US 20040169807A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2004/0169807 A1

Rho et al. (43) Pub. Date: Sep. 2, 2004

(54) LIQUID CRYSTAL DISPLAY

(76) Inventors: **Soo-Guy Rho**, Kyungki-do (KR); **Keun-Kyu Song**, Yongin-city (KR); **Jeong-Ye Choi**, Suwon-city (KR); **Nam-Seok Roh**, Sungnam-city (KR); **Cheol-Woo Park**, Suwon-city (KR); **Mun-Pyo Hong**, Sungnam-city (KR); **Ho-Yong Jeong**, Suwon-city (KR)

Correspondence Address:
Michael A. Cantor
55 Griffin South Road
Bloomfield, CT 06002 (US)

(21) Appl. No.: **10/640,479**

(22) Filed: **Aug. 12, 2003**

(30) **Foreign Application Priority Data**

Aug. 14, 2002 (KR) 2002-48058

Nov. 20, 2002 (KR) 2002-72289

Publication Classification

(51) **Int. Cl.**[7] **G02F 1/1343**

(52) **U.S. Cl.** **349/139**

(57) **ABSTRACT**

A liquid crystal display includes an array pixel including a plurality of pixels arranged in a matrix. The plurality of pixels include a set of pixels including a pair of center pixels adjacent to each other, and a pair of first-color pixels and a pair of second-color pixels obliquely facing each other across the center pixels. Each pixel includes a pixel electrode and a thin film transistor. The liquid crystal display further includes a plurality of gate lines extending in a row direction for transmitting a gate signal to the pixels, and a plurality of data lines extending in a column direction for transmitting data signals to the pixels. The pixels are subject to polarity inversion.

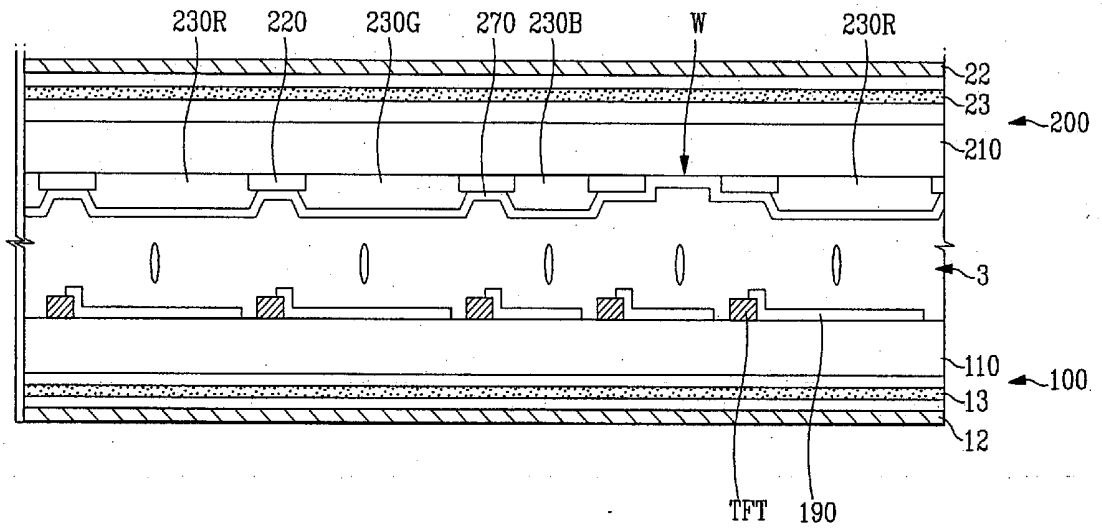


FIG.1

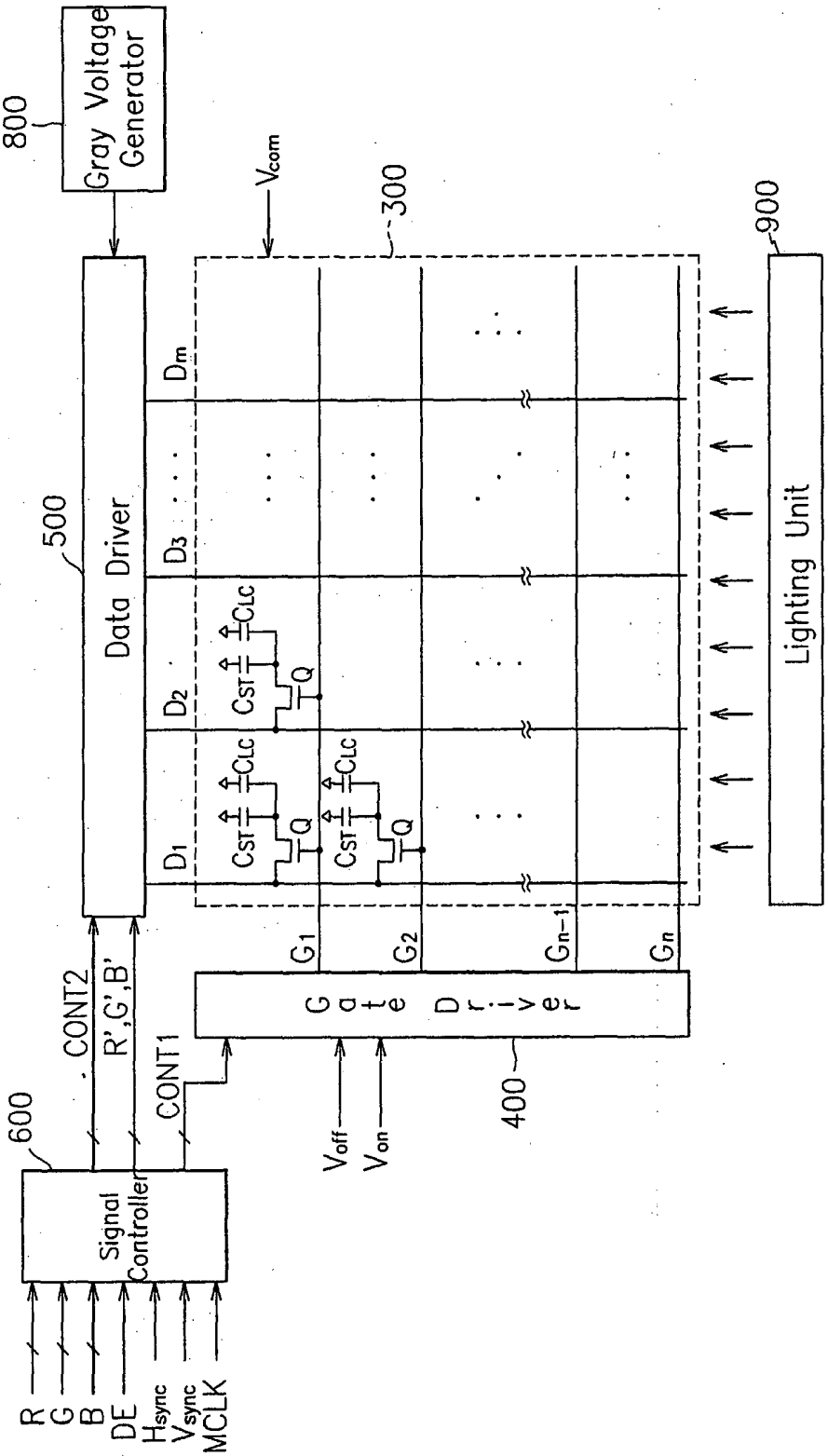
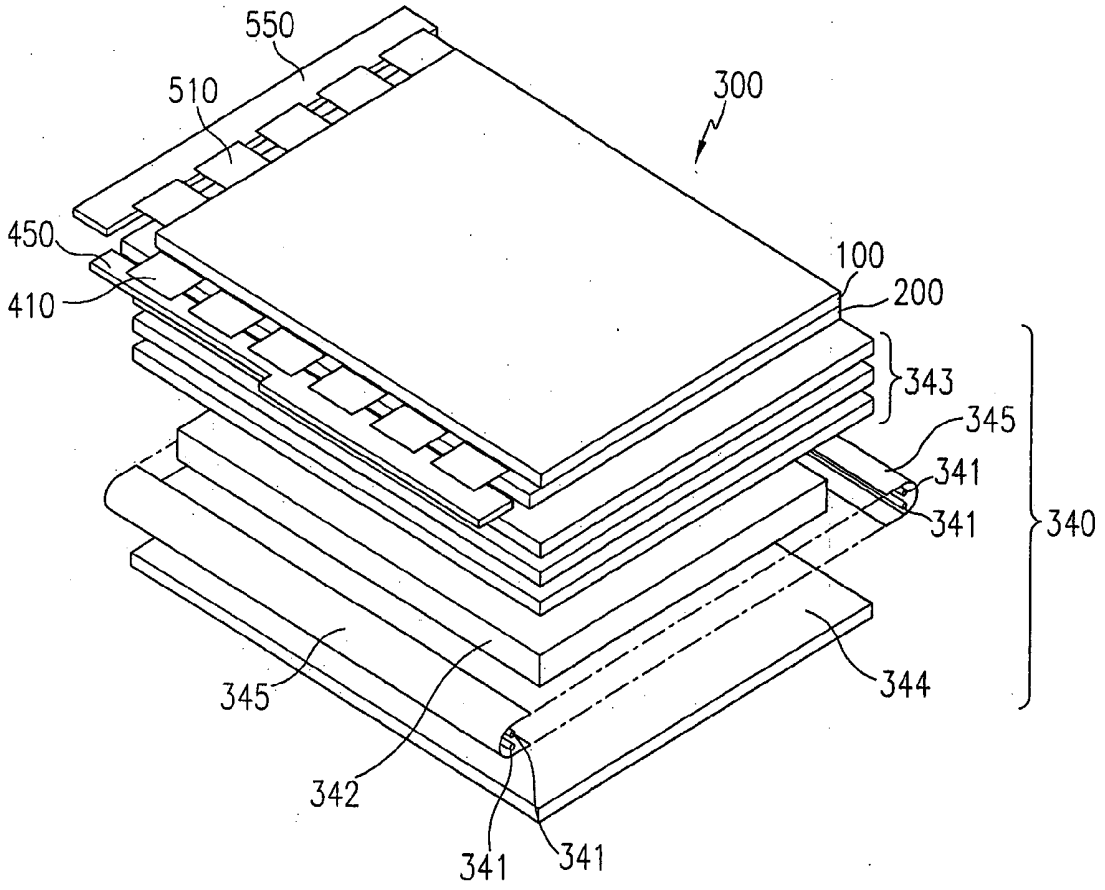

800
Gray Voltage Generator
Vcom
300
900
500
Data Driver
Dm
D3
D2
D1
CST
CLC
Q
Lighting Unit
G1
G2
Gn-1
Gn
Gate Driver
400
CONT2
R',G',B'
CONT1
600
Signal Controller
Voff
Von
R
G
B
DE
Hsync
Vsync
MCLK

FIG.2


550
510
300
450
410
100
200
343
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341
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344

FIG.3

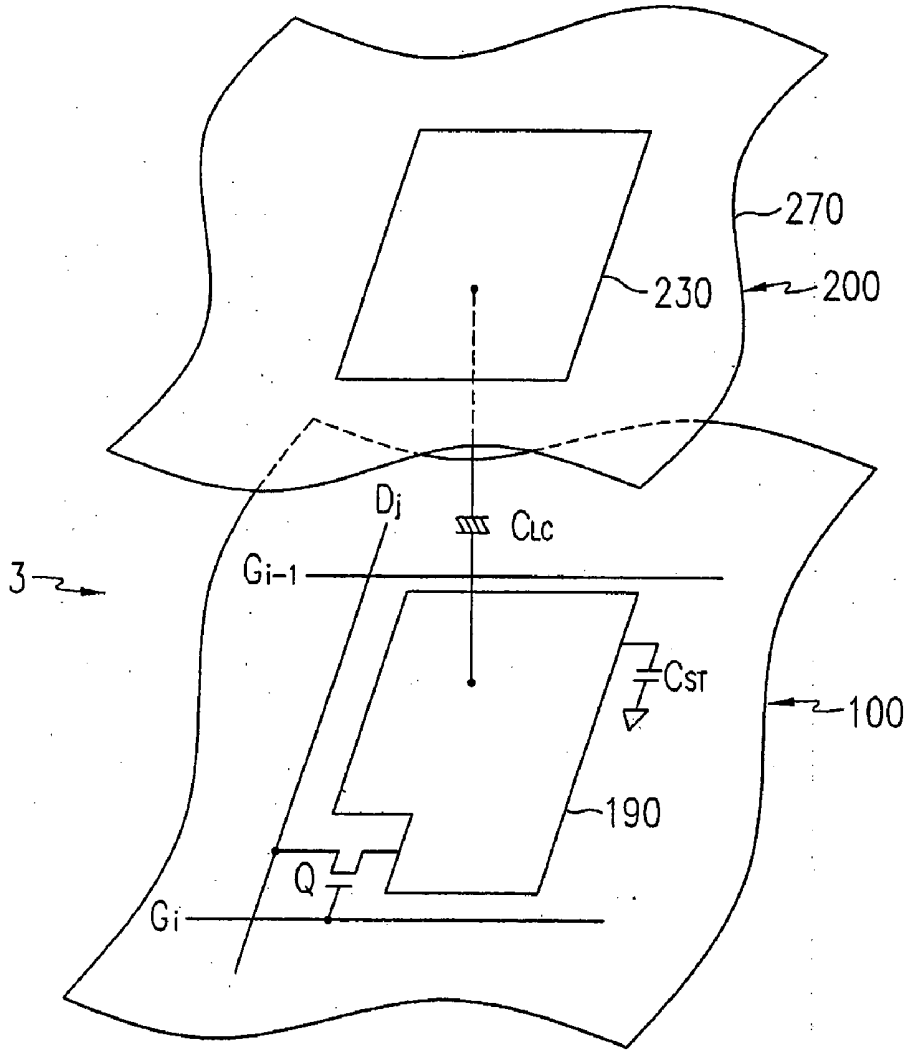


FIG.4A

R	B	G	R	B	G
G	B	R	G	B	R
R	B	G	R	B	G
G	B	R	G	B	R

FIG.4B

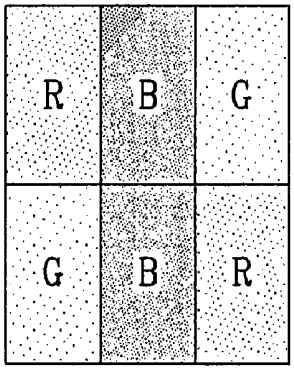


FIG.5A

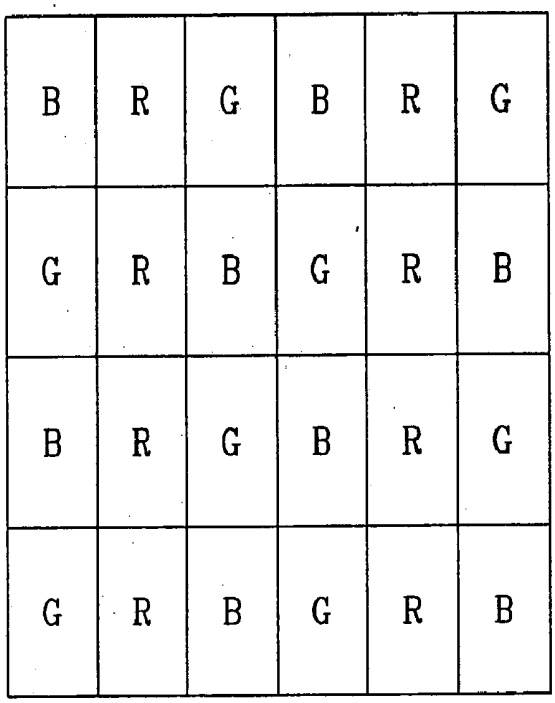


FIG.5B

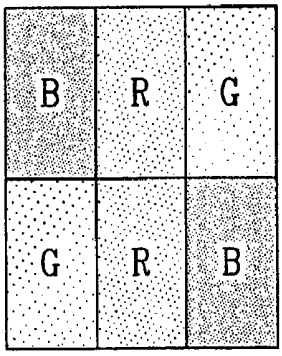


FIG.6

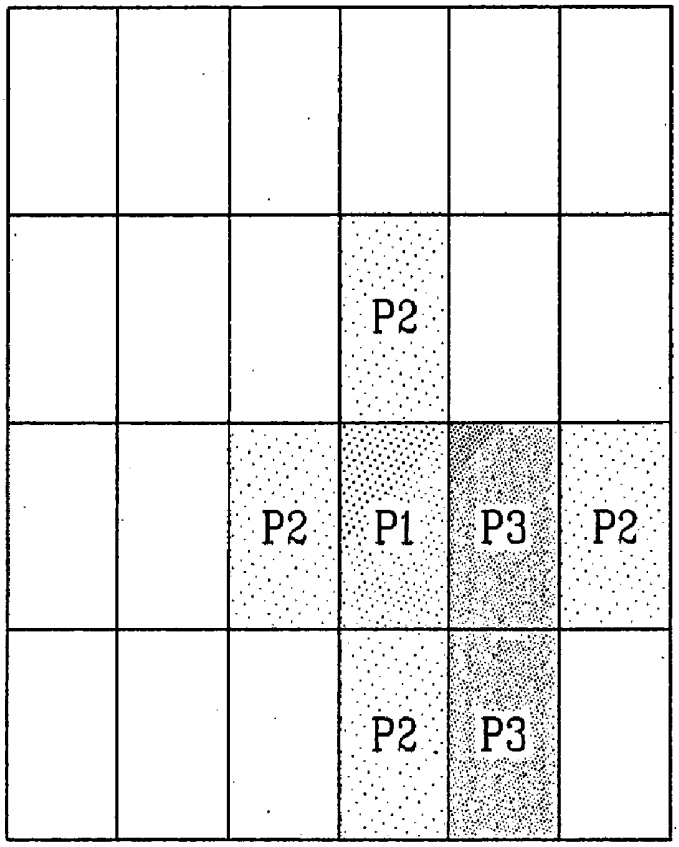
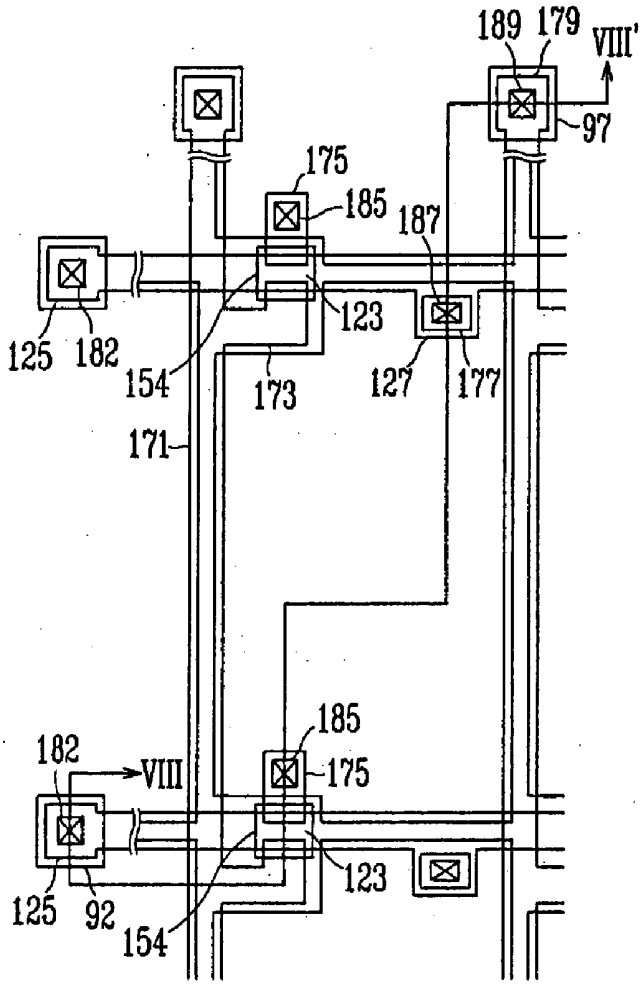


FIG.7


189
179
VIII'
97
175
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187
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177
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185
182
VIII
175
123
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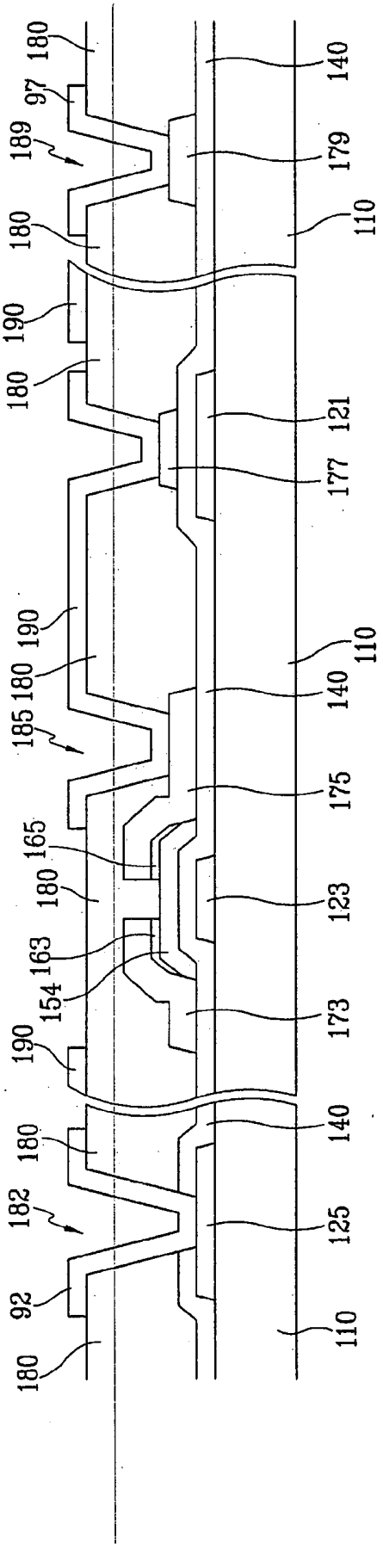
92
154

FIG.8


180
97
189
180
190
180
190
180
185
165
180
163
154
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177
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173
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125
110

