

RESISTOR AND METHOD OF MANUFACTURING THE SAME

FIELD OF THE INVENTION

The present invention relates to a resistor and a method of manufacturing the same.

BACKGROUND OF THE INVENTION

There has been a growing demand more than ever in recent years for miniaturization of electronic components used for circuit boards, in order to increase a density of mounting, as reduction in size of electronic devices continues. A demand has been rising also for resistors having smaller size and higher accuracy in tolerance of resistances, in order to reduce mounting areas on mount boards.

Previously known resistors of such kind include one that is disclosed in Japanese Patent Laid-open Publication, Number H04-102302.

A resistor of the prior art and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 50 is a sectional view depicting a resistor of the prior art.

In the figure, a reference numeral 1 represents an insulating substrate, and a reference numeral 2 represents first upper surface electrode layers provided on an upper surface at both right and left ends of the insulating substrate 1. A reference numeral 3 represents a resistor layer provided in a manner that portions of which overlap with the first upper surface electrode layers 2. A reference numeral 4 represents a first protective layer provided in a manner to cover the resistor layer 3 entirely. A reference numeral 5 represents a trimmed groove provided in the resistor layer 3 and the first protective layer 4 for correcting a resistance. A reference numeral 6 represents a second protective layer provided over an outer surface of the first protective layer 4. A reference numeral 7 represents second upper surface electrode layers provided on upper surfaces of the first upper surface electrode layers 2 in a manner to spread over a full width of the insulating substrate 1. A reference numeral 8 represents side surface electrode layers provided on side surfaces of the insulating substrate 1. Reference numerals 9 and 10 respectively represent nickel-plated layers and solder-plated layers provided over surfaces of the second upper surface electrode layers 7 and the side surface electrode layers 8.

A method of manufacturing the resistor of the prior art constructed as above will be described hereinafter by referring to accompanying figures.

Fig. 51 represents procedural views depicting a method of manufacturing the prior art resistor.

Firstly, first upper surface electrode layers 2 are print-formed on both right and left ends of an upper surface of an insulating substrate 1, as shown in Fig. 51(a).

Secondly, a resistor layer 3 is print-formed on the upper surface of the insulating substrate 1 in a manner that portions of which overlap with the first upper surface electrode layers 2, as shown in Fig. 51(b).

Then, a first protective layer 4 is print-formed to cover the resistor layer 3 entirely, followed by providing a trimmed groove 5 in the resistor layer 3 and the first protective layer 4 with a laser or the like, as shown in Fig. 51(c), in order to make a resistance of the resistor layer 3 to fall within a predetermined range of resistance.

A second protective layer 6 is then print-formed on an upper surface of the first protective layer 4 as shown in Fig. 51(d).

Second upper surface electrode layers 7 are then print-formed on upper surfaces of the first upper surface electrode layers 2 in a manner that they spread over an entire width of the insulating substrate 1 as shown in Fig. 51(e).

Side surface electrode layers 8 are coat-formed on side surfaces at both right and left ends of the first upper surface electrode layers 2 and the insulating substrate 1, in a manner to make an electrical continuity with the first and the second upper surface electrode layers 2 and 7, as shown in Fig. 51(f).

The resistor of the prior art is completed finally, when nickel-plated layers 9 and solder-plated layers 10 are formed by providing solder-plating after nickel-plating over surfaces of the second upper surface electrode layers 7 and the side surface electrode layers 8.

However, as shown in a sectional view of Fig. 52(a) depicting the resistor of the prior art in a mounted position, the resistor having the above structure of the prior art and produced by the manufacturing method described above has a fillet-mounting structure, in which it is soldered with both the side surface electrode layers (not shown in the figure) and the lower surface electrode layers (not shown in the figure), when it is soldered on a circuit board. The resistor thus requires areas 13 for soldering the side surfaces in addition to an area 12 for the resistor component, and therefore a mounting area 14 combining them altogether, as shown in a plan view of Fig. 52(b) depicting of the resistor of the prior art. Furthermore, a proportion occupied by the soldering area with respect to the mounting area increases, if external dimensions of the component are reduced in order to increase a density of mounting. Consequently, the resistor has a problem that a limitation arises in the improvement of mounting density in order to reduce size of electronic devices.

The present invention is intended to solve the above-described problem of the prior art, and it aims at providing a resistor, as well as a method of manufacturing, that can reduce a soldering area occupying in the mounting area, when it is mounted on the circuit board.

DISCLOSURE OF THE INVENTION

In order to solve the foregoing problem, a resistor of the present invention comprises: a substrate; a pair of first upper surface electrode layers provided on side portions of an upper surface toward a portion of respective side surfaces of the substrate; a pair of second upper surface electrode layers provided in a manner to make electrical connections with the first upper surface electrode layers; a resistor layer provided in a manner to make electrical connections with the second upper surface electrode layers; and a protective layer provided to cover at least an upper surface of the resistor layer.

In the above-described resistor, electrodes on side surfaces of the resistor have small surface areas, since the resistor is provided with the pair of first upper surface electrode layers on side portions of the upper surface toward portions of side surfaces of the substrate. Because the resistor is soldered with the small areas of the electrodes on side surfaces, it can reduce an area required to form fillets for soldering, if it is soldered on a circuit board. Accordingly, the resistor is able to reduce a mount area,

including soldering portions, on the mount board.

BRIEF DESCRIPTION OF THE DRAWINGS

- Fig. 1 is a sectional view depicting a resistor of a first exemplary embodiment of the present invention;
- Fig. 2(a) through Fig. 2(c) represent a series of procedural views depicting a process of manufacturing the same resistor;
- Fig. 3(a) through Fig. 3(d) represent another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 4(a) is a sectional view depicting the same resistor in a mounted position;
- Fig. 4(b) is a plan view depicting the same resistor in the mounted position;
- Fig. 5 is a sectional view depicting a resistor of a second exemplary embodiment of the present invention;
- Fig. 6(a) through Fig. 6(c) represent a series of procedural views depicting a process of manufacturing the same resistor;
- Fig. 7(a) through Fig. 7(d) represent another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 8 is a sectional view depicting a resistor of a third exemplary embodiment of the present invention;
- Fig. 9(a) through Fig. 9(c) represent a series of procedural views depicting a process of manufacturing the same resistor;
- Fig. 10(a) through Fig. 10(c) represent another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 11(a) and Fig. 11(b) represent still another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 12(a) is a sectional view depicting the same resistor in a mounted position;
- Fig. 12(b) is a plan view depicting the same resistor in the mounted position;
- Fig. 13 is a sectional view depicting a resistor of a fourth exemplary embodiment of the present invention;
- Fig. 14(a) through Fig. 14(c) represent a series of procedural views depicting a process of manufacturing the same resistor;
- Fig. 15(a) through Fig. 15(c) represent another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 16(a) and Fig. 16(b) represent still another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 17 is a sectional view depicting a resistor of a fifth exemplary embodiment of the present invention;
- Fig. 18(a) through Fig. 18(c) represent a series of procedural views depicting a process of manufacturing the same resistor;
- Fig. 19(a) through Fig. 19(c) represent another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 20(a) and Fig. 20(b) represent still another series of procedural views depicting the process of manufacturing the same resistor;
- Fig. 21 is a sectional view depicting a resistor of a sixth exemplary embodiment of the present invention;
- Fig. 22(a) through Fig. 22(c) represent a series of procedural views depicting a

process of manufacturing the same resistor;

Fig. 23(a) and Fig. 23(b) represent another series of procedural views depicting the process of manufacturing the same resistor;

5 Fig. 24(a) and Fig. 24(b) represent still another series of procedural views depicting the process of manufacturing the same resistor;

Fig. 25(a) is a sectional view depicting the same resistor in a mounted position;

Fig. 25(b) is a plan view depicting the same resistor in the mounted position;

Fig. 26 is a sectional view depicting a resistor of a seventh exemplary embodiment of the present invention;

10 Fig. 27(a) through Fig. 27(c) represent a series of procedural views depicting a process of manufacturing the same resistor;

Fig. 28(a) through Fig. 28(c) represent another series of procedural views depicting the process of manufacturing the same resistor;

15 Fig. 29(a) and Fig. 29(b) represent still another series of procedural views depicting the process of manufacturing the same resistor;

Fig. 30 is a sectional view depicting a resistor of an eighth exemplary embodiment of the present invention;

Fig. 31(a) through Fig. 31(c) represent a series of procedural views depicting a process of manufacturing the same resistor;

20 Fig. 32(a) through Fig. 32(c) represent another series of procedural views depicting the process of manufacturing the same resistor;

Fig. 33(a) is a sectional view depicting the same resistor in a mounted position;

Fig. 33(b) is a plan view depicting the same resistor in the mounted position;

25 Fig. 34 is a sectional view depicting a resistor of a ninth exemplary embodiment of the present invention;

Fig. 35(a) through Fig. 35(c) represent a series of procedural views depicting a process of manufacturing the same resistor;

Fig. 36(a) through Fig. 36(c) represent another series of procedural views depicting the process of manufacturing the same resistor;

30 Fig. 37 is a sectional view depicting a resistor of a tenth exemplary embodiment of the present invention;

Fig. 38(a) through Fig. 38(c) represent a series of procedural views depicting a process of manufacturing the same resistor;

35 Fig. 39(a) through Fig. 39(c) represent another series of procedural views depicting the process of manufacturing the same resistor;

Fig. 40(a) is a sectional view depicting the same resistor in a mounted position;

Fig. 40(b) is a plan view depicting the same resistor in the mounted position;

Fig. 41 is a sectional view depicting a resistor of an eleventh exemplary embodiment of the present invention;

40 Fig. 42(a) through Fig. 42(c) represent a series of procedural views depicting a process of manufacturing the same resistor;

Fig. 43(a) through Fig. 43(d) represent another series of procedural views depicting the process of manufacturing the same resistor;

45 Fig. 44 is a sectional view depicting a resistor of a twelfth exemplary embodiment of the present invention;

Fig. 45(a) through Fig. 45(c) represent a series of procedural views depicting a

process of manufacturing the same resistor;

Fig. 46(a) through Fig. 46(d) represent another series of procedural views depicting the process of manufacturing the same resistor;

5 Fig. 47 is a sectional view depicting a resistor of a thirteenth exemplary embodiment of the present invention;

Fig. 48(a) through Fig. 48(c) represent a series of procedural views depicting a process of manufacturing the same resistor;

Fig. 49(a) through Fig. 49(d) represent another series of procedural views depicting the process of manufacturing the same resistor;

10 Fig. 50 is a sectional view depicting a resistor of the prior art;

Fig. 51(a) through Fig. 51(f) represent a series of procedural views depicting a process of manufacturing the same resistor;

Fig. 52(a) is a sectional view depicting the same resistor in a mounted position; and

15 Fig. 52(b) is a plan view depicting the same resistor in the mounted position.

THE BEST MODE FOR CARRYING OUT THE INEVNTION

(First Exemplary Embodiment)

20 A resistor of a first exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 1 is a sectional view of a resistor of the first exemplary embodiment of this invention.

25 In the figure, a reference numeral 21 represents a substrate containing 96% of alumina. A reference numeral 22 represents first upper surface electrode layers, which are made of fired gold-base metalo-organic compound, and provided on side portions of an upper surface toward portions of side surfaces of the substrate 21. Ridges of these first upper surface electrode layers 22 are rounded. In addition, a surface area of the first upper surface electrode layer 22 occupying the side surface of the substrate 21 is not more than a half of an area of the side surface of the substrate 21. A reference numeral 23 represents second upper surface electrode layers constructed of silver-base conductive powder containing glass for electrically connecting with the first upper surface electrode layers 22. A reference numeral 24 represents a resistor layer having a chief component of ruthenium oxide for electrically connecting with the second upper surface electrode layers 23. A reference numeral 25 is a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 24. Reference numerals 26 and 27 respectively represent a nickel-plated layer and a solder-plated layer provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

40 The resistor of the first exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 2 and Fig. 3 represent a series of procedural views showing a manufacturing method of the resistor of the first exemplary embodiment of this invention.

45 First of all, first upper surface electrode layers 22 are formed, as shown in Fig. 2(a), by printing electrode paste containing gold-base metalo-organic compounds in a

manner to cross over slits 29 made in a horizontal direction through a sheet-formed substrate 21, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 28 and 29 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. During this process, the electrode paste containing gold-base metal-organic compounds gets into the slits 29 of horizontal direction, so as to form the first upper surface electrode layers 22 deeply down into the slits. In addition, the first upper surface electrode layers 22 are fired at a temperature of approximately 850°C in order to make them become secure films. Generally, the slits 28 and 29 are so formed that their depth with respect to a thickness of the substrate 21 becomes equal to or less than a half of the thickness of the substrate 21, so as to avoid it from being cracked during handling in the manufacturing process.

Next, electrode paste containing silver-base conductive powder and glass is printed to form second upper surface electrode layers 23 in a manner that each of them overlaps a portion of the first upper surface electrode layers 22, as shown in Fig. 2(b). The second upper surface electrode layers 23 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 24 in a manner that they connect electrically with the second upper surface electrode layers 23, as shown in Fig. 2(c). The resistor layers 24 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 30 with a YAG laser, as shown in Fig. 3(a) in order to correct resistances of the resistor layers 24 to a predetermined value. The trimming is made by setting trimming probes for measuring a resistance on the second upper surface electrode layers 23 during this process.

