(51) **International Patent Classification:**
G09G 3/32 (2006.01)   *G09G 3/30* (2006.01)
G09G 3/20 (2006.01)

(21) **International Application Number:**
PCT/US2010/034019

(22) **International Filing Date:**
7 May 2010 (07.05.2010)

(25) **Filing Language:**   English

(26) **Publication Language:**   English

(30) **Priority Data:**
12/464,123   12 May 2009 (12.05.2009)   US

(71) **Applicant** *(for all designated States except US)*: **GLOB-AL OLED TECHNOLOGY LLC** [US/US]; 1209 Orange Street, Wilmington, DE 19801 (US).

(71) **Applicant** *(for US only)*: **BOROSON, Michael, L.** [US/US]; c/o 343 State Street, Rochester, NY 14620, United States of America (US).

(72) **Inventor; and**
(75) **Inventor/Applicant** *(for US only)*: **MILLER, Michael, E.** [US/US]; C/o 343 State Street, Rochester, NY 14620 (US).

(74) **Agents: GOODELL, Robert, J.** et al.; Morgan, Lewis & Bockius LLP, 1111 Pennsylvania Avenue, NW, Washington, DC 20004 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

(54) Title: ELECTRO-LUMINESCENT DISPLAY WITH ADDITIONAL PRIMARIES AND ADJUSTABLE WHITE POINT
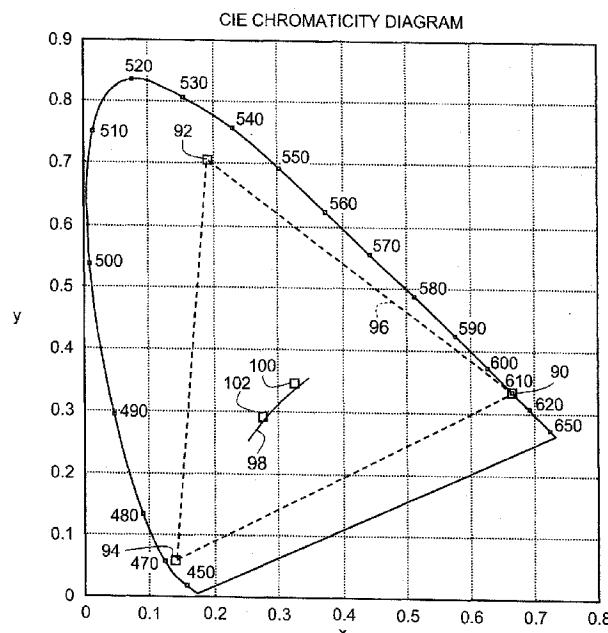
FIG. 5

(57) **Abstract**: The present invention provides an EL display adapted to receive a three-color input image signal, including three gamut-defining EL emitters for emitting red, green, and blue colored light and two additional EL emitters for emitting at least two additional colors of light, the chromaticity coordinates of the at least two additional colors of light lying inside the gamut and near the Plankian Locus; a structure for providing a display white point; and a controller responsive to the provided display white point and the input image signal for providing first separate drive signals for the three gamut-defining EL emitters and second separate drive signals for the two additional EL emitters, wherein the respective luminance values corresponding to the second separate drive signals are each a function of the input image signal and the distances between the display white point and the pseudo-blackbody points of the two additional colors.

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ELECTRO-LUMINESCENT DISPLAY WITH ADDITIONAL PRIMARIES AND ADJUSTABLE WHITE POINT

CROSS REFERENCE TO RELATED APPLICATIONS

5   Reference is made to commonly-assigned U.S. Patent Application Serial No. 12/174,085 filed July 16, 2008 entitled "CONVERTING THREE-COMPONENT TO FOUR-COMPONENT IMAGE" to Ronald S. Cok et al., the disclosure of which is incorporated herein.

10

FIELD OF THE INVENTION

The present invention provides an electro-luminescent display apparatus having an adjustable white point. Specifically, an electro-luminescent display apparatus is provided having at least two in-gamut electro-luminescent
15   emitters for emitting two colors of light to provide an adjustable white point, with reduced power consumption.

BACKGROUND OF THE INVENTION

Flat-panel display devices are widely used in conjunction with computing devices, in portable devices, and for entertainment devices; including
20   televisions. Such displays typically employ a plurality of pixels distributed over a substrate to display images. Each pixel incorporates several, differently-colored emitters, typically red, green, and blue, to represent each image element represented within an input image signal. A variety of flat-panel display technologies are known, for example, plasma displays, field emissive displays
25   (FEDs), liquid crystal displays (LCDs), and electro-luminescent (EL) displays, such as organic light-emitting diode (OLED) displays. To present images on these displays, the display typically receives an image input signal containing three-color-components for each image element which the display utilizes to drive each differently-colored emitter for each pixel.

30   In emissive displays, including plasma, field-emissive and electro-luminescent displays, the amount of visible radiant energy produced by the display is proportional to the amount of power that the display consumes. This

same relationship does not exist in transmissive displays, such as certain LCDs, in which the energy provided to the light source is not modulated as these displays typically create enough light to provide the brightest possible image and then modulate the light rather than the input energy so that only the necessary portion

5   of the light is transmitted to the user.

Displays are used in many professional and consumer electronic devices. In many professional and consumer electronic devices, the user is given the opportunity to adjust the color temperature of the display device. Typically, the color temperature of the display is adjusted to various white points

10   representing different points on or near the Planckian Locus, including colors having color coordinates near the color of standard emitters such as D50, D65, D70 and D95. Further, some display devices provide the ability to change the color temperature of the display at a higher level. For example, the color temperature of the display can be adjusted to D65 when the display is placed in

15   modes, such as those referred to by names such as "Cinema" and the display and to a color temperature such as D93 when placed in modes, such as those referred to by names such as "Standard".

It is known to adjust the color temperature of a display device. For example, in the LCD art, it is known to use multiple illumination sources to enable

20   the adjustment of color temperature in a display. For example, Cornelissen in US Patent No. 6,840,646, entitled "Illumination system and display device" discusses a liquid crystal display device with an adjustable backlight, comprising a low-pressure discharge lamp and additional blue LEDs. By changing the ratio of the power to these two light sources, the color of the LCD backlight can be modified

25   to change the color temperature of the display as it passes through the liquid crystal and red, green, and blue color filters. Similarly, Evanicky in US Patent No. 6,535,190, entitled "Multiple light source color balancing system within a liquid crystal flat panel display" discusses an LCD having fluorescent lamps that serve as the backlight for the LCD, some lamps producing a different color of

30   light than others. By adjusting the ratio of light produced by each of the lamps, the color temperature of the backlight and therefore the color temperature of the

light that is passed through the LCD and its red, green, and blue color filters is modified. Although, this method adds cost to the overall LCD system, these displays make relatively efficient use of the light that is produced, as the light source is directly modified to create the color of light that is needed.

5   Unfortunately, it is not possible to employ adjustable backlights in emissive displays and so this method cannot be applied directly in emissive displays, such as EL displays.

It is also known to adjust the color temperature of a display by adjusting the ratios of the red, green, and blue light-emitting elements to change

10   the color temperature of the display. For example, Inohara et al. in US Patent No. 4,449,148, entitled "Image Display Apparatus" discusses a method for adjusting the color temperate of a CRT by adjusting the ratio of the electron power to the phosphors in the CRT, either by adjusting power or adjusting the on time to each of the red, green, and blue color channels of the CRT. Similar methods are used

15   to adjust the luminance ratio of red, green, and blue emitters in emissive displays, this problem becomes somewhat more complex when additional emitters are added to the display.

However, not all displays have only red, green, and blue emitters. For example, Miller et al in US Patent No. 7,230,594, entitled "Color OLED

20   display with improved power efficiency" discusses an OLED display having red, green, blue and an additional in-gamut emitter, wherein the efficiency of the in-gamut white emitter is significantly higher than the efficiency of the red, green, and blue emitters. As discussed in this patent, the presence of the in-gamut emitter significantly improves the power consumption of the display.

25   In the more than three-color emitter art, it is known to adjust the color temperature of a display having an in-gamut emitter. For example, Murdoch et al. in US Patent No. 6,897,876, entitled "Method for transforming three color input signals to four or more output signals for a color display" describes a method for driving an electro-luminescent display having red, green, blue, and

30   white emitters to color temperatures other than the color of the white emitter. Also, in the LCD art, Higgins in US Patent No. 7,301,543 entitled "Systems and

methods for selecting a white point for image displays" describes a method for adjusting the color temperature of an LCD having red, green, blue, and white emitters using a set of weighting coefficients. These methods allow the color temperature of the display to be adjusted, however, they have the disadvantage

5   that they also have a significant effect on the power consumption of the display. For example, the method discussed by Higgins changes the ratio of light that is blocked by the LCD and in the emissive display case, the ratio of light produced by highly efficient white emitters to the ratio of light produced by lower efficiency red, green, and blue emitters of emissive displays with color filters is altered. As a

10   result, the power consumption of the display can vary dramatically for displays having four or more emitters as the color temperature of the display is changed.

There is a need for an emissive display structure that permits the color temperature to be adjusted in emissive, specifically electro-luminescent displays having four or more color emitter systems, wherein the power efficiency

15   of the resulting display does not vary significantly as a function of color temperature. It is further desirable to maintain high power efficiency, and therefore low display power consumption, regardless of display color temperature.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided an EL

20   display adapted to receive a three-color input image signal, comprising:

a) three gamut-defining EL emitters for emitting red, green, and blue colored light and a first and a second additional EL emitter for emitting two different additional colors of light having chromaticity coordinates specifying respective pseudo-blackbody points, the chromaticity coordinates of the two

25   additional colors of light lying inside a gamut defined by the three gamut-defining emitters and near the Plankian Locus, wherein the two pseudo-blackbody points have respective correlated color temperatures that differ by at least 2000K, and wherein each EL emitter outputs light at a corresponding luminance value in response to a corresponding drive signal;

30   b) means for providing a display white point; and

c) a controller responsive to the provided display white point and the three-color input image signal for providing first separate drive signals for the three gamut-defining EL emitters and second separate drive signals for the two additional EL emitters, wherein the respective luminance values corresponding to

5   the second separate drive signals are each a function of the input image signal and the distances between the display white point and the pseudo-blackbody points of the two additional colors.

In accordance with another aspect of the present invention, there is provided an EL display, adapted to receive a three-color input image signal

10   comprising:

a) three gamut-defining EL emitters for emitting red, green, and blue colored light, wherein the three gamut-defining EL emitters define a gamut and wherein each EL emitter outputs light at a corresponding luminance value in response to a corresponding drive signal;

15   b) three cyan, magenta and yellow additional EL emitters for respectively emitting cyan, magenta and yellow light, wherein each additional EL emitter is within the gamut and has respective chromaticity coordinates, the line between the chromaticity coordinates of the cyan EL emitter and the magenta EL emitter intersects the Planckian Locus to define a first pseudo-blackbody point,

20   the line between the chromaticity coordinates of the yellow EL emitter and the magenta EL emitter intersects the Planckian Locus to define a second pseudo-blackbody point, and the distance between the first and second pseudo -blackbody points along the Planckian Locus is greater than 2000K, and wherein each EL emitter outputs light at a corresponding luminance value in response to a

25   corresponding drive signal.

c) means for providing a display white point; and

d) a controller responsive to the provided display white point and the input image signal for providing first separate drive signals for the three gamut-defining EL emitters and second separate drive signals for the three

30   additional EL emitters, wherein the respective luminance values corresponding to

the second separate drive signals are each a function of the input image signal and the distances between the chromaticity coordinates of the display white point and the first and second pseudo-blackbody points.

An advantage of the present invention is that it can produce images
5 with a range of color temperatures in which high power efficiency is provided regardless of display color temperature. This provides the viewer of the display the flexibility of selecting a display color temperature without increasing the power consumption of the display, thereby maintaining high power efficiency. Some arrangements of the present invention have the added advantage that they
10 provide multiple in-gamut light-emitting elements to extend the useful lifetime of the display device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of the top view of a display system according to one arrangement of the present invention;

15 FIG. 2 is a representation of a user menu useful in providing a means for providing a display color temperature;

FIG. 3 is a schematic of a cross section of a portion of a display panel useful in practicing an arrangement of the present invention;

FIG. 4 is a plot of emitter spectral emission and color filter
20 transmission spectra for emitters and color filters useful in practicing an arrangement of the present invention;

FIG. 5 is a 1931 CIE chromaticity diagram providing the location of color coordinates for EL emitters according to an arrangement of the present invention;

25 FIG. 6 is a plot of emitter spectral emission and color filter transmission spectra for emitters and color filters useful in practicing an arrangement of the present invention;

FIG. 7 is a 1931 CIE chromaticity diagram providing the location of color coordinates for EL emitters according to an arrangement of the present invention;

FIG. 8 is a schematic of a cross section of a portion of a display 5 panel useful in practicing an arrangement of the present invention;

FIG. 9 is a schematic diagram of a controller according to an arrangement of the present invention;

FIG. 10 is a schematic diagram of a controller according to an alternate arrangement of the present invention;

10 FIG. 11 is a schematic of the top view of a display system according to one arrangement of the present invention;

FIG. 12 is a schematic of a cross section of a portion of a display panel useful in practicing an arrangement of the present invention;

FIG. 13 is a plot of emitter spectral emission and color filter 15 transmission spectra for emitters and color filters useful in practicing an arrangement of the present invention;

FIG. 14 is a 1931 CIE chromaticity diagram providing the location of color coordinates for EL emitters according to an arrangement of the present invention; and

20 FIG. 15 is a graph of average power as a function of the distance of the chromaticity coordinates of a white emitter from the white point of the display.

DETAILED DESCRIPTION OF THE INVENTION

One arrangement of the present invention provides an EL display 2 adapted to receive a three-color input image signal 18, which includes a display 25 panel 4, including three gamut-defining EL emitters 6, 8, 10 for emitting red, green, and blue colored light, respectively, and a first and a second additional EL emitter 12, 14 for emitting two additional colors of light having chromaticity coordinates specifying two pseudo-blackbody points, the chromaticity coordinates of the two additional colors of light lying inside a gamut defined by the three

gamut-defining emitters **6, 8, 10** and near the Planckian Locus, wherein the two

pseudo-blackbody points have respective correlated color temperatures that differ

by at least 2000 K. Each EL emitter 6, 8, 10, 12, 14 outputs light at a

corresponding luminance value in response to a corresponding drive signal. The

5   EL display **2** further includes a way of providing a display white point; and a

controller **20** responsive to the provided display white point, which the controller

20 can receive as a white point signal **16**, and the input image signal **18**. The

controller **20** provides first separate drive signals for the three gamut-defining EL

emitters **22** and second separate drive signals **24** for the two additional EL

10   emitters **12, 14**, wherein the respective luminance values corresponding to the

second separate drive signals **24** are each a function of the input image signal and

the distances between the display white point and the two pseudo-blackbody

points of the two additional colors.

