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

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,966,302 A 6/1976 Mikoda et al.
4,015,166 A 3/1977 Ohshima et al.
4,137,481 A 1/1979 Hilsum et al.
4,139,261 A 2/1979 Hilsum
4,170,772 A 10/1979 Bly
4,209,735 A 6/1980 Yoshida

4,225,005 A 9/1980 Okabayashi
4,403,831 A 9/1983 Amano
4,431,270 A 2/1984 Funada et al.
4,474,839 A 10/1984 Takamatsu et al.
4,482,212 A 11/1984 Takamatsu et al.
4,487,480 A 12/1984 Nonomura et al.

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 99/41732 8/1999

OTHER PUBLICATIONS

International Search Report for PCT/US2003/23755 mailed on Mar. 17, 2004.

International Search Report for PCT/US2003/23855 mailed on Aug. 27, 2004.

Horowitz, Paul et al., "The "Mylar" or photoplot", The Art of Electronics, 1989 (2nd edition), p. 833, New York, New York.

Office Action issued in U.S. Appl. No. 11/699,322 mailed Jul. 9, 2009.

Non-Final Office Action issued in U.S. Appl. No. 11/900,009 and mailed Jan. 27, 2010.

Notice of Allowance issued in U.S. Appl. No. 11/699,322 and mailed Mar. 19, 2010.

Non-final Office Acton issued in U.S. Appl. No. 11/900,009 and mailed on Jun. 3, 2010.

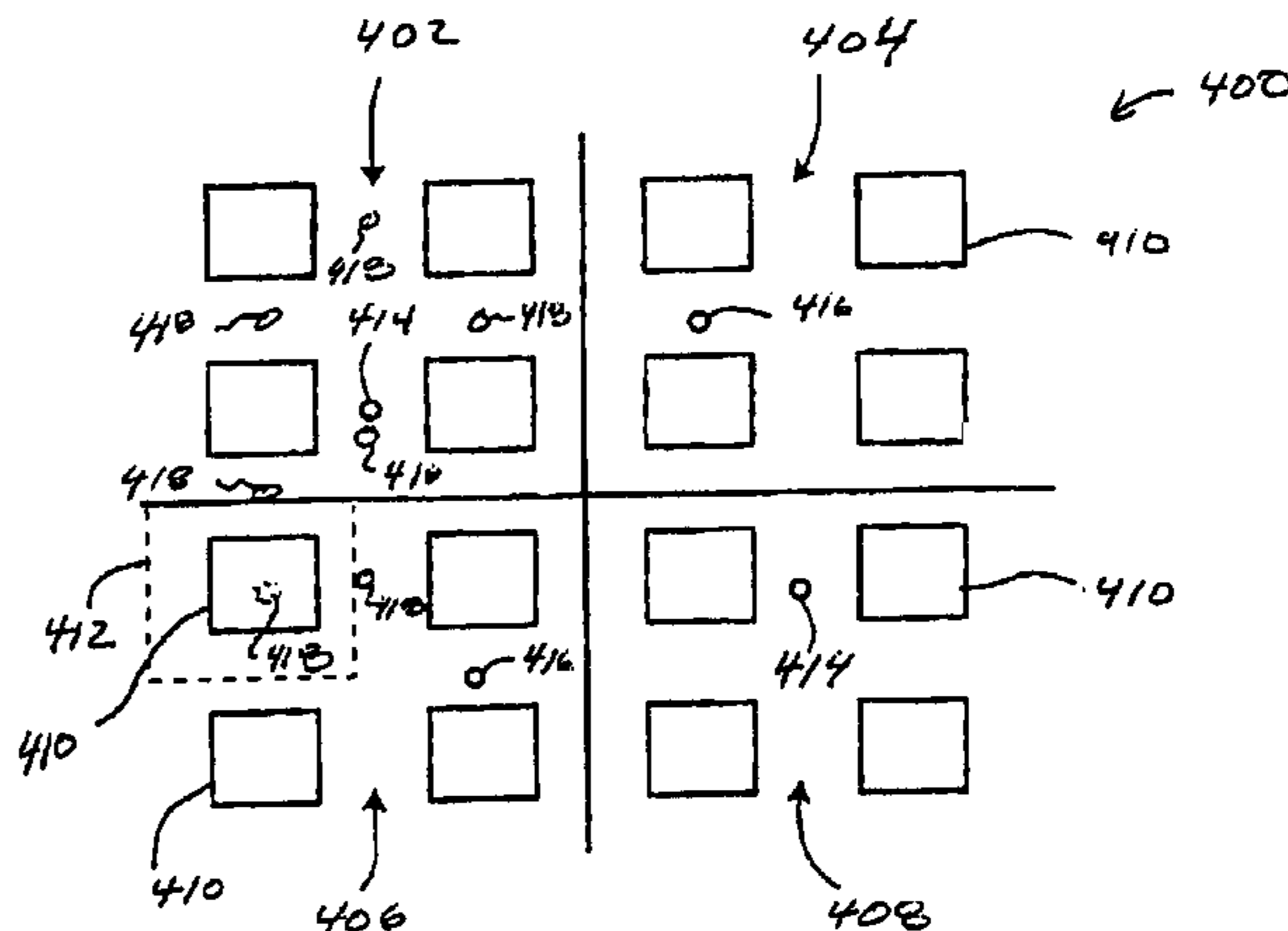
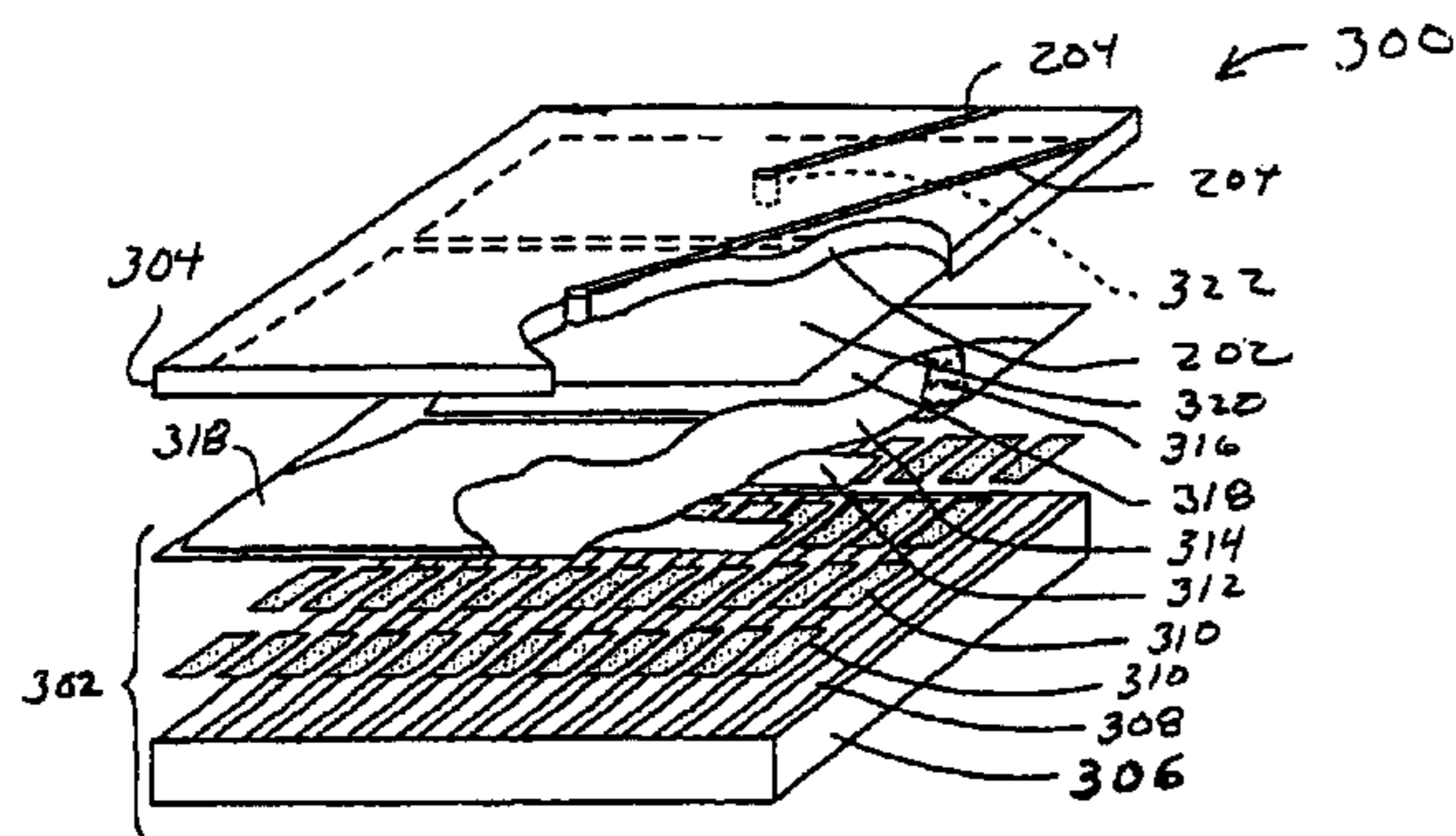
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(57) **ABSTRACT**

