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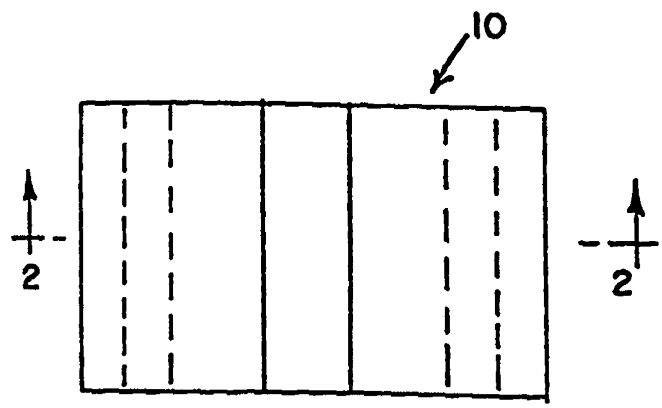
(57) Abstract

The present invention is a device for protecting an electrical circuit. The device includes a resistive element having a first and a second surface. A first electrode is in electrical contact with the first surface of the resistive element and a second electrode is in electrical contact with the second surface of the resistive element. A first end termination electrically connects the circuit and the first electrode. A second end termination electrically connects the second electrode and the circuit. An electrically insulating layer is interposed between the first and second end terminations and is in contact with the first and second electrodes. The end terminations allow for an electrical connection to be made to both electrodes from the same side of the electrical device.



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SURFACE MOUNTABLE ELECTRICAL DEVICE COMPRISING A PTC AND FUSIBLE ELEMENT

DESCRIPTION

Cross-Reference to Related Application

This application is a continuation-in-part of co-pending Application Serial Nos. 08/642,597 and 08/642,655 filed May 3, 1996, and 08/884,711 and 08/885,084 filed June 30, 1997.

Technical Field

The present invention relates generally to a surface mountable electrical circuit protection device and a method for making the device.

Background of the Invention

It is well known that the resistivity of many conductive materials change with temperature. Resistivity of a positive temperature coefficient ("PTC") material increases as the temperature of the material increases. Many crystalline polymers, made electrically conductive by dispersing conductive fillers therein, exhibit this PTC effect. These polymers generally include polyolefins such as polyethylene, polypropylene and ethylene/propylene copolymers. Certain doped ceramics such as barium titanate also exhibit PTC behavior.

At temperatures below a certain value, i.e., the critical or switching temperature, the PTC material exhibits a relatively low, constant resistivity. However, as the temperature of the PTC material increases beyond this point, the resistivity sharply increases with only a slight increase in temperature.

Electrical devices employing polymer and ceramic materials exhibiting PTC behavior have been used as overcurrent protection in electrical circuits. Under normal operating conditions in the electrical circuit, the resistance of the load and the PTC device is such that relatively little current flows through the PTC device. Thus, the temperature of the device due to I^2R heating remains below the critical or switching temperature of the PTC device. The device is said to be in an equilibrium state (i.e., the rate at which heat is generated by I^2R heating is equal to the rate at which the device is able to lose heat to its surroundings).

If the load is short circuited or the circuit experiences a power surge, the current flowing through the PTC device increases and the temperature of the PTC device (due to I^2R heating) rises rapidly to its critical temperature. At this point, a great deal of power is dissipated in the PTC device and the PTC device becomes unstable (i.e., the rate at which the device generates heat is greater than the rate at which the device can lose heat to its surroundings). This power dissipation only occurs for a short period of time (i.e., a fraction of a second), however, because the increased power dissipation will raise the temperature of the PTC device to a value where the resistance of the PTC device has become so high that the current in the circuit is limited to a relatively low value. This new current value is enough to maintain the PTC device at a new, high temperature/high resistance equilibrium point, but will not damage the electrical circuit components. Thus, the PTC device acts as a form of a fuse, reducing the current flow through the short circuit load to a safe, relatively low value when the PTC device is heated to its critical temperature range. Upon interrupting the current in the circuit, or removing the condition responsible for the short circuit (or power surge), the PTC device will cool down below its critical temperature to its normal operating, low resistance state. The effect is a resettable, electrical circuit protection device.

Particularly useful devices of this type generally include a PTC element sandwiched between a pair of laminar electrodes. In order to connect devices of this type to other electrical components, terminals are commonly soldered to the electrode. The soldering process, however, can adversely affect the resistance of a polymeric PTC element. Moreover, since electrical connection generally occurs on opposing sides of the PTC element, devices of this type commonly take up more space on a PC board than is necessary.

Summary of the Invention

We have now discovered that important advantages result from making electrical connection to both electrodes from the same side of the PTC device. The wrap-around configuration of the PTC devices of the present invention allow one to make an electrical connection to an electrode on the opposite side of the PTC device. Further, since electrical devices of the present invention make electrical connection by wrapping a conductive layer around the PTC element rather than putting a conductive layer through an aperture in the PTC element, the device utilizes more cross-sectional area of the PTC element, resulting in higher-rated devices.

Moreover, the manufacturing steps necessary to produce electrical devices according to the present invention allow for numerous strips to be prepared simultaneously, with the final strips ultimately divided into a plurality of electrical devices. This process makes it possible to reduce the size and, hence, the resistance of the electrical devices of the present invention.

In a first aspect of the present invention there is provided a device for protecting an electrical circuit. The device comprises a resistive element having a first and a second surface. A first electrode is in electrical contact with the first surface of the resistive element and a second electrode is in electrical contact with the second surface of the resistive element. A first end termination electrically connects the circuit and the first electrode. A second end termination electrically connects the second electrode and the circuit. An electrically insulating layer is interposed between the first and second end terminations and is in contact with the first and second electrodes.

In a second aspect of the present invention there is provided a device for protecting an electrical circuit. The device comprises a conductive polymer PTC element having a first and a second surface and a first and a second side wall. A first electrode is in electrical contact with the first surface of the PTC element and a second electrode is in electrical contact with the second surface of the PTC element. A first end termination electrically connects the circuit and the first electrode and is in contact the first side wall of the PTC element. A second end termination electrically connects the second electrode and the circuit and is in contact with the second side wall of the PTC element. An electrically insulating layer is interposed between the first and second end terminations and is in contact with the first and second electrodes.

In a third aspect of the present invention there is provided an electrical device for protecting a circuit. The device includes a resistive element in series with a fusible element. The resistive element has a first and a second surface. A first electrode is in electrical contact with the first surface of the PTC element and a second electrode is in electrical contact with the second surface of the PTC element. A first end termination provides electrical connection between the circuit and the first electrode. The fusible element is electrically connected in series with the PTC element. A second end termination provides electrical connection between the fusible element and the circuit.

In a fourth aspect of the present invention there is provided a device for protecting an electrical circuit. The device includes a PTC element in series with a fusible element. The PTC element comprises a conductive polymer and includes first and a second surfaces and first and second side walls. A first electrode is in electrical contact with the first surface of the PTC element and a second electrode is in electrical contact with the second surface of the PTC element. A first end termination provides electrical connection between the circuit and the first electrode and is in contact with the first side wall of the PTC element. The fusible element is electrically connected in series with the PTC element. A second end termination provides electrical connection between the fusible element and the circuit and is in contact with the second side wall of the PTC element.

Brief Description of the Drawings

A better understanding of the present invention will be had upon reference to the following detailed description and accompanying drawings. The size and thickness of the various elements illustrated in the drawings has been greatly exaggerated to more clearly show the electrical devices of the present invention.

FIG. 1 is a top view of an electrical device according to the present invention.

FIG. 2 is a cross-sectional view along line a-a of a first embodiment of the electrical device illustrated in FIG. 1.

FIG. 3 is a cross-sectional view along line a-a of a second embodiment of the electrical device illustrated in FIG. 1.

FIG. 4 is a perspective view of a laminar PTC sheet having a plurality of strips created in a regular pattern.

FIG. 4A is a perspective view of the laminar PTC sheet illustrated in FIG. 4 having a plurality of break points created on each strip.

FIG. 5 is a partial enlarged perspective view of the laminar PTC sheet having a plurality of strips as illustrated in FIG. 4.

FIGS. 6A-6H illustrate the various steps of a preferred method of manufacturing electrical devices of the present invention, as applied to a cross-section of a single strip of the PTC sheet in FIG. 4A.

FIGS. 7A-7D illustrate the steps of a second preferred method of manufacturing electrical devices of the present invention, starting with the device illustrated in FIG. 6E.

FIG. 8 is a cross-sectional view of a preferred embodiment of the device in FIG. 1 soldered to a PC board.

FIGS. 9A-9G illustrate the steps of a third preferred method of manufacturing electrical devices of the present invention as applied to a cross-section of a single strip of the PTC sheet in FIG. 4A.

FIG. 10 is a cross-sectional view of a preferred embodiment of the device in FIGS. 9A-9G soldered to a PC board.

FIGS. 11A-11G illustrate the steps of a fourth preferred method of manufacturing electrical devices of the present invention as applied to a cross-section of a single strip of the PTC sheet in FIG. 4A.

FIG. 12 is a cross-sectional view of a preferred embodiment of the device in FIGS. 11A-11G soldered to a PC board.

FIG. 13 is a front view of a preferred embodiment of a device for protecting an electrical circuit according to the present invention.

FIGS. 14A-14H illustrate the steps of a preferred method of manufacturing the device illustrated in FIG. 13 as applied to a cross-section of a single strip of the laminar PTC sheet in FIG. 4A.

FIG. 15 is a front view of a preferred embodiment of a device for protecting an electrical circuit according to the present invention.

FIGS. 16A-16G illustrate the steps of a preferred method of manufacturing the device illustrated in FIG. 15 as applied to a cross-section of a single strip of the laminar PTC sheet in FIG. 4A.

FIG. 17 is a cross-sectional view of an electrical device according to one embodiment of the present invention wherein a fusible element is electrically connected in series with a PTC element.

FIG. 18 is a cross-sectional view of an electrical device according to another embodiment of the present invention wherein a fusible element is electrically connected in series with a PTC element.

FIG. 19 is a cross-sectional view of an electrical device according to yet another embodiment of the present invention wherein a fusible element is electrically connected in series with a PTC element.

FIGS. 20-21 are top plan views of electrical devices according to the present invention with fusible elements of varying configurations.

Detailed Description of the Invention

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention. For example, the present invention will be described below generally with reference to a polymer PTC element having electrodes formed on the top and bottom surfaces. It is to be understood, however, that the present invention contemplates electrical devices with a ceramic PTC element, or a resistive element that does not exhibit PTC characteristics.

Generally, the resistive element of the present invention will be composed of a PTC composition comprised of a polymer component and a conductive filler component. The polymer component may be a single polymer or a mixture of two or more different polymers. The polymer component may comprise a polyolefin having a crystallinity of at least 40%. Suitable polymers include polyethylene, polypropylene, polybutadiene, polyethylene acrylates, ethylene acrylic acid copolymers, and ethylene propylene copolymers. In a preferred embodiment, the polymer component comprises polyethylene and maleic anhydride (such a polymer is manufactured by Du Pont and sold under the tradename Fusabond™). The conductive filler component is dispersed throughout the polymer component in an amount sufficient to ensure that the composition exhibits PTC behavior. Alternatively, the conductive filler can be grafted to the polymer. Generally, the conductive filler component will be present in the PTC composition by approximately 25-75% by weight. Suitable conductive fillers to be used in the present invention include powders, flakes or spheres of the following metals; nickel, silver, gold, copper, silver-plated copper, or metal alloys. The conductive filler may also comprise carbon black, carbon flakes or spheres, or graphite. In a preferred embodiment, the conductive filler component used in the present invention is carbon black (manufactured by Columbian Chemicals and sold under the tradename Raven™). Particularly useful PTC compositions have a resistivity at approximately 25°C of less than 10 ohm cm, particularly less than 5 ohm cm, and especially less than 3 ohm cm. Suitable PTC compositions for use in the present invention are disclosed in U.S. patent application Serial No. 08/614,038, and U.S. Patent Nos. 4,237,441, 4,304,987, 4,849,133, 4,880,577, 4,910,389 and 5,190,697.

The PTC element has a first electrode in electrical contact with the top surface and a second electrode in electrical contact with the bottom surface. The electrodes may be in direct physical contact with the top and bottom surfaces of the PTC element, however, electrical devices of the present invention may also include a conductive adhesive composition which lies between the electrodes and the PTC element.

In a preferred embodiment, the PTC element is sandwiched between two metal foil electrodes to form a laminate. Alternatively, the electrodes can be formed on the top and bottom surfaces of the PTC element using conventional electroless or electrolytic plating processes. The first and second electrodes preferably comprise a metal selected from the group consisting of nickel, copper, silver, tin, gold and alloys thereof.

Embodiment Illustrated In FIGS. 1-3

With reference now to FIGS. 1-3, the electrical device 10 of the present invention comprises a resistive element 20 having a top surface 30, a bottom surface 40, a first side 50 and a second side 60. Both the top and bottom surfaces 30, 40 have two end portions 70, 80 and 70', 80' separated by mid-portions 90, 90'. A first electrode 100 is formed on the top surface 30 of resistive element 20 and a second electrode 110 is formed on the bottom surface 40 of resistive element 20. As previously mentioned, preferably resistive element 20 is composed of a polymer PTC composition.

An insulating layer 120 is formed on electrodes 100, 110 and the first side 50 and the second side 60 of the resistive element 20. The insulating layer 120 can be composed of a photo resist material, a dielectric material, a ceramic material, a solder mask, or any electrically non-conductive material. The insulating layer 120 has a portion removed from the first electrode 100 to define a first contact point 130 and a portion removed from the second electrode 110 to define a second contact point 140. In the preferred embodiments illustrated in FIGS. 2-3, the first contact point 130 is adjacent the end portion 70 of the top surface 30 of the resistive element 20, while the second contact point 140 is adjacent the end portion 80' of the bottom surface 40 of the resistive element 20 (i.e., the first and second contact points 130, 140 are located on opposite sides and opposite ends of the electrical device 10). While this configuration is preferred, the present invention covers electrical devices having contact points located anywhere along the first and second electrodes provided that electrical connection can be made to both electrodes from the same side of the electrical device.

A first conductive layer 150 is formed on the insulating layer 120 and makes electrical contact with the first and second electrodes 100, 110 at first and second contact points 130, 140. Conductive layer 150 may be comprised of any conductive material, but preferably comprises a metal selected from the group consisting of copper, tin, silver, nickel, gold and alloys thereof. It is important that the first conductive layer wrap-around the sides of the electrical device. This wrap-around configuration allows for electrical connection to be made to both electrodes from the same side of the electrical device.

The first conductive layer 150 has portions removed from insulating layer 120 to form end terminations 155, 156. Each end termination includes a contact point. The end terminations 155, 156 are separated by electrically non-conductive gaps 160, 170. FIGS. 2-3 illustrate an electrical device 10 wherein the electrically non-conductive gaps 160, 170 are formed adjacent the mid-portions 90, 90' of the top and bottom surfaces 30, 40 of resistive element 20. It should be understood, however, that the electrically non-conductive gaps 160, 170 can be formed anywhere in the first conductive layer 150 as long as the electrically non-conductive gaps separate end terminations 155, 156, with each end termination including a contact point. This configuration prevents current from flowing circularly around the electrical device. Instead, current may flow around either end portion of the electrical device via an end termination, to the first contact point, and through the resistive element to the second contact point formed on the opposite side of the electrical device.