Within the current invention, the two or more additional EL

15   emitters **12, 14** are within the gamut, have a high power efficiency and are capable

of producing two pseudo-blackbody points which are separated by a distance large

enough to allow the pseudo-blackbody points to bracket a range of desired white

points. FIG. 15 shows the average power consumption of an EL display having

EL emitters for emitting red, green, blue and white light as a function of the

20   distance of the chromaticity coordinates of the single white emitter from the

desired display white point. This value is plotted for two different white EL

emitters, one having a white point near D65 (e.g., color temperature of 6500 K)

and one having a white point with a color temperature of 10,000 Kelvin. As this

figure shows, if the display white point is D65 and the emitter has chromaticity

25   coordinates that are near D65, the power consumption of the display will be low

and often near a minimum as indicated by point **500** and increase anytime the

color of the white emitter or the color of the display white point changes, such that

the power is increased by more than 10 percent anytime the distance between the

chromaticity coordinates in the 1931 CIE chromaticity diagram is more than 0.05,

30   which is near the point **504**. The same relationship exists if the display white

point is 10,000 Kelvin and the display white point is also 10,000 Kelvin as

indicated by the point **502**. That is, this point **502** indicates a low power that is

near the minimum power for a display white point of 10,000 Kelvin. Once again, the point **506**, which has a distance near 0.05 from the display white point. The distance between these two correlated color temperatures is greater than 0.05, and therefore any display having a single white emitter, which provides images

5   rendered with these two white points will have an increased power consumption when it is required to produce some images at one display white point and other images at a second display white point. It has been determined that when using the arrangement of EL emitters according to the present invention, the EL display 2 can render the input image signal to the EL emitters **6, 8, 10, 12, 14** of the EL

10   display **2,** such that the closest pseudo-blackbody point is used for rendering neutral colors at the desired display white point with a high efficiency.

Because most image sets contain a preponderance of neutral colors, the ability to shift the energy among the EL emitters **12, 14** that form the separate pseudo-blackbody points as the desired display white point is changed, permits the

15   power consumption of the EL display 2 to remain relatively unchanged as a function of display white point. It has also been determined that for most typical image sets, a typical EL display 2 having only a single in-gamut EL emitter, which is near the display white point, will require this single EL emitter to have a very large aperture ratio, typically near or larger than twice the emitting area of

20   the EL emitters **6, 8, 10** for emitting red, green, and blue light. By employing the present invention, the lifetime of the EL display 2 is improved by applying equal-sized EL emitters **6, 8, 10, 12, 14** but increasing the lifetime by providing multiple EL emitters **12, 14** inside the gamut defined by the EL emitters **6, 8, 10** for emitting red, green and blue light.

25   In the context of the present invention, the term "pseudo-blackbody points" refer to two or more colors of light specified by chromaticity coordinates that are "near" the Planckian Locus. In a display system of the present invention having exactly two additional emitters, these pseudo-blackbody points will correspond to the colors of light that are emitted by these two additional EL

30   emitters **12, 14,** requiring that the colors of light that are emitted by these two additional EL emitters **12, 14** are "near" the Planckian Locus. In a display system

of the present invention having more than two additional EL emitters **12, 14,** these pseudo-blackbody points will correspond to colors of light that are created either by an individual additional EL emitter or a combination of light from at least two of the additional EL emitters. When the "pseudo-blackbody point" is created by

5   combining light from two or more of the additional EL emitters, the EL emitters should span the Planckian Locus in such a manner that the appropriate color of light is created to create an appropriate pseudo-blackbody point that is "near" the Planckian Locus.

The term "Planckian Locus" refers to the path or locus that the

10   color of a black body would take in a particular color space as the blackbody temperature changes. In the context of the present invention, a pseudo-blackbody point is "near" pseudo-blackbody the Planckian Locus when it is within a Euclidean distance of plus or minus 0.05 of the nearest point on the Planckian Locus, as depicted on the standard CIE 1931 chromaticity diagram. More

15   specifically, in the context of the present invention, chromaticity coordinates that are "near" the Planckian Locus will have a Euclidean distance within the 1931 chromaticity diagram of plus or minus 0.05 from the nearest point on the Planckian Locus as specified by blackbody radiators having color temperatures between 5000 degrees and 10,000 Kelvin.

20   The term "correlated color temperature" is a property of a color and refers to the temperature of the Planckian radiator having the perceived color most closely resembling that of the given color at the same luminance value and under the same viewing conditions. The correlated color temperature of any color is calculated as the temperature of the blackbody radiator having the smallest

25   Euclidean distance from the color within the 1976 CIE uniform chromaticity space. The term "radiant efficiency" within the context of the present invention is the efficiency with which electrical energy is converted to electromagnetic radiation within the visible spectrum, that is electromagnetic radiation having wavelengths between 380 and 750 nm. For EL emitters of the present invention,

30   this value is specified as the ratio of Watts of electromagnetic energy having wavelengths between 380 and 750 nm that is emitted from the display to the Watts

of power or Amps of current provided to stimulate the EL emitters. This quantity is separate from "luminous efficacy", which is the ratio of luminous flux emitted by the EL emitter to the amount of electricity used to stimulate the EL emitter. Luminous efficacy is typically provided in terms of lumens per watt or candelas

5   per amp, since "luminous efficacy" includes an adjustment, which reflects the varying sensitivity of the human eye to the different wavelengths of electromagnetic energy.

In the present invention, there is provided a structure for providing a display white point, which includes any apparatus for providing a white point

10   signal 16 for specifying a display white point to the controller 20. In one arrangement, this structure includes a user menu that is provided on the EL display 2, and a user input device for selecting between or among display white point options. FIG. 2 shows one such menu 40. In this menu, the user is given multiple options 42, 44, 46 for selecting display white points. These options will

15   commonly indicate a single selected option 42 and allow the user to use an input device, such as a mouse or a button to select one of the remaining options 44, 46. The user can also be given access to a separate control 48 for indicating that they have indicated their desired preference. These options are provided through a graphical user interface as shown in FIG. 2 in some arrangements. Alternately,

20   the display can have a single button, which when pressed, changes the color temperature of the white point of the display. Although the menu 40 shown in FIG. 2 permits the user to explicitly select a color temperature, this explicit control is not necessary and in an alternative arrangement the user is provided with alternate options that allow the implicit control of white point selection, for

25   example, by providing options such as cinema mode (inferring 6500K) and saturated color mode (inferring 9300K). Besides direct user manipulation of display white point, the structure for providing a display white point in other arrangements is a signal associated with the input image signal 18. For example, in some arrangements a video signal is encoded assuming a particular display

30   white point. This display white point is encoded in metadata associated with this video signal. The video signal is provided to the display, thereby providing the display white point (encoded in the metadata) as well as the input image signal 18.

Further, the controller **20** can infer the display white point based upon the source of the input image signal **18**. For example an input image signal **18** provided through a standard video port (e.g., a S-video port) might be assumed to have a display white point, such as 6500K but an input image signal **18** provided through

5   a port more closely associated with a computing platform (e.g., a VGA port) might be assumed to have a different display white point, such as 9300K.

In one arrangement of the present invention, the EL display can include an EL display panel, which is formed from an EL emitter for emitting white light together with an array of color filters. Different color filters are

10   employed to form the EL emitters for emitting red, green, blue and the two additional colors of light. A cross-section of one such display panel is shown in FIG. 3. As shown in this arrangement, the EL display panel **50** will include a substrate **52** on which a drive layer **54** is formed. This drive layer **54** will include electronics, such as active-matrix circuitry, to provide current to each light-

15   emitter. Narrowband color filters **56, 58, 60** are then formed to filter any broadband light emission to form narrowband red, green, and blue light, respectively. In some arrangements, an additional broadband color filter **62** is formed for providing an additional color of light. A second broadband color filter (not shown) can optionally be formed for filtering any broadband light emission to

20   form a second additional color of light, but such a color filter is not necessary. A smoothing layer **64** can additionally be provided for reducing variations in thickness in the region of the color filters. A first electrode **66** is typically formed inside the area defined by each of the color filters and an insulator **68** is typically formed between segments of the electrode to reduce shorting. An EL emissive

25   layer **70** can then be formed over the first electrodes for emitting broadband light. This EL emissive layer **70** will typically include a multi-layer stack that will typically include at least a hole transport layer, a light-emitting layer, and an electron transport layer. The light-emitting layer **70** will typically include multiple species of light-emitting structures or molecules, each species emitting a

30   narrowband of light with a variable wavelength for forming the broadband light emission. Finally, a second electrode **72** will be formed on the opposite side of the EL emissive layer as the first electrode **66**. During operation, the first and

second electrodes **66, 72** will provide an electrical potential, motivating the flow
of current through the EL emissive layer **70** and the EL emissive layer **70** will
emit broadband light in response to the current that passes through this layer. In
such a structure, the second electrode **72** will typically be formed from a reflective

5   metal, such as aluminum. The first electrode **66** will typically be formed from a
transparent oxide, such as Indium Tin Oxide and the light emitted by the EL
emissive layer **70** will typically be emitted in the direction **74** indicated by the
arrow. However, this is not required as the color filters can be formed on the
opposite side of the second electrode **72** and the second electrode **72** can be

10   transparent or semi-transparent and the first electrode **66** can be reflective. The
individual EL emitters within the EL display **50**, depicted as **6, 8, 10, 12,** and 14
of FIG. 1, are defined by a pattern of the first and second electrodes **66, 72** such
that an individual EL emitter is formed by overlapping regions of the first and
second electrodes **66, 72**, which will be patterned to define a two-dimensional

15   array of EL emitters. As shown, this device includes color filters **56, 58, 60** for
each of the three gamut defining emitters and a color filter **62** for one of the two
additional emitters.

          The broadband light provided by the EL emissive layer **70** can
provide a spectrum, such as **80** in FIG. 4. One of the additional EL emitters **12,**

20   **14** in FIG. 1 can emit this light without a color filter, provided the spectrum of
light is such that it has chromaticity coordinates that are inside the gamut of the
gamut-defining EL emitters **6, 8, 10** and near the Planckian Locus. Light having
the spectrum **80** shown in FIG. 4 will have chromaticity coordinates 0.326, 0.346,
which have an Euclidean distance of 0.005 from the Planckian Locus at a

25   correlated color temperature of 5800 Kelvin. The second additional EL emitter
12, 14 will include some form of color filter. This color filter, for example **62** in
FIG. 3, is a dye or pigment based color filter having a spectrum **82** in FIG. 4.
However, this filter can be formed through the design of optical interference
within the layers of the device or other known structures. Employing a color filter

30   having the spectrum **82**, in combination with the EL spectrum **80** shown in FIG. 4
will result in an EL emitter having the spectrum **84**. Light having the spectrum **84**
will have chromaticity coordinates 0.275, 0.290, which have a Euclidean distance

of 0.0016 from the Planckian Locus at a correlated color temperature of 10,500 Kelvin.

When the EL emissive layer 70 provides light having the spectrum 80 and is employed without a color filter and with a color filter having the
5   spectrum 82 to create the two additional emitters as well as employed with three typical narrowband filters, the resulting EL display will provide EL emitters for producing colors having the 1931 CIE chromaticity coordinates provided in FIG. 5. As shown in this figure, by selecting appropriate narrowband color filters for passing long, medium and short wavelength light, the corresponding gamut-
10   defining EL emitters produce light having chromaticity coordinates 90, 92, and 94 for the red, green, and blue EL emitters. These coordinates define a color gamut 96, which specifies the colors that can be formed through combinations of these three colors of light. FIG. 5 also shows a portion of the Planckian locus 98 for color temperatures between 5000 and 25000 Kelvin. The chromaticity
15   coordinates 100 and 102 provided by light having the spectrum 80 and 84, respectively are also shown and provide pseudo-blackbody points according to the present invention. These pseudo-blackbody points besides lying inside the gamut provided by the gamut-defining primaries are near the Planckian Locus, also have correlated color temperatures that differ by more than 2000 Kelvin with one of the
20   pseudo-blackbody points of one of the additional emitters having a correlated color temperature of 6500 Kelvin or less and the second pseudo-blackbody point of the second of the additional emitters having a correlated color temperature of 8000 Kelvin or greater. Within this configuration, because narrow bandpass filters filter the gamut-defining primaries, these narrow bandpass filters reduce
25   their final radiant efficiency significantly. For a broadband emitter having an efficiency of 0.0122 W/A, the red, green, and blue EL emitters have radiant efficiencies of 0.00225, 0.00163, and 0.00220 W/A. However, because the additional EL emitters are not filtered or are filtered using a broadband filter, they have significantly higher radiant efficiencies, having radiant efficiencies of
30   0.00642 and 0.0122 W/A. Therefore, each EL emitter has a respective radiant efficiency and the radiant efficiencies of the two additional emitters are each

higher than all of the respective radiant efficiencies of the gamut-defining EL emitters.

In the previous example, the EL emissive layer **70** within the EL display **50** was assumed to have spectral emission **80** with a low correlated color
5   temperature and a color filter **62** was used to alter the emitted light such to achieve a higher color temperature. However, this is not required and a system of the present invention is formed using an emitter that natively has a high correlated color temperature with a color filter to obtain a lower correlated color temperature. FIG. 6 provides an emitter spectrum **110** for an EL emitter having a
10   high correlated color temperature, specifically 8000 Kelvin, and the spectrum of a filter **112** for reducing the short wavelength energy from the emitter spectrum **110**. By applying this filter, to filter the emitter spectrum **110** of the EL emitter, the filtered emitter spectrum **114** is obtained for an EL emitter in combination with the color filter having the color filter spectrum **112** with a correlated color
15   temperature of 4900 Kelvin. By providing an EL emission layer **70** in FIG. 3 having the emitter spectrum **110** together with a color filer **62** in FIG. 3 having the color filter spectrum **112** together with typical color filters **56, 58, 60** to form red, green, and blue light, the chromaticity coordinates shown in FIG. 7 is obtained. As shown, typical color filters together with the emitter spectrum **110** will result
20   in red, green, and blue emission having the chromaticity coordinates **120, 122, 124,** which form the color gamut **126**. By applying a color filter having filter spectrum **112** within one of the additional EL emitters, the chromaticity coordinates **130** are obtained and the unfiltered EL emission having the spectrum **110** will provide the chromaticity coordinates **132**, each of which are near the
25   Planckian Locus **128**. With this combination, the Euclidean distance of the unfiltered emitter has a distance of 0.020 from the Planckian Locus and the filtered emitter has a distance of 0.0012 from the Planckian Locus. The resulting EL emitters have relative radiant efficiencies of 0.0099, 0.0104, and 0.0156 W/A for the gamut defining EL emitters and 0.073 and 0.0366 W/A for the additional
30   EL emitters.

Although, at least one of the additional EL emitters are formed to include a color filter in the previous arrangement, this is not a necessary requirement. In another arrangement of the present invention shown in FIG. 8, an EL display panel **140** is formed from an EL emitter for emitting white light

5 together with an array of color filters. As shown, different color filters are employed to form the EL emitters for emitting red, green, and blue light. In other arrangements, the color of the additional EL emitters are, however, formed using other methods, such as by tuning the length of optical cavities within the EL display panel **140**. As shown, the EL display panel **140** will typically include a

10 substrate **142** on which a drive layer **144** is formed. This drive layer **144** will include electronics, such as active-matrix circuitry, to provide current to each elemental emitter. A first electrode **146** is formed with an insulator **148** between segments of the electrode to reduce shorting.

