

15 8. The method of manufacturing a chip PTC thermister according to claim 6, wherein said plating resist for masking purpose to be formed on the upper and the lower surfaces of said sheet is made at the same time said protective coating, serving also as plating resist, is formed.

20 9. The method of manufacturing a chip PTC thermister according to claim 7, wherein said plating resist for masking purpose to be formed on the upper and the lower surfaces of said sheet is made at the same time said protective coating, serving also as plating resist, is formed.

25 10. The method of manufacturing a chip PTC thermister according to any one of claim 1 through claim 4 , wherein the step of forming said sheet by sandwiching the upper surface and the lower surface of said electrically conductive polymer having a PTC characteristic with either of the metallic foils



having a pattern formed thereon and the metallic foils, and integrating them by thermal-compression molding, is carried out under a reduced pressure.

11. The method of manufacturing a chip PTC thermister according to claim 5, wherein the step of forming said sheet by sandwiching the upper surface and the lower surface of said electrically conductive polymer having a PTC characteristic with either of the metallic foils having a pattern formed thereon and the metallic foils, and integrating them by thermal-compression molding, is carried out under a pressure lower than an atmospheric pressure.

10

12. The method of manufacturing a chip PTC thermister according to claim 10, wherein said pressure lower than the atmospheric pressure is equal to or lower than 40 torr.

15

13. The method of manufacturing a chip PTC thermister according to claim 11, wherein said pressure lower than the atmospheric pressure is equal to or lower than 40 torr.



ABSTRACT

A method of manufacturing a chip PTC thermister comprises a piece of conductive polymer having a PTC characteristic and metal foils formed by patterning and provided on the upper and the lower sides of the piece under pressure integrally into a sheet, making a hole part in the sheet, applying a protective coat serving as plating resist to upper and lower sides of the sheet , forming an electrode on the by electroplating, and cutting the sheet into a chip. The protective coat is made of a material applicable at a temperature equal to or lower than the melting point of the conductive polymer. The processing temperatures at the step from the step of making a hole part in the sheet to the pre-processing step of the step of forming an electrode by electroplating on the sheet are not above the melting point of the conductive polymer.

Reference Numerals

- 11 Electrically conductive polymer
- 12a First main electrode
- 12b First sub-electrode
- 5 12c Second main electrode
- 12d Second sub-electrode
- 13a First side electrode
- 13b Second side electrode
- 14a First protective coating, also serving as plating resist
- 10 14b Second protective coating, also serving as plating resist
- 21 Electrically conductive polymer
- 22 Metallic foil
- 23 Integrated sheet
- 24 Opening
- 15 25 Protective coating, also serving as plating resist
- 26 Side electrode
- 31 Electrically conductive polymer
- 32 Metallic foil
- 33 Integrated sheet
- 20 34 Opening
- 35 Protective coating, also serving as plating resist
- 36 Side electrode
- 41 Electrically conductive polymer
- 42a First main electrode
- 25 42b First sub-electrode
- 42c Second main electrode
- 42d Second sub-electrode
- 43a First side electrode
- 43b Second side electrode

- 44a First protective coating, also serving as plating resist
- 44b Second protective coating, also serving as plating resist
- 51 Electrically conductive polymer
- 52 Metallic foil
- 5 53 Integrated sheet
- 54 Opening
- 55 Protective coating, also serving as plating resist
- 56 Side electrode
- 61 Electrically conductive polymer
- 10 62 Metallic foil
- 63 Integrated sheet
- 64 Opening
- 65 Protective coating, also serving as plating resist
- 66 Side electrode
- 15 71 Electrically conductive polymer
- 72 Metallic foil
- 73 Integrated sheet
- 74 Opening
- 75 Protective coating, also serving as plating resist
- 20 76 Plating resist for masking
- 77 Side electrode
- 81 Electrically conductive polymer
- 82a, 82b, 82c, 82d Electrode
- 83a, 83b Through-hole
- 25 84a, 84b Electrically conductive member
- 91 Sheet
- 92 Metallic foil
- 93 Integrated sheet
- 94 Through-hole

- 95 Plated film
- 96 Etched groove
- 97, 98 Cutting line
- 99 Chip PTC thermister

FIG. 1A

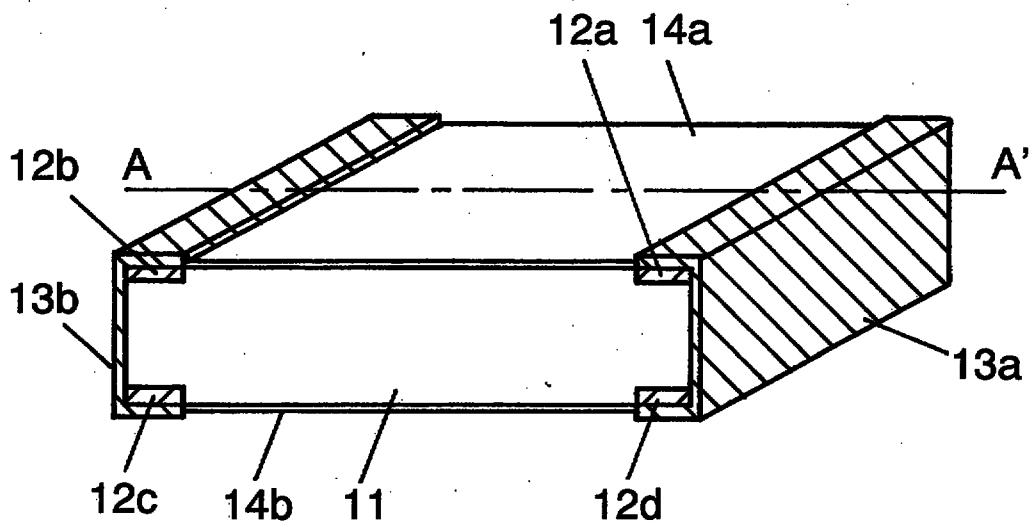


FIG. 1B

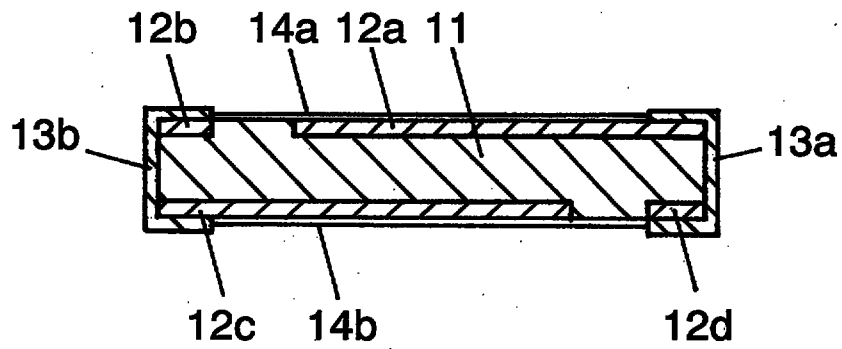


FIG.2(a)

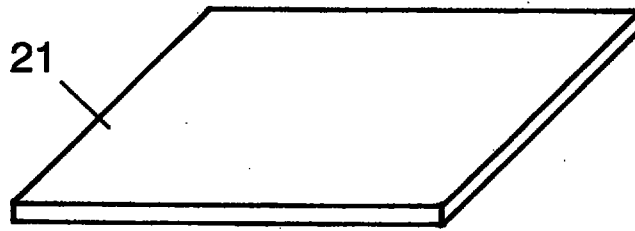


FIG.2(b)