FIG.9

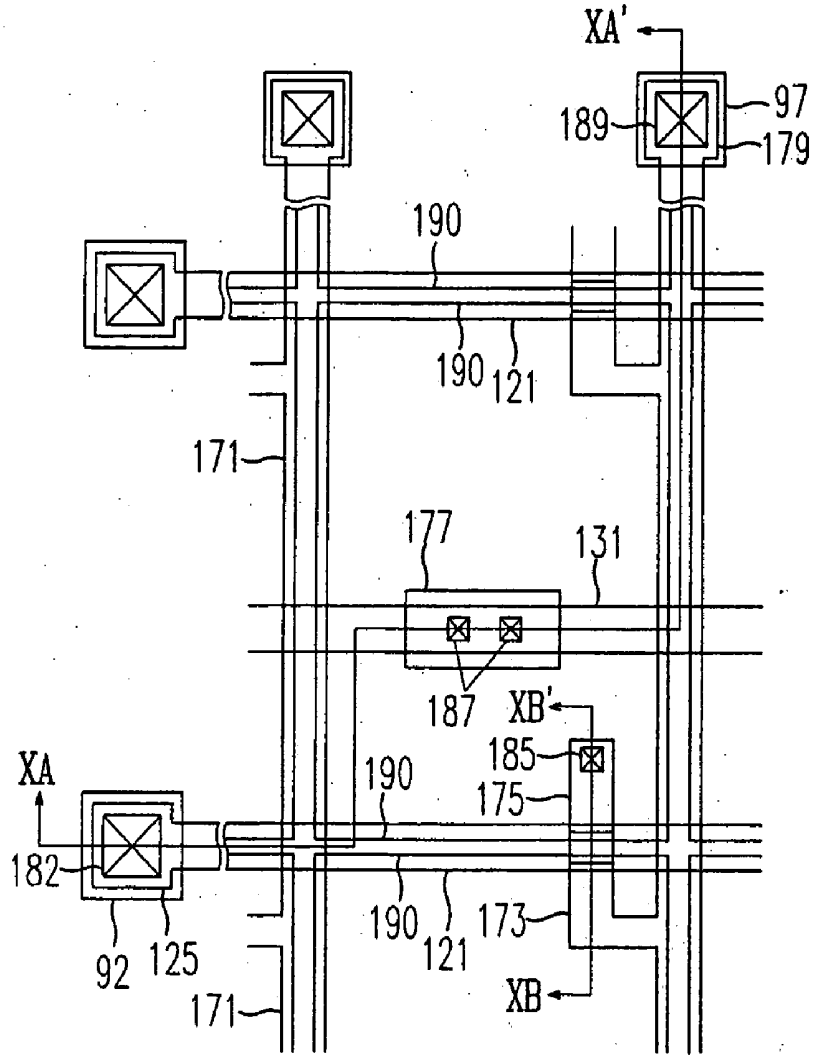
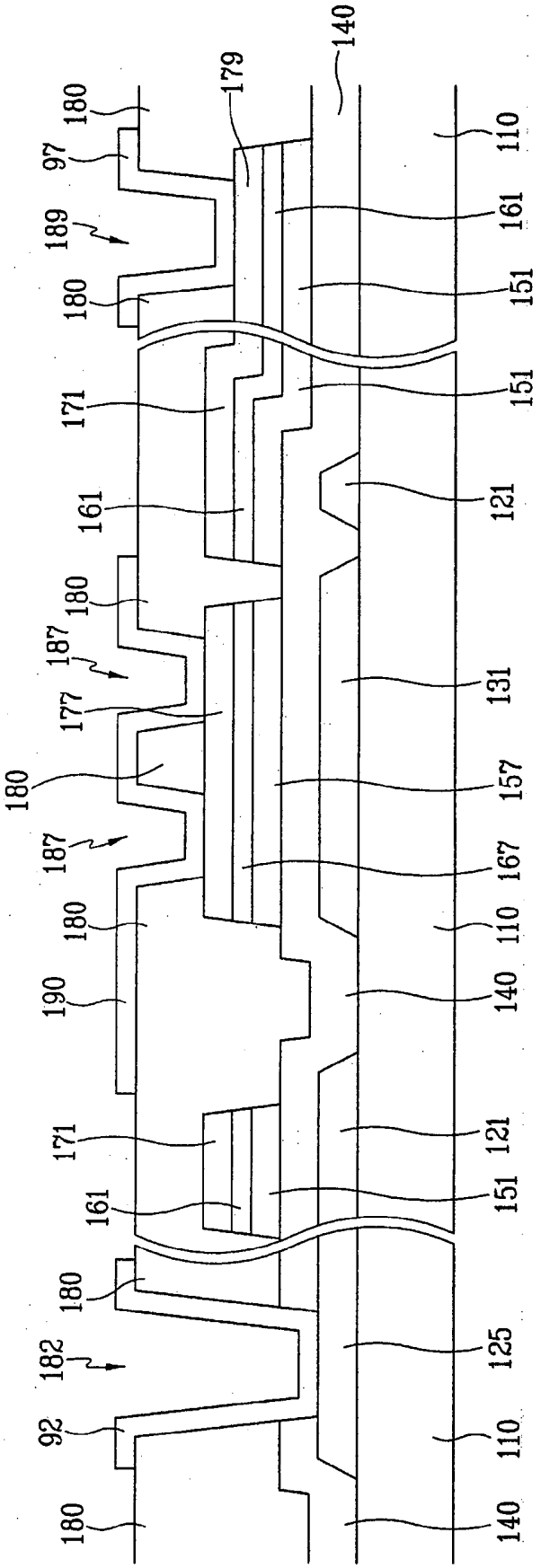

XA'
97
189
179
190
190
121
171
177
131
187
XB'
185
XA
190
175
182
190
121
173
92
125
171
XB

FIG.10A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151
180
182
125
92
110
180
140

FIG.10B

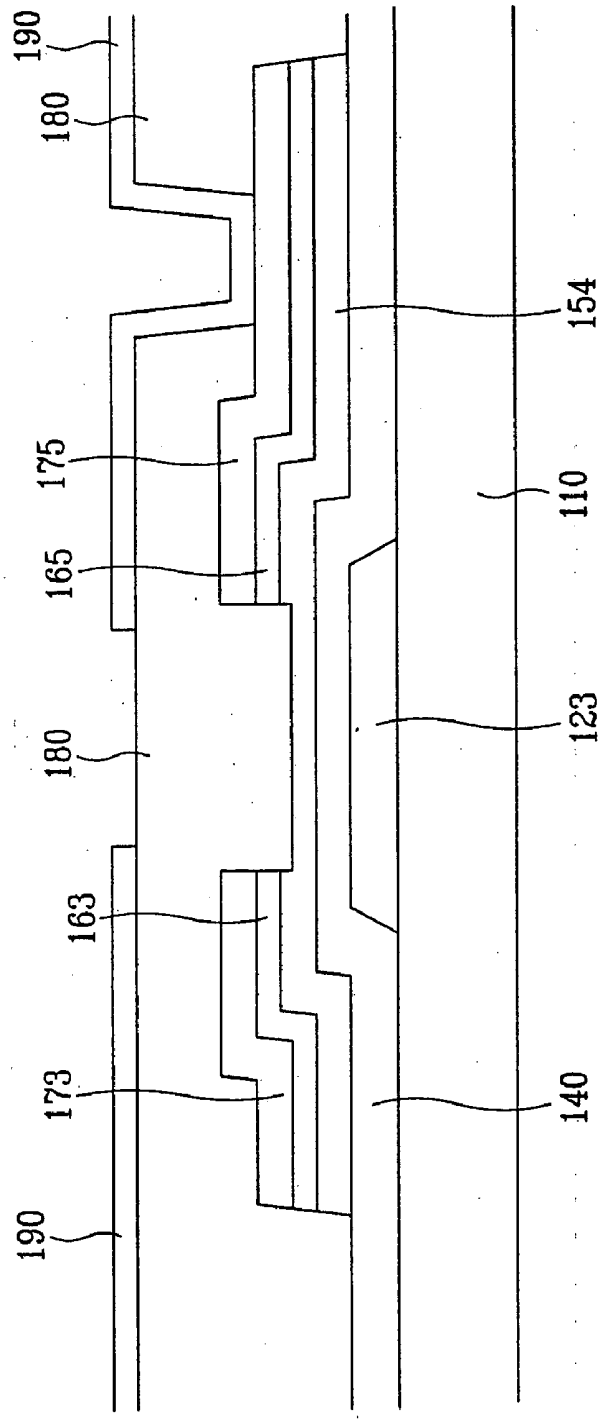


FIG.11

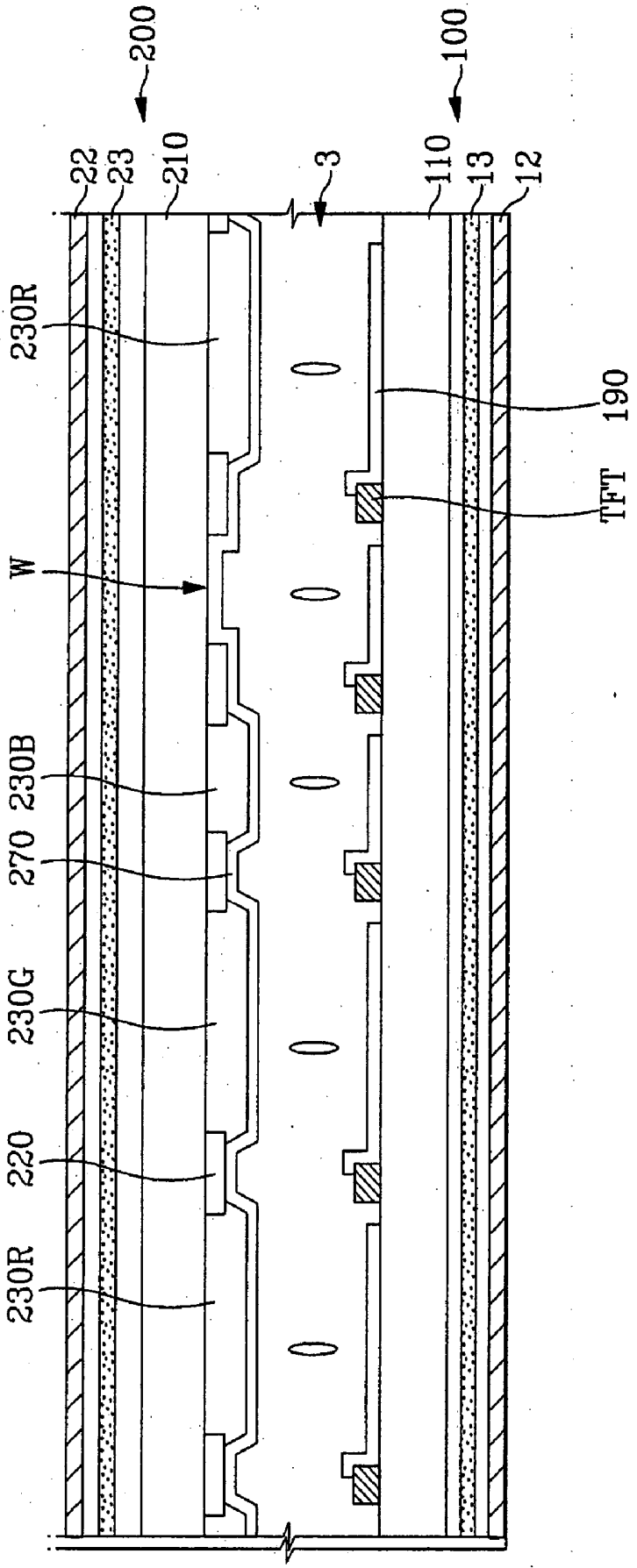

200
100
22
23
210
3
110
13
12
230R
190
TFT
W
230B
270
230G
220
230R

FIG.12

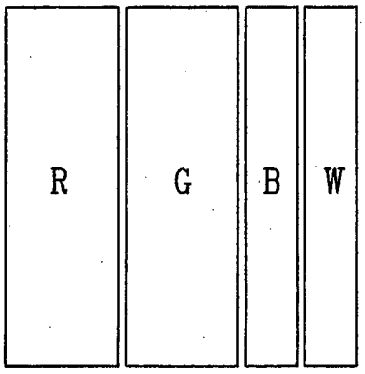


FIG.13

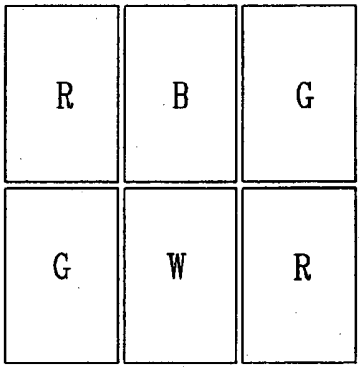


FIG.14

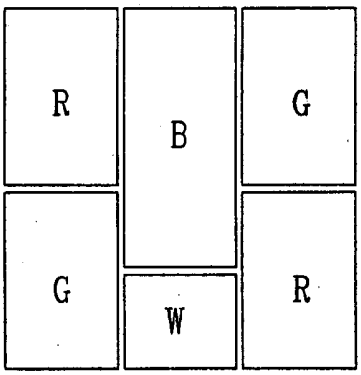


FIG.15

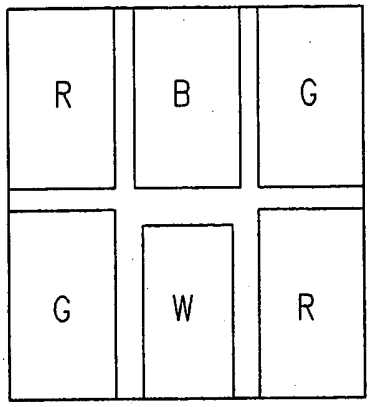

R
B
G
G
W
R

FIG.16

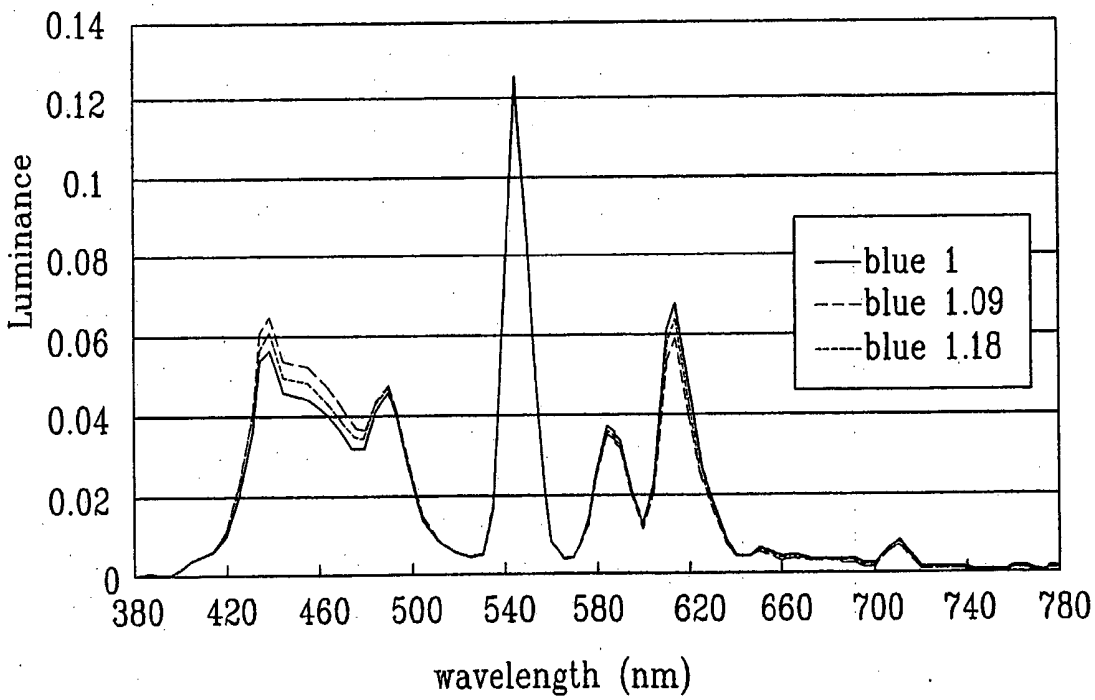

0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Luminance
380
420
460
500
540
580
620
660
700
740
780
wavelength (nm)
blue 1
blue 1.09
blue 1.18

FIG.17

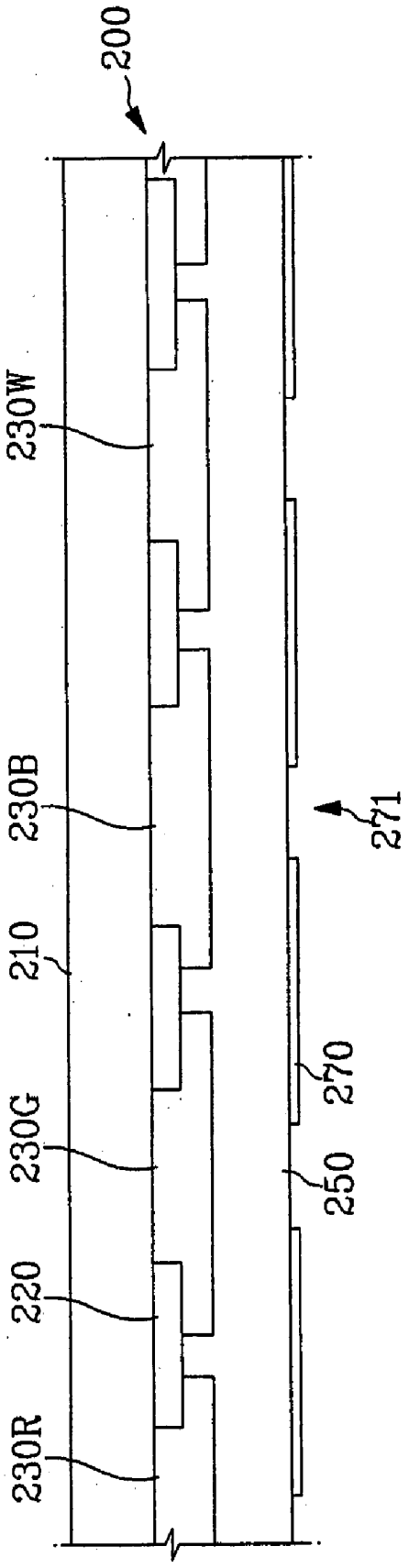


FIG.18

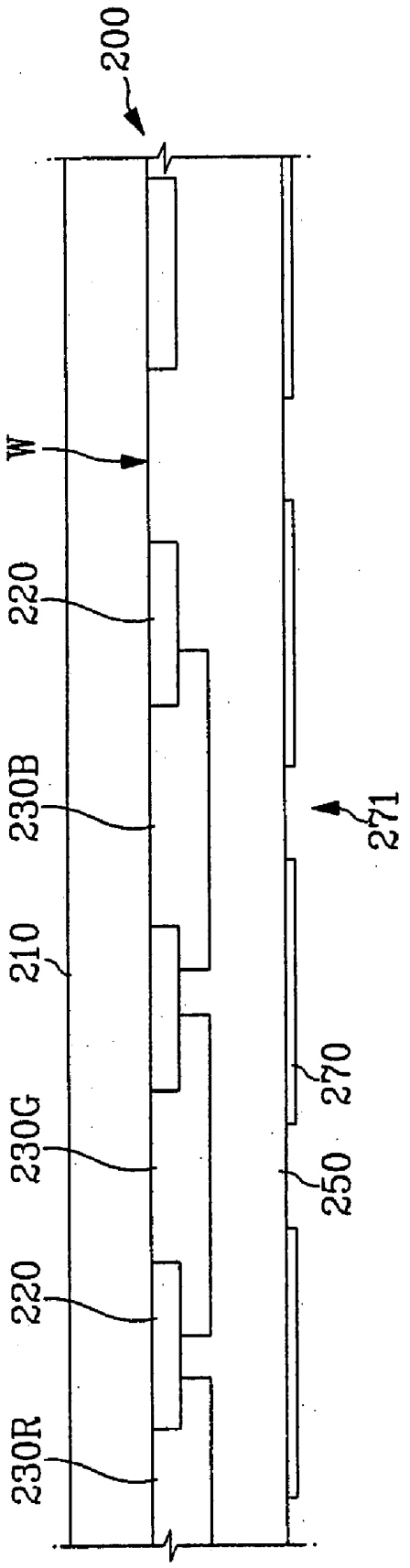


FIG.19

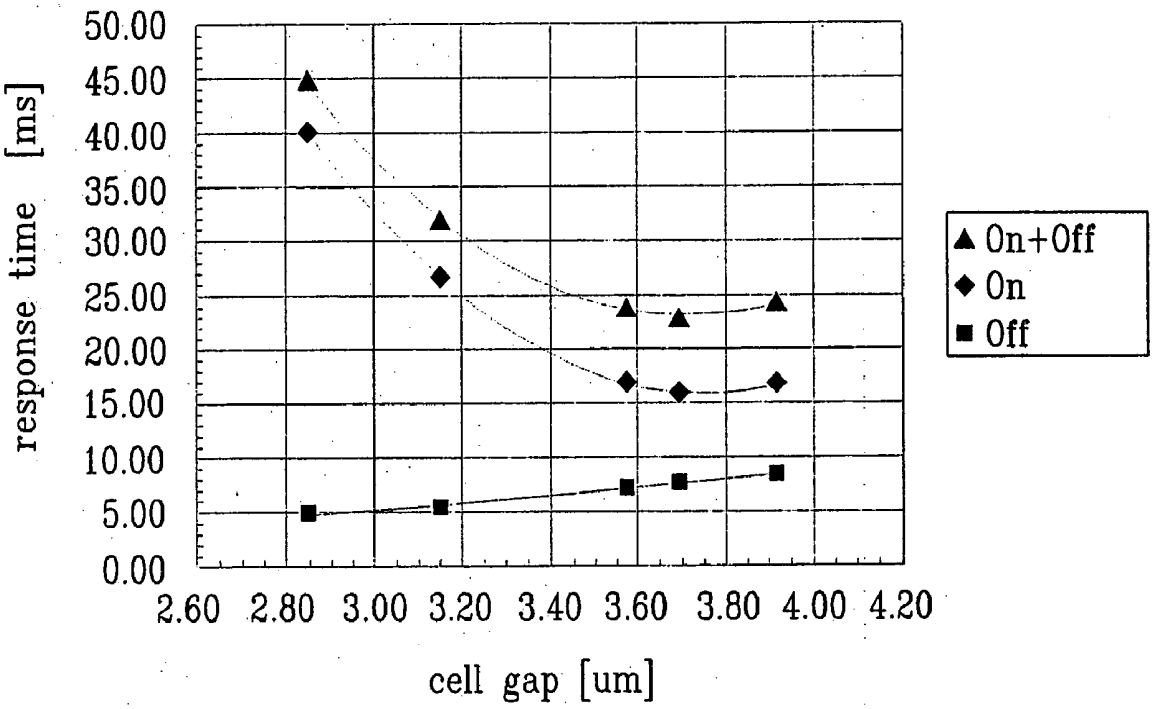
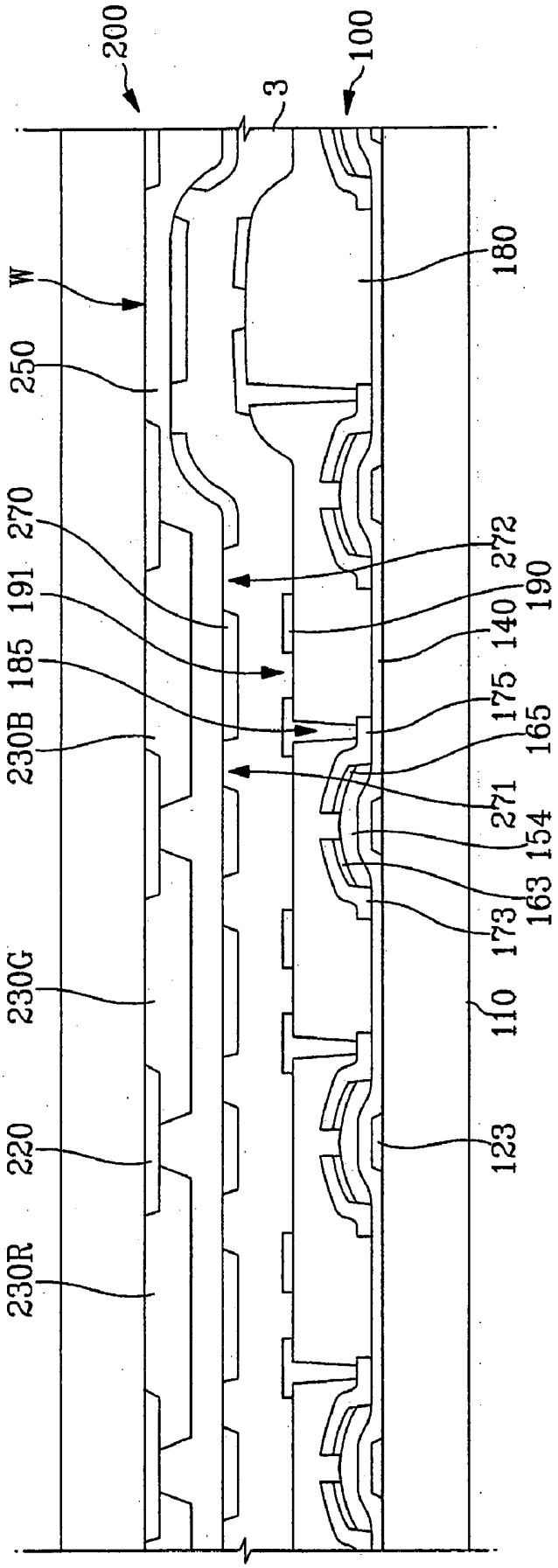

response time [ms]
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20
cell gap [um]
On+Off
On
Off

FIG.20


200
3
100
W
250
270
191
185
230B
230G
220
230R
180
272
190
140
175
165
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154
163
173
110
123

