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(54) **Titre : RESISTANCES POUR MONTAGE EN SURFACE ET PROCEDES DE FABRICATION ASSOCIES**
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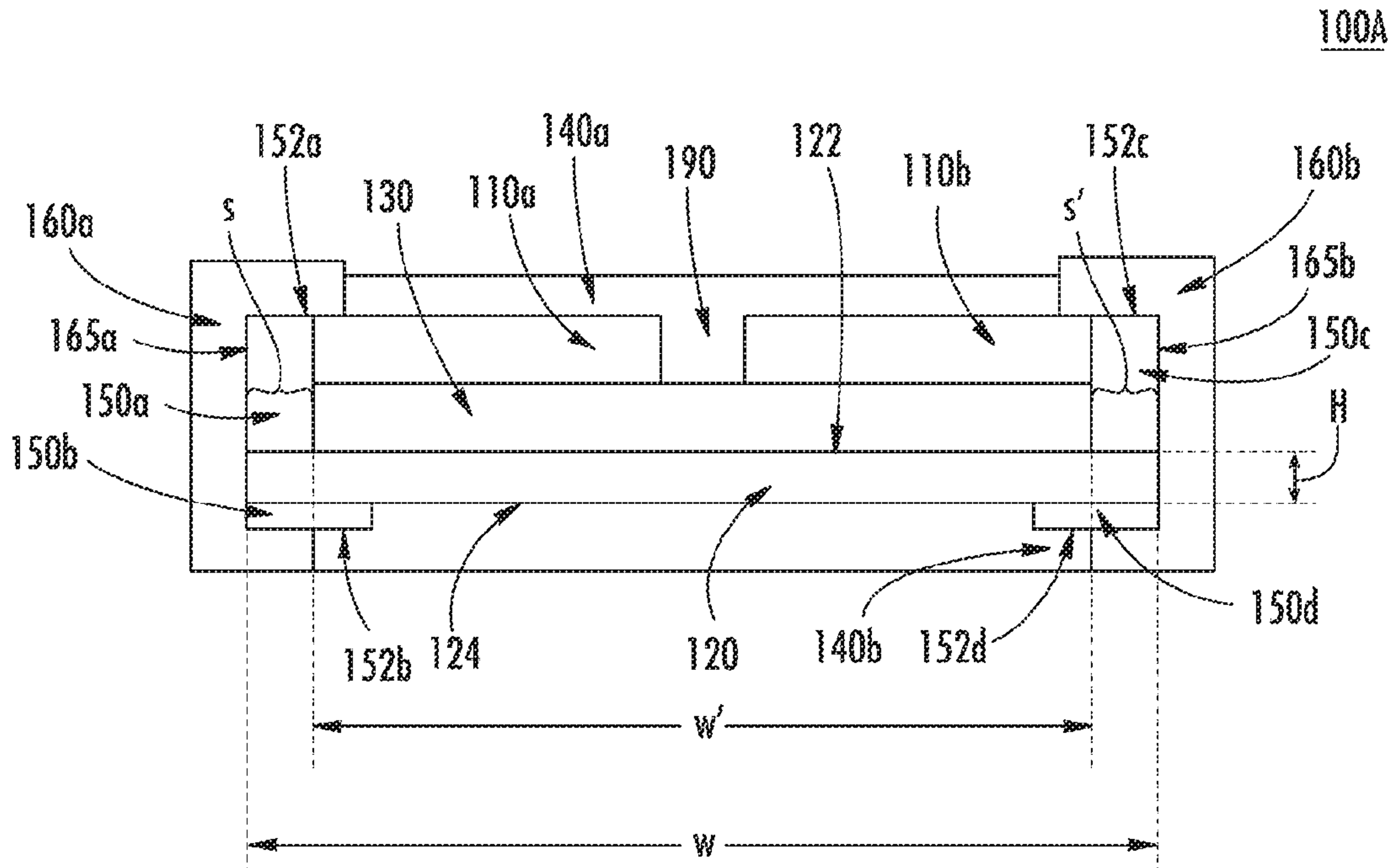

FIG. 1A

(57) **Abrégé/Abstract:**
Resistors and a method of manufacturing resistors are described herein. A resistor includes a resistive element and a plurality of conductive elements. The plurality of conductive elements are electrically insulated from one another via a dielectric material and thermally coupled to the resistive element via an adhesive material disposed between each of the plurality of conductive elements and a surface of the resistive element. The plurality of conductive elements is coupled to the resistive element via conductive layers and solderable layers.

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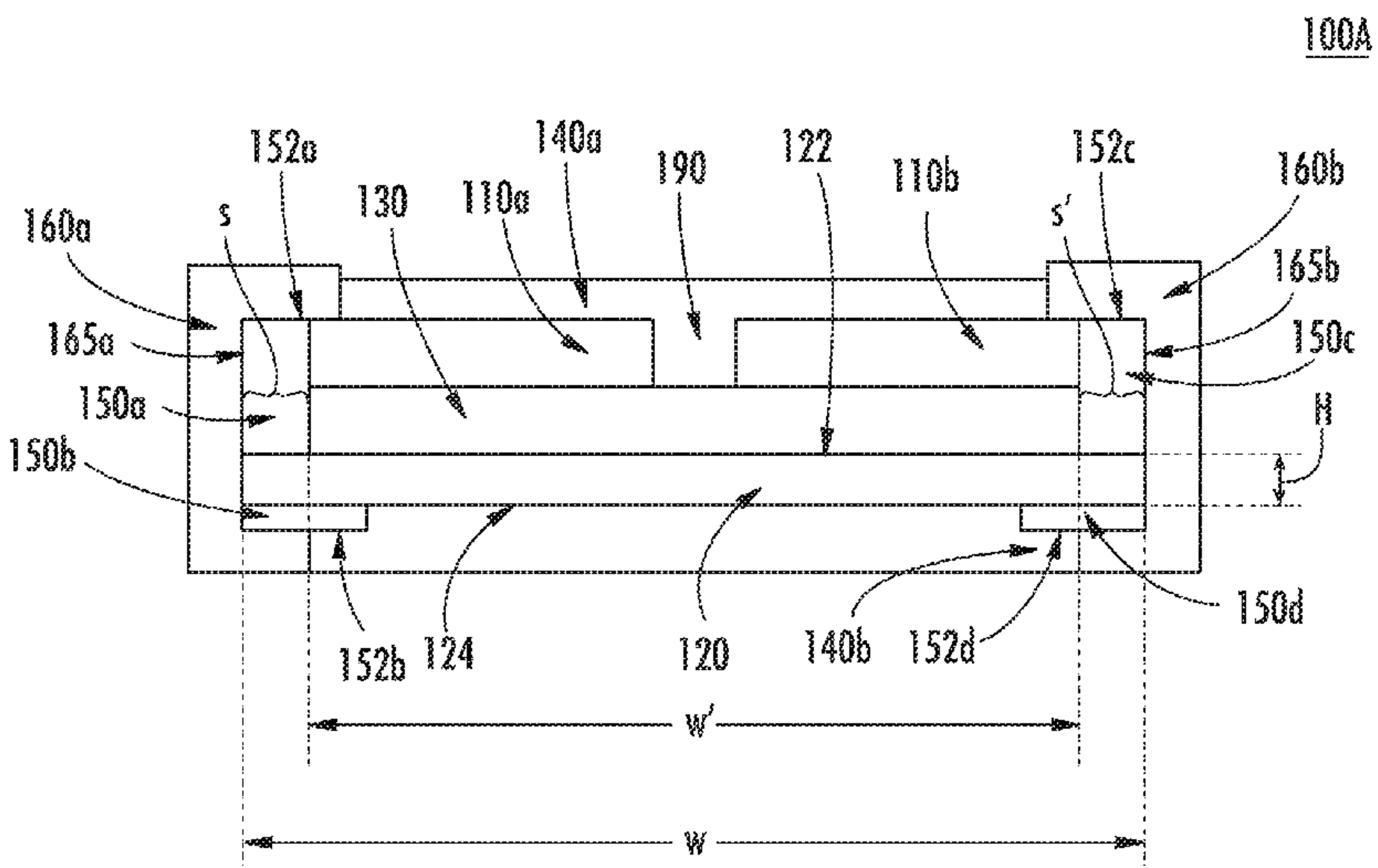


FIG. 1A

(57) Abstract: Resistors and a method of manufacturing resistors are described herein. A resistor includes a resistive element and a plurality of conductive elements. The plurality of conductive elements are electrically insulated from one another via a dielectric material and thermally coupled to the resistive element via an adhesive material disposed between each of the plurality of conductive elements and a surface of the resistive element. The plurality of conductive elements is coupled to the resistive element via conductive layers and solderable layers.

WO 2017/075016 A1

SURFACE MOUNT RESISTORS AND METHODS OF MANUFACTURING SAME

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Patent Application No. 14/928,893, filed October 30, 2015, the entire contents of which is hereby incorporated by reference as if fully set forth herein.

FIELD OF INVENTION

[0002] This application relates to the field of electronic components and, more specifically, resistors and the manufacture of resistors.

BACKGROUND

[0003] Resistors are passive components used in circuits to provide electrical resistance by converting electrical energy into heat, which is dissipated. Resistors may be used in electrical circuits for many purposes, including limiting current, dividing voltage, sensing current levels, adjusting signal levels and biasing active elements. High power resistors may be required in applications such as motor vehicle controls, and such resistors may be required to dissipate many watts of electrical power. Where those resistors are also required to have relatively high resistance values, such resistors should be made to support resistive elements that are very thin and also able to maintain their resistance values under a full power load over a long period of time.