Another paste having a principal component of glass is printed to form protective layers 25, as shown in Fig. 3(b), in order to protect the resistor layers 24, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 25 cross over the slits 28 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 24. The protective layers 25 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 21 in a sheet-form, on which the first upper surface electrode layers 22, the second upper surface electrode layers 23, the resistor layers 24, the trimmed grooves 30, and the protective layers 25 have been formed, is separated into substrate strips 31 by splitting it along the slits 29 of horizontal direction in the substrate 21, as shown in Fig. 3(c). When this is done, the previously formed first upper surface electrode layers 22 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 31 down to the depth of the slits 29 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 22 and the second upper surface electrode layers 23, the substrate strips 31 are finally separated into individual substrate pieces 32 by splitting them along the slits 28 of vertical direction, as shown in Fig. 3(d). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the

figure), and a solder-plated layer, as an outer layer (not shown in the figure) are formed by means of electroplating on exposed surfaces of the first upper surface electrode layers 22 and the second upper surface electrode layers 23, in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the first exemplary embodiment of this invention constructed and manufactured as above is soldered on a circuit board. As shown in a sectional view of Fig. 4(a) depicting the resistor of the first exemplary embodiment of this invention in a mounted position, the resistor is mounted with the surface having the protective layer down, and soldered with both the electrode layers on upper surfaces (not shown in the figure) and resistor layer portion on the side surface of the substrate. However, since these areas in the side surfaces, whereon electrodes are formed, are so small that fillets 33 are barely formed. Accordingly, an actual mount area 36 comes to the sum of a component area 34 and areas 35 required for soldering the side surfaces, as shown in a plan view of Fig. 4(b) depicting the resistor of the first exemplary embodiment of this invention in the mounted position. The invention attains a reduction of approximately 20% in the mount area when compared with a product of the prior art, in the case of a tip resistor in a size of 0.6×0.3 mm.

Accordingly, the structure of this invention requires a small area on a mount board to form fillets of soldering, because of the small areas of electrodes on the side surfaces of the resistor, and therefore it can reduce the mount areas.

In the first exemplary embodiment of this invention, if the solder-plated layers 27 and the protective layer 25 are formed to be on the same plane, or if the solder-plated layers 27 are formed to be higher than the protective layer 25, the resistor is not likely to allow a gap between the solder-plated layers 27 and a land pattern, when it is mounted, thereby further improving quality of mounting.

Besides, other characteristics can be improved in the first exemplary embodiment of this invention, if the second upper surface electrode layers 23 and the protective layer 25 are composed of combinations shown in Table 1.

Table 1

Combination	Second upper surface electrode layers 23	Protective layer 25	Characteristics to be improved
1	Gold-base conductive powder and glass (fired at 850°C)	Glass-base material (fired at 600°C)	Improvement in loaded-life characteristic due to low ion migration
2	Silver-base conductive powder and glass (fired at 850°C)	Resin-base material (hardened at 200°C)	No variation in resistance in manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer.
3	Gold-base conductive powder and glass (fired at 850°C)	Resin-base material (hardened at 200°C)	Both of characteristics of above combinations 1 and 2.

In addition, it is easily conceivable that the mount area can be further reduced if

electrodes are not formed on the side surfaces in the first exemplary embodiment of this invention.

(Second Exemplary Embodiment)

A resistor of a second exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 5 is a sectional view of a resistor of the second exemplary embodiment of this invention.

In the figures, a reference numeral 41 represents a substrate containing 96% of alumina. A reference numeral 42 represents first upper surface electrode layers provided by sputtering gold-base material on side portions of an upper surface toward portions of side surfaces of the substrate 41. Ridges of these first upper surface electrode layers 42 are rounded. In addition, a surface area of the first upper surface electrode layer 42 occupying the side surface of the substrate 41 is not more than a half of an area of the side surface of the substrate 41. A reference numeral 43 represents second upper surface electrode layers composed of silver-base conductive powder containing glass for making electrical connection with the first upper surface electrode layers 42. A reference numeral 44 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the second upper surface electrode layers 43. A reference numeral 45 is a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 44. Reference numerals 46 and 47 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the second exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 6 and Fig. 7 represent a series of procedural views showing a manufacturing method of the resistor of the second exemplary embodiment of this invention.

First of all, gold is deposited in a form of film by sputtering method on an entire upper surface of a sheet-formed substrate 41, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 48 and 49 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. Further, first upper surface electrode layers 42 having a desired electrode pattern are formed, as shown in Fig. 6(a), by a photo-lithographic method which is commonly used for LSI's, and the like. The first upper surface electrode layers 42 are then subjected to heat treatment at a temperature of approximately 300 to 400°C in order to make them become stable films. During this process, the first upper surface electrode layers 42 get into slits 49 of horizontal direction, so as to form the first upper surface electrode layers 42 deeply down into the slits. Generally, the slits 48 and 49 are so formed that their depth with respect to a thickness of the substrate 41 becomes equal to or less than a half of the thickness of the substrate 41, so as to avoid it from being cracked during handling in the manufacturing process.

Next, electrode paste containing silver-base conductive powder and glass is

printed to form second upper surface electrode layers 43 in a manner to make electrical connections with the first upper surface electrode layers 42, as shown in Fig. 6(b). The second upper surface electrode layers 43 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 44 in a manner that they connect electrically with the second upper surface electrode layers 43, as shown in Fig. 6(c). The resistor layers 44 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 50 with a YAG laser, as shown in Fig. 7(a) in order to correct resistances of the resistor layers 44 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the second upper surface electrode layers 43 during this process.

Another paste having a principal component of glass is printed to form protective layers 45, as shown in Fig. 7(b), in order to protect the resistor layers 44, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 45 cross over the slits 48 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 44. The protective layers 45 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 41 in a sheet-form, on which the first upper surface electrode layers 42, the second upper surface electrode layers 43, the resistor layers 44, the trimmed grooves 50, and the protective layers 45 have been formed, is separated into substrate strips 51 by splitting it along the slits 49 of horizontal direction in the substrate 41, as shown in Fig. 7(c). When this is done, the previously formed first upper surface electrode layers 42 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 51 down to the depth of the slits 49 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 42 and the second upper surface electrode layers 43, the substrate strips 51 are finally separated into individual substrate pieces 52 by splitting them along the slits 48 of vertical direction, as shown in Fig. 7(d). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on otherwise exposed surfaces of the first upper surface electrode layers 42 and the second upper surface electrode layers 43 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

Distinctive effects of the resistor of the second exemplary embodiment of this invention constructed and manufactured as above, when it is soldered on a mount board, are same as in the case of the resistor of the foregoing first exemplary embodiment, and therefore they are not described.

In addition, other characteristics can be improved in the second exemplary embodiment of this invention, if the first upper surface electrode layers 42, the second upper surface electrode layers 43, the resistor layer 44 and the protective layer 45 are composed of combinations shown in Table 2.

Table 2

Com-	First upper	Second	Resistor	Protective	Characteristics to be
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bina- tion	surface electrode layers 42	upper surface electrode layers 43	layer 44	layer 45	improved
4	Sputtered gold-base material (heat-treated at 300-400°C)	Gold-base conductive powder and glass (fired at 850°C)	Ruthenium oxide-base material (fired at 850°C)	Glass-base material (fired at 600°C)	Improvement in loaded-life characteristic due to low ion migration.
5	Sputtered gold-base material (heat-treated at 300-400°C)	Silver-base conductive powder and glass (fired at 850°C)	Ruthenium oxide-base material (fired at 850°C)	Resin-base material (hardened at 200°C)	No variation in resistance in manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer.
6	Sputtered gold-base material (heat-treated at 300-400°C)	Gold-base conductive powder and glass (fired at 850°C)	Ruthenium oxide-base material (fired at 850°C)	Resin-base material (hardened at 200°C)	Both of characteristics of above combinations 4 and 5.
7	Sputtered nickel-base material (heat-treated at 300-400°C)	Silver-base conductive powder and resin (hardened at 200°C)	Carbon-resin composition (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 5, with less manufacturing cost than above combination 6 due to use of base metal for first upper surface electrode layers.
8	Sputtered nickel-base material (heat-treated at 300-400°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Carbon-resin composition (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 7, with less manufacturing cost than above combination 7 due to use of base metal for second upper surface electrode layers.

(Third Exemplary Embodiment)

A resistor of a third exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 8 is a sectional view of a resistor of the third exemplary embodiment of this invention.

In Fig. 8, a reference numeral 61 represents a substrate containing 96% of alumina. A reference numeral 62 represents first upper surface electrode layers, which are made of fired gold-base metal-organic compound, provided on side portions of an upper surface toward portions of side surfaces of the substrate 61. A surface area of the first upper surface electrode layer 62 occupying the side surface of the substrate 61 is not more than a half of an area of the side surface of the substrate 61. A reference numeral 63 represents a pair of second upper surface electrode layers composed of silver-base conductive powder containing glass for making electrical connections with the first upper surface electrode layers 62. A reference numeral 64 represents a resistor layer having a chief component of ruthenium oxide for electrically connecting with the second upper surface electrode layers 63. A reference numeral 65 is a protective layer having a chief component of glass provided on an upper surface of the resistor layer 64. A reference numeral 66 represents third upper surface electrode layers composed of silver-base conductive powder containing glass, and provided on portions of upper surfaces of the second upper surface electrode layers 63. Reference numerals 67 and 68 respectively represent a nickel-plated layer and a solder-plated layer provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the third exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the accompanying figures.

Fig. 9 through Fig. 11 represent a series of procedural views showing a manufacturing method of the resistor of the third exemplary embodiment of this invention.

In the beginning, first upper surface electrode layers 62 are formed, as shown in Fig. 9(a), by printing electrode paste containing gold-base metal-organic compound in a manner to cross over slits 70 made in a horizontal direction through a sheet-formed substrate 61, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 69 and 70 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. The first upper surface electrode layers 62 are subjected to calcination at a temperature of approximately 850°C in order to make them become stable films. During this process, the electrode paste gets into the slits 70 of horizontal direction, so as to form the first upper surface electrode layers 62 deeply down in the slits. In general, the slits 69 and 70 are so formed that their depth with respect to a thickness of the substrate 61 becomes equal to or less than a half of the thickness of the substrate 61, in order to avoid it from being cracked during handling in the manufacturing process.

Next, electrode paste containing silver-base conductive powder and glass is printed to form second upper surface electrode layers 63 in a manner to make electrical connections with the first upper surface electrode layers 62, as shown in Fig. 9(b). The second upper surface electrode layers 63 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 64 in a manner that they connect electrically with the second upper surface electrode layers 63, as shown in Fig. 9(c). The resistor layers 64 are then fired

at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 71 with a YAG laser, as shown in Fig. 10(a) in order to correct resistances of the resistor layers 64 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the second upper surface electrode layers 63 during this process.

Another paste having a principal component of glass is printed to form protective layers 65, as shown in Fig. 10(b), in order to protect the resistor layers 64, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 65 cross over the slits 69 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 64. The protective layers 65 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Next, electrode paste containing silver-base conductive powder and glass is printed to form third upper surface electrode layers 66 on portions of upper surfaces of the first upper surface electrode layers 62 and the second upper surface electrode layers 63 in a manner not to cross the slits 70 of horizontal direction, as shown in Fig. 10(c). The third upper surface electrode layers 66 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 61 in a sheet-form, on which the first upper surface electrode layers 62, the second upper surface electrode layers 63, the resistor layers 64, the trimmed grooves 71, the protective layers 65 and the third upper surface electrode layers 66 have been formed, is separated into substrate strips 72 by splitting it along the slits 70 of horizontal direction in the substrate 61, as shown in Fig. 11(a). When this is done, the previously formed first upper surface electrode layers 62 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 72 down to the depth of the slits 70 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 62, the second upper surface electrode layers 63 and the third upper surface electrode layers 66, the substrate strips 72 are finally separated into individual substrate pieces 73 by splitting them along the slits 69 of vertical direction, as shown in Fig. 11(b). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure) are formed by means of electroplating on all exposed surfaces of the first upper surface electrode layers 62, the second upper surface electrode layers 63 and the third upper surface electrode layers 66 in order to prevent electrode-erosion during soldering, and to assure reliability of the soldering.

The resistor of the third exemplary embodiment of this invention constructed and manufactured as above is soldered on a circuit board. The resistor is mounted with the surface having the protective layer down, as shown in a sectional view of Fig. 12(a) depicting a mounted position in the third exemplary embodiment of this invention, and soldered with the first, second and third upper surface electrode layers (not shown in the figure) and the resistor layer portion on a side surface of the substrate. However, since these areas in the side surfaces, whereon the electrodes are formed, are so small that fillets 74 are barely formed. Accordingly, an actual mount area 77 comes to the sum of a component area 75 and areas 76 required for soldering the side surfaces of this component, as shown in a plan view of Fig. 12(b) depicting

the mounted position. The invention attains a reduction of approximately 20% in the mount area when compared with a product of the prior art, in the case of a tip resistor in a size of 0.6×0.3 mm.

