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(54) **THERMAL MANAGEMENT IN ELECTRONIC DISPLAYS**

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See application file for complete search history.

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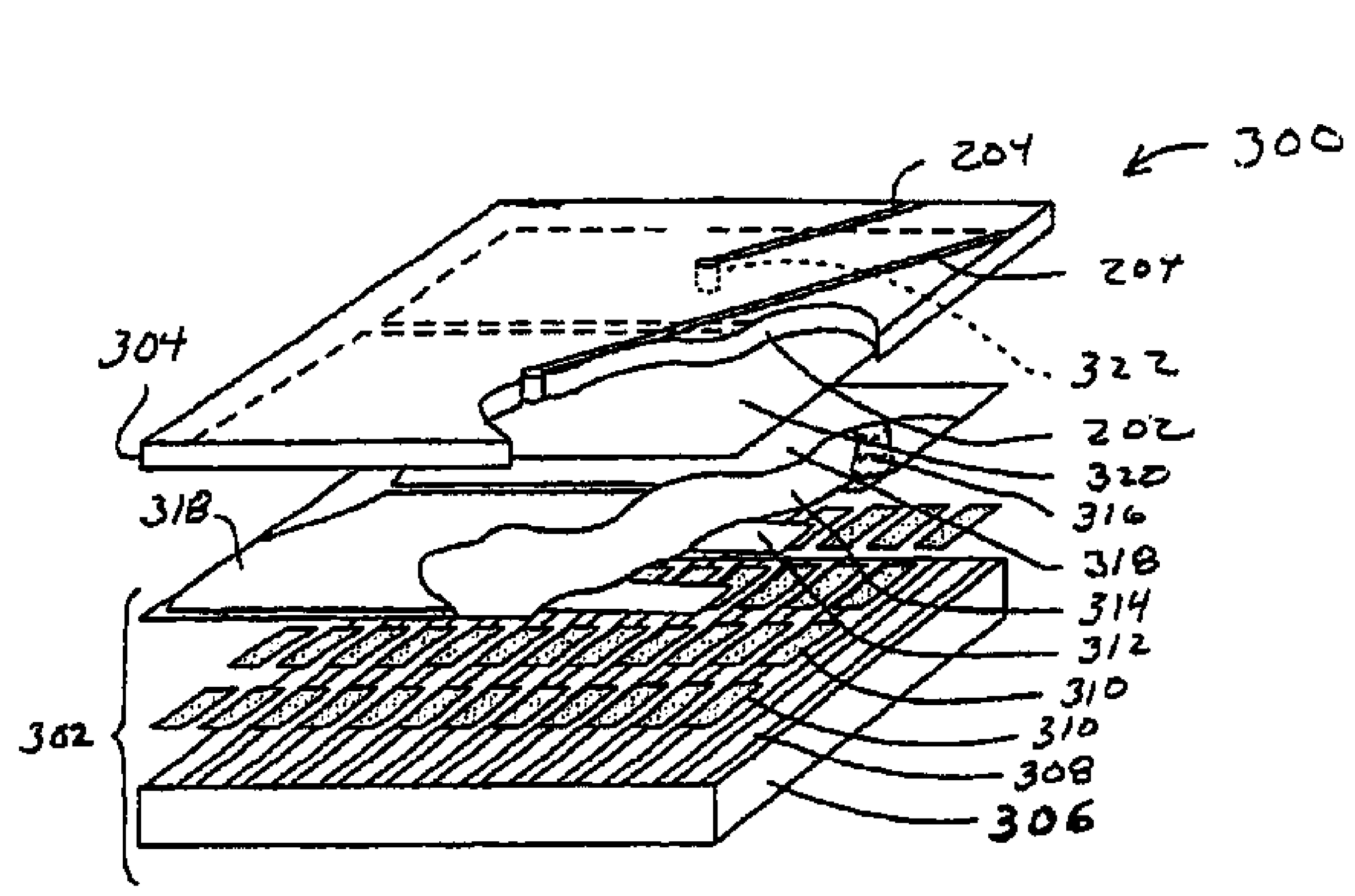
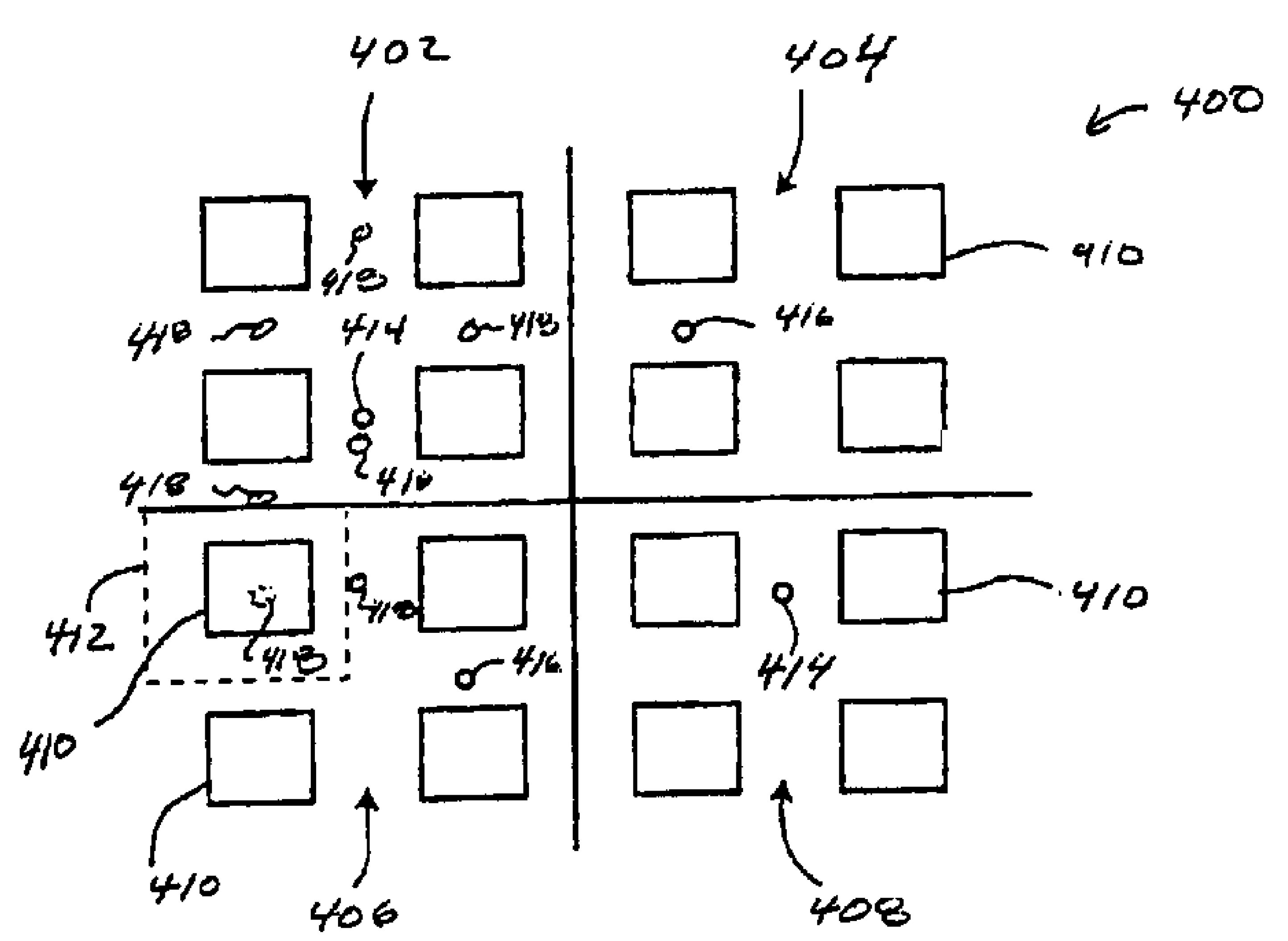
(57) **ABSTRACT**

A display having improved thermal management and a method for producing the display are disclosed. The display includes a pixel structure adjacent a front panel with thermo-mechanical elements extending between a back panel and the pixel structure to dissipate heat generated by the pixel structure.