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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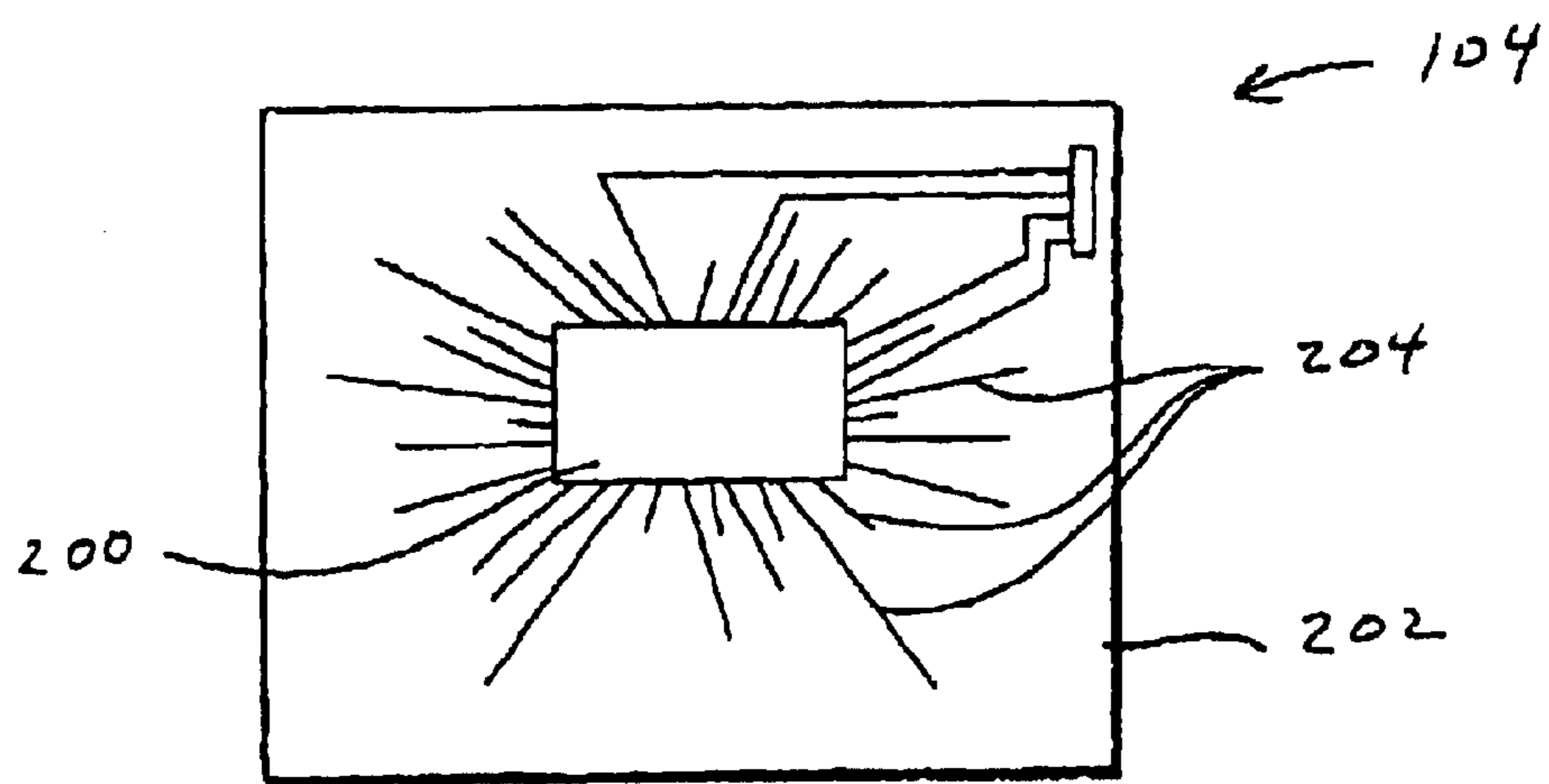
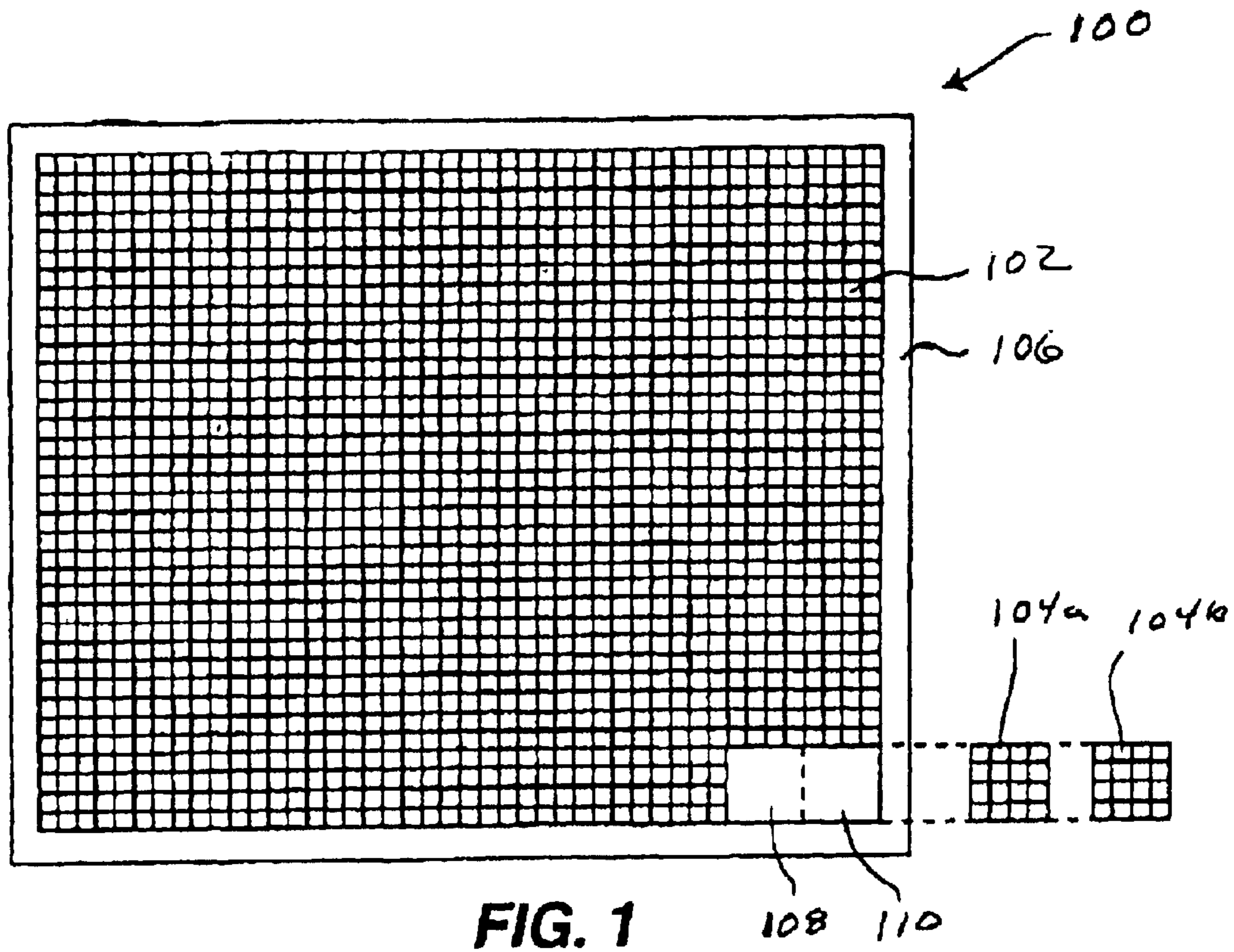
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U.S. PATENT DOCUMENTS							
4,549,174	A	10/1985	Funada et al.	5,596,246	A	1/1997	Budzilek et al.
4,573,766	A	3/1986	Bournay et al.	5,608,551	A	3/1997	Biles et al.
4,580,877	A	4/1986	Washo	5,612,798	A	3/1997	Tuli
4,650,288	A	3/1987	White	5,634,265	A	6/1997	Difrancesco
4,666,254	A	5/1987	Itoh et al.	5,646,480	A	7/1997	Carroll et al.
4,670,690	A	6/1987	Ketchpel	5,654,731	A	8/1997	Stewart et al.
4,672,264	A	6/1987	Higton	5,654,781	A	8/1997	Izumi
4,690,510	A	9/1987	Takamatsu et al.	5,668,058	A	9/1997	Tanioka et al.
4,690,511	A	9/1987	Watanabe	5,668,617	A	9/1997	Na
4,710,680	A	12/1987	Nakatani et al.	5,670,980	A	9/1997	Kuga
4,716,341	A	12/1987	Oida et al.	5,703,437	A	12/1997	Komaki
4,718,751	A	1/1988	Kamijo et al.	5,710,071	A	1/1998	Beddingfield et al.
4,719,385	A	1/1988	Barrow et al.	5,712,528	A	1/1998	Barrow et al.
4,760,389	A	7/1988	Aoki et al.	5,714,841	A	2/1998	Miyazaki
4,775,861	A	10/1988	Saito	5,729,317	A	3/1998	Izumi
4,778,258	A	10/1988	Parks et al.	5,729,896	A	3/1998	Dalal et al.
4,802,873	A	2/1989	Barrow et al.	5,742,371	A	4/1998	Izumi
4,812,017	A	3/1989	Piper	5,754,267	A	5/1998	Izumi
4,828,363	A	5/1989	Yamazaki	5,757,443	A	5/1998	Kobayashi
4,859,904	A	8/1989	Higton et al.	5,760,855	A	6/1998	Nakase et al.
4,862,153	A	8/1989	Nakatani et al.	5,774,107	A	6/1998	Inou
4,906,071	A	3/1990	Takahara et al.	5,777,705	A	7/1998	Pierson et al.
4,914,348	A	4/1990	Kameyama et al.	5,790,219	A	8/1998	Yamagishi et al.
4,916,308	A	4/1990	Meadows	5,796,452	A	8/1998	Pierson
4,917,474	A	4/1990	Yamazaki et al.	5,800,232	A	9/1998	Miyazaki
4,943,143	A	7/1990	Yamashita	5,803,579	A	9/1998	Turnbull et al.
4,963,788	A	10/1990	King et al.	5,808,710	A	9/1998	Pierson
4,985,663	A	1/1991	Nakatani	5,812,226	A	9/1998	Izumi et al.
4,988,168	A	1/1991	Dickerson et al.	5,821,456	A	10/1998	Wille et al.
4,999,539	A	3/1991	Coovert et al.	5,838,405	A	11/1998	Izumi et al.
5,036,249	A	7/1991	Pike-Bieganski et al.	5,847,783	A	12/1998	Hiramoto et al.
5,069,534	A	12/1991	Hirai	5,847,785	A	12/1998	Izumi
5,084,961	A	2/1992	Yoshikawa	5,854,663	A	12/1998	Oh et al.
