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(54) **A TRANSIENT VOLTAGE PROTECTION DEVICE AND METHOD OF MAKING SAME**

SCHUTZVORRICHTUNG GEGEN TRANSIENTE SPANNUNGEN UND VERFAHREN ZU DEREN HERSTELLUNG

DISPOSITIF DE PROTECTION CONTRE LES SURTENSIONS TRANSITOIRES ET SON PROCEDE DE REALISATION

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(56) References cited:
US-A- 3 676 742
US-A- 4 586 105
US-A- 5 477 407

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Description

BACKGROUND

[0001] Applicants' invention relates generally to devices for protecting electrical equipment and to methods of making such devices, which devices are commonly referred to as "surge protection" or "transient voltage suppression" devices. Transient voltage protection devices were developed in response to the need to protect the ever-expanding number of electronic devices upon which today's technological society depends from high voltages. Electrical transient voltages can be created by, for example, electrostatic discharge or transients propagated by human contact. Examples of electrical equipment which typically employ transient voltage protection equipment include, telecommunications systems, computer systems and control systems.

[0002] Recent developments in transient voltage protection technology have centered around usage of a material having a variable impedance which interconnects, for example, a signal conductor with a ground conductor. The variable impedance material exhibits a relatively high resistance (referred to herein as the "off-state") when the voltage and/or current passing through the signal conductor is within a specified range, during which time the signal conductor is ungrounded.

[0003] If, however, the signal conductor experiences a voltage which exceeds the threshold for which the variable impedance material (and the transient voltage protection device generally) has been designed, then the electrical characteristics of the variable impedance material will change such that the material exhibits a relatively low impedance (referred to herein as the "on-state"). At this time, the pulse or transient voltage experienced by the signal conductor will be shunted to the ground conductor, and the voltage associated with the pulse will be clamped at a relatively low value for the duration of the pulse. In this way, the circuitry associated with the signal conductor is protected.

[0004] The variable impedance material will recover after the voltage or current pulse has passed and return to its high impedance state. Thus, the signal conductor and associated circuitry can continue normal operation shortly after the pulse has ended.

[0005] Different types of variable impedance materials, also sometimes referred to as "overstress responsive compositions", are known in the art. These materials can, for example, be fabricated as a mixture of conductive and/or semiconductive particles suspended as a matrix within a binding material, which can, for example, be an insulative resin. Numerous examples of these types of materials can be found in the patent literature including U.S. Patent Nos. 5,393,596 and 5,260,848 to Childers, U.S. Patent Nos. 4,977,357 and 5,068,634 to Shrier and U.S. Patent No. 5,294,374 to Martinez.

[0006] U.S. Patent No. 5,278,535 to Xu et al. describes an electrical overstress pulse protection device which employs a variable impedance material. Specifically, Xu et al. provide a thin flexible laminate for overlay application on the pins of a connector. The laminate includes an electrically insulating substrate, a conductive lamina of apertured pin receiving pads, a separate ground strip adjacent the pads, and an electrically insulating cover. An electrical overstress pulse responsive composite material is positioned such that it bridges the pads and the ground strip.

[0007] This patent to Xu et al., however, uses conventional semiconductor fabrication techniques to create the pulse protection device including forming the substrate from a conventional resin material, e.g., of the type typically used for substrates of printed circuit boards. Similarly, Xu et al. describe forming the conductive elements using etching techniques, which are also well known in the semiconductor fabrication. While these techniques may be appropriate when working with thin film metal conductors, Applicants have determined that other techniques and materials are more desirable when manufacturing signal and ground conductive elements having a greater thickness, e.g., on the order of 0.5-1.0 mils (0.0127 mm to 0.0254 mm), or more.

[0008] US-A-3 676 742 discloses a transient overvoltage protection device comprising a substrate with conductive lines thereon for connecting electrical components and with a spark gap which is filled with air or glass.

[0009] US-A-4 586 105 discloses a high-voltage protection device with a tape-covered spark gap of 2.5 to 15 mils (0.0635 to 0.381 mm) between the discharge points.

SUMMARY

[0010] When forming a gap between a signal conductor and a ground conductor that is to be filled with a variable impedance material, Applicants have discovered that repeatable precision of the gap dimensions are important to producing a commercially desirable product. The precision of the gap dimensions are significant because the electrical characteristics of the device, e.g., the trigger voltage, clamp voltage and current density, are, in part, determined by the size and shape of the gap.

[0011] Accordingly, it would be desirable to develop new techniques for making transient voltage protection devices wherein the gap between a signal conductor and a ground conductor is formed with a high degree of precision, which precision is repeatable in a manufacturing environment and yet techniques are not so expensive that the resulting transient voltage protection devices cannot compete on a cost basis in the marketplace. At the same time, it would be desirable to optimize the materials used to make such devices to achieve these same objectives. These objects are achieved with the features of the claims.

[0012] According to an exemplary embodiment of the present invention, a method for fabricating a transient voltage protection device including, for example, a ground conductor and at least one other conductor comprises the steps of: providing a substrate;

forming a conductive layer on the substrate; and dicing the conductive layer on the substrate to create a gap which separates the conductive layer into at least the ground conductor and the at least one other conductor. The substrate can be formed from a ceramic material or non-ceramic materials such as FR-4. If a ceramic material is used for the substrate, then it is preferable that such a ceramic material have a density of less than about 3.8 gms/cm^3. For example, forsterite and calcium borosilicate are two such ceramic materials. Dicing to create the gap can be accomplished, for example, using a diamond dicing saw having, for example, diamond particles of preferably no more than 5 microns in size.

