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(54) OLED MULTICOLOR DISPLAYS

MEHRFARBIGE OLED-ANZEIGEN

AFFICHEURS MULTICOLORES OLED

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(73) Proprietor: **Global OLED Technology LLC**
Wilmington, Delaware 19801 (US)

(72) Inventor: **SPINDLER, Jeffrey Paul**
Rochester, New York 14617 (US)

(74) Representative: **Wibbelmann, Jobst et al**
Wuesthoff & Wuesthoff
Patent- und Rechtsanwälte
Schweigerstrasse 2
81541 München (DE)

(56) References cited:
US-A1- 2001 043 043 **US-A1- 2005 045 917**

EP 1 875 505 B1

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Description**FIELD OF INVENTION**

5 [0001] The present invention relates to organic light emitting diode (OLED) displays. More specifically, this invention relates to multicolor OLED displays having three or more pixels with improved power efficiency.

BACKGROUND OF THE INVENTION

10 [0002] Color, digital image display devices based on organic light emitting diodes (OLED) are well known. In the simplest form, an OLED is comprised of an anode for hole injection, a cathode for electron injection, and an organic media sandwiched between these electrodes to support charge recombination that yields emission of light. In order to construct an OLED display, a plurality of individually addressable OLED elements are arranged in a matrix of pixels. Each pixel includes an independently addressable OLED and is capable of producing light. Such matrixes can be of the 15 passive type where electroluminescent OLED layers are sandwiched between two sets of orthogonal electrodes (rows and columns). An example of a passive matrix driven OLED display device is described in U.S. Patent 5,276,380. Alternately, the OLED display can be constructed of the active matrix type where one or more circuit elements, such as a transistor or capacitor, is used to drive each OLED. An example of an active matrix driven OLED display device is described in U.S. Patent 5,550,066.

20 [0003] US 2001/0043043 A1 discloses an organic electroluminescent display panel including a substrate, an organic light emitting layer between two electrodes, one of which is transparent, and a color filter layer formed by evaporating a pigment and/or an organic dye, the organic display panel being divided into a plurality of organic electroluminescent devices capable of being independently controlled.

25 [0004] In order to construct a multicolor display, the pixels are arranged to produce a variety of colors. For example, a multicolor display can be constructed to have red, green, and blue pixels. Such a display is referred to as an RGB display. Additional colors can be achieved by such a display by mixing the light emitted by the red, green, and blue subpixels in various ratios.

30 [0005] However, the human eye is less sensitive to light emitted by the red pixels or the blue pixels compared to light emitted by the green pixels. As such, the red and blue pixels need to emit more light to achieve the desired brightness compared to the green pixels. This causes the display to consume a large amount of power.

35 [0006] Other displays, such as described in U.S. Patent 6,693,611, having additional pixels, which emit colors between that of the green, and the red pixels or between that of the blue and green pixels have been proposed. These additional pixels emit light having a color to which the human eye is more sensitive compared to either the red pixels or the blue pixels. As such, one or more of these additional pixels can be combined with one or more of the other pixels to produce 40 mixed colors, such as a white color. The resulting display can produce such mixed colors at a lower power consumption compared to a comparable RGB display.

45 [0007] One approach to constructing such a display having four or more differently colored pixels, as discussed in U.S. Patent 6,693,611, is to provide separate OLED electroluminescent layers for each of the pixels. This results in the need to pattern one or more of the OLED electroluminescent layers such that it is precisely aligned with the desired pixel. Several methods of patterning OLED layers are known in the art. For example, OLED layers can be deposited through a shadow mask in order to selectively deposit only in the desired areas. Shadow masks should then be aligned with the target pixel. Such alignment processes, however, are more complicated and can slow manufacturing throughput. Furthermore, the accuracy of the alignment of the shadow mask to the substrate tends to be poor, thereby requiring large tolerances for the patterned layers resulting in wasted surface area of the display. Shadow masks also tend to cause damage to the OLED pixels when the mask contacts the display substrate. Alternate methods of separately patterning OLED layers for each layer are also known. For example, a method of patterning the OLED layers by transferring the OLED material from a donor sheet by use of a laser is known. However, this method requires the use of consumable donor substrates and complex laser writing equipment. The process of writing each pixel with a laser can also reduce manufacturing throughput. Another example process for patterning OLED layers involves deposition of the OLED materials dissolved in a solvent as droplets by way of an ink jet print head. This method requires the precision placement of the ink jet droplets. As such, complex structures for controlling droplet placement and spread can be required and tolerances for the pixel area can be large.