SUMMARY

[0004] Resistors and methods of manufacturing resistors are described herein.

[0005] According to an embodiment of the present invention, a resistor includes a resistive element and a plurality of separated conductive elements. The plurality of conductive elements may be electrically insulated from one another via a dielectric material and thermally coupled to the resistive

element via an adhesive material disposed between each of the plurality of conductive elements and a surface of the resistive element. The plurality of conductive elements may also be electrically coupled to the resistive element via conductive layers and solderable layers.

[0006] According to another aspect of the invention a resistor is provided comprising a resistive element having an upper surface, a bottom surface, a first side surface, and an opposite second side surface. A first conductive element and a second conductive element are joined to the upper surface of the resistive element by an adhesive. A gap is provided between the first conductive element and the second conductive element. The positioning of the first conductive element and the second conductive leave exposed portions of the upper surface of resistive element adjacent the first side surface and the second side surface of the resistive element. A first conductive layer covers the exposed portion of the upper surface of resistive element adjacent the first side surface, and is in contact with the adhesive and the first conductive element. A second conductive layer covers the exposed portion of the upper surface of resistive element adjacent the second side surface, and is in contact with the adhesive and the second conductive element. A third conductive layer is positioned along a bottom portion of the resistive element, adjacent the first side of the resistive element. A fourth conductive layer is positioned along a bottom portion of the resistive element, adjacent the second side of the resistive element. A dielectric material covers upper surfaces of the first conductive element and the second conductive element and fills the gap between the first conductive element and the second conductive element. A dielectric material is deposited on an outer surface of the resistor, and may be deposited on both the top and bottom of the resistor.

[0007] A method of manufacturing a resistor is also provided. The method comprises the steps of: laminating a conductor to a resistive element using an adhesive; masking and patterning the conductor to divide the conductor into a plurality of conductive elements; selectively removing portions of the adhesive material from the resistive element; plating the resistive element with one or more conductive layers to electrically couple the resistive element to the plurality of conductive elements; and, depositing a dielectric material on at least the plurality of conductive elements to electrically isolate the plurality of conductive elements from each other.

[0008] According to another aspect of the invention a resistor is provided comprising a resistive element, and first and second conductive elements that are electrically insulated from one another by a dielectric material thermally coupled to the resistive element via an adhesive material. A first conductive layer is disposed so as to directly contact a first side surface of the resistive element and a side surface of the first conductive element. A second conductive layer is disposed so as to directly contact a second side surface of the resistive element and a side surface of the second conductive element. First and second solderable layers form lateral sides of the resistor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

[0010] FIG. 1A shows a cross-sectional view of an embodiment of a resistor according to the present invention.

[0011] FIG. 1B shows the resistor of FIG. 1A mounted on a circuit board.

[0012] FIG. 2 shows a flow diagram of an example method of manufacturing the resistor of FIG. 1A.

[0013] FIG. 3 shows a cross-sectional view of an embodiment of a resistor according to the present invention.

[0014] FIG. 4 is a flow diagram of an example method of manufacturing the resistor of FIG. 3.

[0015] FIG. 5 shows a cross-sectional view of an embodiment of a resistor according to the present invention.

[0016] FIG. 6 is a flow diagram of an example method of manufacturing the resistor of FIG. 5.

DETAILED DESCRIPTION

[0017] Certain terminology is used in the following description for convenience only and is not limiting. The words “right,” “left,” “top,” and “bottom” designate directions in the drawings to which reference is made. The words “a” and “one,” as used in the claims and in the corresponding portions of the specification, are defined as including one or more of the referenced item unless specifically stated otherwise. This terminology includes the words above specifically mentioned, derivatives thereof, and words of similar import. The phrase “at least one” followed by a list of two or more items, such as “A, B, or C,” means any individual one of A, B or C as well as any combination thereof.

[0018] FIG. 1A is a diagram of an illustrative resistor 100 (designated as 100A in FIG. 1A and 100B in FIG. 1B) according to an embodiment of the present invention. The resistor 100A illustrated in FIG. 1 includes a resistive element 120 positioned across the resistor, and between a first solderable layer 160a and a second solderable layer 160b, described in greater detail below. In the orientation shown in FIG. 1A for illustrative purposes, the resistive element has a top surface 122 and a bottom surface 124. The resistive element 120 is preferably a foil resistor. The resistive element may be formed from, by way of non-limiting example, copper, alloys of copper, nickel, aluminum, or manganese, or combinations thereof. The resistive element may be formed from alloys of copper-nickel-manganese (CuNiMn), nickel-chromium-aluminum (NiCrAl), or nickel-chromium (NiCr), or other alloys known to those of skill in the art acceptable for use as a foil resistor. The resistive element 120 has a width designated in FIG. 1A as “w”. In addition, the resistive element 120 has a height or thickness designated in FIG. 1A as height “H”.

[0019] As shown in FIG. 1A, a first conductive element 110a and a second conductive element 110b are positioned adjacent opposite side ends of the resistive element 120, with a gap 190 preferably provided between the first conductive element 110a and a second conductive element 110b. The conductive elements 110a and 110b may preferably comprise copper, such as, for example, C110 or C102 copper. However, other metals with good heat transfer properties, such as, for example, aluminum, may be used for the conductive elements, and those of skill in the art will appreciate other acceptable metals for use as the conductive elements. Preferably, the first conductive element 110a and a second conductive element 110b do not extend all the way to the outer side edges (or outer side surfaces) of the resistive element 120, and leave spaces s and s' adjacent the edges of the resistive element 120. Exposed portions of the upper surface 122 of the resistive element 120 face each of the spaces s and s' adjacent the side edges of the resistive element 120.

[0020] The conductive elements 110a and 110b may be laminated to or otherwise bonded, joined or attached to the resistive element 120 via an adhesive material 130, which may comprise, by way of non-limiting example, materials such as DUPONT™ PYRALUX™, or other acrylic, epoxy, or polyimide adhesives in sheet or liquid form. As shown in FIG. 1A, the adhesive material 130 preferably extends only along a central portion of the resistive element, from a side edge of the first conductive element 110a, to the opposite side edge of the second conductive element 110b. The first conductive element 110a, second conductive element 110b, and adhesive material 130 extend along a width adjacent the top surface 122 of the resistive element 120 designated as w'.

[0021] A first conductive layer 150a and a second conductive layer 150c are provided in the spaces s and s', adjacent the top surface 122 of the resistive element 120 and along the outer side edges (or outer side surfaces) of the conductive elements 110a and 110b in order to provide an electrical connection with them. Preferably, the first conductive layer 150a and the second conductive layer 150c are plated to the top surface 122 of the resistive element and along the outer side edges (or outer side surfaces) of the conductive elements 110a and 110b. In a preferred embodiment, copper may be used for the conductive layers. However, any platable and highly conductive metals may be used, as will be appreciated by those of skill in the art.

[0022] As shown in FIG. 1A, additional third 150b and fourth 150d conductive layers are disposed adjacent opposite side ends and along at least portions of the bottom surface 124 of the resistive element 120. The conductive layers 150b and 150d have opposite outer edges that preferably align with the opposite outer side edges (or outer side surfaces) of resistive element 120, and the opposite outer side edges (or outer side surfaces) of first conductive layer 150a and a second conductive layer 150c. Preferably, the third 150b and fourth 150d conductive layers are plated to the bottom surface 124 of the resistive element 120.

[0023] The aligned outer side edges (or outer side surfaces) of the resistive element 120 and the outer side edges (or outer side surfaces) of the conductive layers 150a, 150b, 150c, 150d, form solderable surfaces configured to receive solderable layers. Solderable layers 160a and 160b may be separately attached at the lateral ends 165a and 165b of the resistor 100A to allow the resistor 100A to be soldered to a circuit board, which is described in more detail below with respect to FIG. 1B. As shown in FIG. 1A, the solderable layers 160a and 160b preferably include portions that extend at least partially along bottom surfaces 152b and 152d of the conductive layers 150b and 150d. As shown in FIG. 1A, the solderable layers 160a and 160b preferably include portions that extend along upper surfaces 152a and 152c of the conductive layers 150a and 150c, and also at least partially along an upper surface of the conductive elements 110a and 110b.

[0024] A dielectric material 140 may be deposited on a surface or surfaces of the resistor 100, for example, by coating. The dielectric material 140 may fill spaces or gaps to electrically isolate components from each other. As shown in FIG. 1A, a first dielectric material 140a is deposited on an upper portion of the resistor. The first dielectric material 140a preferably extends between portions of the solderable layers 160a and 160b, and covers the exposed upper surfaces of the conductive elements 110a and 110b. The first dielectric material 140a also fills in the gap 190 between the conductive elements 110a and 110b, covering the exposed portion of the adhesive 130 facing the gap 190. A second dielectric material 140b is deposited along the bottom surface of the resistive element 120, between portions of the solderable layers 160a and 160b, and covering exposed portions of the conductive layers 150b and 150d, and the bottom surface 124 of the resistive element 120.

[0025] FIG. 1B is a diagram of an illustrative resistor 100B mounted on a circuit board 170. The resistor 100B is identical to the resistor 100A, and same parts are given the same numbering in FIG. 1B. In the example illustrated in FIG. 1B, the resistor 100B is mounted to the circuit board 170 using solder connections 180a and 180b between the solderable layers 160a and 160b and corresponding solder pads 175a and 175b on the circuit board 170.