[0013] According to another exemplary embodiment of the present invention, a device comprises a ceramic substrate having a density of less than about 3.8 gms/cm^3, a ground conductor and at least one other conductor formed on the ceramic substrate such that they are substantially co-planar and are separated from one another by a gap; and a variable impedance material disposed within the gap and in contact with both the ground conductor and the at least one other conductor. The ceramic substrate will preferably have a bulk density of less than 3.5 gms/cm^3 and optimally a density of less than 3.0 gms/cm^3. In particular, Applicants have identified forsterite ($2MgSiO_2$) having a bulk density of 2.8 gms/cm^3 and calcium borosilicate, having a bulk density of 2.5 gms/cm^3 as materials which are well suited for substrates according to the present invention. By selecting ceramic or glass-based materials in accordance with the present invention, the gap between the ground and signal conductor can be precisely formed with the desired dimensions and good edge acuity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The features and advantages of Applicants' invention will be understood by reading this description in conjunction with the drawings, in which:

Figure 1A illustrates a portion of a discrete transient voltage protection element;

Figure 1B illustrates the discrete transient voltage protection element of Figure 1A including the variable impedance material;

Figures 2A-2D depict discrete transient voltage protection elements at various stages of manufacture used to illustrate methods of making such elements according to the present invention;

Figure 3 illustrates a diamond dicing saw used to dice a gap between conductors according to the present invention;

Figures 4A-4F illustrate a transient voltage protection device according to the present invention which is adapted to be attached to a connector: and

Figure 5 illustrates a graph of current and voltage associated with a test of a device constructed in accordance with the present invention.

DETAILED DESCRIPTION

[0015] An exemplary embodiment of the present invention is depicted in Figures 1A and 1B. which Figures are used to explain the terminology used herein. Figure 1 shows a discrete transient voltage protection element, i.e., a transient voltage protection element which can be used as part of a circuit board, however other applications of the present invention are contemplated, e.g., using transient voltage protection devices according to the present invention as part of a connector. The discrete transient voltage protection element includes a substrate 10 on which two conductors 12 and 14 are formed. In this example, conductor 12 is the ground conductor, while conductor 14 is a signal or power carrying conductor. A gap 16 is formed between conductors 12 and 14. Note that although Figure 1A illustrates the gap as extending to the surface of substrate 10, preferred embodiments of the present invention include extending the gap into the substrate. As described above, the electrical characteristics of the transient voltage protection element will depend, in part, on the precision with which gap 16 is formed. Thus, precision of the depth, width and uniformity of edges 18 and 20 (referred to herein as "edge acuity") associated with gap 16 is carefully controlled by way of the techniques described below.

[0016] Figure 1B illustrates the discrete transient voltage protection element of Figure 1A, wherein a variable impedance material 22 fills the gap 16. According to the present invention, any known variable impedance material may be used, including those described in the above-mentioned patents, as well as those fabricated from dielectric polymers, glass, ceramic or composites thereof. These materials may, for example, include or be mixed with conductive and/or semiconductive particles in order to provide the desired electrical characteristics. Although any variable impedance material can be used, a currently preferred variable impedance material is that manufactured by SurgX Corporation and identified by SurgX as Formulation #F1-6B.

[0017] Having briefly described the structure of an exemplary discrete transient voltage protection element according to the present invention, a method for manufacturing transient voltage protection devices will now be described with respect to Figures 2A-2F. Many such devices can be fabricated on a single wafer. The process begins by selecting a suitable material for the substrate wafer 30. Although illustrated as a rectangle for simplicity in Figure 2A, those skilled in the art will appreciate that the shape of the wafer provided by a wafer manufacturer may vary and can, for example, be circular.

[0018] Since Applicants have discovered that forming the gap by dicing is a preferred technique to form the desired precisely dimensioned gap between conductors, a ceramic or glass-based material is preferred for substrate 30. Although the present invention contemplates any and all ceramic materials and glass-based materials, it has been found that certain ceramics and glass-based materials are optimal from a manufacturing point of view. In particular, ceramic and glass-based materials should be selected which have a sufficiently low density that a diamond dicing saw can create the gap (1) with sufficient edge acuity and (2) without wearing out the saw so rapidly as to be economically unfeasible.

[0019] Based on their experimentation, Applicants have discovered that preferable ceramics and/or glass-based materials will have a density of less than 3.8 gms/cm^3. preferably less than 3.5 gms/cm^3 and optimally a density of less than 3.0 gms/cm^3. In particular, Applicants have identified forsterite ($2MgSiO_2$) having a bulk density of 2.8 gms/cm^3 and calcium borosilicate, having a bulk density of 2.5 gms/cm^3 as materials which are well suited for substrates according to the present invention. However, those skilled in the art will appreciate that any ceramic, e.g., a material within the ternary MgO-Al_2O_3-SiO_2 system or other materials having similar properties, or glass composite having a sufficiently low bulk density and being otherwise amenable to dicing can be used as a substrate in accordance with the present invention.

[0020] Having selected a suitable substrate 30, the next step, the result of which is illustrated in Figure 2B, is to pattern the substrate with metallization. In this exemplary embodiment, wherein discrete transient voltage protection devices are being manufactured, the metallization can take the form of elongated lines 32 spaced apart on substrate 30 by areas 34. According to one exemplary embodiment of the present invention, the metallization lines 32 can be formed by silk screening silver palladium onto the substrate 30. Of course those skilled in the art will appreciate that other conductive materials could be used including, for example, copper, gold, nickel, etc.