The electrically non-conductive gaps 160, 170 can be formed by a conventional etching process. In FIGS. 2-3, the non-conductive gaps 160, 170 are left vacant, thus exposing insulating layer 120. Alternatively, the non-conductive gaps 160, 170 can be filled with any electrically non-conductive material.

Referring specifically to FIG. 3, in a preferred embodiment of the present invention, a second conductive layer 180 is formed on the first conductive layer 150. The second conductive layer should not bridge non-conductive gaps 160, 170 or any electrically non-conductive material which might fill the non-conductive gaps 160, 170. The second conductive layer 180 is preferably a solder composition which allows the device 10 to be easily connected to the conductive terminals of a PC board. By completely coating the first conductive layer 150 with the second conductive layer

180, the electrical device 10 of the preferred embodiment is symmetrical. Accordingly, the device 10 does not need to be oriented in a special manner before it is mounted to a PC board or connected to additional electrical components. It should be understood, however, that the present invention covers an electrical device 10 where the second conductive layer 180 contacts only a portion of the first conductive layer 150, or is in contact with the first conductive layer 150 on one side of the device only, i.e., a non-symmetrical device.

Electrical devices of the present invention have a resistance at approximately 25°C of less than 1 ohm, preferably less than 0.5 ohm, and especially less than 0.2 ohm.

Embodiments Illustrated In Figures 4-5

The electrical devices of the present invention can be manufactured in various ways. However, as illustrated in FIG. 4, the preferred method provides for carrying out the processing steps on a relatively large laminar sheet 185 which comprises a plurality of strips 186, 186', 186'', etc. The final processing step includes dividing the strips into a plurality of electrical devices. Accordingly, extremely small electrical devices with low resistances can be produced in an economical fashion.

In a preferred method, electrodes are formed on the top and bottom surfaces of a solid laminar PTC sheet of convenient size. As previously mentioned, preferably the PTC sheet is laminated between two metal foil electrodes. Alternatively, electrodes may be plated directly on the top and bottom surfaces of the PTC sheet using conventional electrolytic or electroless plating processes.

Referring to FIG. 4, the terminated laminar PTC sheet is then routed or punched to create a plurality of strips 186, 186', 186'', etc. The strips are created in a regular pattern and preferably have a width, W, approximately the desired length of the final electrical device.

For example, a laminar PTC sheet approximately 6 inches wide by 8 inches long by .0150 inches thick may be routed or punched to create a plurality of strips 186, 186', 186'', etc. approximately 7 inches in length with a width of approximately 0.160 - 0.180 inches or less. The top and bottom surfaces of each strip are composed of the first and second electrodes 100, 110. The side surfaces of each strip are composed of PTC element 20 due to the routing or punching procedure.

After the laminated PTC sheet is routed, a plurality of break points 187, 187', 187'' . . . 187a, 187a', 187a''. . . 187b, 187b', 187b'' . . . etc. are created horizontally across each strip (FIG 4A). The break points allow the final strips to be divided into a plurality of electrical devices by exerting minimal pressure at each break point. Thus, the final strips can be efficiently divided into a plurality of electrical devices by snapping or simply running the strip over an edge. Laboratory tests have indicated that without break points, the conductive layers (described in detail below) tend to smear upon dividing the strips into electrical devices with conventional dicing and shearing techniques. Smeared conductive layers lead to faulty electrical devices and the increased possibility of short circuits.

Generally, the break points are created by removing portions of the electrodes on both the top and bottom surfaces of each strip. This can be accomplished by laminating the routed, terminated PTC sheet illustrated in FIG. 4 with a dry film photo resist material. A masking material is laid over the portions of the photo resist material which are to be developed or cured, leaving a plurality of unmasked regions approximately 5 mils thick stretching horizontally across each strip. Preferably, the unmasked regions are formed on the routed, terminated laminar PTC sheet in the same direction as the direction in which the PTC composition was extruded. Since the polymer chains in the PTC composition are elongated in the direction of extrusion, the brittleness of the PTC sheet is anisotropic. That is, the PTC sheet is stronger in one direction (i.e., perpendicular to the direction of extrusion) than it is in the direction parallel to extrusion. Thus, by creating the break points parallel to the direction of extrusion, the final strips may be easily divided into a plurality of electrical devices.

The unmasked regions should be created to leave a plurality of masked portions having a dimension approximately equal to the desired width of the final electrical device, e.g., 0.100 - 0.150 inches or less. The strips are then exposed to ultraviolet light whereby the unmasked regions of the photo resist material degrade. The degraded photo resist material is rinsed away to expose portions of the electrode surfaces. The exposed portions of the electrodes are then removed by a conventional etching process (e.g., subjecting the exposed electrode surfaces to a ferric chloride solution), thus, creating a plurality break points. Finally, the developed or cured dry film photo resist material is chemically removed by dipping the PTC sheet into a solvent such as potassium hydroxide.

FIG. 5 illustrates a partial enlarged cross-sectional view of several strips of the laminar PTC sheet. While the various process steps are to be carried out after the break points have been formed on the routed PTC sheet, for purposes of clarity, the various process steps will be discussed with reference to a cross-section of a single strip (illustrated in FIGS. 6A-6H and 7A-7D).

Embodiment Illustrated In FIGS. 6A-6H

After the break points have been created on each strip of the routed, terminated laminar PTC sheet (FIG. 6A), the strips of the laminar PTC sheet are coated with an insulating layer 120 (FIG. 6B). The insulating layer 120 may be applied using any one of the following conventional techniques: brushing, laminating, dipping, screen printing or spraying. The insulating layer 120 may comprise any electrically non-conductive material, however, preferred materials include a photo resist material, a ceramic material, a dielectric material, or a solder mask.

A plurality of contact points 130, 140, are formed in a regular pattern on the top and bottom surfaces of each strip (FIGS. 6C-6D). It should be understood that the present invention covers methods where the insulating layer 120 is applied to the strips leaving portions of the electrodes 100, 110 initially exposed to create the contact points 130, 140. Additionally, the present invention covers methods where the insulating layer 120 is initially applied to the entire surface of each strip. Contact points 130, 140 are then formed by removing portions of the insulating layer 120. For example, referring to FIGS. 6B-6D, a positive working photo resist material is used as the insulating layer 120. A mask, reference letter M in FIG. 6C, is applied to the portions of the photo resist material which are to be developed or cured on the surfaces of each strip, leaving portions of the photo resist material which will form the contact points 130, 140 unmasked (shown as cross-hatched portions of the insulating layer in FIG. 6C). The strips are then exposed to ultraviolet light whereby the unmasked portions of the photo resist material degrade. The degraded photo resist material is rinsed away to expose the electrode surfaces (FIG. 6D), thus, forming a plurality of contact points on the top and bottom surfaces of each strip. This process can be reversed using a negative photo resist material (i.e., the unmasked portions will develop or cure upon exposure to ultraviolet light).

After the plurality of contact points 130, 140 has been formed, a first conductive layer 150 is applied to the strips (FIG. 6E). The conductive layer 150 may be applied by a conventional plating technique (e.g., electroless plating). Alternatively, the conductive layer may be applied by dipping, spraying or brushing a conductive material to the strips in a liquid form. In a preferred embodiment the first conductive layer 150 comprises a metal selected from the group consisting of nickel, copper, tin, silver, gold or alloys thereof. The first conductive layer 150 must make electrical contact with the electrodes 100, 110 at each contact point formed on the strips.

As illustrated in FIGS. 2-3 and 6E, the first conductive layer 150 wraps around the end portions of the electrical device 10. This wrap-around configuration makes it possible to make electrical contact to both electrodes from the same side of the electrical device.

In the next step, a plurality of electrically non-conductive gaps 160, 170 are formed in the first conductive layer 150 in a regular pattern on the top and bottom surfaces of each strip (FIGS. 6F-6G). The electrically non-conductive gaps 160, 170 may be formed by applying the first conductive layer 150 initially in a manner which leaves portions of the insulating layer 120 exposed. However, the present invention also covers methods where each strip is completely covered with the first conductive layer 150 and the electrically non-conductive gaps 160, 170 are created by removing portions of the first conductive layer 150 in a regular pattern on the top and bottom surfaces of each strip. Either process results in forming on each strip a plurality of first and second end terminations 155, 156 separated by the electrically non-conductive gaps 160, 170.

For example, with reference to FIGS. 6E-6G, a protective mask, reference letter M in FIG. 6F, is applied to the conductive layer 150, leaving predetermined portions exposed (the exposed portions are represented by the cross-hatched sections of the conductive layer 150 in FIG. 6F). The exposed portions are then removed by a conventional etching process, e.g., subjecting the exposed portions to a ferric chloride solution.

Embodiment Illustrated In FIGS. 7A-7D

Alternatively, the electrically non-conductive gaps 160, 170 and end terminations 155, 156 can be formed by the following method. First conductive layer 150 is applied to each strip, coating insulating layer 120 and contact points 130, 140 (FIG. 6E). Referring now to FIGS. 7A-7D, a photo resist material 190 is applied to the conductive layer 150. If a photo resist material is used to form insulating layer 120, then the second photo resist material 190 used in this step must have an opposite reaction to ultraviolet light (i.e., if a negative-working photo resist material was used to form the insulating layer, than a positive-working photo resist material must be used to form the electrically non-conductive gaps in the conductive layer and vice-versa). A masking material, reference letter M in FIG. 7B, is applied to the outer photo resist layer 190, leaving a plurality of portions of the top and bottom surfaces of the layer 190 exposed in a regular pattern. The strips are then subjected to ultraviolet light, causing the unmasked portions of the outer photo resist layer 190 to degrade. The degraded portions of the photoresist material 190 are rinsed away, leaving a plurality of portions of the first conductive layer 150 exposed in a regular pattern on the top and bottom surfaces of each strip (FIG. 7C). The exposed portions of the conductive layer 150 (shown as cross-hatched sections of the conductive layer in FIG. 7C) are then removed by dipping the strips in a standard etching solution. As a result, portions of insulating layer 120 are exposed. The outer photo resist material 190 is then removed by further exposing the strips to ultraviolet light (FIG. 7D). Since portions of the insulating layer 120 are exposed during this step, it is important to use a photo resist material 190 which has an opposite reaction to ultraviolet light than the photo resist material that may have been used to form insulating layer 120.

As a result of either process, i.e., (1) applying the conductive layer to the entire surface of the strips and then removing portions of the conductive layer or, (2) initially applying the conductive layer in a manner which leaves portions of the insulating layer exposed, first and second end terminations 155, 156 are formed (FIG. 6G).

In the preferred embodiment illustrated in FIGS. 3 and 6H, a second conductive layer 180 is applied to the first conductive layer 150. The second conductive layer 180 is preferably comprised of a solder composition and can be applied by any conventional process, including electrolytic plating or solder dipping. The layer of solder permits the electrical devices 10 of the present invention to be easily connected to the conductive terminals of a PC board.

In the final step, the strips are divided at each break point into a plurality of electrical devices such that each device has a contact point and an electrically non-conductive gap on both sides (i.e., top and bottom) of the device. As previously mentioned, the strips may be divided into a plurality of electrical devices by simply applying a minimal amount of pressure at each break point.

Embodiment Illustrated In Figure 8

With reference to FIG. 8, the arrows indicate the flow of current through the device. The end terminations allow current to flow from a conductive terminal of a PC board, around the outer edge of the device (via the first end termination), to the first electrode at the first contact point. The current then flows through the PTC element to the second electrode. Current exits the device through the contact point of the second end termination and continues to flow through the remainder of the circuit.

Embodiment Illustrated In FIGS. 9A-9G

In another preferred method, electrodes are formed on the top and bottom surfaces of a solid laminar PTC sheet of convenient size. A plurality of break points are also formed as previously described. The process steps for formation of the final electrical device of this embodiment are now described with reference to a cross-section of a single strip (illustrated in FIGS. 9A-9G and 10).

A masking material, reference letter M in FIG. 9B, is applied to the electrodes 100, 110, leaving a plurality of unmasked regions horizontally across each electrode. As previously described, the unmasked portions of the first and second electrodes 100, 110 are then removed by a conventional etching process (e.g., subjecting the exposed electrode surfaces to a ferric chloride solution), thus, creating a plurality of electrically non-conductive gaps 160, 170 in the first and second electrodes. Forming electrically non-conductive gaps 160, 170 directly in the first and second electrodes 100, 110 results in fewer process steps required for the formation of the electrical device 10 of this embodiment.

After creation of the non-conductive gaps 160, 170 on each electrode, the electrodes and the laminated PTC sheet are coated with an insulating layer 120. As shown in FIG. 9C, the insulating layer 120 fills the non-conductive gaps 160, 170. As previously described, the insulating layer 120 may be applied using any one of the following conventional techniques: brushing, laminating, dipping, screen printing or spraying. The insulating layer 120 may comprise any electrically non-conductive material; however, preferred materials include a photo resist material, a ceramic material, a dielectric material, or a solder mask.

After application of the insulating layer 120, a masking material, reference letter M in FIG. 9D, is applied to the side portions of strip. The masking material covers the insulating layer 120 and stops short of the electrically non-conductive gaps 160, 170, leaving the insulating layer 120 on the two top and bottom middle portions of the PTC element exposed. The result is a masked, U-shaped portion 121 of the insulating layer 120 around each end portion of the PTC element (FIG. 9D). The strip is then exposed to ultraviolet light, causing the unmasked portions of the insulating layer 120 to harden or cure. The masked portions are unaffected by the ultraviolet light and rinsed away with a conventional solvent, leaving the two end portions 70, 80 of the PTC sheet and portions of the first and second electrodes 100, 110 exposed (FIG. 9E).

FIG. 9F illustrates the next step in the process wherein a first conductive layer 150 is applied to the exposed ends 70, 80 of the PTC sheet and adjacent to the electrically non-conductive gaps 160, 170 in the electrodes. As previously described, the first conductive layer 150 may be applied by a conventional plating technique (e.g., electrolytic plating). Alternatively, the conductive layer 150 may be applied by electroless plating, direct metallization, or dipping, spraying or brushing a liquid conductive material to the strips. The first conductive layer 150 may comprise a metal selected from the group consisting of nickel, copper, tin, silver, gold or alloys thereof. However, in a preferred embodiment, the first conductive layer 150 is copper. The first conductive layer 150 wraps around the exposed end portions 70, 80 of the electrical device, ending adjacent to the non-conductive gaps 160, 170 formed in the electrodes. The first conductive layer 150 forms first and second end terminations 155, 156 on each end of the device. The end terminations 155, 156 are separated by the electrically non-conductive gaps 160, 170 in the first and second electrodes.