[0026] The conductive elements 110a and 110b are coupled to the resistive element 120 via the adhesive 130 and connected to the resistive element at its lateral or outer side ends or surfaces via the conductive layer 150a and 150c. It is appreciated that the conductive elements 110a and 110b may be thermally and/or mechanically and/or electrically coupled/connected or otherwise bonded, joined or attached to the resistive element 120. It is further appreciated that the conductive elements 110a and 110b may be thermally and/or mechanically and/or electrically coupled/connected or otherwise bonded, joined or attached to the conductive layers 150a and 150c. Of particular note, the conductive layer 150a and 150c makes the electrical connection between the resistive element 120 and the conductive elements 110a and 110b from the surface 122 of the resistive element that is farthest from the circuit board 170 when the resistor 100B is mounted thereon. The thermal, electrical, and/or mechanical coupling/connection between the resistive element 120 and the lateral end of each of the conductive elements 110a and 110b may enable the conductive elements 110a and 110b to be used both as supports for the resistive element 120 and also as a heat spreader. Use of the conductive elements 110a and 110b as a support for the resistive element 120 may enable the resistive element 120 to be made thinner as compared to self-supporting resistive elements, enabling the resistor 100B to be made to have a resistance values of 1mΩ to 20Ω using foil thicknesses between about 0.015” and about 0.001”. In addition to providing support for the resistive element 120, efficient use of the conductive elements 110a and 110b as a heat spreader may enable the resistor 100B to dissipate higher powers as compared to resistors that do not use a heat spreader. For example, a typical power rating for a 2512 size metal strip resistor is 1W. Using the embodiments described herein, the power rating for a 2512 size metal strip resistor may be 3W.

[0027] Further, making the electrical connection between the resistive element 120 and the conductive elements 110a and 110b on a surface of the resistive element that is farthest from the circuit board 170 may avoid exposure of the resistive-element-to-conductive-element-connection to the solder joint between the resistor 100 and the circuit board 170, which may reduce or eliminate risk of failure of the resistor due to the thermal coefficient of expansion (TCE). Further, the use of a conductive layer, such as 150b and 150d, on the side of the resistive element that is closest to the PCB may aid in creating a strong solder joint and centering the resistor on the PCB pads during solder reflow.

[0028] Examples of other resistor designs and methods of manufacturing them are described below with respect to FIGs. 2, 3, 4, 5 and 6 to illustrate different designs that may achieve the same general design goals as the resistors 100A, 100B. However, one of ordinary skill in the art will understand that other resistor designs and manufacturing methods may be made within the scope of this disclosure.

[0029] FIG. 2 is a flow diagram of an illustrative method 200 of manufacturing the resistor of FIG. 1. In the example method illustrated in FIG. 2, a conductive layer and the resistive element 120 may be cleaned (205) and cut, for example, to a desired sheet size (210). The conductive layer and the resistive element 120 may be laminated together using an adhesive material 130 (215). The resistive element 120 and the conductive layer may be masked (220) and patterned (225) as desired. In the example resistor 100, masking and patterning of the conductive layer may be used, for example, to separate the conductive layer to form conductive elements 110a and 110b. At least some of the adhesive material 130 may be selectively removed from the surface 122 of the resistive element 120 (230), for example, to make space for the conductive layer 150a and 150c that will make the electrical connection between the resistive element 120 and the conductive elements 110a and 110b.

[0030] The conductive elements 110a and 110b and the resistive element 120 may be masked, as desired, to create a plating pattern and then may be plated (235). The plating may be used, for example, to deposit one or more of the conductive layers 150a, 150b, 150c and 150d. Once the plating is completed, the masking may be removed so that the resistive element may be calibrated (240), for example, by thinning a resistive foil to a desired thickness or by manipulating the current path by cutting through the resistive foil in specific locations based, for example, on the target resistance value for the resistor. A dielectric material 140 is deposited on the top, bottom, or both top and bottom surfaces of the resistor 100. The dielectric material 140 is preferably deposited on exposed upper surfaces of the conductive elements 110a and 110b (245), for example, by coating. The dielectric material 140a may fill any space between the conductive elements 110a and 110b to electrically isolate them from one another. A plate formed by the method may then be singulated into individual pieces to form individual resistors 100 (250). Solderable layers 160a and 160b may then be attached to, or formed on, the lateral edges 165a and 165b of the individual resistors 100, for example, by plating (255).

[0031] FIG. 3 is a diagram of another illustrative resistor 300 according to an embodiment of the present invention. Similar to resistor 100, resistor 300 illustrated in FIG. 3 includes a resistive element 320 positioned across the resistor, and between a first solderable layer 360a and a second solderable layer 360b, described in greater detail below. In the orientation shown in FIG. 3 for illustrative purposes, the resistive element 320 has a top surface 322 and a bottom surface 324. The resistive element is preferably a foil resistor. The resistive element 320 has a width designated in FIG. 3 as w. In addition, the resistive element 320 has a height or thickness designated in FIG. 3 as height “H”. Exposed portions of the upper surface 322 of the resistive element 320 face each of the spaces s and s' adjacent the side edges of the resistive element 320.

[0032] As shown in FIG. 3, a first conductive element 310a and a second conductive element 310b are positioned adjacent opposite side ends of the resistive element 320 with a gap 390 preferably provided between the first conductive element 310a and the second conductive element 310b. The conductive elements 310a and 310b may preferably comprise copper.

[0033] The conductive elements 310a and 310b may be laminated to or otherwise joined or attached to the resistive element 320 via an adhesive material 330. As shown in FIG. 3, the adhesive material 330 preferably extends only along a central portion of the resistive element, extending along a width adjacent the top surface of the resistive element 320 designed at w'.

[0034] The conductive elements 310a and 310b are shaped such that each conductive element 310a and 310b extends along a portion of the top surface 322 of the resistive element 320, from an outer edge of the gap 390 to a respective outer edge of the adhesive 330, and each has a portion that angles outwardly and downwardly toward the resistive element 320, to be positioned in the spaces s and s' and directly contacting the top surface 322 of the resistive element 320. The angled portions of the conductive elements 310a and 310b are preferably positioned and arranged to provide for intimate contact, electrically, thermally and mechanically, between of the conductive elements 310a and 310b and the surface 322 of the resistive element 320 in the area designated as s, and to provide for intimate contact, electrically, thermally and mechanically, between the conductive elements 310a and 310b and the surface 322 of the resistive element 320 in the area designated as s'. The shape of the upper portions 312a and 312b of the conductive elements 310a and 310b can be varied, and can range from a barely perceptible step, to a rounding such as a rounded edge, to an angle having a slope that could be from a few degrees to somewhat less than 90 degrees, so long as the areas provide for intimate contact as described.

[0035] As shown in FIG. 3, first 350a and second 350b conductive layers are disposed along opposite side ends along the bottom surface 324 of the resistive element 320. The conductive layers 350a and 350b have opposite outer edges that preferably align with the opposite outer edges of resistive element 320, and the opposite outer edges of the conductive elements 310a and 310b. Preferably, the first 350a and second 350b conductive layers are plated to the bottom surface 324 of the resistive element 320.

[0036] The outer side edges (or outer side surfaces) of the resistive element 320, the outer sides of the conductive elements 310a, 310b, and the outer side edges (or outer side surfaces) of conductive layers 350a and 350b, form solderable surfaces configured to receive solderable layers. Solderable layers 360a and 360b may be attached at the lateral ends 365a and 365b of the resistor 300 to allow the resistor 300 to be soldered to a circuit board. As shown in FIG. 3, the solderable layers 360a and 360b preferably include portions that extend along the shaped upper portions 312a and 312b of the conductive elements 310a and 310b, at least partially along an upper surface of the conductive elements 310a and 310b, and also at least partially along a bottom surface of the conductive layers 350a and 350b.

[0037] A dielectric material 340 may be deposited surfaces of the resistor 300, for example, by coating. The dielectric material 340 may fill spaces or gaps to electrically isolate components from each another. As shown in FIG. 3, a first dielectric material 340a is deposited on an upper portion of the resistor 300. The first dielectric material 340a preferably extends between portions of the solderable layers 360a and 360b, and covers the exposed upper surfaces of the conductive elements 310a and 310b. The first dielectric material 340a also fills in the gap 390 between the conductive elements 310a and 310b, covering the exposed portion of the adhesive 330 facing the gaps 390. A second dielectric material 340b is deposited along the bottom surface of the resistive element 320, between portions of the solderable layers 360a and 360b, and covering exposed portions of the conductive layers 350a and 350d, and the bottom surface 324 of the resistive element 320.

[0038] FIG. 4 is a flow diagram of an example method 400 of manufacturing the resistor 300. In the example method illustrated in FIG. 4, a conductive layer and the resistive element 320 may be cleaned (405) and cut, for example, to a desired sheet size (410). The conductive layer and the resistive element 320 may be laminated together using an adhesive material 330 (415). The resistive element 320 and the conductive layer may be masked (420) and patterned (425) as desired. In the example resistor 300, masking and patterning of the conductive layer may be used, for example, to separate the conductive layer to form conductive elements 310a and 310b. At least some of the adhesive material 330 may be selectively removed from the surface 322 of the resistive element 320 (430), for example, to make space for a direct connection with the conductive elements 310a and 310b.

[0039] The conductive elements 310a and 310b and the resistive element 320 may be masked, as desired, to create a plating pattern and then may be plated (435). The plating may be used, for example, to deposit one or more of the conductive layer 350a and 350b on the surface 324 of the resistive element 320. Once the plating is completed, the masking may be removed so that the resistive element may be calibrated (440), for example, by thinning a resistive foil to a desired thickness or by manipulating the current path by cutting through the resistive foil in specific locations based, for example, on the target resistance value for the resistor. The conductive elements 310a and 310b may then be swaged to cover the portions of the surface 322 of the resistive element 320 that were exposed by the selective removing of the adhesive material 330 (445).