[0021] The width and thickness of the lines 32 can be chosen based on the capabilities desired for the discrete transient voltage protection elements to be created. According to one exemplary embodiment, Applicants have found that a width of about 0.040 inches (1.016 mm) and a thickness of between 0.5 - 1.0 mils (0.0127-0.0254 mm), provide good performance, however those skilled in the art will appreciate that these values are purely for illustration herein.

[0022] Once the metallization has been formed on the substrate wafer 30, then the dicing operations are performed to both form the gaps between the conductors and singulate the substrate wafer 30 into its individual discrete transient voltage protection devices. As mentioned above, Applicants have selected dicing over other techniques which could be used to form the gap between the conductors, e.g., cutting the gap with a laser, for its precision with respect to gap width, depth and edge acuity. Details of diamond dicing techniques which can be used to cut the gaps and singulate the wafer substrate 30 are provided below.

[0023] In order to illustrate the diced gap formed between the two conductors, a single discrete device cut from portion 36 of wafer substrate 30 is blown-up as Figure 2C. This device was cut from wafer substrate 30 by dicing horizontally across the wafer substrate 30 along the areas 34 and vertically across metallization 32. By dicing a gap 40 completely through metallization 32 and partially through the wafer substrate 30 and two separate conductors 42 and 44 are formed, one of which can be grounded when attached to a printed circuit board (not shown).

[0024] The gap 40 can be diced so as to have any desired width, for example, between 0.5 and 3.0 mils (0.0127 and 0.0762 mm), preferably between 0.8 and 1.1 mils (0.0203 and 0.02794 mm) and most preferably about 1 mil (0.0254 mm). Those skilled in the art will appreciate that other gap widths may be desired, for example the gap width can be increased to increase the clamp voltage or simply to render manufacturing less complex, and that such variations are within the scope of the present invention. The device can then be terminated by capping each end with a conductive material 46.

[0025] The gap is then filled with a variable impedance material 48 as illustrated in Figure 2D. As mentioned above, any known variable impedance material can be used, however the currently preferred material is available from SurgX Corporation and is identified as their formulation #F1-6B. In the exemplary embodiment illustrated in Figure 2D, a circular portion of the variable impedance material 48 can be applied to bridge the gap 40 and have an approximately circular footprint thereon of approximately 0.050 inches (1.27 mm). According to one exemplary embodiment, the variable impedance material 48 is forced into the gap 40 using a syringe so that the material substantially completely fills gap 40. To ensure that the variable impedance material 48 contacts substantially the entire surface area of the gap edges of each conductor (i.e., edges 18 and 20 in Figure 1), the gap 40 can be diced below the surface of the substrate wafer 30. For example, the gap can extend about 0.005 inches (0.127 mm) beyond the metallization into the substrate wafer 30.

[0026] Dicing is the preferred technique for forming the gap between the conductors into which the variable impedance material is introduced due to the precision with which the gap can thus be manufactured, amongst other reasons. Dicing involves applying a compressive force to a material such that it chips away to form an opening. Thus, in order to obtain a gap with sufficient precision in terms of width, depth and edge acuity, the parameters of the dicing operation should be carefully controlled. According to exemplary embodiments of the present invention, a diamond dicing saw is used as illustrated in Figure 3.

[0027] The saw includes a saw hub 50 and a spindle 52 on which the saw blade 54 is rotatably mounted. Alternatively, a hubless saw can be used. The saw blade 54 can, for example be 1 mil (0.0254 mm) thick and is, preferably, electroplated with a solution of nickel and diamond particles. The size of the diamond particles affects the size of the chips and, thus, the edge acuity. Accordingly, Applicants have found that the diamond particles should preferably be 5 microns or less. Other dicing parameters will also impact the precision of the gap. In particular, the exposure ("E" in Figure 3) of the blade 54 beyond the hub 50 should be minimized to avoid blade wobble and associated inaccuracies in the gap width. Moreover, the feed speed of the substrate through the saw and the spindle speed of the blade should also be considered as will be appreciated by those skilled in the art.

[0028] While the foregoing exemplary embodiments have been described in terms of discrete transient voltage protection elements which can be incorporated directly into printed circuit boards, those skilled in the art will also appreciate that the present invention can be applied to any physical transient voltage protection device construction. For example, the manufacturing steps described previously for producing and dividing a plurality of discrete devices from a large wafer also can be used to produce a through-hole electrical protection device for use with any of a variety of electrical connectors, for example, an RJ-type (i.e., telephone) connector, a D-Sub connector (i.e., multiple pin computer cable connectors), etc. Such electrical protection devices will have substantially the same structural characteristics in all of the electrical connectors except for variations in the shape/size and circuit pattern as will be appreciated by those skilled in the art.

[0029] For each connector, the connector-related device will be used to permit at least one connector pin to pass through a through-hole in the device, at least one ground pin passing through at least one ground through-hole in the device, and the ground through-hole(s) in the device will be electrically isolated from the other through-hole(s) until an over-voltage condition is experienced. As an example of this type of embodiment of the present invention, therefore, only a protection device for an RJ-11 type connector will be described for illustrative purposes.