With reference to FIG. 9G, a second conductive layer 180 is applied to the first conductive layer 150. The second conductive layer 180 is preferably comprised of a solder composition (i.e., a tin/lead mixture) and can be applied by any conventional process, including electrolytic plating or solder dipping. The layer of solder permits the electrical devices 10 of the present invention to be easily connected to the conductive terminals of a PC board. To further improve solderability, a nickel layer may be applied to the copper layer prior to the application of the solder layer.

The final step in the process again involves dividing the strips at each break point into a plurality of electrical devices. The strips may also be divided into individual electrical devices by using a conventional shearing or punching process.

Embodiment Illustrated In FIG. 10

With reference to FIG. 10, the arrows indicate the flow of electrical current through the device, which is in a manner different from the previously-described embodiments of the present invention. The first end termination 155 allows current to flow from a conductive terminal of a PC board, up through the second 110 (or bottom) electrode. The current flows through the PTC element 20 to the first 100 (or top) electrode. Current then flows around the second end termination 156, exits the device, and continues to flow through the remainder of the circuit.

Embodiment Illustrated In FIGS. 11A-11G

In another preferred method, electrodes are formed on the top and bottom surfaces of a solid laminar PTC sheet of convenient size. A plurality of break points are also formed as previously described. The process steps for formation of the final electrical device of this embodiment are now described with reference to a cross-section of a single strip (illustrated in FIGS. 11A-11G and 12).

A masking material, reference letter M in FIG. 11B, is applied to the electrodes 100, 110, leaving a plurality of unmasked regions horizontally across each electrode. Optionally, a stencil material having a plurality of blackened areas is laid over the masking material with the blackened areas aligned with the unmasked regions of the electrodes (not shown). The strip is then exposed to ultraviolet light, which penetrates through the stencil material, except the blackened areas, and to the masked portions. The stencil is removed and as previously described, the unmasked portions of the first and second electrodes 100, 110 are then removed by a conventional etching process (e.g., subjecting the exposed electrode surfaces to a ferric chloride solution), thus, creating a plurality of electrically non-conductive gaps 160, 170 in the first and second electrodes. In this preferred embodiment, the non-conductive gap 160 in the first electrode is formed at the end of the electrode adjacent the first end portion 70 of the device (FIG. 11B). Forming electrically non-conductive gaps 160, 170 directly in the first and second electrodes 100, 110 results in fewer process steps required for the formation of the electrical device 10 of this embodiment.

After creation of the non-conductive gaps 160, 170 on each electrode, the electrodes and the laminated PTC sheet are coated with an insulating layer 120. As shown in FIG. 11C, the insulating layer 120 fills the non-conductive gaps 160, 170. The insulating layer 120 is applied by any of the techniques previously described. The insulating layer 120 may comprise any electrically non-conductive material, but preferred materials include a photo resist material, a ceramic material, a dielectric material, or a solder mask.

With reference to FIG. 11D, after application of the insulating layer 120, a masking material, reference letter M, is applied to the top and bottom surfaces of each strip. In this preferred embodiment, the masking material covers the insulating layer 120 on the first end portion 70 leaving an L-shaped area 120a of insulating material, adjacent the first electrically non-conductive gap 160. On the opposed second end portion 80, the masking material covers the insulating layer falling just short of the second electrically non-conductive gap 170, resulting in a U-shaped area 120b of insulating layer (FIG. 11D). The strip is then exposed to ultraviolet light curing the unmasked portions of the insulating layer 120. The masked portions of the insulating layer 120 are rinsed away, leaving the two end portions 70, 80 of the PTC sheet and portions of the first and second electrodes 100, 110 exposed (FIG. 11E).

FIG. 11F illustrates the next step in the process wherein a first conductive layer 150 is applied by a conventional plating technique (e.g., electrolytic plating), or alternatively, by dipping, spraying or brushing a liquid conductive material to the strips. The first conductive layer 150 is also in contact with the exposed ends 70, 80 of the PTC sheet and adjacent to the electrically non-conductive gaps 160, 170 in the electrodes. While the first conductive layer 150 may comprise a metal selected from the group consisting of nickel, copper, tin, silver, gold or alloys thereof, in this preferred embodiment, the first conductive layer 150 is copper. The first conductive layer 150 forms an L-shaped end termination 155 around the first end portion 70 of the electrical device, and a U-shaped end termination 156 around the second end portion 80 of the PTC device (FIG. 11F). The end terminations 155, 156 are adjacent to and separated by the electrically non-conductive gaps 160, 170 in the first and second electrodes.

With reference to FIG. 11G, a second conductive layer 180 is applied to the first conductive layer 150. The second conductive layer 180 is preferably comprised of a solder composition (i.e., a tin/lead mixture) and can be applied by any conventional process, including electrolytic plating or solder dipping. The layer of solder permits the electrical devices 10 of the present invention to be easily connected to the conductive terminals of a PC board.

The final step in the process again involves dividing the strips at each break point into a plurality of electrical devices; e.g., shearing, snapping, or punching.

Embodiment Illustrated In FIG. 12

With reference to FIG. 12, the arrows indicate the flow of electrical current through the device 10. The end terminations 155, 156 allow current to flow from a conductive terminal of a PC board, up through the second 110 (or bottom) electrode. The current flows through the PTC element 20 to the first 100 (or top) electrode. Current then flows around the U-shaped end termination 156, exits the device, and continues to flow through the remainder of the circuit. While previous embodiments were symmetrically oriented, the device of this embodiment works most efficiently when attached to the circuit board in the manner illustrated in FIG. 12, or where the current enters at the U-shaped end termination 156 and exits via the L-shaped end termination 155.

Embodiment Illustrated In FIG. 13

With reference to FIG. 13 there is illustrated a preferred embodiment of a device 10 for protecting an electrical circuit. The device 10 comprises a resistive element 20 having first and second surfaces 30,40, and first and second side walls 31,32. As previously mentioned, preferably the resistive element 20 exhibits PTC behavior and comprises a conductive polymer. A first electrode 100 is in electrical contact with the first surface 30 of the resistive element 20 and a second electrode 110 is in electrical contact with the second surface 40 of the resistive element 20. The device 10 includes first and second end terminations 155,156. The first end termination 155 electrically connects the circuit to be protected with the second electrode 110. The second end termination 156 electrically connects the first electrode 100 with the circuit to be protected. An electrically insulating layer 120 is interposed between the first and second end terminations 155,156 and is in contact with the first and second electrodes 100,110. The electrically insulating layer 120 acts as a barrier to current flow through the device

10, ensuring that current flows from the first end termination 155 to the second electrode 110, through the resistive element 20 to the first electrode 100, and from the first electrode 100 to the second end termination 156.

In the preferred embodiment of FIG. 13, the electrically insulating layer 120 is formed on the first and second electrodes 100,110. To ensure proper current flow through the device 10, the insulating layer 120 contacts the first and second surfaces 30,40 of the resistive. The contact point with the first surface 30 of the resistive element 20 is intermediate the first end termination 155 and the first electrode 100. The contact point with the second surface 40 of the resistive element 20 is intermediate the second end termination 156 and the second electrode 110.

In the preferred embodiment illustrated in FIG. 13, the first and second end terminations 155,156 are each comprised of a first conductive layer 150 and a second conductive layer 180. The end terminations 155,156 wrap-around the side walls 31,32 of the resistive element 20. In this embodiment, the first conductive layer 150 of the first and second end terminations 155,156 contact a portion of the first and second surfaces 30,40 of the resistive element 20, respectively. In the preferred wrap-around configuration, the first conductive layer 150 of the first and second end terminations 155,156 also contacts the first and second side walls 31,32 of the resistive element 20.

The first end termination 155 must be in electrical contact with the second electrode 110 and the second end termination 156 must be in electrical contact with the first electrode 100. However, in the preferred embodiment of FIG. 13, the first end termination 155 is in direct physical contact with the second electrode 110 and the second end termination 156 is in direct physical contact with the first electrode 100.

The preferred materials for use in the device 10 illustrated in FIG. 13 are the same as those previously discussed in connection with the embodiments illustrated in FIGS. 1-12.

Embodiments Illustrated In FIGS. 14A-14H

The process for manufacturing the device 10 illustrated in FIG. 13 is similar to the process explained above with respect to FIGS. 6A-6H, 7A-7D, 9A-9G and 11A-11G. The process is carried out on a routed laminar PTC sheet as illustrated in FIG. 4A. However, for purposes of clarity, the various process steps will be discussed with reference to a cross-section of a single strip.

With reference to FIGS. 14A-14C gates 210 are formed in the electrodes 100,110. The routed sheet is precleaned and a photo resist material 200 is applied to each strip of the sheet. A photo resist material 200 is imaged using a mask or photolithographic art work as is well known in the art to define the gates 210 on the top and bottom of the device 10. As will be explained further below, the gates 210 will allow the insulating layer 120 to contact the first and second surfaces 30,40 of the resistive element 20 and form an insulating barrier between the first end termination 155 and the first electrode 100, and the second end termination 156 and the second electrode 110.

The unmasked photo resist material is cured and developed, removing the unmasked material and exposing the electrodes 100,110 under the gates 210 (FIG. 14B). The exposed portions of the electrodes 100,110 are etched away by subjecting the electrode portions to a ferric chloride solution (indicated in FIG. 14B by arrows).

As a result, portions of the first and second surfaces 30,40 of the resistive element 20 are exposed. The remaining photo resist material is then stripped away and the panel is cleaned (FIG. 14C).

With reference to FIGS. 14D-14F, the end terminations 155,156 are defined. Insulating layer 120 comprising a dielectric material is applied to the device 10 by any conventional method (e.g., screen print or spray application). Solder mask is the preferred dielectric material. The end terminations are imaged onto the solder mask material 120 using a mask or photolithographic art work. As shown in FIG. 14E, the unmasked material 220 is cured and developed, removing the uncured material 220 and exposing portions of electrodes 100',110' and the side walls 31,32 of the resistive element 20. With reference to FIG. 14F, the exposed portions of the electrodes 100',110' are removed by a conventional etching process (e.g., dipping in a ferric chloride solution).

Finally, referring to FIGS. 14G-14H, the first and second end terminations 155,156 are created by depositing a first conductive layer 150 to the exposed end portions (indicated by reference numeral 20' in FIG 14F) of the resistive element 20. Preferably, the first conductive layer 150 comprises copper and is deposited using a conventional electrolytic plating process and has a thickness of approximately 0.001 inch to approximately 0.0015 inch. To improve the solderability of the device 10 to a conventional PC board, a second conductive layer 180 is applied to the first conductive layer 150 (FIG. 14H). In a preferred embodiment, the second conductive layer 180 comprises a mixture of tin and lead (e.g., solder).

Embodiment Illustrated In FIG. 15

In the preferred embodiment of the present invention illustrated in FIG. 15 there is provided a surface-mountable device 10 for protecting an electrical circuit comprising a resistive element 20 in series with a fusible element 250.

The resistive element 20 has first and second surfaces 30,40 and first and second side walls 31,32. A first electrode 100 is in electrical contact with the first surface 30 and a second electrode 110 is in electrical contact with the second surface 40.

Similar to the embodiment illustrated in FIG 13, the device shown in FIG. 15 has a first end termination 155 which provides an electrical connection between the circuit to be protected and the second electrode 110. However, since the fusible element 250 is electrically connected in series with the resistive element 20, the second end termination 156 provides an electrical connection between the fusible element 250 and the circuit to be protected.

A first electrically insulating layer 120 is formed on the first electrode

100 and is interposed between the first electrode 100 and the fusible element 250. The insulating layer 120 comprises a main portion 120a and a sub-portion 120b. The fusible element 250 is electrically connected to the resistive element 20 through a conductive member 260.

In the preferred embodiment illustrated in FIG. 15, the conductive member 260 extends through the first insulating layer 120 and the first electrode 100, and contacts the resistive element 20 at a point on the first surface 30 intermediate the main portion 120a and the sub-portion 120b of the insulating layer 120.

The main portion 120a of the insulating layer 120 contacts the resistive element 20 intermediate the first electrode 100 and the second end termination 156, acting as a barrier to direct current flow from the first electrode 100 to the second end termination 156. Likewise, the sub-portion 120b of the insulating layer 120 contacts the resistive element 20 intermediate the first end termination 155 and the first electrode 100, acting as a barrier to direct current flow from the first end termination 155 to the first electrode 100.

A second electrically insulating layer 121 is formed on the second electrode 110. The second insulating layer 121 makes contact with the resistive element 20 intermediate the second electrode 110 and the second end termination 156, acting as a barrier to direct current flow from the second electrode 110 to the second end termination 156.

As shown in FIG. 15, the fusible element 250 extends from the sub-portion 120b of the insulating layer 120 to the second end termination 156. A protective layer 270 covers the fusible element 250 to protect the fusible element from impact and oxidation.

The end terminations 155,156 of the device illustrated in FIG. 15 are also comprised of first and second conductive layers 150,180, respectively. The end terminations 155,156 preferably include the wrap-around configuration contacting the first and second surfaces 30,40 and the side walls 31,32 of the resistive element, respectively.

The preferred materials for use in the device 10 illustrated in FIG. 15 are the same as those previously discussed in connection with the embodiments illustrated in FIGS. 1-14.

Embodiment Illustrated In FIGS. 16A-16G

The device 10 comprising a fusible element 250 electrically connected in series with a resistive element 20 can be manufactured by a method similar to the methods discussed above.

In the first step illustrated in FIG 16A, using the photolithographic, etching and dielectric applications discussed above, portions of the first and second electrodes 100,110 are removed to develop the gate (i.e., the aperture through the first electrode 100 and the first insulating layer 120 where the conductive member 260 will be formed) and the end terminations. In developing the gate, the main portion 120a and the sub-portion 120b of the insulating layer 120 are formed.

Referring to FIG. 16B, a conductive material is plated onto the exposed portions of the resistive element forming the conductive member 260 and the first conductive layer 150 of the end terminations 155,156, respectively.

Next, the entire strip is electroless plated with copper (FIG. 16C). To form the fusible element 250, a photo resist material is applied to the strip, the fusible element 260 is imaged onto the resist material, and the material is cured and developed. The unprotected electroless copper layer is etched away and the cured photo resist is stripped, leaving behind the fusible element 260 (FIG. 16D).

Referring to FIG. 16E, the protective layer 270 comprised of a dielectric material is applied to the fusible element 250 by coating the entire surface of the strip comprising the fusible element 250. Referring now to FIG 16F, the protective layer 270 is imaged and developed to expose the first conductive layer 150 of the end terminations 155,156. In doing so, a small portion of the fusible element 250 in direct contact with the first conductive layer 150 of the second end termination 156 is also exposed.

Finally, a second conductive layer 180 is applied to the first conductive layer 150, completing the first and second end terminations 155,156. Each strip in the laminated sheet is then divided into a plurality of devices for protecting electrical circuits.

In the finished device 10 illustrated in FIG. 15 and made according to the method illustrated in FIGS. 16A-16G, electrical current flows from the circuit into first end termination 155 to the second electrode 110. Current then travels through the resistive element 20 to the first electrode 100 and through the conductive member 260 to the fusible element 250. From the fusible element 250, the current flows through the second end termination 156 and out to the circuit.