SUMMARY OF THE INVENTION

55 [0008] It is an object of the present invention to avoid the above mentioned problems and provide a multicolor OLED display with improved power efficiency that reduces the need for precisely patterning one or more of the OLED layers. [0009] This object is achieved by an OLED display having at least first, second, and third differently colored pixels,

comprising:

5 a) a first light emitting layer provided over a substrate for the first and second pixels and a second light emitting, layer provided over the substrate for the first, second, and third pixels, wherein the first and second light emitting layers produce light having different spectra, and wherein the light produced by overlapping the first and second light emitting layers has substantial spectral components corresponding to the light output desired for the first and second pixels, and the light produced by the second light emitting layer has substantial spectral components corresponding to the light output desired for the third pixel; and

10 b) first and second color filters in operative relationship with the first and second pixels.

ADVANTAGES

[0010] The present invention provides a multicolor OLED display having at least three different color pixels that can be made more effectively.

[0011] Because of the organization of the design of the multicolor OLED display, simplified manufacturing steps can be used with fewer precise alignments or patterning steps.

[0012] A feature of the present invention is that multicolor OLED displays made in accordance with the present invention can provide improved power efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

25 FIG. 1 shows a multicolor OLED display having three differently colored pixels;
 FIG. 2 shows a top side view of a pixel according to the first embodiment of the present invention;
 FIG. 3 shows a cross section view of a group of pixels taken along the line 3-3' of FIG. 2;
 FIG. 4 shows a top side view of a pixel according to the second embodiment of the present invention;
 FIG. 5 shows a cross section view of a group of pixels taken along the line 5-5' of FIG. 4;
 FIG. 6 shows a multicolor OLED display having four differently colored pixels;
 30 FIG. 7 shows a top side view of a pixel according to the third embodiment of the present invention;
 FIG. 8 shows a cross section view of a group of pixels taken along the line 8-8' of FIG. 7;
 FIG. 9 shows a multicolor OLED display having five differently colored pixels;
 FIG. 10 shows a top side view of a pixel according to the fourth embodiment of the present invention;
 FIG. 11 shows a cross section view of a group of pixels taken along the line 11-11' of FIG. 10; and
 35 FIG. 12 shows the EL Spectra for OLED devices of Examples 1 to 3.

DETAILED DESCRIPTION OF THE INVENTION

40 [0014] FIG. 1 shows an example of a multicolor OLED display including three pixels that produce different colored light emission. For example, pixel **11a** preferably produces red light, pixel **11b** preferably produces green light, and pixel **11c** preferably produces blue light. These pixels can be arranged in groups, such as pixel group **10**. Although it is shown that each pixel group includes each of the differently colored pixels, the present invention is not limited to this case. Instead, some colored pixels can be present in greater number than other colored pixels.

45 [0015] FIG. 2 shows a top side view of pixels **11a**, **11b**, and **11c** according to the first embodiment of the present invention. In a passive matrix configuration, these pixels can be addressed by providing a matrix of orthogonal electrodes such as first electrodes **110a**, **110b**, and **110c** and second electrode **130**. That is, pixel **11a** is constructed from first electrode **110a** and second electrode **130**, pixel **11b** is constructed from first electrode **110b** and second electrode **130**, and pixel **11c** is constructed from first electrode **110c** and second electrode **130**. In this configuration, all pixels in a column share the same first electrode and all pixels in a row share the same second electrode. As such, these pixels are arranged into a stripe pattern. However, the present invention is not limited to this arrangement and other arrangements such as delta pattern arrangements and quad arrangements can be applied by one skilled in the art. Furthermore, the present invention is not limited to the passive matrix configuration and an active matrix driving scheme can be applied by one skilled in the art.