50 Claims, 6 Drawing Sheets





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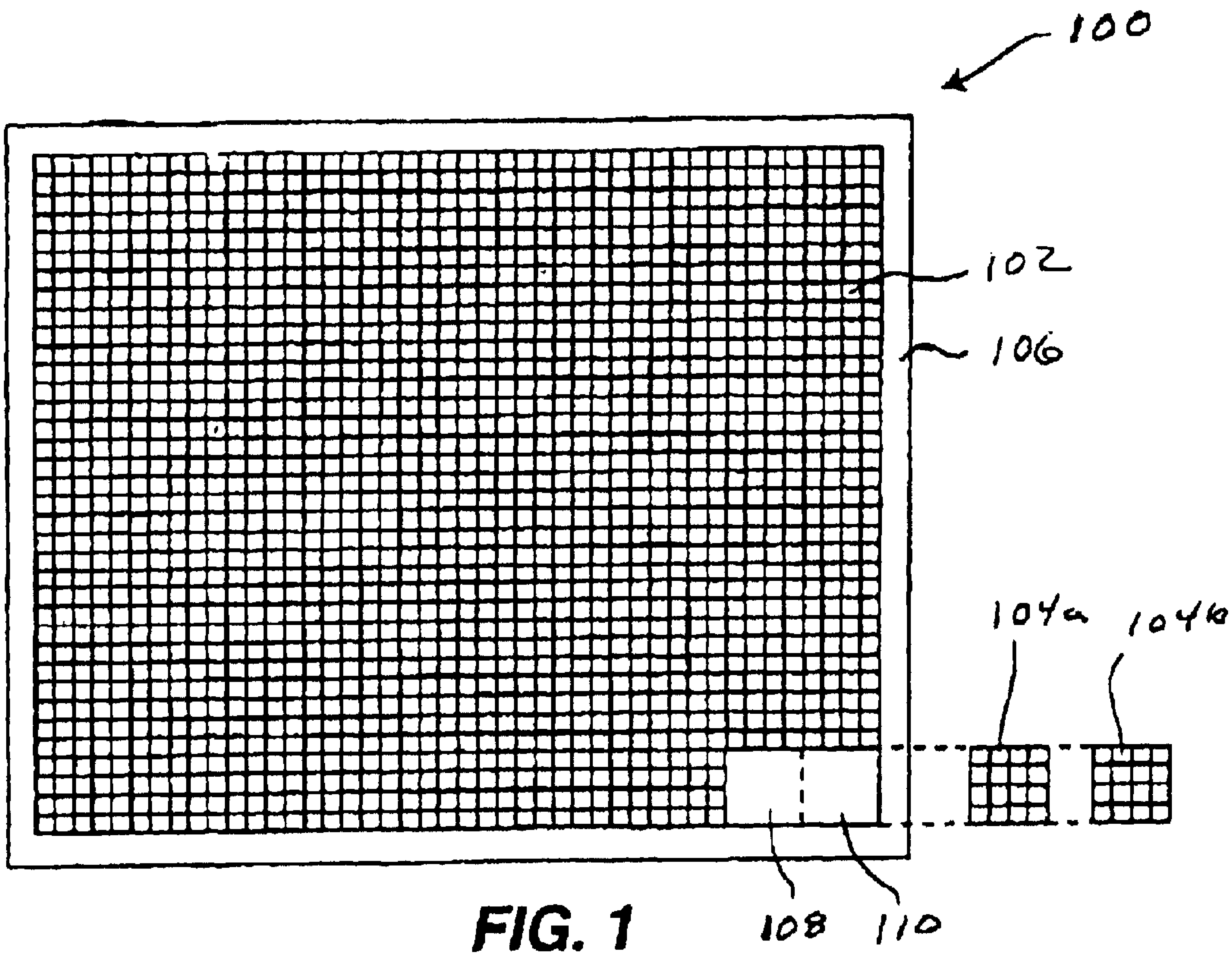


FIG. 1

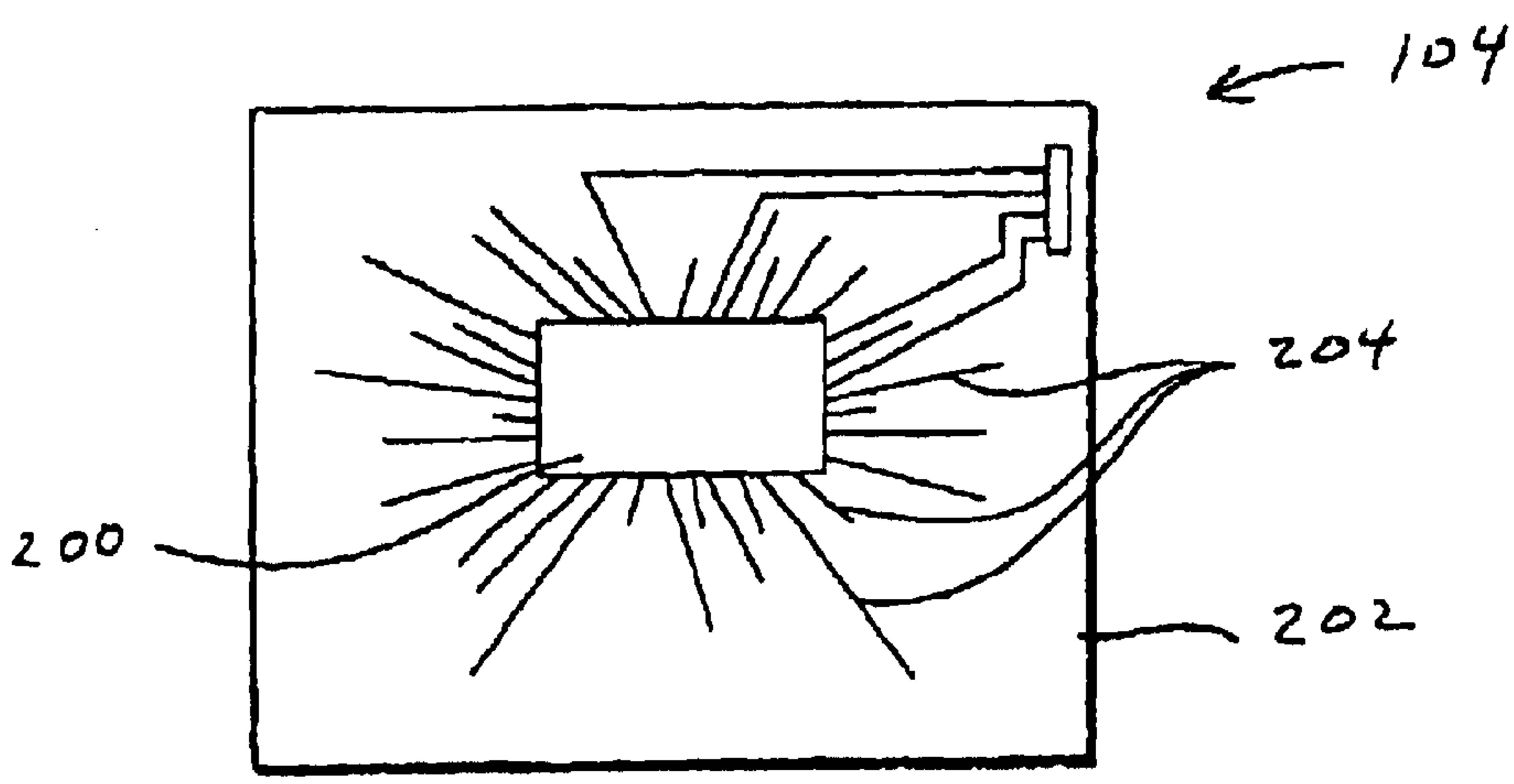
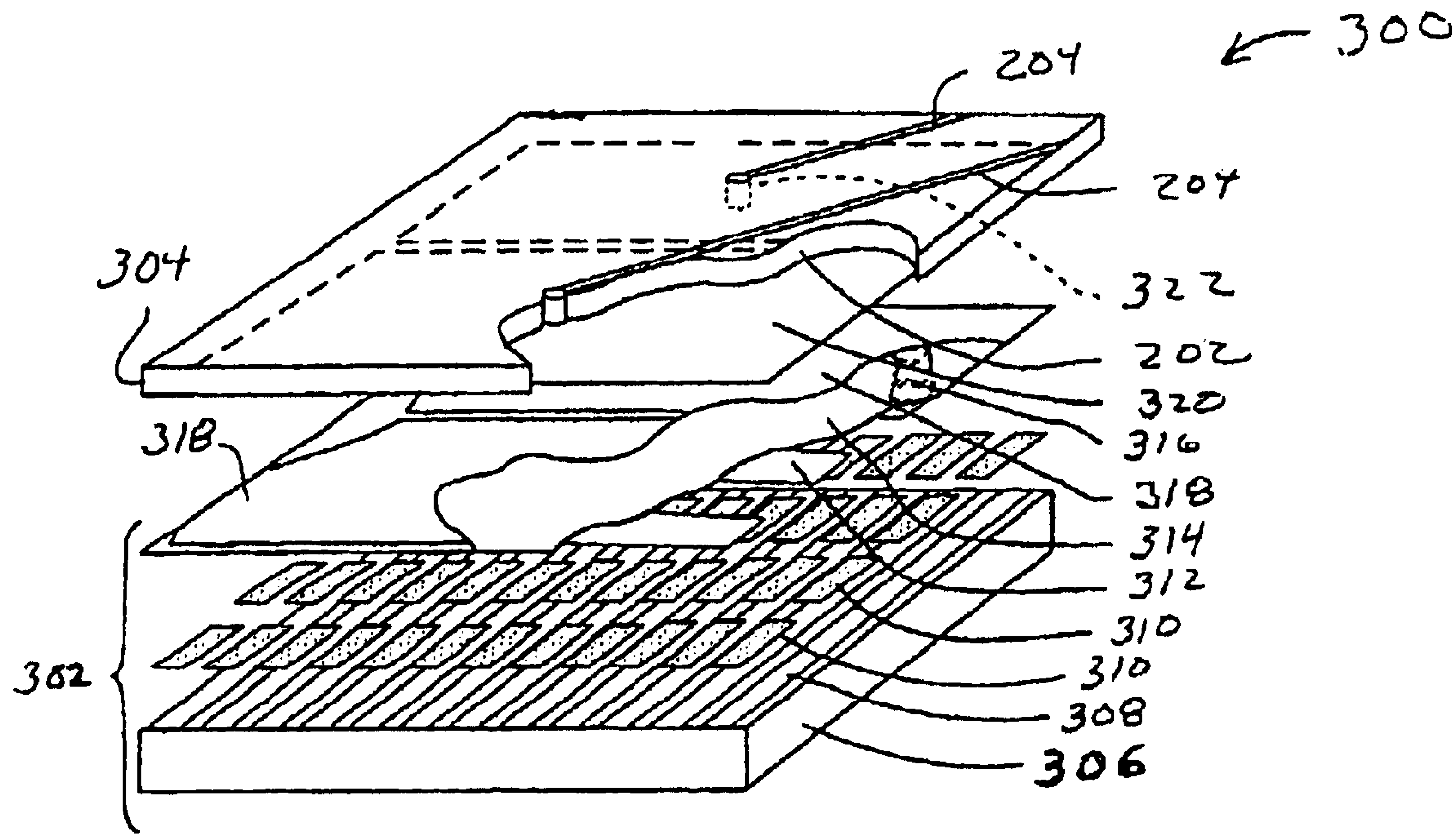