__Embodiment Illustrated In FIGS. 17-18__

Referring now to the embodiments illustrated in **Figures 17-18**, there is shown a circuit protection device 10 having a fusible element 250 electrically connected in series with a PTC element 210. Similar to the embodiments described above, the PTC element 210 has first and second sidewalls 31,32 connected to top and bottom surfaces 30,40. First and second electrodes 100,110 are in electrical contact with the PTC element 210.

An insulating layer 120 is deposited on the first and second electrodes 100,110 and wraps around the sidewalls 31,32 of the PTC element 210. Portions of the insulating layer 120 are removed to form first and second contact points 290,300.

A first conductive layer 310 is deposited on the insulating layer 120 and is in electrical contact with the first electrode 100. A second conductive layer 320 is also deposited on the insulating layer 120 and is in electrical contact with the second electrode 110. Preferably, the first conductive layer 310 is in direct physical contact with the first electrode 100 at the first contact point 290 and the second conductive layer 320 is in direct physical contact with the second electrode 110 at the second contact point 300. In order to make electrical contact from the same side of the device 10, the first conductive layer 310 wraps around the first sidewall 31 of the PTC element 210.

As shown in FIG. 17, the second conductive layer 320 may be adjacent the bottom surface 40 of the PTC element only. Alternatively, as shown in FIG. 18, the second conductive layer 320 may wrap around the second sidewall 32 of the PTC element 210. In either embodiment, the insulating layer 120 is interposed between the PTC element 210 and both conductive layers 310,320 except for the electrical connections made at first and second contact points 290,300.

In contrast to the embodiments illustrated in FIGS. 17 and 18, the insulating layer 120 is not required to wrap completely around the first and second sidewalls 31,32 of the PTC element 210.

Embodiment Illustrated In FIG. 19

For example, with reference to FIG. 19, the insulating layer 120 only wraps around a portion of the sidewalls 31,32. Portions of the first and second electrodes 100,110 adjacent to the sidewalls 31,32 and extending the length of the sidewalls 31,32 are removed to form insulation channels 325. The insulation channels 325 are filled by the insulating layer 120 to prevent short circuits from occurring between the conductive layers 310,320 and the electrodes 100,110. In essence, the PTC element 210 is "framed" at each corner by the insulating layer 120.

In another embodiment (not shown), the insulating layer 120 does not wrap around and extend down the sidewalls 31,32. In this embodiment, however, it is preferred to include the insulation channels 325 to prevent short circuits as discussed above.

In the embodiments illustrated in FIG. 19 and wherein the insulating layer 120 does not wrap around and extend down the sidewalls 31,32, the first and second conductive layers 310,320 wrap around and are in direct contact with at least a portion of the sidewalls 31,32 of the PTC element 210.

Referring now to FIGS. 17-19 a portion of the first conductive layer 310 adjacent a central portion of the PTC element 210 (i.e., between first and second sidewalls 31,32) forms a fusible element 250 such that the PTC element 210 and the fusible element 250 are electrically connected in series. The fusible element 250 may take numerous shapes and sizes according to the desired electrical rating of the device 10. For example, the fusible element 250 illustrated in FIG. 21 has a comb-like or serpentine configuration which can be varied to accommodate different ratings. Generally, however, the fusible element 250 will take a configuration similar to the narrow longitudinal strip illustrated in FIG. 20, with a width, W, between about 0.0001 - 0.1 inch and a length, L, between about 0.005 - 0.150 inch.

The fusible element 250 is comprised of a conductive material having an electrical resistivity less than the electrical resistivity of the PTC element 210. Generally the conductive material will be a metal or metal alloy (e.g., nickel, copper, silver, tin, gold and alloys thereof). In a preferred embodiment, the fusible element 250 comprises copper and includes a diffusion bar 340. The diffusion bar 340 is composed of a quantity of tin (or alloy thereof) deposited on the fusible element 250 and acts to lower the melting point of the copper in contact with the tin (or alloy thereof). Thus, the blowing temperature of the fusible element 250 is reduced. The blowing temperature of the fusible element 250 can be controlled by varying the amount of tin (or alloy thereof) deposited on the copper. Additionally, by reducing the blowing temperature of the fusible element 250 a lower melting point material may be used to form the insulating layer 120 (the layer upon which the first conductive layer 310 and fusible element 250 are deposited).

The diffusion bar 340 also increases the overall melting energy, I^2t, of the device 10.

With reference to FIGS. 18 and 19, a second insulating layer 330 is deposited on and covers the fusible element 250 and the diffusion bar 340. Preferably, the second insulating layer 330 is composed of a transparent material. Colored, clear materials may also be used for insulating layer 330. Color coding may be accomplished through the use of a colored insulating layer 330. In other words, different colors of dielectric material can correspond to different amperages, providing the user with a ready means of determining the amperage of any given device. The transparency of the insulating layer 330 permits the user to visually inspect the fusible element 250 prior to installation, and during use, of the electrical device.

The second insulating layer 330 cooperates with the first insulating layer 120 to isolate the first conductive layer 310 from the second conductive layer 320 and decrease the likelihood of a short circuit occurring between the layers 310,320.

As previously mentioned, first and second conductive layers 310,320 preferably comprise copper. With reference to FIGS. 18 and 19 a third conductive layer

350, preferably comprising nickel, is deposited on the first and second 310,320 conductive layers. A fourth conductive layer 360, preferably solder, tin or a mixture of tin and lead, is deposited on the third conductive layer 350 to promote solderability to additional components (e.g., a printed circuit board).

The nickel layer acts as a barrier layer between the copper and solder layers. Without the nickel layer, the copper layer would diffuse into the solder layer or visa-versa forming an intermetallic region. The intermetallic region could alter the physical and electrical characteristics of the device.

The third and fourth conductive layers 350,360 are interrupted by electrically non-conductive gaps 370,380. The gaps 370,380 prevent current from flowing circularly around the PTC element 210 rather than flowing through the PTC element 210 and the fusible element 250.

It should be understood that the first and second contact points 290,300 may be formed at any point along the first and second electrodes 100,110. For example, as illustrated in FIGS. 17-19, the contact points 290,300 may be formed closer to either the first or second sidewall 31,32 of the PTC element 210 than to the other sidewall of the PTC element 210. Alternatively, as illustrated in FIGS. 6-8, the first contact point 290 may be formed closer to the first sidewall 31 than the second sidewall 32, while the second contact point 300 is formed closer to the second sidewall 32 than the first sidewall 31.

As discussed above, the insulating layers 120,330 may be comprised of any electrically non-conducting material; however, in a preferred embodiment the insulating layers are formed from a material consisting of photo resist, dielectric, ceramic, epoxy and solder mask.

The first and second conductive layers 310,320 may be formed from a metal selected from the group consisting of nickel, copper, silver, tin, zinc, gold and alloys thereof. As previously mentioned, copper is especially preferred.

The PTC element 210 is comprised of a crystalline polymer having a conductive filler dispersed therein. The preferred compositions discussed above with respect to resistive element 20 (referenced in FIGS. 2-3 and 6-8) are also the preferred compositions for the PTC element 210 (referenced in FIGS. 17-19).

The electrical devices illustrated in FIGS. 17-21 can be manufactured according to the processing steps discussed above for the devices illustrated in FIGS. 1-8. For example, the device illustrated in FIG. 19 can be manufactured by starting with the terminated laminar sheet illustrated in FIG. 4A. The insulation channels 325 are formed by etching away portions of the electrodes 100,110. The insulating layer 120 is applied to the first and second electrodes 100,110, filling the insulation channels 325. The first and second contact points 290,300 are created according to the previously discussed photolithographic and etching processes. The first conductive layer 310 is disposed on the insulating layer 120 making electrical contact with the first contact point 290. Portions of the first conductive layer 310 are etched away to form fusible element 250. The diffusion bar 340 is applied to the fusible element 250 by any conventional deposition process.

At this point, second insulating layer 330 is deposited on the first conductive layer 310, covering the fusible element 250 and the diffusion bar 340. The second conductive layer 320 is then disposed on the insulating layers 120,330 making electrical contact with the second electrode 270 at the second contact point 300. A portion of the second conductive layer 320 is etched away, leaving behind a portion which wraps around the second sidewall 32 of the PTC element 210. A portion of the second insulating layer 330 is then removed, exposing a portion of the first conductive layer 310 that wraps around the first sidewall 31 of the PTC element 210.

The strips are completely coated with third and fourth conductive layers 350,360. Portions of the third and fourth conductive layers 350,360 are then etched away to form electrically non-conductive gaps 370,380. As a result, first and second end terminations 400, 410 are created. In the final step, the strips are divided at each break point into a plurality of electrical devices. The electrical devices have an electrical resistance at approximately 25°C of less than 1 ohm, preferably less than 0.5 ohm and especially less than 0.1 ohm.

CLAIMS

What is claimed is:

1. A device for protecting an electrical circuit comprising:

a resistive element having a first and a second surface;

a first electrode in electrical contact with the first surface of the resistive element and a second electrode in electrical contact with the second surface of the resistive element;

a first end termination electrically connecting the circuit and the second electrode;

a second end termination electrically connecting the first electrode and the circuit; and

an electrically insulating layer interposed between the first and second end terminations and in contact with the first and second electrodes.

2. The device of Claim 1, wherein the resistive element exhibits PTC behavior.

3. The device of Claim 1, wherein the resistive element is comprised of a conductive polymer.

4. The device of Claim 1, wherein the electrically insulating layer is in contact with the first and the second surfaces of the resistive element.

5. The device of Claim 2, wherein the electrically insulating layer is in contact with the first surface of the resistive element at a point intermediate the first end termination and the first electrode.

6. The device of Claim 2, wherein the electrically insulating layer is in contact with the second surface of the resistive element at a point intermediate the second end termination and the second electrode.

7. The device of Claim 1, wherein the first end termination contacts a portion of the first and second surfaces of the resistive element.

8. The device of Claim 1, wherein the first end termination is in direct physical contact with the second electrode.

9. The device of Claim 1, wherein the second end termination is in direct physical contact with the first electrode.

10. The device of Claim 1, wherein the resistive element further includes a first and a second side wall, the first end termination contacting the first side wall and the second end termination contacting the second side wall.

11. The device of Claim 1, wherein the first and second end terminations are comprised of a first and a second conductive layer, respectively.

12. The device of Claim 9, wherein the first conductive layer comprises a metal selected from the group consisting of tin, silver, copper, nickel, gold and alloys thereof.

13. The device of Claim 9, wherein the second conductive layer comprises tin.

14. The device of Claim 9, wherein the first conductive layer comprises copper and the second conductive layer comprises solder.

15. The device of Claim 1, wherein the electrically insulating layer comprises a material selected from the group consisting of photo resist, dielectric, ceramic and solder mask.

16. The electrical device of Claim 1, wherein the electrodes comprise a metallic foil.

17. A device for protecting an electrical circuit comprising:

a resistive element having a first and a second surface;

a first electrode in electrical contact with the first surface of the PTC element and a second electrode in electrical contact with the second surface of the PTC element;

a first end termination providing electrical connection between the circuit and the second electrode;

a fusible element electrically connected in series with the PTC element; and

a second end termination providing electrical connection between the fusible element and the circuit.

18. The device of Claim 17, wherein the resistive element exhibits PTC behavior.

19. The device of Claim 17, wherein the resistive element is comprised of a conductive polymer.

20. The device of Claim 17 further including a conductive member electrically connecting the resistive element with the fusible element.

21. The device of Claim 17 further including a first electrically insulating layer interposed between the first electrode and the fusible element.

22. The device of Claim 21, wherein the first electrically insulating layer comprises a main portion and a sub-portion, and a conductive member electrically connects the resistive element and the fusible element at a point intermediate the sub-portion and the main portion of the first electrically insulating layer.

23. The device of Claim 21 further including a second electrically insulating layer in contact with the second electrode.

24. The device of Claim 23, wherein the second electrically insulating layer acts as a barrier to direct current flow from the second electrode to the second end termination.

25. The device of Claim 17 further including a protective layer covering the fusible element.

26. The device of Claim 17, wherein the first and second end terminations are comprised of a first and a second conductive layer, respectively.

27. The device of Claim 20, wherein the fusible element is in direct contact with the conductive member and the second end termination.

28. The device of Claim 26, wherein the first conductive layer comprises a metal selected from the group consisting of tin, silver, copper, nickel, gold and alloys thereof.

29. The device of Claim 26, wherein the second conductive layer comprises tin.

30. The device of Claim 26, wherein the first conductive layer comprises copper and the second conductive layer comprises solder.

31. The device of Claim 21, wherein the first electrically insulating layer comprises a material selected from the group consisting of photo resist, dielectric, ceramic and solder mask.

32. The device of Claim 23, wherein the second electrically insulating layer comprises a material selected from the group consisting of photo resist, dielectric, ceramic and solder mask.

33. A device for protecting an electrical circuit comprising:

a conductive polymer PTC element having a first and a second surface and a first and a second side wall;

a first electrode in electrical contact with the first surface of the PTC element and a second electrode in electrical contact with the second surface of the PTC element;

a first end termination electrically connecting the circuit and the first electrode and contacting the first side wall of the PTC element;

a second end termination electrically connecting the second electrode and the circuit and contacting the second side wall of the PTC element; and

an electrically insulating layer interposed between the first and second end terminations and in contact with the first and second electrodes.

34. An electrical device for protecting a circuit comprising:

a conductive polymer PTC element having a first and a second surface and a first and a second side wall;

a first electrode in electrical contact with the first surface of the PTC element and a second electrode in electrical contact with the second surface of the PTC element;

a first end termination providing electrical connection between the circuit and the first electrode and contacting the first side wall of the PTC element;

a fusible element electrically connected in series with the PTC element; and

a second end termination providing electrical connection between the fusible element and the circuit and contacting the second side wall of the PTC element.

35. An electrical device comprising:

a PTC element having first and second sidewalls connected to top and bottom surfaces;

a first and second electrode in electrical contact with the PTC element;

an insulating layer deposited on the first and second electrodes, the insulating layer having portions removed to form first and second contact points;

a first conductive layer in electrical contact with the first electrode;

a second conductive layer in electrical contact with the second electrode; and

a portion of the first conductive layer forming a fusible element such that the PTC element and the fusible element are electrically connected in series.

36. The device of Claim 35, wherein the insulating layer wraps around the first and second sidewalls of the PTC element.

37. The device of Claim 35, wherein the first conductive layer wraps around the first sidewall of the PTC element.

38. The device of Claim 37, wherein the insulating layer is interposed between the first sidewall of the PTC element and the first conductive layer.

39. The device of Claim 35, wherein the first and second conductive layers wrap around the first and second sidewalls of the PTC element, respectively.

40. The device of Claim 39, wherein the insulating layer is interposed between the first sidewall of the PTC element and the first conductive layer and interposed between the second sidewall of the PTC element and the second conductive layer.

41. The device of Claim 35, wherein a second insulating layer covers the fusible element.

42. The device of Claim 35, wherein the first conductive layer is in direct physical contact with the first electrode at the first contact point and the second conductive layer is in direct physical contact with the second electrode at the second contact point.