[0040] A dielectric material 340 may be deposited on one or both of the bottom surface 324 of the resistive element 320, and the conductive elements 310a and 310b (450), for example, by coating. The dielectric material 340a may fill any space between the conductive elements 310a and 310b to electrically isolate them from one another. A plate formed by the method may then be singulated into individual pieces to form individual resistors 300 (455). Solderable layers 360a and 360b may then be attached to, or formed on, the lateral edges 365a and 365b of the individual resistors 300, for example, by plating (460).

[0041] FIG. 5 is a diagram of another illustrative resistor 500 according to an embodiment of the present invention. Similar to the resistors 100 and

300, the resistor 500 illustrated in FIG. 5 includes a resistive element 520 positioned across the resistor, and between a first solderable layer 560a and a second solderable layer 560b, described in greater detail below. In the orientation shown in FIG. 5 for illustrative purposes, the resistive element has a top surface 522 and a bottom surface 524. The resistive element 520 is preferably a foil resistor. The resistive element 520 has a width designated in FIG. 5 as w'. In addition, the resistive element 520 has a height or thickness designated in FIG. 5 as height "H". Exposed sides of the resistive element 520 face each of the spaces designated as s and s' in FIG. 5 adjacent the side edges of the resistive element 520.

[0042] As shown in FIG. 5, a first conductive element 510a and a second conductive element 510b are positioned adjacent opposite side ends of the resistive element 520, with a gap 590 preferably provided between the first conductive element 510a and a second conductive element 510b. The conductive elements 510a and 510b may preferably comprise copper. Preferably, the first conductive element 510a and a second conductive element 510b are aligned with the outer edges of the resistive element 520.

[0043] The conductive elements 510a and 510b may be laminated to or otherwise joined or attached to the resistive element 520 via an adhesive material 530. As shown in FIG. 5, the adhesive material 530 preferably extends along the entire upper surface 522 of the resistive element 520. The resistive element 520 and the adhesive material 530 have a width designated as w'.

[0044] A first conductive layer 550a and a second conductive layer 550b are provided in spaces s and s', along the outer side edges (or outer side surfaces) of the resistive element 520, the adhesive 530 and each of the conductive elements 510a and 510b in order to make an electrical connection between them. Preferably, the first conductive layer 550a and the second conductive layer 550b are plated to the bottom surface 524 of the resistive element 520 and along the outer edges of the resistive element 520 and the conductive elements 510a and 510b.

[0045] The aligned outer side edges (or outer side surfaces) of the resistive element 520, adhesive material 530, and conductive layers 550a, 550b, form solderable surfaces configured to receive solderable layers. Solderable layers 560a and 560b may be separately attached at the lateral ends 565a and 565b of the resistor 500 to allow the resistor 500 to be soldered to a circuit board. As shown in FIG. 5, the solderable layers 560a and 560b preferably include portions that extend at least partially along bottom surfaces of the conductive layers 550a and 550b, and also at least partially along an upper surface of the conductive layers 550a and 550b and the conductive elements 510a and 510b.

[0046] A dielectric material 540 may be deposited on surfaces of the resistor 500, for example, by coating. The dielectric material 540 may fill spaces or gaps to electrically isolate them from one another. As shown in FIG. 5, a first dielectric material 540a is deposited on an upper portion of the resistor. The first dielectric material 540a preferably extends between portions of the solderable layers 560a and 560b, and covers the exposed upper surfaces of the conductive elements 510a and 510b. The first dielectric material 540a also fills in the gap 590 between the conductive elements 510a and 510b, covering the exposed portion of the adhesive 530 facing the gap 590. A second dielectric material 540b is deposited along the bottom surface of the resistive element 520, between portions of the solderable layers 560a and 560b, and covering exposed portions of the conductive layers 550a and 550b, and bottom surface 524 of the resistive element 520.

[0047] FIG. 6 is a flow diagram of an example method of manufacturing the resistor 500. In the example method illustrated in FIG. 6, a conductive layer and the resistive element 520 may be cleaned (605) and cut, for example, to a desired sheet size (610). The conductive layer and the resistive element 520 may be laminated together using an adhesive material 530 (615). The resistive element 520 and the conductive layer may be masked (620) and patterned (625) as desired. In the example resistor 500, masking and patterning of the conductive layer may be used, for example, to separate the conductive layer to form conductive elements 510a and 510b.

[0048] The conductive elements 510a and 510b and the resistive element 520 may be masked, as desired, to create a plating pattern and then may be plated (630). The plating may be used, for example, to deposit one or more of the conductive layer 550a and 550b. Once the plating is completed, the masking may be removed so that the resistive element may be calibrated (635), for example, by thinning a resistive foil to a desired thickness or by manipulating the current path by cutting through the resistive foil in specific locations based, for example, on the target resistance value for the resistor. A dielectric material 540 may be deposited on one or both of the resistive element 520, and the conductive elements 510a and 510b (640) (e.g., by coating). The dielectric material 540a may fill any space between the conductive elements 510a and 510b to electrically isolate them from one another. A plate formed by the method may then be singulated into individual pieces to form individual resistors 500 (645). Solderable layers 560a and 560b may then be attached to, or formed on, the lateral edges 565a and 565b of the individual resistors 500, for example, by plating (650). In the embodiments illustrated in FIGs. 5 and 6, the adhesive material 530 may be sheared during singulation, eliminating the need to remove certain adhesive materials, such as Kapton, in a secondary lasing operation to expose the resistive element before plating.

[0049] Although the features and elements of the present invention are described in the example embodiments in particular combinations, each feature may be used alone without the other features and elements of the example embodiments or in various combinations with or without other features and elements of the present invention.

* * *

CLAIMS

What is claimed is:

1. A resistor comprising:

a resistive element having an upper surface, a bottom surface, a first side surface, and an opposite second side surface; and

a first conductive element comprising a heat spreader and a second conductive element comprising a heat spreader joined to the upper surface of the resistive element by an adhesive, wherein a gap is provided between the first conductive element and the second conductive element, and wherein the positioning of the first conductive element and the second conductive element leaves exposed portions of the upper surface of resistive element adjacent the first side surface and the second side surface of the resistive element;

a first conductive layer covering the exposed portion of the upper surface of resistive element adjacent the first side surface, and in contact with the first conductive element;

a second conductive layer covering the exposed portion of the upper surface of resistive element adjacent the second side surface, and in contact with the second conductive element;

a third conductive layer positioned along the bottom surface of the resistive element, adjacent the first side of the resistive element;

a fourth conductive layer positioned along the bottom surface of the resistive element, adjacent the second side of the resistive element;

a dielectric material covering upper surfaces of the first conductive element and the second conductive element and filling the gap between the first conductive element and the second conductive element;

wherein the first conductive layer, second conductive layer, third conductive layer, and fourth conductive layer do not cover the first side surface or second side surface of the resistive element; and

a dielectric material deposited on a surface of the resistor.

2. The resistor of claim 1, further comprising:

a first solderable layer covering a first side of the resistor, the first solderable layer in contact with the first conductive layer, the resistive element, and the third conductive layer; and,

a second solderable layer covering a second side of the resistor, the second solderable layer in contact with the second conductive layer, the resistive element, and the fourth conductive layer.

3. The resistor of claim 2, wherein the first solderable layer covers at least a portion of the upper surface of the first conductive element, and at least a portion of a bottom surface of the third conductive layer.

4. The resistor of claim 3, wherein the second solderable layer covers at least a portion of the upper surface of the second conductive element, and at least a portion of a bottom surface of the fourth conductive layer.

5. The resistor of claim 1, wherein the first conductive element and the second conductive element are thermally coupled to the resistive element by an adhesive.

6. The resistor of claim 5, wherein the adhesive is positioned only between the first and second conductive elements and the resistive element.

7. The resistor of claim 5, wherein at least a portion of the adhesive is positioned adjacent the first side surface of the resistive element, and wherein the first conductive layer is in contact with a portion adhesive joining the resistive element to the first conductive element.

8. The resistor of claim 7, wherein at least a portion of the adhesive is positioned adjacent the second side surface of the resistive element, and wherein

the second conductive layer is in contact with a portion adhesive joining the resistive element to the second conductive element.

9. The resistor of claim 1, wherein the first conductive layer and the second conductive layer each have an upper portion that is flat, stepped, angled or rounded.

10. The resistor of claim 1, wherein a first dielectric material covers at least a portion of the top of the resistor, and a second dielectric material covers at least a portion of the bottom of the resistor.

11. The resistor of claim 1, wherein the first conductive layer and the third conductive layer are formed as a single conductive layer.

12. The resistor of claim 11, wherein the second conductive layer and the fourth conductive layer are formed as a single conductive layer.

13. The resistor of claim 1, wherein the resistive element comprises copper-nickel-manganese (CuNiMn), nickel-chromium-aluminum (NiCrAl), or nickel-chromium (NiCr).

14. The resistor of claim 1, wherein the resistive element has a thickness of about 0.001" to about 0.015".

15. The resistor of claim 1, wherein the conductive elements comprise copper or aluminum.

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

laminating a conductor comprising a heat spreader to an upper surface of a resistive element using an adhesive;

masking and patterning the conductor to divide the conductor into a plurality of conductive elements;

selectively removing portions of the adhesive material from the resistive element;

plating exposed portions of the upper surface of the resistive element with one or more conductive layers to thermally couple the resistive element to the plurality of conductive elements;

plating one or more conductive layers on a bottom surface of the resistive element; and

depositing a dielectric material on at least the plurality of conductive elements to electrically isolate the plurality of conductive elements from each other;

wherein the conductive layers on the upper surface and bottom surface of the resistive element do not cover a first side surface or a second side surface of the resistive element.