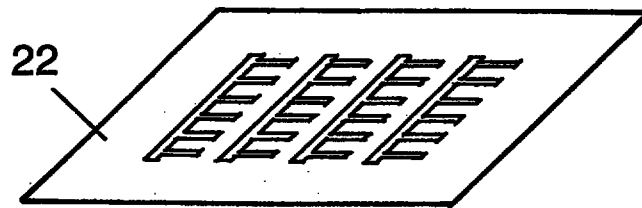


FIG.2(c)

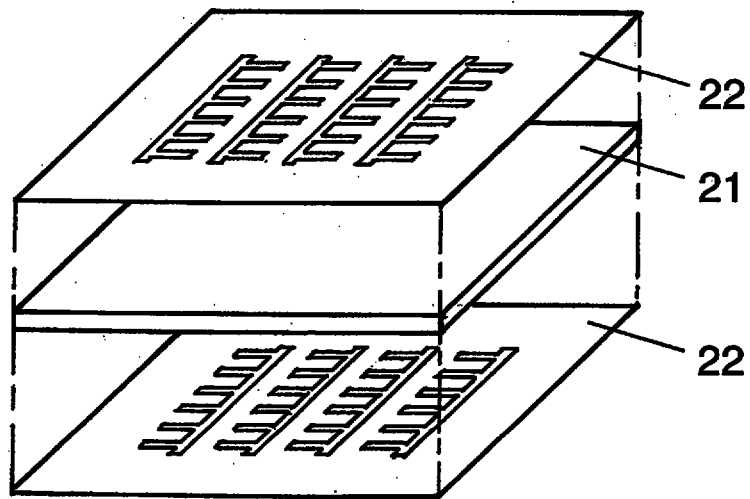


FIG.2(d)

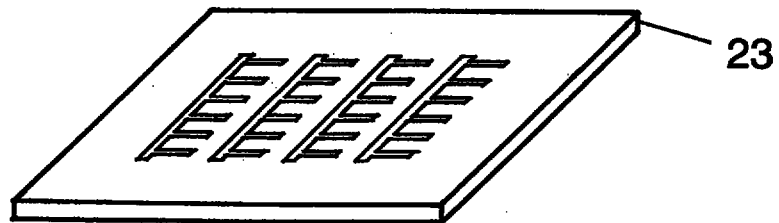


FIG.3(a)

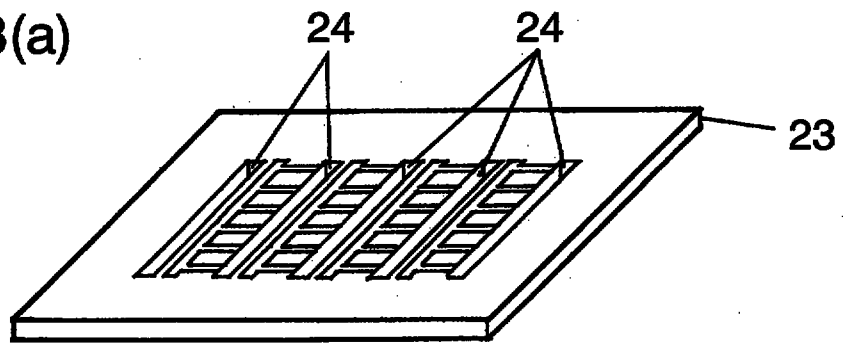


FIG.3(b)

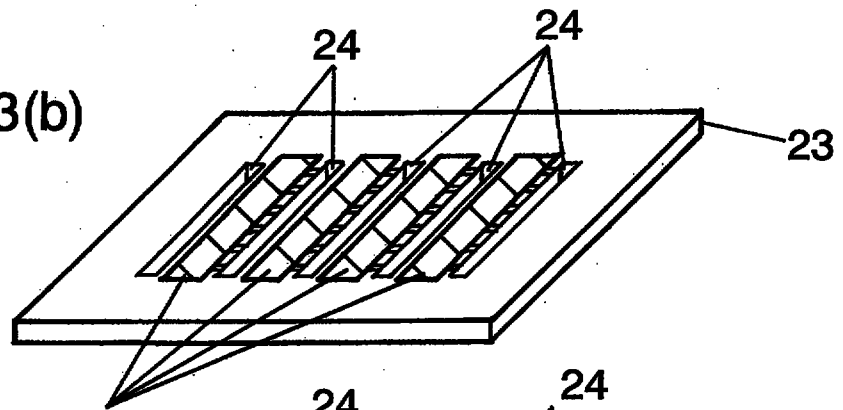


FIG.3(c)

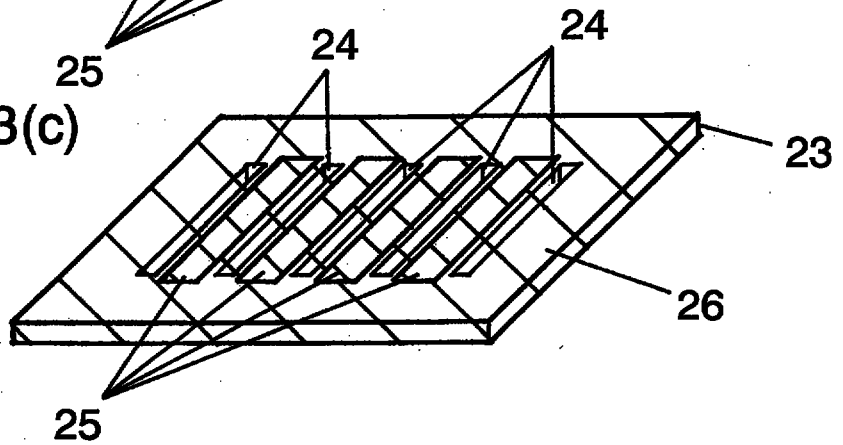


FIG.3(d)

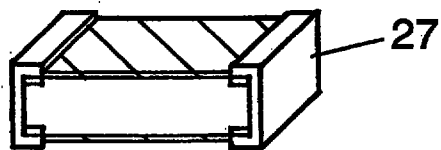


FIG. 4

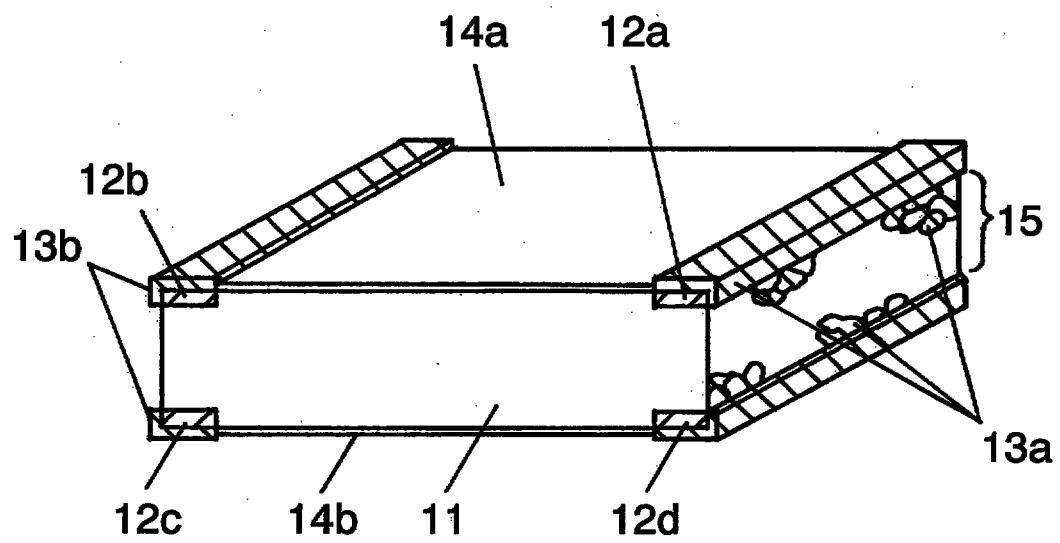


FIG.5(a)