43. The device of Claim 35, wherein portions of the first and second electrodes adjacent the first and second sidewalls of the PTC element have been removed to form insulation channels, the insulation channels being filled by the insulating layer.

44. The device of Claim 35, wherein the PTC element is comprised of a crystalline polymer having a conductive filler dispersed therein.

45. The device of Claim 35 further comprising a third conductive layer disposed on the first and second conductive layers.

46. The device of Claim 45 further comprising a fourth conductive layer disposed on the third conductive layer.

47. The device of Claim 35, wherein the first and second contact points are formed closer to either the first or second sidewall of the PTC element than the other sidewall of the PTC element.

48. The device of Claim 35, wherein the first contact point is closer to the first sidewall of the PTC element than the second sidewall of the PTC element and the second contact point is closer to the second sidewall of the PTC element than the first sidewall of the PTC element.

49. The device of Claim 35, wherein the insulating layer is formed from a material selected from the group consisting of photo resist, dielectric, ceramic, epoxy and solder mask.

50. The device of Claim 35, wherein the first conductive layer comprises a metal selected from the group consisting of nickel, copper, silver, tin, zinc, gold and alloys thereof.

51. The device of Claim 35, wherein the second conductive layer comprises a metal selected from the group consisting of nickel, copper, silver, tin, zinc, gold and alloys thereof.

52. The device of Claim 35, wherein the first and second conductive layers comprise copper.

53. The device of Claim 45, wherein the third conductive layer comprises nickel.

54. The device of Claim 46, wherein the fourth conductive layer comprises solder.

55. The device of Claim 35, wherein the fusible element has a width, W, between about 0.0001 - 0.1 inch and a length, L, between about 0.005 - 0.150 inch.

56. An electrical device comprising:

a PTC element having first and second sidewalls connected to top and bottom surfaces, the PTC element composed of a crystalline polymer having a conductive filler dispersed therein;

first and second electrodes in electrical contact with the PTC element;

a first insulating layer disposed on the first and second electrodes;

a first conductive layer in electrical contact with the first electrode at a first contact point, a portion of the first conductive layer forming a fusible element such that the fusible element is electrically connected in series with the PTC element;

a second conductive layer in electrical contact with the second electrode at a second contact point;

a second insulating layer covering the fusible element;

a third conductive layer disposed on the second conductive layer; and

a fourth conductive layer disposed on the third conductive layer.

57. The device of Claim 56, wherein the fusible element further includes a diffusion bar.

58. The device of Claim 57, wherein the diffusion bar comprises tin or an alloy thereof.

59. The device of Claim 56, wherein the PTC element and the fusible element each have a resistance at approximately 25°C, the resistance of the PTC element being greater than the resistance of the fusible element.

60. The device of Claim 56, wherein the fusible element is serpentine shaped.

61. The device of Claim 56, wherein the second insulating layer is composed of a transparent material.

62. The device of Claim 56, wherein the first conductive layer comprises a metal selected from the group consisting of nickel, copper, silver, tin, zinc, gold and alloys thereof.

63. The device of Claim 56, wherein the second conductive layer comprises a metal selected from the group consisting of nickel, copper, silver, tin, zinc, gold and alloys thereof.

64. The device of Claim 56, wherein the first and second conductive layers comprise copper.

65. The device of Claim 56, wherein the third conductive layer comprises nickel.

66. The device of Claim 56, wherein the first and second insulating layers are formed from a material selected from the group consisting of photo resist, dielectric, ceramic, epoxy and solder mask.

67. The device of Claim 56, wherein the fourth conductive layer comprises a mixture of tin and lead.

68. An electrical circuit protection device comprising:

a PTC element having first and second sidewalls connected to top and bottom surfaces, the PTC element composed of a crystalline polymer having carbon particles dispersed therein and an electrical resistivity at approximately 25°C of less than 10 ohm cm;

first and second electrodes in electrical contact with the PTC element;

a first insulating layer composed of a dielectric material and disposed on the first and second electrodes, the insulating layer having portions removed to form first and second contact points;

a first conductive layer comprising copper, being in electrical contact with the first electrode at the first contact point, and wrapping around the sidewall of the PTC element, a portion of the first conductive layer forming a fusible element such that the fusible element is electrically connected in series with the PTC element;

a second insulating layer composed of a dielectric material covering the fusible element;

a second conductive layer comprising copper, being in electrical contact with the second electrode at the second contact point, and wrapping around the second sidewall of the PTC element;

a third conductive layer comprising nickel and being disposed on the first and second conductive layers; and,

a fourth conductive layer comprising solder and being disposed on the third conductive layer.