5,106,197	A	4/1992	Ohuchida et al.	5,856,856	A	1/1999	Malhi
5,122,870	A	6/1992	Takeda et al.	5,875,011	A	2/1999	Pierson et al.
5,142,386	A	8/1992	Ishihara	5,880,705	A	3/1999	Onyskevych et al.
5,149,671	A	9/1992	Koh et al.	5,880,795	A	3/1999	Nagata et al.
5,150,238	A	9/1992	Vogeley et al.	5,891,753	A	4/1999	Akram
5,173,839	A	12/1992	Metz, Jr.	5,903,325	A	5/1999	Ilcisin et al.
5,179,459	A	1/1993	Plesinger	5,905,557	A	5/1999	Yaniv
5,182,489	A	1/1993	Sano	5,909,260	A	6/1999	Ilcisin et al.
5,184,235	A	2/1993	Sukegawa	5,914,562	A	6/1999	Khan et al.
5,189,539	A	2/1993	Suzuki	5,929,562	A	7/1999	Pichler
5,233,448	A	8/1993	Wu	5,929,959	A	7/1999	Iida et al.
5,235,451	A	8/1993	Bryan	5,932,967	A	8/1999	Chikazawa
5,260,818	A	11/1993	Wu	5,936,600	A	8/1999	Ohashi et al.
5,272,553	A	12/1993	Yamamoto et al.	5,940,157	A	8/1999	Nakamura et al.
5,293,262	A	3/1994	Adachi et al.	5,946,063	A	8/1999	Izumi
5,295,008	A	3/1994	Mizobata et al.	5,959,710	A	9/1999	Yaniv
5,302,468	A	4/1994	Namiki et al.	5,965,907	A	10/1999	Huang et al.
5,304,895	A	4/1994	Ujihara	5,977,718	A	11/1999	Christensen
5,342,477	A	8/1994	Cathey	6,005,649	A	12/1999	Krusius et al.
5,367,390	A	11/1994	Scheffer et al.	6,019,654	A	2/2000	Kim
5,377,027	A	12/1994	Jelley et al.	6,025,893	A	2/2000	Kadowaki et al.
5,386,341	A	1/1995	Olson et al.	6,034,657	A	3/2000	Tokunaga et al.
5,412,495	A	5/1995	Kim	6,051,928	A	4/2000	Choi et al.
5,422,747	A	6/1995	Wakita	6,055,030	A	4/2000	Izumi
5,457,356	A	10/1995	Parodos	6,064,153	A	5/2000	Ilcisin et al.
5,461,400	A	10/1995	Ishii et al.	6,064,454	A	5/2000	Kim et al.
5,493,075	A	2/1996	Chong et al.	6,066,512	A	5/2000	Hashimoto
5,514,933	A	5/1996	Ward et al.	6,067,143	A	5/2000	Tomita
5,515,191	A	5/1996	Swirbel	6,069,446	A	5/2000	Kim
5,523,873	A	6/1996	Bradford et al.	6,072,274	A	6/2000	Jondrow
5,525,867	A	6/1996	Williams	6,075,504	A	6/2000	Stoller
5,532,906	A	7/1996	Hanari et al.	6,091,194	A	7/2000	Swirbel et al.
5,537,233	A	7/1996	Miura et al.	6,091,468	A	7/2000	Kim et al.
5,563,621	A	10/1996	Silsby	6,097,609	A	8/2000	Kabadi
5,565,885	A	10/1996	Tamanoi	6,100,584	A	8/2000	Noritake et al.
5,585,695	A	12/1996	Kitai	6,108,029	A	8/2000	Lo
5,592,193	A	1/1997	Chen	6,133,689	A	10/2000	Watkins et al.
				6,140,765	A	10/2000	Kim et al.