FIG.21

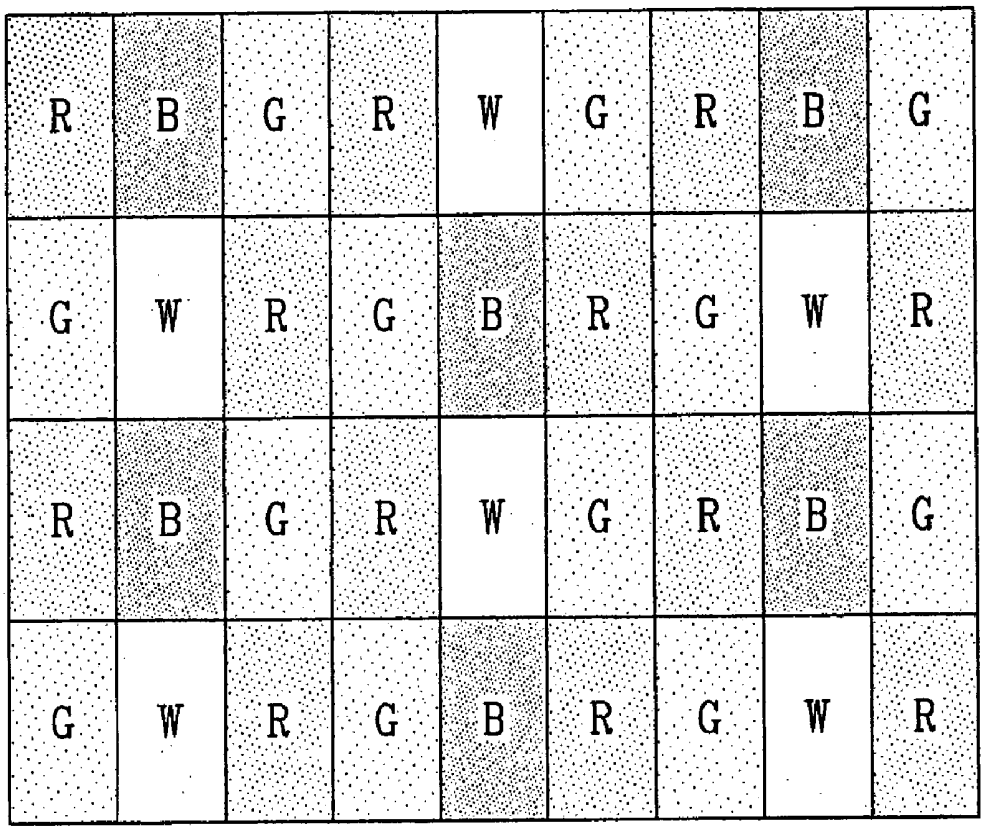

FIG.22

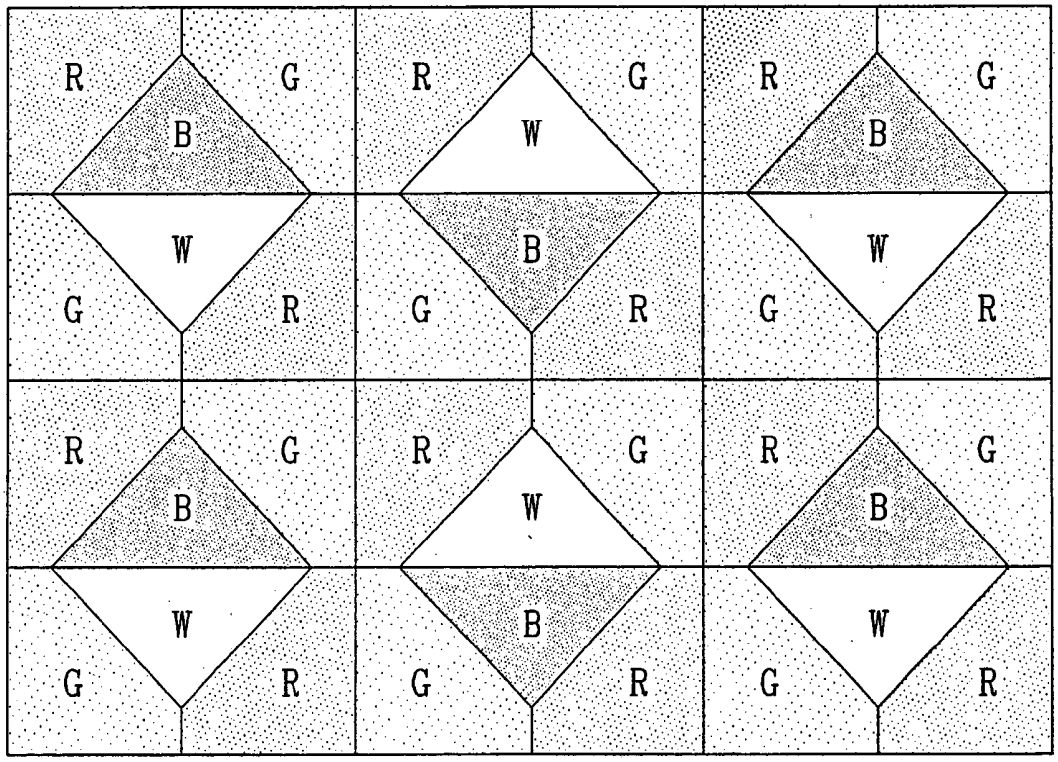

FIG.23

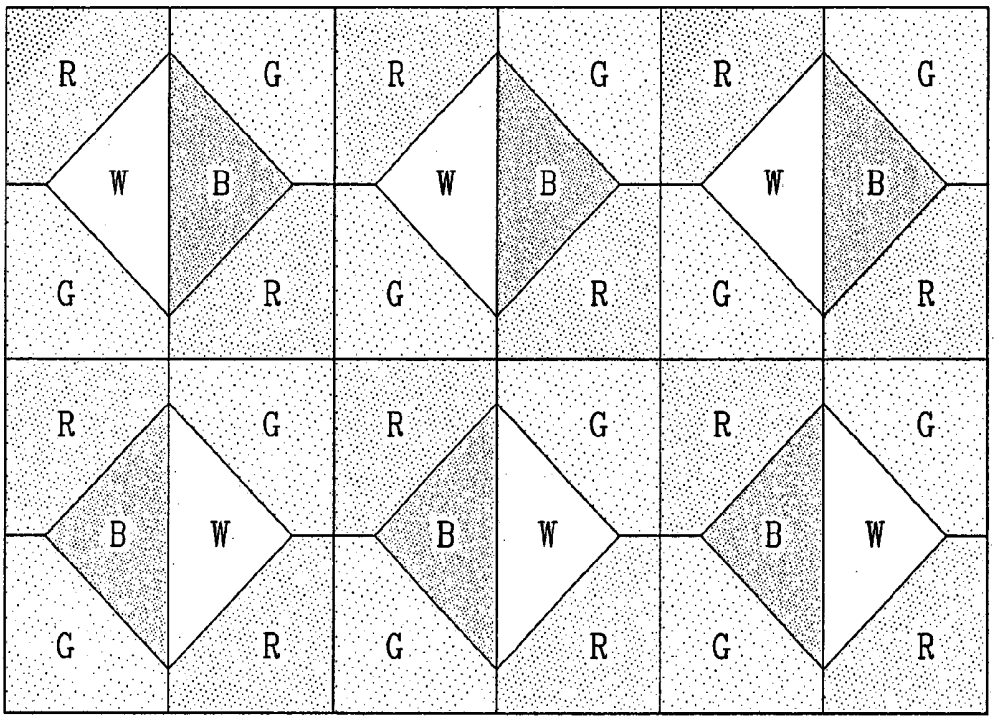

FIG. 24

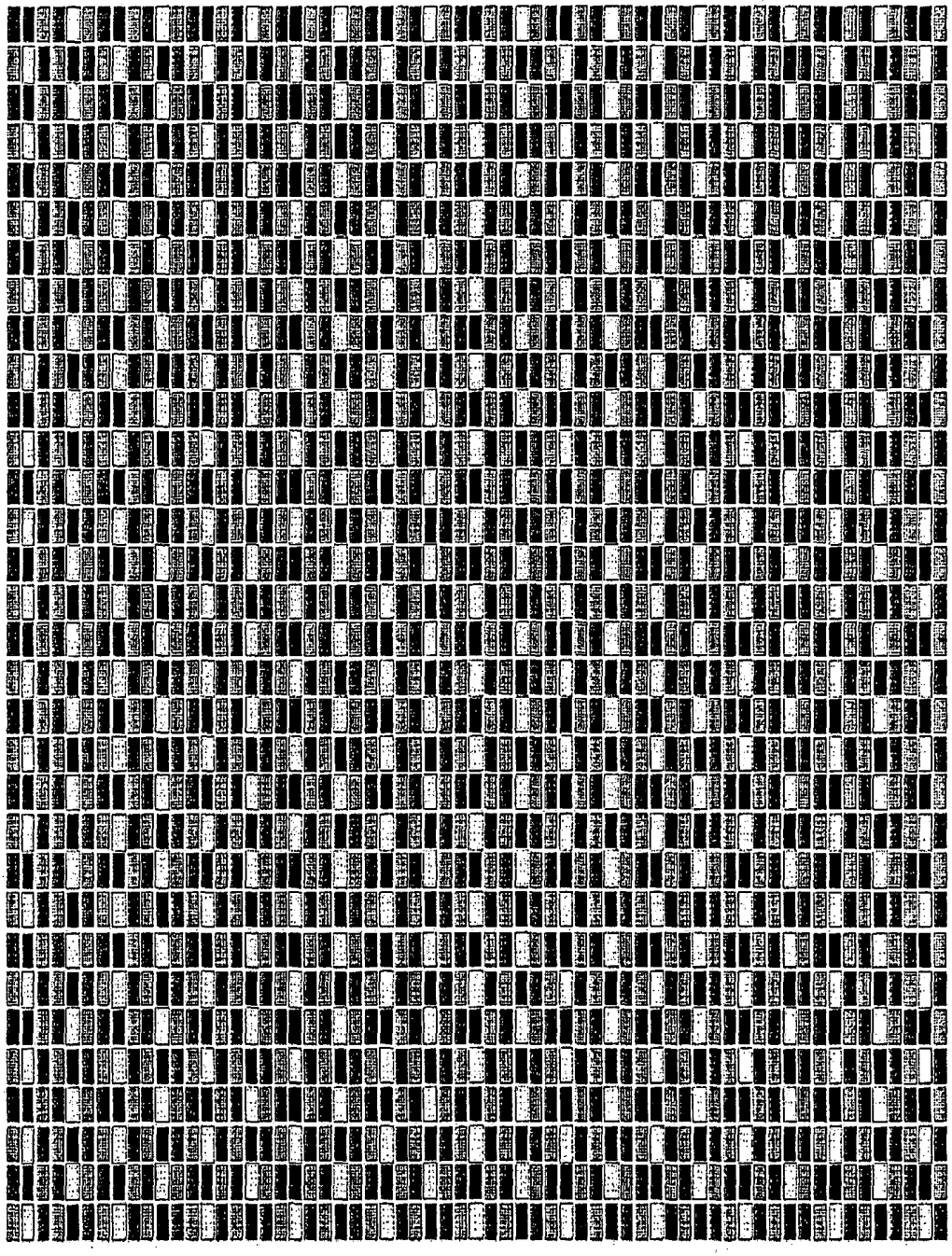

FIG.25

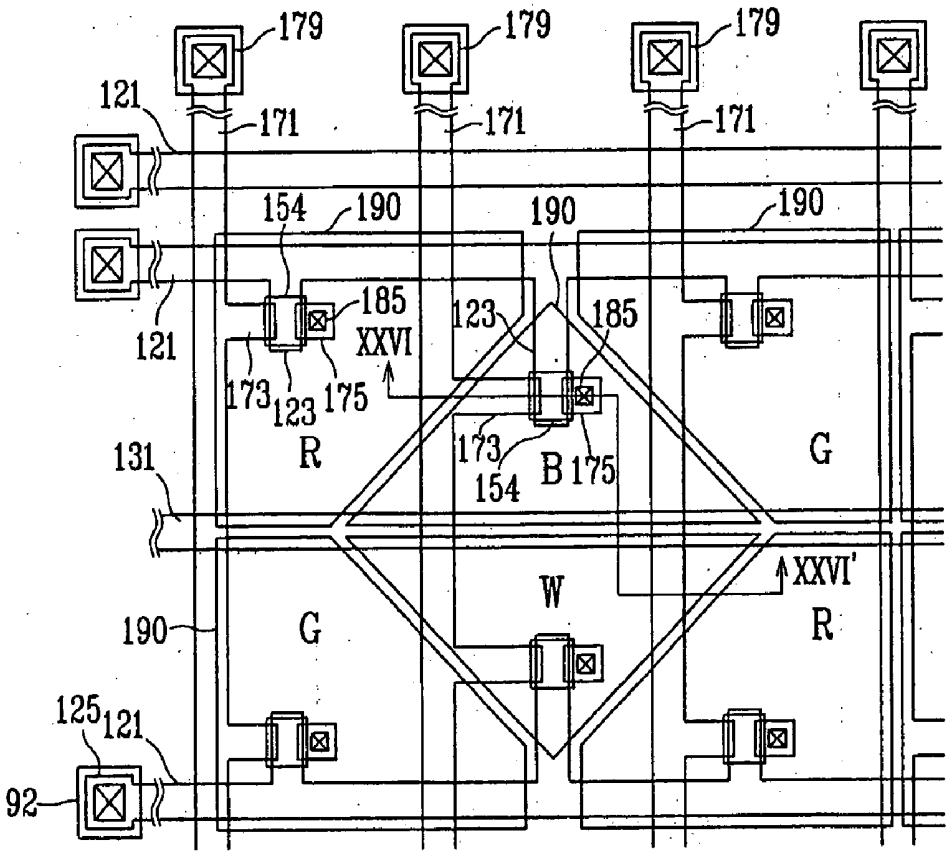
179
179
179
121
171
171
171
154
190
190
190
185
XXVI
123
185
121
173
123
175
R
173
154
B
175
G
131
XXVI'
W
190
G
R
125
121
92

FIG.26

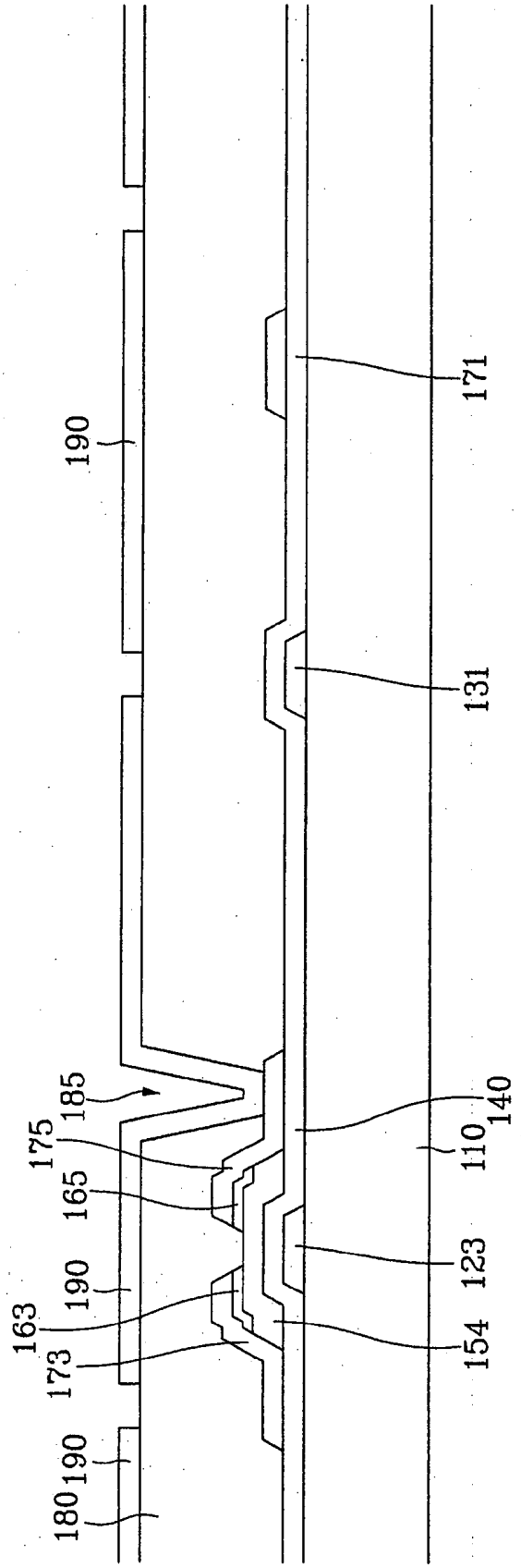

FIG.27

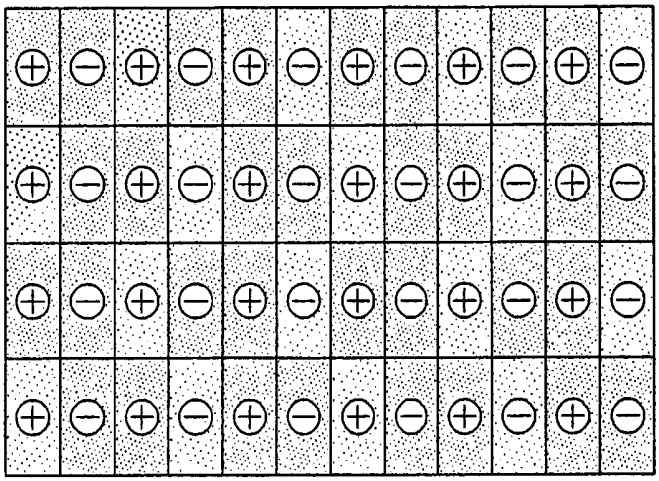

FIG.28

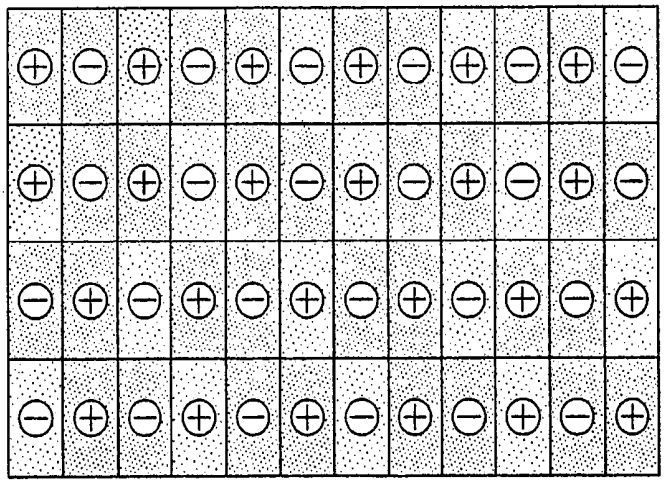

FIG.29

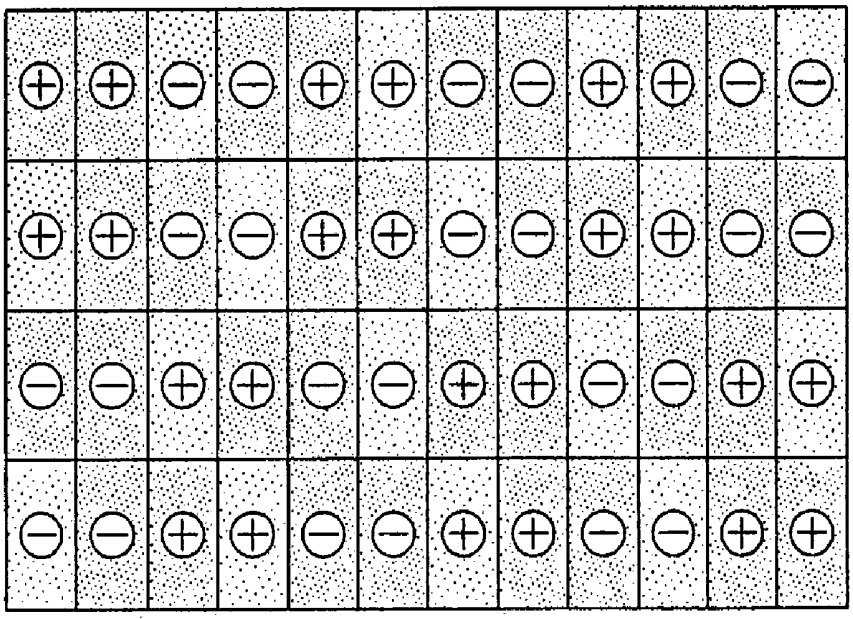

FIG.1

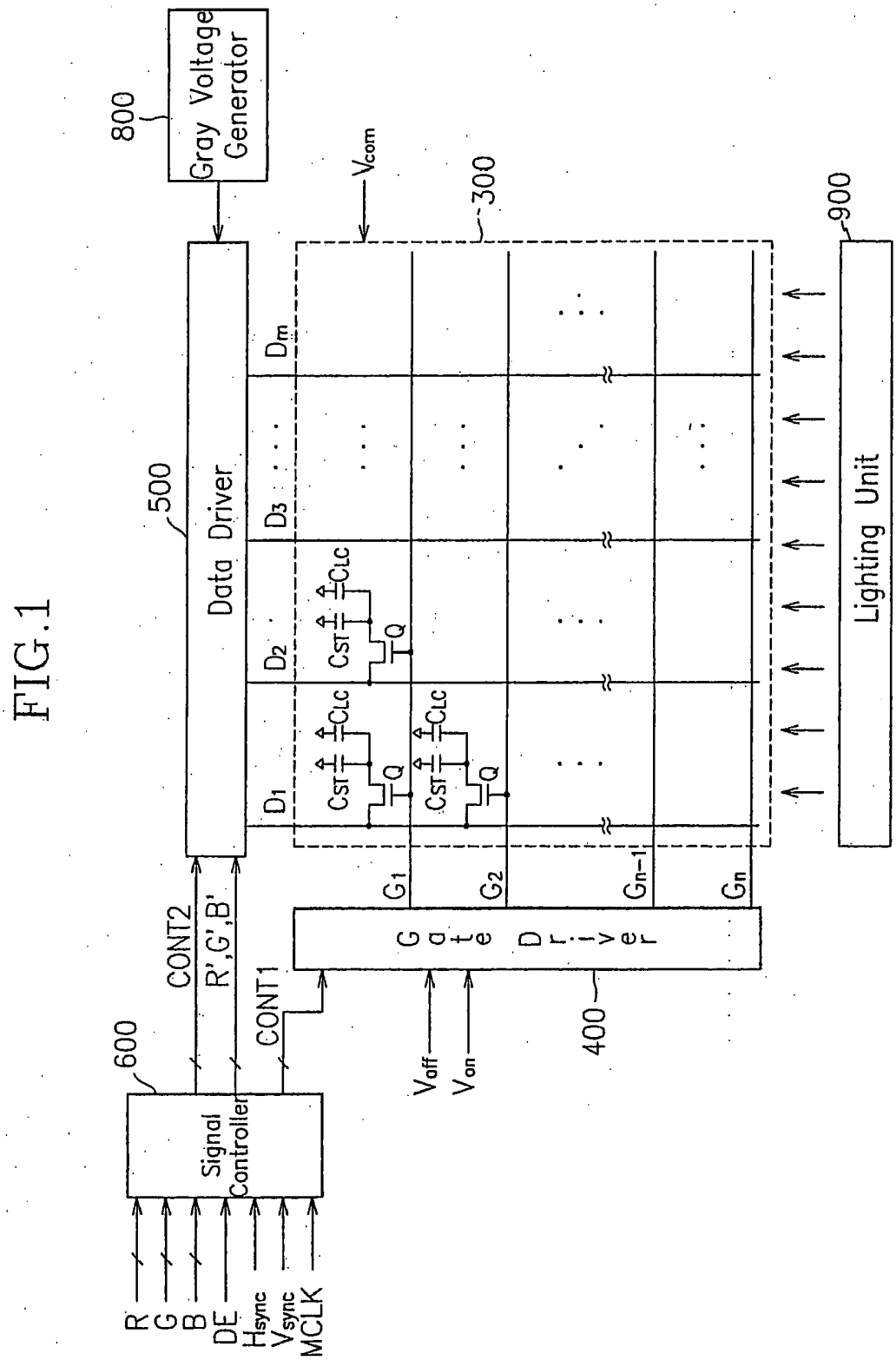
800
Gray Voltage Generator
Vcom
300
900
500
Data Driver
Dm
D3
D2
D1
Clc
Cst
Q
Lighting Unit
G1
G2
Gn-1
Gn
Gate Driver
400
CONT2
R',G',B'
CONT1
600
Signal Controller
Voff
Von
R
G
B
DE
Hsync
Vsync
MCLK