FIG. 2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204
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304
322
202
320
316
318
318
314
312
310
310
308
306
302

FIG. 3

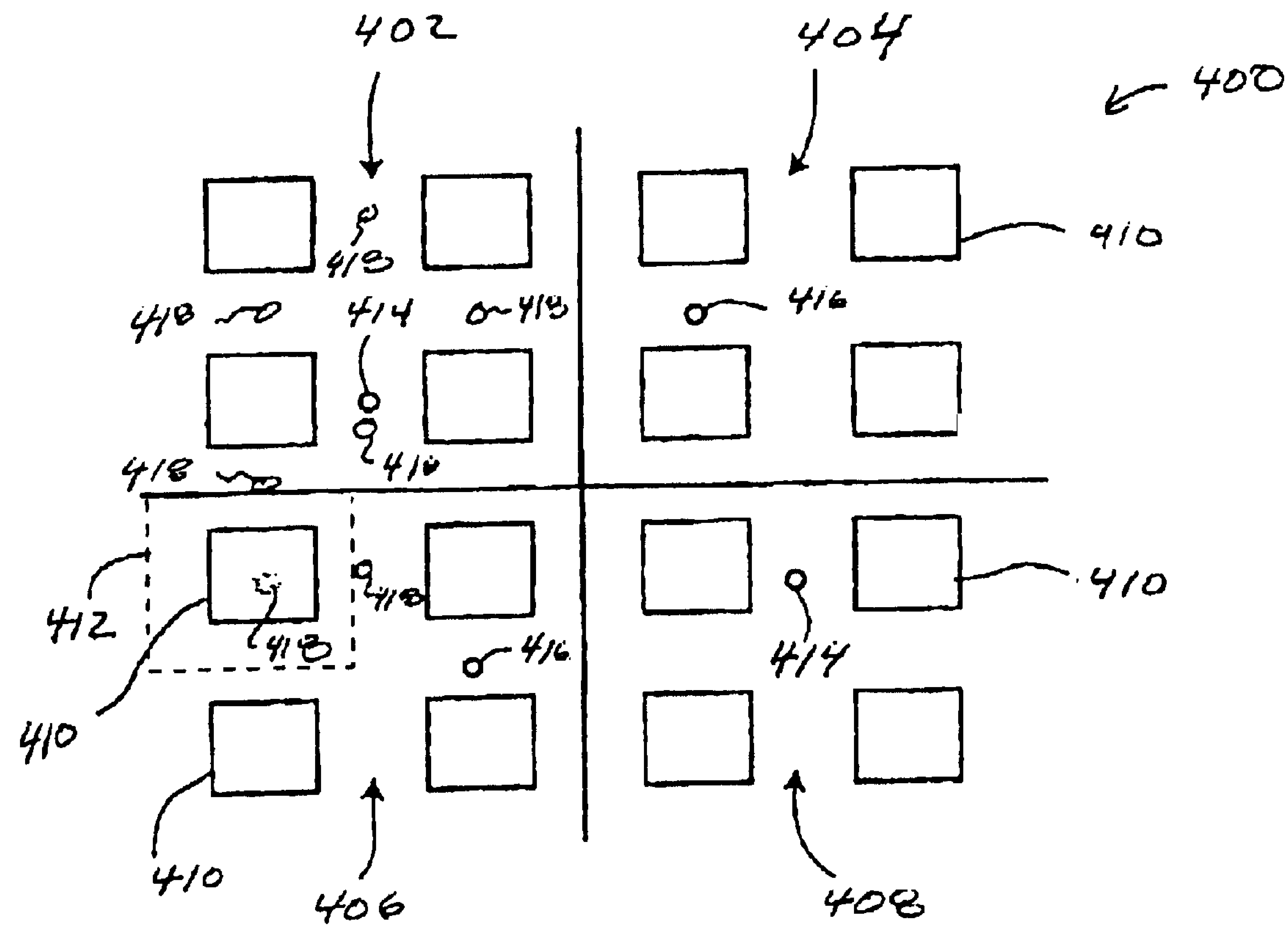
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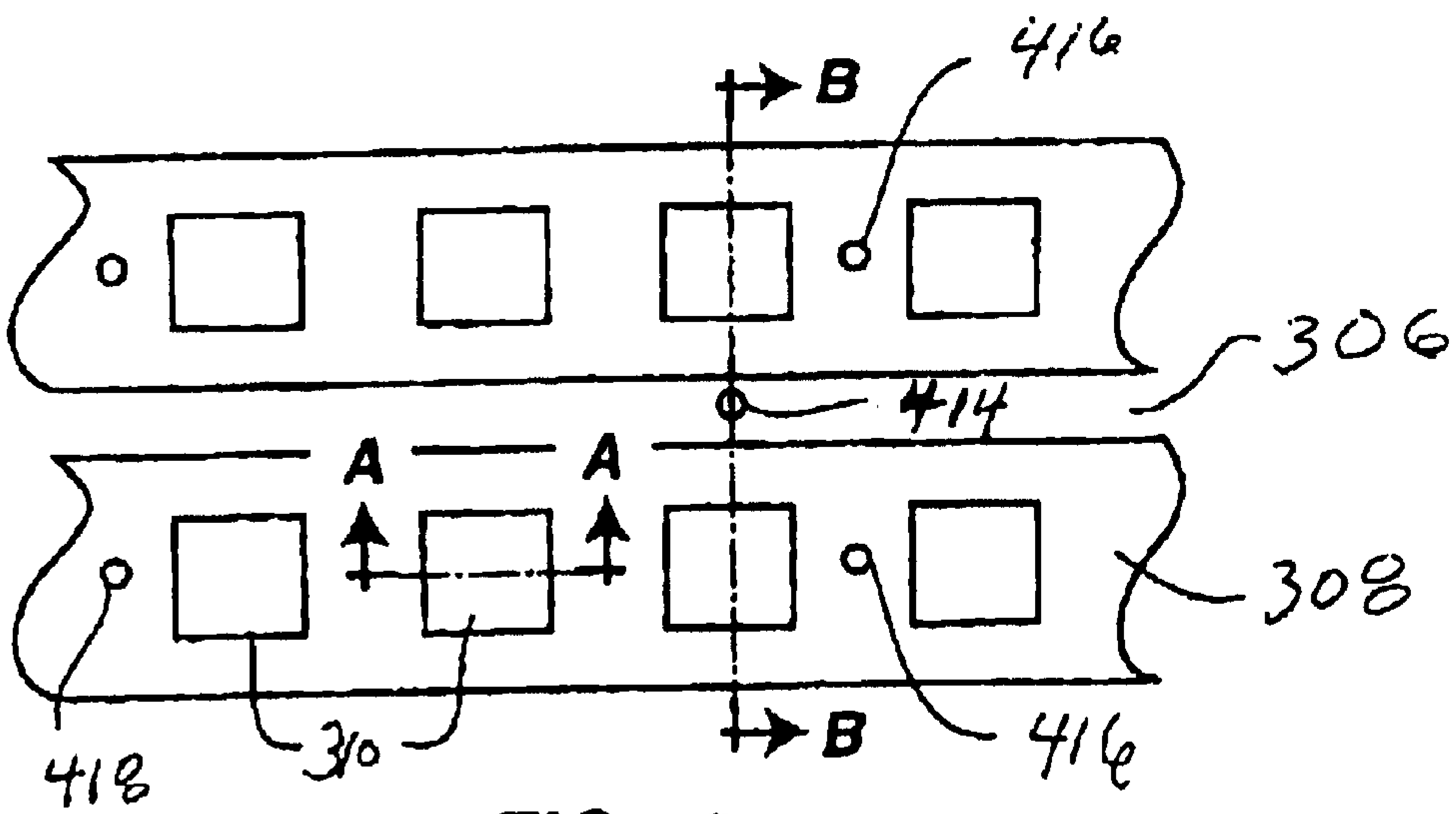
FIG. 4