US RE41,914 E

Page 3

6,144,438 A	11/2000	Izumi	6,373,142 B1	4/2002	Hoang
6,147,666 A	11/2000	Yaniv	6,384,529 B2	5/2002	Tang et al.
6,147,739 A	11/2000	Shibatani	6,400,428 B1	6/2002	Izumi
6,157,355 A	12/2000	Ide	6,404,412 B1	6/2002	Van Asma
6,184,968 B1	2/2001	Taylor-Smith	6,410,415 B1	6/2002	Estes et al.
6,188,459 B1	2/2001	Kim	6,410,841 B1	6/2002	Oh et al.
6,198,518 B1	3/2001	Kuga	6,417,898 B1	7/2002	Izumi
6,218,784 B1	4/2001	Jang et al.	6,420,830 B1	7/2002	Youn
6,252,564 B1	6/2001	Albert et al.	6,437,505 B1	8/2002	Baret et al.
6,268,843 B1	7/2001	Arakawa	6,439,731 B1	8/2002	Johnson et al.
6,271,598 B1	8/2001	Vindasius et al.	6,462,803 B2	10/2002	Kumagai et al.
6,274,978 B1	8/2001	Roach et al.	6,466,294 B1	10/2002	Yamagishi et al.
6,275,220 B1	8/2001	Nitta	6,479,945 B2	11/2002	Buzak et al.
6,275,279 B1	8/2001	Asuma et al.	6,483,482 B1	11/2002	Kim
6,275,280 B1	8/2001	Kajita et al.	6,495,958 B1	12/2002	Moon
6,285,433 B1	9/2001	Kawasaki	6,498,592 B1	12/2002	Matthies
6,320,312 B1	11/2001	Kim et al.	6,501,528 B1	12/2002	Hamada
6,329,752 B1	12/2001	Choi	6,541,919 B1	4/2003	Roach et al.
6,337,672 B1	1/2002	Inoguchi et al.	6,624,570 B1	9/2003	Nishio et al.
6,344,714 B1	2/2002	Su et al.	6,683,665 B1	1/2004	Matthies
6,346,973 B1	2/2002	Shibamoto et al.	6,785,144 B1	8/2004	Akram
6,359,235 B1	3/2002	Hayashi	2002/0008463 A1	1/2002	Roach
6,366,269 B1	4/2002	Watkins et al.	2002/0012096 A1	1/2002	Uchiyama
6,369,792 B1	4/2002	Kikinis	2003/0011300 A1	1/2003	Palanisamy et al.
6,370,019 B1	4/2002	Matthies et al.	2003/0011302 A1	1/2003	Palanisamy