[0030] Figure 4A depicts a transient voltage protection device for an RJ-11 type connector according to an exemplary embodiment of the present invention. Therein, a ceramic or glass-based substrate 60 has a metallization layer 62 screened thereon as described above. However, in this exemplary embodiment, the conductors are patterned to provide for through-holes which will mate with the pins of an RJ-11 type connector when the device is attached thereto. Next, as illustrated in Figure 4B, two gaps 64 and 66 are diced through the metallization layer 62 and partially through the substrate 60. This has the affect of separating the six conductive portions surrounding the through-hole areas from a central conductive "bus" 68. Subsequently, as shown in Figure 4C, a conductive material 70 is disposed between the conductor surrounding through-hole area (i.e,. the through-hole for the ground pin of the RJ-11 connector) and the conductive "bus" 68. This establishes conductive "bus" 68 as a grounded plane which is proximate each of the conductors associated with the other through-hole areas. An alternative embodiment is illustrated in Figure 4D, wherein the pins, e.g., pin 67, mate with saddles, e.g., saddle 69, formed in the ceramic substrate 60. To provide a firm electrical and/or mechanical connection between the pins and the saddles, the pins can be soldered to the metallized surfaces of the saddles, as represented by solder patch 71.

[0031] In either embodiment, a variable impedance material 74 is deposited over the area including the gaps 66 and 64 and forced into the gap to provide an over-voltage responsive electrical connection between the conductive "bus" 68 and each of the conductors 76-84, each of which will be associated with a corresponding pin of the RJ-11 connector to which the device is attached. Lastly, an encapsulating material 86 can be provided to cover the variable impedance material 74 to, for example, protect the variable impedance material and prevent electrical charges from other circuitry from being applied across the variable impedance material.

[0032] The through-holes can be made in the area 72 and within conductors 76-84 by drilling, laser micromachining or other methods recognized by those skilled in the art. The size of the through-holes will depend on the diameter of the leads extending from the particular connector. For example, the through-hole hole diameter can range from 20 mils to 40 mils (0.508 mm to 1.016 mm), but more typically are 30 mils (0.762 mm) in diameter. The device 88 illustrated in Figure 4E, as well as other exemplary embodiments wherein the transient voltage suppression device is intended to be used in connection with a connector having pins or leads, can then be mounted in mating relationship with the pins or leads and the substrate can be affixed to the connector body using solder or other adhering techniques.

[0033] Figure 5 is a graph of current through, and voltage across, a device constructed in accordance with the present invention as illustrated and described with respect to Figures 2A-2D. Therein, as an input, Applicants applied a 1000-4-2 standard 8 kV pulse as specified by the Electrotechnical Commission (IEC). This standard pulse is intended to simulate the pulse which would be applied to electrical circuitry by the discharge of static electricity associated with a human body. In the graphs, the upper waveform (I) represents the current conducted by the transient voltage suppression device, which flows into ground, while the lower waveform depicts the voltage across the device during the test.

[0034] In the particular test illustrated in Figure 5, the device triggered (i.e., entered its on-state) at 188 V. The pulse was clamped at 41.3 V and peak current was 42.8 A. Thus, when compared with conventional transient voltage protection devices, devices constructed in accordance with the present invention can be seen from Figure 5 to rapidly limit the transient voltage to a value which is substantially less than that of the prospective pulse value. Additionally, devices constructed in accordance with the present invention exhibit relatively low leakage current and low capacitance.

[0035] It is, of course, possible to embody the invention in specific forms other than those described above without departing from the invention. The embodiments described above are merely illustrative and should not be considered restrictive in any way. For example, although the dicing of the gap was described above as being performed at the same time that the wafer cut into individual devices, the dicing of the gap could be performed at a later stage, i.e., each device could be individually gapped. Moreover, although the preceding exemplary embodiments focus on ceramic and glass-based substrates, dicing techniques could also be used to create gaps between conductors in other substrates such as resin materials (e.g., FR-4) etc.

[0036] The scope of the invention is determined by the claims rather than the preceding description, and all variations and equivalents which fall within the scope of the claims are intended to be embraced therein.

Claims

1. A method of making a transient voltage protection device comprising:

(a) forming conductive lines (32) on a wafer substrate (30) where the lines form conductive paths between electronic components;
(b) forming a gap (16, 40) of 3 mils (0.0762 mm) or less in at least one of said lines (32) by cutting the line with a saw or a laser such that two conductors (42, 44) separated by the gap (16, 40) are formed;
(c) covering the gap (16, 40) to prevent contamination of the air space in the gap or filling the gap with a variable impedance material (48), such as a neat unfilled polymer or glass or ceramic or composites thereof;
(d) dicing the substrate (30), thereby separating the substrate into individual transient voltage protection units, each comprising said two conductors (42, 44) separated by the gap; and
(e) capping the ends (46) of each conductor (42, 44) of the individual transient voltage protection units with conductive material, whereby the electric separation of said conductors by the gap is maintained.

2. A method of claim 1 wherein the gap is less than about 1 mil (0.0254 mm).

3. A transient over-voltage protection device comprising:

(a) a substrate (60) having a conductive layer (62) comprising two gaps (64, 66) defining a central conductive bus (68) therebetween and conductive portions (76 to 84) on both sides of the central conductive bus (68) which are dimensioned to mate with connector pins or leads (67). wherein
(b) the gaps (64, 66) are adapted to isolate the conductive bus (68) from the conductive portions (76 to 84) having through-holes (72) or saddles (69) for the pins or leads of the connector, and
(c) the gaps (64, 66) are filled with a variable impedance material (74) to provide an over-voltage responsive electrical connection between the conductive bus (68) and each of the conductive portions (76 to 84).