B
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306
414
A
A
308
418
310
B
416

FIG. 5

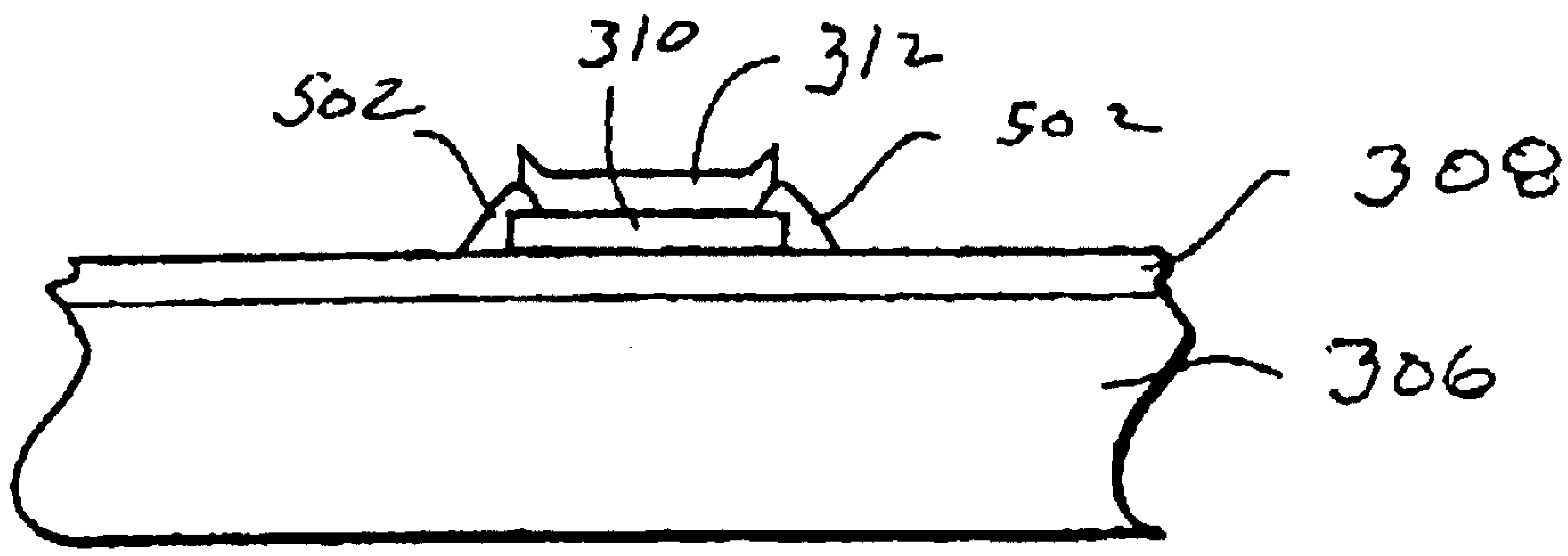

FIG. 5A

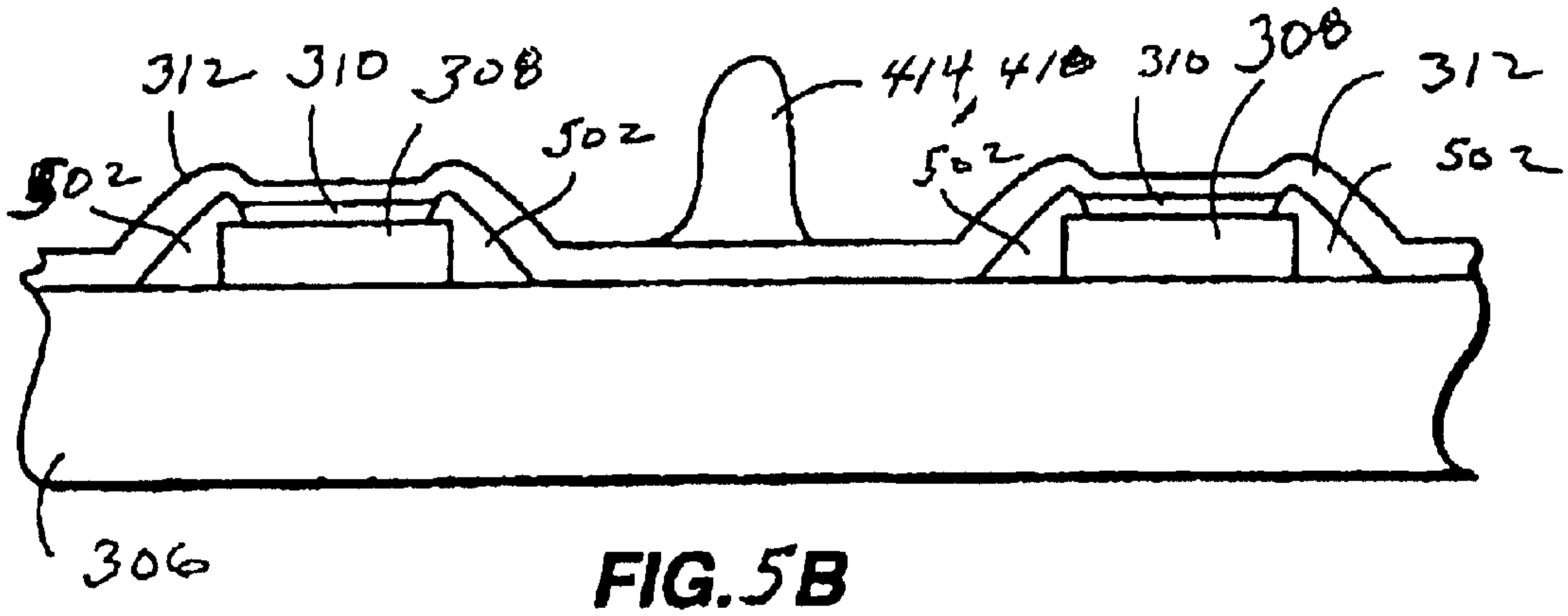

FIG. 5B

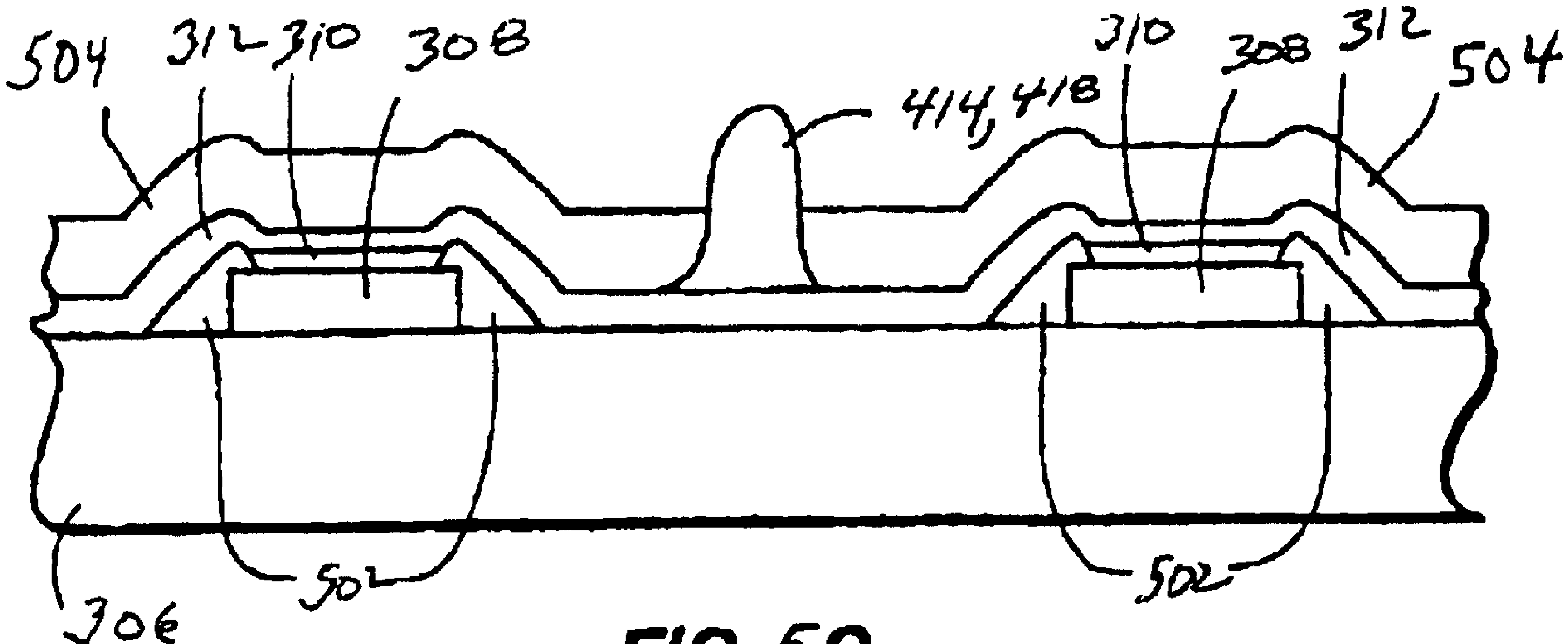

FIG. 5C

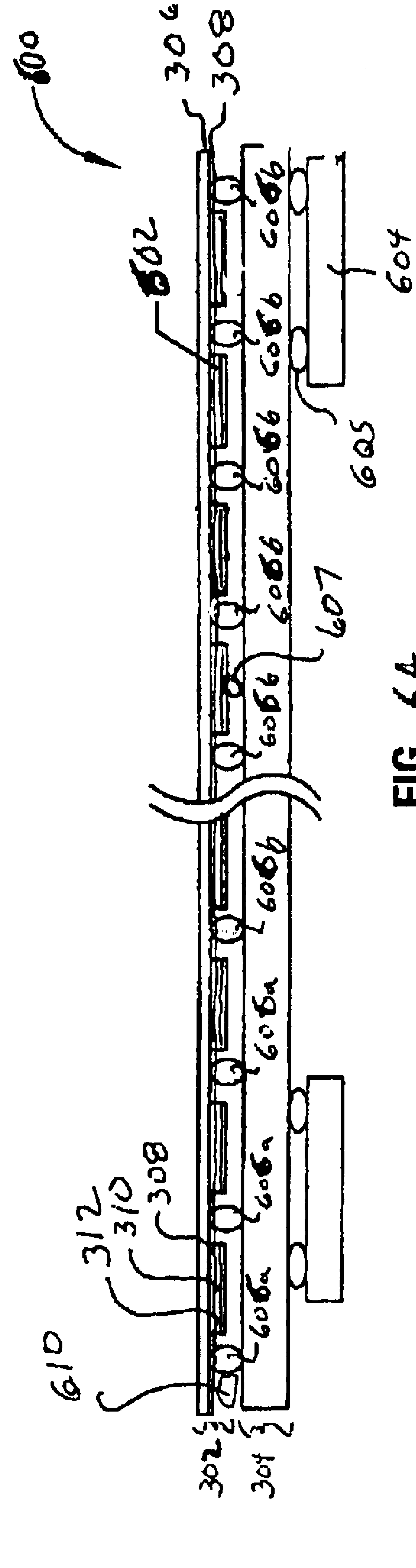

FIG. 6A

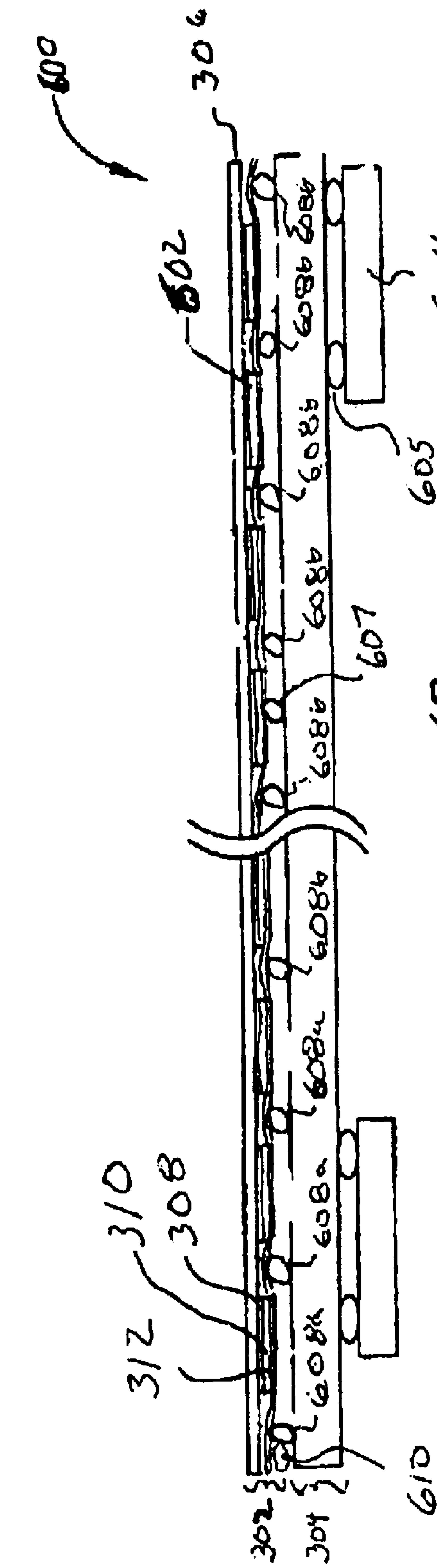

FIG. 6B

THERMAL MANAGEMENT IN ELECTRONIC DISPLAYS

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and claims the benefit of U.S. Provisional Application No. 60/379,456, filed May 10, 2002, for "Array Electrical Interconnections."

FIELD OF THE INVENTION

The present invention relates to the field of electronic displays and, more particularly, to thermal management of these electronic displays.

BACKGROUND OF THE INVENTION

Many presently available electronic displays employ one or more arrays of picture elements (hereinafter "pixels") to display an image. Each pixel typically includes a light emitting material that emits light when a current is passed therethrough to illuminate the pixel. The current passing through the light emitting material of an illuminated pixel and through current supply lines supplying current thereto generates heat in the electronic display.

Generally, the output characteristic of each pixel within an array is thermally sensitive. When the heat generated from illuminating the pixels within the array is not properly managed (i.e., dissipated), the array may develop localized "hot spots," which are small areas of an array that are significantly hotter than surrounding areas. These hot spots may lead to changes in the output characteristics of individual pixels or groups of pixels within the array, thereby causing different output characteristics to develop in individual pixels and groups of pixels within the array. These hotspots may also reduce the image quality of an electronic display and reduce its useful life.

Accordingly, displays with improved thermal management and methods for producing such displays are needed. The present invention fulfills this need among others.

SUMMARY OF THE INVENTION