FIG.2

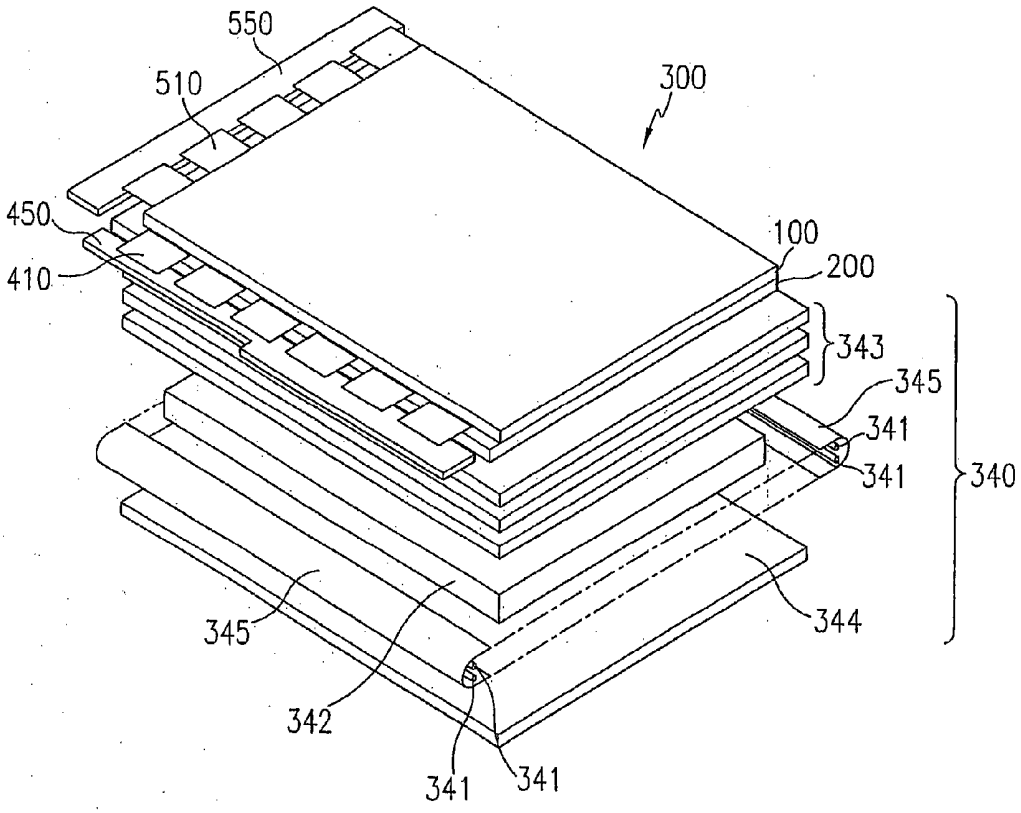
550
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FIG.3

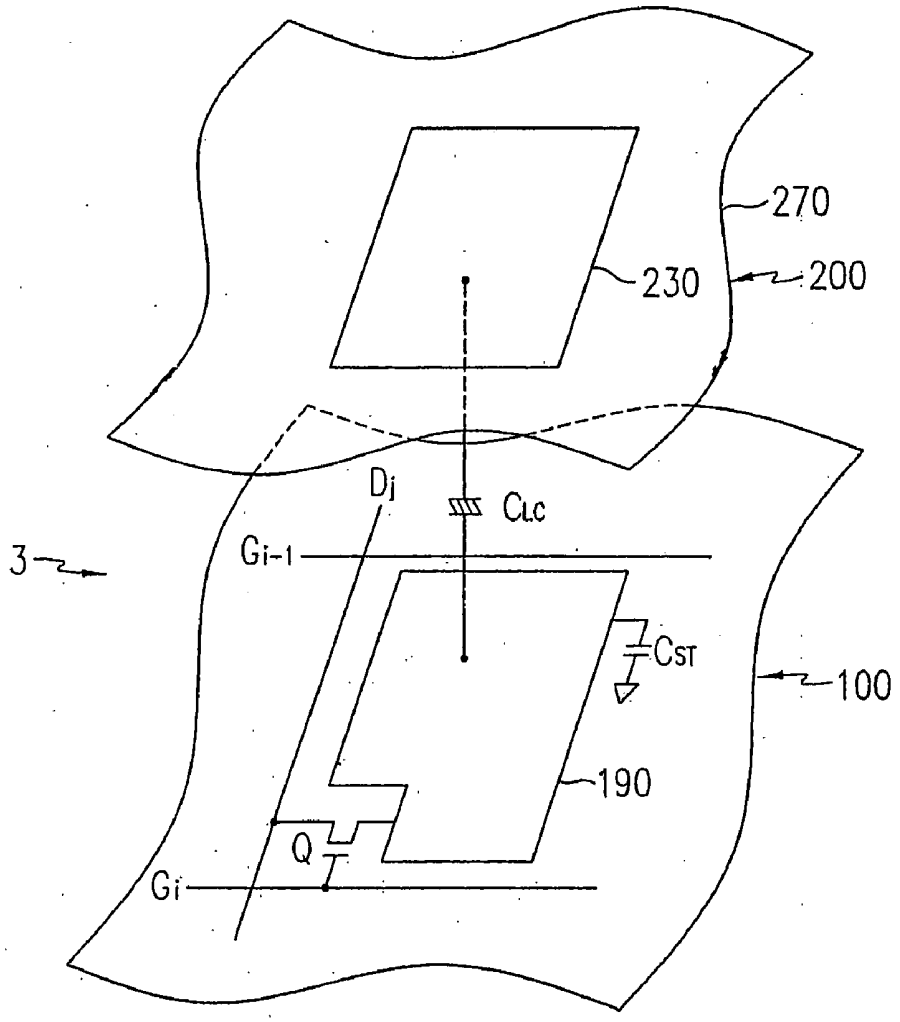


FIG.4A

R	B	G	R	B	G
G	B	R	G	B	R
R	B	G	R	B	G
G	B	R	G	B	R

FIG.4B

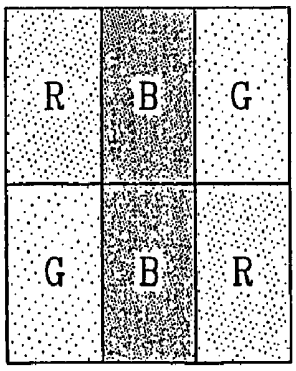


FIG.5A

B	R	G	B	R	G
G	R	B	G	R	B
B	R	G	B	R	G
G	R	B	G	R	B

FIG.5B

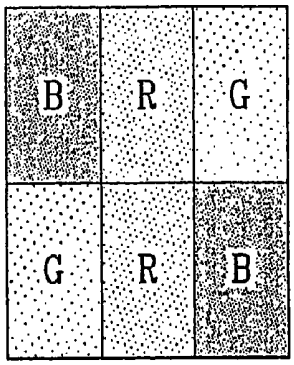


FIG.6

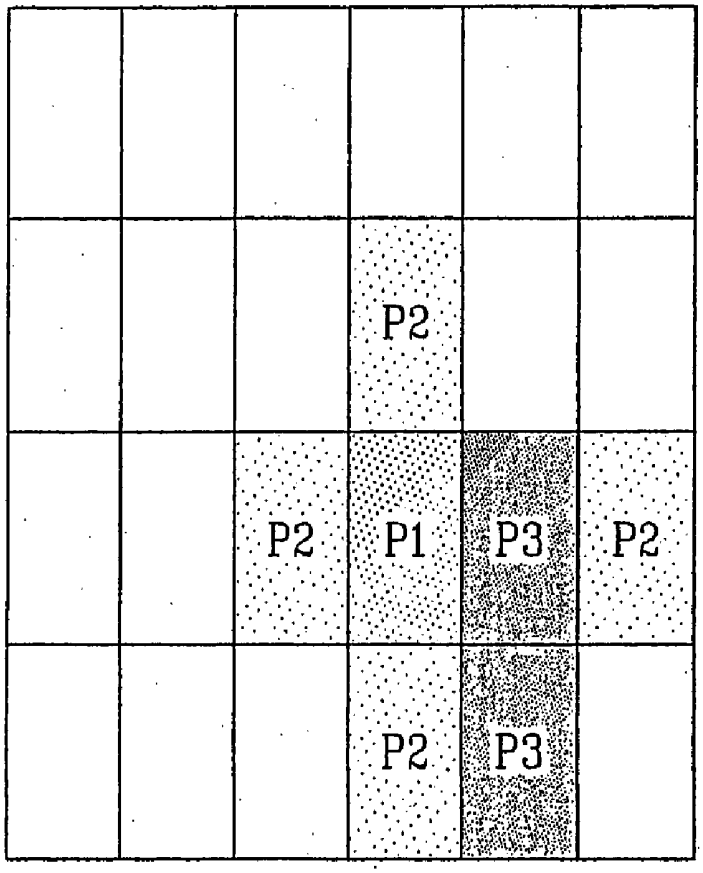
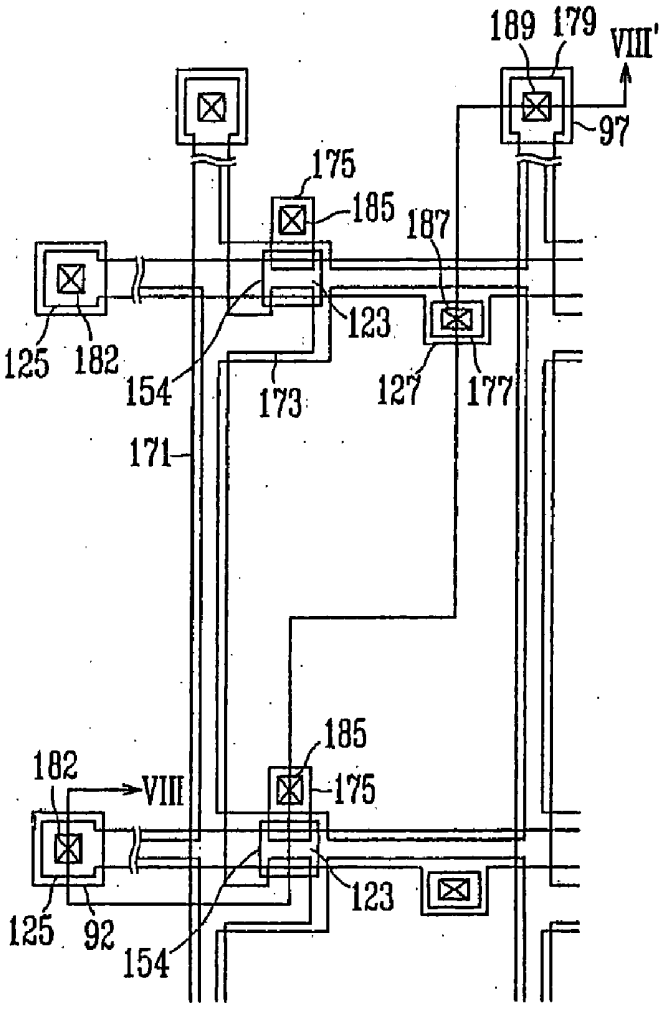


FIG.7


189
179
VIII'
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182
VIII
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123
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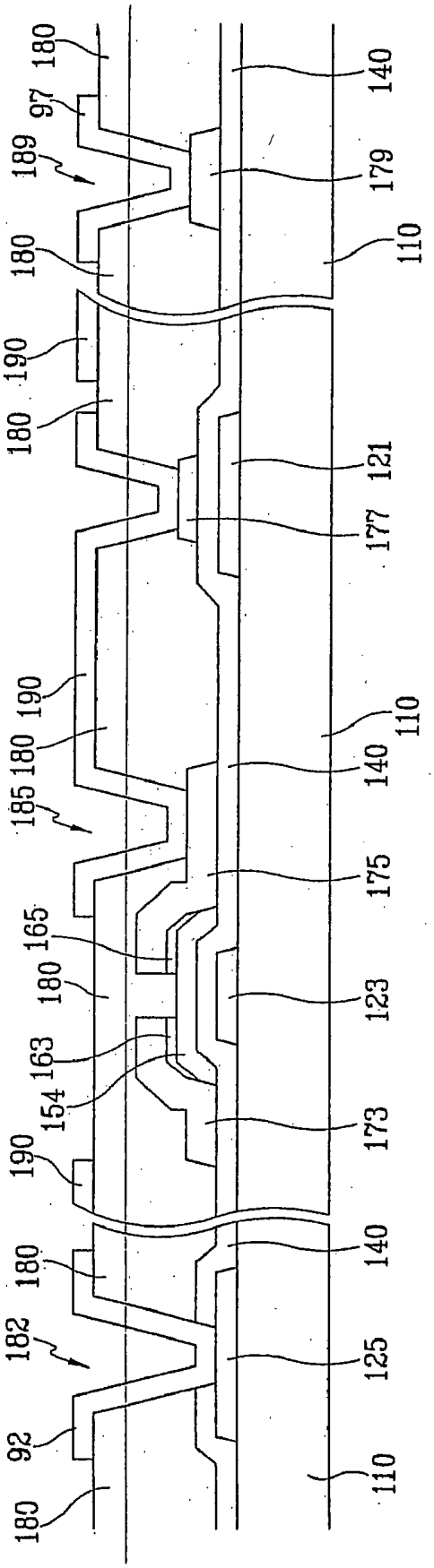
92
154

FIG.8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177
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173
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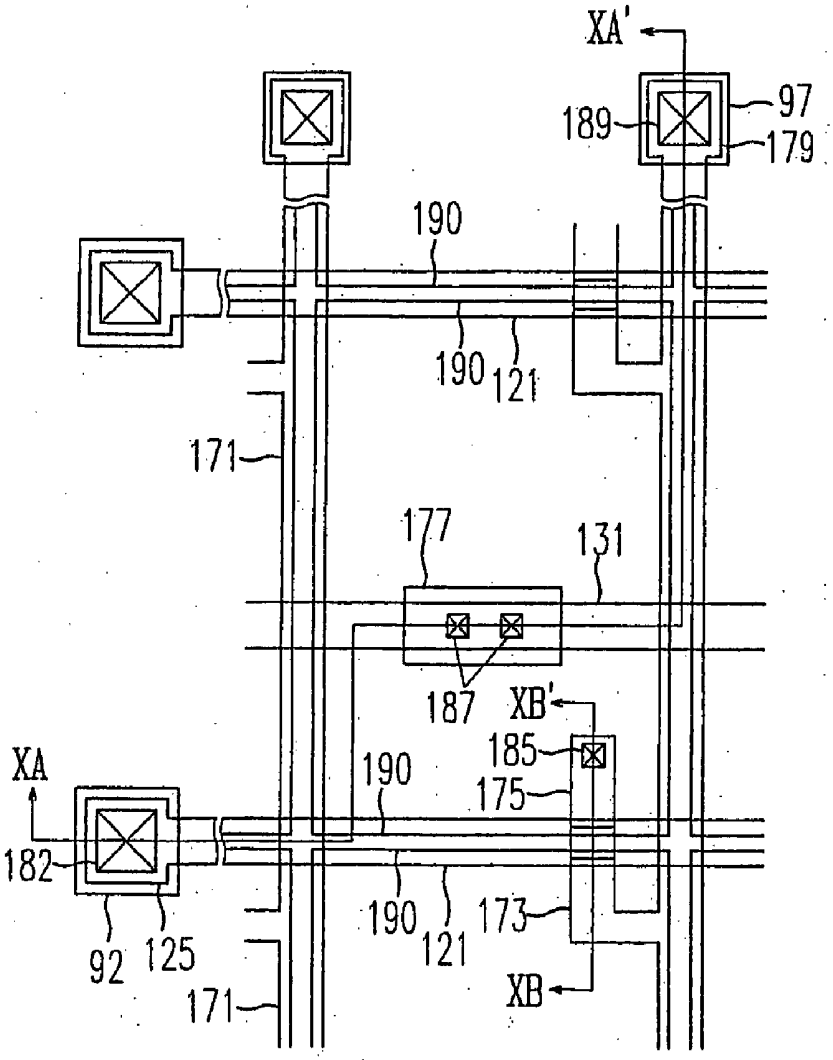
FIG.9


XA'
97
189
179
190
190
121
171
177
131
187
XB'
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XA
190
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182
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121
173
92
125
XB
171

FIG.10A

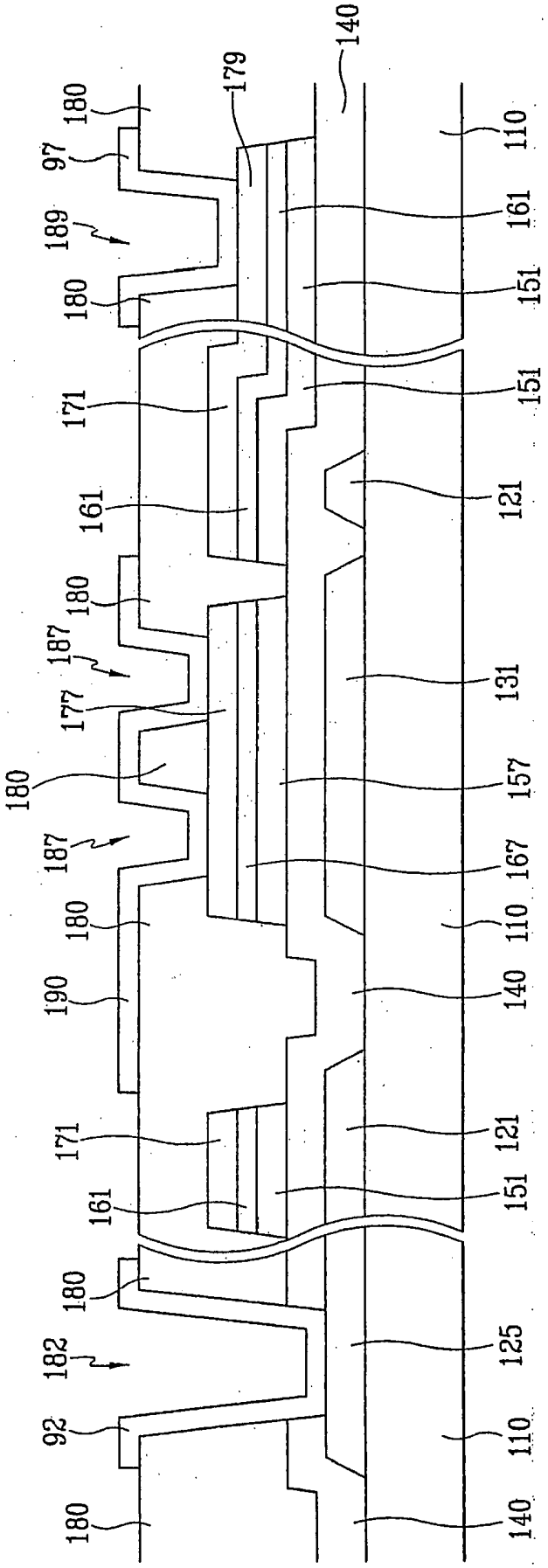

140
179
180
97
189
180
171
161
180
187
177
180
187
180
190
171
161
180
182
92
180
110
161
151
151
121
131
157
167
110
140
121
151
125
110
140