A variable-thickness, non-emitting layer **166** is formed over the

15 first electrode **146**. This variable-thickness, non-emitting layer will be relatively transparent and will have a different thickness in the first additional EL emitter, for example the one indicated by region **168**, than in the second additional EL emitter, for example the one indicated by region **170**. The purpose of this variable-thickness, non-emitting layer **166** is to introduce a different optical cavity

20 length within the optical structure of the EL display device.

An EL emissive layer **150** can then be formed over the first electrodes and the variable-thickness, non-emitting layer **166** for emitting broadband light. This EL emissive layer **150** will typically include a multi-layer stack that will typically include at least a hole transport layer, a light-emitting

25 layer, and an electron transport layer. The light-emitting layer within the EL emissive layer **150** will typically include multiple species of light-emitting structures or molecules, each species emitting a narrowband of light with a variable wavelength for forming the broadband light emission. A second electrode **152** will be formed on the opposite side of the EL emissive layer as the

30 first electrode **146**. During operation, the first and second electrodes **146, 152** will provide an electrical potential, motivating the flow of current through the EL

emissive layer **150** and the EL emissive layer **150** will emit broadband light in response to the current that passes through this layer. In such a structure, the second electrode **152** will typically be formed from a transparent or semi-transparent material, including materials such as Indium Tin Oxide or thin silver.

5   The first electrode **146** will typically be formed from a reflective metal, such as Aluminum. The device can then be designed to include a low optical index layer, **176**, for example an air gap above the second electrode **152** within the regions of light emission. This low optical index layer **176** is formed, for example, by applying a second substrate **162** above the second electrode **152**. This second

10   substrate **162** is made to include narrow band color filters **154**, **156**, and **158** for filtering the broadband light emitted from the light-emitting layer **150** together with a smoothing layer **160** in this arrangement. In this arrangement, the narrowband color filters **154**, **156**, **158** filter broadband light emission to provide red, green, and blue light.

15   This arrangement permits light produced in the EL emissive layer **150** to be emitted in the direction of the arrow **164**. Narrowband color filters **154**, **156**, **158** are then formed to filter any broadband light emission to form narrowband red, green, and blue light, respectively. A second broadband color filter (not shown) can optionally be formed for filtering any broadband light

20   emission to form one or both of the additional EL emitters, but such a color filter is not necessary.

                Further detail can now be provided with regards to the variable-thickness, non-emitting layer **166**. By selecting the thickness of this variable-thickness, non-emitting layer, the optical cavity length for each EL emitter is

25   designed to preferentially emit certain wavelengths of light as compared to others. Within a device of the present invention, the optical cavity length will be selected by changing the thickness of this variable thickness, non-emitting layer **166** such that a first of the additional EL emitters, such as the one indicated by region **170**, preferentially emits short wavelength light. The second of the additional EL

30   emitters preferentially emits medium or long wavelength light. In a device, such as this, the optical cavity length is the distance from the top of the first electrode

146 (ie., the interface between the first electrode 146 and the EL light-emitting layer 150) and the top of the second electrode 152 (i.e., the interface between the second electrode layer 152 and low optical index layer 176. As such, this non-emitting layer 166 has a different thickness in the first additional EL emitter

5   region 168 than the second additional EL emitter region 170. In one arrangement, this non-emitting layer 166 is a transparent inorganic conductor. For example, a metal oxide, such as Indium Tin Oxide is patterned on top of the first electrode 146 using known methods to form this variable-thickness non-emitting layer 166. In another example, wherein the EL emitting layer contains organic compounds,

10   this variable-thickness non-emitting layer 166 is an organic semiconductor, such as NPB, which is patterned through a shadowmask or through laser transfer techniques. In yet other arrangements, particularly arrangements, wherein the EL emitting layer contains inorganic materials, such as quantum dots, this variable thickness non-emitting layer 166 is an inorganic semiconductor.

15   By varying the thickness of this variable-thickness non-emitting layer 166 between the first and second additional EL emitter regions 168, 170, it is possible to provide two additional colors of light having chromaticity coordinates specifying pseudo-blackbody points according to the present invention. It is further advantageous, however, to also vary the thickness of this layer 166 among

20   the EL emitters for emitting red, green, and blue light. Specifically, the efficiency of the red, green, and blue EL emitters is improved when the thickness of the non-emitting layer 166 within the gamut-defining EL emitter for forming blue light, indicated by region 174 is closer to the thickness of the non-emitting layer 166 within the additional EL emitter with the higher color temperature, indicated by

25   region 170, than to the thickness of the non-emitting layer within the additional EL emitter with the lower color temperature. The formation of an EL emitter having a higher color temperature is achieved by designing the cavity length to preferentially emit short wavelength light, particularly light having a wavelength of 420 nm or lower. To reduce the number of steps necessary to complete a

30   display of the present invention, when the first additional EL emitter in region 168 has a higher correlated color temperature higher than the EL emitter in the second additional EL emitter region 170, the thickness of the variable thickness, non-

emitting layer within the gamut-defining EL emitter for emitting blue colored light will be equal to the thickness of the non-emitting layer within the first additional EL emitter region **168**. It is further useful for the thickness of the non-emitting layer within the gamut-defining EL emitter for forming red or green

5   light, indicated by region **172a, 172b** to be closer to the thickness of the non-emitting layer within the additional EL emitter, indicated by region **168**, with the lower color temperature than to the thickness of the non-emitting layer within the additional EL emitter with the higher color temperature. The formation of an EL emitter with a lower color temperature is obtained by designing the cavity length

10   to preferentially emit medium or long wavelength light, particularly light having a wavelength between 500 and 600 nm. Once again, to reduce the number of steps required to make this variable thickness layer, when the EL emitter in the first additional EL emitter region **168** has a higher correlated color temperature than the EL emitter in the second additional EL emitter region **170** the thickness of the

15   non-emitting layer within the gamut-defining EL emitter for emitting red or green colored light will be equal to the thickness of the non-emitting layer within the second additional EL emitter region **170**. In a particularly preferred arrangement, the thickness of the non-emitting layer within both the regions **172a, 172b** of the gamut-defining EL emitters for emitting red and green colored light will be equal

20   to the thickness of the non-emitting layer within the second additional EL emitter **170**.

The device shown in FIG. 8 employs a top-emitting structure for emitting light in the direction opposite the substrate. However, this is not necessary and the variable thickness non-emitting layer **166** is employed in

25   bottom emitting structures to achieve some arrangements of an EL display of the present invention. Although, it is sometimes simpler to include a very low optical index layer **176** in an appropriate location within a top-emitting EL device as shown in FIG. 8, it is not necessary for the low optical index layer **176** to have an optical index as low as air since only a relatively small color change is required

30   between the first and second additional EL emitter regions **168, 170** of the present invention. Therefore, the inclusion of solid-state materials within layers of the device is useful in forming the low optical index layer **176** as long as the optical

index of these materials is lower than the optical index of the light-emitting layer 150. In a bottom-emitting OLED device, materials typically formed within the drive layer 144 can provide the low optical index layer 176.

5   To fully appreciate the present invention, it is necessary to return again to a discussion of the controller 20 in FIG. 1. As discussed earlier, this controller 20 is responsive to the provided display white point, which is provided in signal 16 and the input image signal 18 for providing first separate drive signals 22 for the three gamut-defining EL emitters 6, 8, 10 and second separate drive signals 24 for the two additional EL emitters 12, 14, wherein the respective

10   luminance values corresponding to the second separate drive signals are each a function of the input image signal and the distances between the display white point and the pseudo-blackbody points of the two additional EL emitters 12,14. Specifically, when the input image signal corresponds to the provided display white point, the controller will provide second separate drive signals such that the

15   additional EL emitter having a pseudo-blackbody point closest to the chromaticity coordinates of the provided display white point has a higher luminance value than the additional emitter having the pseudo-blackbody point furthest from the chromaticity coordinates of the provided display white point. The controller 20 can employ numerous methods to achieve this result.

20   A controller useful within the EL display of the present invention is shown in FIG. 9. As shown, the controller 180 includes a receive input image signal unit 184 for receiving the input image signal 182. This unit can perform any basic decoding steps, such as decompressing the input image signal 182 and converting the input image signal 182 to a three-color channel linear intensity

25   using methods that are well known in the art. A receive white point unit 188 is also provided to receive a signal 186 indicating the color of the desired display white point. Based upon the desired display white point, the selected adaptation matrix unit 190, selects a color transform, typically a three by three matrix for rotating the input image signal to the desired display white point. The apply

30   adaptation matrix unit 192 then applies this transform to the decoded input image signal to normalize the input image signal to the desired display white point.

Based upon the display white point that is received by the receive white point unit
188, the determine first normalization matrix unit 194 then selects an appropriate
normalization matrix. During this selection process, the unit 194 determines
which of the two additional EL emitters has a pseudo-blackbody point furthest

5   from the chromaticity coordinates of the display white point and selects or
computes a matrix to rotate the output of the apply adaptation matrix unit 192
from the display white point to the chromaticity coordinates of the additional EL
emitter having a pseudo-blackbody point furthest from the display white point.
The determined matrix is then applied to the input data stream after application of

10   the adaptation matrix by the apply first normalization matrix unit 196. A
minimum value of the three color channel is then determined for each pixel in the
image signal after application of the first normalization matrix by the determine
min unit 198. A subtract min unit 200 is then used to subtract the minimum value
from the each channel of the three channel signal for each pixel after application

15   of the first normalization matrix. This minimum value is then added to the
intensity for an additional color channel corresponding to the EL emitter having a
pseudo-blackbody point furthest from the chromaticity coordinates of the desired
display white point by the add min unit 202. The determine second normalization
matrix unit 204 then determines a matrix to rotate the color coordinates of the

20   three nonzero color components to the color of the second pseudo-blackbody
point. The apply second normalization matrix unit 206 then applies this matrix to
rotate the color coordinates of the three nonzero color components after the Add
Min Unit 202 to the pseudo-blackbody point of the EL emitter having
chromaticity coordinates closest to the chromaticity coordinates of the desired

25   display white point. A second determine min unit 208 again determines the
minimum of the resulting three nonzero channels for each pixel. This minimum is
then subtracted from the signal that is acquired after applying the second
normalization matrix unit by the subtract min unit 210. An add min unit 212 is
then applied to add this minimum value to the fifth color channel corresponding to

30   the EL emitter having chromaticity coordinates nearest the chromaticity
coordinates of the display white point 132. The two zero values that are provided
by the subtract min units 200, 212 together with the nonzero value for the

resulting value for the remaining three color channel in the input image signal is
then used to form a first drive signal **216** by the form first and second drive signal
unit **214**. The values for the two additional channels are then used to form the
second drive signal **218** by the form first and second drive signal unit **214**.

5   Besides formatting this data appropriately, this unit **214** will also apply any
transforms necessary to convert the linear intensity values provided by the add
min unit **212** to code values, voltages, or currents that are used to drive the EL
emitters within the EL display. When this method is applied appropriately and the
input image signal is a typical RGB signal having equal R, G, and B values (i.e.,

10   the input color is white and therefore corresponds to the provided display white
point), and when the pseudo-blackbody point for one of the emitters is equal to or
very near the desired display white point the first and second drive signals will
drive practically all of the display luminance through the EL emitter having a
pseudo-blackbody point that is near or equal to the display white point.

15   Therefore, the additional emitter having a pseudo-blackbody point closest to the
chromaticity coordinates of the provided display white point produces higher
luminance values than the additional emitter having the pseudo-blackbody point
furthest from the chromaticity coordinates of the provided display white point.

           In some arrangements of the present invention, the controller can
20   perform additional image processing steps. For example, the display white point
can have a corresponding luminance value that is either specified or inferred and
the controller can adjust the luminance value of the display white point in
response to the input image signal. In one example, the input image signal **182**
can contain three color channels for an array of pixels that compose a series of

25   image or video frames. The controller **180**, can additionally include optional units
220, 222, 224, and **226** as shown in FIG. 10. The determined max unit **220** can
determine the maximum non-zero intensity values in each frame for each channel
after the add min unit **212** performs its calculations. The determine ratio unit **222**
can then calculate ratios between the maximum possible intensity values and the

30   maximum non-zero intensity values for each channel in each frame. The
determine min ratio unit **224** can then determine the minimum of these ratios.
Finally, the scale values unit **226** can scale the intensity values resulting from the

add min unit **212** by the minimum ratio as determine by the determine min ratio
unit **224**. This scale value will always be greater than or equal to 1. Therefore,
the controller **180** in FIG. 10 will adjust the luminance value of the display white
point for each frame in response to a saturation of the input image signal since
5   images containing bright saturated colors will tend to have lower minimum ratio
values. Similar methods for adjusting the luminance value of the display white
point in response to the input image signal have been discussed in US Patent
Application No. 12/174,085, filed July 16, 2008 entitled "Converting Three-
Component To Four-Component Image" to Ronald S. Cok et al hereby included
10   by reference.

One of the primary advantages of the present invention is that the
display consumes similar amounts of power as the white point of the display is
modified. Employing a display panel having emission similar to that shown in
FIG. 6, a display is constructed having only a single additional EL emitter as is
15   known in the prior art for emitting light inside the gamut or with the two
additional EL emitters of the present invention. Power for each of these displays
is shown in Table 1 as a function of display white point. In this example, the
single white emitter in the RGBW system has a correlated color temperature of
8000 Kelvin. Therefore, when an RGBW display is constructed using this single
20   white emitter, the minimum power of the display occurs for color temperatures
near 8000 Kelvin and increases for other color temperatures. As shown, the
power consumption is 3.9 W when the white point of the display is 10,000 Kelvin
and increases to 4.35 W when the color temperature of the display is set to 6500
degrees K, increasing by over 10 percent. However, when the second additional
25   emitter is provided in the inventive example, the power increases from only 3.65
W at 10,000K to 3.73W at 6500K, only a 2% change in power. Further the power
consumption is lower in general when the second emitter is added, providing 14
percent lower power at the 6500 degree Kelvin condition.