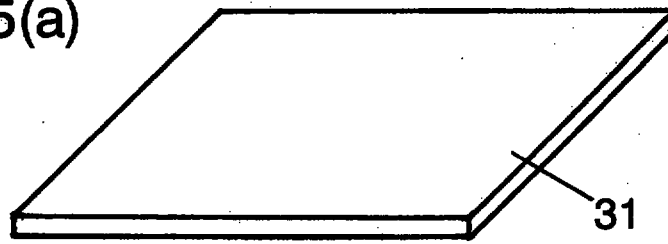


FIG.5(b)

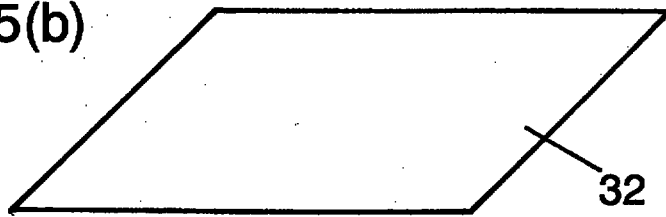


FIG.5(c)

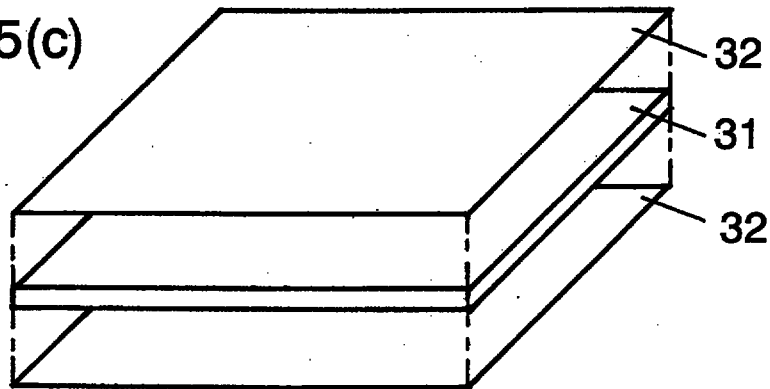


FIG.5(d)

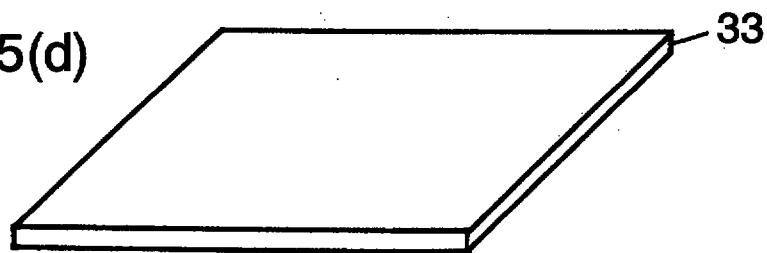
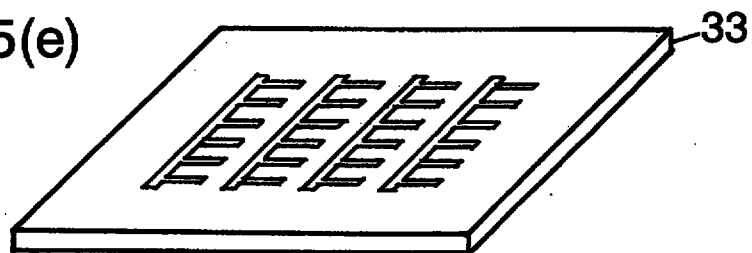


FIG.5(e)



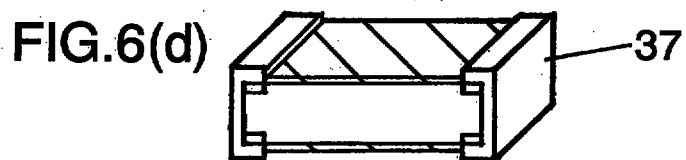
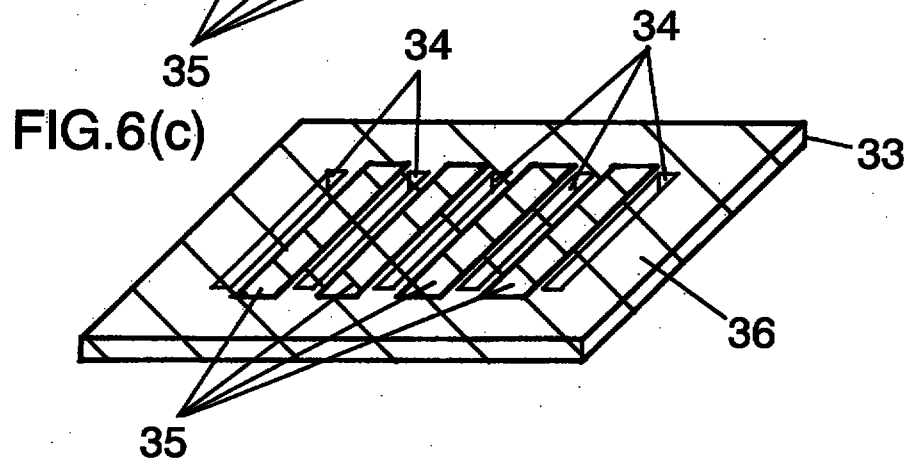
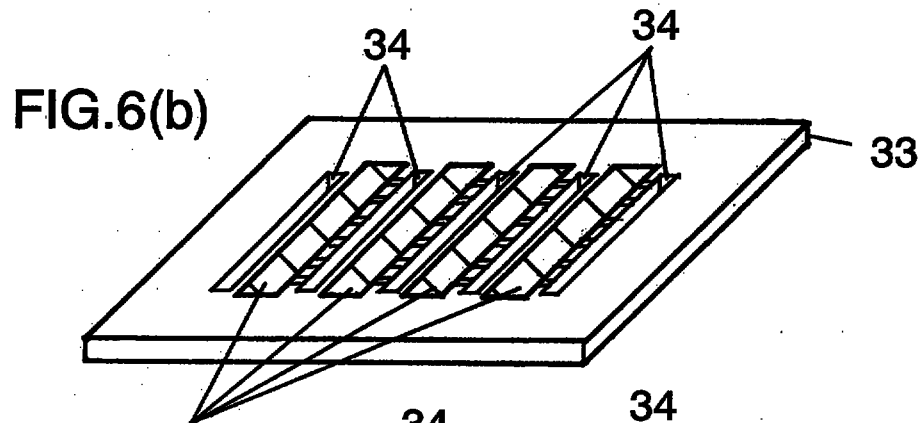
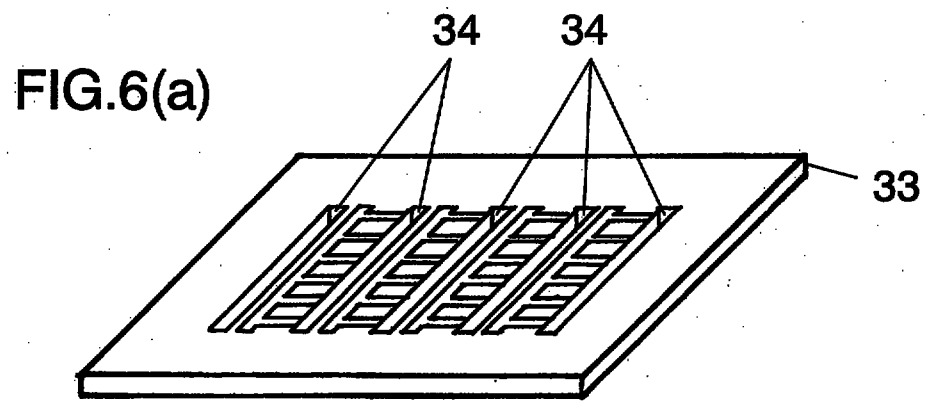