17. The method of claim 16, further comprising the step of plating solderable layers to the side surfaces of the resistor.

18. (Canceled)

19. The method of claim 17, wherein the solderable layers are in contact with the resistive element, the conductive elements, the conductive layers, and the adhesive.

20. A resistor comprising:

a resistive element;

first and second conductive elements that are electrically insulated from one another by a dielectric material, the first and second conductive elements thermally coupled to an upper surface of the resistive element via an adhesive material;

wherein the first conductive element has a first outer edge in alignment with a first outer edge of the resistive element so as to form a generally planar first side surface, and the second conductive element has a second outer edge in alignment with a second outer edge of the resistive element so as to form a generally planar second side surface;

a first conductive layer disposed so as to directly contact the first side surface and extend along at least a portion of the bottom surface of the resistive element;

a second conductive layer disposed so as to directly contact the second side surface and extend along at least a portion of the bottom surface of the resistive element; and,

first and second solderable layers forming lateral sides of the resistor.

21. (New) A resistor comprising:

a resistive element having an upper surface configured to be positioned away from an attached circuit board, a bottom surface, a first side surface, and an opposite second side surface; and

a first conductive element comprising a heat spreader thermally coupled to the upper surface of the resistive element adjacent the first side surface, the first conductive element having an outer side edge; and

a second conductive element comprising a heat spreader thermally coupled to the upper surface of the resistive element adjacent the second side surface, the second conductive element having an outer side edge, wherein a gap is provided between the first conductive element and the second conductive element;

wherein the first side surface of the resistive element and the outer edge of the first conductive element are in alignment and form a first flat side surface, and wherein the second side surface of the resistive element and the outer edge of the second conductive element are in alignment and form a second flat side surface;

a first conductive layer contacting the first flat side surface and thermally coupled to the first conductive element and electrically coupled to first side of the resistive element;

a second conductive layer contacting the second flat side surface and thermally coupled to the second conductive element and electrically coupled to the second side of the resistive element;

a first dielectric material covering upper surfaces of the first conductive element and the second conductive element and filling the gap between the first conductive element and the second conductive element; and,

a second dielectric material deposited on at least portions of the bottom surface of the resistor.

22. (New) The resistor of claim 21, further comprising a first bottom conductive layer extending from the first conductive layer below at least a portion of the bottom surface of the resistive element.

23. (New) The resistor of claim 22, further comprising a second bottom conductive layer extending from the second conductive layer below at least a portion of the bottom surface of the resistive element.

24. (New) The resistor of claim 23, further comprising an adhesive applied along the upper surface of the resistive element.

25. (New) The resistor of claim 24, wherein the first conductive element and the second conductive element are joined to the resistive element by the adhesive.

26. (New) The resistor of claim 24, wherein the first dielectric material covers at least a portion of the adhesive, and the second dielectric material covers at least a portion of the bottom surface of the resistor.

27. (New) The resistor of claim 25, wherein at least a portion of the adhesive is positioned adjacent the first flat side surface, and wherein the first conductive layer is in at least partial contact with the adhesive.

28. (New) The resistor of claim 27, wherein at least a portion of the adhesive is positioned adjacent the second flat side surface, and wherein the second conductive layer is in at least partial contact with the adhesive.

29. (New) The resistor of claim 21, wherein the first conductive layer and the second conductive layer each have an upper portion that is flat.

30. (New) A method of manufacturing a resistor, the method comprising:

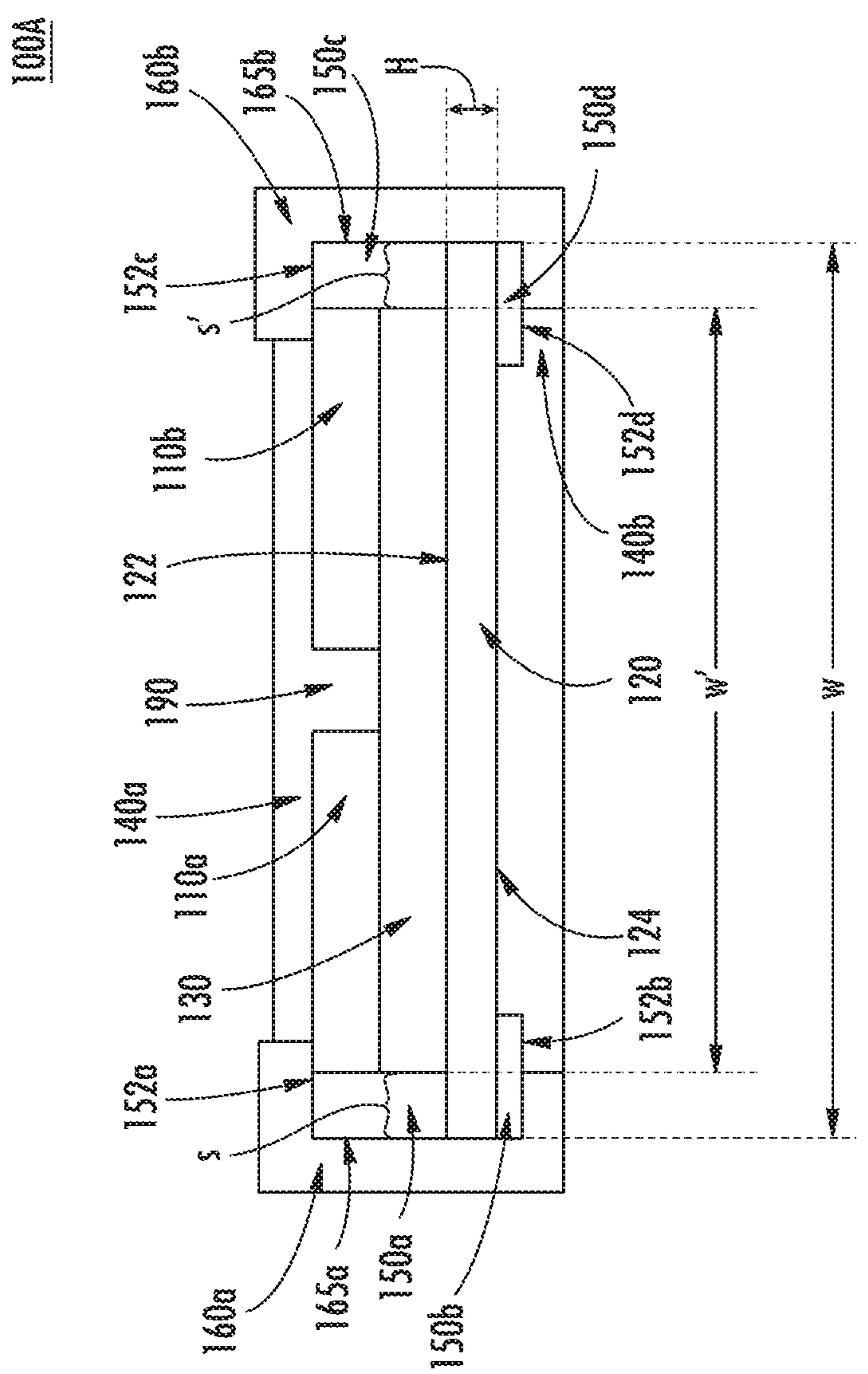
laminating a conductor comprising a heat spreader to an upper surface of a resistive element configured to be positioned away from a circuit board using an adhesive, wherein outer edges of the conductor are aligned with outer edges of the resistive element to form outer flat side surfaces;

masking and patterning the conductor to divide the conductor into a plurality of conductive elements;

plating the resistive element with conductive layers along each of the flat side surfaces to thermally and electrically couple the resistive element to the plurality of conductive elements; and

depositing a dielectric material on at least the plurality of conductive elements to electrically isolate the plurality of conductive elements from each other.