Therefore, the structure according to the third exemplary embodiment of this invention requires a small area on a mount board to form fillets of soldering, because of the small areas of electrodes on the side surfaces of the resistor, and thereby it can reduce the mount areas.

In the third exemplary embodiment of this invention, if solder-plated layers 68 and the protective layer 65 are formed to be on the same plane, or if the solder-plated layers 68 are formed to be higher than the protective layer 65, the resistor is not likely to allow a gap between the solder-plated layers 68 and a land pattern 76, when it is mounted, thereby further improving quality of mounting.

Besides, other characteristics can be improved in the third exemplary embodiment of this invention, if the second upper surface electrode layers 63, the protective layer 65 and the third upper surface electrode layers 66 are composed of combinations shown in Table 3.

Table 3

Combina- tion	Second upper surface electrode layers 63	Third upper surface electrode layers 66	Protective layer 65	Characteristics to be improved
1	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Glass-base material (fired at 600°C)	No variation in resistance during manufacturing process, and small deviation in resistance of products, due to low processing temperature of third upper surface electrode layers 66.
2	Silver-base conductive powder (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Glass-base material (fired at 600°C)	Same characteristic as above combination 1, with less manufacturing cost due to use of base metal for third upper surface electrode layers 66.
3	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Small deviation in resistance of products, due to less variation in manufacturing process than above combination 1, as protective layer 65 is processed at lower temperature
4	Silver-base conductive powder and glass (fired at	Nickel-base conductive powder and resin (hardened at	Resin-base material (hardened at 200°C)	Same characteristic as above combination 3, with less manufacturing cost due to use of base metal for third upper surface electrode layers 66.

	850°C)	200°C)		
5	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and glass (fired at 600°C)	Glass-base material (fired at 600°C)	Improvement in loaded-life characteristic due to low ion migration.
6	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Glass-base material (fired at 600°C)	Both of characteristics of above combinations 1 and 5.
7	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Glass-base material (fired at 600°C)	Both of characteristics of above combinations 2 and 5.
8	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both of characteristics of above combinations 3 and 5.
9	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both of characteristics of above combinations 4 and 5.

In addition, it is easily conceivable that the mount area can be further reduced if electrodes are not formed on the side surfaces in the third exemplary embodiment of this invention.

5

(Fourth Exemplary Embodiment)

A resistor of a fourth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

10 Fig. 13 is a sectional view of a resistor of the fourth exemplary embodiment of this invention.

15 In Fig. 13, a reference numeral 81 represents a substrate containing 96% of alumina. A reference numeral 82 represents first upper surface electrode layers provided by sputtering gold-base material on side portions of an upper surface and portions of side surfaces of the substrate 81. A surface area of the first upper surface

electrode layer 82 occupying the side surface of the substrate 81 is not more than a half of an area of the side surface of the substrate 81. A reference numeral 83 represents second upper surface electrode layers containing silver-base conductive powder and glass for making electrical connections with the first upper surface electrode layers 82.

5 A reference numeral 84 represents a resistor layer having a chief component of ruthenium oxide for electrically connecting with the second upper surface electrode layers 83. A reference numeral 85 is a protective layer having a chief component of glass, and provided on an upper surface of the resistor layer 84. A reference numeral 86 represents third upper surface electrode layers composed of silver-base conductive powder containing glass, provided on portions of the first upper surface electrode layers 82 and the second upper surface electrode layers 83. Reference numerals 87 and 88 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

10 The resistor of the fourth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 14 through Fig. 16 represent a series of procedural views showing a manufacturing method of the resistor of the fourth exemplary embodiment of this invention.

20 First of all, gold is deposited in a form of film by sputtering method on an entire upper surface of a sheet-formed substrate 81, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 89 and 90 in a vertical direction as well as a horizontal direction in order to separate it into strips and individual pieces in the subsequent steps. Further, first upper surface electrode layers 82 having a desired electrode pattern are formed, as shown in Fig. 14(a), by photo-lithographic method which is normally used for LSI's, and the like. The first upper surface electrode layers 82 are subjected to heat treatment at a temperature of approximately 300 to 400°C in order to make them become stable films. During this process, the first upper surface electrode layers 82 get into the slits 90 of horizontal direction, so as to form the first upper surface electrode layers 82 deeply down in the slits. Generally, the slits 89 and 90 are so formed that their depth with respect to a thickness of the substrate 81 becomes equal to or less than a half of the thickness of the substrate 81, so as to avoid it from being cracked during handling in the manufacturing process.

35 Next, electrode paste containing silver-base conductive powder and glass is printed to form second upper surface electrode layers 83 in a manner to make electrical connections with the first upper surface electrode layers 82, as shown in Fig. 14(b). The second upper surface electrode layers 83 are then fired at a temperature of approximately 850°C in order to make them become stable films.

40 Resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 84 in a manner that they connect electrically with the second upper surface electrode layers 83, as shown in Fig. 14(c). The resistor layers 84 are then fired at a temperature of approximately 850°C in order to make them become stable films.

45 Next, trimming is made to form trimmed grooves 91 with a YAG laser, as shown in Fig. 15(a) in order to correct resistances of the resistor layers 84 to a predetermined

value. The trimming is made with trimming probes for measuring a resistance set on the second upper surface electrode layers 83 during this process.

Another paste having a principal component of glass is printed to form protective layers 85, as shown in Fig. 15(b), in order to protect the resistor layers 84, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 85 cross over the slits 89 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 84. The protective layers 85 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Next, electrode paste containing silver-base conductive powder and glass is printed to form third upper surface electrode layers 86 on portions of upper surfaces of the first upper surface electrode layers 82 and the second upper surface electrode layers 83 in a manner not to cross the slits 90 of horizontal direction, as shown in Fig. 15(c). The third upper surface electrode layers 86 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 81 in a sheet-form, on which the first upper surface electrode layers 82, the second upper surface electrode layers 83, the resistor layers 84, the trimmed grooves 91, the protective layers 85 and the third upper surface electrode layers 86 have been formed, is separated into substrate strips 92 by splitting it along the slits 90 of horizontal direction in the substrate 81, as shown in Fig. 16(a). When this is done, the previously formed first upper surface electrode layers 82 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 92 down to the depth of the slits 90 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 82, the second upper surface electrode layers 83 and the third upper surface electrode layers 86, the substrate strips 82 are finally separated into individual substrate pieces 93 by splitting them along the slits 89 of vertical direction, as shown in Fig. 16(b). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure) are formed by means of electroplating on all exposed surfaces of the first upper surface electrode layers 82, the second upper surface electrode layers 83 and the third upper surface electrode layers 86 in order to prevent electrode-erosion during soldering, and to assure reliability of the soldering.

Distinctive effects of the resistor of the fourth exemplary embodiment of this invention constructed and manufactured as above, when it is soldered on a mount board, are same as in the case of the above-described third exemplary embodiment, and therefore they are not described further.

In addition, other characteristics can be improved in the fourth exemplary embodiment of this invention, if the first upper surface electrode layers 82, the second upper surface electrode layers 83, the resistor layer 84, the protective layer 85 and the third upper surface electrode layers 86 are composed of combinations shown in Table 4.

Table 4

Combina- tion	First upper surface electrode layers 82	Second upper surface electrode layers 83	Third upper surface electrode layers 86	Resistor layer 84	Characteristics to be improved
				Protective layer 85	
10	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and glass (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 1 in Table 1.
				Glass-base (fired at 600°C)	
11	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 2 in Table 1.
				Glass-base (fired at 600°C)	
12	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 3 in Table 1.
				Resin-base (hardened at 200°C)	
13	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 4 in Table 1.
				Resin-base (hardened at 200°C)	
14	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and glass (fired at 600°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 5 in Table 1.
				Glass-base (fired at 600°C)	

15	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 6 in Table 1.
				Glass-base (fired at 600°C)	
16	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 7 in Table 1.
				Glass-base (fired at 600°C)	
17	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 8 in Table 1.
				Resin-base (hardened at 200°C)	
18	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 9 in Table 1.
				Resin-base (hardened at 200°C)	
19	Sputtered nickel-base material	Silver-base conductive powder and resin (hardened at 200°C)	Silver-base conductive powder and resin (hardened at 200°C)	Carbon-resin comp. (hardened at 200°C)	Save electricity, as material needing low temp processing is used for second upper surface electrode layers 83 and resistor layer 84.
				Resin-base (hardened at 200°C)	
20	Sputtered nickel-base material	Silver-base conductive powder and resin (hardened at 200°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Carbon-resin comp. (hardened at 200°C)	Same characteristic as combination 19, with less manufacturing cost due to use of base metal for third upper surface electrode layers 86.
				Resin-base (hardened at 200°C)	

In addition, it is easily conceivable that the mount area can be further reduced if electrodes are not formed on the side surfaces in the fourth exemplary embodiment of this invention.

5 (Fifth Exemplary Embodiment)

A resistor of a fifth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

10 Fig. 17 is a sectional view of a resistor of the fifth exemplary embodiment of this invention.

In Fig. 17, a reference numeral 101 represents a substrate containing 96% of alumina. A reference numeral 102 represents first upper surface electrode layers composed of silver-base conductive powder containing glass, and provided on side portions of a main surface of the substrate 101. A reference numeral 103 represents a resistor layer having a chief component of ruthenium oxide for electrically connecting with the first upper surface electrode layers 102. A reference numeral 104 is a protective layer having a chief component of glass, and provided on an upper surface of the resistor layer 103. A reference numeral 105 represents second upper surface electrode layers formed by means of sputtering gold-base material on upper surfaces and portions of side surfaces of the first upper surface electrode layers 102. A surface area of the second upper surface electrode layer 105 occupying the side surface of the substrate 101 is not more than a half of an area of the side surface of the substrate 101. A reference numeral 106 represents third upper surface electrode layers composed of silver-base conductive powder containing glass, overlapping portions of upper surfaces of the first upper surface electrode layers 102 and the second upper surface electrode layers 105. Reference numerals 107 and 108 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

30 The resistor of the fifth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 18 through Fig. 20 represent a series of procedural views showing a manufacturing method of the resistor of the fifth exemplary embodiment of this invention.

35 First of all, electrode paste containing silver-base conductive powder and glass is printed to form first upper surface electrode layers 102, as shown in Fig. 18(a), in a manner not to cross over slits 110 made in a horizontal direction through a sheet-formed substrate 101, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 109 and 110 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps.

45 Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 103 in a manner that they connect electrically with the first upper surface electrode layers 102, as shown in Fig. 18(b). The resistor layers 103 are then fired at a temperature of approximately 850°C in order to make them become

stable films.

Next, trimming is made to form trimmed grooves 111 with a YAG laser, as shown in Fig. 18(c) in order to correct resistances of the resistor layers 103 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the first upper surface electrode layers 102 during this process.

Another paste having a principal component of glass is printed to form protective layers 104, as shown in Fig. 19(a), in order to protect the resistor layers 103, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 104 cross over the slits 109 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 103. The protective layers 104 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Resist material composed of resin is coated over an entire upper surface of the substrate 101, and openings in a film-forming pattern of the desired second upper surface electrode layers 105 are prepared in the resist material by photo-lithographic method, as shown in Fig. 19(b). Furthermore, a gold is deposited in a form of film on the entire upper surface of the substrate by sputtering method, and the resist material is then removed except for portions of the film-forming pattern for the desired second upper surface electrode layers 105. These steps complete the second upper surface electrode layers 105. During the above process, the second upper surface electrode layers 105 get into the slits 110 of horizontal direction, and thereby the second upper surface electrode layers 105 can be formed deeply down to the deep in the slits.

Generally, the slits 109 and 110 are so formed that their depth with respect to a thickness of the substrate 101 becomes equal to or less than a half of the thickness of the substrate 101, so as to avoid it from being cracked during handling in the manufacturing process.

Next, electrode paste containing silver-base conductive powder and glass is printed to form third upper surface electrode layers 106 in a manner to overlap with portions of upper surfaces of the first upper surface electrode layers 102 and the second upper surface electrode layers 105, as shown in Fig. 19(c). The third upper surface electrode layers 106 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Then, the substrate 101 in a sheet-form, on which the first upper surface electrode layers 102, the second upper surface electrode layers 105, the third upper surface electrode layers 106, the resistor layers 103, the trimmed grooves 111 and the protective layers 104 have been formed, is separated into substrate strips 112 by splitting it along the slits 110 of horizontal direction in the substrate 101, as shown in Fig. 20(a). When this is done, the previously formed second upper surface electrode layers 105 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 112 down to the depth of the slits 110 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 102, the second upper surface electrode layers 105 and the third upper surface electrode layers 106, the substrate strips 112 are finally separated into individual substrate pieces 113 by splitting them along the slits 109 of vertical direction, as shown in Fig. 20(b). A resistor is now completed when a nickel-plated

layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on all exposed surfaces of the first upper surface electrode layers 102, the second upper surface electrode layers 105 and the third upper surface electrode layers 106 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

Distinctive effects of the resistor of the fifth exemplary embodiment of this invention constructed and manufactured as above, when it is soldered on a mount board, are same as in the case of the foregoing third exemplary embodiment, and therefore they are not described.