FIG. 7A

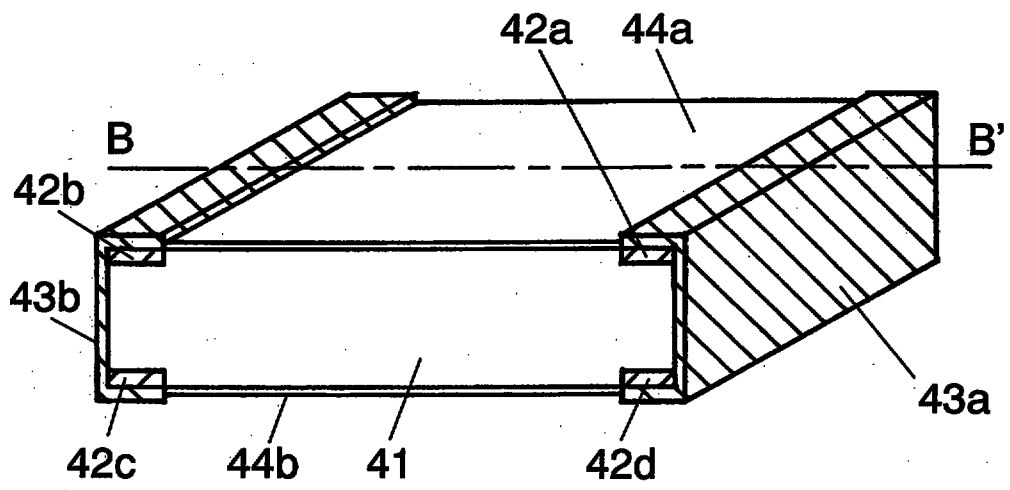


FIG. 7B

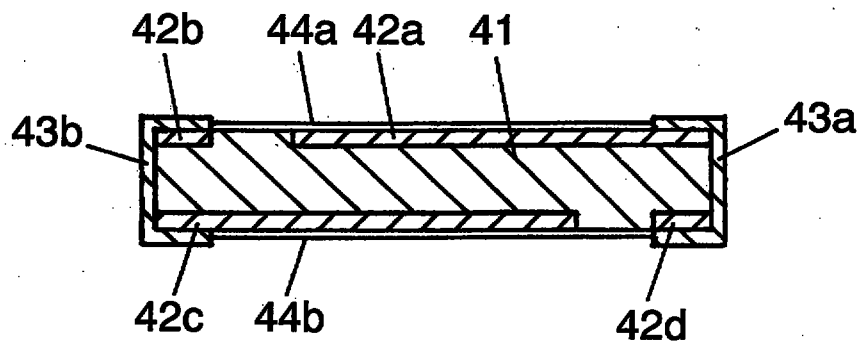


FIG.8(a)



FIG.8(b)



FIG.8(c)

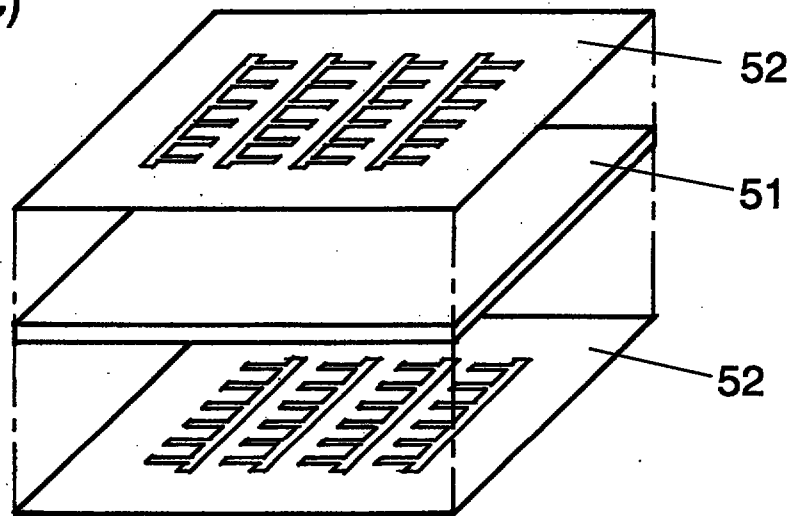


FIG.8(d)

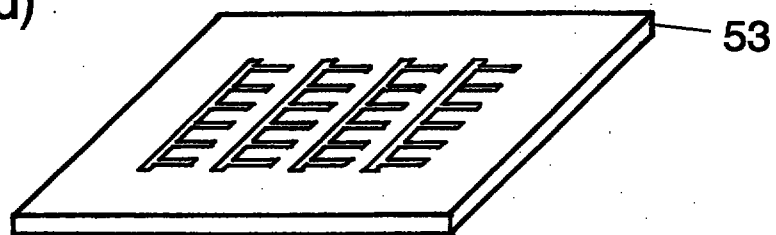


FIG.9(a)

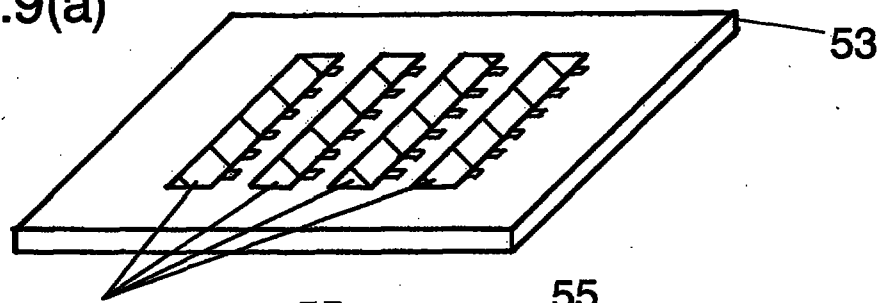


FIG.9(b)