A display in accordance with the present invention includes a front panel and a back panel spaced from the front panel to define a space therebetween. At least one pixel structure is adjacent the front panel in the space between the front and back panels and a plurality of electrical connections extend between the back panel and the at least one pixel structure. A plurality of thermo-mechanical elements extend between the back panel and the at least one pixel structure to dissipate heat from the at least one pixel structure toward the back panel. At least a portion of at least one of the thermo-mechanical elements is positioned between adjacent pixel structures of the at least one pixel structure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front plan drawing of a tiled display (with two tiles removed) in accordance with the present invention;

FIG. **2** is a perspective drawing of the back side of a tile suitable for use in the tiled display of FIG. **1**;

FIG. **3** is an exploded perspective drawing of a tile in accordance with the present invention;

FIG. **4** is a pixel diagram of an exemplary pixel and connection layout for portions of four tiles in accordance with the present invention; i

FIG. **5** is a top view of a display material formed upon a column electrode in accordance with the present invention;

FIG. **5**A is a cross-sectional view taken along line A—A of FIG. **5** depicting column and row electrodes along a column electrode;

FIG. **5**B is a cross-sectional view taken along line B—B of FIG. **5** depicting column and row electrodes along a row electrode;

FIG. **5**C is a cross-sectional view similar to the cross-sectional view of FIG. **5**B with an additional insulating layer;

FIG. **6**A is a cross-sectional view of an assembled tile along a column electrode in accordance with the present invention; and

FIG. **6**B is a cross-sectional view of an assembled tile along a row electrode in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention is described in terms of exemplary embodiments, which are illustrated in the drawing figures. The drawing figures are not to scale and may be exaggerated to aid in the description of the invention. Although the invention is described in terms of an organic light emitting diode (OLED) display device, it is contemplated that it may be practiced with other emissive display technologies employing elements such as electroluminescent elements, light emitting diodes, field emissive elements, plasma elements, or cathodoluminescent elements; or with reflective display technologies employing elements such as bistable, reflective cholesteric (BRC) liquid crystal elements.