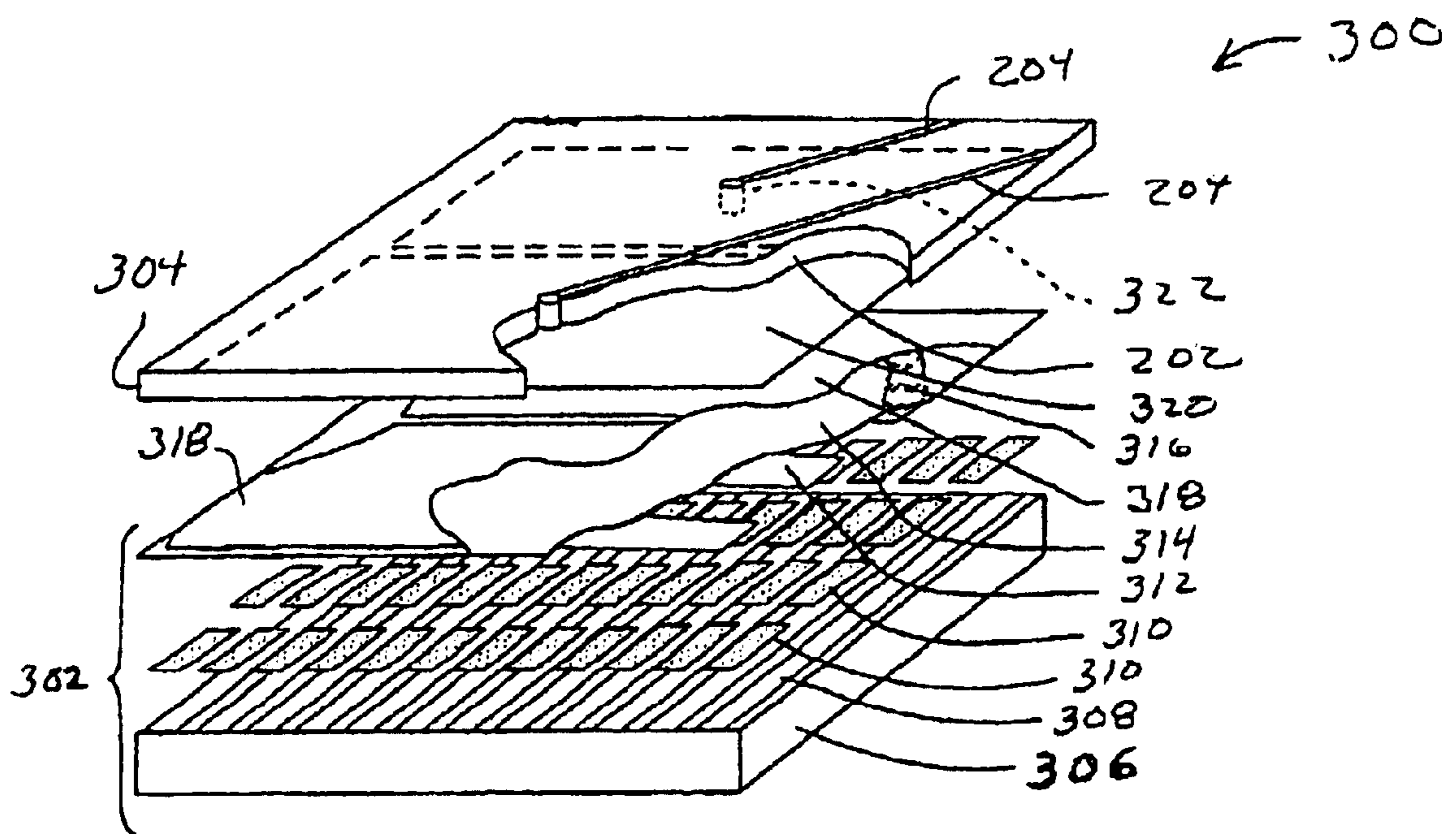


FIG. 3

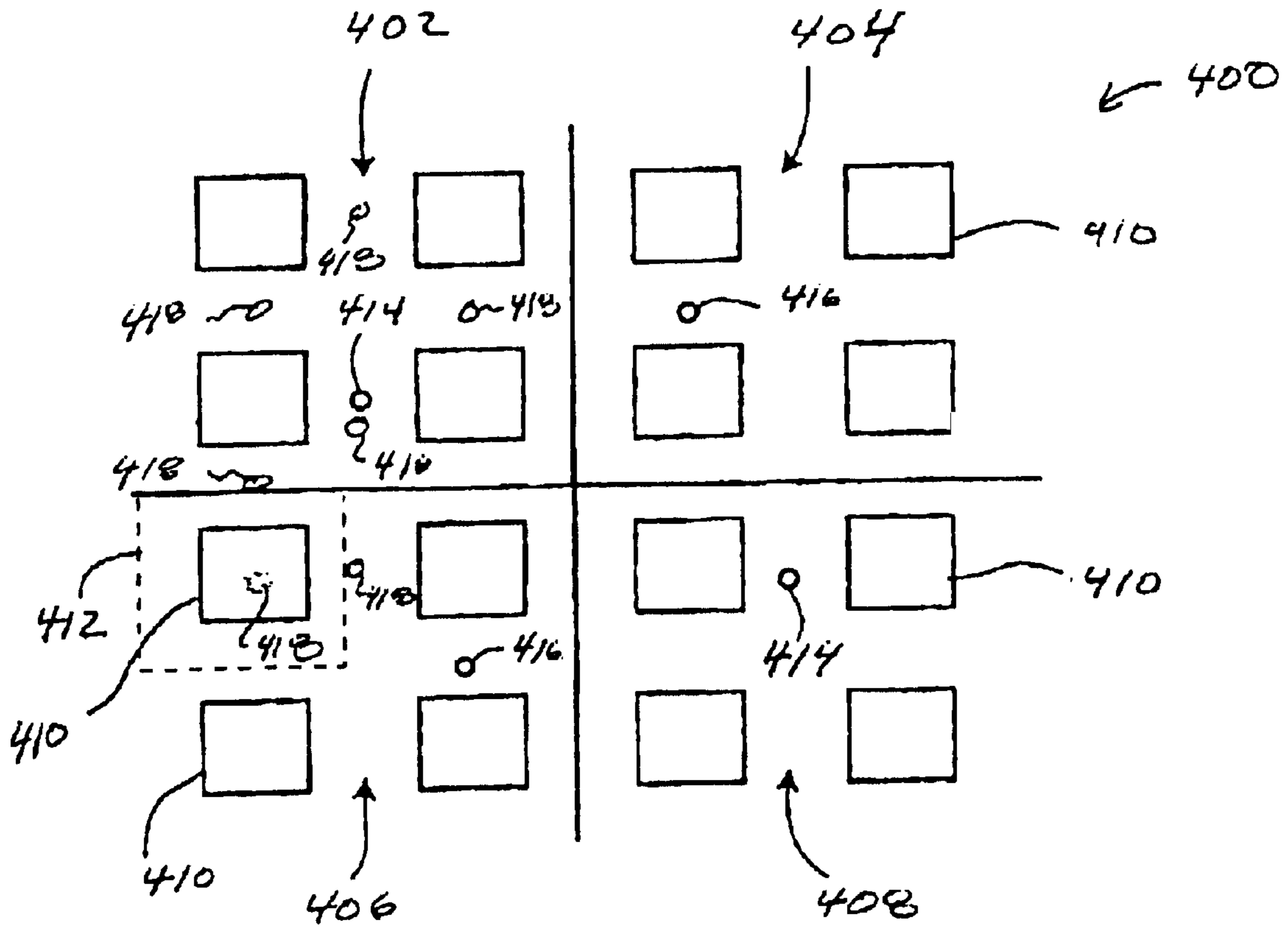


FIG. 4

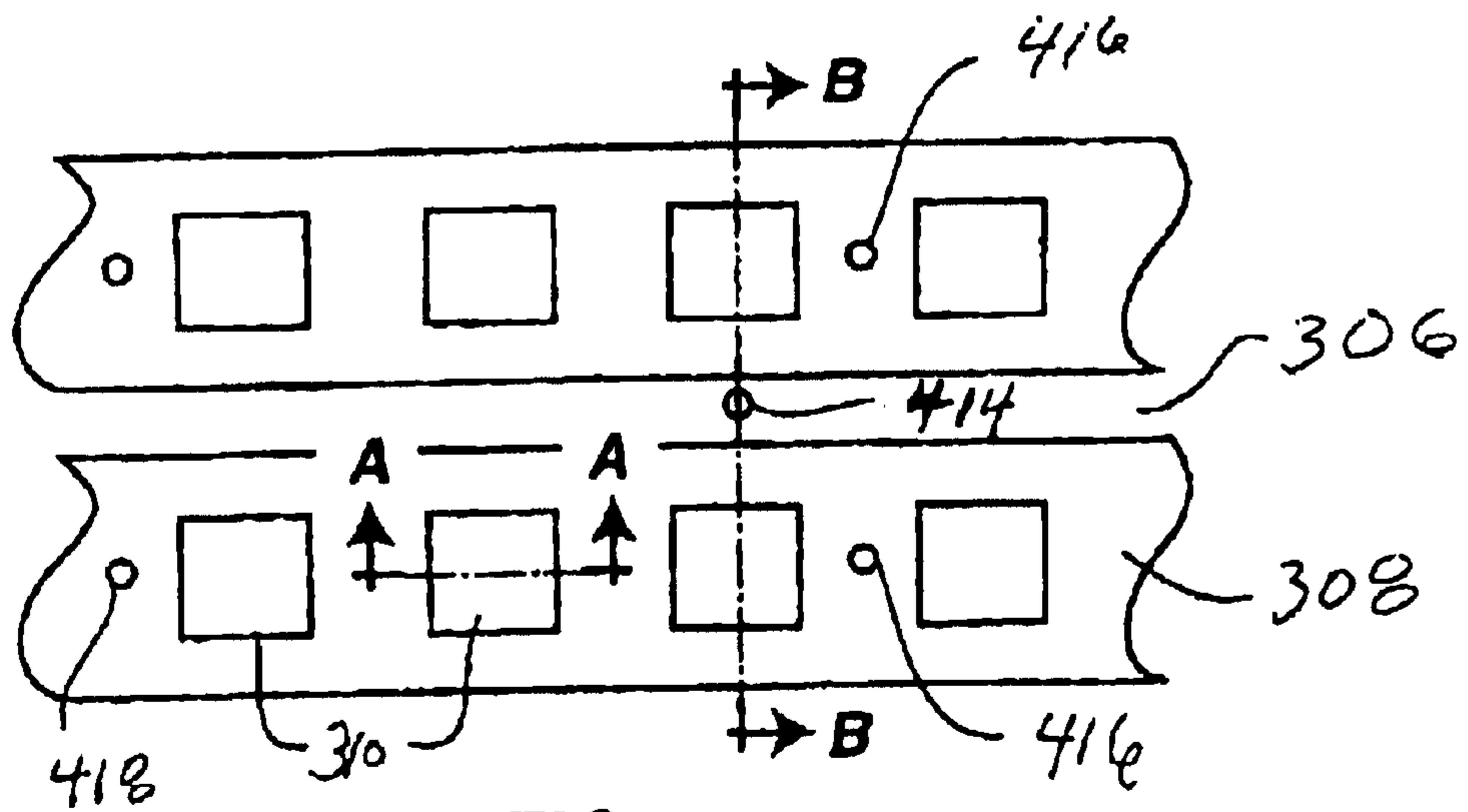


FIG. 5

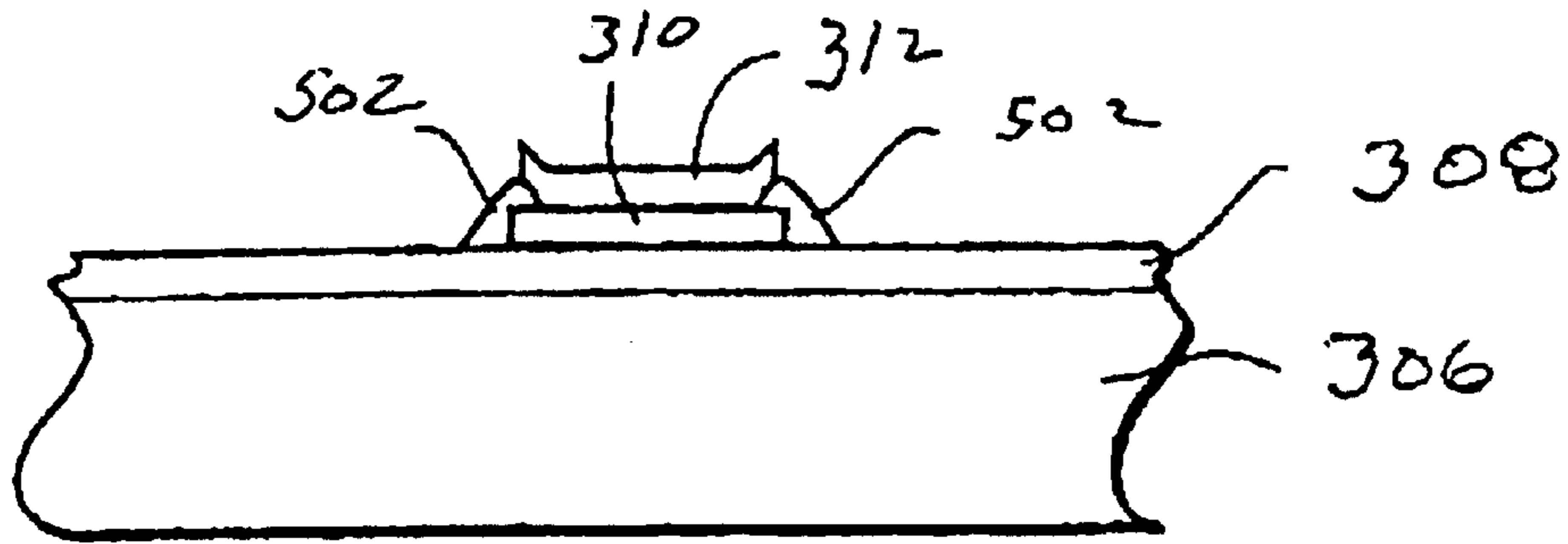


FIG. 5A

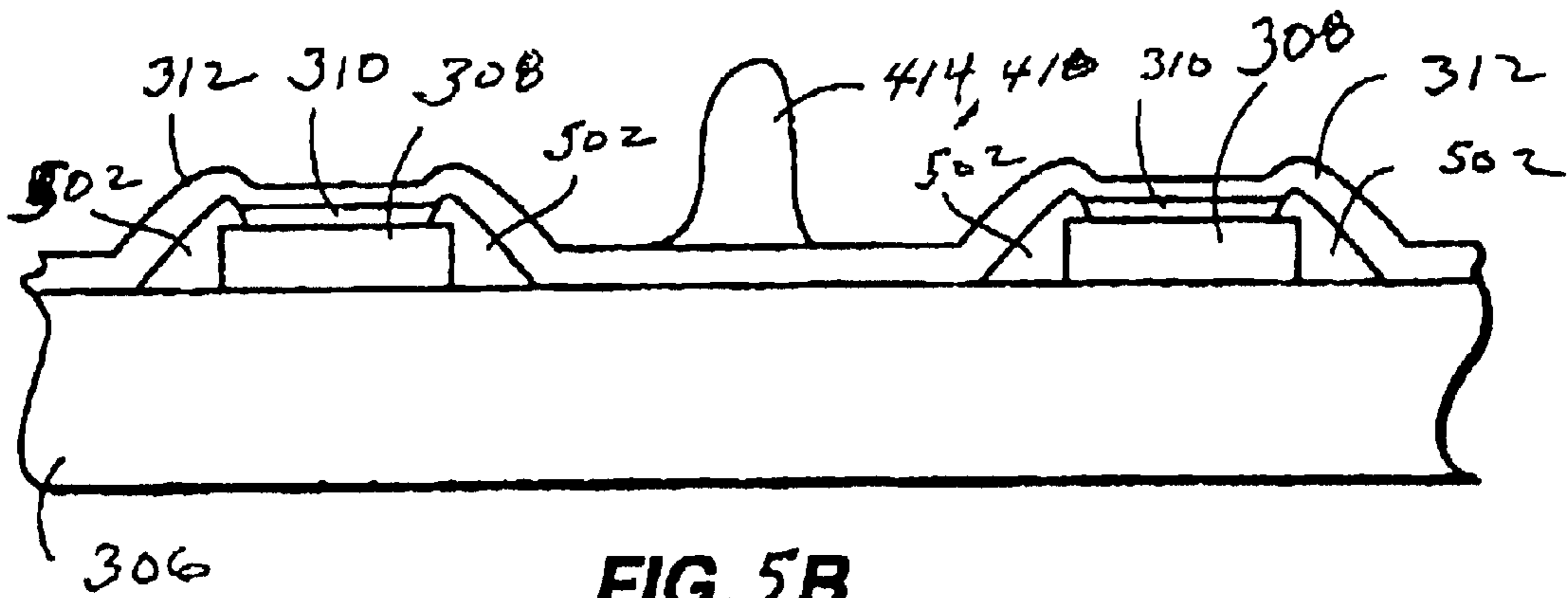


FIG. 5B

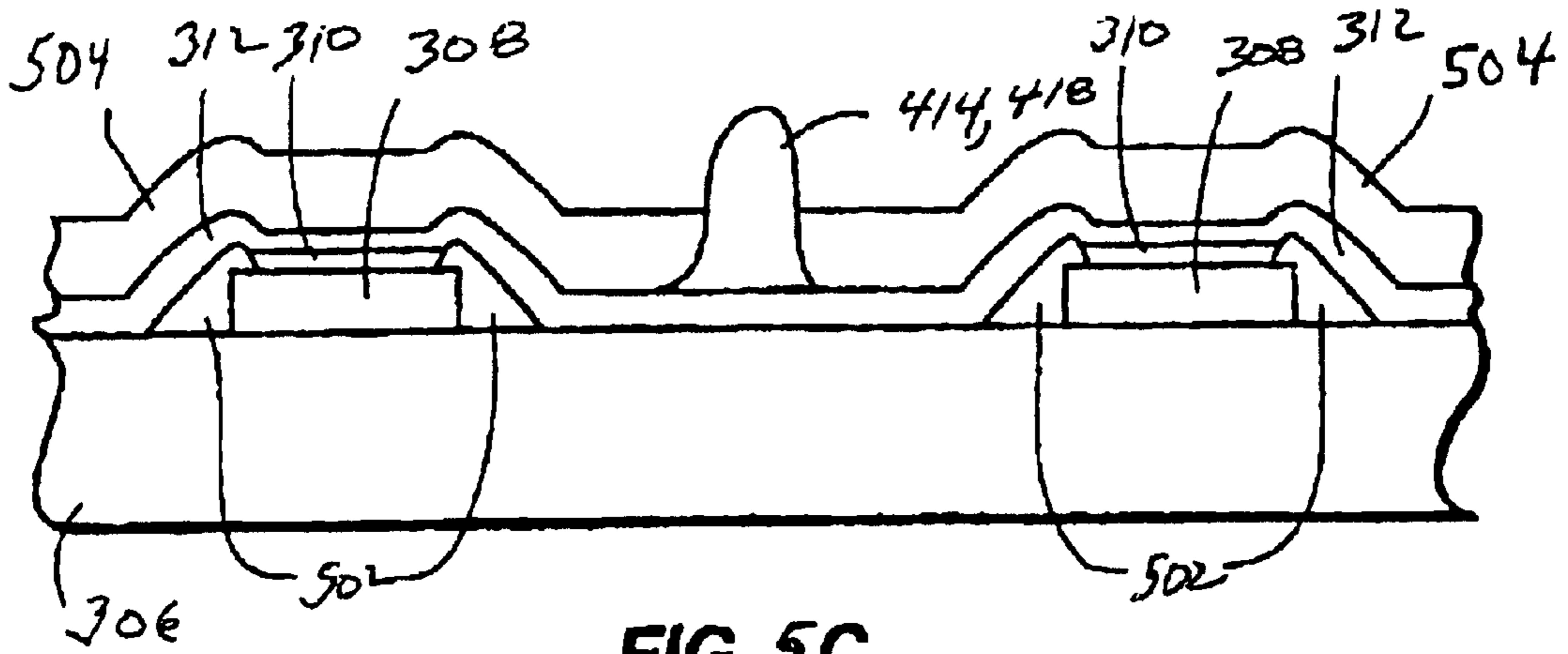


FIG. 5C

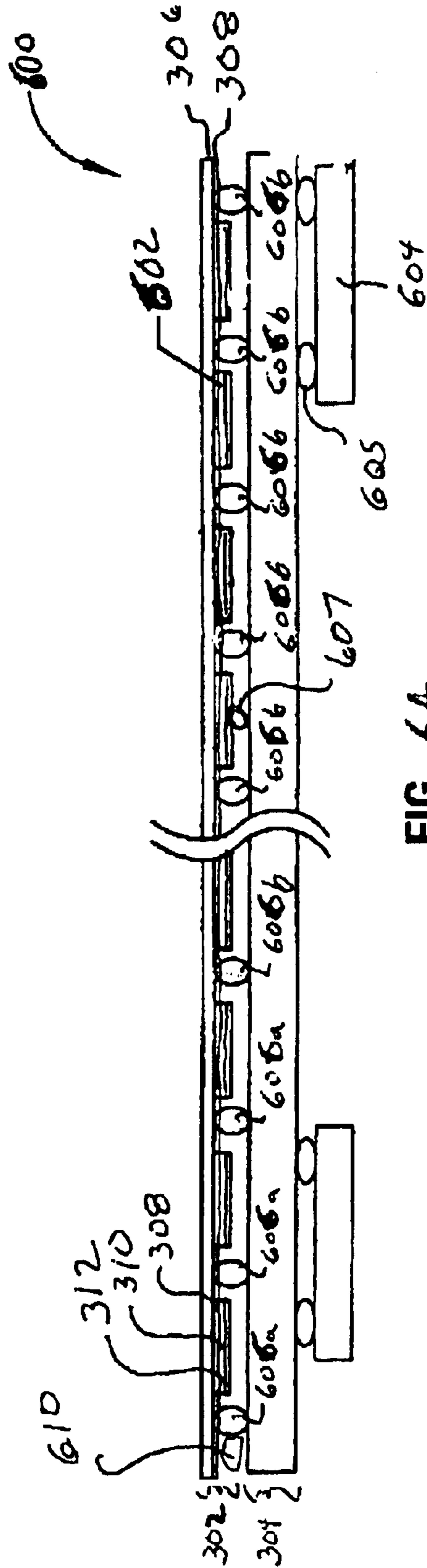


FIG. 6A

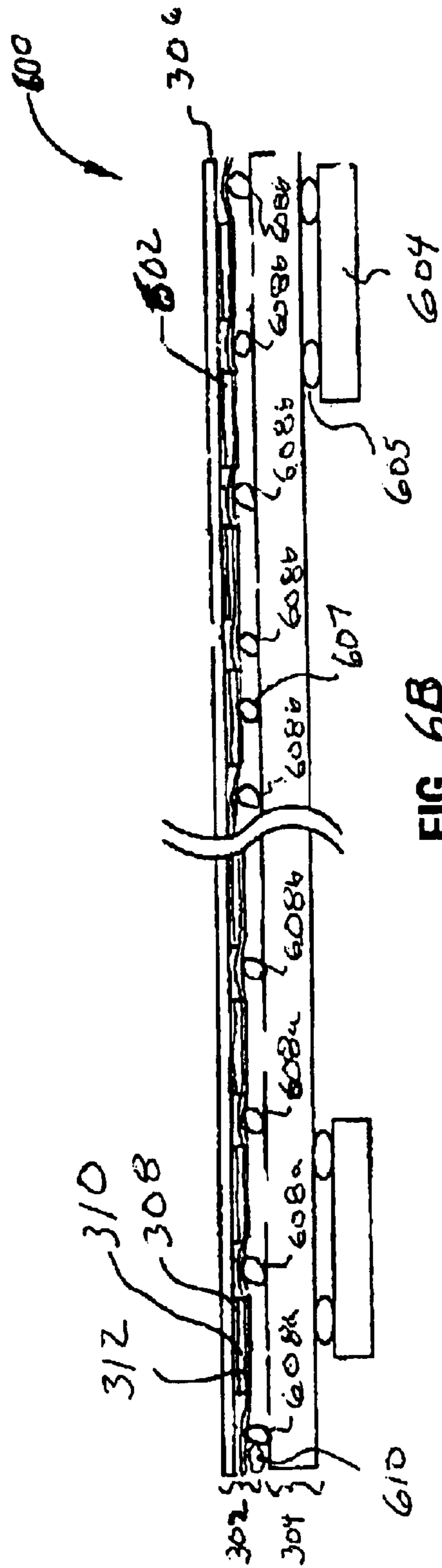


FIG. 6B

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

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

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

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

FIG. 6B 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 104a and 104b 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.

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FIG. 5 shows a view of a portion of a display module of an electronic pixel structure according to the present invention. FIGS. 5A and 5B 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. 