FIG.10B

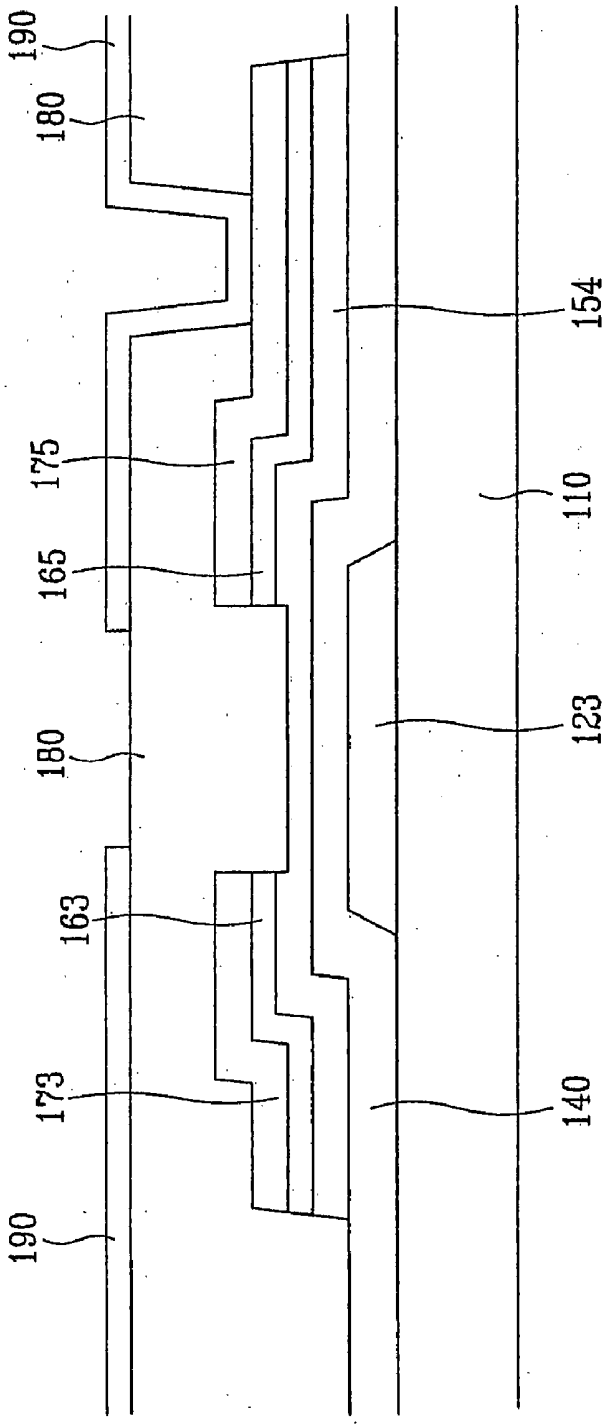


FIG.11

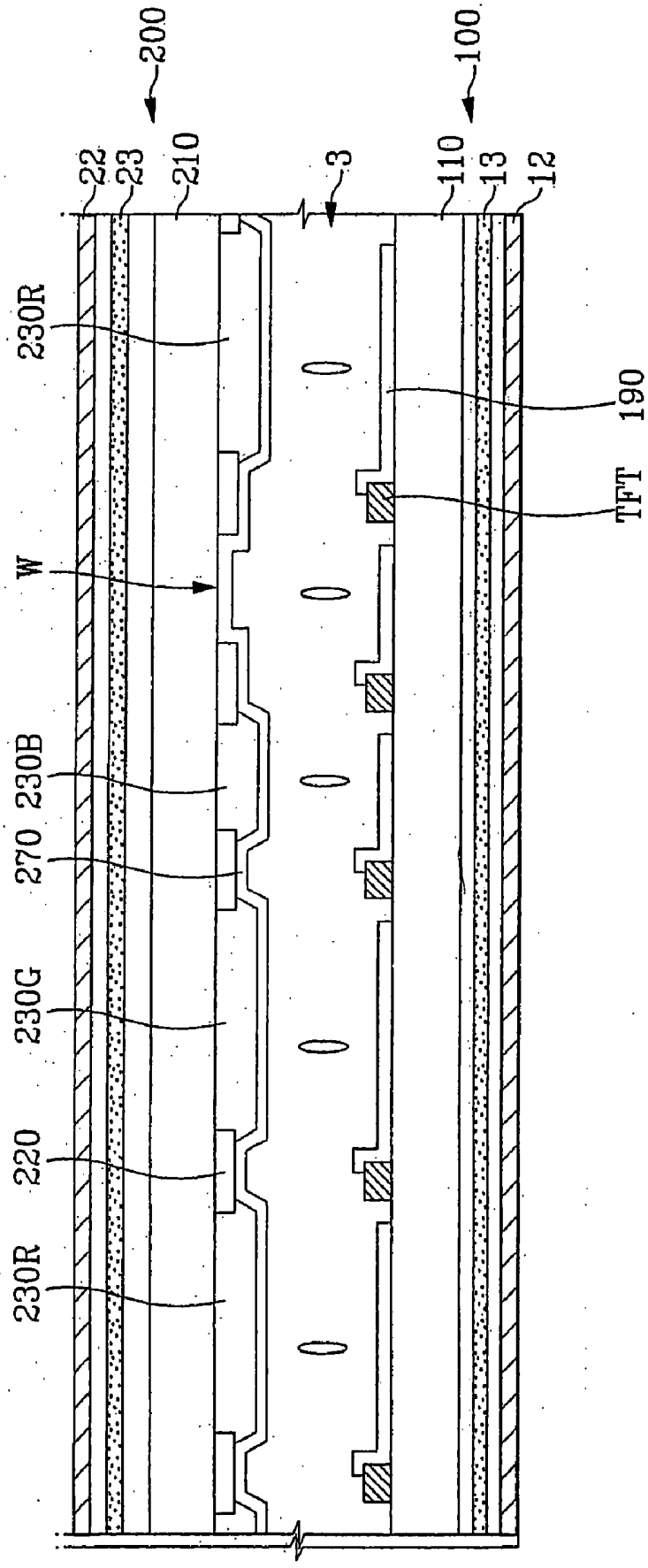

200
100
22
23
210
3
110
13
12
230R
190
TFT
W
230B
270
230G
220
230R

FIG.12

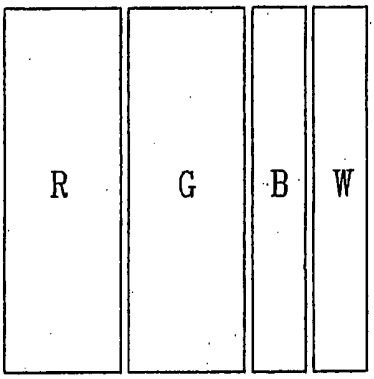


FIG.13

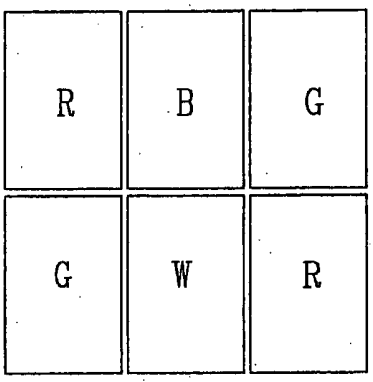


FIG.14

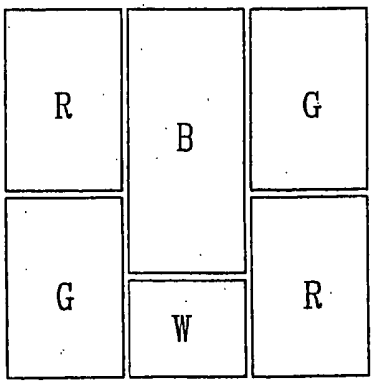


FIG.15

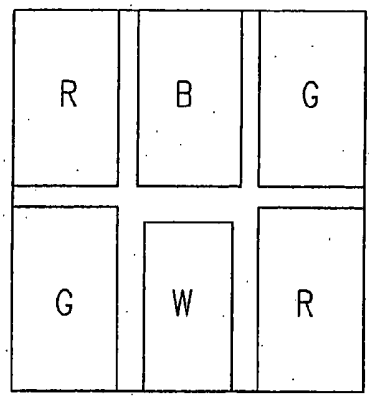

R
B
G
G
W
R

FIG.16

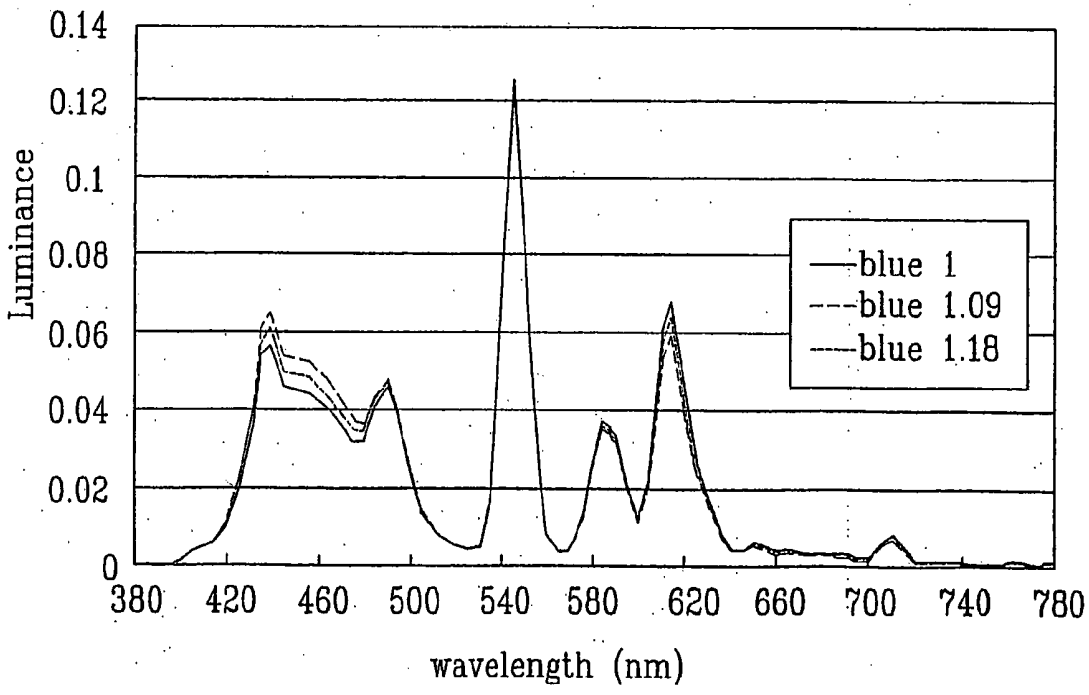

0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Luminance
380
420
460
500
540
580
620
660
700
740
780
wavelength (nm)
blue 1
blue 1.09
blue 1.18

FIG.17

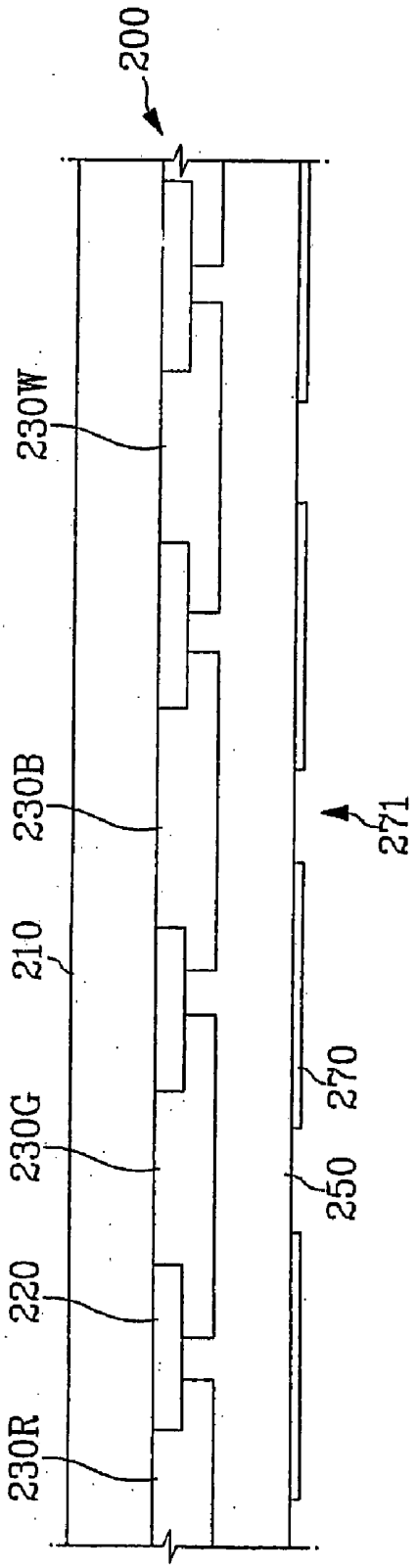


FIG.18

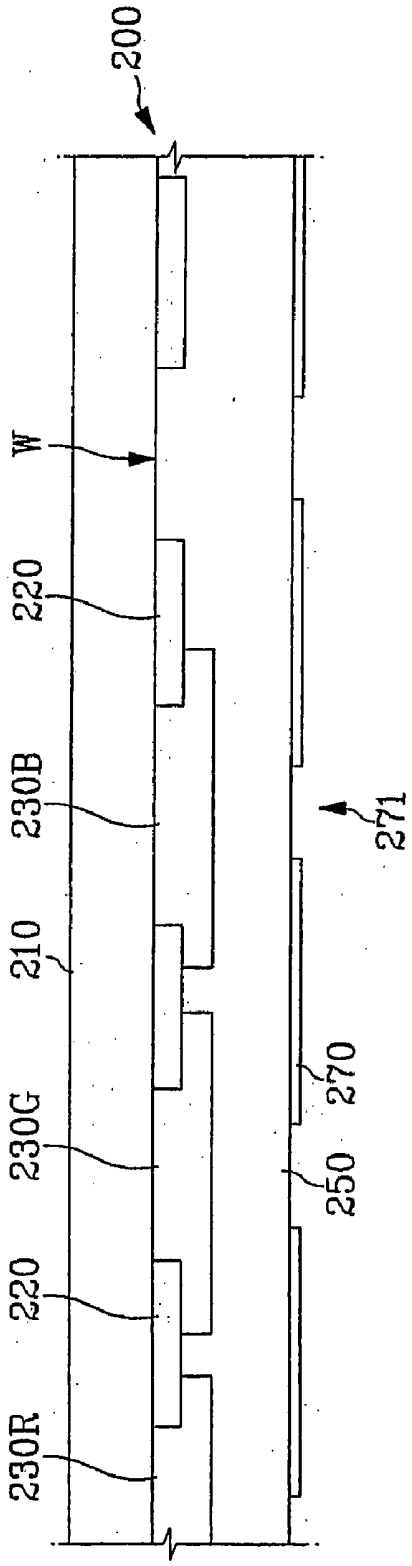


FIG.19

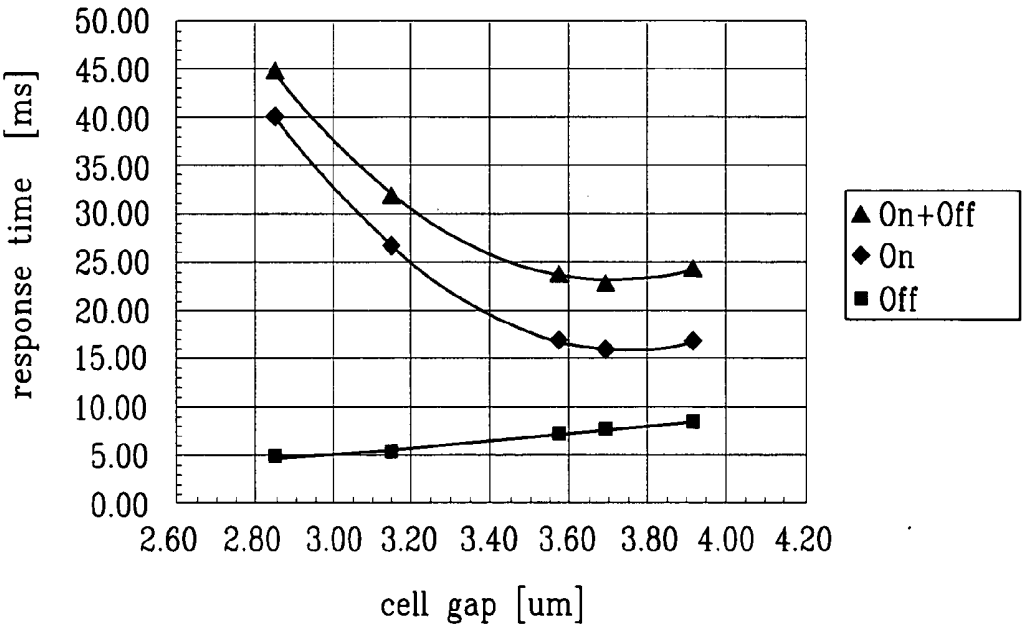

response time [ms]
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20
cell gap [um]
On+Off
On
Off