	6500 K	7500 K	10,000 K
RGBW	4.35 W	4.05 W	3.90 W

Inventive Example	3.73 W	3.61 W	3.65 W

In another arrangement, the EL display 302 in FIG. 11 of the present invention is adapted to receive a three-color input image signal 320. This EL display 302 includes three gamut-defining EL emitters 306, 308, 310 formed

5   on a substrate 304 for emitting red, green, and blue colored light, respectively. The chromaticity coordinates of the three gamut-defining EL emitters define a gamut and each EL emitter outputs light at a corresponding luminance value in response to a corresponding drive signal. Also included are three additional (cyan, magenta, and yellow) EL emitters 316, 314, 312 for respectively emitting

10   cyan, magenta, and yellow light. In this EL display 302 each additional EL emitter 312, 314, 316 is within the gamut of the gamut-defining primaries 306, 308, 310 and has respective chromaticity coordinates. Within this EL display, a line drawn between the chromaticity coordinates of the cyan EL emitter 316 and the magenta EL emitter 314 will intersect the Planckian Locus to define a first

15   pseudo-blackbody point. A line drawn between the chromaticity coordinates of the yellow EL emitter 312 and the chromaticity coordinates of the magenta EL emitter 314 will intersect the Planckian Locus to define a second pseudo-blackbody point. The distance between the first and second pseudo-blackbody points along the Planckian Locus will be greater than 2000K. Each of the

20   additional EL emitter outputs light at a corresponding luminance value in response to a corresponding drive signal. The EL display 302 will further include a structure for providing a display white point in response to a white point signal 322; and a controller 318 responsive to the provided display white point and the input image signal 320 for providing first separate drive signals 324 for the three

25   gamut-defining EL emitters 306, 308, 310 and second separate drive signals 326 for the three additional EL emitters 312, 314, 316. Within the present invention the respective luminance values corresponding to the second separate drive signals 316 are each a function of the input image signal 320 and the distances between the chromaticity coordinates of the display white point and the first and second

30   pseudo-blackbody points. In some arrangements, when the input image signal

320 corresponds to the provided display white point, the sum of the luminance values of the additional emitters defining a pseudo-blackbody point closest to the chromaticity coordinates of the provided display white point is higher than the sum of the luminance values of the additional emitters defining a pseudo-

5   blackbody point furthest from the provided display white point.

FIG. 12 shows a cross-section of the display panel within the display of FIG. 11. This display panel 340 includes a substrate 342. A drive layer 344 is formed on this substrate. Color filters 346, 348, 350, 352, 354 are formed over the substrate and a smoothing layer 356 is applied. As shown in FIG. 12, six

10   EL emitters are formed on the display panel 340 by applying five color filters having different spectra corresponding to the red, green, blue and two of the cyan, magenta and yellow EL emitters. Three of these color filters, 346, 348, and 350 are narrowband color filters for forming the gamut-defining primaries of a display of the present invention. Two of these color filters 348 and 350 are broadband

15   color filters for filtering broadband light in an efficient manner. Although a sixth filter providing a broadband filter can be applied to form a third in-gamut EL emitter, this filter is not necessary. Therefore, the display will include corresponding color filters for each of the three gamut-defining EL emitters and exactly two of the three additional EL emitters. Above the smoothing layer 344,

20   the first electrodes 358 are formed with insulators 360. An EL light-emitting layer 362 is formed over the first electrodes 358 and a second electrode 364 is formed over the EL light-emitting layer 344. In this device, the light emitted within each EL emitter passes in a direction 366, as indicated by the arrow. In desirable arrangements, the EL emitter without a filter will typically emit light that has a

25   yellow or cyan bias. When the EL emitter without a filter emits light that has a yellow bias, the broadband filters 348, 350 will be cyan and magenta filters. When the EL emitter without a filter emits light that has a cyan bias, the broadband filters 348, 350 will be yellow and magenta filters.

FIG. 13 shows the emission spectrum 380 of a broadband emitter

30   as a function of wavelength. This particular emitter has a yellow bias, having chromaticity coordinates of 0.326, 0.346, having a correlated color temperature of

about 5800 Kelvin. Also shown in FIG. 13 are color filter spectra **382, 384** for

cyan and magenta color filters, respectively, which are useful in practicing one

arrangement of the present invention. It should be acknowledged, however, that if

the emitter had a cyan bias, it would be necessary to include magenta and yellow

5   color filters.

FIG. 14 provides a 1931 CIE chromaticity diagram including

points that are achieved by applying the broadband emitter having the emission

spectrum **380**, together with narrowband red, green, and blue color filters and the

broadband filters having spectra **382** and **384** from FIG. 13. As shown in FIG. 14

10   a display panel, such as **340** in FIG. 12, is formed employing these filters which

include EL emitters for emitting red, green, and blue light having the chromaticity

coordinates **390, 392,** and **394.** The chromaticity coordinates **390, 392,** and **394**

for the EL emitters form a gamut **396.** Inside this gamut are the chromaticity

coordinates **398, 400, 402** corresponding to cyan, magenta, and yellow EL

15   emitters, respectively. A line **404** is drawn between the chromaticity coordinates

398 of the cyan EL emitter and the chromaticity coordinates **400** of the magenta

EL emitter, which intersects the Planckian Locus **408** to define a first pseudo-

blackbody point **406.** This first pseudo-blackbody point **404** lies on the Planckian

Locus and has a color temperature of about 19,500 Kelvin. A line **410** drawn

20   between the chromaticity coordinates of the yellow EL emitter **402** and the

magenta EL emitter **400** intersects the Planckian Locus **408** to define a second

pseudo-blackbody point **412**, having a color temperature of about 5800 Kelvin.

The distance between the first and second pseudo-blackbody points along the

Planckian Locus is greater than 2000 Kelvin, in fact, in this example, this

25   difference is nearly 14,000 Kelvin.

As in the earlier arrangements, the EL display of the present

invention that employs the display panel **340** would further include a structure for

providing a display white point; and a controller responsive to the provided

display white point and the input image signal. This controller would provides

30   first separate drive signals for the three gamut-defining EL emitters and second

separate drive signals for the three additional EL emitters, wherein the respective

luminance values corresponding to the second separate drive signals are each a function of the input image signal and the distances between the chromaticity coordinates of the display white point and the first and second pseudo-blackbody points. The controller **180** shown in FIG. 10 can also be employed within this

5 arrangement. However, the form first and second drive signal unit **214** would transform the intensities for the first and second pseudo-blackbody points to cyan, magenta, and yellow intensity values by multiplying each of these intensity values by two separate weighting values for the cyan, magenta, and yellow intensity values and summing these for each channel. These weighting values simply

10 represent the ratio of each of the EL emitters required to create each of the pseudo-blackbody points. This controller can also employ other algorithms for converting red, green, and blue input intensity values to separate signals for driving red, green, and blue gamut defining EL emitters as well as cyan, magenta, and yellow EL emitters as are known in the art.

15   To demonstrate the benefit of this display device, power consumption was determined for an EL display having a red, green, blue, and the same yellowish white EL emitter as provided within this previous example. Power consumption was also determined for an EL display as described within this example. These power determinations were performed using the same typical

20 image set, however it was determined at two different color temperatures, including 6500 Kelvin and 10,000 Kelvin. The resulting values are shown in Table 2. As shown in this Table 2, a display having only the red, green, blue and yellowish white EL emitter has draws about 4.8 W for a color temperature of 6500K. However, when this same display was used to provide images with a

25 color temperature of 10,000K, the power consumption of the display increased significantly to more than 5.5 W. However, when using the display of the present invention having red, green, and blue gamut-defining EL emitters together with cyan, magenta, and the yellowish-white emitter as described in the example, the power was nearly equivalent regardless of color temperature increasing only from

30 4.3 to 4.4 W for this display configuration. It is also noteworthy that inclusion of the additional cyan and magenta emitters decreased power ay at least 10% regardless of color temperature, their addition is primarily useful when the color

temperature of the display is adjusted as it reduces the sensitivity of the power

consumption of the display to changes in display white point, effectively reducing

the power consumption by 20% in this example when the display is driven to a

white point of 10,000 Kelvin.

5   Table 2

	6500 K	10,000K
RGBY	4.8 W	5.5 W
RGBCMY	4.3 W	4.4 W

Although the example arrangement shown in FIG. 11 provides a

broadband emitter together with three narrowband and two broadband filters,

other arrangements of EL displays are formed which fulfill the requirements of the

10   present invention. This includes displays including various optical cavity

configurations and patterning of materials having different color emission.

In a preferred arrangement, the EL display of the present invention

includes Organic Light Emitting Diodes (OLEDs), which are composed of small

molecule or polymeric OLEDs as disclosed in but not limited to U.S. Patent No.

15   4,769,292, by Tang et al., and U.S. Patent No. 5,061,569, by VanSlyke et al.

Many combinations and variations of organic light emitting materials can be used

to fabricate such a panel.

The invention has been described in detail with particular reference

to certain preferred embodiments thereof, but it will be understood that variations

20   and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

2	EL display
4	display panel
6	red gamut-defining EL emitter
8	green gamut-defining EL emitter
10	blue gamut-defining EL emitter
12	first additional EL emitter
14	second additional EL emitter
16	white point signal
18	three-color input image signal
20	controller
22	drive signal for the gamut-defining EL emitters
24	drive signals for the additional EL emitters
40	menu
42	display white point option
44	display white point option
46	display white point option
48	separate control
50	EL display panel
52	substrate
54	drive layer
56	narrowband color filter for forming red light
58	narrowband color filter for forming green light
60	narrowband color filter for forming blue light
62	additional broadband color filter
64	smoothing layer
66	first electrode
68	insulator
70	EL emissive layer
72	second electrode
74	direction of light emission
80	EL spectrum

82	color filter spectrum
84	filtered EL spectrum
90	red EL emitter chromaticity coordinates
92	green EL emitter chromaticity coordinates
94	blue EL emitter chromaticity coordinates
96	color gamut
98	Planckian Locus
100	additional EL emitter chromaticity coordinates
102	additional EL emitter chromaticity coordinates
110	emitter spectrum
112	filter spectrum
114	filtered emitter spectrum
120	red chromaticity coordinates
122	green chromaticity coordinates
124	blue chromaticity coordinates
126	color gamut
128	Planckian Locus
130	additional emitter chromaticity coordinates
132	additional emitter chromaticity coordinates
140	EL display panel
142	substrate
144	drive layer
146	first electrode
148	insulator
150	EL emissive layer
152	second electrode
154	narrowband color filter
156	narrowband color filter
158	narrowband color filter
160	smoothing layer
162	second substrate
164	direction of light emission

166   variable thickness, non-emitting layer

168   region of first additional EL emitter

170   region of second additional EL emitter

172a   region of EL emitter for emitting red or green light

172b   region of EL emitter for emitting red or green light

174   region of EL emitter for emitting blue light

176   low optical index layer

180   controller

182   input image signal

184   receive input image signal unit

186   display white point signal

188   receive white point unit

190   select adaptation matrix unit

192   apply adaptation matrix unit

194   determine first normalization matrix unit

196   apply first normalization matrix unit

198   determine min unit

200   subtract min unit

202   add min unit

204   determine second normalization matrix unit

206   apply second normalization matrix unit

208   second determine min unit

210   subtract min unit

212   add min unit

214   form first and second drive signal unit

216   first drive signal

218   second drive signal

220   determine max unit

222   determine ratio unit

224   determine min ratio unit

226   scale values unit

302   EL display

304 substrate

306   red gamut-defining EL emitter

308   green gamut-defining EL emitter

310   blue gamut-defining EL emitter

312   additional EL emitter

314   additional EL emitter

316   additional EL emitter

318   controller

320   input image signal

322   white point signal

324   first separate drive signals

326   second separate drive signals

340   display panel

342   substrate

344   drive layer

346   narrowband color filter

348   narrowband color filter

350   narrowband color filter

352   broadband color filter

354   broadband color filter

356   smoothing layer

358   first electrode

360   insulators

362   EL light-emitting layer

364   second electrode

366   light-emission direction

380   emission spectrum

382   color filter spectrum

384   color filter spectrum

390   red chromaticity coordinates

392   green chromaticity coordinates

394   blue chromaticity coordinates

396	gamut
398	cyan chromaticity coordinates
400	magenta chromaticity coordinates
402	yellow chromaticity coordinates
404	line
406	first pseudo-blackbody point
408	Planckian Locus
410	line
412	second pseudo-blackbody point
500	point near minimum power for D65
502	point near minimum power for 10,000 Kelvin
504	point near a distance of 0.05 from the display white point of D65
506	point near a distance of 0.05 from the display white point of 10,000 Kelvin

CLAIMS:

1) An EL display adapted to receive a three-color input image signal, comprising:

5   a) three gamut-defining EL emitters for emitting red, green, and blue colored light and a first and a second additional EL emitter for emitting two different additional colors of light having chromaticity coordinates specifying respective pseudo-blackbody points, the chromaticity coordinates of the two additional colors of light lying inside a gamut defined by the three gamut-defining

10   emitters and near the Plankian Locus, wherein the two pseudo-blackbody points have respective correlated color temperatures that differ by at least 2000K, and wherein each EL emitter outputs light at a corresponding luminance value in response to a corresponding drive signal;

          b) means for providing a display white point; and

15   c) a controller responsive to the provided display white point and the three-color input image signal for providing first separate drive signals for the three gamut-defining EL emitters and second separate drive signals for the two additional EL emitters, wherein the respective luminance values corresponding to the second separate drive signals are each a function of the input image signal and

20   the distances between the display white point and the pseudo-blackbody points of the two additional colors.

2) The EL device of claim 1, wherein when the input image signal corresponds to the provided display white point, the additional emitter having a

25   pseudo-blackbody point closest to the chromaticity coordinates of the provided display white point has a higher luminance value than the additional emitter having the pseudo-blackbody point furthest from the chromaticity coordinates of the provided display white point.

30 3) The EL device of claim 1, wherein one of the pseudo-blackbody points of the two additional EL emitters has a correlated color temperature of 6500K or less and the second has a correlated color temperature of 8000K or greater.

4) The EL device of claim 1, wherein each EL emitter has a respective radiant efficiency and the radiant efficiencies of the two additional emitters are both higher than all of the respective radiant efficiencies of the gamut-defining EL emitters.

5) The EL device of claim 1, further including corresponding color filters for each of the three gamut defining emitters and one of the two additional emitters.

6) The EL device of claim 1, further including a non-emitting layer having a variable thickness, wherein the non-emitting layer has a different thickness in the first additional EL emitter than the second additional EL emitter.

7) The EL device of claim 6, wherein the non-emitting layer is a transparent inorganic conductor or an organic semiconductor.

8) The EL device of claim 6, wherein the non-emitting layer has a different thickness in a first selected gamut-defining EL emitter than in a second selected gamut-defining EL emitter.

9) The EL device of claim 8, wherein the first additional EL emitter has a higher correlated color temperature than the second additional EL emitter, and wherein the thickness of the non-emitting layer within the gamut-defining EL emitter for emitting blue colored light is equal to the thickness of the non-emitting layer within the selected first additional EL emitter.

10) The EL device of claim 8, wherein the first additional EL emitter has a a higher correlated color temperature than the second additional EL emitter, and wherein the thickness of the non-emitting layer within the gamut-defining EL emitter for emitting red or green colored light is equal to the thickness of the non-emitting layer within the second additional EL emitter.

11)   The EL device of claim 1, wherein the display white point has a

corresponding luminance value and the controller adjusts the luminance value of

the display white point in response to the input image signal.

5   12)   The EL device of claim 6, wherein the controller adjusts the luminance

value of the display white point in response to a saturation of the input image

signal.