5A and 5B, an insulator 502 such as SiO₂ 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. 5B, an electrical connection 414 is shown as formed upon the row electrode 312 passing between adjacent pixel structures. The conductor 414 shown in FIG. 5B 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. 5C 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. 5–5C, 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

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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. 6A and 6B 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. 6A 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 606a. The electrical connections 606a extend between the circuit module 304 and the pixel structure 602. Specifically, the electrical connections 606a 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 606b, that dissipate heat generated in the pixel structure 602 toward the circuit module 304. In certain exemplary embodiments, the thermo-mechanical elements 606b also provide redundant electrical connections.

In an exemplary embodiment, the thermo-mechanical elements 606b have a larger cross-sectional area than the electrical connections 606a to improve the thermal transfer capabilities of the thermo-mechanical elements. In certain exemplary embodiments, the thermo-mechanical elements 606b are sized to maximize thermal transfer capabilities without adversely affecting the operation of the display. Although the thermo-mechanical elements 606b in FIG. 6A are shown as extending from the circuit module 304 to the column electrode 308 near the front panel 306, the thermo-mechanical elements 606b 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. 6B 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 608a. The electrical connections 608a extend between the circuit module 304 and the

pixel structure **602**. Specifically, the electrical connections **608a** 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 **608b**, that dissipate heat generated in the pixel structure **602** toward the circuit module **304**. In certain exemplary embodiments, the thermo-mechanical elements **606b** also provide a redundant electrical connection.

Although the thermo-mechanical elements **608b** in FIG. **6B** are shown as extending from the circuit module **304** to the row electrode **312** near the front panel **306**, the thermo-mechanical elements **608b** 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. **6A** and **6B**, 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 Technology, 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 **606b**, **608b**. 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 **606a**, **608a** 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 heat 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 ele-

ments 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

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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.

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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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