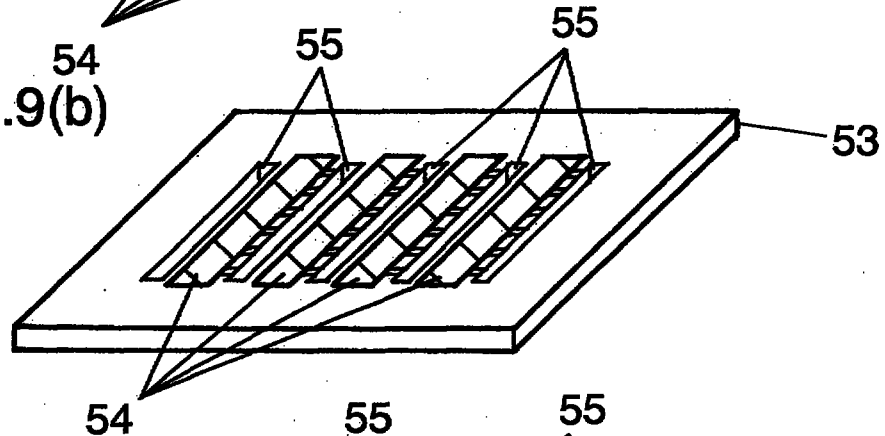


FIG.9(c)

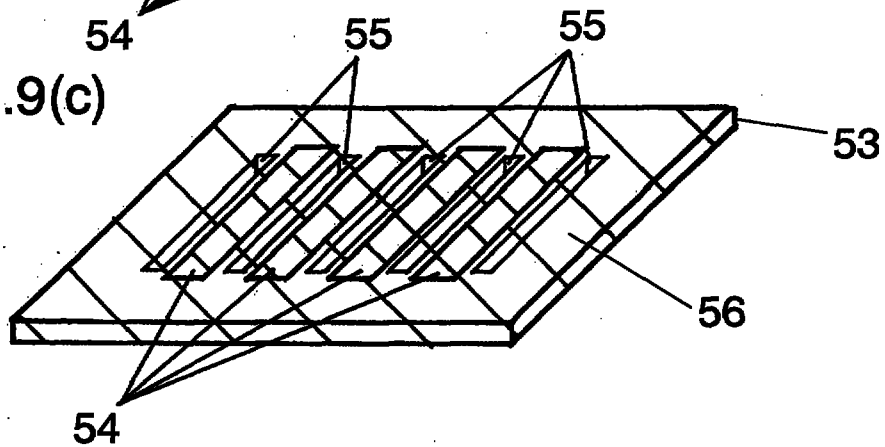


FIG.9(d)

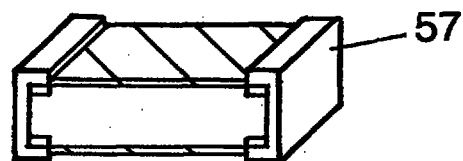


FIG.10(a)

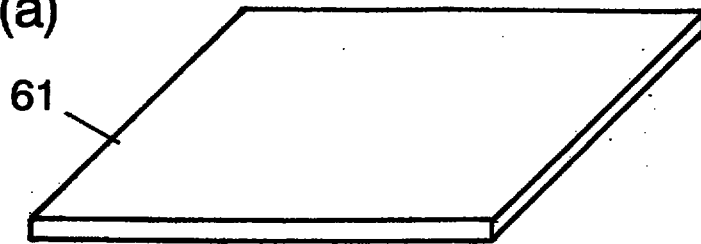


FIG.10(b)

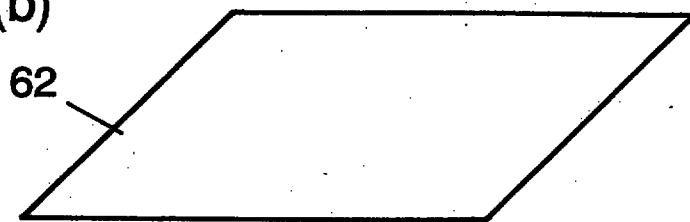


FIG.10(c)

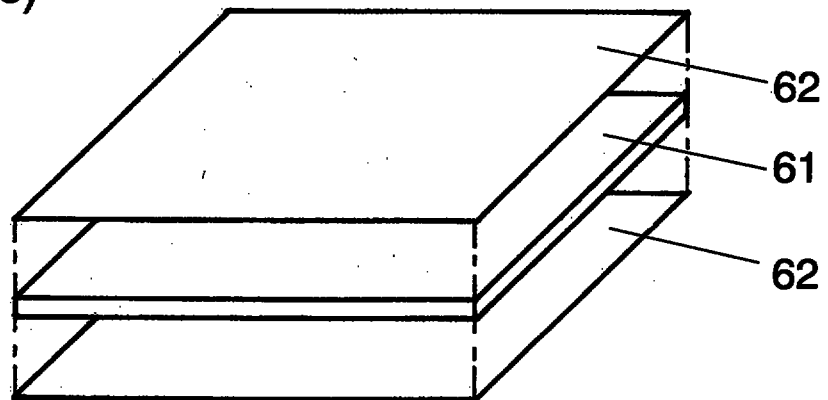


FIG.10(d)

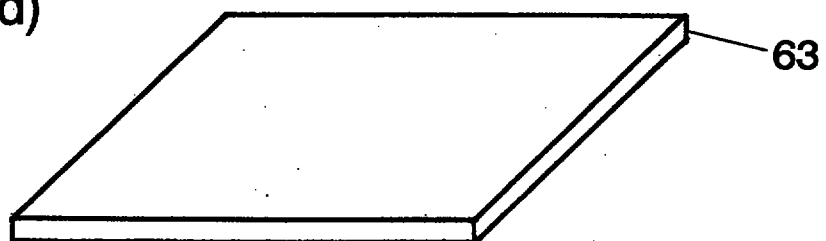


FIG.10(e)

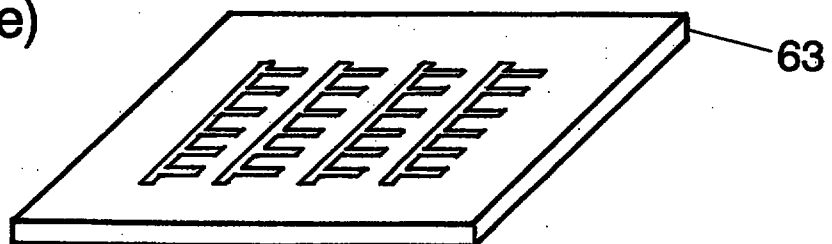


FIG.11(a)

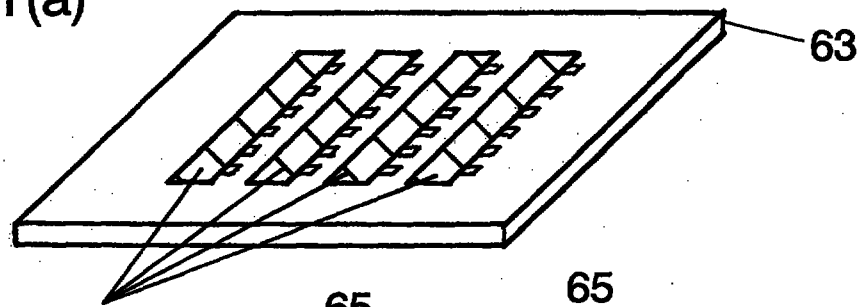


FIG.11(b)