4. A device according to claim 3, wherein the width of the gaps (64, 66) is less than 1 mil (0.0254 mm).

Patentansprüche

1. Verfahren zur Herstellung einer Vorrichtung zum Schutz vor transienten Spannungen, mit den Schritten:

(a) Ausbilden von leitenden Leitungen (32) auf einem Scheibensubstrat (30), wobei die Leitungen Leitungswege zwischen elektronischen Komponenten bilden;
(b) Ausbilden eines Spalts (16, 40) von 3 mil (0,0762 mm) oder weniger in mindestens einer der Leitungen (32) durch Trennen der Leitung mit einer Säge oder einem Laser, so daß zwei durch den Spalt (16, 40) getrennte Leiter (42, 44) ausgebildet werden;
(c) Überziehen des Spalts (16, 40), um eine Kontamination des Luftraums im Spalt zu verhindern, oder Füllen des Spalts mit einem impedanzvariablen Material (48), z. B. einem sauberen ungefüllten Polymer oder Glas oder Keramik oder von Verbundstoffen daraus;
(d) Sägen des Substrats (30), wobei das Substrat in einzelne Einheiten zum Schutz vor transienten Spannungen getrennt wird, die jeweils zwei durch den Spalt getrennte Leiter (42, 44) aufweisen;
(e) Abdecken der Enden (46) jedes Leiters (42, 44) der einzelnen Einheiten zum Schutz vor transienten Spannungen mit leitendem Material, so daß die elektrische Trennung der Leiter durch den Spalt erhalten bleibt.

2. Verfahren nach Anspruch 1, wobei der Spalt kleiner als etwa 1 mil (0,0254 mm) ist.

3. Vorrichtung zum Schutz vor transienten Überspannungen mit:

(a) einem Substrat (60) mit einer leitenden Schicht (62) mit zwei Spalten (64, 66), die einen mittigen leitenden Bus (68) zwischen sich definieren, und leitenden Abschnitten (76 bis 84) auf beiden Seiten des mittigen leitenden Busses (68), die so bemessen sind, daß sie mit den Verbinderanschlußstiften oder Leitungen (67) ineinandergreifen, wobei
(b) die Spalte (64, 66) dafür angepaßt sind, den leitenden Bus (68) von den leitenden Abschnitten (76 bis 84) mit Durchgangslöchern (72) oder Schalen (69) für die Anschlußstifte oder Leitungen des Verbinders zu trennen, und
(c) die Spalte (64, 66) mit einem impedanzvariablen Material (74) gefüllt sind, um eine überspannungsempfindliche elektrische Verbindung zwischen dem leitenden Bus (68) und jedem der leitenden Abschnitte (76 bis 84) herzustellen.

4. Vorrichtung nach Anspruch 3, wobei die Breite der Spalte (64, 66) kleiner ist als 1 mil (0,0254 mm).

Revendications

1. Procédé de fabrication d'un dispositif de protection contre les tensions transitoires comprenant les étapes consistant à :

(a) former des lignes conductrices (32) sur un substrat de tranche (30) où les lignes forment des pistes conductrices entre des composants électroniques ;
(b) former une distance d'isolement (16, 40) de 3 mils (0,0762 mm) ou moins dans au moins une desdites lignes (32) en coupant la ligne avec une scie ou un laser de sorte que deux conducteurs (42, 44) séparés par la distance d'isolement (16, 40) soient formés ;
(c) couvrir la distance d'isolement (16, 40) pour empêcher la contamination de l'espace d'air dans la distance d'isolement ou remplir la distance d'isolement avec un matériau d'impédance variable (48), tel qu'un polymère ou un verre ou une céramique propre sans charge ou des composites de ceux-ci ;
(d) découper le substrat (30) en dés, séparant ainsi le substrat en unités individuelles de protection contre les tensions transitoires, chacune comprenant lesdits deux conducteurs (42, 44) séparés par la distance d'isolement ; et
(e) encapsuler les extrémités (46) de chaque conducteur (42, 44) des unités individuelles de protection contre les tensions transitoires avec un matériau conducteur, moyennant quoi la séparation électrique desdits conducteurs par la distance d'isolement est maintenue.

2. Procédé selon la revendication 1, dans lequel la distance d'isolement est inférieure à environ 1 mil (0,0254 mm).

3. Dispositif de protection contre les surtensions transitoires comprenant :

(a) un substrat (60) comportant une couche conductrice (62) comprenant deux distances d'isolement (64, 66) définissant un bus conducteur central (68) entre celles-ci et des parties conductrices (76 à 84) des deux côtés du bus conducteur central (68) qui sont dimensionnées pour s'accoupler avec des broches ou fils de connecteur (67),
dans lequel
(b) les distances d'isolement (64, 66) sont adaptées pour isoler le bus conducteur (68) par rapport aux parties conductrices (76 à 84) comportant des trous débouchants (72) ou collerettes (69) pour les broches ou fils du connecteur, et
(c) les distances d'isolement (64, 66) sont remplies avec un matériau d'impédance variable (74) pour fournir une connexion électrique efficace en surtension entre le bus conducteur (68) et chacune des parties conductrices (76 à 84).

4. Dispositif selon la revendication 3, dans lequel la largeur des distances d'isolement (64, 66) est inférieure à 1 mil (0,0254 mm).