13)   An EL display, adapted to receive a three-color input image signal

10   comprising:

a) three gamut-defining EL emitters for emitting red, green, and blue

colored light, wherein the three gamut-defining EL emitters define a gamut and

wherein each EL emitter outputs light at a corresponding luminance value in

response to a corresponding drive signal;

15   b) cyan, magenta and yellow additional EL emitters for respectively

emitting cyan, magenta and yellow light, wherein each additional EL emitter is

within the gamut and has respective chromaticity coordinates, the line between the

chromaticity coordinates of the cyan EL emitter and the magenta EL emitter

intersects the Planckian Locus to define a first pseudo-blackbody point, the line

20   between the chromaticity coordinates of the yellow EL emitter and the magenta

EL emitter intersects the Planckian Locus to define a second pseudo-blackbody

point, the distance between the first and second pseudo-blackbody points along

the Planckian Locus is greater than 2000K, and wherein each EL emitter outputs

light at a corresponding luminance value in response to a corresponding drive

25   signal.

c) means for providing a display white point; and

d) a controller responsive to the provided display white point and the input

image signal for providing first separate drive signals for the three gamut-defining

EL emitters and second separate drive signals for the three additional EL emitters,

30   wherein the respective luminance values corresponding to the second separate

drive signals are each a function of the input image signal and the distances

between the chromaticity coordinates of the display white point and the first and second pseudo-blackbody points.

14) The EL device of claim 13, wherein when the input image signal
5 corresponds to the provided display white point, the sum of the luminance values of the additional emitters defining a pseudo-blackbody point closest to the chromaticity coordinates of the provided display white point is higher than the sum of the luminance values of the additional emitters defining a pseudo-blackbody point furthest from the provided display white point.

10

15) The EL device of claim 13, wherein the second pseudo-blackbody point has a correlated color temperature of 6500K or less and the first pseudo-blackbody point has a correlated color temperature of 8000K or greater.

15 16) The EL device of claim 13, wherein each EL emitter has a respective radiant efficiency and the radiant efficiencies of the three additional emitters are all higher than all of the respective radiant efficiencies of the gamut-defining EL emitters.

20 17) The EL device of claim 13, further including corresponding color filters for each of the three gamut-defining EL emitters and exactly two of the three additional EL emitters.

18) The EL device of claim 13, wherein the display white point has a
25 corresponding luminance value and the controller adjusts the luminance value of the display white point in response to the input image signal.

19) The EL device of claim 18, wherein the controller adjusts the luminance value of the display white point in response to a saturation of the input image
30 signal.

FIG. 1

2/15

DISPLAY OPTIONS

DISPLAY WHITE POINT:

42 ~ ⊘ 5000K

44 ~ ◯ 6500K

46 ~ ◯ 9300K

40 ~

48 ~ OK

FIG. 2

FIG. 3

FIG. 4

FIG. 5

6/15

FIG. 6

FIG. 7

8/15

FIG. 8

FIG. 9

10/15

FIG. 10

FIG. 11

12/15

FIG. 12

FIG. 13

CIE CHROMATICITY DIAGRAM
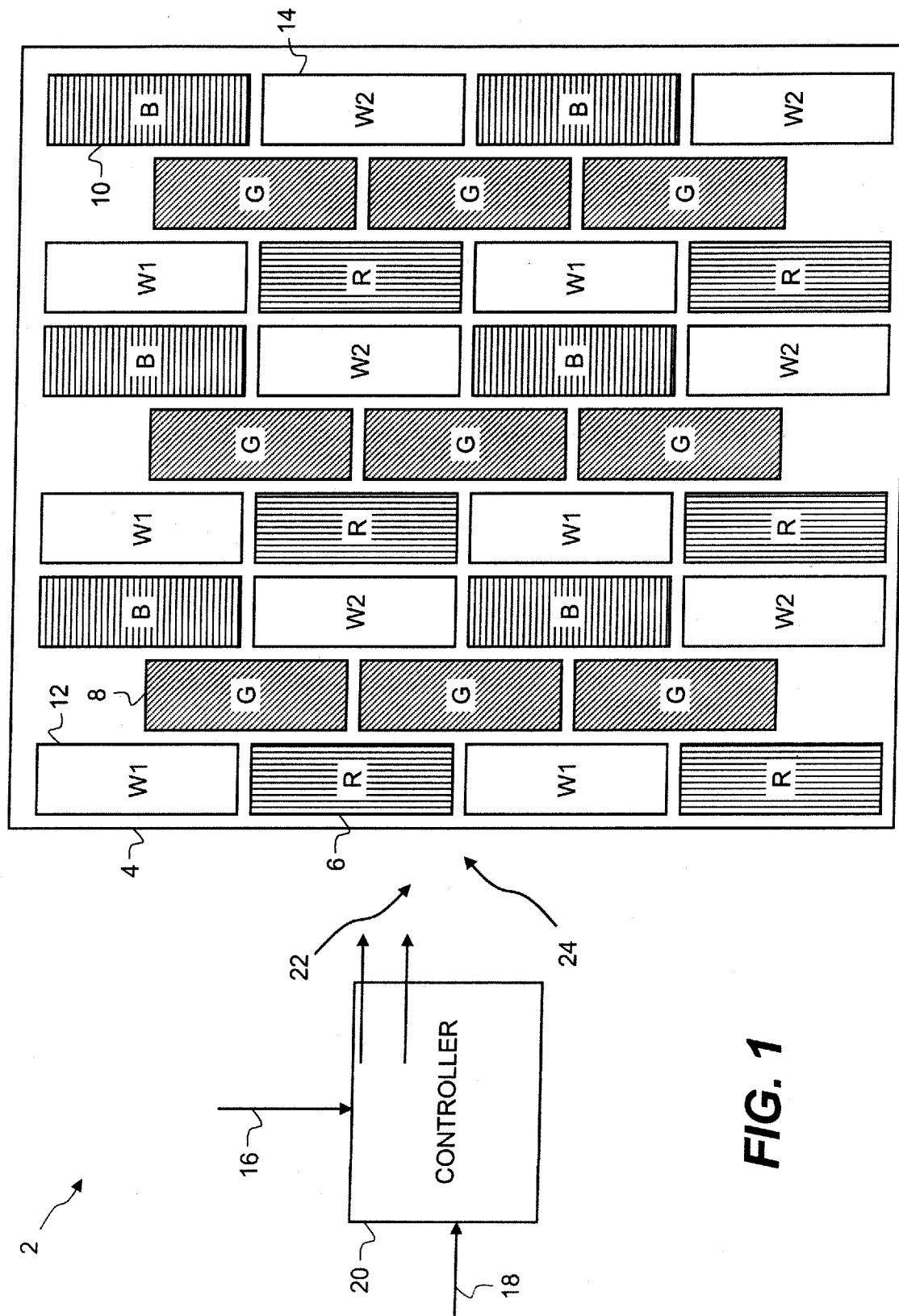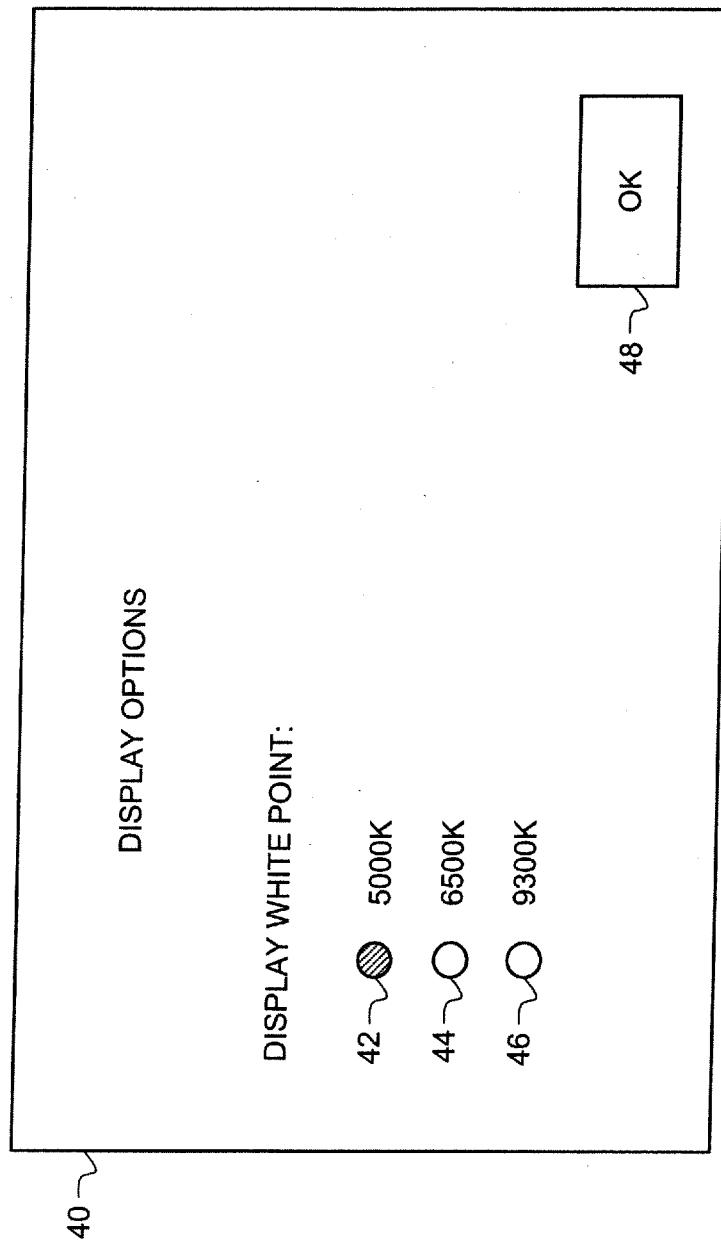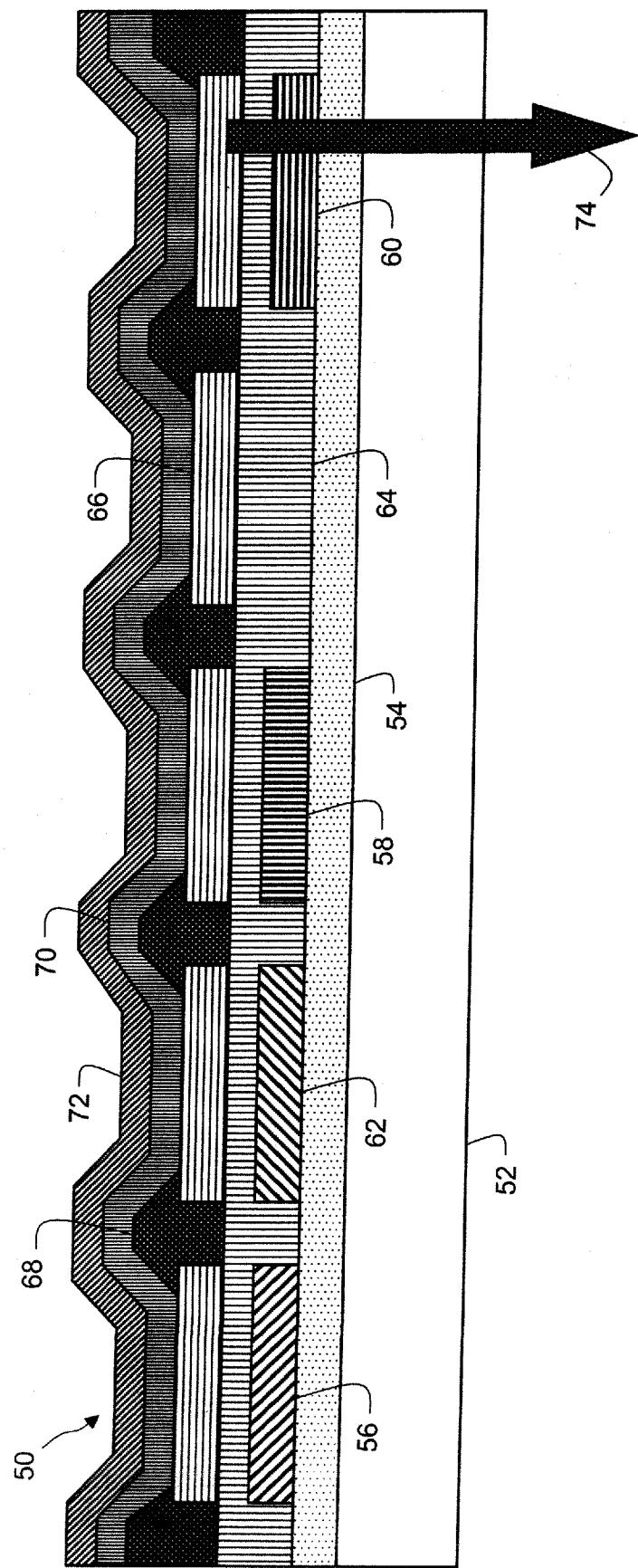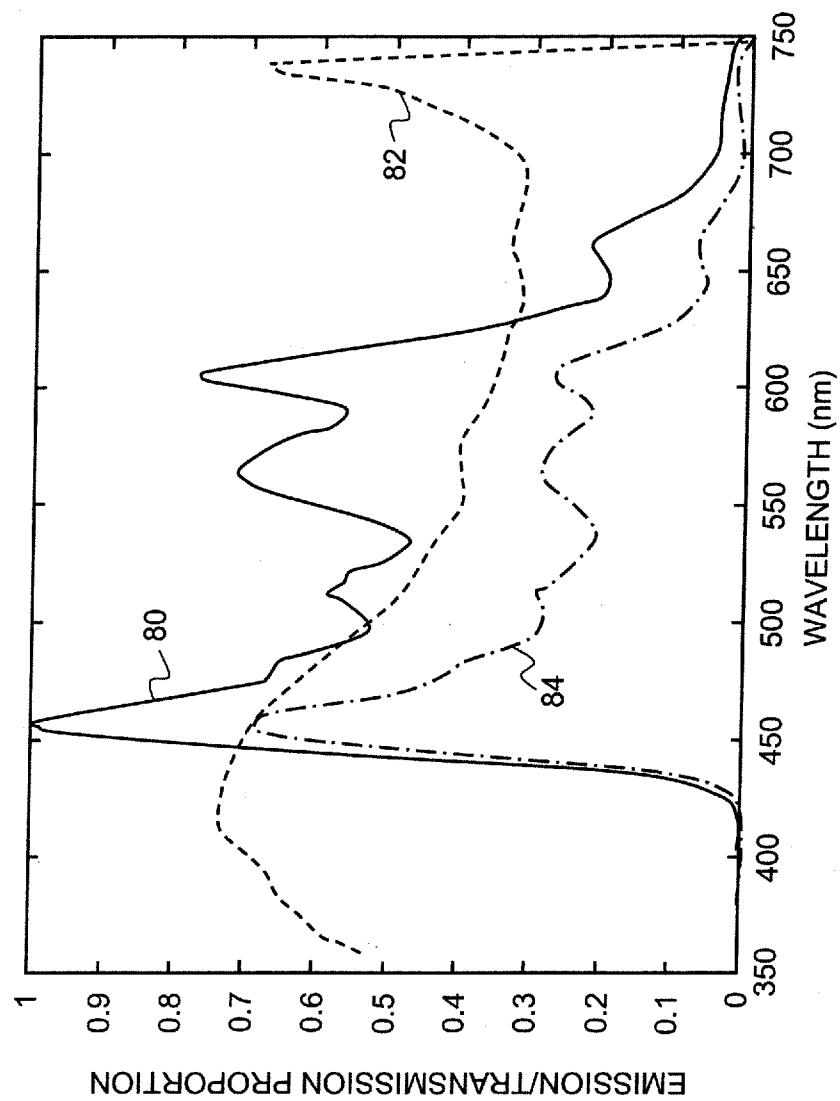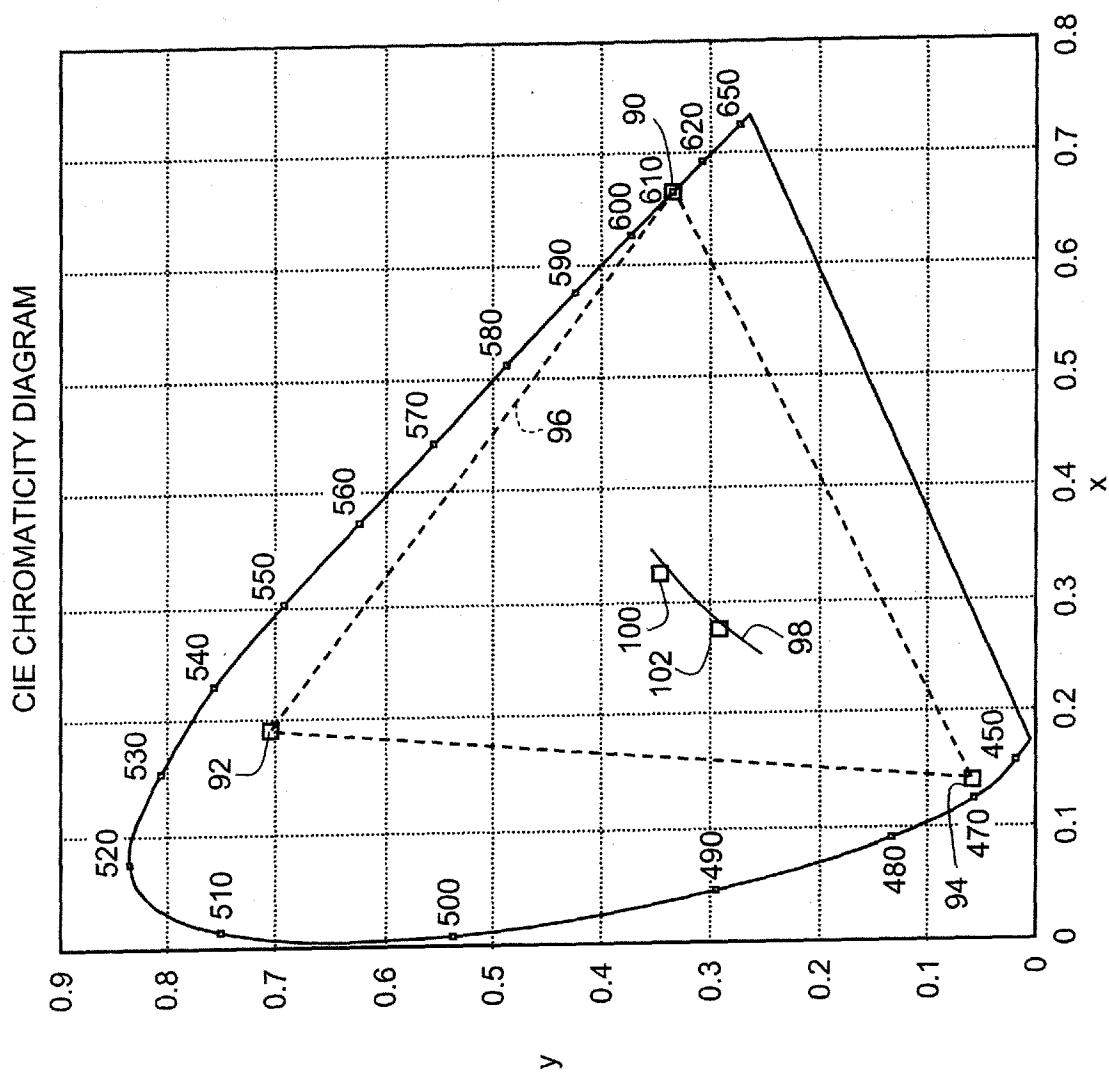