69. The device of Claim 68, wherein the device has a resistance at approximately 25°C of less than 1 ohm.

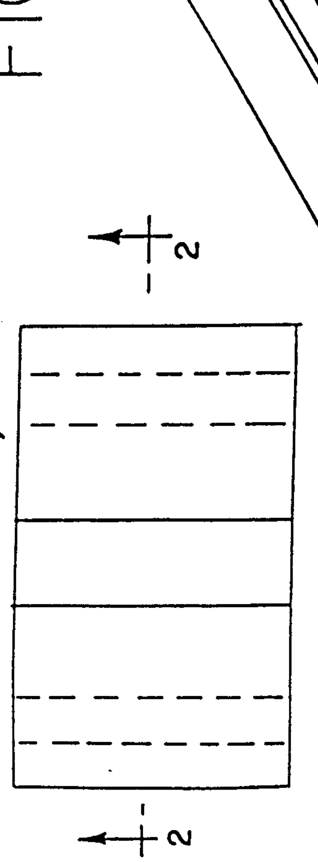


FIG. 1

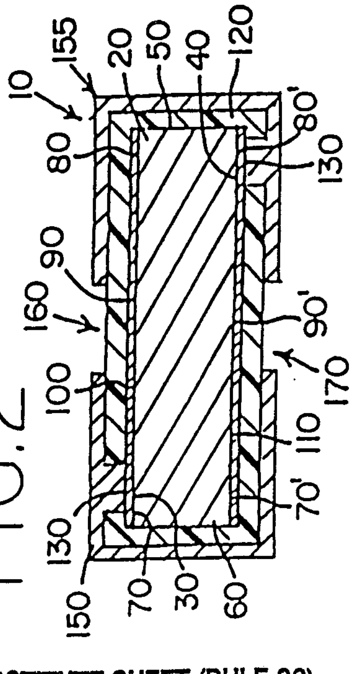


FIG. 2

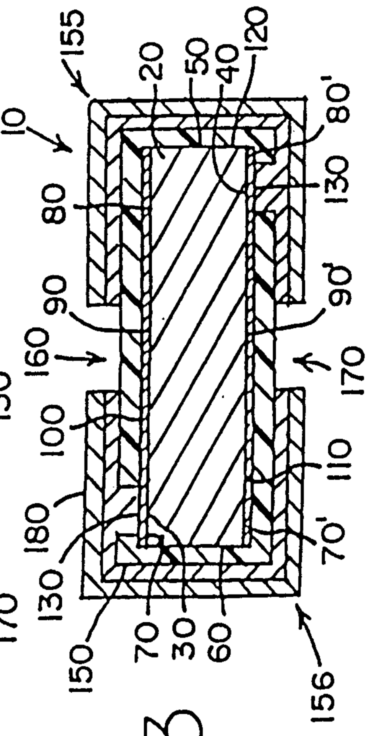


FIG. 3

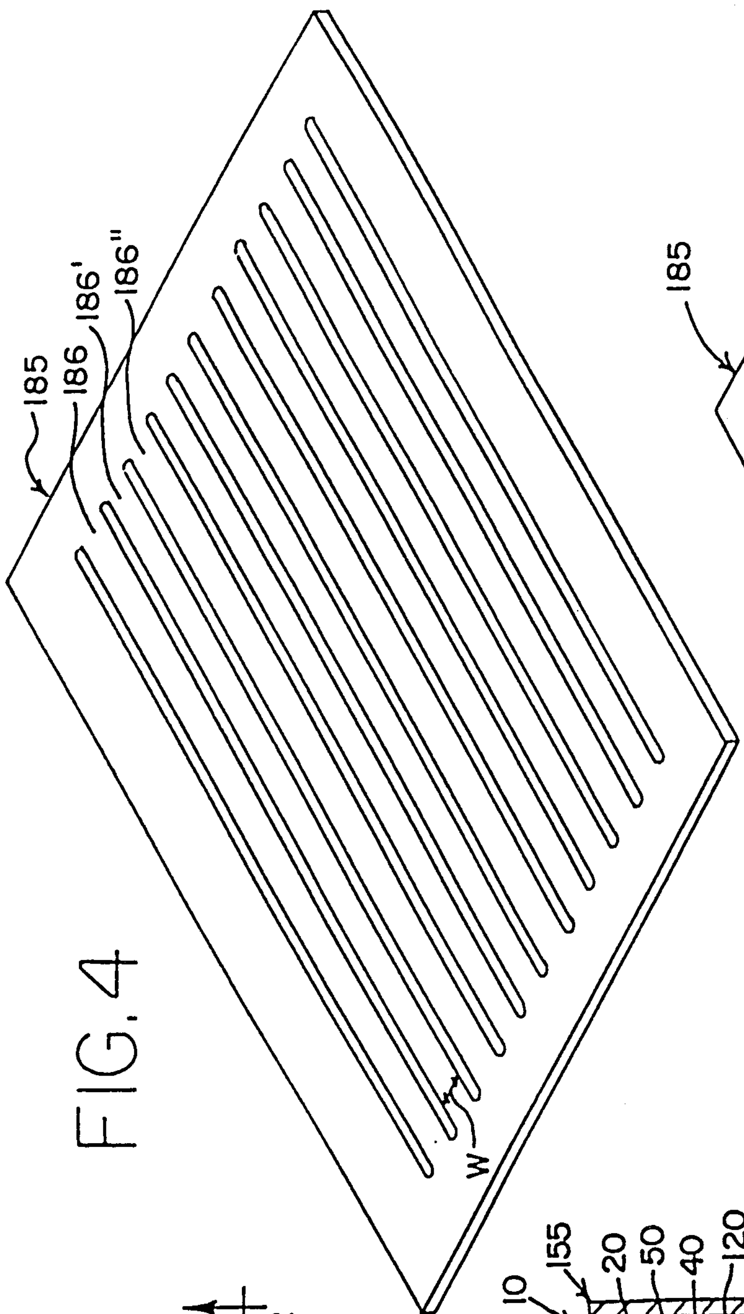


FIG. 4

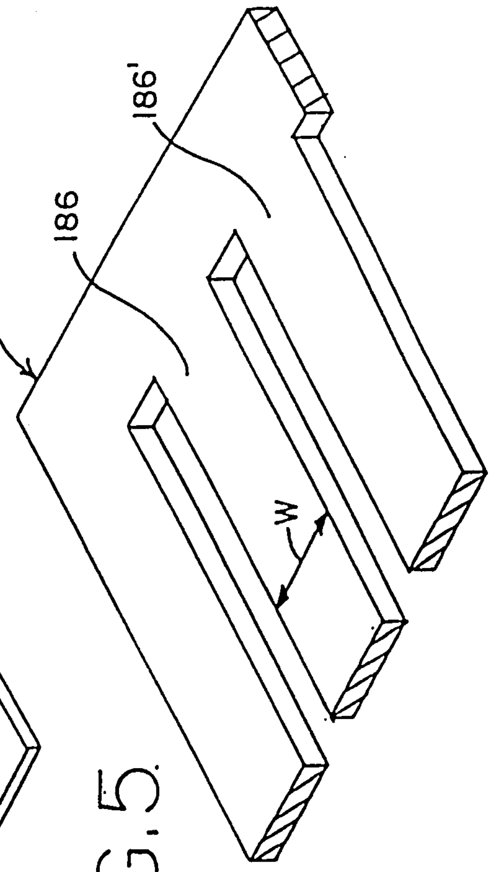


FIG. 5

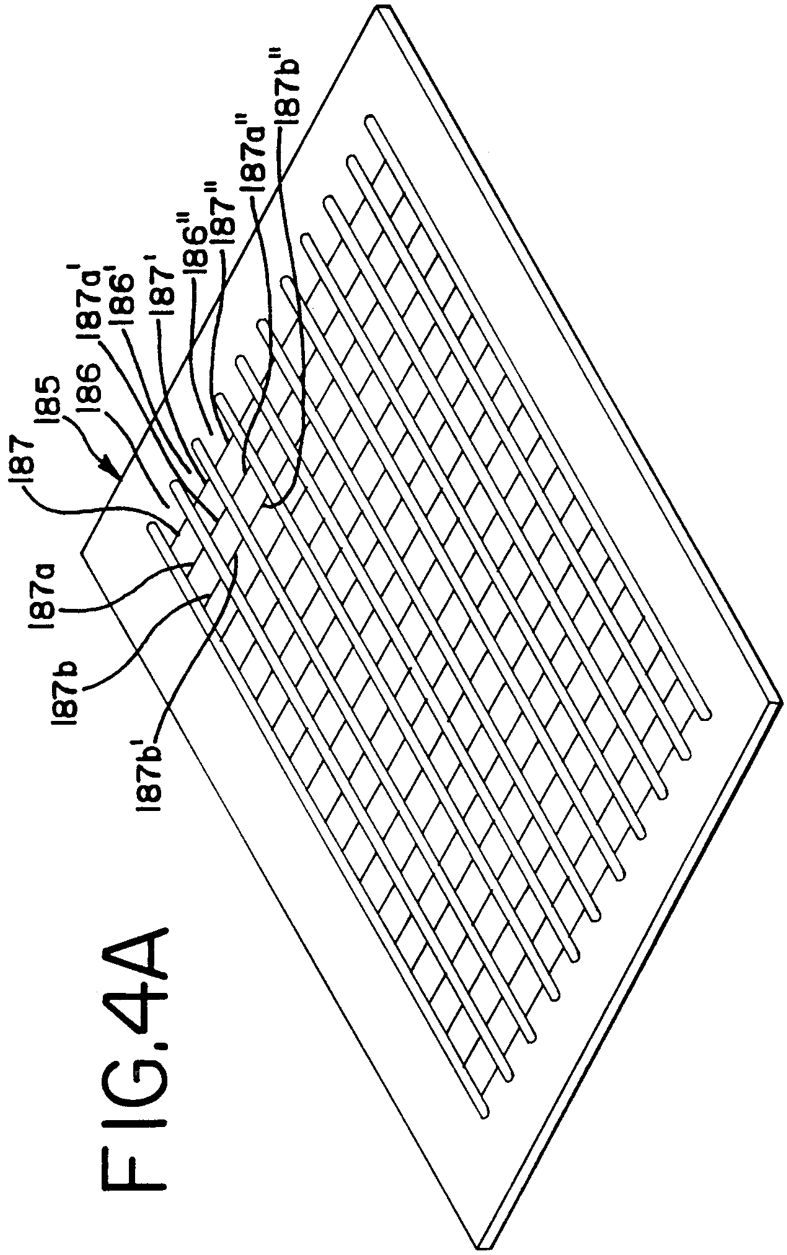


FIG.4A

FIG.6A

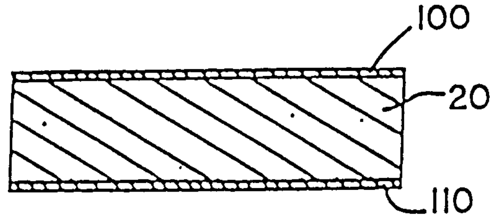


FIG.6B

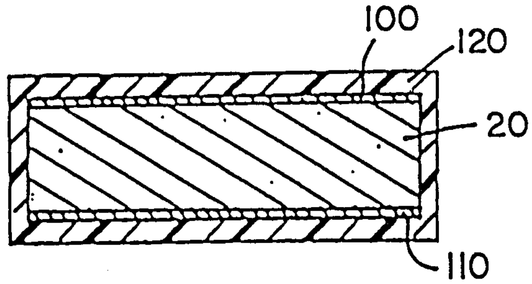


FIG.6C

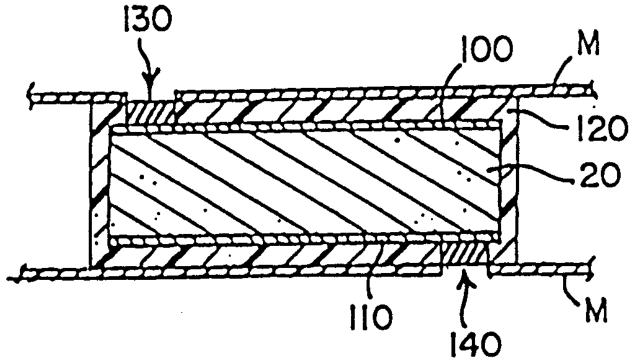


FIG.6D

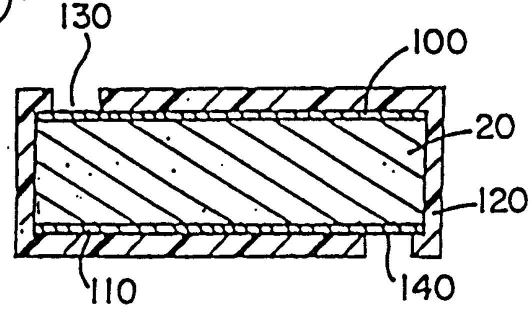


FIG.6E

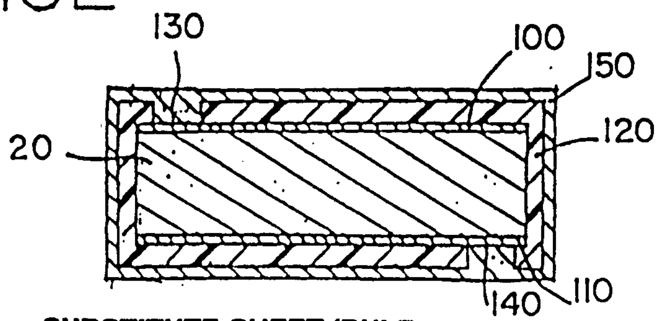


FIG.6F

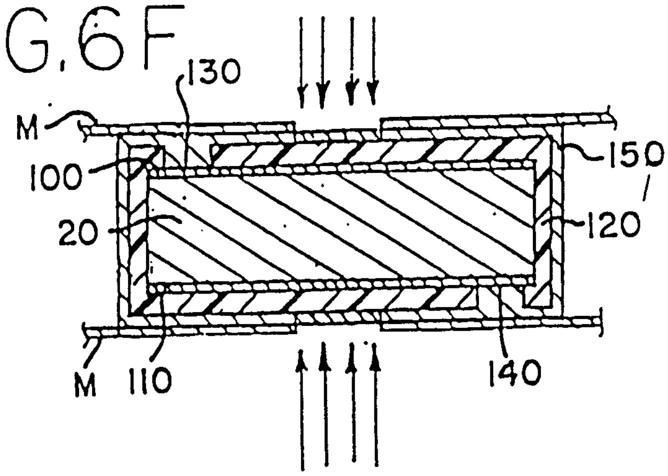


FIG.6G

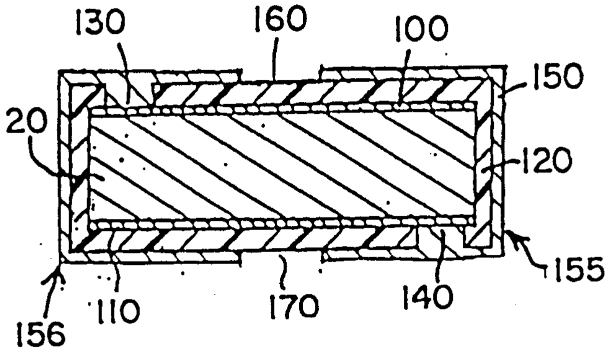


FIG.6H

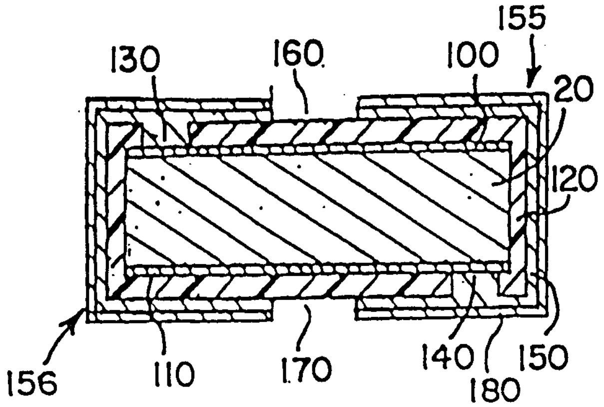


FIG. 7A

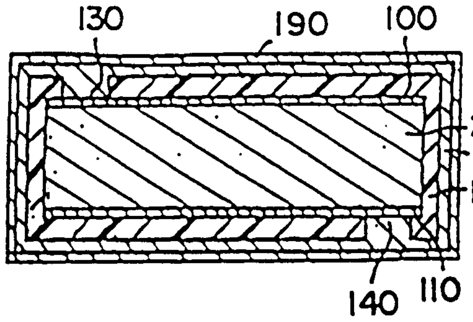


FIG. 7B

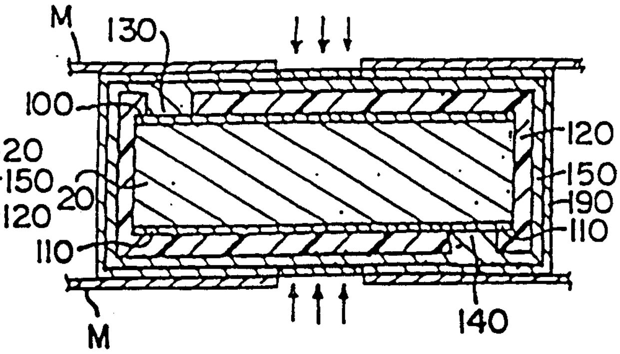


FIG. 7C

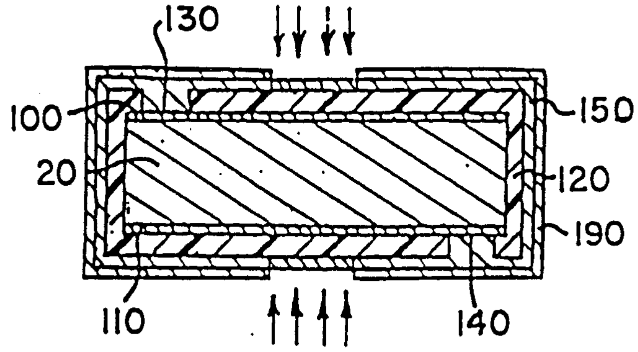


FIG. 7D

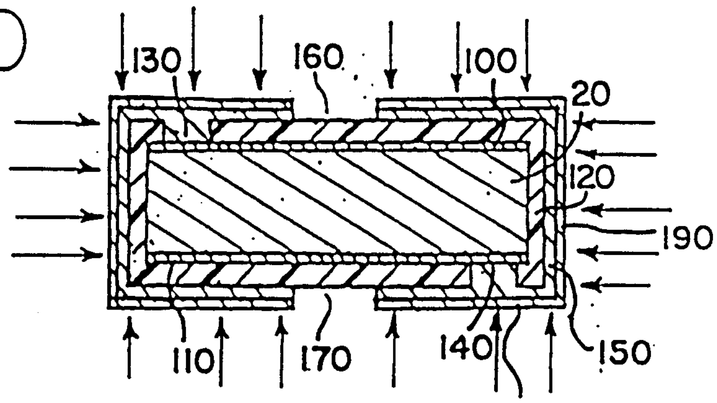


FIG. 8

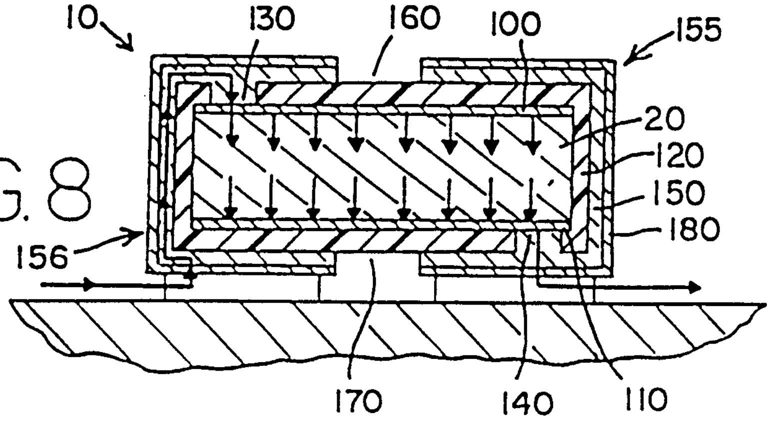


FIG.9A

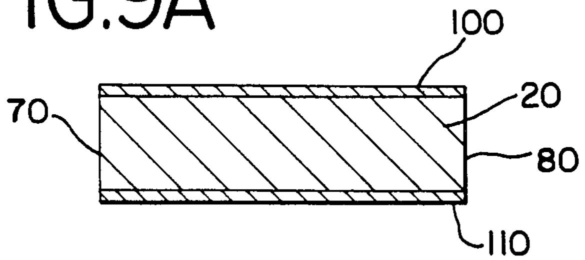


FIG.9B

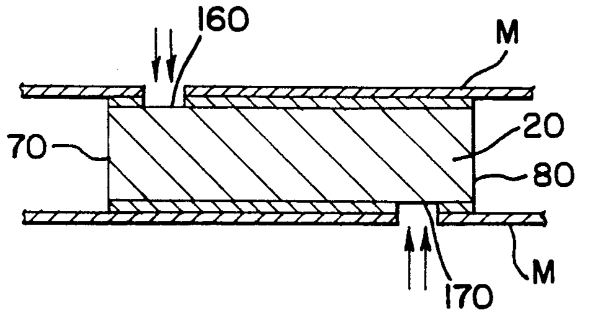


FIG.9C

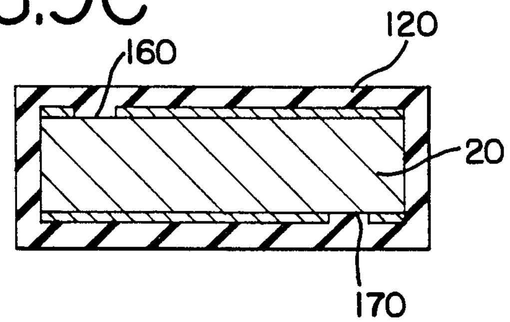


FIG.9D

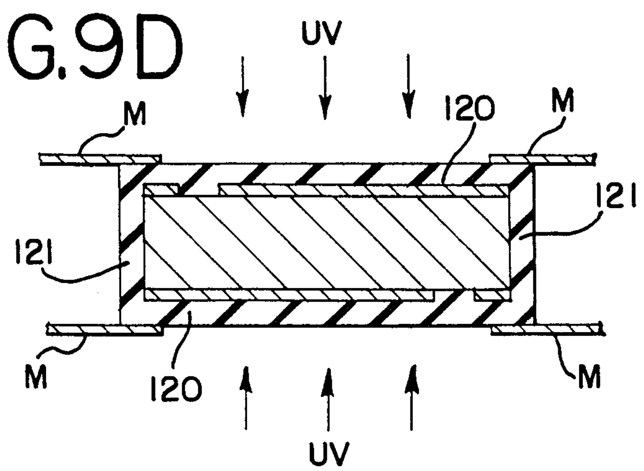


FIG.9E

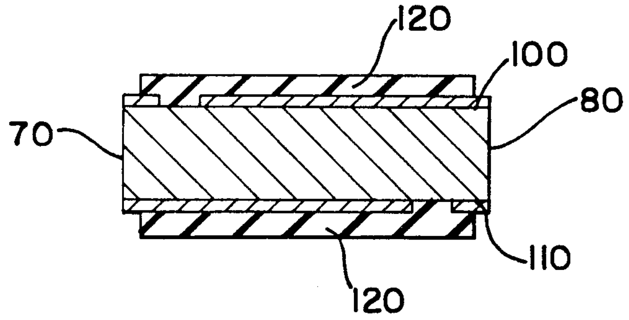


FIG.9F

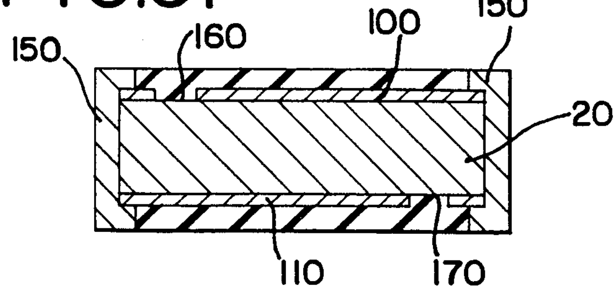


FIG.9G

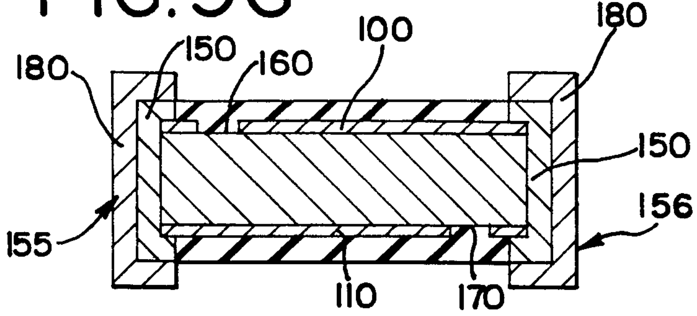


FIG.10