FIG. **1** is a front plan view of a partially assembled exemplary display **100** according to one aspect of the present invention. The display **100** is a tiled display in which emissive or reflective elements that form pixel structures (represented by pixel **102**) are built in relatively small arrays to form tiles **104**. The illustrated tiles **104** each include sixteen pixels, however, each tile may contain fewer pixels or more pixels, e.g. tens, hundreds, or even thousands of pixels. The tiles **104** are then assembled into a frame **106** to produce the display **100**. Alternatively, the tiles **104** may be assembled side-to-side in rows and columns without a frame. In this instance, the individual tiles may be held together by millions. The display **100** is shown in FIG. **1** with two tiles **104**a and **104**b missing. These tiles are inserted into the display in a first position **108** and a second position **110** to complete the display **100**. Although the invention is described in terms of a tiled display that includes a plurality of tiles, those of skill in the art will recognize that the invention can be used in non-tiled displays as well.

FIG. **2** is a back plan view of a tile **104** suitable for use in the display **100** of FIG. **1**. The tile **104** includes at least one integrated circuit **200** mounted on a circuit board **202**. Conductive traces **204** coupled to vias (not shown) extend through the circuit board **202** to connect the integrated circuit **200** to the pixel structures **102** (FIG. **1**) on the front of the tile **104**.

FIG. **3** is an exploded perspective diagram that shows an exemplary display tile **300**. The exemplary display tile **300** is formed in two parts: the display module **302** and the circuit module **304**. In an exemplary embodiment, these two parts are formed separately and then joined to form a complete tile.

The display module **302** includes a transparent front panel **306**, e.g., a float glass plate. A plurality of pixel structures are formed adjacent the front panel **306**. Each pixel structure includes a column electrode **308**, display material **310**, and a row electrode **312**. The column electrodes **308** are formed on the front panel **306**. In an exemplary embodiment, the column electrodes **308** are formed by depositing thin bands of a transparent conductor, e.g., indium-tin oxide (ITO), using well known processes.

The display materials **310** are then deposited on the column electrodes **308** to define the active area of the pixel structure, which is described in further detail below. In an exemplary embodiment, the display materials **310** are red, green, and blue OLED materials that are selectively deposited on top of the column electrodes **308** to form a "color" display tile **300**.

The row electrodes **312** are then formed on the display materials **310**. In the illustrated embodiment, the row electrodes **312** are substantially perpendicular to the column electrodes **308** and together form a grid pattern that allows each of the active pixel areas to be addressed by specifying a column number and a row number. In an exemplary embodiment, the row electrodes **312** are formed from a polysilicon material or from a metal such as aluminum using standard deposition techniques.

An insulating layer **314** is formed on top of the row electrodes **312**. The exemplary insulating layer **314** may be formed from any of a number of insulating materials. In an exemplary embodiment, the insulating layer **314** is desirably formed using low-temperature processes to protect the display materials **310**. Exemplary insulating layers **314** known low-temperature inorganic materials, that can be formed using low-temperature processes. The insulating layer **314** may be applied using thick film or thin film deposition techniques. The insulating layer **314** includes a plurality of openings **316** enabling electrical connection with the row electrodes **312** or column electrodes **308** of the pixel structures and enabling thermo-mechanical connections to one or more locations within the display module **302**. The formation of electrical connections and thermo-mechanical connections are described in further detail below.

On top of the insulating layer **314** are deposited a plurality of conductor traces **318**. In an exemplary embodiment, the conductor traces **318** are formed using vapor deposited aluminum or a metallic ink or paste, such as silver combined with a solvent, which is deposited using thick film processes. Each of the conductor traces **318** is electrically coupled to one of the column electrodes **308** or one of the row electrodes **312**, and/or thermo-mechanically connected to one or more positions within the display module **302**, by vias (not shown) that extend through the openings **316** in the insulating layers **314**. Via is used in the broadest sense and includes conductors that go through openings in the layer(s) and those that go around the edge of a layer(s).

Each of the exemplary conductor traces-**318** makes electrical contact with only one row electrode **312** or one column electrode **308**. To ensure that a good connection is made, however, each conductor trace **318** may connect to its corresponding row or column electrode **312**, **308** at several locations. Because each conductor trace **318** makes electrical contact with only one row or column electrode, the number of conductor traces **318** is greater than or equal to the sum of the number of column electrodes **308** and the number of row electrodes **312** in the tile **300**.

The circuit module **304** includes image processing and display driving circuitry **200** (FIG. **2**), a circuit board **202**, conductive traces **204**, and connecting pads **320**. The circuit board **202** is a back panel that is spaced from the front panel **306** to accommodate the pixel structures in a space therebetween.

Vias **322** electrically connect the conductive traces **204** to the connecting pads **320** through the circuit board **202**. In an exemplary embodiment, the conductive traces **204**, vias **322**, and connecting pads **320** are formed using thick film deposition processes to apply a metallic ink or paste. In an alternative exemplary embodiment, the connecting pads **320** are formed from vapor-deposited aluminum. In an exemplary embodiment, each connecting pad **320** of the circuit module **304** corresponds to a conductor trace **318** of the display module **302**.

The display module **302** and the circuit module **304** are combined to form the display tile **300**. In an exemplary embodiment, the connecting pads **320** are electrically connected to the corresponding conductor traces **318** by applying an anisotropically conductive adhesive between the display module **302** and the circuit module **304**. Alternative methods for electrically connecting the connecting pads **320** to the conductor traces **318** will be readily apparent to those of skill in the art.

FIG. **4** shows a pixel structure layout **400** suitable for use in a display such as that shown in FIG. **1**. FIG. **4** illustrates portions of 4 tiles **402**, **404**, **406**, **408**. In the layout shown in FIG. **4**, active portions of the pixel structures (represented by active portions **410**) are positioned within respective pixel structure regions (represented by pixel region **412**). Row electrodes (see FIG. **3**) and column electrodes (see FIG. **3**) may be electrically coupled by electrical connections **414** and **416**, respectively, to corresponding vias on the circuit module **304** (FIG. **1**). In certain exemplary embodiments, the electrical connections **414** and **416** are vias formed from a conductive material such as indium-tin (InSn) solder or a silver-filled epoxy adhesive.

In an exemplary embodiment of the present invention, thermo-mechanical elements **418** are provided to thermally couple the pixel structures to the circuit module **304** (FIG. **1**). The thermo-mechanical elements **418** may be positioned throughout each pixel structure and, in certain embodiments, are positioned between adjacent pixel structures within the display module **302**. For example, thermo-mechanical elements **418** may be placed between each active pixel area not having an electrical connection via **414**, **416**; next to the electrical connections; under the active pixel area (element shown in phantom); or essentially anywhere on and in the vicinity of the display module **302** to dissipate heat from the display module **302** to the circuit module **304**.

In certain exemplary embodiments, the thermo-mechanical elements **418** provide a redundant electrical connection between the row and column electrodes and the circuit module **302**. In these embodiments, the thermo-mechanical elements **418** may be vias formed from the same materials as the electrical connections **414**, **416**, e.g., InSn solder or a silver filled epoxy adhesive. In certain other exemplary embodiments, one or more of the thermo-mechanical elements **418** are electrically non-functional. In accordance with this embodiment, the thermo-mechanical elements **418** may be separated from conductors on one or both ends of the via **418** with a passivation layer or may be formed from a dielectric material such as an epoxy filled with materials having suitable thermal conduction properties, e.g., diamond, BN, AlN, and/or SiC. The selection of suitable material for forming the thermo-mechanical elements **418** will be readily apparent to those of skill in the related arts.

FIG. **5** shows a view of a portion of a display module of an electronic pixel structure according to the present invention. FIGS. **5**A and **5**B illustrate cross-sectional views taken along lines A—A and B—B, respectively, of FIG. **5** to illustrate an exemplary pixel structure according to the present invention.

A transparent column electrode **308**, e.g., ITO is formed on the front panel **306**. A display material **310** formed upon the column electrode **308** defines the active portion **410** (FIG. **4**) of the pixel structure. As shown in FIGS. **5**A and **5**B, an insulator **502** such as SiO_2 is then deposited on the ends of the display material **310**. A row electrode **312** is then formed upon the display material **310** and the insulator **502**. The insulator **502** allows the row electrode **312** to be formed wide enough to completely encapsulate the display material without shorting the row electrode **312** to the column electrode **308**. Thus, the row electrode **312**, the insulator **502**, the column electrode **308**, and possibly the front plate **306** encapsulate the display material **310**. This encapsulation seals the display materials **310** to help prevent exposure of the display materials **310** to conditions including oxygen and water vapor to provide more predictable performance over a longer lifetime. In another exemplary embodiment of the present invention, the insulator **502** covers the display material **310** and the row electrode **312** contacts the display material **310** through a via (not shown) formed in the insulator **502**.