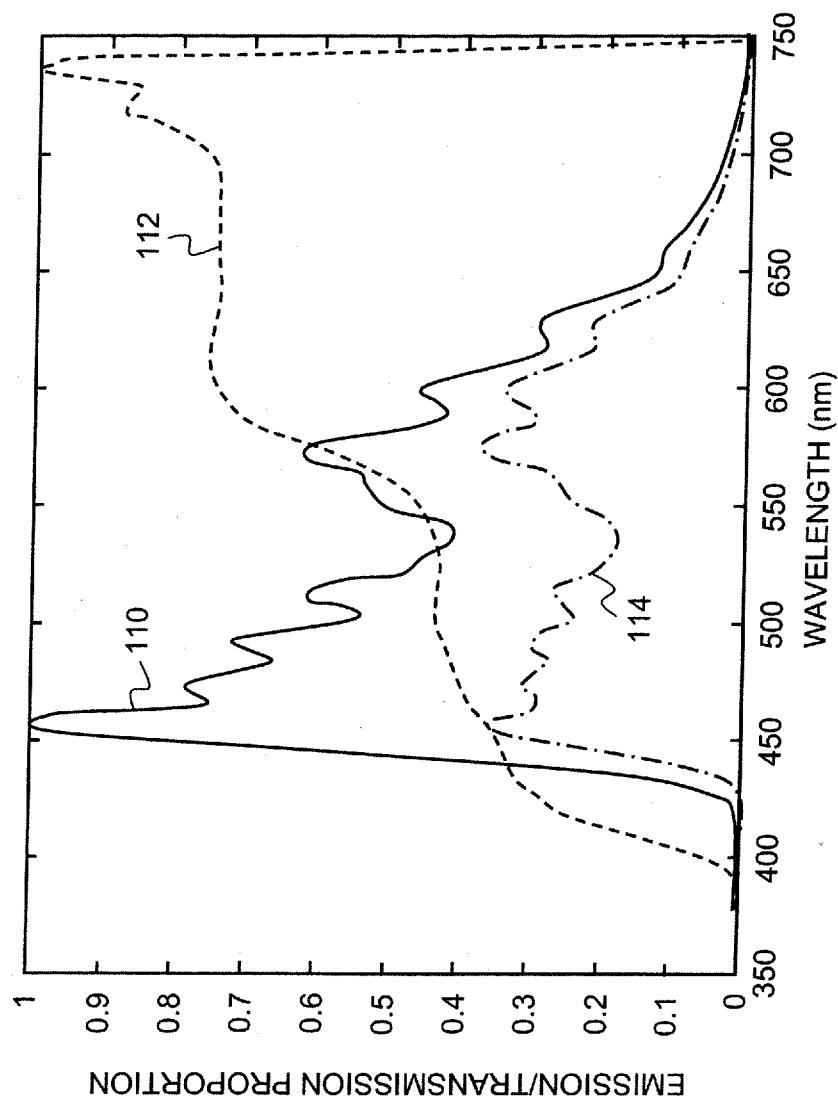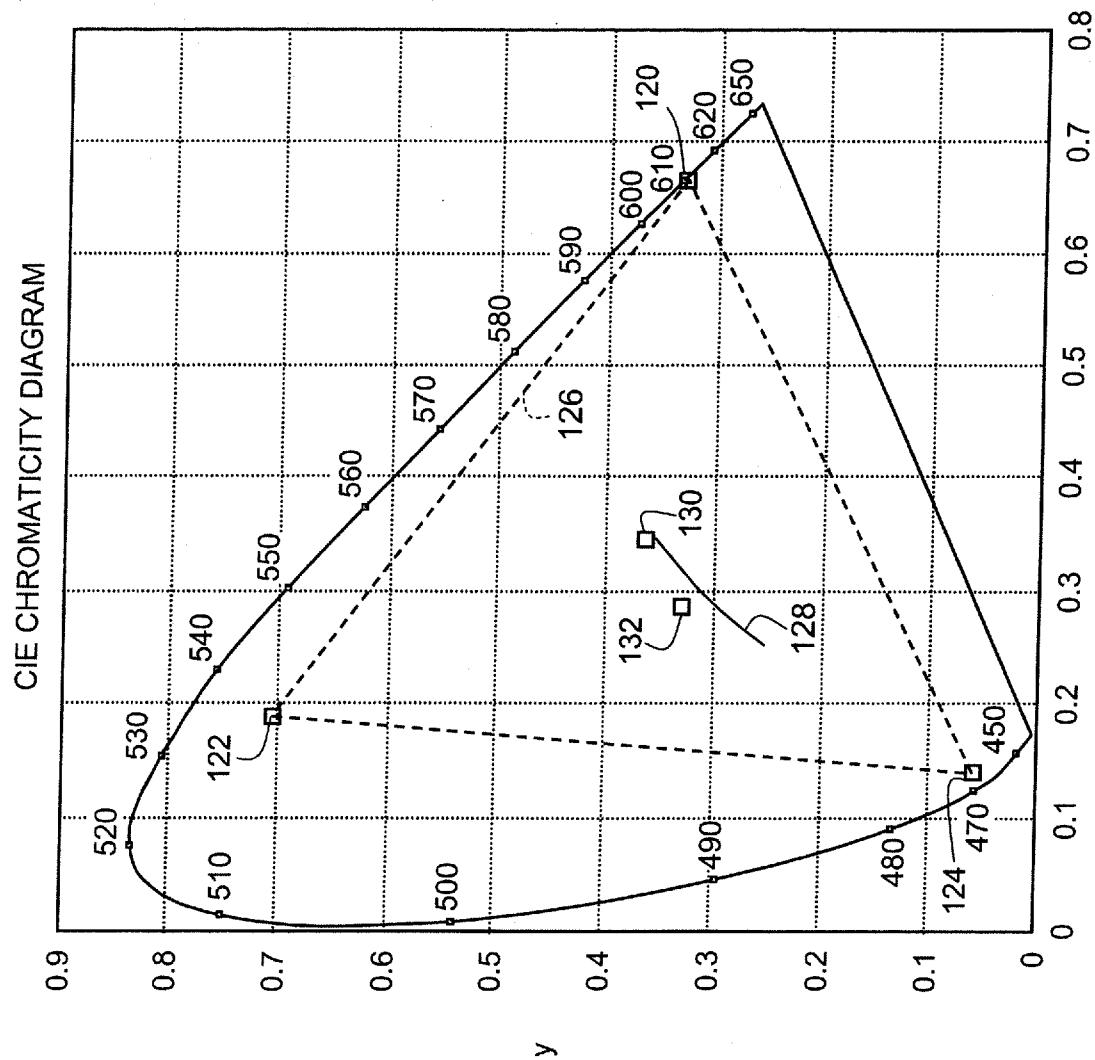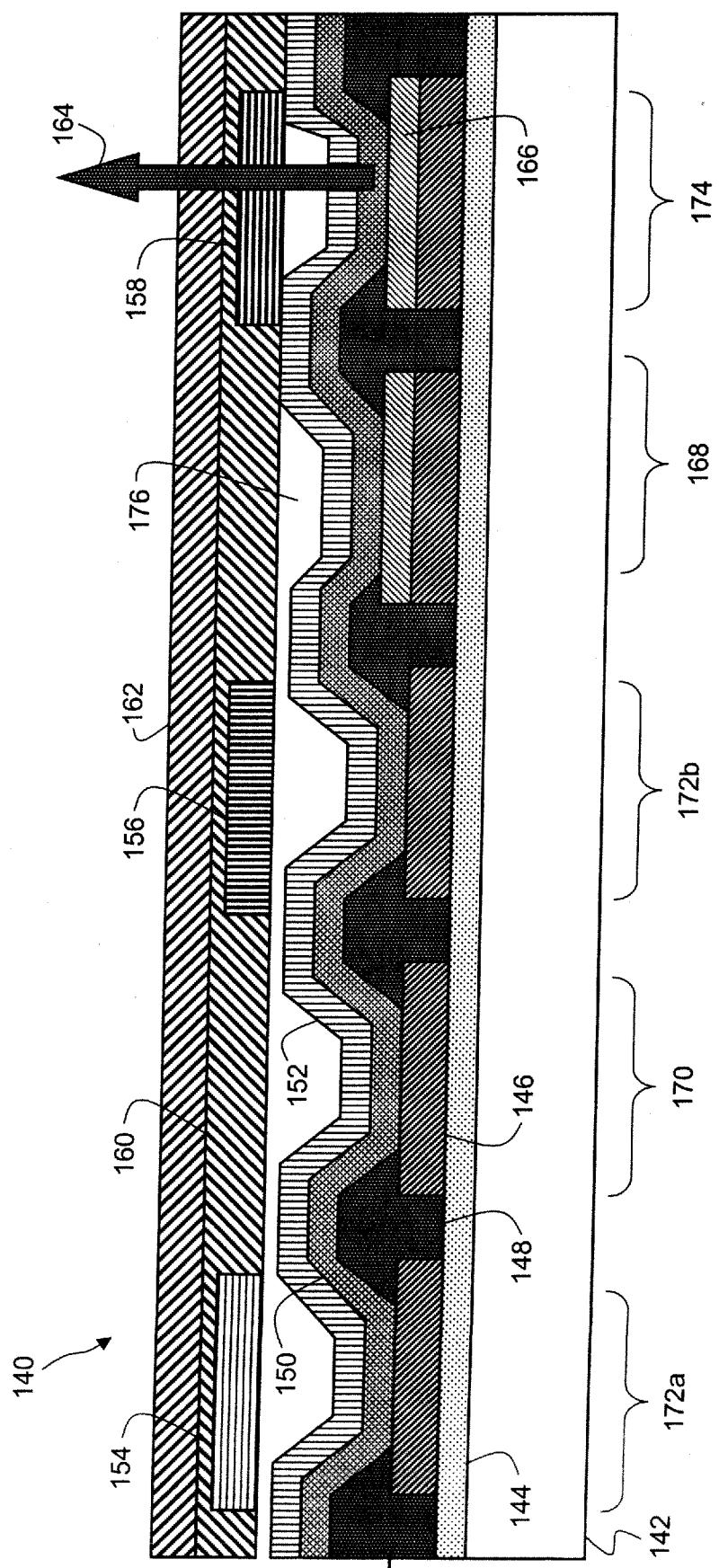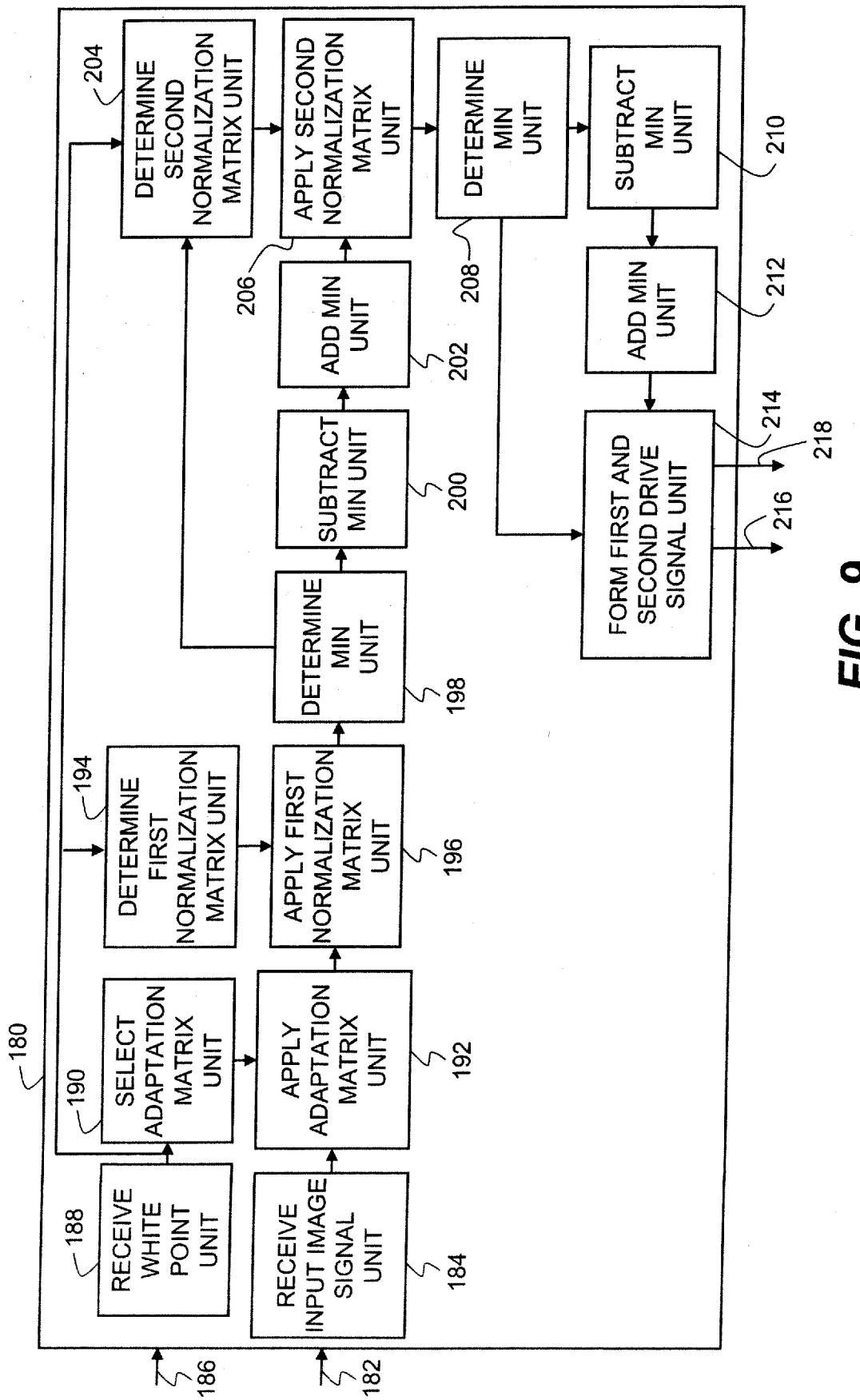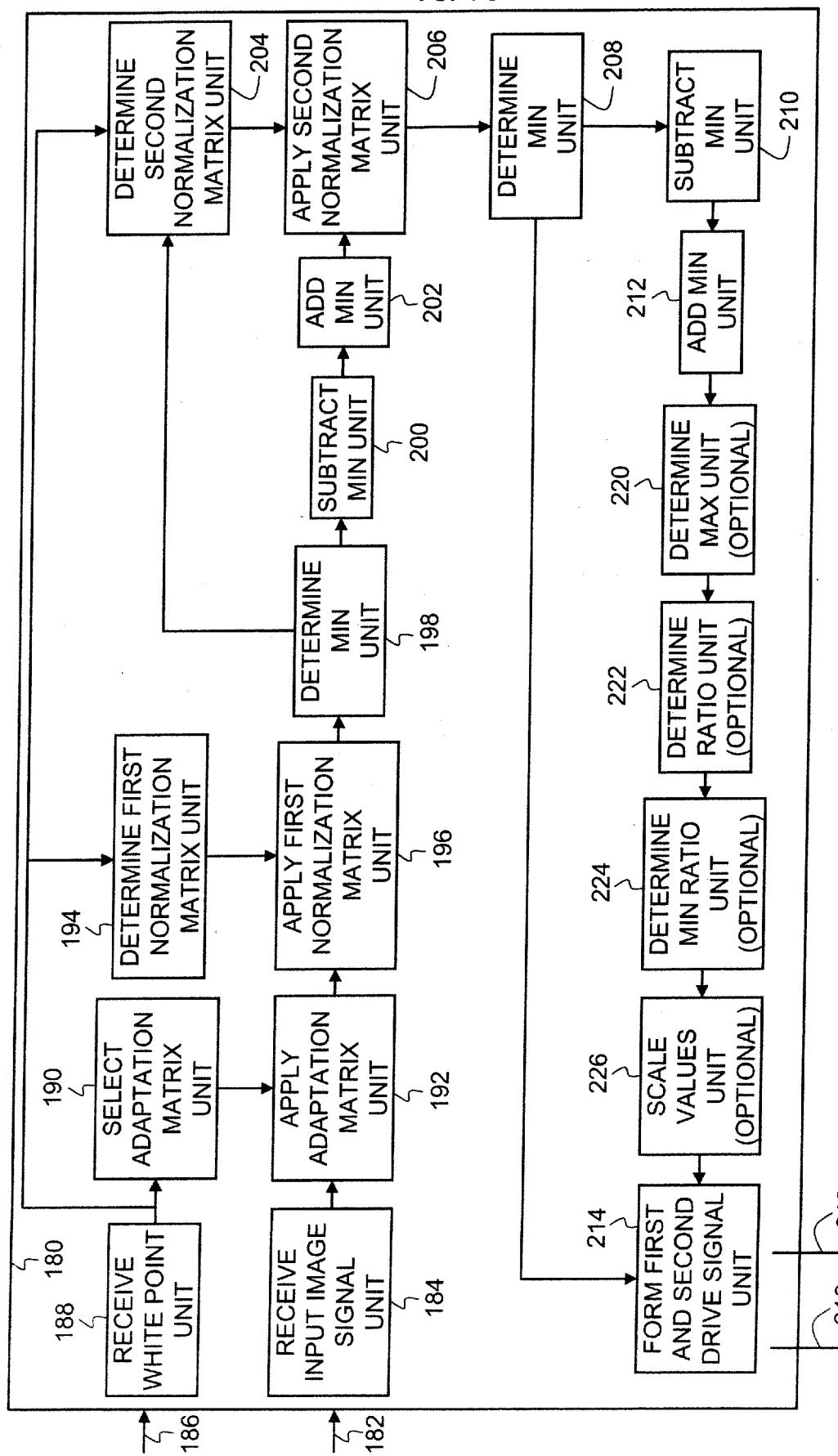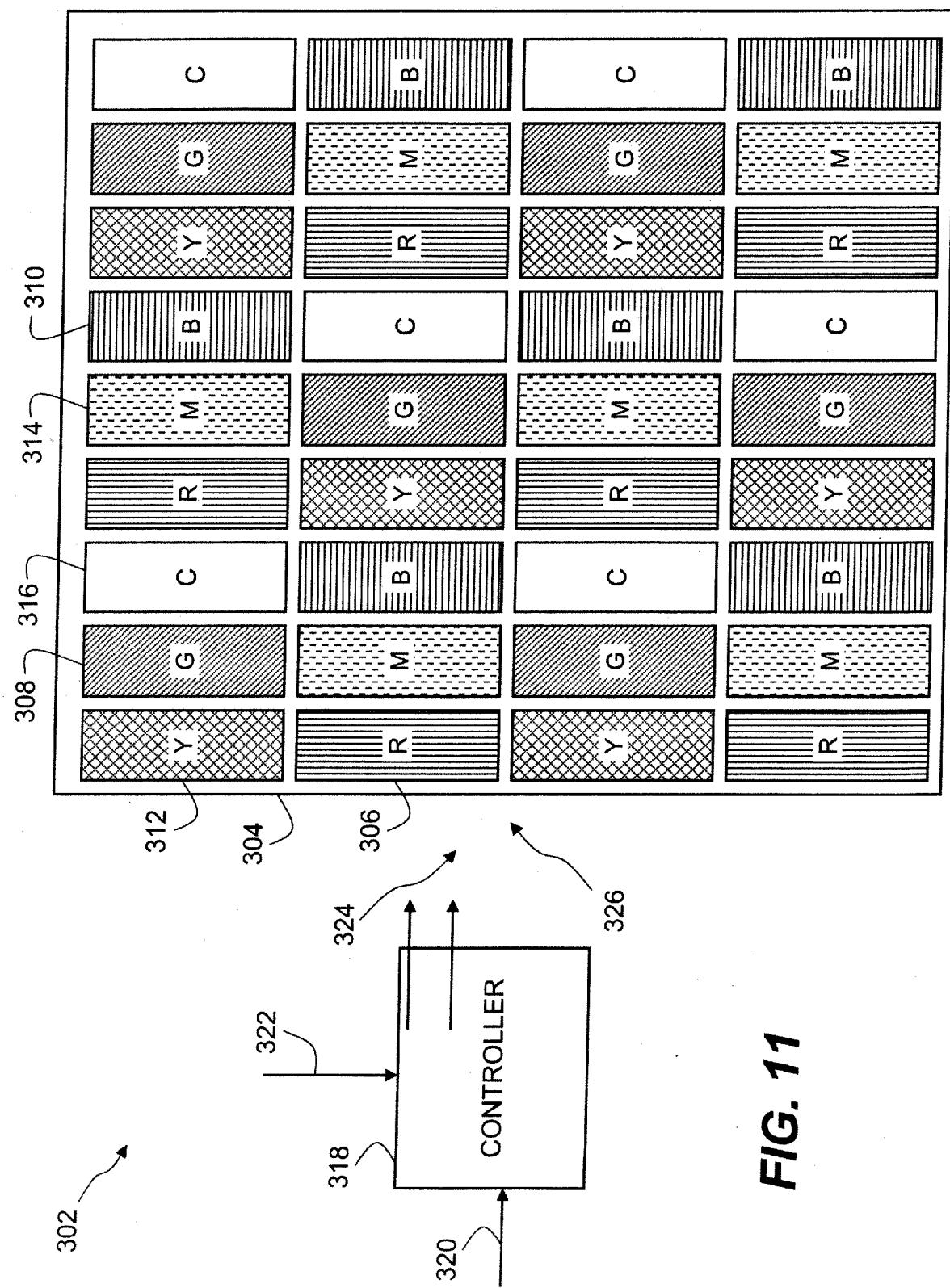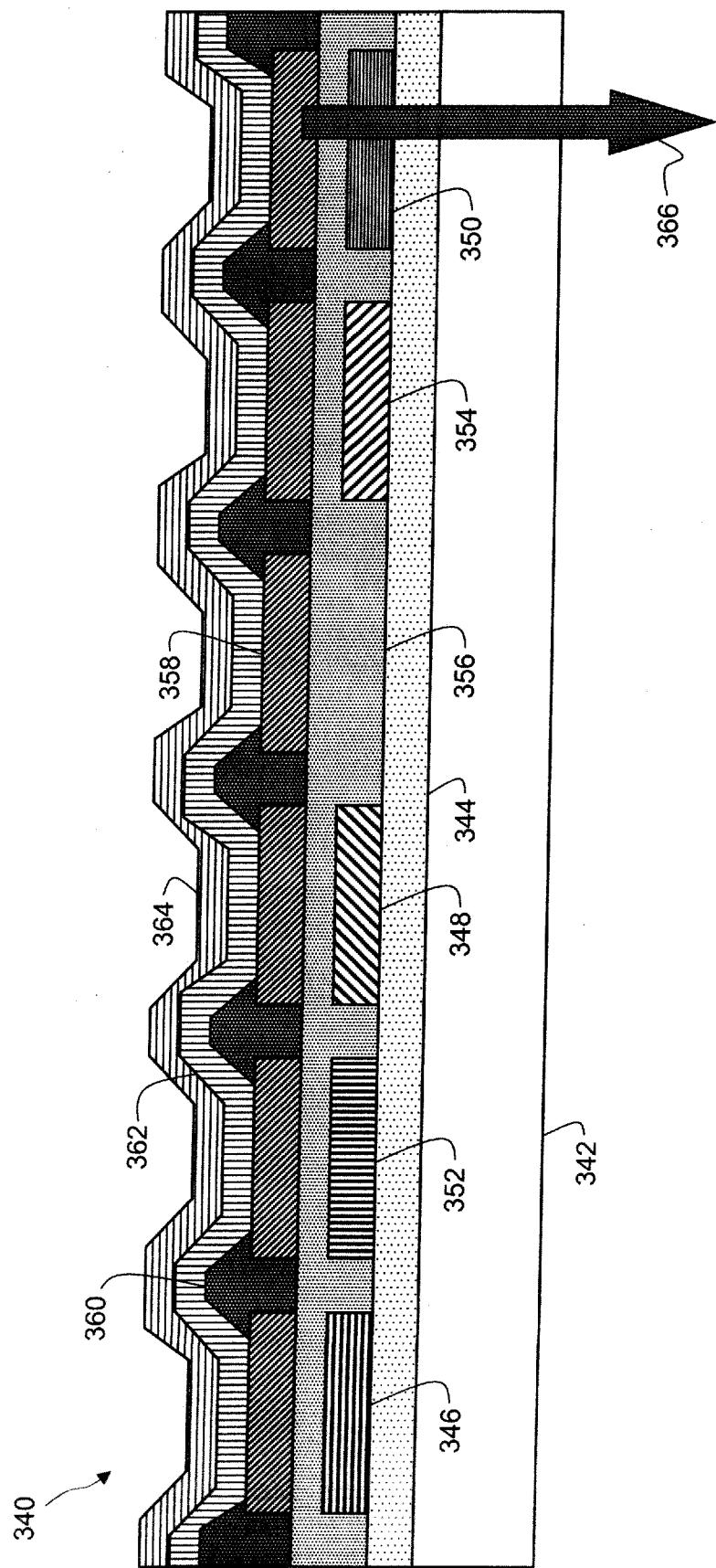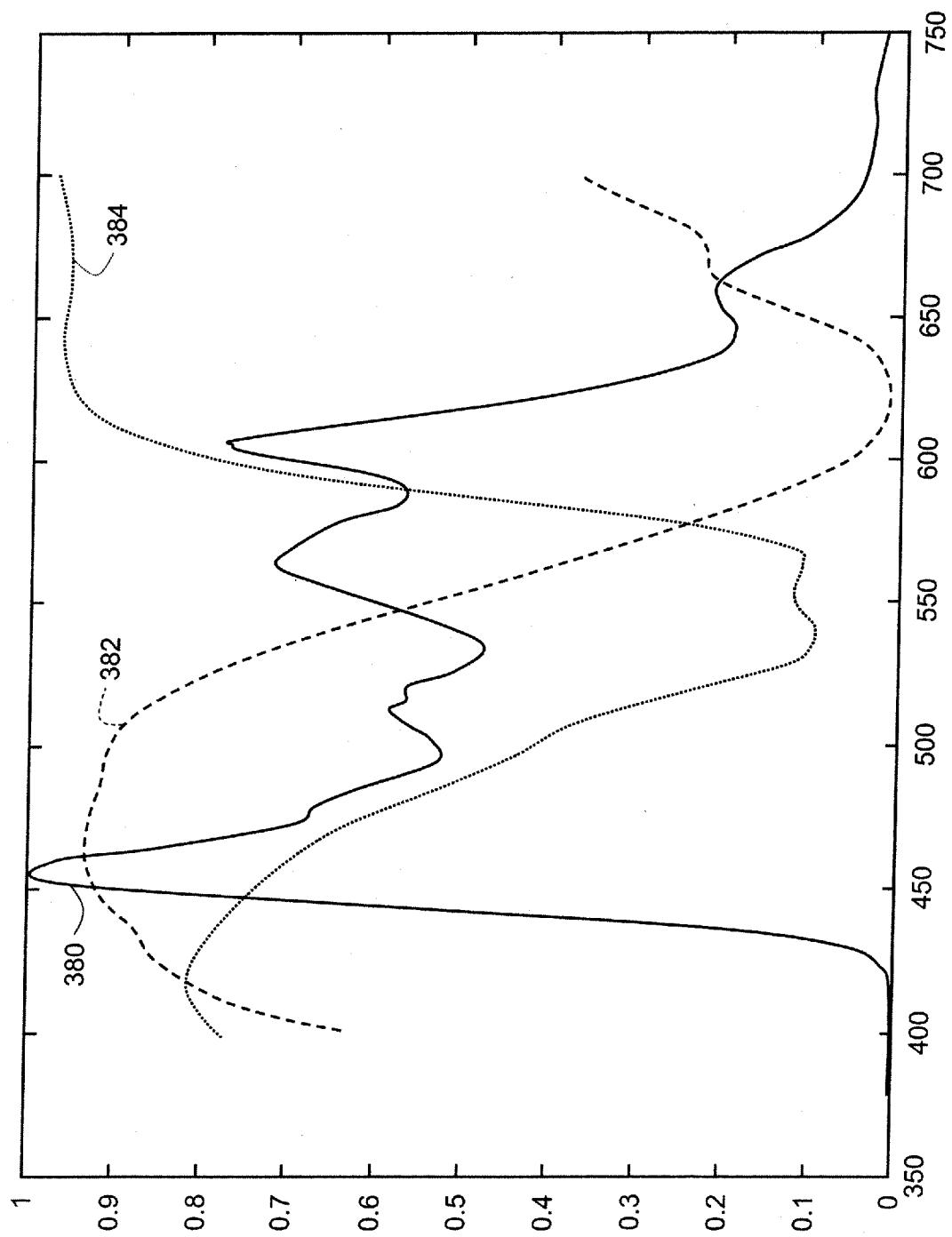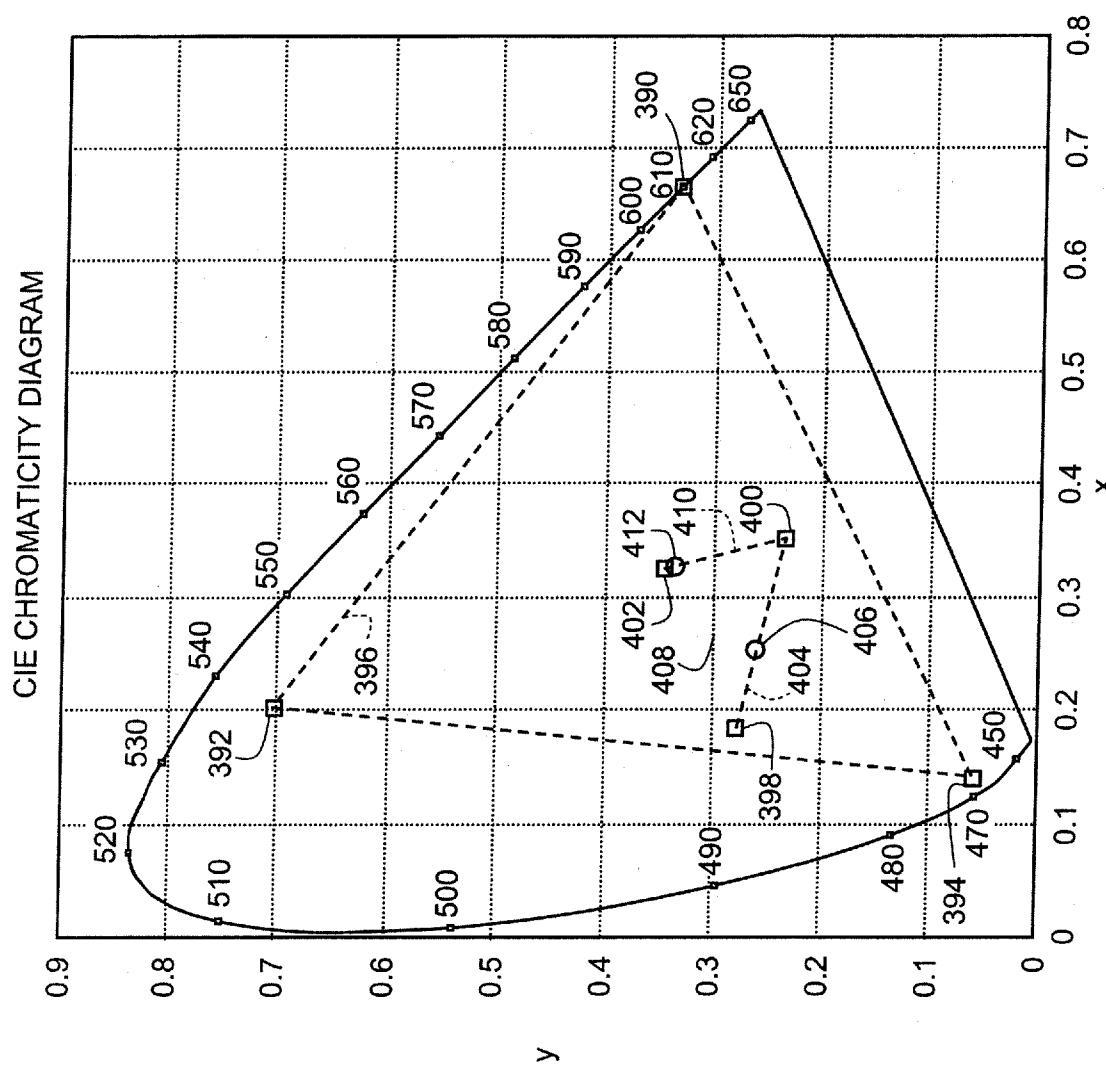
FIG. 14
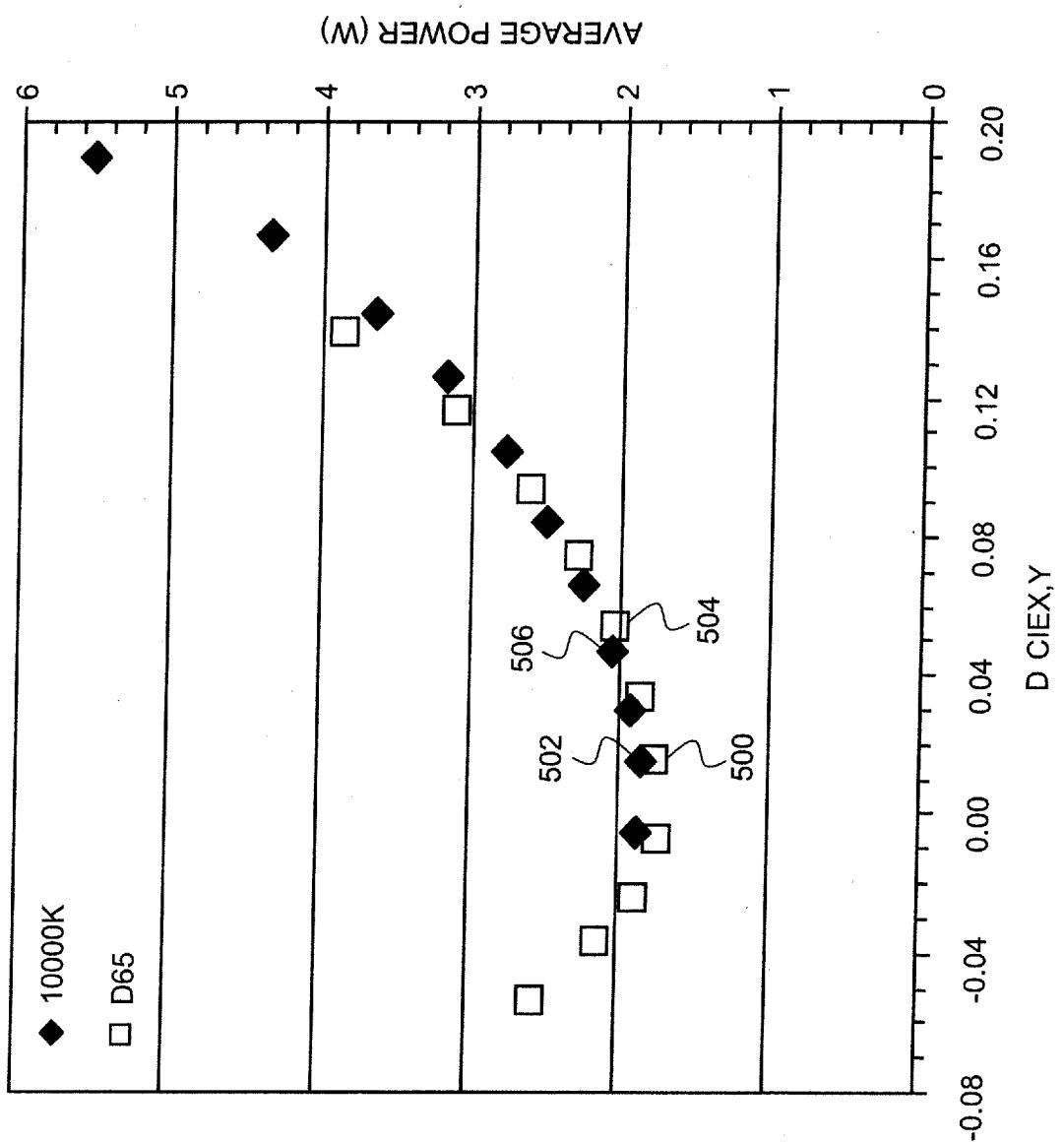
FIG. 15