31. (New) The method of claim 30, further comprising forming bottom conductive layers extending from the conductive layers below the bottom surface of the resistive element.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165b
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122
190
140a
110a
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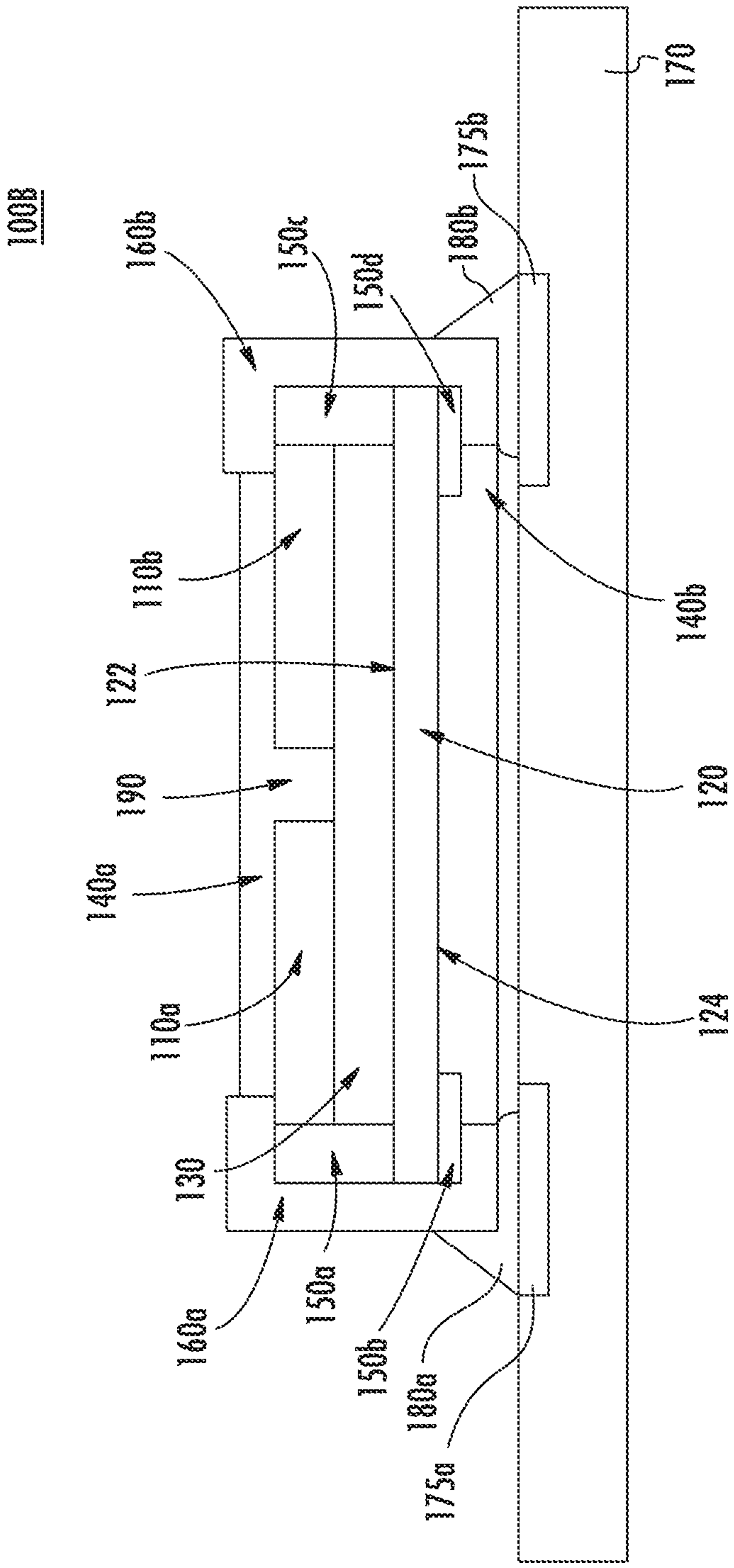
140b
120
124
152b
W'
W

FIG. 1A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175a

FIG. 1B

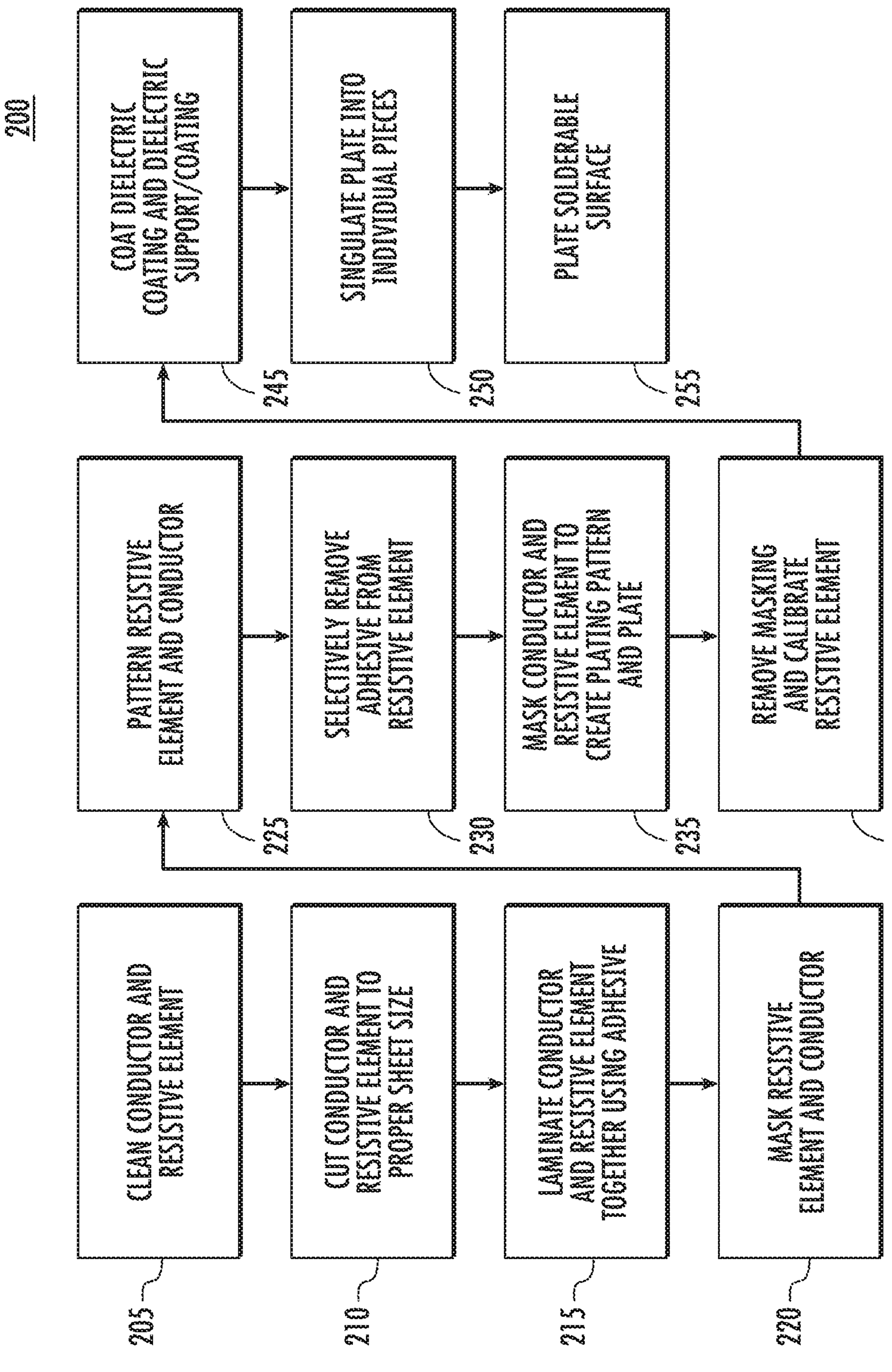
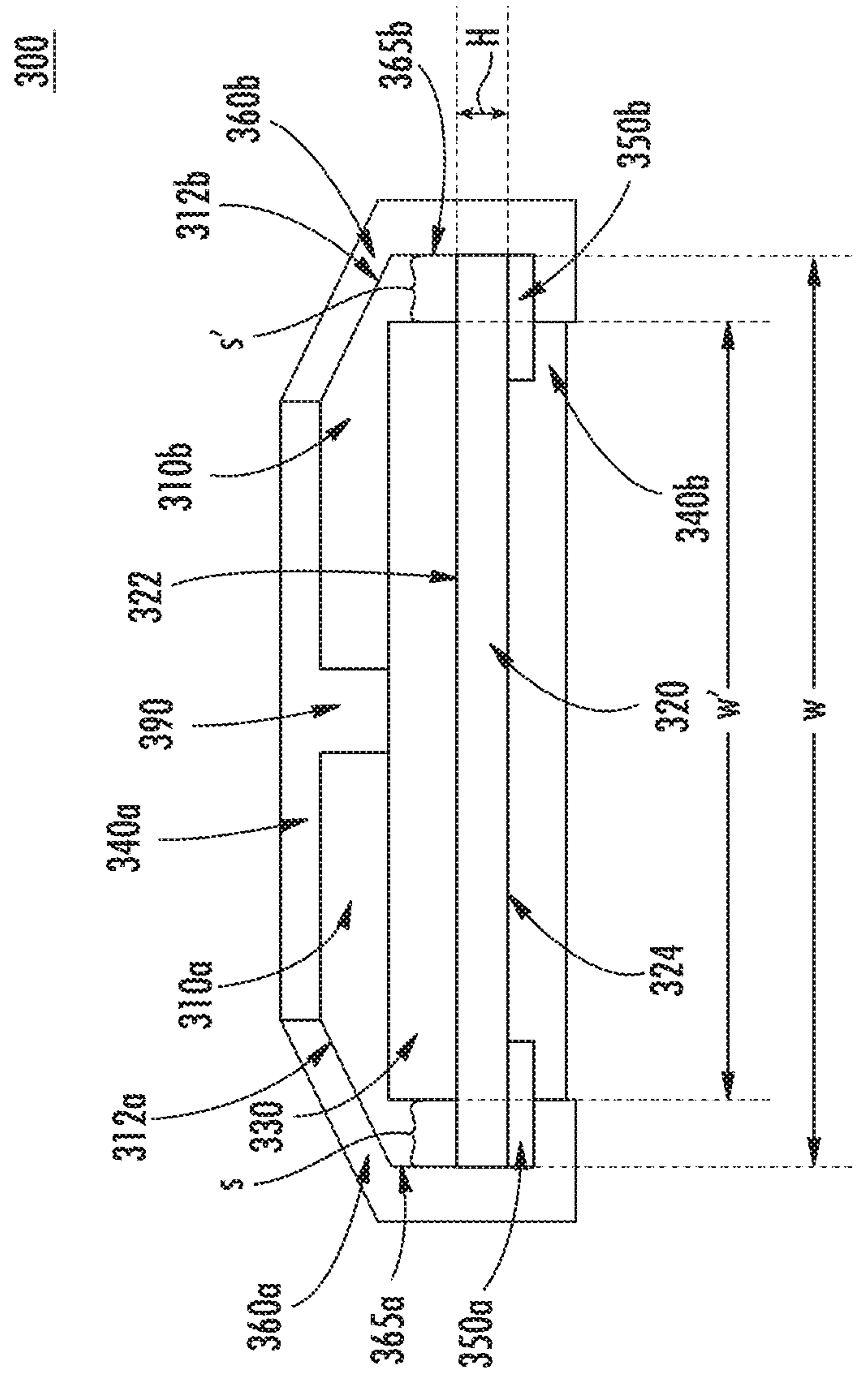