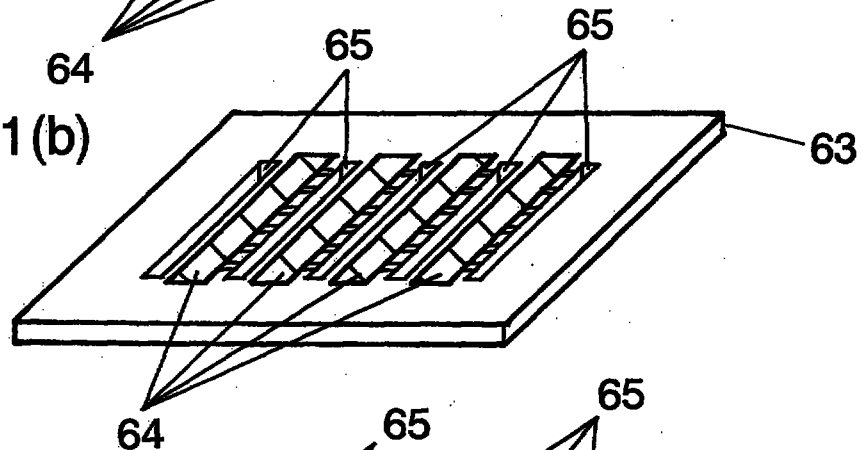


FIG.11(c)

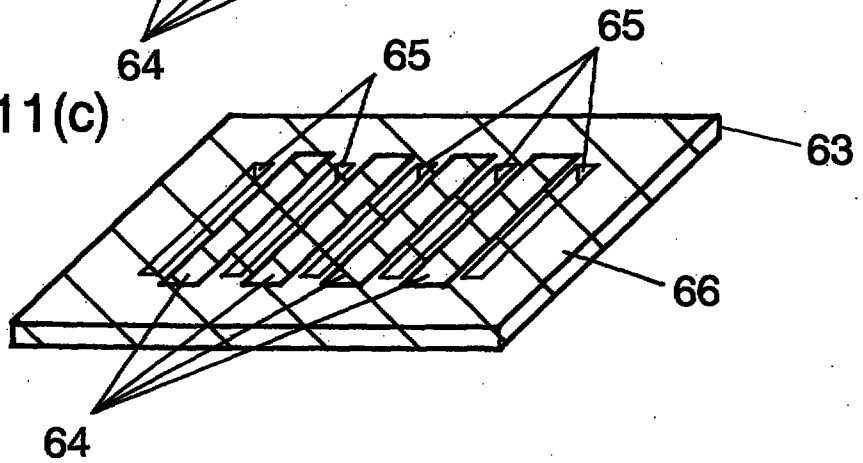


FIG.11(d)

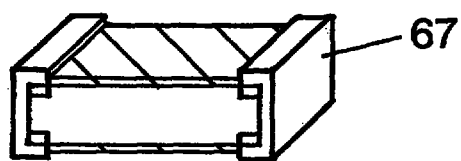


FIG.12(a)

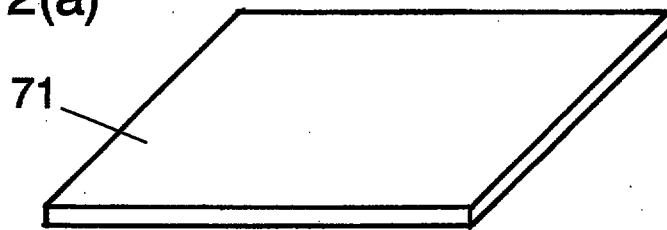


FIG.12(b)

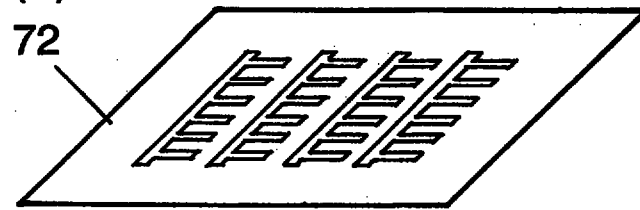


FIG.12(c)

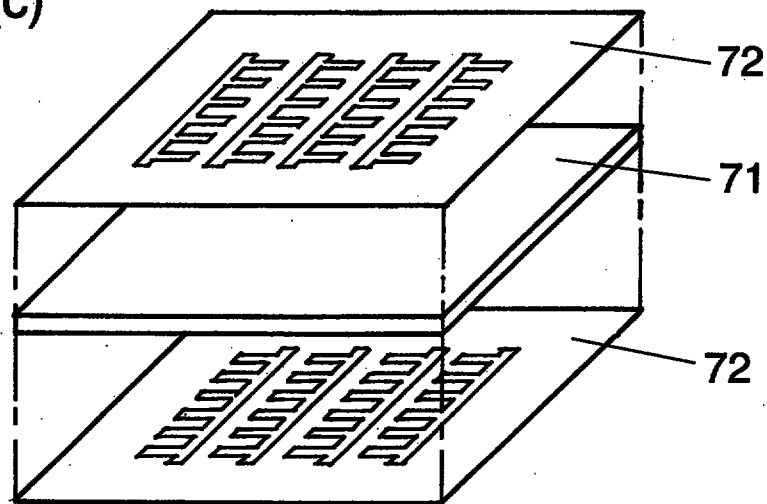


FIG.12(d)

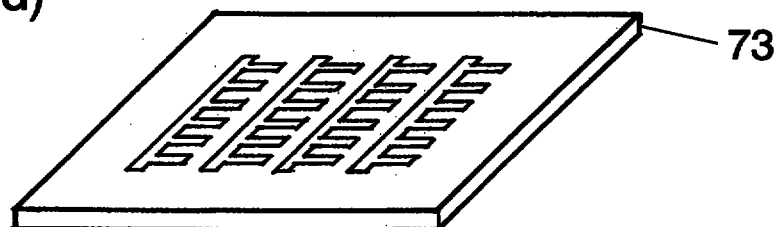


FIG.13(a)

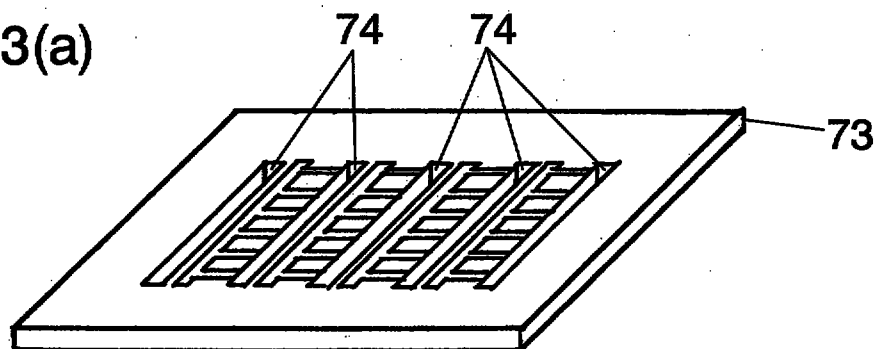


FIG.13(b)