FIG.20

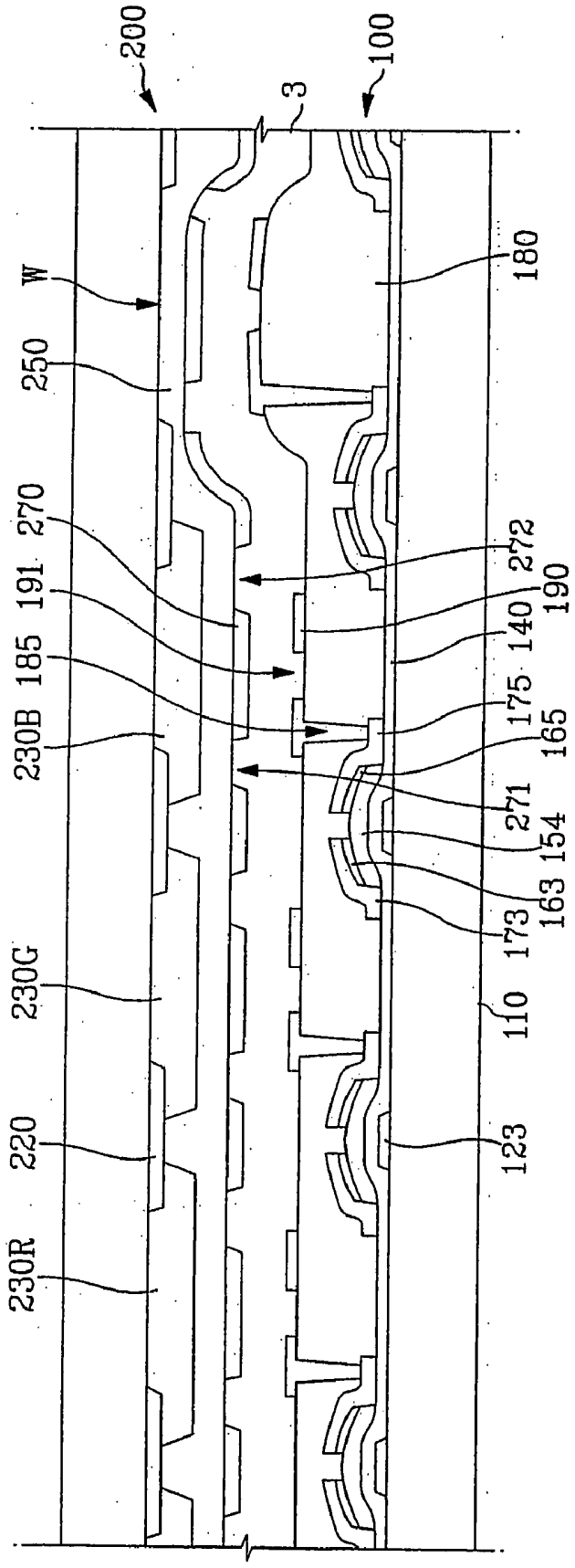

200
3
100
180
W
250
270
191
185
230B
272
190
140
175
165
271
154
163
173
110
123
230G
220
230R

FIG.21

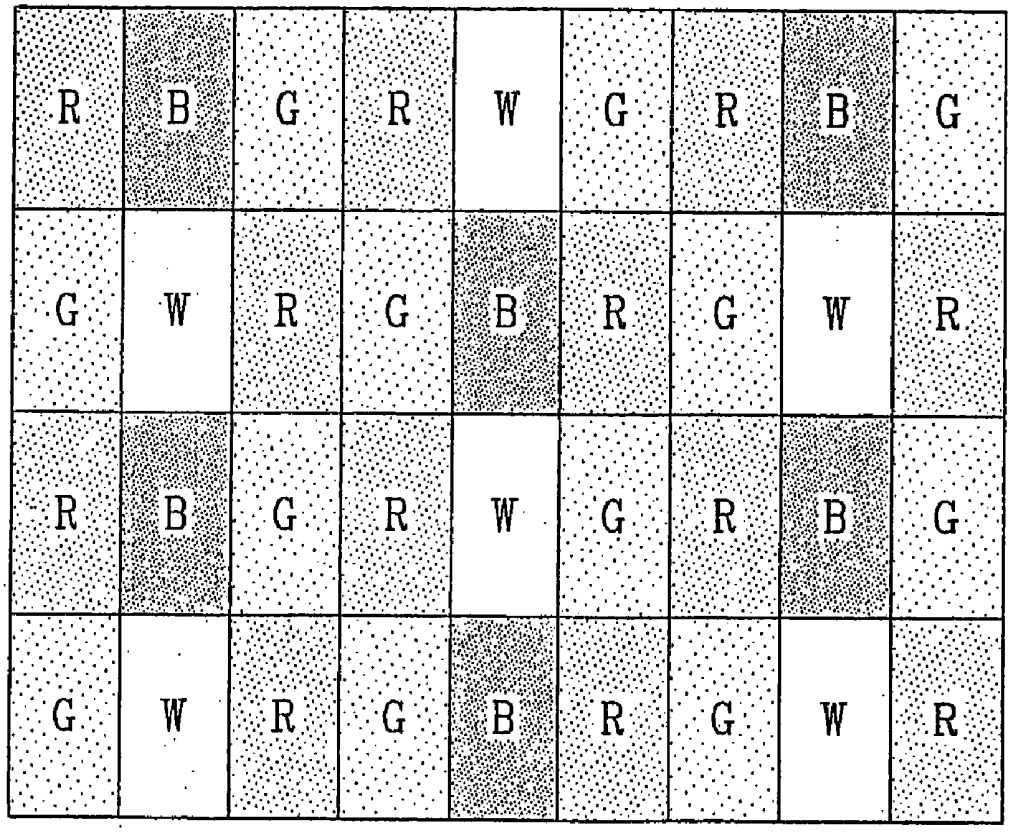


FIG.22

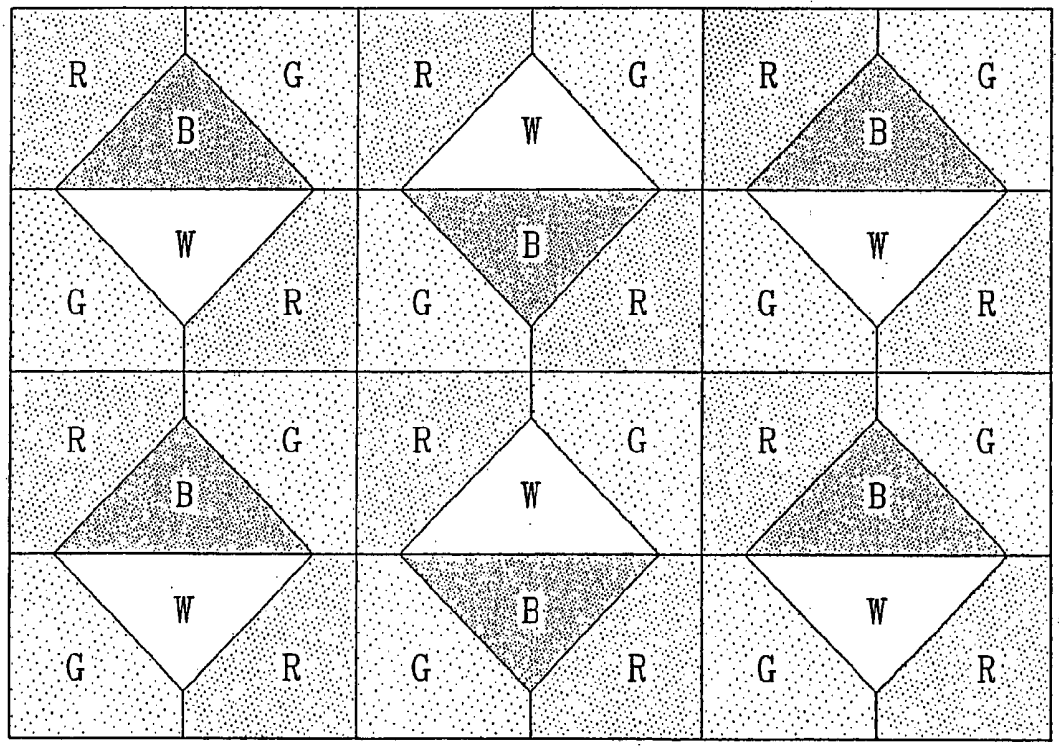


FIG.23

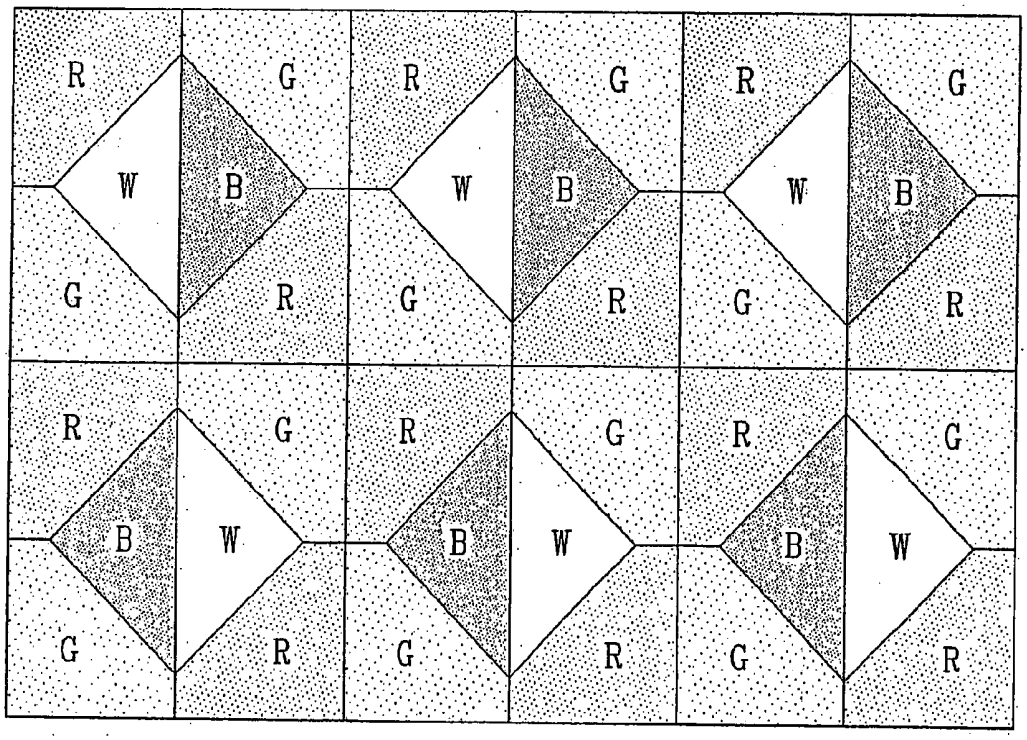


FIG. 24

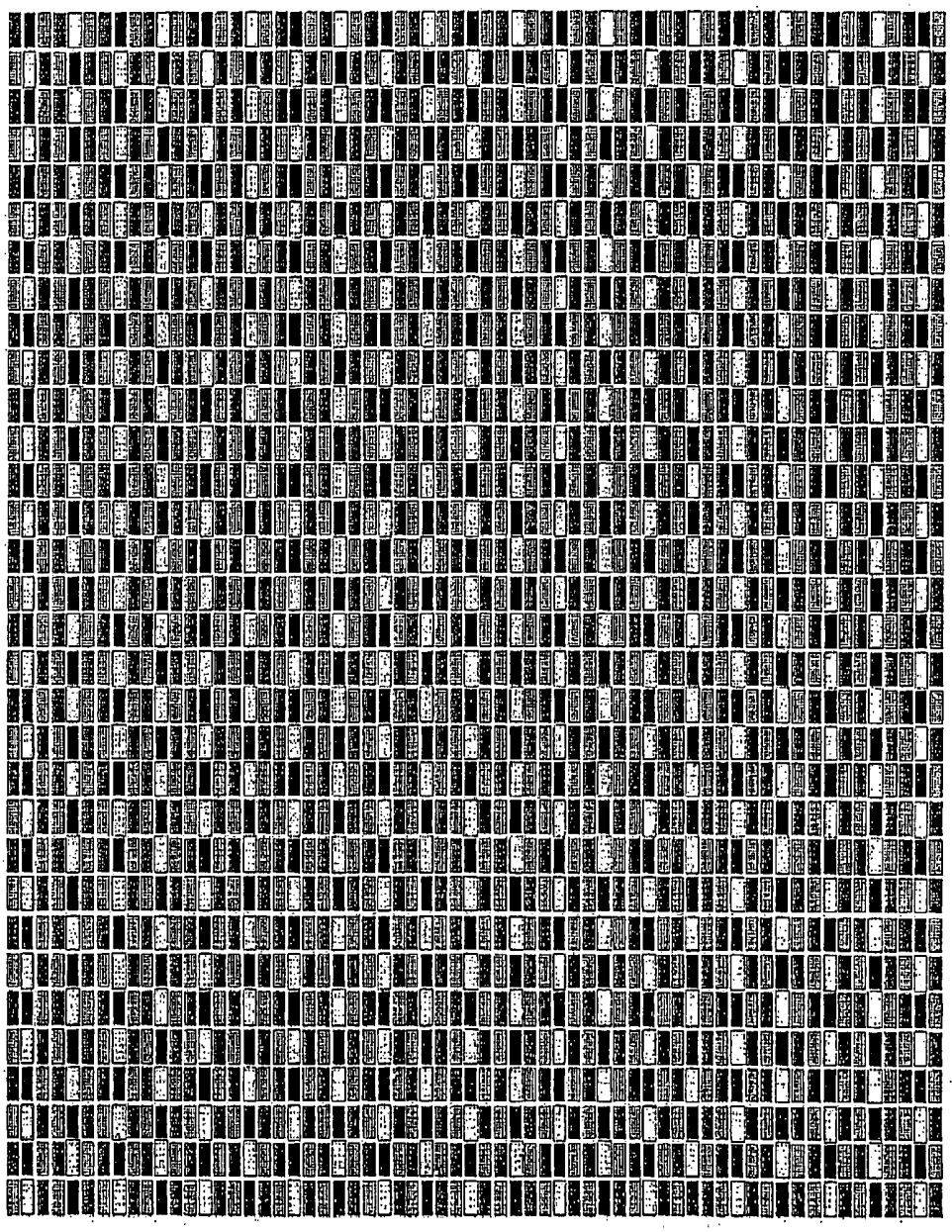


FIG.25

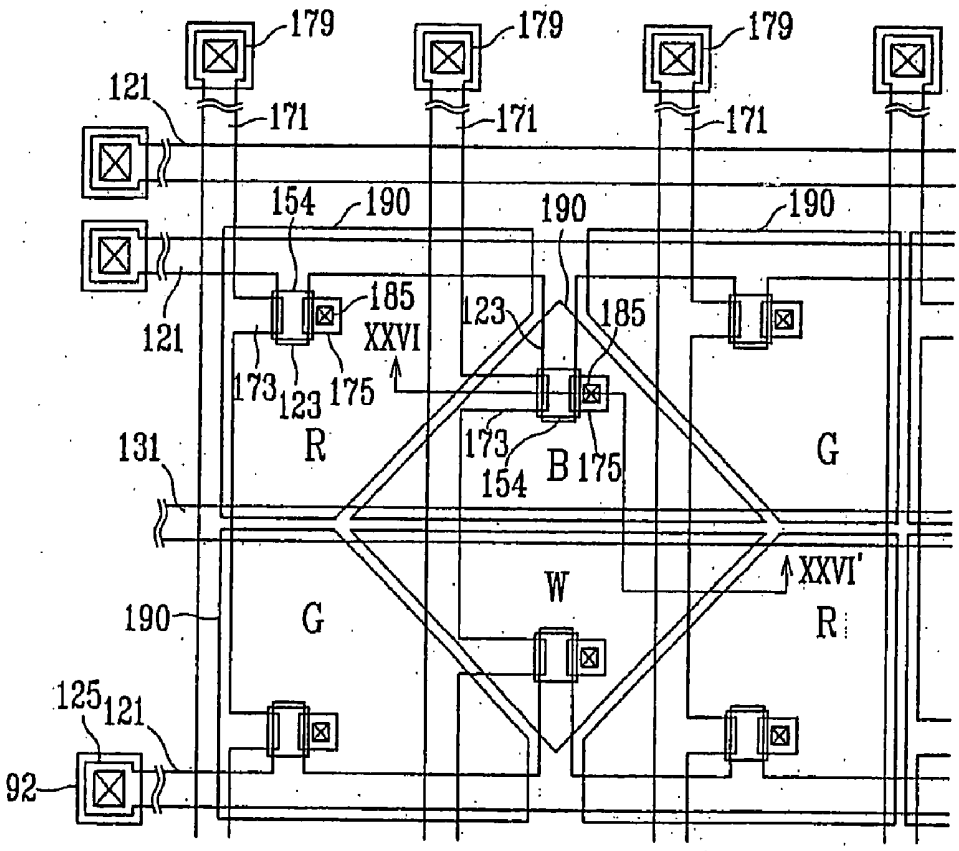

179
179
179
121
171
171
171
154
190
190
190
185
123
185
XXVI
121
173
123
175
R
173
154
B
175
G
131
XXVI'
W
190
G
R
125
121
92

FIG.26

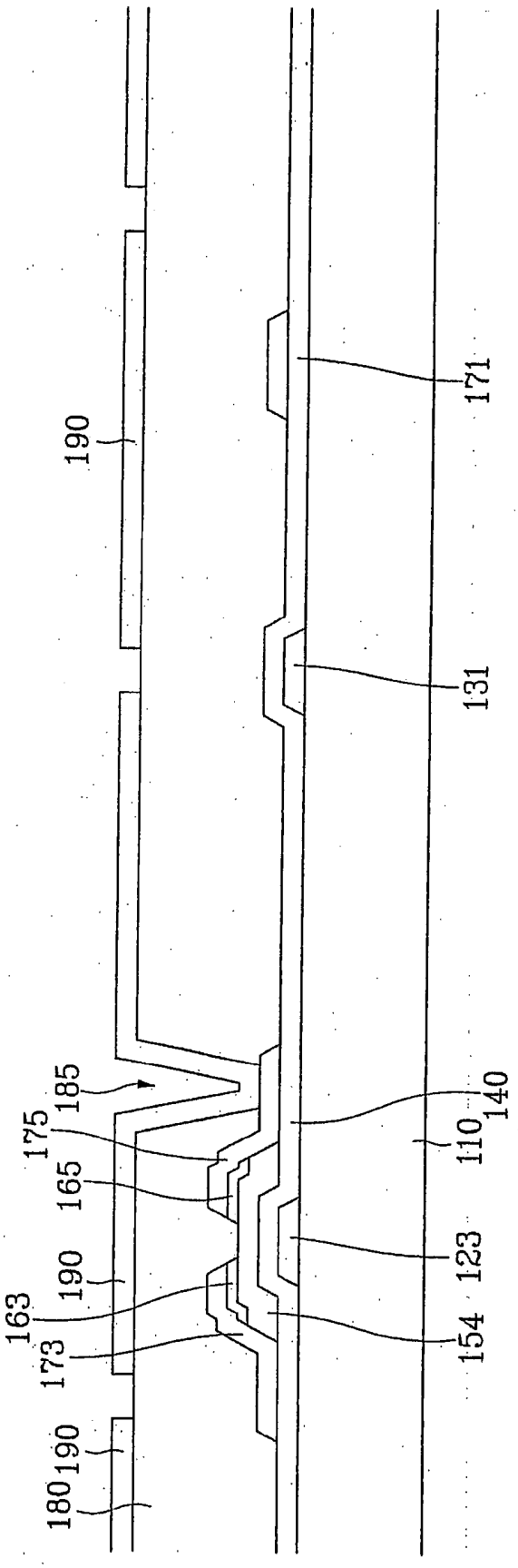


FIG.27

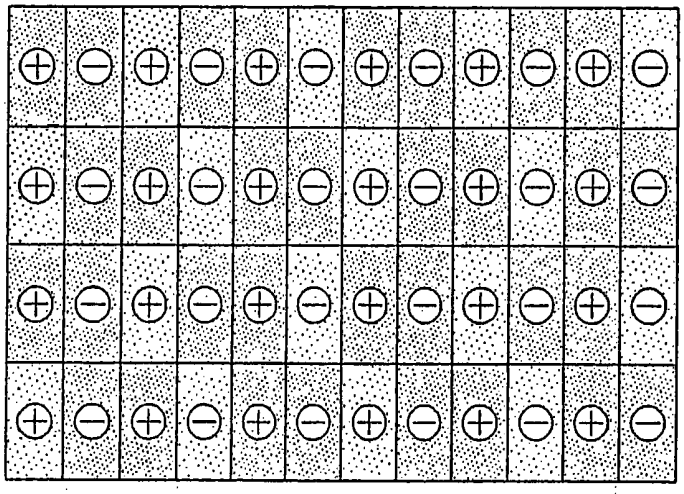


FIG.28

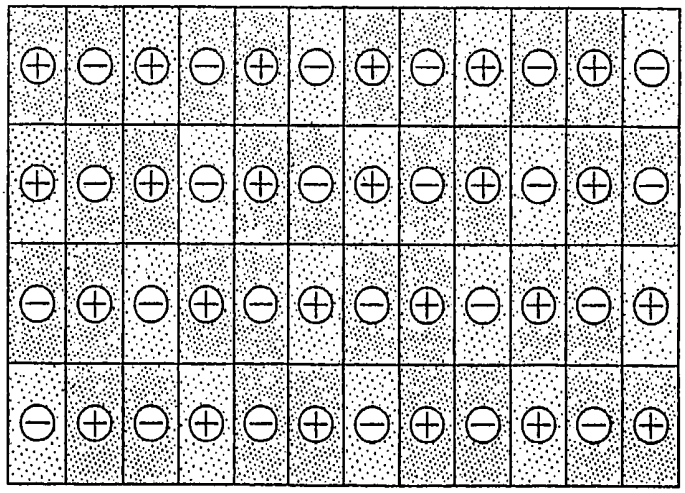
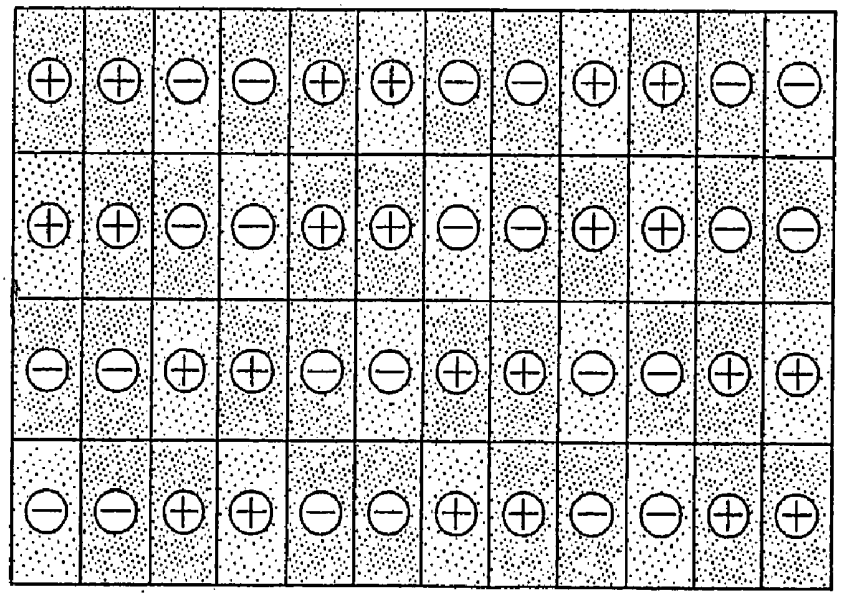


FIG.29



LIQUID CRYSTAL DISPLAY

BACKGROUND OF THE INVENTION

[0001] (a) Field of the Invention

[0002] The present invention relates to a liquid crystal display.

[0003] (b) Description of Related Art

[0004] Generally, a liquid crystal display (LCD) includes a liquid crystal panel assembly including two panels provided with two kinds of field generating electrodes such as pixel electrodes and a common electrode and a liquid crystal layer with dielectric anisotropy interposed therebetween. The variation of the voltage difference between the field generating electrodes, i.e., the variation in the strength of an electric field generated by the electrodes changes the transmittance of the light passing through the LCD, and thus desired images are obtained by controlling the voltage difference between the electrodes.

[0005] The LCD includes a plurality of pixels with pixel electrodes and red (R), green (G) and blue (B) color filters. The pixels are driven to perform display operation by way of the signals applied thereto through display signal lines. The signal lines include gate lines (or scanning signal lines) for carrying the scanning signals, and data lines for carrying data signals. Each pixel has a thin film transistor (TFT) connected to one of the gate lines and one of the data lines to control the data signals applied to the pixel electrode.

[0006] Meanwhile, there are several types of arrangement of the red (R), green (G) and blue (B) color filters. Examples are a stripe type where the color filters of the same color are arranged in the same pixel columns, a mosaic type where the red, green and blue color filters are arranged in turn along the row and column directions, and a delta type where the pixels are arranged zigzag in the column direction and the red, green and blue color filters are arranged in turn. The delta type correctly represents a circle or a diagonal line.

[0007] The ClairVoyante Laboratories has proposed a pixel arrangement called the "PenTile Matrix.," which is advantageous in displaying high resolution images while gives minimized design cost. In such a pixel arrangement, the unit pixel of blue is common to two dots, and the neighboring blue pixels receive the data signals from one data driving IC while being driven by two different gate driving ICs. With the use of the PenTile Matrix pixel structure, the resolution of the ultra extended graphics array (UXGA) level can be realized by way of a display device of the super video graphics array (SVGA) level. Furthermore, the number of low-cost gate driving ICs is increased, but the number of high-cost data driving ICs is decreased. This minimizes the production cost for the display device.

[0008] However, with the PenTile Matrix pixel structure, as the size of the blue pixel is different from the size of the red and the green pixels, it is required to make alteration of the storage capacity due to the difference in the liquid crystal charge rate. Furthermore, as two blue pixels are driven by way of one line, the pixel polarities are non-uniformly made.

SUMMARY OF THE INVENTION

[0009] A liquid crystal display is provided, which includes: an array of a plurality of sets of pixels, each set including blue and white pixels adjacent to each other, a pair of red pixels obliquely facing each other across the blue and the white pixels, and a pair of green pixels obliquely facing each other across the blue and the white pixels and adjacent to the red pixels, each pixel including a pixel electrode and a thin film transistor; a plurality of gate lines extending in a row direction for transmitting a gate signal to the pixels; and a plurality of data lines extending in a column direction for transmitting data signals to the pixels.

[0010] It is preferable that the blue pixel and the white pixel in a set of pixels have equal polarity, the red pixels in the set have equal polarity, and the green pixels in the set have equal polarity. The polarity of the pixels may be subject to column inversion or 2×1 inversion.

[0011] Alternatively, it is preferable that the blue pixel and the white pixel in a set of pixels have equal polarity, the red pixels in the set have opposite polarity, and the green pixels in the set have opposite polarity. The polarity of the pixels may be subject to 2×1 inversion.

[0012] The relative positions of the blue pixel and the white pixel in two sets of pixels adjacent in a column direction or in a row direction are reversed.

[0013] The pixels have rectangular shapes and the blue and the white pixels are arranged in the column direction to form a separate column or the blue and the whit pixels have triangular shapes to form a diamond shape. A boundary line between the blue pixel and the white pixel may extend in the row direction or the column direction.

[0014] The red pixels in adjacent two columns may be located in different rows and the red pixels in adjacent rows are located in different columns. The green pixels in adjacent two columns are placed in different rows and the green pixels in adjacent rows are located in different columns. Either the blue pixels or the white pixels in two sets of pixels adjacent in the row direction are located in different rows, or the blue pixels or the white pixels in two sets adjacent in the column direction are located in different columns.

[0015] The liquid crystal display is preferably driven by rendering.

[0016] The liquid crystal display may further include a backlight unit providing light for the pixels. The light emitted from the backlight unit preferably has a color coordinate (x, y) where x ranges from about 0.31 to about 0.34, and y ranges from about 0.32 to about 0.35.

[0017] The red, green and blue pixels may further include red, green and blue organic filters containing red, green and blue pigments, respectively, and the white pixels may include transparent organic filters.

[0018] The red, green, blue and white pixels may further include a common electrode formed on the organic filters and/or an overcoat located between the organic filters and the common electrode.

[0019] The transparent organic filter may include the same material as the overcoat.

[0020] Preferably, the height of a surface of the overcoat is substantially uniform.

[0021] The red, green, blue and white pixels may further include red, green and blue color filters, respectively. The

red, green, blue and white pixels further include: a protective layer formed on the thin film transistors, having a plurality of protrusions, and facing the color filters; a common electrode formed on the color filters; and a liquid crystal interposed between the pixel electrode and the common electrode. The protrusions are provided in the white pixels, and height of the common electrode is smaller at the white pixel than at the red, the green and the blue pixels.

[0022] Preferably, the distance between the common electrode and a surface of the protective layer is substantially uniform.

[0023] The pixel electrodes and the common electrode may have cutouts.

[0024] A liquid crystal display is provided, which includes: an array pixel including a plurality of pixels arranged in a matrix, the plurality of pixels including a set of pixels including a pair of center pixels adjacent to each other, and a pair of first-color pixels and a pair of second-color pixels obliquely facing each other across the center pixels, each pixel including a pixel electrode and a thin film transistor; a plurality of gate lines extending in a row direction for transmitting a gate signal to the pixels; and a plurality of data lines extending in a column direction for transmitting data signals to the pixels, wherein the pixels are subject to polarity inversion.

[0025] The center pixels in a set of pixels have equal polarity, the first-color pixels in the set have equal polarity, and the second-color pixels in the set have equal polarity.

[0026] The polarity inversion includes column inversion or 2×1 inversion.

[0027] The center pixels in a set of pixels have equal polarity, the first-color pixels in the set have opposite polarity, and the second-color pixels in the set have opposite polarity.

[0028] The polarity inversion may include 2×1 inversion.

[0029] The center pixels represent blue color, and the first-color pixels and the second-color pixels represent green and red colors, respectively. Alternatively, the center pixels represent red color, and the first-color pixels and the second-color pixels represent green and blue colors, respectively. Alternatively, the center pixels represent blue and white colors, and the first-color pixels and the second-color pixels represent green and red colors, respectively.

[0030] The center pixels may have different saturation, and the center pixels preferably represent red color.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The above and other advantages of the present invention will become more apparent by describing preferred embodiments thereof in detail with reference to the accompanying drawings in which:

[0032] **FIG. 1** is a block diagram of an LCD according to an embodiment of the present invention;

[0033] **FIG. 2** is an exploded perspective view of an LCD according to an embodiment of the present invention;

[0034] **FIG. 3** is an equivalent circuit diagram of a pixel of an LCD according to an embodiment of the present invention;

[0035] **FIGS. 4A and 5A** illustrate spatial arrangements of pixels of LCDs according to embodiments of the present invention;

[0036] **FIGS. 4B and 5B** illustrates a group of pixels forming a dot, which is an elementary unit for an image in the pixel arrangements shown in **FIGS. 4A and 5A**, respectively;

[0037] **FIG. 6** is an exemplary pixel group for a rendered LCD according to an embodiment of the present invention;

[0038] **FIG. 7** is a layout view of an exemplary TFT array panel for an LCD according to an embodiment of the present invention;

[0039] **FIG. 8** is a sectional view of the TFT array panel shown in **FIG. 7** taken along the line VIII-VIII';

[0040] **FIG. 9** is a layout view of an exemplary TFT array panel for an LCD according to another embodiment of the present invention;

[0041] **FIGS. 10A and 10B** are sectional views of the TFT array panel shown in **FIG. 9** taken along the line XA-XA' and the line XB-XB', respectively;

[0042] **FIG. 11** is a sectional view of an LCD according to another embodiment of the present invention;

[0043] FIGS. **12** to **15** illustrate pixel arrangements of LCDs according to embodiments of the present invention;

[0044] **FIG. 16** is a graph showing an exemplary light spectrum of a light source according to an embodiment of the present invention.

[0045] **FIGS. 17 and 18** are sectional views of color filter array panels for an LCD according to other embodiments of the present invention;

[0046] **FIG. 19** is a graph illustrating the response time as a function of the cell gap of an LCD;

[0047] **FIG. 20** is a sectional view of an LCD according to another embodiment of the present invention;

[0048] FIGS. **21** to **23** illustrate pixel arrangements for an LCD according to other embodiments of the present invention;

[0049] **FIG. 24** is a picture for illustrating the visibility of an LCD having the pixel arrangement shown in **FIG. 21**;

[0050] **FIG. 25** is a layout view of a TFT array panel for an LCD according to another embodiment of the present invention;

[0051] **FIG. 26** is a sectional view of the TFT array panels shown in **FIG. 25** taken along the line XXVI-XXVI'; and

[0052] FIGS. **27** to **29** illustrate various polarity inversions of an LCD according to embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0053] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the inventions are shown.

[0054] In the drawings, the thickness of layers and regions are exaggerated for clarity. Like numerals refer to like elements throughout. It will be understood that when an element such as a layer, region or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present.

[0055] Now, LCDs according to embodiments of this invention will be described in detail with reference to the accompanying drawings.

[0056] **FIG. 1** is a block diagram of an LCD according to an embodiment of the present invention, **FIG. 2** is an exploded perspective view of an LCD according to an embodiment of the present invention, and **FIG. 3** is an equivalent circuit diagram of a pixel of an LCD according to an embodiment of the present invention.

[0057] Referring to **FIG. 1**, an LCD according to an embodiment of the present invention includes a LC panel assembly **300**, a gate driver **400** and a data driver **500** which are connected to the panel assembly **300**, a gray voltage generator **800** connected to the data driver **500**, a lighting unit **900** for illuminating the panel assembly **300**, and a signal controller **600** controlling the above elements.

[0058] In structural view, the LCD according to an embodiment of the present invention includes a LC module **350** including a display unit **330** and a backlight unit **340**, as shown in **FIG. 2**.

[0059] The display unit **330** includes the LC panel assembly **300**, a plurality of gate flexible printed circuit (FPC) films **410** and a plurality of data FPC films **510** attached to the LC panel assembly **300**, and a gate printed circuit board (PCB) **450** and a data PCB **550** attached to the associated FPC films **410** and **510**, respectively.

[0060] The LC panel assembly **300**, in structural view shown in **FIGS. 2 and 3**, includes a lower panel **100**, an upper panel **200** and a liquid crystal layer **3** interposed therebetween while it includes a plurality of display signal lines G_1-G_n and D_1-D_m and a plurality of pixels connected thereto and arranged substantially in a matrix in circuital view shown in **FIGS. 1 and 3**.

[0061] The display signal lines G_1-G_n and D_1-D_m are provided on the lower panel **100** and include a plurality of gate lines G_1-G_n transmitting gate signals (called scanning signals) and a plurality of data lines D_1-D_m transmitting data signals. The gate lines G_1-G_n extend substantially in a row direction and are substantially parallel to each other, while the data lines D_1-D_m extend substantially in a column direction and are substantially parallel to each other.

[0062] Each pixel includes a switching element Q connected to the display signal lines G_1-G_n and D_1-D_m, and an LC capacitor C_{LC} and a storage capacitor C_{ST} that are connected to the switching element Q. The storage capacitor C_{ST} may be omitted if unnecessary.

[0063] The switching element Q such as a TFT is provided on the lower panel **100** and has three terminals: a control terminal connected to one of the gate lines G_1-G_n; an input terminal connected to one of the data lines D_1-D_m; and an output terminal connected to the LC capacitor C_{LC} and the storage capacitor C_{ST}.

[0064] The LC capacitor C_{LC} includes a pixel electrode **190** on the lower panel **100**, a common electrode **270** on the upper panel **200**, and the LC layer **3** as a dielectric between the electrodes **190** and **270**. The pixel electrode **190** is connected to the switching element Q, and the common electrode **270** covers the entire surface of the upper panel **100** and is supplied with a common voltage Vcom. Alternatively, both the pixel electrode **190** and the common electrode **270**, which have shapes of bars or stripes, are provided on the lower panel **100**.

[0065] The storage capacitor C_{ST} is an auxiliary capacitor for the LC capacitor C_{LC}. The storage capacitor C_{ST} includes the pixel electrode **190** and a separate signal line (not shown), which is provided on the lower panel **100**, overlaps the pixel electrode **190** via an insulator, and is supplied with a predetermined voltage such as the common voltage Vcom. Alternatively, the storage capacitor C_{ST} includes the pixel electrode **190** and an adjacent gate line called a previous gate line, which overlaps the pixel electrode **190** via an insulator.