In addition, other characteristics can be improved in this fifth exemplary embodiment of the invention, if the first upper surface electrode layers 102, the resistor layer 103, the protective layer 104, the second upper surface electrode layers 105, and the third upper surface electrode layers 106 are composed of combinations shown in Table 5.

Table 5

Combina- tion	Second upper surface electrode layers 105	First upper surface electrode layers 102	Third upper surface electrode layers 106	Resistor layer 103	Characteristics to be improved
				Protective layer 104	
21	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 1 in Table 1.
				Glass-base (fired at 600°C)	
22	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 2 in Table 1.
				Glass-base (fired at 600°C)	
23	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 3 in Table 1.
				Resin-base (hardened at 200°C)	

24	Sputtered gold-base material	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 4 in Table 1.
				Resin-base (hardened at 200°C)	
25	Sputtered nickel-base material	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 23, with less manufacturing cost due to use of base metal for second upper surface electrode layers 105.
				Resin-base (hardened at 200°C)	
26	Sputtered nickel-base material	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 25, with less manufacturing cost due to use of base metal for third upper surface electrode layers 106.
				Resin-base (hardened at 200°C)	
27	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and glass (fired at 600°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 5 in Table 1.
				Glass-base (fired at 600°C)	
28	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 6 in Table 1.
				Glass-base (fired at 600°C)	
29	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 7 in Table 1.
				Glass-base (fired at 600°C)	

30	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 8 in Table 1.
				Resin-base (hardened at 200°C)	
31	Sputtered gold-base material	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 9 in Table 1.
				Resin-base (hardened at 200°C)	
32	Sputtered nickel-base material	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristics as combination 25 as well as combination 5 in Table 1.
				Resin-base (hardened at 200°C)	
33	Sputtered nickel-base material	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Ruthenium oxide-base (fired at 850°C)	Same characteristic as combination 26 as well as combination 5 in Table 1.
				Resin-base (hardened at 200°C)	

In addition, it is easily conceivable that the mount area can be further reduced if electrodes are not formed on the side surfaces in the fifth exemplary embodiment of this invention.

5

(Sixth Exemplary Embodiment)

A resistor of a sixth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

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Fig. 21 is a sectional view of a resistor of the sixth exemplary embodiment of this invention.

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In Fig. 21, a reference numeral 121 represents a substrate containing 96% of alumina. A reference numeral 122 represents a pair of upper surface electrode layers composed of thin films of gold-base material provided on sides portions of a main surface of the substrate 121. A reference numeral 123 represents a resistor layer composed of a thin film of nickel-chrome base or chrome-silicon base compound

provided on an upper surface of the substrate 121. A reference numeral 124 is a protective layer composed of epoxy-group resin, or the like material provided on an upper surface of the resistor layer 123. A reference numeral 125 represents side surface electrode layers composed of thin films of nickel-base material provided on side surfaces of the substrate 121. Reference numerals 126 and 127 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering. Ridges of these nickel-plated layers 126 and solder-plated layers 127 are rounded. Each surface area of the solder-plated layers 127 occupying the side surface of the substrate 121 is not more than a half of an area of the side surface of the substrate 121.

The resistor of the sixth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 22 through Fig. 24 represent a series of procedural views showing a manufacturing method of the resistor of the sixth exemplary embodiment of this invention.

First of all, electrode paste consisting of metallic-organic substance, etc. having a principal component of gold and the like material is screen-printed in a manner not to cross over slits 129 made in a horizontal direction through an upper surface of sheet-formed substrate 121, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 128 and 129 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. After the electrode paste consisting of metallic-organic substance and the like is dried, it is fired under a condition of approximately 850°C for about 45 minutes in a belt-conveyed continuous kiln in order to disperse only organic components and to bake only metal components of the electrode paste onto the substrate 121, to form upper surface electrode layers 122 in thin film, as shown in Fig. 22(a).

Next, as shown in Fig. 22(b), nickel-chrome, chrome-silicon, or the like compound is deposited by sputtering method on an entire upper surface of the sheet-formed substrate 121, on which the upper surface electrode layers 122 (not shown in this figure) are formed, to form an integral resistor layer 130.

The total resistor layer 130 is then processed by photo-lithographic method, the same method as normally used for LSI's, etc. to form resistor layers 123 of a desired pattern, as shown in Fig. 22(c). The resistor layers 123 are thermally treated at a temperature of approximately 300 to 400°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 131 with a YAG laser, as shown in Fig. 23(a) in order to correct resistances of the resistor layers 123 to a predetermined value. Trimming probes for measuring a resistance are set on the upper surface electrode layers 122 in this process. The trimming is made by serpentine cutting method (a plurality of straight cuts), which is capable of adjusting the resistance freely from a low value to a high value.

Epoxy-base resin paste is screen-printed to form a printing pattern of individual protective layers corresponding to their respective resistor layers 123, as shown in Fig.

23(b), in order to protect the resistor layers 123, of which resistances have been corrected. Then, the epoxy-base resin paste is thermally cured to form the protective layers 124 under a condition of approximately 200°C for about 30 minutes in a belt furnace in order to ensure a firm adhesion to the substrate 121. For this process, the printing pattern of the protective layers may be made in such a shape that the protective layers cross over the slits 128 of vertical direction, and connectively cover a plurality of the horizontally aligned resistor layers 123.

Subsequently, as shown in the same figure, side surface electrode layers 125 comprising a thin film of nickel-chrome base compound are formed by sputtering in a manner to cross over the slits 129 of horizontal direction, and to electrically connect with the upper surface electrode layers 122. In this process, a resist layer is formed in advance in an area other than portions where the side surface electrode layers are formed. After a nickel-chrome layer is formed by sputtering over an entire surface of the substrate, the nickel-chrome layer of the area other than the side surface electrode layers is removed at the same time the resist layer is removed by lift-off method.

Then, the substrate 121 in a sheet-form is subjected to a primary separation into substrate strips 132, as shown in Fig. 24(a), by splitting it along the slits 129 of horizontal direction in the substrate 121. When this is done, the side surface electrode layers 125 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 132 down to the depth of the slits 129 of horizontal direction.

Finally, as a preparatory process for plating exposed surfaces of the upper surface electrode layers 122 and the side surface electrode layers 125, a secondary separation is made to separate the substrate strips 132 into individual substrate pieces 133, as shown in Fig. 24(b). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the upper surface electrode layers 122 and the side surface electrode layers 125, if necessary in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the sixth exemplary embodiment of this invention constructed and manufactured as above was soldered on a circuit board. The resistor was mounted with the surface having the protective layer down, and soldered with both the upper surface electrode layers (not shown in the figure) and the resistor layer portion on side surface of the substrate, as shown in a sectional view of Fig. 25(a) depicting the mounted position. However, since areas, whereon the side surface electrodes are formed, were so small, fillets 134 were barely formed. Accordingly, an actual mount area 137 came to the sum of a component area 135 and areas 136 required for soldering the side surfaces, as shown in a plan view of Fig. 25(b) depicting the mounted position. The invention could attain a reduction of approximately 20% in the mount area as compared to a product of the prior art, in the case of a tip resistor in a size of 0.6×0.3 mm.

Therefore, the structure according to the present invention requires a small area on a mount board to form fillets of soldering, because of the small areas of the side surface electrodes of the resistor, and thereby it can reduce the mount areas.

Moreover, the side surface electrode layers 125 formed by sputtering can

provide such advantages as strong adhesion to the substrate, realizing a linearity in boundary lines between the substrate 121 and the solder-plated layers 127 on the side surfaces of the substrate 121, and high quality of the external appearance.

In addition, it is easily conceivable that the mount area can be further reduced if the side surface electrode layers 125 are not formed in the sixth exemplary embodiment of this invention. However, if the side surface electrode layers 125 are not formed, the resistor forms no fillet at all, thereby giving rise to a problem that makes an automated inspection by image recognition inexecutable, in consideration of the fact that inspection of soldering is usually carried out by means of image recognition after mounting components in the current manufacturing process of electronic devices.

In the sixth exemplary embodiment of this invention, if solder-plated layers 127 and the protective layer 124 are formed to be on the same plane, or if the solder-plated layers 127 are formed to be higher than the protective layer 124, the resistor is not likely to allow a gap between the solder-plated layers 127 and a land pattern, when it is mounted, thereby further improving quality of mounting.

Furthermore, similar effect can be attained with other combinations of the upper surface electrode layers 122, the resistor layer 123 and the protective layer 124, beside the above combination in the structure of the sixth exemplary embodiment of this invention. These combinations and their respective characteristics are outlined in Table 6.

Table 6

Combination	Upper surface electrode layers 122	Resistor layer 123	Protective layer 124	Characteristics
1	Silver or gold-base conductive powder and glass (fired at 850°C)	Ruthenium oxide-base material (fired at 850°C)	Resin-base material (hardened at 200°C)	High accuracy in resistance due to low forming temperature of protective layer.
2	Silver or gold-base conductive powder and glass (fired at 850°C)	Ruthenium oxide-base material (fired at 850°C)	Glass-base material (fired at 600°C)	High resistance to humidity due to protective layer composed of glass.
3	Silver or gold-base conductive powder and glass (fired at 850°C)	Carbon-resin comp. (hardened at 200°C)	Resin-base material (hardened at 200°C)	Capable of saving energy due to low forming temperature of resistor layer, in addition to characteristic of combination 1.
4	Silver or gold-base conductive powder and glass (fired at 850°C)	Ni-Cr base or Cr-Si base sputtered film	Resin-base material (hardened at 200°C)	Same characteristic as combination 1.
5	Gold-base metal-	Ruthenium	Resin-base	Low manufacturing cost due

	organic compound (fired at 850°C)	oxide-base material (fired at 850°C)	material (hardened at 200°C)	to small amount of gold used, in addition to characteristic of combination 1.
6	Gold-base metalo- organic compound (fired at 850°C)	Ruthenium oxide-base material (fired at 850°C)	Glass-base material (fired at 600°C)	Low manufacturing cost due to small amount of gold used, in addition to characteristic of combination 2
7	Gold-base metalo- organic compound (fired at 850°C)	Carbon- resin comp. (hardened at 200°C)	Resin-base material (hardened at 200°C)	Low manufacturing cost due to small amount of gold used, in addition to characteristic of combination 3
8	Gold-base metalo- organic compound (fired at 850°C)	Ni-Cr base or Cr-Si base sputtered film	Resin-base material (hardened at 200°C)	(Combination of the first exemplary embodiment)
9	Sputtered nickel- base, copper-base, or gold base material	Ni-Cr base or Cr-Si base sputtered film	Resin-base material (hardened at 200°C)	Inexpensive construction, if base metal of nickel or copper is used, in addition to characteristic of combination 7.

(Seventh Exemplary Embodiment)

A resistor of a seventh exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 26 is a sectional view of a resistor of the seventh exemplary embodiment of this invention.

In Fig. 26, a reference numeral 141 represents a substrate containing 96% of alumina. A reference numeral 142 represents a pair of first upper surface electrode layers composed of thin films of gold-base material provided on side portions of an upper surface of the substrate 141. A reference numeral 143 represents a resistor layer composed of a thin film of nickel-chrome base or chrome-silicon base compound provided between the first upper surface electrode layers 142. A reference numeral 144 represents a protective layer composed of epoxy-group resin, or the like material provided on an upper surface of the resistor layer 143. A reference numeral 145 represents a pair of second upper surface electrode layers composed of silver or nickel-base conductive powder containing resin. A reference numeral 146 represents side surface electrode layers provided on side surfaces of the substrate 141 in a manner to connect with the first upper surface electrode layers 142 or the second upper surface electrode layers 145. Reference numerals 147 and 148 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering. Ridges of these nickel-plated layers 147 and

solder-plated layers 148 are rounded. Each surface area of the solder-plated layers 148 on the side surfaces of the substrate 121 is not more than a half of an area of the side surface of the substrate 141.

The resistor of the seventh exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 27 through Fig. 29 represent a series of procedural views showing a manufacturing method of the resistor of the seventh exemplary embodiment of this invention.

First of all, electrode paste containing metallo-organic compounds, etc. having a principal component of gold and the like material is screen-printed in a manner not to cross over slits 150 made in a horizontal direction through an upper surface of sheet-formed substrate 141, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 149 and 150 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. After the electrode paste containing metallo-organic compounds, etc. is dried, it is fired under a condition of approximately 850°C for about 45 minutes in a belt furnace in order to disperse only organic components and to deposit only metal components of the electrode paste onto the substrate 141, to form upper surface electrode layers 142 in thin film, as shown in Fig. 27(a).

Next, as shown in Fig. 27(b), nickel-chrome, chrome-silicon, or the like compound is deposited by sputtering method on an entire upper surface of the sheet-formed substrate 141, on which the upper surface electrode layers 142 (not shown in this figure) are formed, to form an integral resistor layer 151.