FIG. **5** illustrates exemplary positions of electrical connections **414** and **416** for electrically coupling row electrodes and column electrodes, respectively, to the circuit module **304**. In addition, thermo-mechanical elements **418** for thermally connecting to the pixel structure are illustrated. In FIG. **5**B, an electrical connection **414** is shown as formed upon the row electrode **312** passing between adjacent pixel structures. The conductor **414** shown in FIG. **5**B is illustrated as a conductive bump. In an exemplary embodiment, one or more additional electrical connections **414** and/or thermo-mechanical elements **418** are formed on the row electrode **312** in a similar manner. In certain exemplary embodiments, the thermo-mechanical elements **418** provide redundant electrical connections. In alternative embodiments, a passivation layer (not shown) is positioned on at least one end of the thermo-mechanical elements **418** or the thermo-mechanical elements **418** are formed from a dielectric material. Thus, in accordance with these embodiments, the thermo-mechanical via is electrically non-functional.

FIG. **5**C is a cross-sectional view taken along line B—B of FIG. **5** illustrating an insulating pad **504** formed upon the row electrodes **312**, column electrodes **308**, and the display materials **310**. In an exemplary embodiment, the electrical connections **414** and the thermo-mechanical elements **418** are formed in apertures in the insulating pad **504**. In certain exemplary embodiments, electrically non-functional thermo-mechanical elements may be placed directly over or adjacent to the active elements and on top of the insulating pad **504**.

In the embodiment illustrated in FIGS. **5**–**5**C, the electrical connections **414**, **416** are connected directly to the row and column electrodes **312**, **308**, respectively. In an alternative embodiment, one or more of the electrical connections **414**, **416** may be connected to a corresponding row and/or column electrode through a conductive trace (not shown) to allow greater flexibility in the placement of the connections **414**, **416**. The thermo-mechanical element **418** is illustrated as connected directly to the row and/or column electrodes **312**/**308**. In alternative exemplary embodiments, the thermo-mechanical elements **418** may be connected to various other locations within the pixel structure to dissipate heat formed in that structure. In certain exemplary embodiments, one or more of the thermo-mechanical elements **418** may be connected to row or column electrodes and/or various other locations within the pixel structure through conductive traces (not shown) to allow greater flexibility in the placement of the elements **418**. The formation of a suitable conductive trace will be readily apparent to those of skill in the art.

FIGS. **6**A and **6**B are cross-sectional views of an assembled electronic display tile **600** viewed, respectively, along a column electrode **308** and along a row electrode **312** in accordance with the present invention. The tile **600** includes a display module **302** and a circuit module **304**, each comprised of multiple layers. The display module **302** includes a front panel **306** and a pixel structure (represented by pixel structure **602**) adjacent the front panel **306**. Each pixel structure includes a column electrode **308**, a display material **310**, and a row electrode **312**. The circuit module **304** is a back panel positioned substantially parallel to the front panel **306**. The circuit module **304** is spaced from the front panel **306** to define a space therebetween in which the pixel structure **602** is formed. Integrated circuits (represented by integrated circuit **604**) are positioned upon the circuit module **304** on a side of the circuit module opposite the display module. The integrated circuit **604** is connected to the circuit module **304** in a conventional manner, e.g., with solder **605**. Many tile components depicted in FIG. **3** are omitted to facilitate description of the present invention, e.g., circuit module vias **322**, circuit module conductive traces **204**, insulating layers **314**, conductor traces **318**, and connecting pads **320**.

FIG. **6**A illustrates a plurality of connections **606** that extend from the back panel **304** toward the front panel **306**. One or more of the connection **606** are electrical connections, e.g., connections **606**a. The electrical connections **606**a extend between the circuit module **304** and the pixel structure **602**. Specifically, the electrical connections **606**a extend from the circuit module **304** to a column electrode **308** of the pixel structure **602**. In addition, one or more of the connections are thermo-mechanical elements, e.g., connections **606**b, that dissipate heal generated in the pixel structure **602** toward the circuit module **304**. In certain exemplary embodiments, the thermo-mechanical elements **606**b also provide redundant electrical connections.

In an exemplary embodiment, the thermo-mechanical elements **606**b have a larger cross-sectional area than the electrical connections **606**a to improve the thermal transfer capabilities of the thermo-mechanical elements. In certain exemplary embodiments, the thermo-mechanical elements **606**b are sized to maximize thermal transfer capabilities without adversely affecting the operation of the display. Although the thermo-mechanical elements **606**b in FIG. **6**A are shown as extending from the circuit module **304** to the column electrode **308** near the front panel **306**, the thermo-mechanical elements **606**b may extend to essentially any depth and may be positioned at essentially any location on the circuit module **304**. Those of skill in the art will recognize that the connections **606** may include conductor traces **318** and connecting pads **320** (FIG. **3**) present between the circuit module **304** and the depth to which the connection **606** extends.

FIG. **6**B illustrates a plurality of connections **608** that extend from the back panel **304** toward the front panel **306**. One or more of the connection **608** are electrical connections, e.g., connections **608**a. The electrical connections **608**a extend between the circuit module **304** and the pixel structure **602**. Specifically, the electrical connections **608**a extend from the circuit module **304** to a row electrode **312** of the pixel structure **602**. In addition, one or more of the connections are thermo-mechanical elements, e.g., connections **608**b, that dissipate heat generated in the pixel structure **602** toward the circuit module **304**. In certain exemplary embodiments, the thermo-mechanical elements **606**b also provide a redundant electrical connection.

Although the thermo-mechanical elements **608**b in FIG. **6**B are shown as extending from the circuit module **304** to the row electrode **312** near the front panel **306**, the thermo-mechanical elements **608**b may extend to essentially any depth and may be positioned at essentially any location on the circuit module **304**. For example, a thermo-mechanical element **607** may be positioned directly under a pixel structure. Those of skill in the art will recognize that the connections **608** may include conductor traces **318** and connecting pads **320** (FIG. **3**) present between the circuit module **304** and the depth to which the connection **608** extends.

Referring to FIGS. **6**A and **6**B, in certain exemplary embodiments, an underfill encapsulant **610** encapsulates the area surrounding the components in the space defined by the circuit module **304** and the front panel **306**. In an exemplary embodiment, the underfill encapsulant **610** is selected based on its heat dissipation properties. When positioned within the space defined by the circuit module **304** and the front panel **306**, the underfill encapsulant **610** dissipates heat generated by the pixel structure to the circuit module **304**. In certain exemplary embodiments, the underfill encapsulant is an alumina filled epoxy such as EPO-TEK H77 supplied by Epoxy Technoloy, Inc. of Billerica, Mass., USA. In certain other exemplary embodiments, the underfill encapsulant includes a filler material including diamond, BN, AlN, BeO and/or SiC. In certain other exemplary embodiments, the filler material includes small concentrations of highly conductive metal particles such as Al and Cu by themselves and in combination with non-metallic fillers.

In certain exemplary embodiments, the circuit module **304** includes at least one layer selected based on its heat dispersion properties. In an exemplary embodiment, the at least one layer dissipates at least the heat received from the pixel structure **602** at the circuit module **304** via the thermo-mechanical elements **606**b, **608**b. In certain exemplary embodiments, the at least one layer dissipates heat received from the pixel structure **602** at the circuit module **304** via the electrical connections **606**a, **608**a and/or the underfill encapsulant **610** as well. In an exemplary embodiment, the at least one layer is formed from a material selected from alumina or aluminum nitride.

In certain exemplary embodiments, reflections from the row electrodes **312** and the connections **606**, **608** are minimized by minimizing their surface area or by coating the "viewer side" of these components black. The column electrodes **308**, which in an exemplary embodiment are transparent, are not an issue since they reflect only a small amount of light. Coating the viewer side of the row electrodes **312** and the connections **606**, **608** black can be accomplished by first depositing a conductive black coating (e.g. carbon black) in all areas where viewable metal electrodes or connections will be later deposited. In certain embodiments, the shape of the connections may be such that reflections are minimized, e.g, having an oval cross-section with the widest portion perpendicular to the nearest active pixel area **410** (FIG. **4**). Various other techniques and shapes for minimizing reflections will be readily apparent to those of skill in the art and are considered within the scope of the present invention.

In certain exemplary embodiments, the connections **606**, **608** are designed to reflect light from the display material **310** toward the viewer side of the display. In accordance with this embodiment, stray light (i.e., light emitted from the display material in a direction that is not viewable on the display side) is reflected toward the display side to increase the amount of visible light emitted by the display material. In this manner, the connections **606**, **608** contribute to the efficiency of the pixel structure. Accordingly, displays with increased light output or displays with similar light output emitted from smaller sized display materials are achievable. In addition, reflecting the light toward the viewer side reduces the amount of light absorbed by the pixel structure, thereby preventing this stray light from generating heat within the pixel structure.

Although the invention is illustrated and described herein with reference to specific embodiments, the invention is not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

What is claimed:

1. A display comprising:

a front panel;

a back panel spaced from the front panel, the front and back panels defining a space therebetween;

at least one pixel structure adjacent the front panel in the space between the front and back panels;

a plurality of electrical connections extending between the back panel and the at least one pixel structure; and

a plurality of thermo-mechanical elements extending between the back panel and the at least one pixel structure to dissipate heat from the at least one pixel structure toward the back panel, wherein at least one of the plurality of thermo-mechanical elements is positioned between adjacent pixel structures of the at least one pixel structure.