[0066] For color display, each pixel represents its own color by providing one of a plurality of color filters **230** in an area occupied by the pixel electrode **190**. The color filter **230** shown in **FIG. 3** is provided in the corresponding area of the upper panel **200**. Alternatively, the color filter **230** is provided on or under the pixel electrode **190** on the lower panel **100**.

[0067] Preferably, the color of the color filter **230** is one of the primary colors such as red, green and blue. Hereinafter, a pixel is referred to as red, greed or blue pixel based on the color represented by the pixel and indicated by reference numerals R, G or B.

[0068] Referring to **FIG. 2**, the backlight unit **340** includes a plurality of lamps **341** illuminating light, a light guide **342** and a plurality of optical sheets **343** disposed under the panel assembly **300** and guiding and diffusing light from the lamps **341** to the panel assembly **300**, a reflector **344** disposed under the lamps **341** and reflecting the light from the lamps **341** toward the panel assembly **300**, and a pair of lamp covers **345** covering the lamps. The lamps **341** and the lamp covers **345** are disposed at lateral sides of the light guide **342**.

[0069] The lamps **341** are illustrated as the lighting unit **900** and preferably include fluorescent lamps such as CCFL (cold cathode fluorescent lamp) and EEFL (external electrode fluorescent lamp). An LED is another example of the lamp **341**.

[0070] A pair of polarizers (not shown) polarizing the light from the lamps **341** are attached on the outer surfaces of the panels **100** and **200** of the panel assembly **300**.

[0071] **FIGS. 4A and 5A** illustrate spatial arrangements of pixels of LCDs according to embodiments of the present invention.

[0072] Referring to **FIGS. 4A and 5A**, a plurality of pixels having substantially equal size are arranged in a matrix including a plurality of pixel row and a plurality of pixel columns.

[0073] Each pixel row includes pixels representing three colors, i.e., red pixels R, green pixels G, and blue pixels B. The sequence of the pixels in a pixel row shown in **FIG. 4A** is the red pixel R, the blue pixel B, and the green pixel G or

the green pixel G, the blue pixel B, and the red pixel R. On the contrary, the sequence of the pixels in a pixel row shown in **FIG. 5A** is the blue pixel B, the red pixel R, and the green pixel G or the green pixel G, the red pixel R, and the blue pixel B.

[**0074**] The pixel columns include a plurality of bicolor columns and a plurality of unicolor columns. As shown in **FIG. 4**A, each bicolor column includes red pixels R and green pixels G and each unicolor column includes blue pixels B. As shown in **FIG. 5**A, each bicolor column includes blue pixels B and green pixels G and each unicolor column includes red pixels R.

[**0075**] When viewing only bicolor columns, any two pixels adjacent to each other in a row direction or a column direction represent different colors and thus the bicolor columns form a checkerboard pattern. Each unicolor column is interposed between the bicolor columns.

[**0076**] **FIGS. 4B and 5B** illustrates a group of pixels forming a dot, which is an elementary unit for an image in the pixel arrangements shown in **FIGS. 4A and 5A**, respectively.

[**0077**] Each group includes six pixels, i.e., two adjacent center pixels in a unicolor column and four pixels in bicolor columns, which are adjacent to the respective center pixels in the row direction.

[**0078**] An LCD having the above-described pixel arrangement are rendered for increasing resolution and this will be described in detail with reference to **FIG. 6**.

[**0079**] **FIG. 6** is an exemplary pixel group for a rendered LCD according to an embodiment of the present invention.

[**0080**] Referring to **FIG. 6**, an exemplary pixel group for rendering is centered on any pixel P1 in a bicolor pixel. The pixel group includes four pixels P2 in bicolor columns and two pixels in a unicolor column, which are adjacent to the center pixel P1. The rendering may give about half weight to the center pixel P1.

[**0081**] In the meantime, since the pixels representing the same colors in bicolor columns face each other obliquely in a symmetrical manner as shown in **FIGS. 4B, 5B** and **6** and are seen as mixed. On the contrary, the pixels in unicolor columns are arranged in stripes and do not make symmetry with the pixels in the bicolor columns, which may cause incomplete color mixture and deteriorate image quality. In particular, the bicolor columns shown in **FIG. 4B** represent green and red, which are mixed to form yellow. Since yellow has luminosity higher than blue, the bicolor columns may be seen brighter than the unicolor columns. On the contrary, blue and green in the bicolor columns shown in **FIG. 5B** are mixed to form cyan, which has similar luminosity to red, and thus the brightness difference may not be detected.

[**0082**] The brightness difference may be much reduced by differentiating saturation of two pixels in two adjacent red pixels R in a unicolor column shown in **FIG. 5B**.

[**0083**] For example, the saturation of a red pixel R right to a blue pixel B and left to a green pixel G is lower than that of a red pixel R left to a blue pixel B and right to a green pixel G. The red pixel R right to a relatively dark, blue pixel B has lower saturation but higher luminosity than the blue pixel B, while the red pixel B right to a relatively bright, green pixel G has higher saturation but lower luminosity than the green pixel G. Accordingly, the brightness difference between two adjacent pixels in the row direction and the column direction is reduced.

[**0084**] The saturation difference may be obtained by differentiating the amount of pigment mixed to photoresist to form color filters **230** shown in **FIG. 1**. However, other methods may be also used for the saturation difference.

[**0085**] An exemplary detailed structure of a TFT array panel for an LCD according to an embodiment of the present invention will be described with reference to **FIGS. 7 and 8**.

[**0086**] **FIG. 7** is a layout view of an exemplary TFT array panel for an LCD according to an embodiment of the present invention, and **FIG. 8** is a sectional view of the TFT array panel shown in **FIG. 7** taken along the line VIII-VIII'.

[**0087**] A plurality of gate lines **121** for transmitting gate signals are formed on an insulating substrate **110**. Each gate line **121** extends substantially in a transverse direction and a plurality of portions of each gate line **121** form a plurality of gate electrodes **123**. Each gate line **121** includes a plurality of expansions **127** protruding downward.

[**0088**] The gate lines **121** include a low resistivity conductive layer preferably made of Ag containing metal such as Ag and Ag alloy or Al containing metal such as Al and Al alloy. The gate lines **121** may have a multilayered structure including a low resistivity conductive layer and another layer preferably made of Cr, Ti, Ta, Mo or their alloys such as MoW alloy having good physical, chemical and electrical contact characteristics with other materials such as ITO (indium tin oxide) and IZO (indium zinc oxide). A good exemplary combination of such layers is Cr and Al—Nd alloy.

[**0089**] The lateral sides of the gate lines **121** are tapered, and the inclination angle of the lateral sides with respect to a surface of the substrate **110** ranges about 30-80 degrees.

[**0090**] A gate insulating layer **140** preferably made of silicon nitride (SiNx) is formed on the gate lines **121**.

[**0091**] A plurality of semiconductor islands **154** preferably made of hydrogenated amorphous silicon (abbreviated to "a-Si") are formed on the gate insulating layer **140**.

[**0092**] A plurality of ohmic contact islands **163** and **165** preferably made of silicide or n+ hydrogenated a-Si heavily doped with n type impurity are formed on the semiconductor islands **154**. The ohmic contact islands **163** and **165** are located in pairs on the semiconductor islands **154**.

[**0093**] The lateral sides of the semiconductor islands **154** and the ohmic contacts **163** and **165** are tapered, and the inclination angles thereof are preferably in a range between about 30-80 degrees.

[**0094**] A plurality of data lines **171**, a plurality of drain electrodes **175**, and a plurality of storage capacitor conductors **177** are formed on the ohmic contacts **163** and **165** and the gate insulating layer **140**.

[**0095**] The data lines **171** for transmitting data voltages extend substantially in the longitudinal direction and intersect the gate lines **121**. A plurality of branches of each data line **171**, which extend toward the drain electrodes **175**, form

a plurality of source electrodes **173**. Each pair of the source electrodes **173** and the drain electrodes **175** are separated from each other and opposite each other with respect to a gate electrode **123**. A gate electrode **123**, a source electrode **173**, and a drain electrode **175** along with a semiconductor island **154** form a TFT having a channel formed in the semiconductor island **154** disposed between the source electrode **173** and the drain electrode **175**.

[**0096**] The storage capacitor conductors **177** overlap the expansions **127** of the gate lines **121**.

[**0097**] The data lines **171**, the drain electrodes **175**, and the storage capacitor conductors **177** also include a low resistivity conductive layer preferably made of Ag containing metal such as Ag and Ag alloy or Al containing metal such as Al and Al alloy. The data lines **171**, the drain electrodes **175**, and the storage capacitor conductors **177** may have a multilayered structure including a low resistivity conductive layer and another layer preferably made of Cr, Ti, Ta, Mo or their alloys such as MoW alloy having good physical, chemical and electrical contact characteristics with other materials such as ITO (indium tin oxide) and IZO (indium zinc oxide). A good exemplary combination of such layers is Cr and Al—Nd alloy.

[**0098**] The lateral sides of the data lines **171**, the drain electrodes **175**, and the storage capacitor conductors **177** are tapered, and the inclination angle of the lateral sides with respect to a surface of the substrate **110** ranges about 30-80 degrees.

[**0099**] The ohmic contacts **163** and **165** interposed only between the underlying semiconductor islands **154** and the overlying data lines **171** and the overlying drain electrodes **175** thereon and reduce the contact resistance therebetween.

[**0100**] A passivation layer **180** is formed on the data lines **171**, the drain electrodes **175**, the storage conductors **177**, and the exposed portions of the semiconductor islands **154**. The passivation layer **180** is preferably made of photosensitive organic material having a good flatness characteristic, low dielectric insulating material such as a-Si:C:O and a-Si:O:F formed by plasma enhanced chemical vapor deposition (PECVD), or inorganic material such as silicon nitride. Alternatively, the passivation layer **180** may includes both a SiNX film and an organic film.

[**0101**] The passivation layer **180** has a plurality of contact holes **185**, **187** and **189** exposing the drain electrodes **175**, the storage conductors **177**, and end portions **179** of the data lines **171**, respectively. The passivation layer **180** and the gate insulating layer **140** has a plurality of contact holes **182** exposing end portions **125** of the gate lines **121**.

[**0102**] A plurality of pixel electrodes **190** and a plurality of contact assistants **92** and **97**, which are preferably made of IZO or ITO, are formed on the passivation layer **180**.

[**0103**] The pixel electrodes **190** are physically and electrically connected to the drain electrodes **175** through the contact holes **185** and to the storage capacitor conductors **177** through the contact holes **187** such that the pixel electrodes **190** receives the data voltages from the drain electrodes **175** and transmits the received data voltages to the storage capacitor conductors **177**.

[**0104**] Referring back to **FIG. 3**, the pixel electrodes **190** supplied with the data voltages generate electric fields in cooperation with the common electrode **270** on the other panel **200**, which reorient liquid crystal molecules in the liquid crystal layer **3** disposed therebetween.

[**0105**] As described above, a pixel electrode **190** and a common electrode **270** form a liquid crystal capacitor C_{LC}, which stores applied voltages after turn-off of the TFT Q. An additional capacitor called a "storage capacitor," which is connected in parallel to the liquid crystal capacitor C_{LC}, is provided for enhancing the voltage storing capacity. The storage capacitors are implemented by overlapping the pixel electrodes **190** with the gate lines **121** adjacent thereto (called "previous gate lines"). The capacitances of the storage capacitors, i.e., the storage capacitances are increased by providing the expansions **127** at the gate lines **121** for increasing overlapping areas and by providing the storage capacitor conductors **177**, which are connected to the pixel electrodes **190** and overlap the expansions **127**, under the pixel electrodes **190** for decreasing the distance between the terminals.

[**0106**] The pixel electrodes **190** overlap the gate lines **121** and the data lines **171** to increase aperture ratio but it is optional.

[**0107**] The contact assistants **92** and **97** are connected to the exposed end portions **125** of the gate lines **121** and the exposed end portions **179** of the data lines **171** through the contact holes **182** and **189**, respectively. The contact assistants **92** and **97** are not requisites but preferred to protect the exposed portions **125** and **179** and to complement the adhesiveness of the exposed portion **125** and **179** and external devices.

[**0108**] According to another embodiment of the present invention, the pixel electrodes **190** are made of transparent conductive polymer. For a reflective or transflective LCD, the pixel electrodes **190** include opaque reflective metal.

[**0109**] A TFT array panel for an LCD according to another embodiment of the present invention will be described in detail with reference to **FIGS. 9, 10A** and **10**B.

[**0110**] **FIG. 9** is a layout view of an exemplary TFT array panel for an LCD according to another embodiment of the present invention, and **FIGS. 10A and 10B** are sectional views of the TFT array panel shown in **FIG. 9** taken along the line XA-XA' and the line XB-XB', respectively.

[**0111**] As shown in the figures, a layered structure of a TFT array panel of an LCD according to this embodiment is almost the same as that shown in **FIGS. 7 and 8**. That is, a plurality of gate lines **121** including a plurality of gate electrodes **123** are formed on a substrate **110**, and a gate insulating layer **140** is formed thereon. A plurality of semiconductor stripes **151** including a plurality of extensions **154** corresponding to the semiconductor islands **154** shown in **FIGS. 7 and 8** are formed on the gate insulating layer **140**, and a plurality of ohmic contact stripes **161** including a plurality of extensions **163** corresponding to the ohmic contact islands **163** shown in **FIGS. 7 and 8** and a plurality of ohmic contact islands **165** are formed on the semiconductor stripes **151**. A plurality of data lines **171** including a plurality of source electrodes **173**, a plurality of drain electrodes **175**, and a plurality of storage capacitor conductors **177** are formed on the ohmic contacts **161** and **165**, and a passivation layer **180** is formed thereon. A plurality of contact holes **182**, **185**, **187** and **189** are provided at the

passivation layer **180** and/or the gate insulating layer **140**, and a plurality of pixel electrodes **190** and a plurality of contact assistants **92** and **97** are formed on the passivation layer **180**.

[**0112**] Different from the TFT array panel shown in **FIGS. 7 and 8**, the TFT array panel according to this embodiment provides a plurality of storage electrode lines **131**, which are separated from the gate lines **121**, on the same layer as the gate lines **121**, and overlaps the storage electrode lines **131** with the storage capacitor conductors **177** to form storage capacitors without expansions of the gate lines **121**. The storage electrode lines **131** are supplied with a predetermined voltage such as the common voltage. The storage electrode lines **131** along with the storage capacitor conductors **177** may be omitted if the storage capacitance generated by the overlapping of the gate lines **121** and the pixel electrodes **190** is sufficient.

[**0113**] In addition, as well as the semiconductor stripes **151** and the ohmic contacts **161** and **165**, a plurality of semiconductor islands **157** and a plurality of ohmic contacts **167** thereover are provided between the storage conductors **177** and the gate insulating layer **140**.

[**0114**] The semiconductor stripes and islands **151** and **157** have almost the same planar shapes as the data lines **171**, the drain electrodes **175** and the storage capacitor conductors **177** as well as the underlying ohmic contacts **161**, **165** and **167**, except for the extensions **154** where TFTs are provided. In particular, the semiconductor islands **157**, the ohmic contact islands **167** and the storage conductors **177** have substantially the same planar shape. The semiconductor stripes **151** include some exposed portions, which are not covered with the data lines **171**, the drain electrodes **175** and the storage conductors **177**, such as portions located between the source electrodes **173** and the drain electrodes **175**.

[**0115**] **FIG. 11** is a sectional view of an LCD according to another embodiment of the present invention, and FIGS. **12** to **15** illustrate pixel arrangements of LCDs according to embodiments of the present invention.

[**0116**] As shown in **FIG. 11**, an LCD according to another embodiment of the present invention includes a lower panel **100**, an upper panel **200** facing the lower panel **200**, and a liquid crystal layer **3** interposed between the lower and the upper panels and containing liquid crystal molecules aligned in a predetermined direction. The LCD further includes upper and lower polarizers **12** and **22**, and upper and lower compensation films **13** and **23**. The liquid crystal molecules vary in their orientations under the application of electric fields. The transmittance of the light is changed depending upon the orientations of the liquid crystal molecules.

[**0117**] The lower panel **100** includes a lower substrate **110** preferably made of a transparent insulating material such as glass, a plurality of thin film transistors TFT formed on the lower substrate **110**, and a plurality of pixel electrodes **190** connected to the TFTs and preferably made of a transparent conductive material such as ITO and IZO. Each TFT switches data voltages applied to the pixel electrode **190**.

[**0118**] The lower compensation film **13** and the lower polarizer **12** are attached to the outer surface of the lower substrate **110**. The lower compensation film **13** has biaxiality or uniaxiality. The lower compensation film **13** may be omitted.

[**0119**] The upper panel **200** includes an upper substrate **210** preferably made of a transparent insulating material such as glass, a black matrix **220** defining a plurality of pixel areas arranged in a matrix, a plurality of red, green and blue color filters **230**R, **230**G and **230**B formed in the pixel areas defined by the black matrix **220**, and a common electrode **270** preferably made of a transparent conductive material such as ITO and IZO.

[**0120**] The red, green and blue color filters **230**R, **230**G and **230**B are arranged in turn. The pixel areas without any of the red, green and blue color filters **230**R, **230**G and **230**B represent white pixel areas W, which equally intercept or pass all the components of incident light. Since the white pixel area W has no color filter, the inner surface of the color filter panel **200** on the white pixel area W has smaller height than on the other pixel areas R, G and B and the cell gap of the white pixel area W is larger than that at the other pixel areas.

[**0121**] In this specification, the term "pixel" indicates a basic functional element for displaying images, which includes a pixel electrode **190**, a portion of the common electrode **270** opposite the pixel electrode **190**, a portion of the liquid crystal layer **3** located between the pixel electrode **190** and the corresponding portion of the common electrode **270**, a TFT, and a color filter **230**R, **230**G or **230**B. In addition, the term "pixel area" means the area occupied by a pixel. However, for convenience of description, the two terms "pixel" and "pixel area" will not be distinctly used in this specification.

[**0122**] Referring to **FIG. 12**, the numbers of the red, green, blue and white pixels areas R, G, B and W are the same. The red, green, blue and white pixel areas R, G, B and W are arranged in turn along the row direction. Each of the blue pixel areas B and the white pixel areas W has a size equal to about half of each of the red pixel areas R and the green pixel areas G. Therefore, the sum of one white pixel area W and one blue pixel area B is nearly the same as one red pixel area R or one green pixel area G.

[**0123**] Referring to **FIG. 13, a** 2×3 pixel matrix including identical pixels forms a dot which is a basic element of an image. The first pixel row includes red, blue and green pixels arranged in sequence, and the second pixel row includes green, white and red pixels arranged in sequence.

[**0124**] The arrangement of the pixels shown in **FIG. 14** is almost the same as that shown in **FIG. 13** except that the blue pixel B is enlarged, while the white pixel W is reduced.

[**0125**] The pixel arrangement shown in **FIG. 15** is almost the same as that shown in **FIG. 13** except that portions of the black matrix BM surrounding the white pixel W is enlarged to have a width wider than other portions, which is established to hide the disclination lines generated due to the height difference.

[**0126**] The upper compensation film **23** and the upper polarizer **22** are attached to the outer surface of the upper substrate **210**. The upper compensation film **23** has biaxiality or uniaxiality. The upper compensation film **23** may be omitted.

[**0127**] Since the color filter **230**R, **230**G and **230**B transmits one thirds of incident light the light transmittance of a white pixel is about three times that of other color pixels. In

this embodiment, since one dot includes red, green, blue and white pixels, the optical efficiency is improved without increasing the total area of the dot.

[0128] Assume that the amount of the light passing through the lower polarizer **12** is one.

[0129] For a dot including three pixels, i.e., red, green and blue pixels, the area of each pixel is one thirds of the total area of the dot. Since the light transmittance of the color filter is one thirds, the total light transmittance of the dot is equal to $\frac{1}{3}\times\frac{1}{3}+\frac{1}{3}\times\frac{1}{3}+\frac{1}{3}\times\frac{1}{3}=\frac{1}{3}\approx 33.3\%$.

[0130] For a dot shown in **FIG. 12**, the area of each of red and green pixels is one thirds of the total area, while the area of each of blue and white pixels is one sixths of the total area. Since the light transmittance of the white pixel is one, while that of the other pixels is one thirds, the total light transmittance of the dot equals to $\frac{1}{3}\times\frac{1}{3}+\frac{1}{3}\times\frac{1}{3}+\frac{1}{6}\times\frac{1}{3}+\frac{1}{6}\times 1=\frac{4}{9}\approx 44.4\%$. Accordingly, the brightness is increased to be about 1.5 times compared with a three-color LCD.

[0131] Although the area of the blue pixel is smaller than the red pixel or the green pixel, the variation of the amount of the blue light is relatively insensitive to a person compared with red and green light, and hence, the influence of the areal reduction on the image quality is relatively small.

[0132] However, the areal reduction of the blue pixel gives slight deformation in the images, that is, it makes the images yellowish.

[0133] In order to solve such a problem, the light source **341** emits a light with increased blue component to prevent yellowish images.

[0134] The light emitted from the light source **341** of the backlight unit **340** shown in **FIG. 2** has a color coordinate (x, y) where x ranges from about 0.31 to about 0.34 and y ranges from about 0.32 to about 0.35. Such a light contains the blue component more than the light emitted from a light source for a conventional LCD backlight. In order to obtain such a light source, the blue color emitting material to be contained in the light source **341** should be increased by a predetermined amount.

[0135] **FIG. 16** is a graph showing an exemplary light spectrum of a light source according to an embodiment of the present invention. Compared with the curve for a conventional light source represented by "blue 1", the curves represented by "blue 1.09" and "blue 1.18" show enhanced peaks at wavelength in a range of about 440-470 nm, which indicates blue light, and decreased peaks at wavelength in a range of about 620-650 nm, which indicates red light.

[0136] Meanwhile, since the white pixel W has no color filter, the light out of the white pixel W from the light source **531** may look bluish. However, the larger cell gap of the white pixel W, which makes the incident light yellowish, prevents the light from being bluish.

[0137] **FIGS. 17 and 18** are sectional views of color filter array panels for an LCD according to other embodiments of the present invention.

[0138] Referring to **FIG. 17, a** color filter array panel **200** includes a transparent insulating substrate **210**, a black matrix **220** formed on the insulating substrate **210** having a plurality of apertures defining pixel areas, a plurality of red, green, blue and transparent color filters **230**R, **230**G, **230**B and **230**W formed in respective pixel areas, an overcoat **250** formed on the color filters **230**R, **230**G, **230**B and **230**W, and a common electrode **270** formed on the overcoat **250**. It is preferable that the transparent color filters **230**W include a transparent organic material such as a photosensitive material without pigment.

[0139] A color filter array panel **200** shown in **FIG. 18** includes no transparent color filter.

[0140] Instead, portions of an overcoat **250** in white pixel areas W have larger thickness than other portions thereof to make the height difference of the surface equal to or less than about 0.0.2 microns. Accordingly, the cell gap for all pixels is nearly uniform, and the color filter array panel **200** is manufactured by relatively simple process compared with that shown in **FIG. 17** since the step of forming a transparent color filter **230**W is omitted.

[0141] The color filter array panels **200** shown in **FIGS. 17 and 18** reduces step difference between the white pixels W and the other pixels R, G and B by providing the transparent color filters **230**W or by increasing the thickness of the overcoat **250** at the white pixels W.

[0142] The reduced step difference and the uniform cell gap prevent the yellowish light of the white pixel W and the discilnation lines at the steps.

[0143] Preferably, the cell gap or the thickness of the liquid crystal layer is equal to about 3.7 microns and the thickness of the color filters is about 1.5 to 1.6 microns.

[0144] **FIG. 19** is a graph illustrating the response time as a function of the cell gap of an LCD.

[0145] As shown in **FIG. 19**, the response time become reduced as the increase of the cell gap. When the cell gap reaches about 3.7 microns, the response time has a minimum value. As the cell gap goes away from 3.7 microns, the response time becomes increased again.

[0146] **FIG. 20** is a sectional view of an LCD according to another embodiment of the present invention.

[0147] Referring to **FIG. 20**, an LCD according to this embodiment includes a TFT array panel **100**, a color filter array panel **200**, and a liquid crystal layer **3** interposed therebetween.