The total resistor layer 151 is then processed by photo-lithographic method, the same method as normally used for LSI's, etc. to form resistor layers 143 of a desired pattern, as shown in Fig. 27(c). The resistor layers 143 are thermally treated at a temperature of approximately 300 to 400°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 152 with a YAG laser, as shown in Fig. 28(a) in order to correct resistances of the resistor layers 143 to a predetermined value. Trimming probes for measuring a resistance are set on the upper surface electrode layers 142 in this process. The trimming is made by serpentine cutting method (a plurality of straight cuts), which is capable of adjusting the resistance freely from a low value to a high value.

Epoxy-base resin paste is screen-printed to form a printing pattern of individual protective layers corresponding to their respective resistor layers 143, as shown in Fig. 28(b), in order to protect the resistor layers 143, of which resistances have been corrected. Then, the epoxy-base resin paste is thermally cured to form the protective layers 144 under a condition of approximately 200°C for about 30 minutes in a belt-conveyed continuous hardening kiln in order to ensure a firm adhesion to the substrate 141. For this process, the printing pattern of the protective layers may be made in such a shape that the protective layers cross over the slits 149 of vertical direction, and connectively cover a plurality of the horizontally aligned resistor layers 143.

Next, second upper surface electrode layers 145 are formed as shown in the

same figure by screen-printing conductive paste composed of silver-base or nickel-base conductive powder containing resin in a manner to cover the upper surface electrode layers 142, followed by thermally setting them in a belt-furnace under a condition of approximately 200°C for about 30 minutes in order to ensure a firm adhesion to the substrate 141.

Subsequently, as shown in Fig. 28(c), side surface electrode layers 146 comprising a thin film of nickel-chrome base compound are formed by sputtering in a manner to cross over the slits of horizontal direction (not shown in the figure), and to electrically connect with the upper surface electrode layers 142. In this process, a resist layer is formed in advance in an area other than portions where the side surface electrode layers are formed. After a nickel-chrome layer is formed by sputtering over an entire surface of the substrate, the nickel-chrome layer in the area other than the side surface electrode layers is removed at the same time the resist layer is removed by lift-off method.

Then, the substrate 141 in a sheet-form is subjected to a primary separation into substrate strips 153, as shown in Fig. 29(a), by splitting it along the slits 150 of horizontal direction in the substrate 141. When this is done, the side surface electrode layers 146 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 153 down to the depth of the slits 150 of horizontal direction.

Finally, as a preparatory process for plating exposed surfaces of the second upper surface electrode layers 145 and the side surface electrode layers 146, a secondary separation is made to separate the substrate strips 153 into individual substrate pieces 154, as shown in Fig. 29(b). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the second upper surface electrode layers 145 and the side surface electrode layers 146, if necessary in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the seventh exemplary embodiment of this invention constructed and manufactured as above provides the same advantages as what has been described in the sixth exemplary embodiment, when it is soldered on a circuit board, and therefore they will not be described.

In addition, similar effect can be attained with other combinations of the first upper surface electrode layers 142, the second upper surface electrode layers 145, the resistor layer 143 and the protective layer 144, beside the above combination in the structure of the seventh exemplary embodiment of this invention. These combinations and their respective characteristics are outlined in Table 7.

Table 7

Combination	First upper surface electrode layers 142	Second upper surface electrode layers 145	Resistor layer 143	Protective layer 144	Characteristics
1	Silver-base or gold-base conductive powder and	Silver-base or gold-base conductive powder and	Ruthenium oxide-base material (fired at	Glass-base material (fired at 600°C)	High resistance to humidity.

	glass (fired at 850°C)	glass (fired at 600°C)	850°C)		
2	Silver-base or gold-base conductive powder and glass (fired at 850°C)	Silver-base or nickel-base material and resin (hardened at 200°C)	Ruthenium oxide-base material (fired at 850°C)	Resin-base material (hardened at 200°C)	Same characteristic as combination 1 of Table 1
3	Silver-base or gold-base conductive powder and glass (fired at 850°C)	Silver-base or nickel-base material and resin (hardened at 200°C)	Ni-Cr base or Cr-Si base sputtered film	Resin-base material (hardened at 200°C)	Same as above.
4	Gold-base metalo-organic compound (fired at 850°C)	Silver-base or gold-base conductive powder and glass (fired at 600°C)	Ruthenium oxide-base material (fired at 850°C)	Glass-base material (fired at 600°C)	Same characteristic as combination 5 of Table 1.
5	Gold-base metalo-organic compound (fired at 850°C)	Silver-base or nickel-base material and resin (hardened at 200°C)	Ni-Cr base or Cr-Si base sputtered film	Resin-base material (hardened at 200°C)	(Combination of second exemplary embodiment)
6	Gold-base metalo-organic compound (fired at 850°C)	Silver-base or nickel-base material and resin (hardened at 200°C)	Carbon-resin composit (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as combination 7 of Table 1.
7	Sputtered nickel-base, copper-base, or gold base material	Silver-base or nickel-base material and resin (hardened at 200°C)	Ni-Cr base or Cr-Si base sputtered film	Resin-base material (hardened at 200°C)	Same characteristic as combination 9 of Table 1.
8	Sputtered nickel-base, copper-base, or gold base material	Silver-base or nickel-base material and resin (hardened at 200°C)	Carbon-resin composit (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as combination 9 of Table 1.

(Eighth Exemplary Embodiment)

5 A resistor of an eighth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 30 is a sectional view of a resistor of the eighth exemplary embodiment of this invention.

In Fig. 30, a reference numeral 161 represents a substrate containing 96% of alumina. A reference numeral 162 represents upper surface electrode layers composed

of silver-base conductive powder containing glass, and provided on side portions of a main surface and portions of side surfaces of the substrate 161. Ridges of these upper surface electrode layers 162 are rounded. In addition, a surface area of each of the upper surface electrode layers 162 on the side surfaces of the substrate 161 is not more than a half of an area of the side surface of the substrate 161. A reference numeral 163 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the upper surface electrode layers 163. A reference numeral 164 represents a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 163. Reference numerals 165 and 166 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the eighth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 31 and Fig. 32 represent a series of procedural views showing a manufacturing method of the resistor of the eighth exemplary embodiment of this invention.

First, electrode paste containing silver-base conductive powder and glass is printed to form upper surface electrode layers 162, as shown in Fig. 31(a), in a manner to cross over slits 168 made in a horizontal direction through a sheet-formed substrate 161, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 167 and 168 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. The upper surface electrode layers 162 are then fired at a temperature of approximately 850°C in order to make them become stable films. During this process, the electrode paste gets into the slits 168 of horizontal direction, and that the upper surface electrode layers 162 can be formed deeply down in the slits. Generally, the slits 167 and 168 are so formed that their depth with respect to a thickness of the substrate 161 becomes equal to or less than a half of the thickness of the substrate 161, so as to avoid it from being cracked during handling in the manufacturing process.

Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 163 in a manner that they connect electrically with the upper surface electrode layers 162, as shown in Fig. 31(b). The resistor layers 163 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 169 with a YAG laser, as shown in Fig. 31(c) in order to correct resistances of the resistor layers 163 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the upper surface electrode layers 162 during this process.

Another paste having a principal component of glass is printed to form protective layers 164, as shown in Fig. 32(a), in order to protect the resistor layers 163, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 164 cross over the slits 167 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 163. The protective layers 164 are then fired at a temperature of approximately 600°C

in order to make them become stable films.

Then, the substrate 161 in a sheet-form is separated into substrate strips 170 by splitting it along the slits 168 of horizontal direction in the substrate 161, on which the upper surface electrode layers 162, the resistor layers 163, the trimmed grooves 169, and the protective layers 164 are formed, as shown in Fig. 32(b). When this is done, the previously formed upper surface electrode layers 162 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 170 down to the depth of the slits 168 of horizontal direction.

As a preparatory process for plating exposed surfaces of the upper surface electrode layers 162, the substrate strips 170 are finally separated into individual substrate pieces 171 by splitting them along the slits 167 of vertical direction, as shown in Fig. 32(c). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the upper surface electrode layers 162 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the eighth exemplary embodiment of this invention constructed and manufactured as above was soldered on a circuit board. The resistor was mounted with the surface having the protective layer down, and soldered with both the upper surface electrode layers (not shown in the figure) and the resistor layer on side surfaces of the substrate, as shown in a sectional view of Fig. 33(a) depicting a mounted position. However, since areas in the side surfaces, whereon the electrodes are formed, were so small, fillets 173 were barely formed. Accordingly, an actual mount area 176 came to the sum of a component area 174 and areas 175 required for soldering the side surfaces of this component, as shown in a plan view of Fig. 33(b) depicting the mounted position. The invention could attain a reduction of approximately 20% in the mount area as compared to a component of the prior art, in the case of a tip resistor in a size of 0.6×0.3 mm.

Therefore, the structure according to the eighth exemplary embodiment of the present invention requires a small area on a mount board to form fillets of soldering, because of the small areas of the side surface electrodes on the resistor, and thereby it can reduce the mount areas.

In the eighth exemplary embodiment of this invention, if solder-plated layers 166 and the protective layer 164 are formed to be on the same plane, or if the solder-plated layers 166 are formed to be higher than the protective layer 164, the resistor is not likely to allow a gap between the solder-plated layers 166 and a land pattern, when it is mounted, thereby further improving quality of mounting.

In addition, other characteristics (specified in Table 8) can be improved in this eighth exemplary embodiment of the invention, if the upper surface electrode layers 162 and the protective layer 164 are constituted of combinations shown in Table 8.

Table 8

Combination	Upper surface electrode layers 162	Protective layer 164	Characteristics to be improved
1	Gold-base conductive powder and glass (fired at 850°C)	Glass-base material (fired at	Improvement in loaded-life characteristic due to low ion migration

		600°C)	
2	Silver-base conductive powder and glass (fired at 850°C)	Resin-base material (hardened at 200°C)	No variation in resistance in manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer 34.
3	Gold-base conductive powder and glass (fired at 850°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 1 and 2.
4	Gold-base metalo- organic compound (fired at 850°C)	Glass-base material (fired at 600°C)	Same characteristics as above combinations 1, and low manufacturing cost due to less amount of gold used than combination 1.
5	Gold-base metalo- organic compound (fired at 850°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 3 and 4.

In addition, it is easily conceivable that the mount area can be further reduced if the side surface electrodes are not formed in the eighth exemplary embodiment of this invention. However, if the side surface electrodes are not formed, the resistor forms no fillet at all, thereby giving rise to a problem that makes an automated inspection by image recognition inexecutable, in consideration of the fact that inspection of soldering is usually carried out by means of image recognition after mounting components in the current manufacturing process of electronic devices.

10 (Ninth Exemplary Embodiment)

A resistor of a ninth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 34 is a sectional view of a resistor of the ninth exemplary embodiment of this invention.

In Fig. 34, a reference numeral 181 represents a substrate containing 96% of alumina. A reference numeral 182 represents upper surface electrode layers provided by sputtering gold-base material on side portions of a main surface and portions of side surfaces of the substrate 181. Ridges of these upper surface electrode layers 182 are rounded. In addition, a surface area of each of the upper surface electrode layers 182 on the side surfaces of the substrate 181 is not more than a half of an area of the side surface of the substrate 181. A reference numeral 183 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the upper surface electrode layers 182. A reference numeral 184 represents a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 183. Reference numerals 185 and 186 respectively represent nickel-plated layers

and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the ninth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 35 and Fig. 36 represent a series of procedural views showing a manufacturing method of the resistor of the ninth exemplary embodiment of this invention.

First, gold is deposited in a form of film by sputtering method on an entire upper surface of a sheet-formed substrate 181, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 187 and 188 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. Further, upper surface electrode layers 182 having a desired electrode pattern are formed, as shown in Fig. 35(a), by photo-lithographic method which is normally used for LSI's, and the like. The upper surface electrode layers 182 are subjected to a heat treatment at a temperature of approximately 300 to 400°C in order to make them become stable films. During this process, the upper surface electrode layers 182 get into slits 188 of horizontal direction, and the upper surface electrode layers 182 can be formed deeply down in the slits. Generally, the slits 187 and 188 are so formed that their depth with respect to a thickness of the substrate 181 becomes equal to or less than a half of the thickness of the substrate 181, so as to avoid it from being cracked during handling in the manufacturing process.

Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 183 in a manner that they connect electrically with the upper surface electrode layers 182, as shown in Fig. 35(b). The resistor layers 183 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 189 with a YAG laser, as shown in Fig. 35(c) in order to correct resistances of the resistor layers 183 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the upper surface electrode layers 182 during this process.

Another paste having a principal component of glass is printed to form protective layers 184, as shown in Fig. 36(a), in order to protect the resistor layers 183, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 184 cross over the slits 187 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 183. The protective layers 184 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 181 in a sheet-form, on which the upper surface electrode layers 182, the resistor layers 183, the trimmed grooves 189, and the protective layers 184 are formed, is separated into substrate strips 190 by splitting it along the slits 188 of horizontal direction in the substrate 181, as shown in Fig. 36(b). When this is done, the previously formed upper surface electrode layers 182 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 190 down to the depth of the slitting

s 188 of horizontal direction.

As a preparatory process for plating exposed surfaces of the upper surface electrode layers 182, the substrate strips 190 are finally separated into individual substrate pieces 191 by splitting them along the slits 187 of vertical direction, as shown in Fig. 36(c). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the upper surface electrode layers 182 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the ninth exemplary embodiment of this invention constructed and manufactured as above provides the same advantages as what has been described in the eighth exemplary embodiment, when it is soldered on a circuit board, and therefore they will not be described.