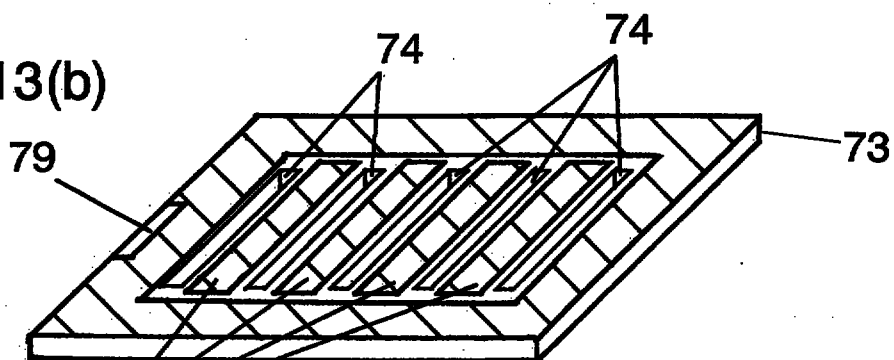


FIG.13(c)

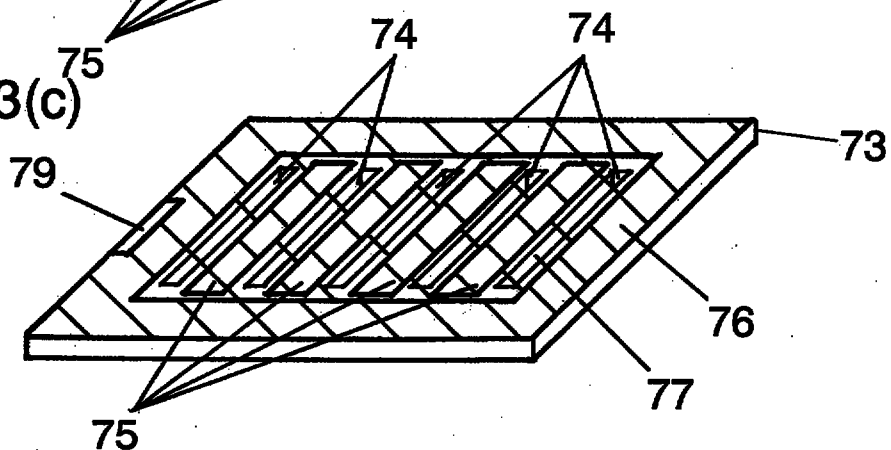


FIG.13(d)