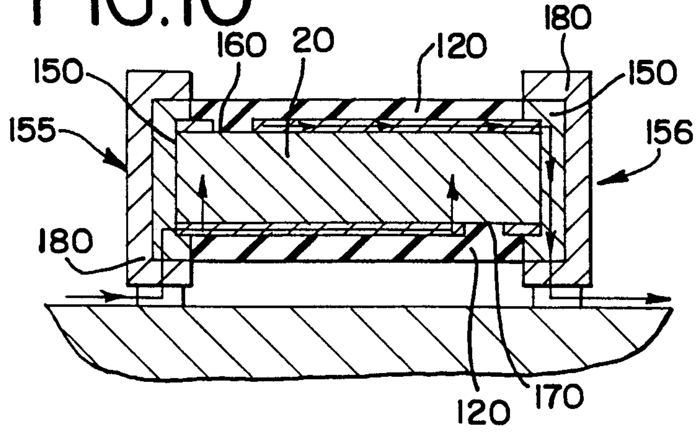


FIG. 11A

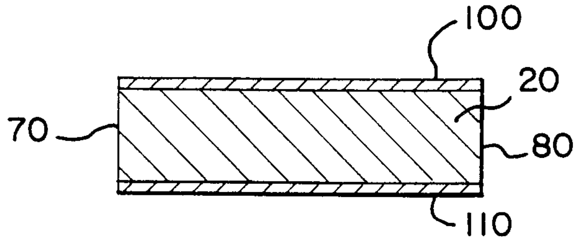


FIG. 11B

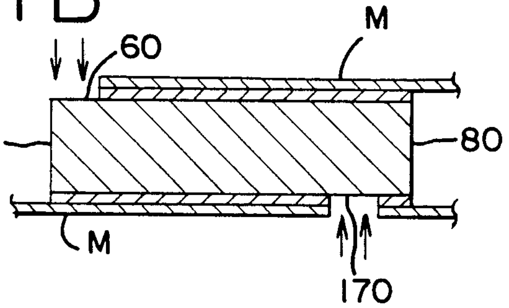


FIG. 11C

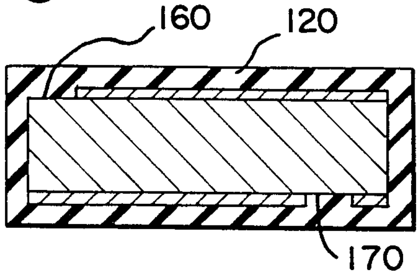


FIG. 11D

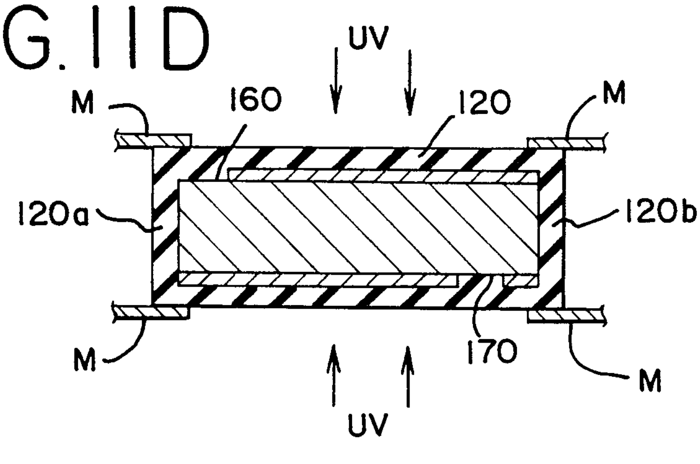


FIG. 11E

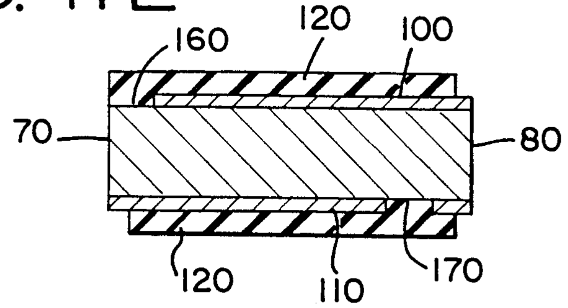


FIG. 11F

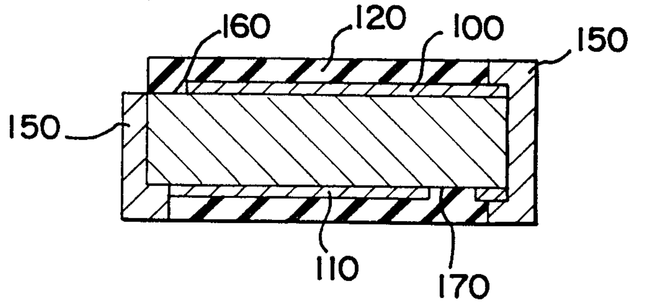


FIG. 11G

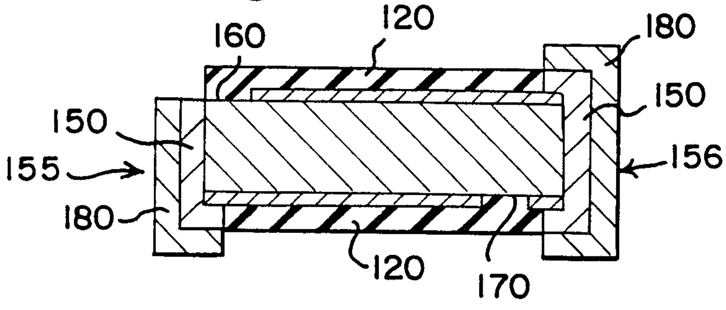


FIG. 12

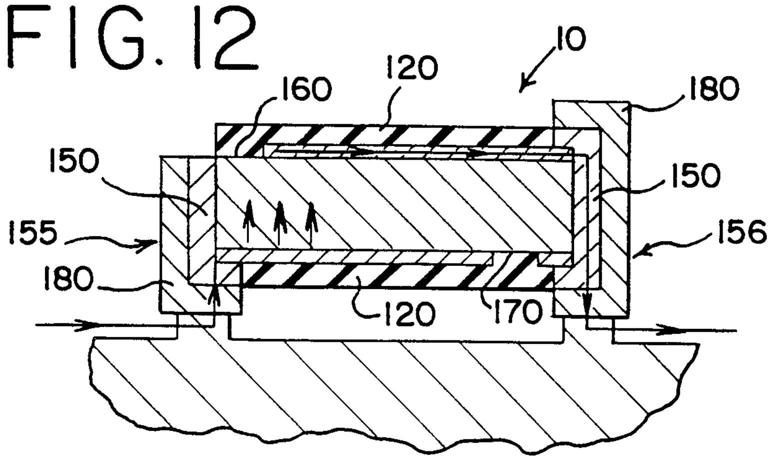


FIG.13

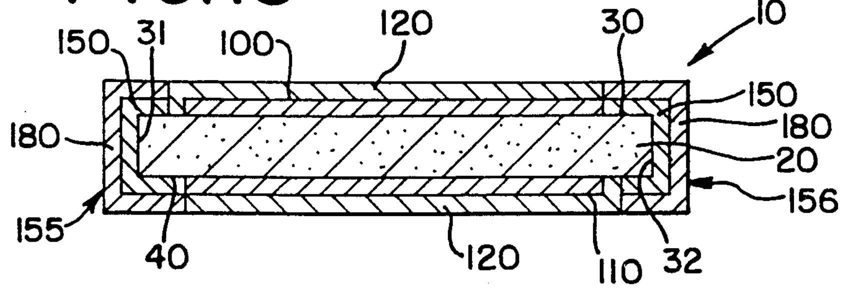


FIG.14A

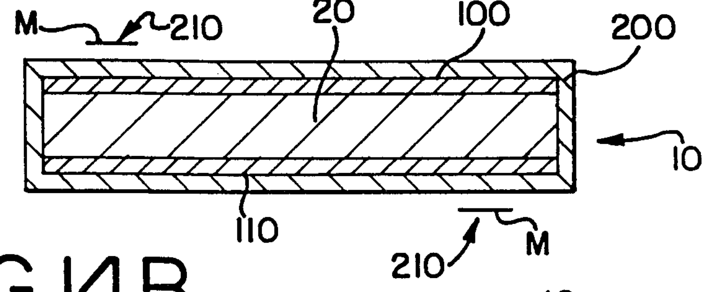


FIG.14B

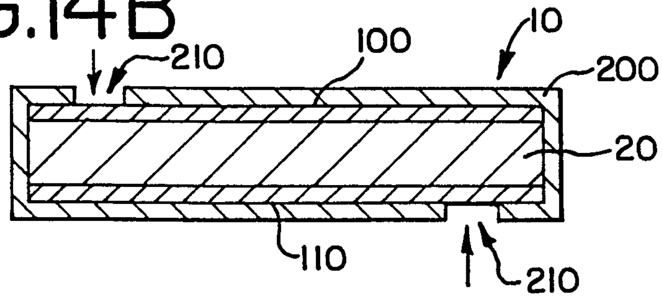


FIG.14C

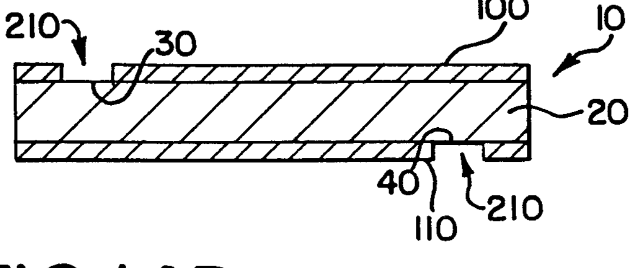


FIG.14D

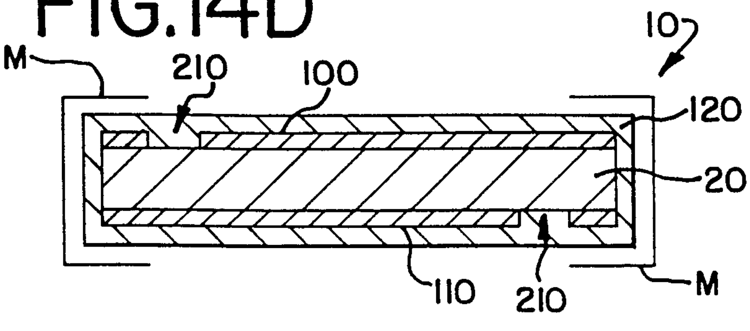


FIG.14E

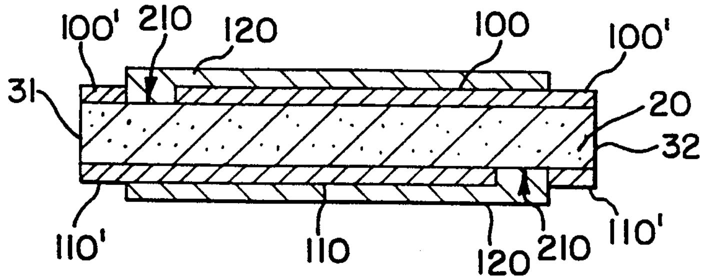


FIG.14F

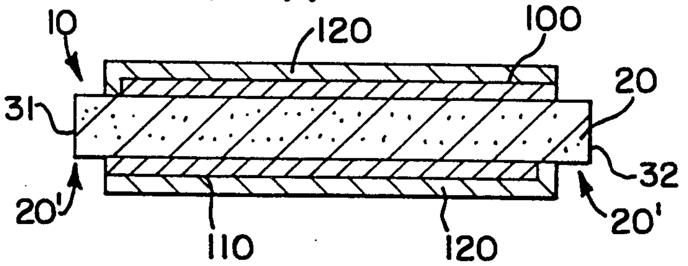


FIG.14G

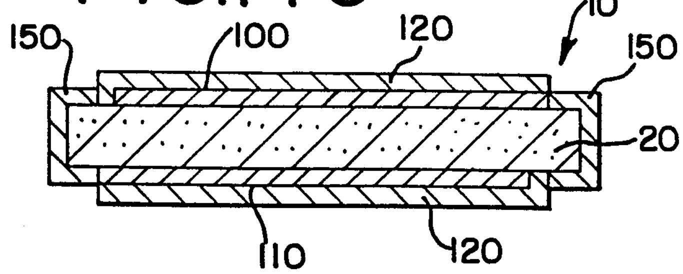


FIG.14H

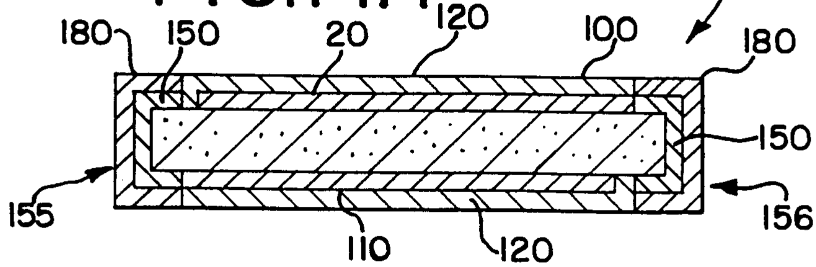


FIG.15

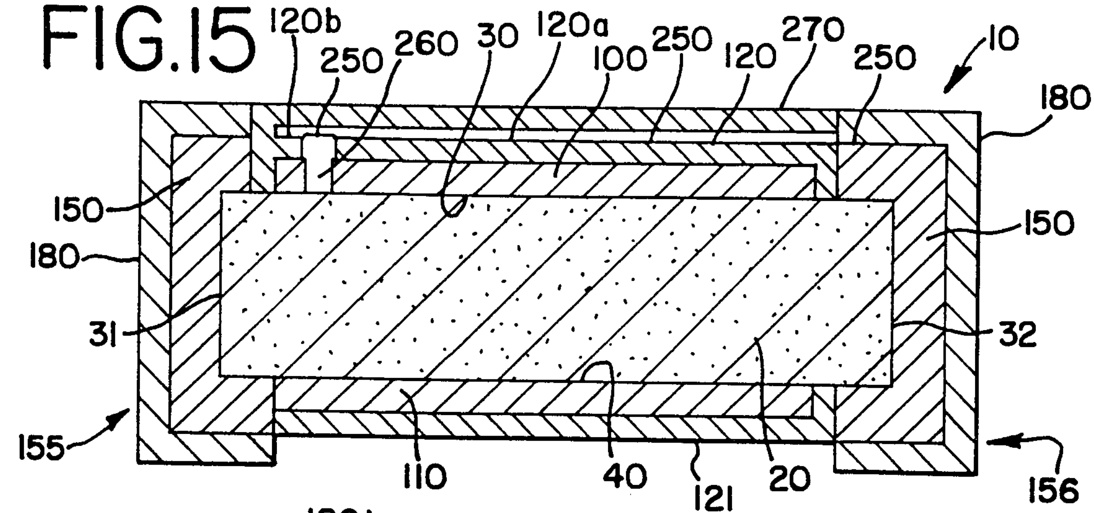


FIG.16A

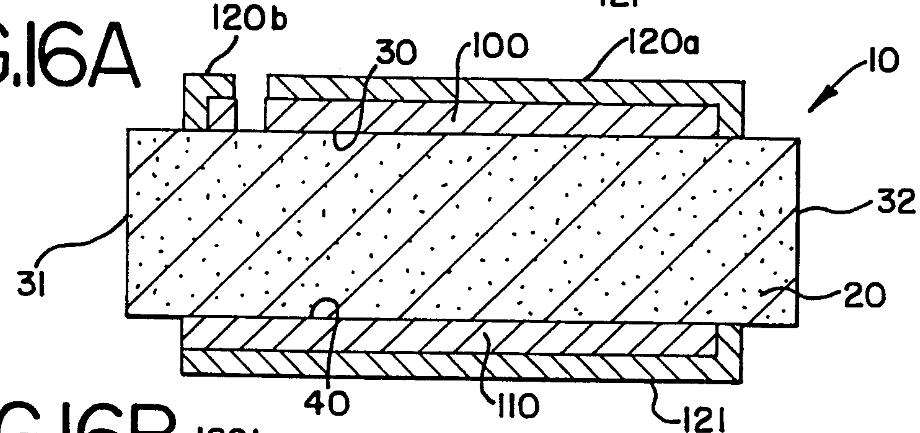


FIG.16B

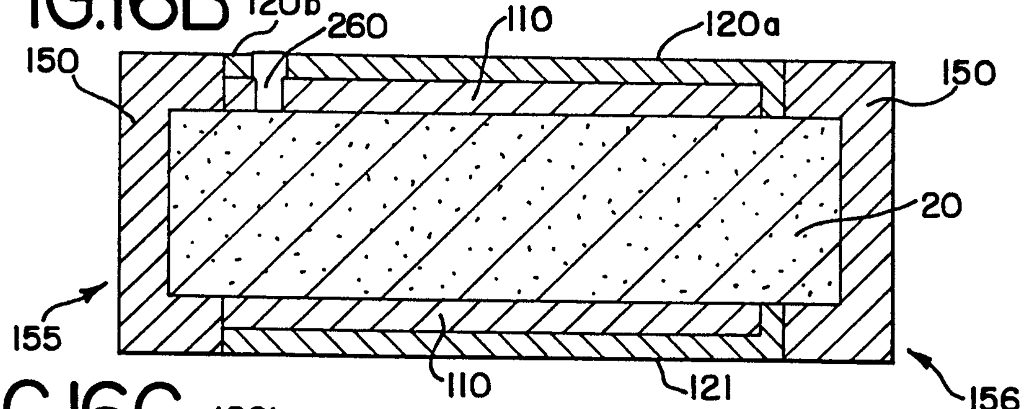


FIG.16C

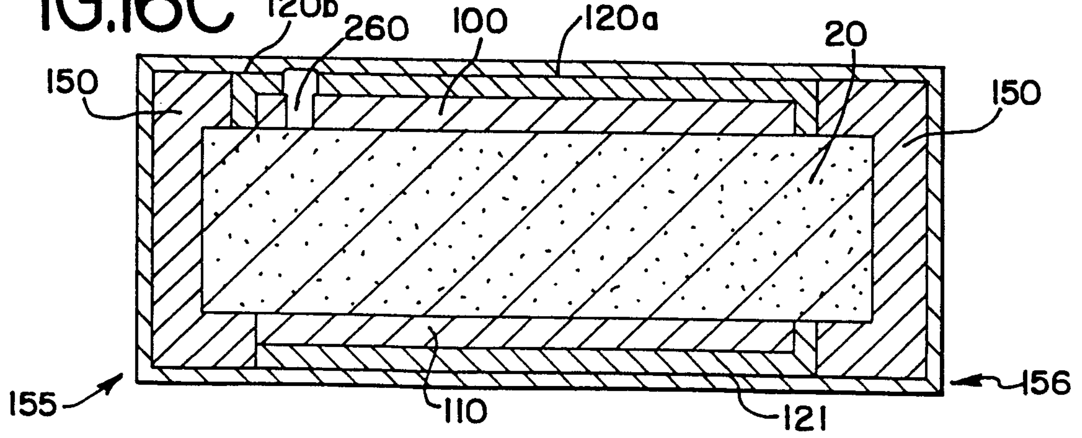


FIG.16D

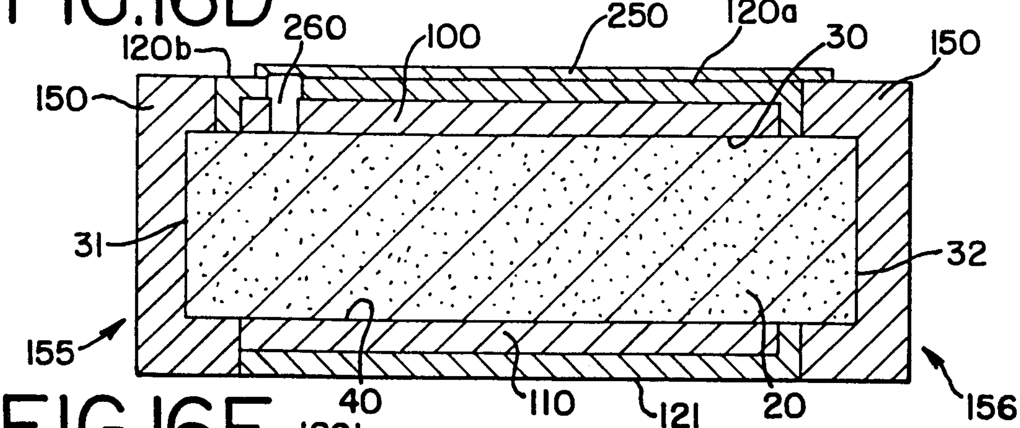


FIG.16E

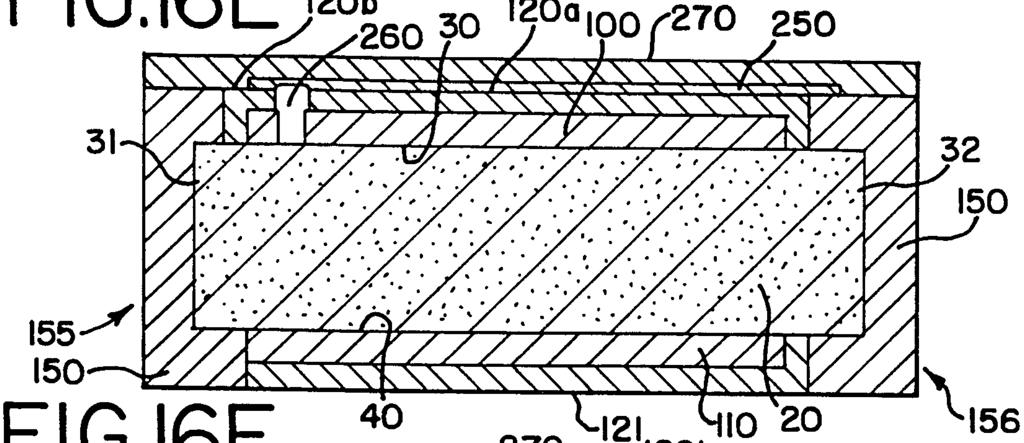


FIG.16F

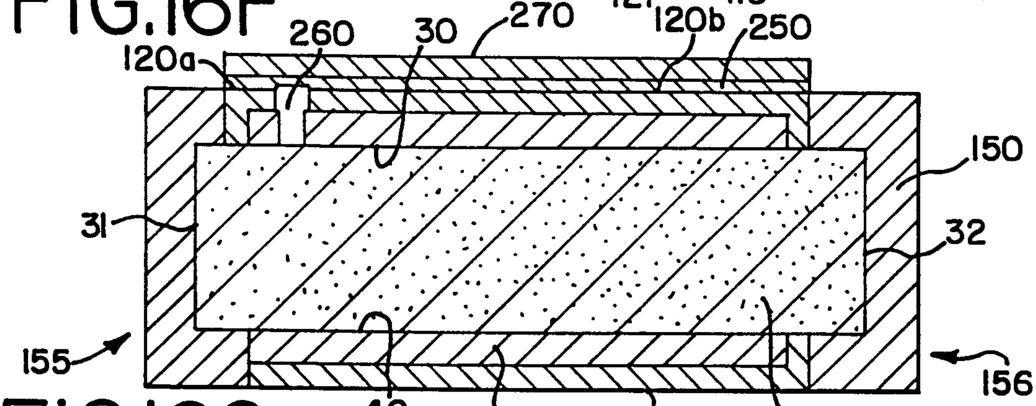


FIG.16G

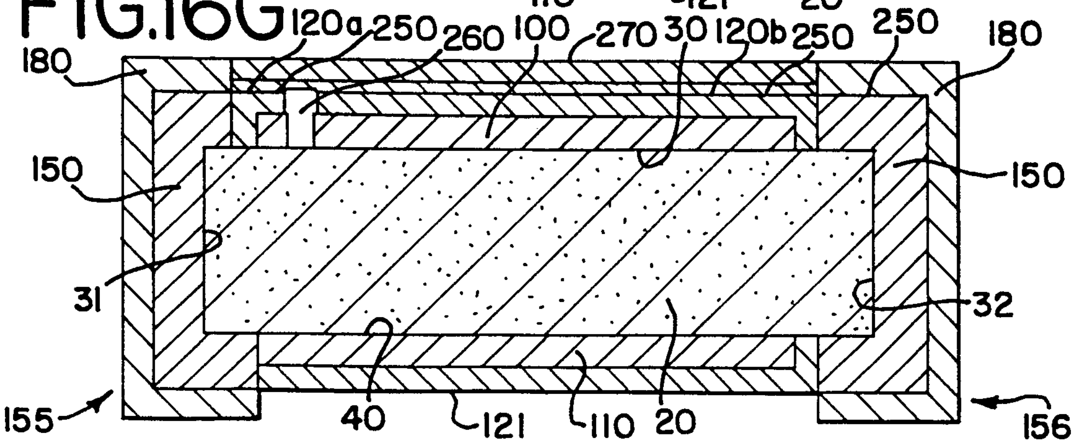


FIG. 17

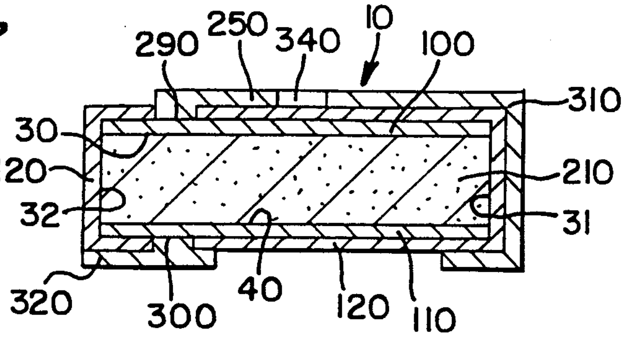


FIG. 18

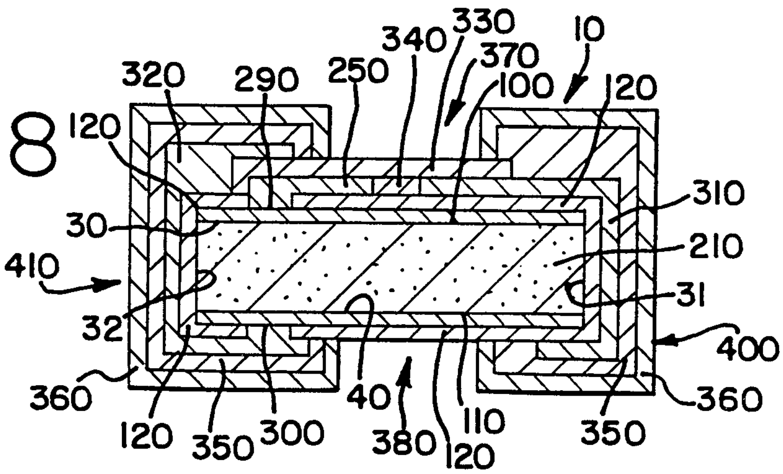