In addition, other characteristics (specified in Table 9) can be improved in this ninth exemplary embodiment of the invention, if the upper surface electrode layers 182, resistor layer 183 and the protective layer 184 are constituted of combinations shown in Table 9.

Table 9

Combina- tion	Upper surface electrode layers 182	Resistor layer 183	Protective layer 184	Characteristics to be improved
6	Sputtered gold- base material (heat- treated at 300-400°C)	Ruthenium oxide-base material (fired at 850°C)	Resin-base material (hardened at 200°C)	No variation in manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer
7	Sputtered gold- base material (heat- treated at 300-400°C)	Carbon- resin composit. (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 6, with less cost and capable of saving electric energy due to lower process temperature of resistor layer than combination 6.
8	Sputtered nickel-base material (heat- treated at 300-400°C)	Carbon- resin composit. (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 7, with less manufacturing cost due to use of base metal for electrode material as opposed to combination 7.

20 (Tenth Exemplary Embodiment)

A resistor of a tenth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 37 is a sectional view of a resistor of the tenth exemplary embodiment of this invention.

In Fig. 37, a reference numeral 201 represents a substrate containing 96% of

alumina. A reference numeral 202 represents first upper surface electrode layers composed of silver-base conductive powder containing glass, provided on side portions of a main surface and portions of side surfaces of the substrate 201. A surface area of each of the first upper surface electrode layers 202 on the side surfaces of the substrate 201 is not more than a half of an area of the side surface of the substrate 201. A reference numeral 203 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the first upper surface electrode layers 202. A reference numeral 204 represents a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 203. A reference numeral 205 represents second upper surface electrode layers composed of silver-base conductive powder containing glass, provided on upper surfaces of the first upper surface electrode layers 202. Ridges of the second upper surface electrode layers 205 are rounded. Reference numerals 206 and 207 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the tenth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 38 and Fig. 39 represent a series of procedural views showing a manufacturing method of the resistor of the tenth exemplary embodiment of this invention.

First, electrode paste containing silver-base conductive powder and glass is printed to form first upper surface electrode layers 202, as shown in Fig. 38(a), in a manner to cross over slits 209 made in a horizontal direction through a sheet-formed substrate 201, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 208 and 209 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. The first upper surface electrode layers 202 are then fired at a temperature of approximately 850°C in order to make them become stable films. During this process, the electrode paste gets into the slits 209 of horizontal direction, thereby the first upper surface electrode layers 202 can be formed down deeply in the slits. Generally, the slits 208 and 209 are so formed that their depth with respect to a thickness of the substrate 201 becomes equal to or less than a half of the thickness of the substrate 201, so as to avoid it from being cracked during handling in the manufacturing process.

Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 203 in a manner that they connect electrically with the first upper surface electrode layers 202, as shown in Fig. 38(b). The resistor layers 203 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 210 with a YAG laser, as shown in Fig. 38(c) in order to correct resistances of the resistor layers 203 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the first upper surface electrode layers 202 during this process.

Another paste having a principal component of glass is printed to form protective layers 204, as shown in Fig. 39(a), in order to protect the resistor layers 203,

of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 204 cross over the slits 208 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 203. The protective layers 204 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Next, electrode paste containing silver-base conductive powder and glass is printed to form second upper surface electrode layers 205 on upper surfaces of the first upper surface electrode layers 202, as shown in Fig. 39(b), in a manner not to cross over slits 209 of horizontal direction. For this process, the printing pattern of the second upper surface electrode layers 205 may be made in such a shape that the second upper surface electrode layers cross over the slits 208 of vertical direction, above the plurality of horizontally aligned first upper surface electrode layers 202. The second upper surface electrode layers 205 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 201 in a sheet-form, on which the first upper surface electrode layers 202, the resistor layers 203, the trimmed grooves 210, the protective layers 204 and the second upper surface electrode layers 205 are formed, is separated into substrate strips 211 by splitting it along the slits 209 of horizontal direction in the substrate 201, as shown in Fig. 39(c). When this is done, the previously formed first upper surface electrode layers 202 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 211 down to the depth of the slits 209 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 202 and the second upper surface electrode layers 205, the substrate strips 211 are finally separated into individual substrate pieces 212 by splitting them along the slits 208 of vertical direction, as shown in Fig. 39(d). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the first upper surface electrode layers 202 and the second upper surface electrode layers 205 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the tenth exemplary embodiment of this invention constructed and manufactured as above was soldered on a mount board. The resistor was mounted with the surface having the protective layer down, and soldered with both the upper surface electrode layers (not shown in the figure) and the resistor layer on sides of the substrate, as shown in a sectional view of Fig. 40(a) depicting a mounted position. However, since areas in the side surfaces, whereon electrodes are formed, were so small, fillets 213 were barely formed. Accordingly, an actual mount area 216 came to the sum of a component area 214 and areas 215 required for soldering the side surfaces of this component, as shown in a plan view of Fig. 40(b) depicting the mounted position. The invention could attain a reduction of approximately 20% in the mount area as compared to a component of the prior art, in the case of a tip resistor in a size of 0.6×0.3 mm.

Therefore, the structure according to the present invention requires a small area on a mount board to form fillets of soldering, because of the small areas of the side surface electrodes on the resistor, and thereby it can reduce the mount areas.

In the tenth exemplary embodiment of this invention, if solder-plated layers 207 and the protective layer 204 are formed to be on the same plane, or if the solder-plated layers 207 are formed to be higher than the protective layer 204, the resistor is not likely to allow a gap between the solder-plated layers 207 and a land pattern, when it is mounted, thereby further improving quality of mounting.

In addition, other characteristics (specified in Table 10) can be improved in this tenth exemplary embodiment of the invention, if the first upper surface electrode layers 202, the protective layer 204 and the second upper surface electrode layers 205 are constituted of combinations shown in Table 10.

Table 10

Combina- tion	First upper surface electrode layers 202	Second upper surface electrode layers 205	Protective layer 204	Characteristics to be improved
1	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	No variation in resistance during manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer 204.
2	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 1, with less manufacturing cost due to use of base metal for second upper surface electrode layers 205.
3	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and glass (fired at 600°C)	Glass-base material (hardened at 600°C)	Improvement in loaded-life characteristic due to low ion migration.
4	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 1 and 3.
5	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 2 and 3.
6	Gold-base	Silver-base	Glass-base	Same characteristic as above

	metalo-organic compound (fired at 850°C)	conductive powder and glass (fired at 600°C)	material (hardened at 600°C)	combination 3, and low cost due to reduction in amount of gold used.
7	Gold-base metalo-organic compound (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 1 and 6.
8	Gold-base metalo-organic compound (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 2 and 6.

In addition, it is easily conceivable that the mount area can be further reduced if electrodes are not formed on the side surfaces in the tenth exemplary embodiment of this invention. However, if the electrodes are not formed on the side surfaces, the resistor forms no fillet at all, thereby giving rise to a problem that makes an automated inspection by image recognition inexecutable, in consideration of the fact that inspection of soldering is usually carried out by means of image recognition after mounting components in the current manufacturing process of electronic devices.

10 (Eleventh Exemplary Embodiment)

A resistor of an eleventh exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 41 is a sectional view of a resistor of the eleventh exemplary embodiment of this invention.

In Fig. 41, a reference numeral 221 represents a substrate containing 96% of alumina. A reference numeral 222 represents first upper surface electrode layers provided on side portions of a main surface and portions of side surfaces of the substrate 221 by means of sputtering gold-base material. A surface area of each of the first upper surface electrode layers 222 on the side surfaces of the substrate 221 is not more than a half of an area of the side surface of the substrate 221. A reference numeral 223 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the first upper surface electrode layers 222. A reference numeral 224 represents a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 223. A reference numeral 225 represents second upper surface electrode layers composed of silver-base conductive powder containing glass, provided on upper surfaces of the first upper surface electrode layers 222. Ridges of the second upper surface electrode layers 225 are rounded. Reference numerals 226 and 227 respectively represent nickel-plated layers

and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the eleventh exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 42 and Fig. 43 represent a series of procedural views showing a manufacturing method of the resistor of the eleventh exemplary embodiment of this invention.

First, gold is deposited in a form of film by sputtering method on an entire upper surface of a sheet-formed substrate 221, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 228 and 229 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. Further, first upper surface electrode layers 222 having a desired electrode pattern are formed, as shown in Fig. 42(a), by photo-lithographic method which is normally used for LSI's, and the like. The first upper surface electrode layers 222 are subjected to heat treatment at a temperature of approximately 300 to 400°C in order to make them become stable films. During this process, the first upper surface electrode layers 222 get into slits 229 of horizontal direction, thereby the upper surface electrode layers 222 can be formed down deeply in the slits. Generally, the slits 228 and 229 are so formed that their depth with respect to a thickness of the substrate 221 becomes equal to or less than a half of the thickness of the substrate 221, so as to avoid it from being cracked during handling in the manufacturing process.

Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 223 in a manner that they connect electrically with the first upper surface electrode layers 222, as shown in Fig. 42(b). The resistor layers 223 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 230 with a YAG laser, as shown in Fig. 42(c) in order to correct resistances of the resistor layers 223 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the first upper surface electrode layers 222 during this process.

Another paste having a principal component of glass is printed to form protective layers 224, as shown in Fig. 43(a), in order to protect the resistor layers 223, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 224 cross over the slits 228 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 223. The protective layers 224 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Next, electrode paste containing silver-base conductive powder and glass is printed to form second upper surface electrode layers 225 on upper surfaces of the first upper surface electrode layers 222, as shown in Fig. 43(b), in a manner not to cross over slits 229 of horizontal direction. The second upper surface electrode layers 225 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 221 in a sheet-form on which the first upper surface

electrode layers 222, the resistor layers 223, the trimmed grooves 230, the protective layers 224 and second upper surface electrode layers 225 are formed, is separated into substrate strips 231 by splitting it along the slits 229 of horizontal direction in the substrate 221, as shown in Fig. 43(c). When this is done, the previously formed first upper surface electrode layers 222 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 231 down to the depth of the slits 229 of horizontal direction.

As a preparatory process for plating exposed surfaces of the first upper surface electrode layers 222 and the second upper surface electrode layers 225, the substrate strips 231 are finally separated into individual substrate pieces 232 by splitting them along the slits 228 of vertical direction, as shown in Fig. 43(d). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the upper surface electrode layers 222 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the eleventh exemplary embodiment of this invention constructed and manufactured as above provides the same advantages as what has been described in the tenth exemplary embodiment, when it is soldered on a mount board, and therefore they will not be described.

In addition, other characteristics (specified in Table 11) can be improved in this eleventh exemplary embodiment of the invention, if the first upper surface electrode layers 222, the protective layer 224 and the second upper surface electrode layers 225 are constituted of combinations shown in Table 11.

Table 11

Combina- tion	First upper surface electrode layers 222	Second upper surface electrode layers 225	Protective layer 224	Characteristics to be improved
9	Sputtered gold-base material (heat- treated at 300- 400°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	No variation in resistance during manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer 224.
10	Sputtered gold-base material (heat- treated at 300- 400°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 9, with less manufacturing cost due to use of base metal for second upper surface electrode layers.
11	Sputtered nickel-base material (heat- treated	Silver-base conductive powder and resin	Resin-base material (hardened at 200°C)	Requires carbonic resin-base material for resistor layer. Carbonic resin-base material can provide saving of

	at 300- 400°C)	(hardened at 200°C)		electricity.
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(Twelfth Exemplary Embodiment)

A resistor of a twelfth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 44 is a sectional view of a resistor of the twelfth exemplary embodiment of this invention.

In Fig. 44, a reference numeral 241 represents a substrate containing 96% of alumina. A reference numeral 242 represents first upper surface electrode layers composed of silver-base conductive powder containing glass, provided on side portions of a main surface of the substrate 241. A reference numeral 243 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the first upper surface electrode layers 242. A reference numeral 244 represents a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 243. A reference numeral 245 represents second upper surface electrode layers composed of silver-base conductive powder containing glass, provided on upper surfaces of the first upper surface electrode layers 242 and portions of side surfaces of the substrate 241. A surface area of each of the second upper surface electrode layers 245 on the side surfaces of the substrate 241 is not more than a half of an area of the side surface of the substrate 241. Ridges of the second upper surface electrode layers 245 are rounded. Reference numerals 246 and 247 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

Fig. 45 and Fig. 46 represent a series of procedural views showing a manufacturing method of the resistor of the twelfth exemplary embodiment of this invention.

First, electrode paste containing silver-base conductive powder and glass is printed to form first upper surface electrode layers 242, as shown in Fig. 45(a), in a manner to cross over slits 249 made in a horizontal direction through a sheet-formed substrate 241, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 248 and 249 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps. The first upper surface electrode layers 242 are then fired at a temperature of approximately 850°C in order to make them become stable films. Generally, the slits 248 and 249 are so formed that their depth with respect to a thickness of the substrate 241 becomes equal to or less than a half of the thickness of the substrate 241, so as to avoid it from being cracked during handling in the manufacturing process.

Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 243 in a manner that they connect electrically with the first upper surface electrode layers 242, as shown in Fig. 45(b). The resistor layers 243 are then fired at a temperature of approximately 850°C in order to make them become stable films.

Next, trimming is made to form trimmed grooves 250 with a YAG laser, as

shown in Fig. 45(c) in order to correct resistances of the resistor layers 243 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the first upper surface electrode layers 242 during this process.

Another paste having a principal component of glass is printed to form protective layers 244, as shown in Fig. 46(a), in order to protect the resistor layers 243, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 244 cross over the slits 248 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 243, which form lines. The protective layers 244 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Next, electrode paste containing silver-base conductive powder and glass is printed to form second upper surface electrode layers 245 on an upper surface of the first substrate 242, as shown in Fig. 46(b), in a manner to cross over slits 249 of horizontal direction in the substrate 241. During this process, the electrode paste gets into the slits 249 of horizontal direction, thereby the second upper surface electrode layers 245 can be formed down to the deep in the slits. For this process, the printing pattern of the second upper surface electrode layers 245 may be made in such a shape that the second upper surface electrode layers cross over the slits 248 of vertical direction, over the plurality of horizontally aligned first upper surface electrode layers 242. The second upper surface electrode layers 245 are then fired at a temperature of approximately 600°C in order to make them become stable films.

Then, the substrate 241 in a sheet-form on which the first upper surface electrode layers 242, the resistor layers 243, the trimmed grooves 250, the protective layers 244 and the second upper surface electrode layers 245 are formed, is separated into substrate strips 251 by splitting it along the slits 249 of horizontal direction in the substrate 241, as shown in Fig. 46(c). When this is done, the previously formed second upper surface electrode layers 245 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 251 down to the depth of the slits 249 of horizontal direction.

As a preparatory process for plating exposed surfaces of the second upper surface electrode layers 245, the substrate strips 251 are finally separated into individual substrate pieces 252 by splitting them along the slits 248 of vertical direction, as shown in Fig. 46(d). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the second upper surface electrode layers 245 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

The resistor of the twelfth exemplary embodiment of this invention constructed and manufactured as above provides the same advantages as what has been described in the tenth exemplary embodiment, when it is soldered on a mount board, and therefore they will not be described.

In addition, other characteristics (specified in Table 12) can be improved in this twelfth exemplary embodiment of the invention, if the first upper surface electrode layers 242, the protective layer 244 and the second upper surface electrode layers 245 are constituted of combinations shown in Table 12.

Table 12

Combina- tion	First upper surface electrode layers 242	Second upper surface electrode layers 245	Protective layer 244	Characteristics to be improved
12	Silver-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	No variation in resistance during manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer 244.
13	Silver-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 12, with less manufacturing cost due to use of base metal for second upper surface electrode layers.
14	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and glass (fired at 600°C)	Glass-base material (hardened at 600°C)	Improvement in loaded-life characteristic due to low ion migration.
15	Gold-base conductive powder and glass (fired at 850°C)	Silver-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 12 and 14.
16	Gold-base conductive powder and glass (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 13 and 14.
17	Gold-base metalo- organic compound (fired at 850°C)	Silver-base conductive powder and glass (fired at 600°C)	Glass-base material (hardened at 600°C)	Same characteristic as above combination 14, and low cost due to reduction in amount of gold used.
18	Gold-base metalo- organic compound	Silver-base conductive powder and resin	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 12 and 17.

	(fired at 850°C)	(hardened at 200°C)		
19	Gold-base metalo-organic compound (fired at 850°C)	Nickel-base conductive powder and resin (hardened at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 13 and 17.

(Thirteenth Exemplary Embodiment)

A resistor of a thirteenth exemplary embodiment of the present invention and a method of manufacturing the same will be described hereinafter by referring to accompanying figures.

Fig. 47 is a sectional view of a resistor of the thirteenth exemplary embodiment of this invention.

In Fig. 47, a reference numeral 261 represents a substrate containing 96% of alumina. A reference numeral 262 represents first upper surface electrode layers composed of silver-base conductive powder containing glass, provided on side portions of a main surface of the substrate 261. A reference numeral 263 represents a resistor layer having a chief component of ruthenium oxide, for electrically connecting with the first upper surface electrode layers 262. A reference numeral 264 represents a protective layer having a chief component of glass, provided on an upper surface of the resistor layer 263. A reference numeral 265 represents second upper surface electrode layers formed by means of sputtering gold-base material in positions on upper surfaces and portions of side surfaces of the first upper surface electrode layers 262. A surface area of each of the second upper surface electrode layers 265 on the side surfaces of the substrate 261 is not more than a half of an area of the side surface of the substrate 261. Ridges of the second upper surface electrode layers 265 are rounded. Reference numerals 266 and 267 respectively represent nickel-plated layers and solder-plated layers provided, as occasion demands, for a purpose of assuring reliability, etc. during soldering.

The resistor of the thirteenth exemplary embodiment of this invention constructed as above is manufactured in a manner, which will be described hereinafter by referring to the figures.

Fig. 48 and Fig. 49 represent a series of procedural views showing a manufacturing method of the resistor of the thirteenth exemplary embodiment of this invention.

First, electrode paste containing silver-base conductive powder and glass is printed to form first upper surface electrode layers 262, as shown in Fig. 48(a), in a manner not to cross over slits 269 made in a horizontal direction on a sheet-formed substrate 261, which has a superior heat-resisting property and an insulating property as it contains 96% alumina, and a surface of which is provided with a plurality of slits 268 and 269 in a vertical direction as well as in a horizontal direction in order to separate it into strips and then into individual pieces in the subsequent steps.

Next, resistive paste having a principal component of ruthenium oxide is printed to form resistor layers 263 in a manner that they connect electrically with the first

upper surface electrode layers 262, as shown in Fig. 48(b). The resistor layers 263 are then fired at a temperature of approximately 850°C in order to make them become stable films.

5 Next, trimming is made to form trimmed grooves 270 with a YAG laser, as shown in Fig. 48(c) in order to correct resistances of the resistor layers 263 to a predetermined value. The trimming is made with trimming probes for measuring a resistance set on the first upper surface electrode layers 262 during this process.

10 Another paste having a principal component of glass is printed to form protective layers 264, as shown in Fig. 49(a), in order to protect the resistor layers 263, of which resistances have been corrected. For this process, a printing pattern may be made in such a shape that the protective layers 264 cross over the slits 268 of vertical direction to connectively cover a plurality of the horizontally aligned resistor layers 263. The protective layers 264 are then fired at a temperature of approximately 600°C in order to make them become stable films.

15 Resist material composed of resin is coated over an entire upper surface of the substrate 261, and openings having a film-forming pattern of the desired second upper surface electrode layers 265 are made in the resist material by photo-lithographic method, as shown in Fig. 49(b). Furthermore, gold is deposited in a form of film on the entire upper surface of the substrate 261 by sputtering method, and the resist material is then removed except for portions of the film-forming pattern for the desired second upper surface electrode layers 265. These steps compose the second upper surface electrode layers 265. During the above process, the second upper surface electrode layers 265 get into the slits 269 of horizontal direction, and thereby the second upper surface electrode layers 265 can be formed down deeply in the slits.

25 Generally, the slits 268 and 269 are so formed that their depth with respect to a thickness of the substrate 261 becomes equal to or less than a half of the thickness of the substrate 261, so as to avoid it from being cracked during handling in the manufacturing process.

30 Then, the substrate 261 in a sheet-form, on which the first upper surface electrode layers 262, the resistor layers 263, the trimmed grooves 270, the protective layers 264 and the second upper surface electrode layers 265 are formed, is separated into substrate strips 271 by splitting it along the slits 269 of horizontal direction in the substrate 261, as shown in Fig. 49(c). When this is done, the previously formed second upper surface electrode layers 265 lie in their respective positions on the side surfaces along a longitudinal direction of the substrate strips 271 down to the depth of the slits 269 of horizontal direction.

35 As a preparatory process for plating exposed surfaces of the upper surface electrode layers 265, the substrate strips 271 are finally separated into individual substrate pieces 272 by splitting them along the slits 268 of vertical direction, as shown in Fig. 49(d). A resistor is now completed when a nickel-plated layer, as an intermediate layer (not shown in the figure), and a solder-plated layer, as an outer layer (not shown in the figure), are formed by means of electroplating on exposed surfaces of the second upper surface electrode layers 265 in order to prevent electrode-erosion during soldering and to assure reliability of the soldering.

45 The resistor of the thirteenth exemplary embodiment of this invention constructed and manufactured as above provides the same advantages as what has

been described in the tenth exemplary embodiment, when it is soldered on a mount board, and therefore they will not be described.

- 5 In addition, other characteristics (specified in Table 13) can be improved in this thirteenth exemplary embodiment of the invention, if the first upper surface electrode layers 262, the protective layer 264 and the second upper surface electrode layers 265 are constituted of combinations shown in Table 13.

Table 13

Combina- tion	First upper surface electrode layers 262	Second upper surface electrode layers 265	Protective layer 264	Characteristics to be improved
20	Silver-base conductive powder and glass (fired at 850°C)	Sputtered gold-base material (heat- treated at 200°C)	Resin-base material (hardened at 200°C)	No variation in resistance during manufacturing process, and small deviation in resistance of products, due to low processing temperature of protective layer 264.
21	Silver-base conductive powder and glass (fired at 850°C)	Sputtered nickel-base material (hardened at 200°C)	Glass-base material (fired at 600°C)	Less manufacturing cost due to use of base metal for second upper surface electrode layers.
22	Gold-base conductive powder and glass (fired at 850°C)	Sputtered gold-base material (heat- treated at 200°C)	Glass-base material (fired at 600°C)	Improvement in loaded-life characteristic due to low ion migration.
23	Gold-base conductive powder and glass (fired at 850°C)	Sputtered gold-base material (heat- treated at 200°C)	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 20 and 22.
24	Gold-base conductive powder and glass (fired at 850°C)	Sputtered nickel-base material (heat- treated at 200°C)	Glass-base material (hardened at 200°C)	Both characteristics of above combinations 21 and 22.
25	Gold-base conductive powder and glass	Sputtered nickel-base material (heat- treated	Resin-base material (hardened at 200°C)	Both characteristics of above combinations 21, 22 and 20.

	(fired at 850°C)	at 200°C)		
26	Gold-base metalo-organic compound (fired at 850°C)	Sputtered gold-base material (heat-treated at 200°C)	Glass-base material (fired at 600°C)	Same characteristic as above combination 22, and low manufacturing cost due to reduction in amount of gold used.
27	Gold-base metalo-organic compound (fired at 850°C)	Sputtered gold-base material (heat-treated at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 23, and low manufacturing cost due to reduction in amount of gold used.
28	Gold-base metalo-organic compound (fired at 850°C)	Sputtered gold-base material (heat-treated at 200°C)	Glass-base material (hardened at 200°C)	Same characteristic as above combination 24, and low manufacturing cost due to reduction in amount of gold used.
29	Gold-base metalo-organic compound (fired at 850°C)	Sputtered nickel-base material (heat-treated at 200°C)	Resin-base material (hardened at 200°C)	Same characteristic as above combination 25, and low manufacturing cost due to reduction in amount of gold used.

INDUSTRIAL APPLICABILITY

As has been described, a resistor of the present invention comprises: a substrate; a pair of first upper surface electrode layers provided on side portions of an upper surface toward portions of side surfaces of the substrate; a pair of second upper surface electrode layers provided in a manner to make electrical connections with the first upper surface electrode layers; a resistor layer provided in a manner to make electrical connections with the second upper surface electrode layers; and a protective layer provided to cover at least an upper surface of the resistor layer. The above-described structure provides the resistor with side surface electrodes having a small surface area, since the pair of first upper surface electrode layers are disposed on side portions of the upper surface toward portions of the side surfaces of the substrate. Because the resistor is soldered with the side surface electrodes of the small area, it can reduce an area required to form fillets of soldering, when it is soldered on a mount board. Accordingly, the resistor is able to reduce an actual mount area, including soldering portions, on the mount board.

What is claimed is:

1. A resistor comprising:
 a substrate;
 5 a pair of first upper surface electrode layers, each provided on a side portion of an upper surface toward a portion of a side surface of said substrate;
 a pair of second upper surface electrode layers provided in a manner to make electrical connections with said first upper surface electrode layers;
 a resistor layer provided in a manner to make electrical connections with said
 10 second upper surface electrode layers; and
 a protective layer provided in a manner to cover at least an upper surface of said resistor layer.
- 15 2. The resistor according to claim 1, wherein portions of said first upper surface electrode layers located on the side surfaces of said substrate are disposed on a side adjacent to said resistor layer in a direction of height of said substrate.
- 20 3. The resistor according to claim 2, wherein each of the portions of said first upper surface electrode layers located on the side surfaces of said substrate has a surface area equal to or less than a surface area of the side surface of said substrate.
- 25 4. The resistor according to claim 1, wherein said first upper surface electrode layers and said second upper surface electrode layers are covered by plated layers, and further that said plated layers are formed to be on the same plane with, or greater in height than said protective layer.
- 30 5. The resistor according to claim 1, wherein said first upper surface electrode layers are composed of fired gold-base organic metal compound or sputtered gold-base material.
- 35 6. The resistor according to claim 5, wherein said second upper surface electrode layers are composed of silver-base or gold-base conductive powder containing glass.
7. The resistor according to claim 6, wherein said protective layer is composed of resin-base or glass-base material.
- 40 8. The resistor according to claim 1, wherein said first upper surface electrode layers are composed by means of sputtering nickel-base material.
9. The resistor according to claim 8, wherein said second upper surface electrode layers, said resistor layer and said protective layer are constructed of resin-base material.
- 45 10. The resistor according to claim 1, wherein said first upper surface electrode layers and said second upper surface electrode layers are disposed in



positions not to be in contiguous to sides of said substrate in a longitudinal direction thereof.