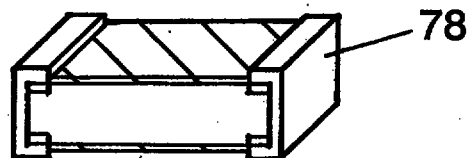


FIG. 14A

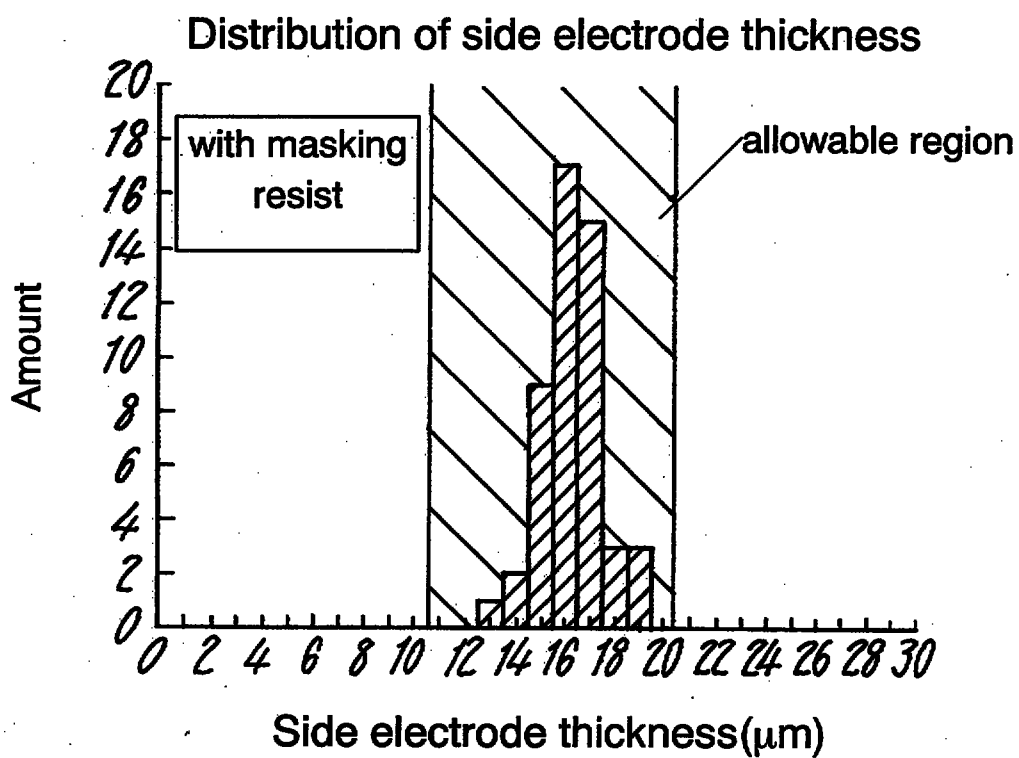


FIG. 14B

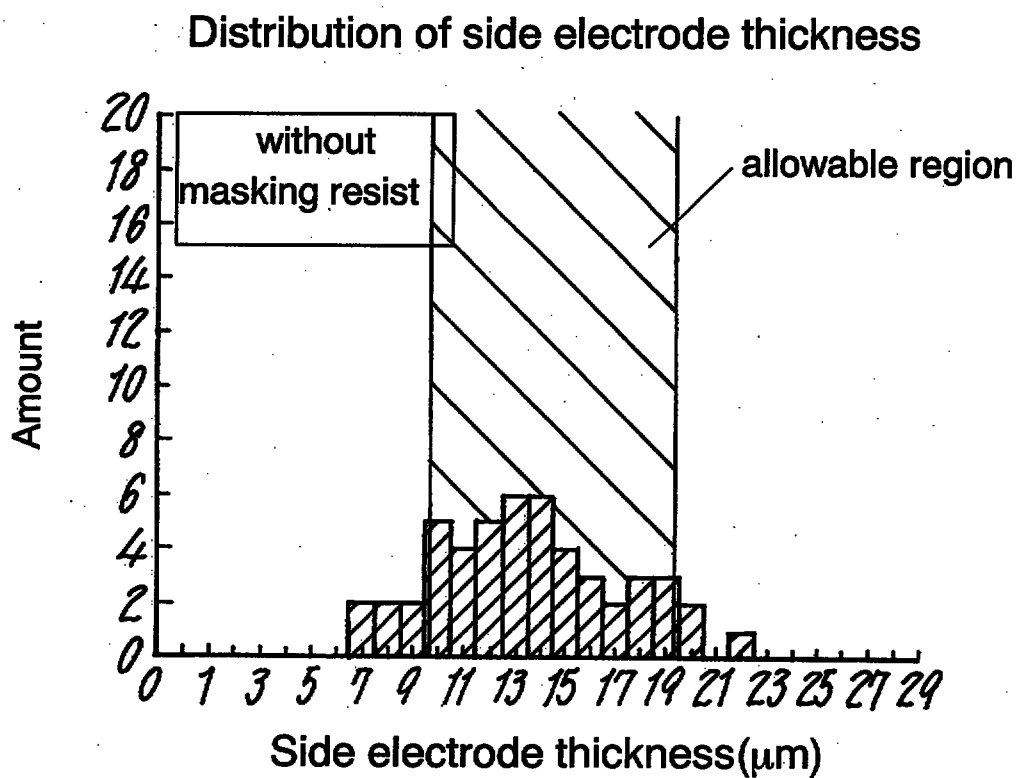


FIG. 15A Prior Art

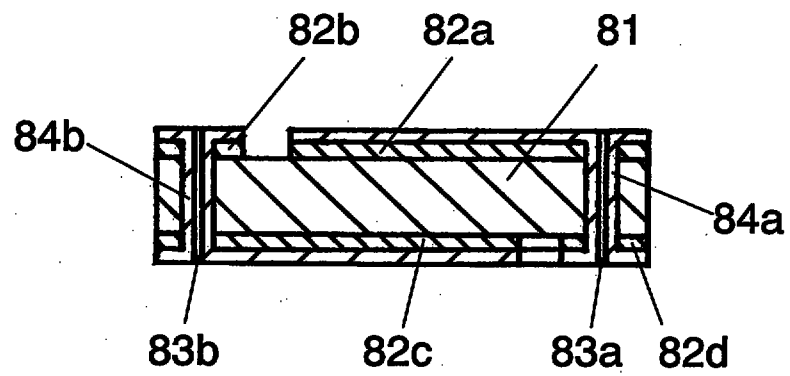


FIG. 15B Prior Art

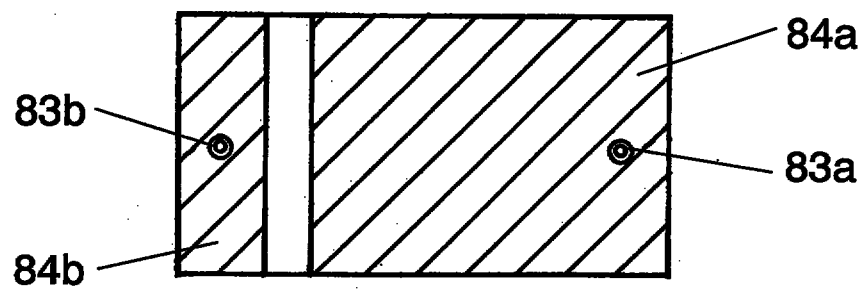


FIG.16(a)

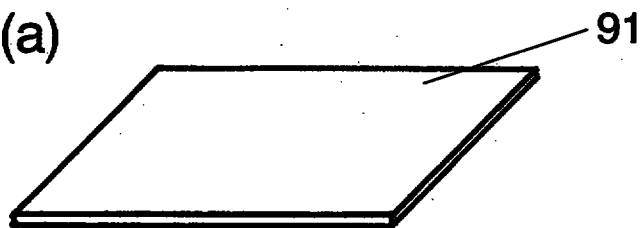


FIG.16(b)

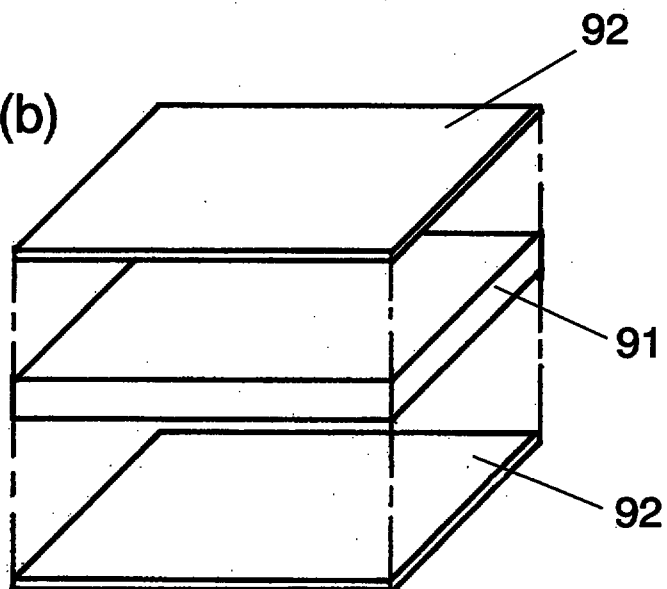


FIG.16(c)

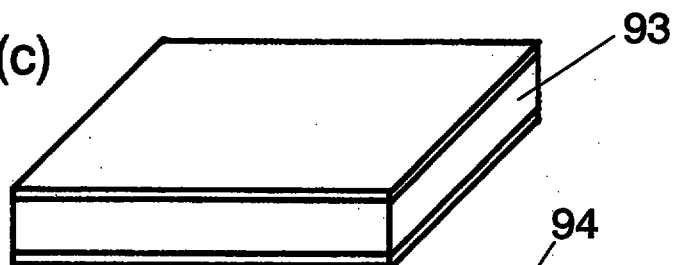


FIG.16(d)

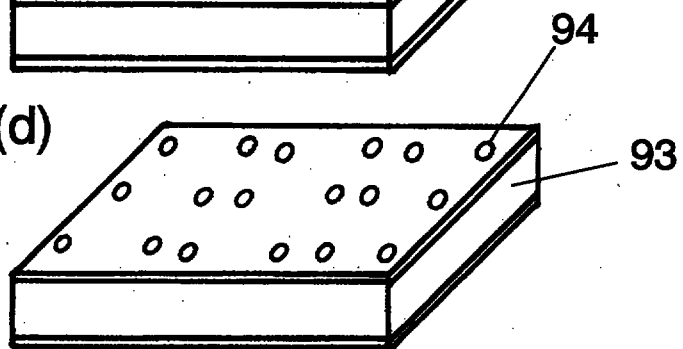


FIG.17(a)

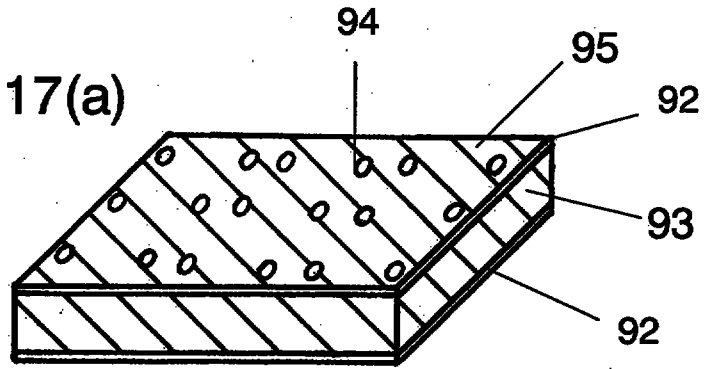


FIG.17(b)

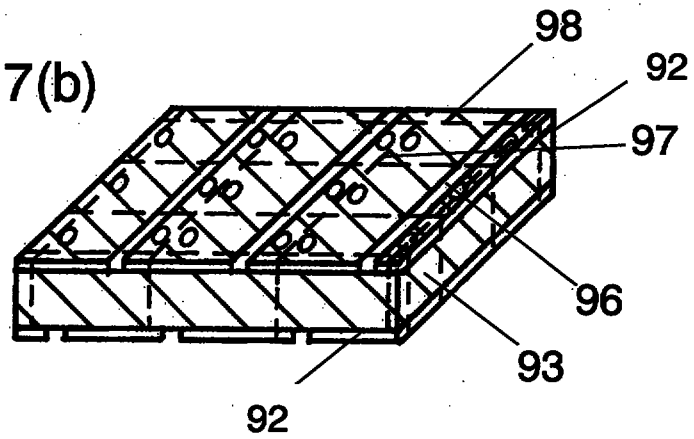


FIG.17(c)