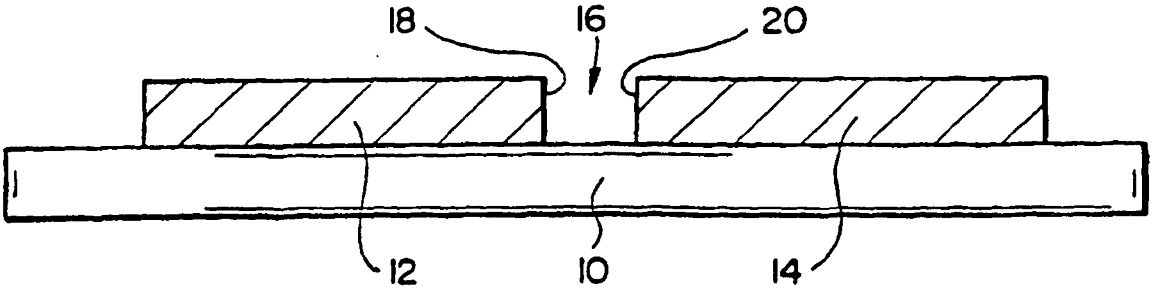

FIG_1A

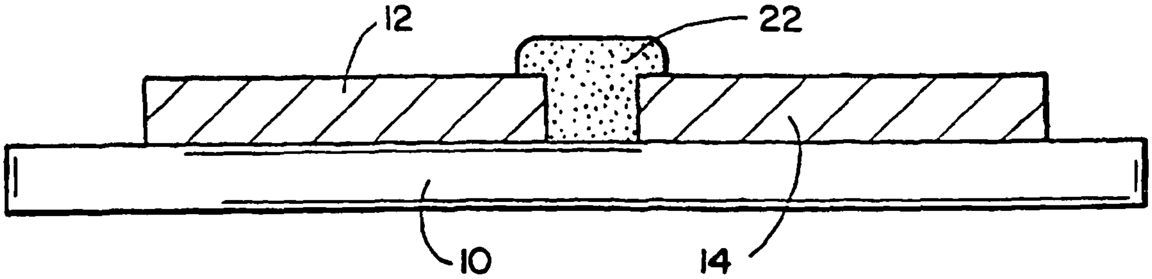

FIG_1B

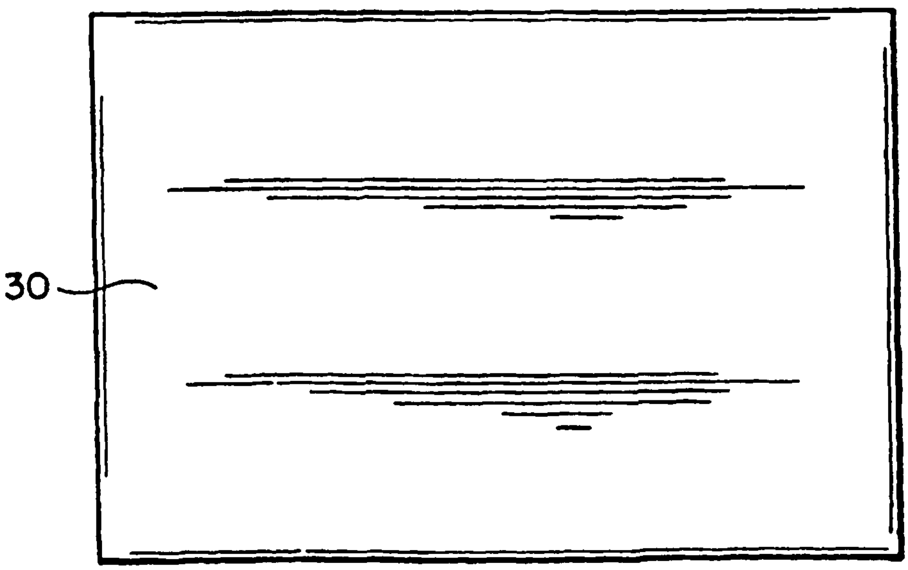

FIG_2A

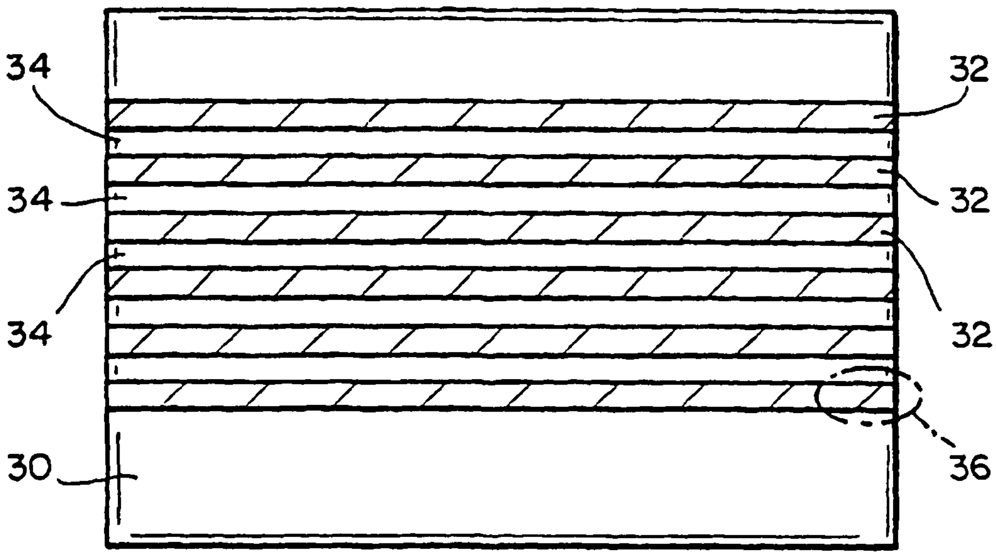

FIG_2B

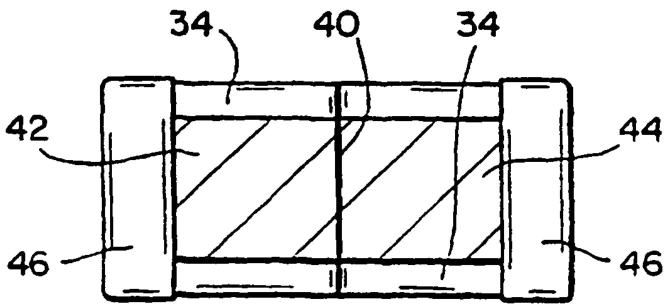