11. A method of manufacturing a resistor comprising the steps of:

- 5 providing a first upper surface electrode layer by pouring electrode paste on a sheet-formed substrate having a splitting slit, in a manner that said electrode paste crosses over an upper surface of said splitting slit, and fills in said splitting slit;
- providing a second upper surface electrode layer in a manner to make an electrical connection with said first upper surface electrode layer;
- 10 providing a resistor layer in a manner to make an electrical connection with said second upper surface electrode layer;
- providing a protective layer in a manner to cover at least an upper surface of said resistor layer;
- 15 separating said sheet-formed substrate, whereon said first upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and
- separating said substrate strips into individual substrate pieces.

12. A method of manufacturing a resistor comprising the steps of:

- 20 providing a first upper surface electrode layer by means of sputtering on a sheet-formed substrate having a splitting slit, in a manner to cross over an upper surface of said splitting slit, and to fill in said splitting slit;
- providing a second upper surface electrode layer in a manner to make an electrical connection with said first upper surface electrode layer;
- 25 providing a resistor layer in a manner to make an electrical connection with said second upper surface electrode layer;
- providing a protective layer in a manner to cover at least an upper surface of said resistor layer;
- 30 separating said sheet-formed substrate, whereon said first upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and
- separating said substrate strips into individual substrate pieces.

13. A resistor comprising:

- 35 a substrate;
- a pair of first upper surface electrode layers, each provided on a side portion of an upper surface toward a portion of a side surface of said substrate;
- a pair of second surface electrode layers provided in a manner to make electrical connections with said first upper surface electrode layers;
- 40 a resistor layer provided in a manner to make electrical connections with said second upper surface electrode layers;
- third upper surface electrode layers provided at least on portions of upper surfaces of said second upper surface electrode layers; and
- 45 a protective layer provided in a manner to cover at least an upper surface of said resistor layer.



14. A resistor comprising:

a substrate;

a pair of first upper surface electrode layers provided on an upper surface of said substrate;

5 a resistor layer provided in a manner to make electrical connection with said first upper surface electrode layers;

second upper surface electrode layers provided at least on upper surfaces of said first upper surface electrode layers and portions of side surfaces of said substrate;

10 a protective layer provided in a manner to cover at least said resistor layer; and

third upper surface electrode layers overlapping at least portions of said first upper surface electrode layers.

15. A method of manufacturing a resistor comprising the steps of:

15 providing a first upper surface electrode layer by pouring electrode paste on a sheet-formed substrate having a splitting slit, in a manner that said electrode paste crosses over a side portion of an upper surface of said substrate and an upper surface of said splitting slit, and also fills in said splitting slit;

20 providing a second upper surface electrode layer in a manner to make an electrical connection with said first upper surface electrode layer;

providing a resistor layer in a manner to make an electrical connection with said second upper surface electrode layer;

25 providing a protective layer in a manner to cover at least an upper surface of said resistor layer;

providing a third upper surface electrode layer overlapping at least a portion of an upper surface of said second upper surface electrode layer;

separating said sheet-formed substrate, whereon said third surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and

30 separating said substrate strips into individual substrate pieces.

16. A method of manufacturing a resistor comprising the steps of:

35 providing a first upper surface electrode layer by means of sputtering on a sheet-formed substrate having a splitting slit, in a manner to cross over a side portion of an upper surface of said substrate and an upper surface of said splitting slit, and to fill in said splitting slit;

providing a second upper surface electrode layer in a manner to make an electrical connection with said first upper surface electrode layer;

40 providing a resistor layer in a manner to make an electrical connection with said second upper surface electrode layer;

providing a protective layer in a manner to cover at least an upper surface of said resistor layer;

45 providing a third upper surface electrode layer overlapping at least a portion of an upper surface of said second upper surface electrode layer;

separating said sheet-formed substrate, whereon said third upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said



sheet-formed substrate; and
separating said substrate strips into individual substrate pieces.

17. A method of manufacturing a resistor comprising the steps of:
- 5 providing a first upper surface electrode layer on a side portion of an upper surface of a sheet-formed substrate having a splitting slit, in a manner not to cross over an upper surface of said splitting slit;
 - providing a resistor layer in a manner to make an electrical connection between said first upper surface electrode layer;
 - 10 providing a protective layer in a manner to cover at least an upper surface of said resistor layer;
 - providing a second upper surface electrode layer by means of sputtering in a manner to connect electrically with at least said first upper surface electrode layer, to cross over an upper surface of said splitting slit, and to fill in said splitting slit, said
 - 15 second upper surface electrode layer;
 - providing a third upper surface electrode layer in a manner to overlap at least a portion of an upper surface of said first upper surface electrode layer;
 - separating said sheet-formed substrate, whereon said third upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said
 - 20 sheet-formed substrate; and
 - separating said substrate strips into individual substrate pieces.

18. A resistor comprising:
- a substrate;
 - 25 a pair of upper surface electrode layers, each provided on a side portion of an upper surface of said substrate;
 - a resistor layer provided in a manner to make electrical connections with said upper surface electrode layers;
 - a protective layer provided in a manner to cover at least said resistor layer;
 - 30 and
 - side surface electrode layers provided on portions of side surfaces of said substrate in a manner to make electrical connections with said upper surface electrode layers.

19. A resistor comprising:
- a substrate;
 - a pair of first upper surface electrode layers, each provided on a side portion of an upper surface of said substrate;
 - a resistor layer provided in a manner to make electrical connections with said
 - 40 first upper surface electrode layers;
 - second upper surface electrode layers provided at least on upper surfaces of said first upper surface electrode layers;
 - a protective layer provided in a manner to cover at least an upper surface of said resistor layer; and
 - 45 side surface electrode layers provided on portions of side surfaces of said substrate in a manner to make electrical connections with either of said first upper



surface electrode layers and said second upper surface electrode layers.

20. A method of manufacturing a resistor comprising the steps of:

- 5 providing a pair of upper surface electrode layers on an upper surface of a sheet-formed substrate having a splitting slit, in a manner not to cross over said splitting slit;
- providing a resistor layer in a manner to make an electrical connection between said upper surface electrode layers;
- 10 providing a protective layer in a manner to cover at least an upper surface of said resistor layer;
- providing a pair of side surface electrode layers in a manner to cross over said splitting slit between adjacent two of said upper surface electrode layers and to make electrical connections with said two upper surface electrode layers;
- 15 separating said sheet-formed substrate, whereon said upper surface electrode layers are formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and
- separating said substrate strips into individual substrate pieces.

21. A method of manufacturing a resistor comprising the steps of:

- 20 providing a pair of first upper surface electrode layers on an upper surface of a sheet-formed substrate having a splitting slit, in a manner not to cross over said splitting slit;
- providing a resistor layer in a manner to make electrical connections between said upper surface electrode layers;
- 25 providing a protective layer in a manner to cover at least an upper surface of said resistor layer;
- providing second upper surface electrode layers in a manner to cover at least upper surfaces of said first upper surface electrode layers;
- 30 providing a pair of side surface electrode layers in a manner to cross over said splitting slit between adjacent two of said first upper surface electrode layers or said second upper surface electrode layers, and to make electrical connections with either of said first upper surface electrode layers and said second upper surface electrode layers;
- 35 separating said sheet-formed substrate, whereon said upper surface electrode layers are formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and
- separating said substrate strips into individual substrate pieces.

22. A resistor comprising:

- 40 a substrate;
- a pair of upper surface electrode layers, each provided on a side portion of a major surface and a portion of a side surface of said substrate;
- a resistor layer provided in a manner to make electrical connections with said upper surface electrode layers; and
- 45 a protective layer provided in a manner to cover at least an upper surface of said resistor layer.



23. A method of manufacturing a resistor comprising the steps of:

providing an upper surface electrode layer by pouring electrode paste on a sheet-formed substrate having a splitting slit, in a manner that said electrode paste crosses over an upper surface of said splitting slit, and also fills in said splitting slit;

providing a resistor layer in a manner to make an electrical connection with said upper surface electrode layer;

providing a protective layer in a manner to cover at least upper surfaces of said upper surface electrode layer and said resistor layer;

separating said sheet-formed substrate, whereon said upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and

separating said substrate strips into individual substrate pieces.

24. A method of manufacturing a resistor comprising the steps of:

providing an upper surface electrode layer by means of sputtering on a sheet-formed substrate having a splitting slit, in a manner to cross over an upper surface of said splitting slit, and to fill in said splitting slit;

providing a resistor layer in a manner to make an electrical connection with said upper surface electrode layer;

providing a protective layer in a manner to cover at least upper surfaces of said upper surface electrode layer and said resistor layer;

separating said sheet-formed substrate, whereon said upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and

separating said substrate strips into individual substrate pieces.

25. A resistor comprising:

a substrate;

a pair of first upper surface electrode layers, each provided on a side portion of an upper surface and a portion of a side surface of said substrate;

a resistor layer provided in a manner to make electrical connections with said first upper surface electrode layers;

second upper surface electrode layers provided at least on upper surfaces of said first upper surface electrode layers; and

a protective layer provided in a manner to cover at least an upper surface of said resistor layer.

26. A resistor comprising:

a substrate;

a pair of first upper surface electrode layers provided on an upper surface of said substrate;

a resistor layer provided in a manner to make electrical connections with said first upper surface electrode layers;

second upper surface electrode layers provided at least on upper surfaces of said first upper surface electrode layers and portions of side surfaces of said substrate;



and

a protective layer provided in a manner to cover at least said resistor layer.

27. A method of manufacturing a resistor comprising the steps of:

- 5 providing a first upper surface electrode layer by pouring electrode paste on a sheet-formed substrate having a splitting slit, in a manner that said electrode paste crosses over a side of an upper surface of said substrate and an upper surface of said splitting slit, and also fills in said splitting slit;
- 10 providing a resistor layer in a manner to make an electrical connection between said first upper surface electrode layer;
- providing a protective layer in a manner to cover at least upper surfaces of said first upper surface electrode layer and said resistor layer;
- providing a second upper surface electrode layer connecting electrically with at least said first upper surface electrode layer
- 15 separating said sheet-formed substrate, whereon said second upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and
- separating said substrate strips into individual substrate pieces.

28. A method of manufacturing a resistor comprising the steps of:

- 20 providing a first upper surface electrode layer by means of sputtering on a sheet-formed substrate having a splitting slit, in a manner to cross over a side of an upper surface of said substrate and an upper surface of said splitting slit, and to fill in said splitting slit;
- 25 providing a resistor layer in a manner to make an electrical connection with said first upper surface electrode layer;
- providing a protective layer in a manner to cover at least upper surfaces of said first upper surface electrode layer and said resistor layer;
- 30 providing a second upper surface electrode layer connecting electrically with at least said first upper surface electrode layer;
- separating said sheet-formed substrate, whereon said second upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and
- separating said substrate strips into individual substrate pieces.

29. A method of manufacturing a resistor comprising the steps of:

- 35 providing a first upper surface electrode layer on a side portion of an upper surface of a sheet-formed substrate having a splitting slit, in a manner not to cross over an upper surface of said splitting slit;
- 40 providing a resistor layer in a manner to make an electrical connection with said first upper surface electrode layer;
- providing a protective layer in a manner to cover at least upper surfaces of said first upper surface electrode layer and said resistor layer;
- 45 providing a second upper surface electrode layer by pouring electrode paste in a manner to connect electrically with at least said first upper surface electrode layer, to cross over an upper surface of said splitting groove, and to fill in said splitting slit;



separating said sheet-formed substrate, whereon said second upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and

separating said substrate strips into individual substrate pieces.

5

30. A method of manufacturing a resistor comprising the steps of:

providing a first upper surface electrode layer on a side portion of an upper surface of a sheet-formed substrate having a splitting slit, in a manner not to cross over an upper surface of said splitting slit;

10

providing a resistor layer in a manner to make an electrical connection between said first upper surface electrode layer;

providing a protective layer in a manner to cover at least upper surfaces of said first upper surface electrode layer and said resistor layer;

15

providing a second upper surface electrode layer by means of sputtering in a manner to connect electrically with at least said first upper surface electrode layer, to cross over an upper surface of said splitting slit in said sheet-formed substrate, and to fill in said splitting slit;

separating said sheet-formed substrate, whereon said second upper surface electrode layer is formed, into substrate strips along said splitting slit provided in said sheet-formed substrate; and

20

separating said substrate strips into individual substrate pieces.