[0148] The color filter array panel **200** includes an upper panel **210** preferably made of a transparent insulating material such as glass, a black matrix **220** formed on the upper panel **210** and defining a plurality of pixel areas arranged in a matrix, a plurality of red, green and blue color filters **230**R, **230**G and **230**B disposed substantially in the pixel areas, an overcoat **250** formed on the color filters **230**R, **230**G and **230**B, and a common electrode **270** preferably made of a transparent conductive material such as ITO and IZO and having a plurality of cutouts **271**.

[0149] The red, green and blue color filters **230**R, **230**G and **230**B are arranged in turn. The pixel areas without any of the red, green and blue color filters **230**R, **230**G and **230**B represent white pixel areas W, which equally intercept or pass all the components of incident light. Since the white pixel area W has no color filter, the inner surface of the color filter panel **200** on the white pixel area W form a basin.

[0150] The TFT array panel **100** may have a structure shown in **FIGS. 5 and 6**. That is the TFT array panel **100** includes a plurality of gate electrodes **123** formed on an insulating substrate **110**, a gate insulating layer **140** formed on the gate electrodes **123**, a plurality of semiconductors **154** preferably made of amorphous silicon formed on the gate insulating layer **140** opposite the gate electrodes **123**, a plurality of ohmic contacts **163** and **165** formed on the semiconductors **154**, a plurality of source and drain electrodes **173** and **175** respectively formed on the ohmic contacts **163** and **165**, a protective layer **180** covering the source and the drain electrodes **173** and **175** and having a plurality of contact holes **181** exposing the drain electrodes **175**, and a plurality of pixel electrodes connected to the drain electrodes **175** through the contact holes **181** and having a plurality of cutouts **191**.

[0151] The surface of the protective layer **180** is protruded at the white pixel W to form a plateau.

[0152] The basins of the color filter array panel and the plateaus of the TFT array panel face each other such that the white pixels W have nearly the same cell gap as the other pixels.

[0153] The above-described protective layer **180** is formed by photolithography with a photo mask having a translucent area as well as a transparent area and an opaque area. After depositing the protective layer **180** and coating a photoresist film thereon, the photo mask is aligned such that the transparent area and the opaque area face the contact hole **181** and the white pixel area W, while the translucent area faces remaining areas. After exposure and development, a portion of the photoresist film on the contact hole **180** is removed to expose a portion of the protective layer **180**, a portion on the white pixel area W is left over, and the other portions have reduced thickness. The contact hole **181** is formed by etching using the photoresist film as an etching mask, and the photoresist film suffers ashing such that the portions of the photoresist film with reduced thickness is removed to expose portions of the protective layer **180**. Consequently, the photoresist film is left over only on the white pixel area W. The protective layer **180** is etched using the photoresist film as an etching mask such that the exposed portions of the protective layer **180** are thinned to form a plateau on the white pixel area W.

[0154] Meanwhile, a plurality of photolithography steps are introduced in manufacturing the TFT array panel **100**, and the use of a photo mask having translucent areas as well as transparent and opaque areas reduce the number of photolithography steps. Several layers having different patterns can be made by using a photoresist film having position-dependent thickness made by using the photo mask. For instance, the semiconductors **154**, the ohmic contacts **163** and **165**, and the source and the drain electrodes **163** and **165** are formed by using such a photoresist film, and thus, the TFT array panel **100** can be completed using less masks compared with the case using photo masks having only transparent and opaque areas. In this case, the source and the drain electrodes **163** and **165**, and the ohmic contacts have substantially the same planar shape, and the semiconductors **154** except for the channel region has substantially the same planar shape as the source and the drain electrodes **163** and **165**.

[0155] The TFT array panel **100** and the color filter array panel **200** are aligned to be assembled. Thereafter, a liquid crystal material **3** is injected into a gap between the panels **100** and **200** and subject to vertical alignment. A pixel region, which indicates a portion of the liquid crystal layer **3** in a pixel, is partitioned into a plurality of domains by the cutouts **191** and **271** of the pixel electrode **190** and the common electrode **270**. The domains are classified into four kinds depending upon the tilt directions of the liquid crystal molecules therein upon application of electric field. The several kinds of the domains give wide viewing angle.

[0156] FIGS. **21** to **23** illustrate pixel arrangements for an LCD according to other embodiments of the present invention.

[0157] Referring to FIGS. **21** to **23**, an LCD according to this embodiment includes red, blue and green pixels R, B and G arranged like a PenTile Matrix and white pixels W adjacent to the blue pixels B.

[0158] For a descriptive purpose, it is considered a set of pixels including blue and white pixels B and W adjacent to each other, a pair of red pixels R obliquely facing each other across the blue and the white pixels B and W, and a pair of green pixels G obliquely facing each other across the blue and the white pixels B and W and adjacent to the red pixels R. Then, the pixel arrangements shown in FIGS. **21** to **23** are obtained by repeatedly arranging such sets of pixels. It is noted that the relative positions of the blue pixel B and the white pixel W in two sets of pixels adjacent in a column direction or in a row direction are reversed.

[0159] The blue pixel B and the white pixel W shown in **FIG. 21** have rectangular shapes as the red and the green pixels R and G and are arranged in the column direction to form a separate column.

[0160] Alternatively, the blue pixel B and the white pixel W shown in **FIGS. 22 and 23** have isosceles triangular shapes, and a pair of the blue and the white pixels B and W face their bottom sides to form a diamond shape. The blue and the white pixels B and W shown in **FIG. 22** are arranged in the column direction, while those shown in **FIG. 23** are arranged in a row direction. Accordingly, a boundary line between the blue pixel B and the white pixel W shown in **FIG. 22** match the boundary line between the pixel rows, while a boundary line between the blue pixel B and the white pixel W shown in **FIG. 23** match the boundary line between the pixel columns.

[0161] Referring to **FIGS. 21 and 22**, the relative positions of the blue pixel B and the white pixel W in two sets of pixels adjacent in the row direction are reversed. However, referring to **FIG. 23**, the relative positions of the blue pixel B and the white pixel W in two sets of pixels adjacent in the column direction are reversed.

[0162] In this arrangement, the red pixels R in adjacent two columns are located in different rows, while those in adjacent rows are located in different columns. Likewise, the green pixels in adjacent two columns are placed in different rows, while those in adjacent rows are located in different columns. In addition, the blue pixels B or the white pixels W in two sets adjacent in the row direction are located in different rows as shown in **FIGS. 21 and 22**, or alternatively, the blue pixels B or the white pixels W in two sets adjacent in the column direction are located in different columns as shown in **FIG. 23**. Accordingly, the same color pixels,

particularly the blue pixels are arranged in zigzag along the column direction and the row direction.

[0163] A dot for displaying an image preferably includes an above-described set of pixels including a pair of blue and white pixels B and W, a pair of red pixels R, and a pair of green pixels G.

[0164] However, when using rendering, a dot may include a pair of blue and white pixels B and W and a pair of red and green pixels in a column.

[0165] In any cases, these pixel arrangements prevent vertical line pattern generated in a three color LCD where the same color pixels such as blue pixels are arranged in the column direction and the resolution is not sufficiently high. Therefore, an LCD having a PenTile Matrix pixel arrangement realizes improved image quality.

[0166] **FIG. 24** is a picture for illustrating the visibility of an LCD having the pixel arrangement shown in **FIG. 21**. As shown in **FIG. 24**, no vertical line pattern is recognizable.

[0167] Exemplary TFT array panels for an LCD having the pixel arrangements shown in **FIGS. 21 and 22** will be now described with reference to **FIGS. 25 and 26**.

[0168] **FIG. 25** is a layout view of a TFT array panel for an LCD according to another embodiment of the present invention, and **FIG. 26** is a sectional view of the TFT array panels shown in **FIG. 25** taken along the line XXVI-XXVI'.

[0169] As shown in **FIGS. 25 and 26**, a layered structure of a TFT array panel of an LCD according to this embodiment is almost the same as that shown in **FIGS. 5 and 6**. That is, a plurality of gate lines **121** including a plurality of gate electrodes **123** are formed on a substrate **110**, and a gate insulating layer **140**, a plurality of semiconductor islands **154**, and a plurality of ohmic contact islands **163** and **165** are sequentially formed thereon. A plurality of data lines **171** including a plurality of source electrodes **173** and a plurality of drain electrodes **175** are formed on the ohmic contacts **161** and **165** and the gate insulating layer **140**, and a passivation layer **180** is formed thereon. A plurality of contact holes **182**, **185** and **189** are provided at the passivation layer **180** and/or the gate insulating layer **140**, and a plurality of pixel electrodes **190** and a plurality of contact assistants **92** and **97** are formed on the passivation layer **180**.

[0170] Referring to **FIGS. 25 and 26**, the pixel electrodes **190** of the pixels R, G, B and W resemble the shapes of the corresponding pixels shown in **FIG. 22**. A plurality of storage lines **131** extending substantially parallel to the gate lines **121** and made of the same material as the gate wire are formed on the substrate **110**. The gate lines **121** and the storage lines **131** are located near the boundaries of the pixel rows, and the pixel electrodes **190** and the TFTs are symmetrically arranged with respect to the storage lines **131**. The storage lines **131** overlap the pixel electrodes **190** adjacent thereto to form a plurality of storage capacitors.

[0171] Referring back to **FIGS. 1 and 2**, the gray voltage generator **800** generates two sets of a plurality of gray voltages related to the transmittance of the pixels and is provided on the data PCB **550**. The gray voltages in one set have a positive polarity with respect to the common voltage Vcom, while those in the other set have a negative polarity with respect to the common voltage Vcom.

[0172] The gate driver **400** preferably includes a plurality of integrated circuit (IC) chips mounted on the respective gate FPC films **410**. The gate driver **400** is connected to the gate lines G_1-G_n of the panel assembly **300** and synthesizes the gate-on voltage Von and the gate off voltage Voff from the driving voltage generator **700** to generate gate signals for application to the gate lines G_1-G_n.

[0173] The data driver **500** preferably includes a plurality of IC chips mounted on the respective data FPC films **510**. The data driver **500** is connected to the data lines D_1-D_m of the panel assembly **300** and applies data voltages selected from the gray voltages supplied from the gray voltage generator **800** to the data lines D_1-D_m.

[0174] According to another embodiment of the present invention, the IC chips of the gate driver **400** and/or the data driver **500** are mounted on the lower panel **100**, while one or both of the drivers **400** and **500** are incorporated along with other elements into the lower panel **100** according to still another embodiment. The gate PCB **450** and/or the gate FPC films **410** may be omitted in both cases.

[0175] The signal controller **600** controlling the drivers **400** and **500**, etc. is provided on the data PCB **550** or the gate PCB **450**.

[0176] Now, the operation of the LCD will be described in detail.

[0177] The signal controller **600** is supplied with RGB image signals R, G and B and input control signals controlling the display thereof such as a vertical synchronization signal Vsync, a horizontal synchronization signal Hsync, a main clock MCLK, and a data enable signal DE, from an external graphic controller (not shown). After generating gate control signals CONT1 and data control signals CONT2 and processing the image signals R, G and B suitable for the operation of the panel assembly **300** on the basis of the input control signals and the input image signals R, G and B, the signal controller **600** provides the gate control signals CONT1 for the gate driver **400**, and the processed image signals R', G' and B' and the data control signals CONT2 for the data driver **500**.

[0178] The gate control signals CONT1 include a vertical synchronization start signal STV for informing of start of a frame, a gate clock signal CPV for controlling the output time of the gate-on voltage Von, and an output enable signal OE for defining the width of the gate-on voltage Von. The data control signals CONT2 include a horizontal synchronization start signal STH for informing of start of a horizontal period, a load signal LOAD or TP for instructing to apply the appropriate data voltages to the data lines D_1-D_m, an inversion control signal RVS for reversing the polarity of the data voltages (with respect to the common voltage Vcom) and a data clock signal HCLK.

[0179] The data driver **500** receives a packet of the image data R', G' and B' for a pixel row from the signal controller **600** and converts the image data R', G' and B' into the analogue data voltages selected from the gray voltages supplied from the gray voltage generator **800** in response to the data control signals CONT2 from the signal controller **600**.

[0180] Responsive to the gate control signals CONT1 from the signals controller **600**, the gate driver **400** applies

the gate-on voltage Von to the gate line G_1-G_n, thereby turning on the switching elements Q connected thereto.

[0181] The data driver **500** applies the data voltages to the corresponding data lines D_1-D_m for a turn-on time of the switching elements Q (which is called "one horizontal period" or "1H" and equals to one periods of the horizontal synchronization signal Hsync, the data enable signal DE, and the gate clock signal CPV). Then, the data voltages in turn are supplied to the corresponding pixels via the turned-on switching elements Q.

[0182] The difference between the data voltage and the common voltage Vcom applied to a pixel is expressed as a charged voltage of the LC capacitor C_{LC}, i.e., a pixel voltage. The liquid crystal molecules have orientations depending on the magnitude of the pixel voltage and the orientations determine the polarization of light passing through the LC capacitor C_{LC}. The polarizers convert the light polarization into the light transmittance.

[0183] By repeating this procedure, all gate lines G_1-G_n are sequentially supplied with the gate-on voltage Von during a frame, thereby applying the data voltages to all pixels. When the next frame starts after finishing one frame, the inversion control signal RVS applied to the data driver **500** is controlled such that the polarity of the data voltages is reversed (which is called "frame inversion"). The inversion control signal RVS may be also controlled such that the polarity of the data voltages flowing in a data line in one frame are reversed (which is called "line inversion"), or the polarity of the data voltages in one packet are reversed (which is called "dot inversion").

[0184] Various types of inversions for an LCD according to embodiments of the present invention are described in detail with reference to FIGS. **27-29**.

[0185] The inversions shown in FIGS. **27-29** can be adapted to the pixel arrangements shown in **FIGS. 4A and 4B**, **5**A and **5**B, **13-15**, **21-23**. As described above, the pixel arrangements are formed by repeatedly arranging a group of pixels including six pixels, i.e., two pixels near the center and four pixels disposed at both sides of the two pixels. Hereinafter, the two pixels near the center are referred to as center pixels, and the remaining four pixels are referred to as peripheral pixels. For a three color LCD, the center pixels represent one of red, green and blue colors, while the peripheral pixels represent the remaining two colors. For a four color LCD, the center pixels are blue and white pixels B and W, while the peripheral pixels are red and green pixels R and G.

[0186] **FIG. 27** illustrates a column inversion that makes two adjacent pixels in a row have opposite polarity and two adjacent pixels in a column have equal polarity.

[0187] As shown in **FIG. 27**, since the pixels representing the same color in a pixel group have equal polarity, flicker, which is generated in dot inversion, is not generated. In addition, since the adjacent pixels in a row have opposite polarity and the adjacent pixels in a row for a color or a dot also have opposite polarity, horizontal cross-talk is prevented such that the characteristics of horizontal display are improved.

[0188] **FIG. 28** illustrates a 2×1 inversion that makes two adjacent pixels in a row have opposite polarity and the polarity in a column alternate every two pixels.

[0189] The inversion shown in **FIG. 28** also prevents the flicker since the pixels representing the same color in a pixel group have equal polarity. Since the adjacent pixels in a row have opposite polarity and the adjacent pixels in a row for a color also have opposite polarity, horizontal cross-talk is prevented such that the characteristics of horizontal display are improved. Moreover, since the polarity for any one color is inverted every pixel in a column, vertical cross-talk is also prevented.

[0190] **FIG. 29** illustrates a 2×2 inversion that the polarity in a column and in a row is alternate every two pixels.

[0191] As shown in **FIG. 28**, the center pixels have equal polarity while the peripheral pixel pairs representing the same color have different polarity. However, since the peripheral pixel pairs representing corresponding colors have both positive and negative polarity, the brightness is averaged to be uniform and thus the flicker is prevented. Since the polarity in a row for a color is inverted every two pixels, the characteristics of horizontal display are improved. Furthermore, since the polarity for any one color is inverted in a column, vertical cross-talk is also prevented.

[0192] Although preferred embodiments of the present invention have been described in detail hereinabove, it should be clearly understood that many variations and/or modifications of the basic inventive concepts herein taught which may appear to those skilled in the present art will still fall within the spirit and scope of the present invention, as defined in the appended claims.

What is claimed is:

1. A liquid crystal display comprising:

an array of a plurality of sets of pixels, each set including blue and white pixels adjacent to each other, a pair of red pixels obliquely facing each other across the blue and the white pixels, and a pair of green pixels obliquely facing each other across the blue and the white pixels and adjacent to the red pixels, each pixel including a pixel electrode and a thin film transistor;

a plurality of gate lines extending in a row direction for transmitting a gate signal to the pixels; and

a plurality of data lines extending in a column direction for transmitting data signals to the pixels.

2. The liquid crystal display of claim 1, wherein the blue pixel and the white pixel in a set of pixels have equal polarity, the red pixels in the set have equal polarity, and the green pixels in the set have equal polarity.

3. The liquid crystal display of claim 2, wherein the polarity of the pixels are subject to column inversion.

4. The liquid crystal display of claim 2, wherein the polarity of the pixels are subject to 2×1 inversion.

5. The liquid crystal display of claim 1, wherein the blue pixel and the white pixel in a set of pixels have equal polarity, the red pixels in the set have opposite polarity, and the green pixels in the set have opposite polarity.

6. The liquid crystal display of claim 5, wherein the polarity of the pixels are subject to 2×1 inversion.

7. The liquid crystal display of claim 1, wherein relative positions of the blue pixel and the white pixel in two sets of pixels adjacent in a column direction or in a row direction are reversed.

8. The liquid crystal display of claim 1, wherein the pixels have rectangular shapes and the blue and the white pixels are arranged in the column direction to form a separate column.

9. The liquid crystal display of claim 1, wherein the blue pixel and the white pixel have triangular shapes to form a diamond shape.

10. The liquid crystal display of claim 9, wherein a boundary line between the blue pixel and the white pixel extends in the row direction or the column direction.

11. The liquid crystal display of claim 1, wherein the red pixels in adjacent two columns are located in different rows and the red pixels in adjacent rows are located in different columns, wherein the green pixels in adjacent two columns are placed in different rows and the green pixels in adjacent rows are located in different columns, and wherein either the blue pixels or the white pixels in two sets of pixels adjacent in the row direction are located in different rows, or the blue pixels or the white pixels in two sets adjacent in the column direction are located in different columns.

12. The liquid crystal display of claim 1, wherein the liquid crystal display is driven by rendering.

13. The liquid crystal display of claim 1, further comprising a backlight unit providing light for the pixels, wherein light emitted from the backlight unit has a color coordinate (x, y) where x ranges from about 0.31 to about 0.34, and y ranges from about 0.32 to about 0.35.

14. The liquid crystal display of claim 1, wherein the red, green and blue pixels further comprise red, green and blue organic filters containing red, green and blue pigments, respectively, and the white pixels include transparent organic filters.

15. The liquid crystal display of claim 14, wherein the red, green, blue and white pixels further comprise a common electrode formed on the organic filters.

16. The liquid crystal display of claim 15, wherein the red, green, blue and white pixels further comprise an overcoat located between the organic filters and the common electrode.

17. The liquid crystal display of claim 16, wherein the transparent organic filter includes the same material as the overcoat.

18. The liquid crystal display of claim 15, wherein the height of a surface of the overcoat is substantially uniform.

19. The liquid crystal display of claim 1, wherein the red, green, blue and white pixels further comprise red, green and blue color filters, respectively, and

the red, green, blue and white pixels further comprise:

a protective layer formed on the thin film transistors, having a plurality of protrusions, and facing the color filters;

a common electrode formed on the color filters; and

a liquid crystal interposed between the pixel electrode and the common electrode,

wherein the protrusions are provided in the white pixels, and height of the common electrode is smaller at the white pixel than at the red, the green and the blue pixels.

20. The liquid crystal display of claim 19, wherein distance between the common electrode and a surface of the protective layer is substantially uniform.

21. The liquid crystal display of claim 14, wherein the pixel electrodes and the common electrode have cutouts.

22. A liquid crystal display comprising:

an array pixel including a plurality of pixels arranged in a matrix, the plurality of pixels including a set of pixels including a pair of center pixels adjacent to each other, and a pair of first-color pixels and a pair of second-color pixels obliquely facing each other across the center pixels, each pixel including a pixel electrode and a thin film transistor;

a plurality of gate lines extending in a row direction for transmitting a gate signal to the pixels; and

a plurality of data lines extending in a column direction for transmitting data signals to the pixels,

wherein the pixels are subject to polarity inversion.

23. The liquid crystal display of claim 22, wherein the center pixels in a set of pixels have equal polarity, the first-color pixels in the set have equal polarity, and the second-color pixels in the set have equal polarity.

24. The liquid crystal display of claim 23, wherein the polarity inversion includes column inversion.

25. The liquid crystal display of claim 23, wherein the polarity inversion includes 2×1 inversion.

26. The liquid crystal display of claim 22, wherein the center pixels in a set of pixels have equal polarity, the first-color pixels in the set have opposite polarity, and the second-color pixels in the set have opposite polarity.

27. The liquid crystal display of claim 26, wherein the polarity inversion includes 2×1 inversion.

28. The liquid crystal display of claim 22, wherein the center pixels represent blue color, and the first-color pixels and the second-color pixels represent green and red colors, respectively.

29. The liquid crystal display of claim 22, wherein the center pixels represent red color, and the first-color pixels and the second-color pixels represent green and blue colors, respectively.

30. The liquid crystal display of claim 22, wherein the center pixels represent blue and white colors, and the first-color pixels and the second-color pixels represent green and red colors, respectively.

31. The liquid crystal display of claim 22, wherein the center pixels have different saturation.

32. The liquid crystal display of claim 31, wherein the center pixels represent red color.

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专利名称(译)	液晶显示器		
公开(公告)号	US20040169807A1	公开(公告)日	2004-09-02
申请号	US10/640479	申请日	2003-08-12
[标]申请(专利权)人(译)	RHO SOO GUY 宋瑾KYU CHOI JEONG YE ROH NAM SEOK 朴喆愚 HONG MUN PYO JEONG HO YONG		
申请(专利权)人(译)	RHO SOO-GUY 宋槿KYU 崔贞YE ROH NAM硕 PARK CHEOL-WOO HONG MUN杓 JEONG HO-YONG		
当前申请(专利权)人(译)	RHO SOO-GUY 宋槿KYU 崔贞YE ROH NAM硕 PARK CHEOL-WOO HONG MUN杓 JEONG HO-YONG		
[标]发明人	RHO SOO GUY SONG KEUN KYU CHOI JEONG YE ROH NAM SEOK PARK CHEOL WOO HONG MUN PYO JEONG HO YONG		
发明人	RHO, SOO-GUY SONG, KEUN-KYU CHOI, JEONG-YE ROH, NAM-SEOK PARK, CHEOL-WOO HONG, MUN-PYO JEONG, HO-YONG		
IPC分类号	G02F1/133 G02F1/1335 G02F1/13357 G02F1/1343 G09F9/30 G09F9/35 G09G3/20 G09G3/34 G09G3/36		
CPC分类号	G02F1/133514 G02F1/1336 G02F1/133615 G02F1/134309 G02F1/1362 G02F2201/52 G09G2340/0457 G09G3/3614 G09G3/3648 G09G2300/0452 G09G2320/0209 G09G2320/0233 G09G3/3607		
优先权	1020020072289 2002-11-20 KR 1020020048058 2002-08-14 KR		
其他公开文献	US6888604		

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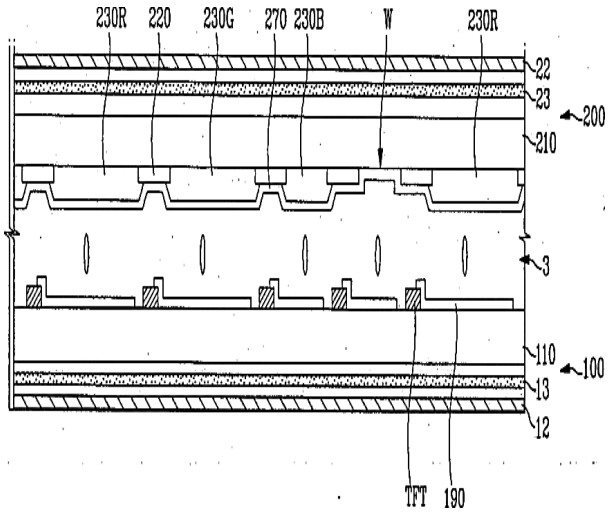
摘要(译)

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