200
CLEAN CONDUCTOR AND RESISTIVE ELEMENT
205
CUT CONDUCTOR AND RESISTIVE ELEMENT TO PROPER SHEET SIZE
210
LAMINATE CONDUCTOR AND RESISTIVE ELEMENT TOGETHER USING ADHESIVE
215
MASK RESISTIVE ELEMENT AND CONDUCTOR
220
PATTERN RESISTIVE ELEMENT AND CONDUCTOR
225
SELECTIVELY REMOVE ADHESIVE FROM RESISTIVE ELEMENT
230
MASK CONDUCTOR AND RESISTIVE ELEMENT TO CREATE PLATING PATTERN AND PLATE
235
REMOVE MASKING AND CALIBRATE RESISTIVE ELEMENT
240
COAT DIELECTRIC COATING AND DIELECTRIC SUPPORT/COATING
245
SINGULATE PLATE INTO INDIVIDUAL PIECES
250
PLATE SOLDERABLE SURFACE
255

FIG. 2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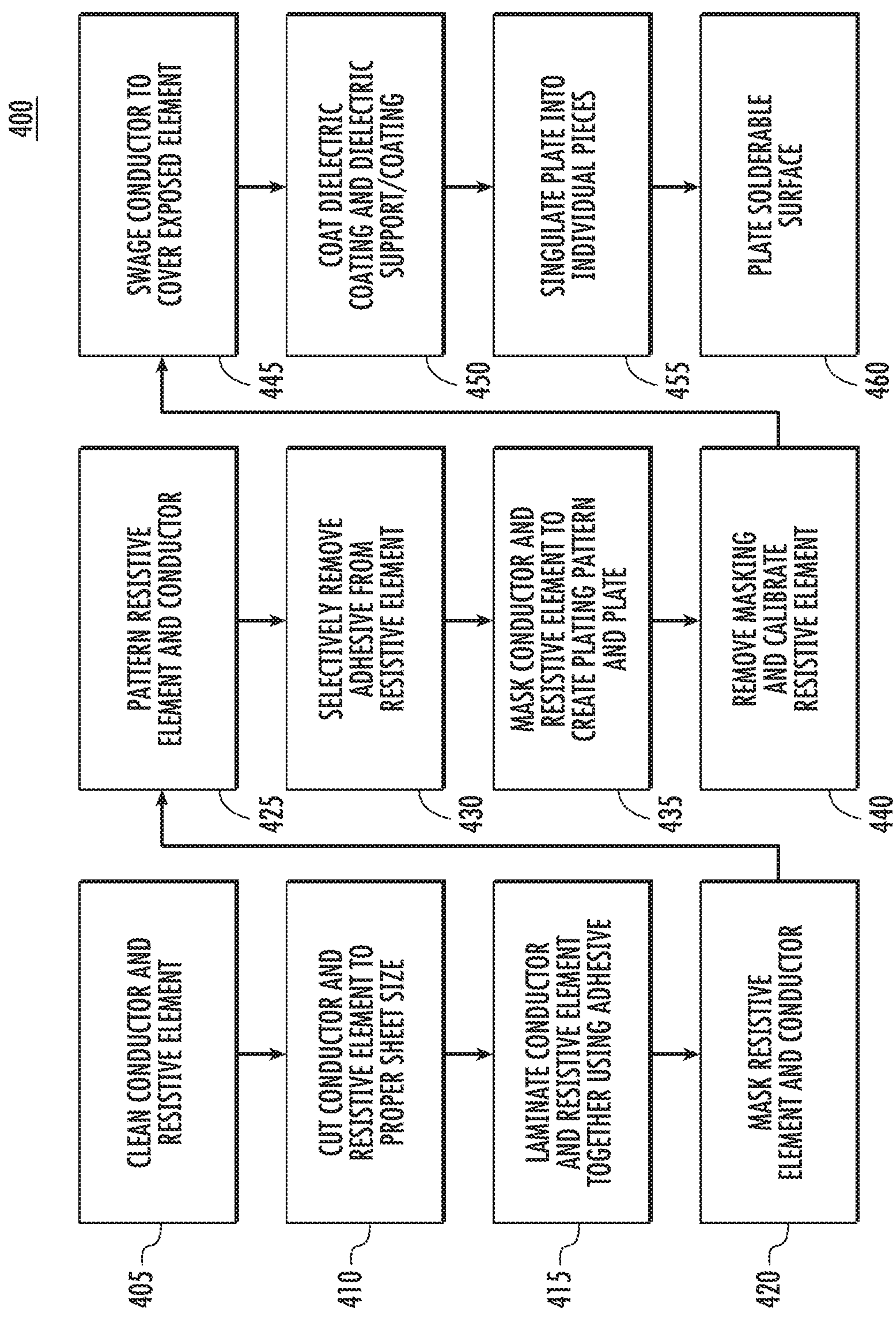
365b
H
312b
350b
s'
310b
322
390
340a
310a
312a
330
s
360a
365a
350a
340b
320
w'
w
324

FIG. 3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405
CLEAN CONDUCTOR AND RESISTIVE ELEMENT
410
CUT CONDUCTOR AND RESISTIVE ELEMENT TO PROPER SHEET SIZE
415
LAMINATE CONDUCTOR AND RESISTIVE ELEMENT TOGETHER USING ADHESIVE
420
MASK RESISTIVE ELEMENT AND CONDUCTOR
425
PATTERN RESISTIVE ELEMENT AND CONDUCTOR
430
SELECTIVELY REMOVE ADHESIVE FROM RESISTIVE ELEMENT
435
MASK CONDUCTOR AND RESISTIVE ELEMENT TO CREATE PLATING PATTERN AND PLATE
440
REMOVE MASKING AND CALIBRATE RESISTIVE ELEMENT
445
SWAGE CONDUCTOR TO COVER EXPOSED ELEMENT
450
COAT DIELECTRIC COATING AND DIELECTRIC SUPPORT/COATING
455
SINGULATE PLATE INTO INDIVIDUAL PIECES
460
PLATE SOLDERABLE SURFACE

FIG. 4

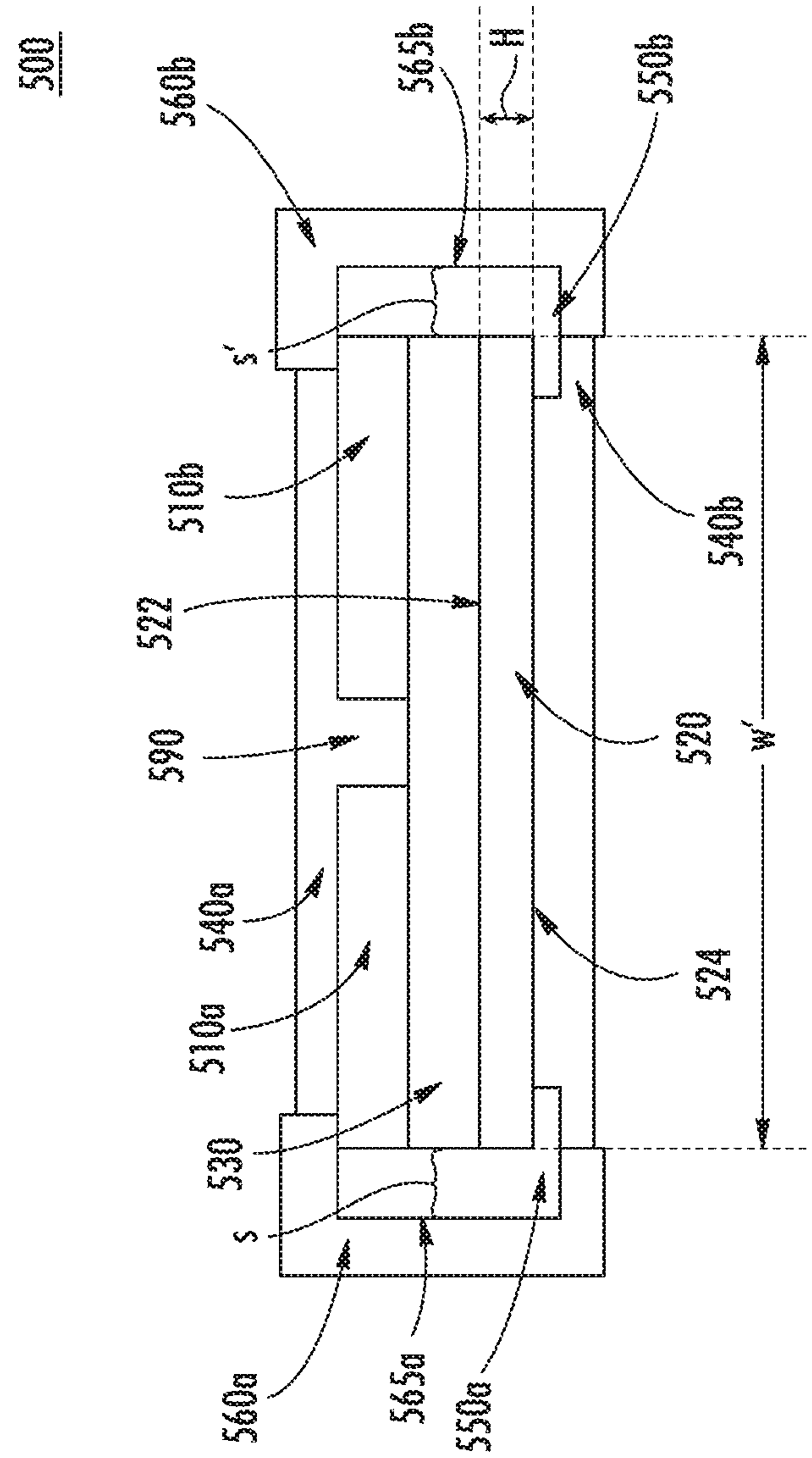
500
560b
565b
H
550b
s'
510b
540b
522
520
590
W'
540a
510a
524
530
s
560a
565a
550a