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV.   G09G3/32   G09G3/20
ADD.   G09G3/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2008/018798 A1 (PARK KYONG-TAE [KR] ET AL) 24 January 2008 (2008-01-24) * abstract paragraph [0071] – paragraph [0077]; figure 4 -----	1,2,4,5, 11,13, 14,17,18
A	WO 2009/001579 A1 (SHARP KK [JP]; NAKANISHI KAZUHIRO; ITOH MOTOMITSU) 31 December 2008 (2008-12-31) * abstract -/--	1,13

| X | Further documents are listed in the continuation of Box C. | | X | See patent family annex. |

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 July 2010	29/07/2010

| Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31–70) 340-2040,
Fax: (+31–70) 340-3016 | Authorized officer

Corsi, Fabio |

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	& US 2010/103201 A1 (NAKANISHI KAZUHIRO [JP] ET AL) 29 April 2010 (2010-04-29) * abstract paragraph [0002] - paragraph [0009] paragraph [0099] - paragraph [0105]; figures 1,2 paragraph [0130] - paragraph [0136]; figures 14,15 -----	1,13
A	US 2006/044226 A1 (LIEDENBAUM COEN THEODORUS HUBE [NL] ET AL) 2 March 2006 (2006-03-02) * abstract paragraph [0002] paragraphs [0010] - [0022] paragraphs [0041], [0044] - [0045]; figures 3-4 paragraph [0064]; figure 5 -----	1,2,13, 14
A	JP 2007 141737 A (SHARP KK) 7 June 2007 (2007-06-07) * abstract paragraphs [0002] - [0003] paragraph [0011]; figures 2-3 paragraph [0014]; figure 6 paragraphs [0019] - [0032] paragraphs [0052] - [0063]; figures 1-2 paragraphs [0067] - [0069] paragraphs [0074] - [0082]; figure 4 paragraph [0087] paragraph [0092] paragraph [0099] paragraph [0120] - paragraph [0125]; figure 5 -----	1,13

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 2008018798	A1	24-01-2008	CN	101114423 A	30-01-2008
			EP	1883059 A1	30-01-2008
			KR	20080009497 A	29-01-2008
WO 2009001579	A1	31-12-2008	CN	101663702 A	03-03-2010
			US	2010103201 A1	29-04-2010
US 2006044226	A1	02-03-2006	AU	2003253179 A1	04-05-2004
			CN	1689064 A	26-10-2005
			EP	1556849 A1	27-07-2005
			WO	2004036535 A1	29-04-2004
			JP	2006503411 T	26-01-2006
			KR	20050065605 A	29-06-2005
JP 2007141737	A	07-06-2007	NONE		

专利名称(译)	电致发光显示屏，具有额外的原色和可调节的白点		
公开(公告)号	EP2430630A1	公开(公告)日	2012-03-21
申请号	EP2010722869	申请日	2010-05-07
[标]申请(专利权)人(译)	全球OLED TECH		
申请(专利权)人(译)	全球OLED科技有限责任公司		
当前申请(专利权)人(译)	全球OLED科技有限责任公司		
[标]发明人	MILLER MICHAEL E BOROSON MICHAEL L		
发明人	MILLER, MICHAEL, E. BOROSON, MICHAEL, L.		
IPC分类号	G09G3/32 G09G3/20 G09G3/30 G09G3/3208 H01L27/32 H01L51/52		
CPC分类号	G09G3/2003 G09G3/30 G09G3/3208 G09G2300/0452 G09G2320/0666 G09G2330/021 H01L27/3213 H01L27/322 H01L51/5265		
优先权	12/464123 2009-05-12 US		
其他公开文献	EP2430630B1		
外部链接	Espacenet		

摘要(译)

本发明提供一种适于接收三色输入图像信号的EL显示器，包括三个用于发射红色，绿色和蓝色光的色域限定EL发射器和两个用于发射至少两种附加颜色光的附加EL发射器，位于色域内和Plankian轨迹附近的至少两种其他颜色光的色度坐标;用于提供显示白点的结构;响应于所提供的显示白点和输入图像信号的控制器，用于为三个色域限定的EL发射器提供第一单独的驱动信号，为两个附加的EL发射器提供第二单独的驱动信号，其中相应的亮度值对应于第二个EL发射器单独的驱动信号每个都是输入图像信号和显示白点与两种附加颜色的伪黑体点之间的距离的函数。