FIG_2C

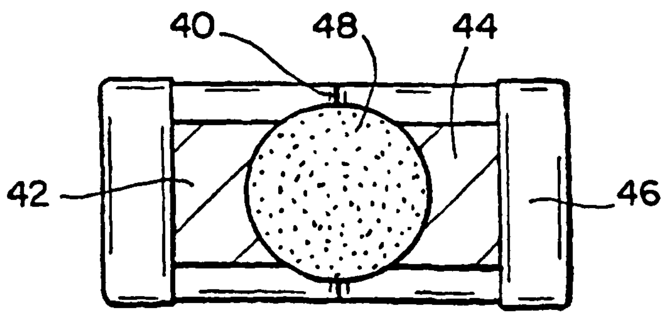

FIG_2D

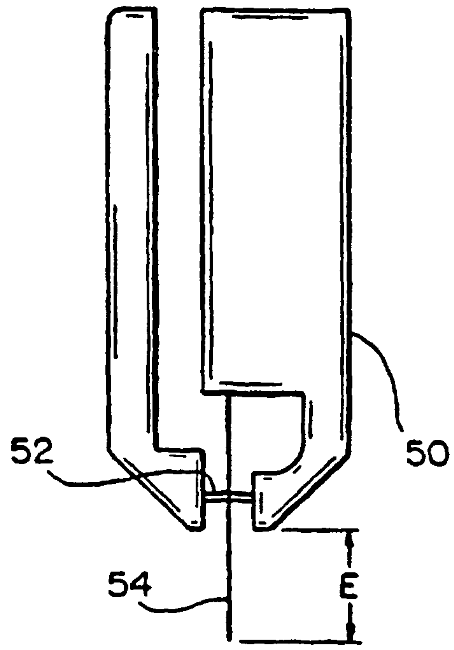

FIG_3

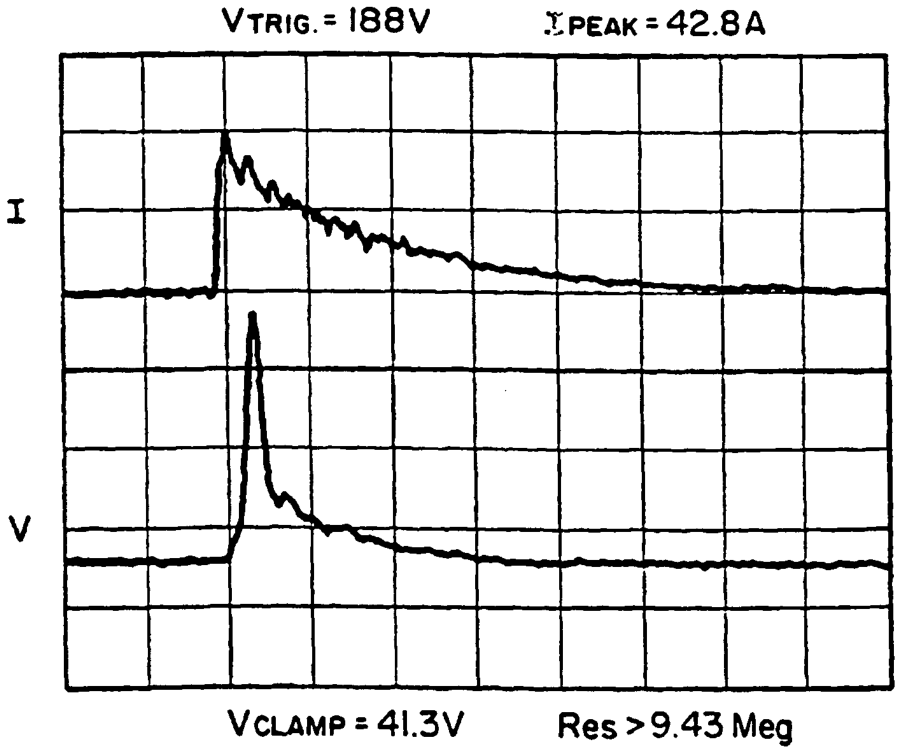

FIG_5

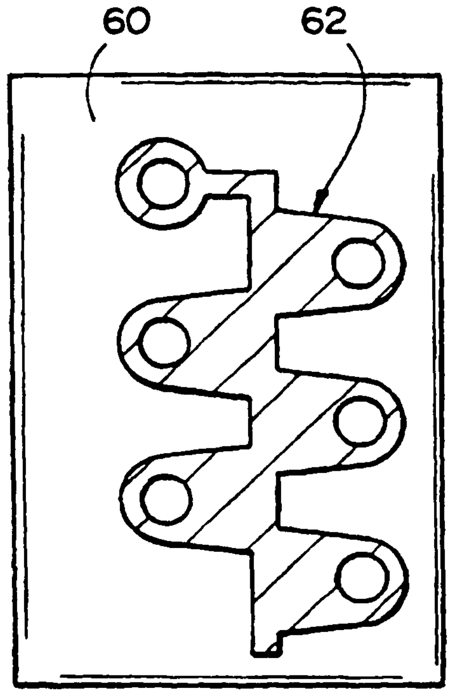

FIG_4A