FIG. 5

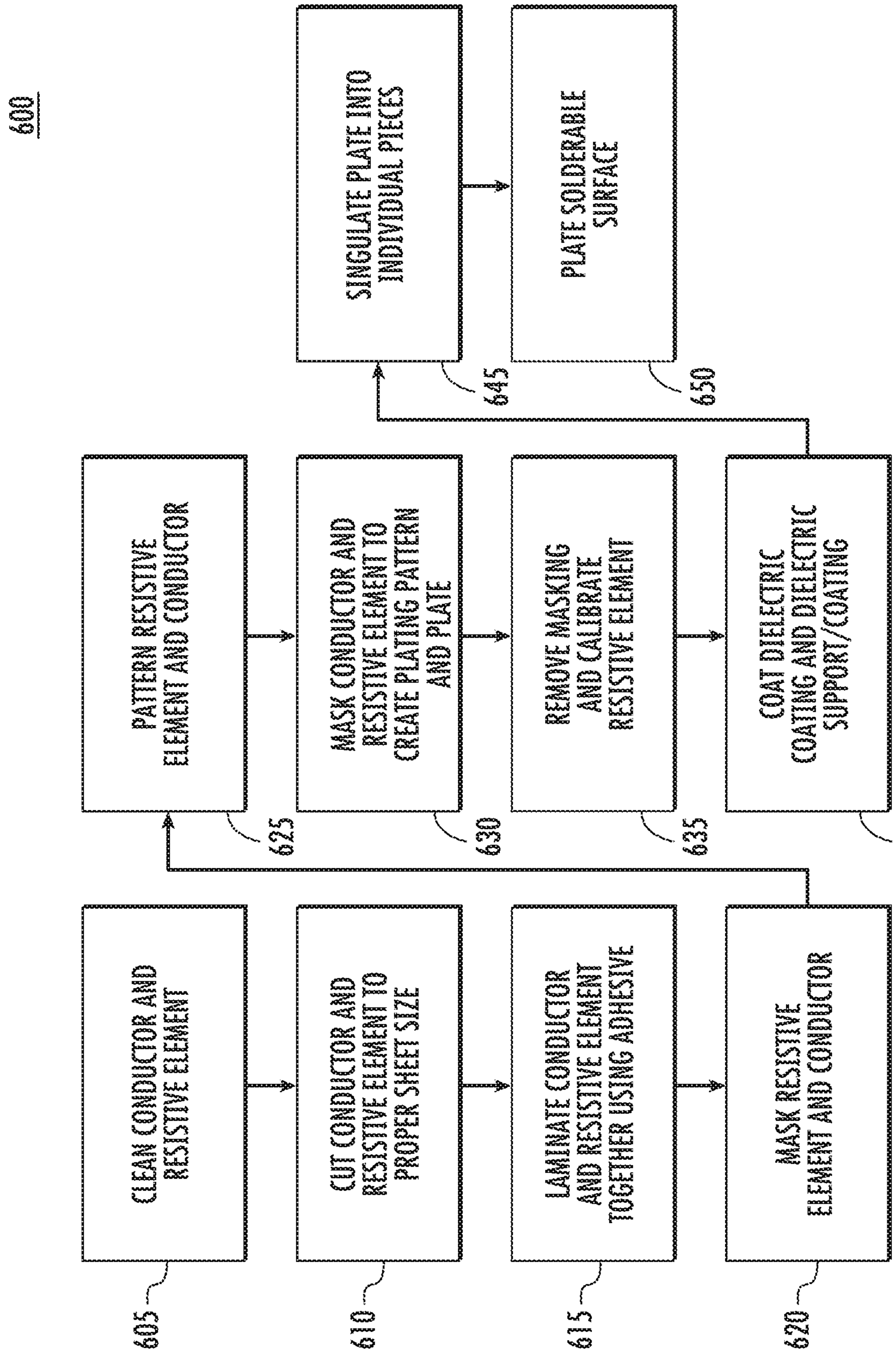
600
CLEAN CONDUCTOR AND RESISTIVE ELEMENT
605
CUT CONDUCTOR AND RESISTIVE ELEMENT TO PROPER SHEET SIZE
610
LAMINATE CONDUCTOR AND RESISTIVE ELEMENT TOGETHER USING ADHESIVE
615
MASK RESISTIVE ELEMENT AND CONDUCTOR
620
PATTERN RESISTIVE ELEMENT AND CONDUCTOR
625
MASK CONDUCTOR AND RESISTIVE ELEMENT TO CREATE PLATING PATTERN AND PLATE
630
REMOVE MASKING AND CALIBRATE RESISTIVE ELEMENT
635
COAT DIELECTRIC COATING AND DIELECTRIC SUPPORT/COATING
640
SINGULATE PLATE INTO INDIVIDUAL PIECES
645
PLATE SOLDERABLE SURFACE
650

FIG. 6

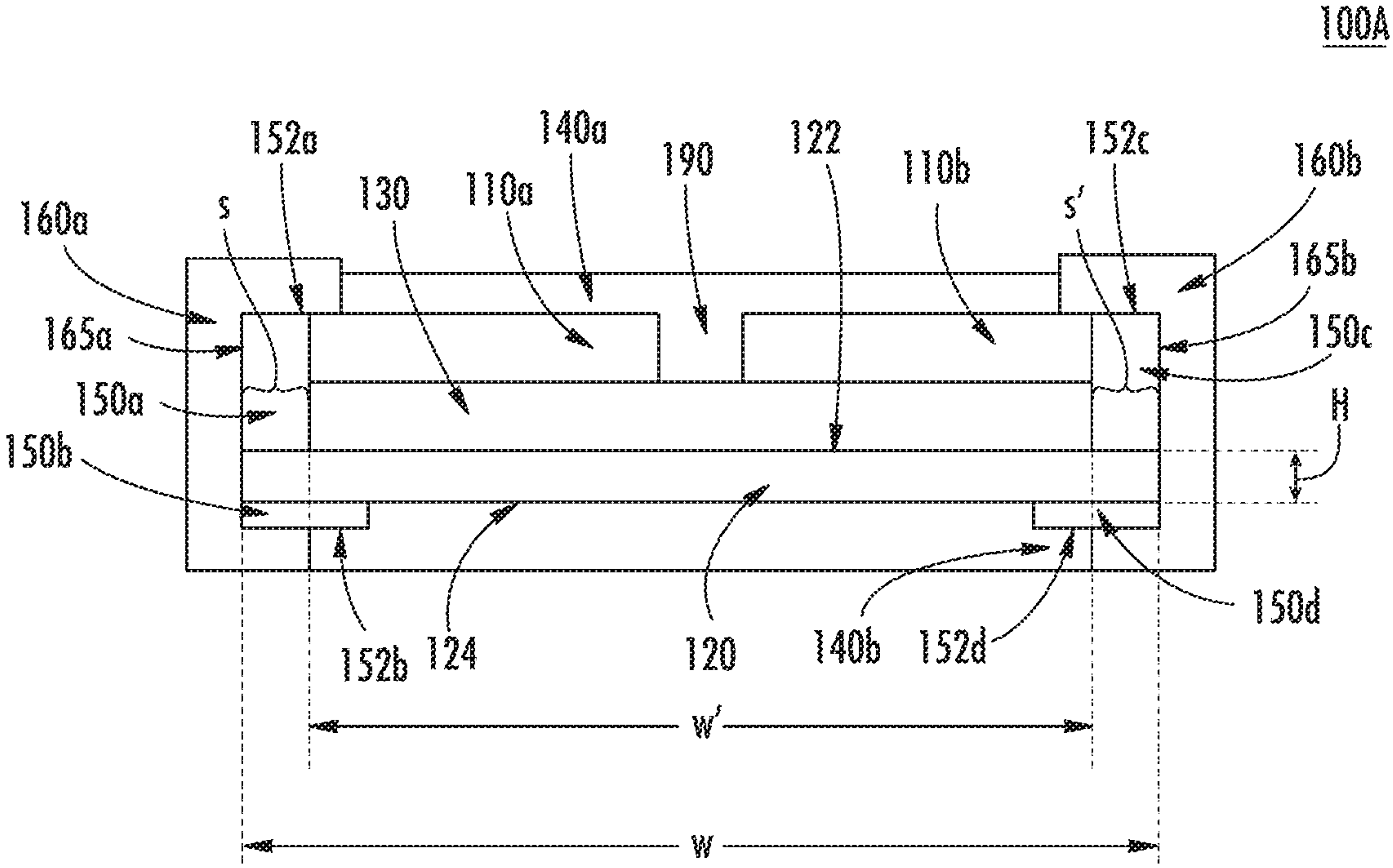
100A
152a
140a
190
122
110b
152c
160b
130
110a
s
s'
165b
160a
165a
150c
150a
H
150b
152b
124
120
140b
152d
150d
W'
W

FIG. 1A