2. The display of claim **1**, wherein the plurality of thermo-mechanical elements are separate from the plurality of electrical connections.

3. The display of claim **1**, wherein the plurality of thermo-mechanical elements comprise a material selected from a group consisting of InSn solder and silver-filled epoxy adhesive.

4. The display of claim **1**, wherein the plurality of electrical connections are formed from materials used to form the plurality of thermo-mechanical elements.

5. The display of claim **1**, wherein at least one of the plurality of thermo-mechanical elements is larger than one or more of the plurality of electrical connections.

6. The display of claim **1**, wherein the back panel comprises a thermally conductive material for dissipating at least the heal received at the back panel via the plurality of thermo-mechanical elements.

7. The display of claim **1**, wherein the back panel is formed from a material selected from a group consisting of alumina and aluminum nitride.

8. The display of claim **1**, further comprising:

an underfill encapsulant filling the space between the front and back panels to further dissipate heat from the at least one pixel structure toward the back panel.

9. The display of claim **8**, wherein the underfill encapsulant is an alumina filled epoxy.

10. The display of claim **8**, wherein the underfill encapsulant includes a filler selected from a group consisting of diamond, BN, AlN, BeO, and SiC.

11. The display of claim **1**, wherein the at least one pixel structure comprises a display material selected from a group consisting of organic light emitting diodes (OLED), light emitting diodes, field emissive elements, plasma elements, cathodoluminescent elements, **[**end**]** *and* bistable, reflective cholesteric (BRC) liquid crystal elements.

12. An electronic display comprising:

a front panel;

a back panel spaced from the front panel, the front and back panels defining a space therebetween;

at least one pixel structure having a top surface adjacent the front panel and a bottom surface, each of the at least one pixel structure having a first electrode on the top surface and a second electrode on the bottom surface;

a first electrical connection via extending between the back panel and the first electrode of one of the at least one pixel structure;

a second electrical connection via extending between the back panel and the second electrode of the one of the at least one pixel structure; and

at least one thermo-mechanical via extending between the back panel and the one of the at least one pixel structure to dissipate heat from the one of the at least one pixel structure to the back panel, wherein the at least one thermo-mechanical via is positioned between adjacent pixel structures of the at least one pixel structure.

13. The display of claim **12**, wherein the at least one thermo-mechanical via is electrically isolated from the first and second electrodes.

14. The display of claim **12**, wherein the at least one pixel structure comprises a display material selected from a group consisting of organic light emitting diodes (OLED), light emitting diodes, field emissive elements, plasma elements, cathodoluminescent elements, and bistable, reflective cholesteric (BRC) liquid crystal elements.

15. The display of claim **12**, wherein the at least one thermo-mechanical via is formed from a material selected from a group consisting of InSn solder and silver-filled epoxy adhesive.

16. The display of claim **12**, wherein the back panel comprises a thermally conductive material for dissipating at least the heat received at the back panel via the at least one thermo-mechanical via.

17. The display of claim **12**, wherein the back panel is formed from a material selected from a group consisting of alumina and aluminum nitride.

18. The display of claim **12**, further comprising:

an underfill encapsulant filling the space between the front and back panels to further dissipate heat from the at least one pixel structure toward the back panel.

19. The display of claim **18**, wherein the underfill encapsulant is an alumina filled epoxy.

20. The display of claim **18**, wherein the underfill encapsulant includes a filler selected from a group consisting of diamond, BN, AlN, BeO, and SiC.

21. A display comprising:

a front panel;

a back panel spaced from the front panel;

at least one pixel structure adjacent to the front panel; and

a plurality of thermo-mechanical elements extending between the back panel and the at least one pixel structure and configured to dissipate heat from the at least one pixel structure toward the back panel, wherein at least one of the plurality of thermo-mechanical elements is positioned between the at least one pixel structure and another pixel structure positioned adjacent to the at least one pixel structure.

22. The display of claim 21, further comprising a plurality of electrical connections extending between the back panel and the at least one pixel structure.

23. The display of claim 22, wherein the plurality of thermo-mechanical elements are separate from the plurality of electrical connections.

24. The display of claim 22, wherein the plurality of electrical connections and the plurality of thermo-mechanical elements are formed from the same material.

25. The display of claim 22, wherein at least one of the plurality of thermo-mechanical elements is larger than at least one of the plurality of electrical connections.

26. The display of claim 22, wherein a second thermo-mechanical element of the plurality of thermo-mechanical elements is positioned adjacent to at least one of the plurality of electrical connections.

27. The display of claim 22, wherein a second thermo-mechanical element of the plurality of thermo-mechanical elements is positioned under an active pixel area of the at least one pixel structure.

28. The display of claim 21, wherein the at least one of the plurality of thermo-mechanical elements is further configured to dissipate heat from a display module toward a circuit module, and wherein the display module includes the at least one pixel structure.

29. The display of claim 21, wherein the plurality of thermo-mechanical elements comprise a material selected from the group consisting of InSn solder and silver-filled epoxy adhesive.

30. The display of claim 21, wherein the back panel comprises a thermally-conductive material configured to dissipate heat received at the back panel via the plurality of thermo-mechanical elements.

31. The display of claim 21, wherein the back panel comprises a material selected from the group consisting of alumina and aluminum nitride.

32. The display of claim 21, further comprising an encapsulant filling a space between the front and back panels and configured to dissipate heat from the at least one pixel structure.

33. The display of claim 32, wherein the encapsulant is an epoxy comprising alumina.

34. The display of claim 32, wherein the encapsulant comprises a filler selected from the group consisting of diamond, boron nitride, aluminum nitride, beryllium oxide, and silicon carbide.

35. The display of claim 21, wherein the at least one pixel structure comprises a display material selected from the group consisting of organic light emitting diodes (OLED), light emitting diodes, field emissive elements, plasma elements, cathodoluminescent elements, and bistable reflective cholesteric (BRC) liquid crystal elements.

36. An electronic display comprising:

a front panel;

a back panel spaced apart from the front panel;

at least one pixel structure including a first surface having a first electrode and a second surface having a second electrode, wherein the first surface is positioned adjacent to the front panel;

a first conductive via extending between the back panel and the first electrode;

a second conductive via extending between the back panel and the second electrode; and *at least one thermo-mechanical via extending between the back panel and the at least one pixel structure and configured to dissipate heat from the at least one pixel structure, wherein the at least one thermo-mechanical via is positioned between the at least one pixel structure and another pixel structure positioned adjacent to the at least one pixel structure.*

37. The display of claim 36, wherein the at least one thermo-mechanical via is electrically isolated from the first electrode and the second electrode.

38. The display of claim 36, wherein the at least one pixel structure comprises a display material selected from the group consisting of organic light emitting diodes (OLED), light emitting diodes, field emissive elements, plasma elements, cathodoluminescent elements, and bistable reflective cholesteric (BRC) liquid crystal elements.

39. The display of claim 36, wherein the at least one thermo-mechanical via is formed from a material selected from the group consisting of InSn solder and silver-filled epoxy adhesive.

40. The display of claim 36, wherein the back panel comprises a thermally conductive material configured to dissipate heat received at the back panel from the at least one thermo-mechanical via.

41. The display of claim 36, wherein the back panel comprises alumina or aluminum nitride.

42. The display of claim 36, further comprising an encapsulant filling a space between the front and the back panel and configured to dissipate heat from the at least one pixel structure.

43. The display of claim 42, wherein the encapsulant is an epoxy comprising alumina.

44. The display of claim 42, wherein the encapsulant comprises a filler selected from the group consisting of diamond, boron nitride, aluminum nitride, beryllium oxide, and silicon carbide.

45. The display of claim 36, further comprising a display material deposited onto the first electrode to define an active area of the at least one pixel structure.

46. An apparatus comprising:

a display including a front panel and a back panel, wherein the front panel and the back panel are spaced apart;

at least one pixel structure having a surface adjacent to the front panel; and

at least one thermo-mechanical element extending between the back panel and the at least one pixel structure and configured to conduct heat from the at least one pixel structure to the back panel, wherein the at least one thermo-mechanical element is positioned between the at least one pixel structure and another pixel structure positioned adjacent to the at least one pixel structure.

47. The apparatus of claim 46, further comprising a plurality of electrical connections extending between the back panel and the at least one pixel structure.

48. The apparatus of claim 46, wherein the back panel comprises a thermally-conductive material configured to dissipate heat received at the back panel via the at least one thermo-mechanical element.

49. The apparatus of claim 46, further comprising an underfill encapsulant provided between the front panel and the back panel and configured to direct heat from the at least one pixel structure toward the back panel.

50. The apparatus of claim 46, wherein the at least one thermo-mechanical element is a via.

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