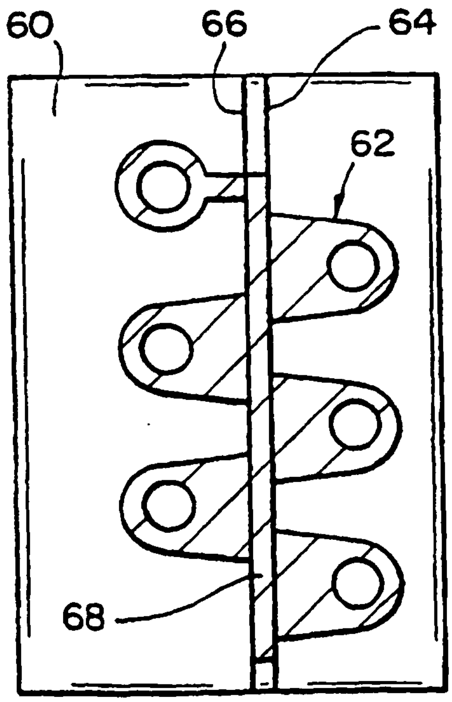

FIG_4B

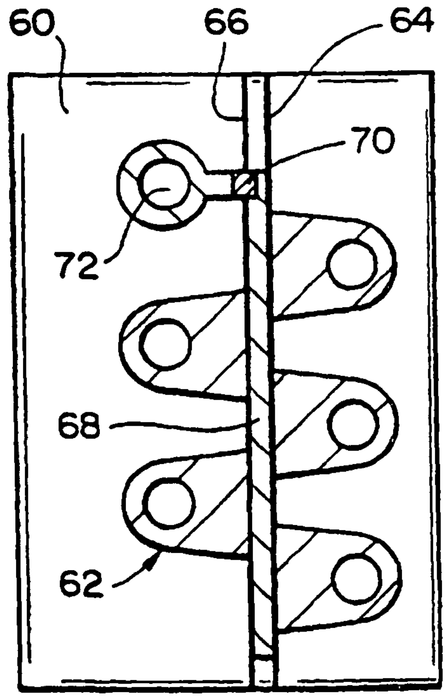

FIG_4C

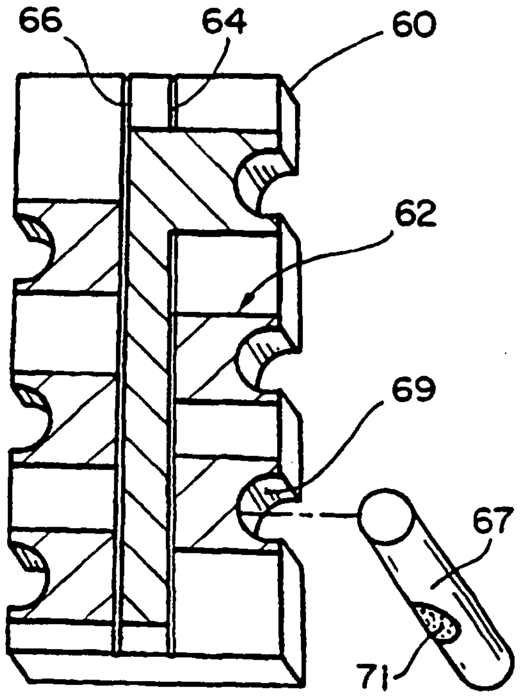

FIG_4D

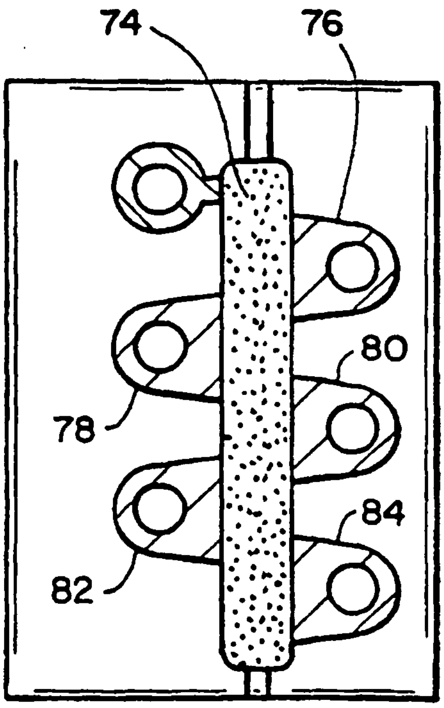

FIG_4E

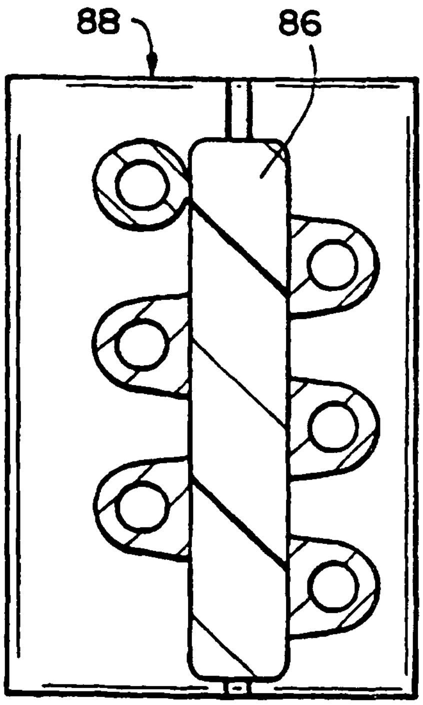

FIG_4F