FIG. 19

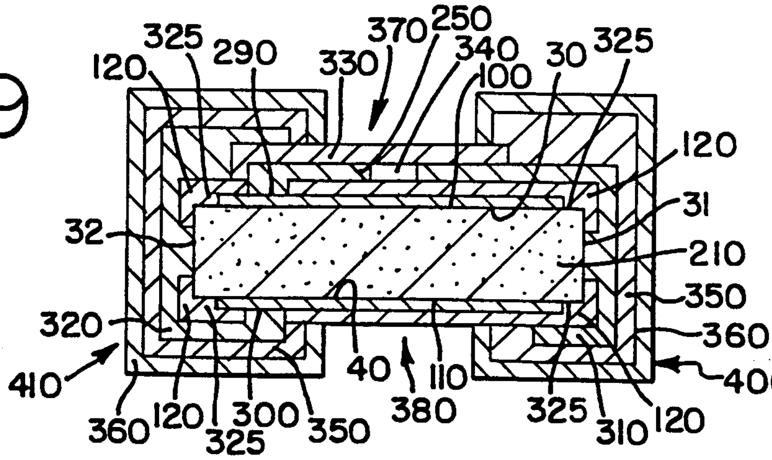


FIG. 20

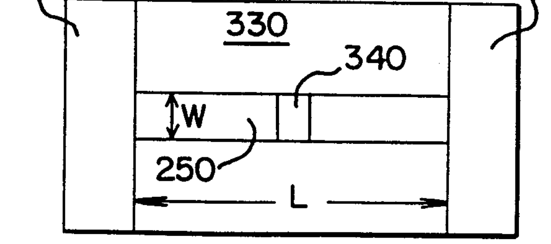
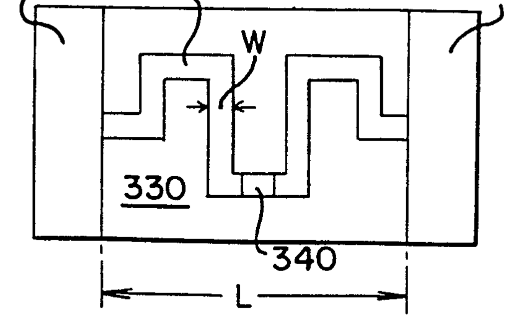


FIG. 21



INTERNATIONAL SEARCH REPORT

Int ational Application No
PCT/US 98/24922

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01C1/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 663 702 A (SHAW JR PHILIP C ET AL) 2 September 1997	1-55
A	see the whole document	56-69
X	WO 97 28543 A (LITTELFUSE INC) 7 August 1997 cited in the application	1-16,33
A	see claims 1,10; figures 1-8	17-32, 34-69
X	WO 96 41356 A (LITTELFUSE INC) 19 December 1996	1-16
A	see abstract; figures 1-14	17-69
A	WO 95 33276 A (LITTELFUSE INC) 7 December 1995 see abstract; figures 1-12	1-69

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 March 1999	31/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mausser, T

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/24922

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5663702	A	02-09-1997	NONE		
WO 9728543	A	07-08-1997	US	5699607 A	23-12-1997
			AU	1953697 A	22-08-1997
WO 9641356	A	19-12-1996	AU	6597296 A	30-12-1996
			CA	2223746 A	19-12-1996
			CN	1191623 A	26-08-1998
			EP	0834180 A	08-04-1998
WO 9533276	A	07-12-1995	US	5552757 A	03-09-1996
			AU	691620 B	21-05-1998
			AU	2602495 A	21-12-1995
			CA	2191346 A	07-12-1995
			EP	0761012 A	12-03-1997
			JP	9510824 T	28-10-1997
			US	5844477 A	01-12-1998
			US	5790008 A	04-08-1998