55 [0016] According to the present invention, light emitting layer **123a** is provided for pixels **11a** and **11b** so as to be common between both of these pixels. This requires light emitting layer **123a** to be precisely aligned or patterned to these pixels. Light emitting layer **123c** is provided for pixels **11a**, **11b**, and **11c** and is common to all pixels, thus requiring no patterning step. In this manner, the number of precision aligned depositions required to form these three differently colored pixels is reduced from three to one. Light emitting layer **123a** can be formed from a single step, such as for

example, deposition through a single shadow mask, precise placement of one or more droplets from the same ink jet head, or transfer from the same donor sheet. As such, this layer can be continuously formed between pixels **11a** and **11b** as shown. This can be achieved, for example, by using a single opening in the shadow mask to deposit the entire layer. Similarly, light emitting layer **123c** can be formed from a single source. Such a continuous arrangement is preferred to reduce surface area allocated for alignment tolerances in the manufacturing process. To facilitate such a continuous arrangement, the pixels, which share the same light emitting layer, are preferably disposed to be adjacent to one and other. For example, pixel **11a** is adjacent to pixel **11b** as shown.

[0017] Light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between red and green, otherwise referred to as yellow-orange. Light emitting layer **123a** is arranged so as to produce light having spectral components corresponding to the desired colors of both pixel **11a** and pixel **11b**. This can be achieved by forming a light emitting layer of materials that emit a wide spectrum of light in the red, red-orange, orange, yellow-orange, yellow, yellow-green, and green wavelengths. Similarly, light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a blue color. Light emitting layer **123c** is arranged so as to produce light having spectral components corresponding to the desired color of pixel **11c**. Although light emitting layers **123a** and **123c** are overlapped for pixels **11a** and **11b**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired colors of both pixels **11a** and **11b**. In order to achieve the red color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission, or in operative relationship, in pixel **11a** to absorb undesired spectral components for pixel **11a** and pass the desired spectral components corresponding to the desired red color. Color filter **140a** can be constructed, for example, to transmit red light and absorb light having lower wavelengths. In order to achieve the green color desired for pixel **11b**, color filter **140b** is formed in operative relationship, that is, at least partially in the path of the light emission between the pixel and the viewer, in pixel **11b** to absorb undesired spectral components for pixel **11b** and pass the desired spectral components corresponding to the desired a green color. That is, color filter **140b** can be constructed, for example, to transmit green light and absorb light having different wavelengths. The blue color desired for pixel **11c** can be achieved with or without the use of a color filter.

[0018] An alternate three pixel embodiment can be achieved by providing a first pixel emitting blue light, a second pixel emitting green light, a third pixel emitting red light. In this alternate embodiment case, the first light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between blue and green, otherwise referred to as blue-green. Light emitting layer **123a** is arranged so as to produce light having spectral components corresponding to the desired colors of both pixel **11a** and pixel **11b**. This can be achieved by forming a light emitting layer of materials that emit a wide spectrum of light in the blue, blue-green, green-blue and green wavelengths. Similarly, light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a red color. Light emitting layer **123c** is arranged so as to produce light having spectral components corresponding to the desired color of pixel **11c**. Although light emitting layers **123a** and **123c** are overlapped for pixels **11a** and **11b**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired colors of both pixels **11a** and **11b**. In order to achieve the blue color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission, or in operative relationship, in pixel **11a** to absorb undesired spectral components for pixel **11a** and pass the desired spectral components corresponding to the desired blue color. Color filter **140a** can be constructed, for example, to transmit blue light and absorb light having higher wavelengths. In order to achieve the green color desired for pixel **11b**, color filter **140b** is formed in the path of the light emission, or in operative relationship, in pixel **11b** to absorb undesired spectral components for pixel **11b** and pass the desired spectral components corresponding to the desired green color. Color filter **140b** can be constructed, for example, to transmit green light and absorb light having different wavelengths. The red color desired for pixel **11c** can be achieved with or without the use of a color filter.

[0019] FIG. 3 shows a cross sectional view of the device of FIG. 2 taken along line 3-3'. FIG. 3 shows that pixels **11a**, **11b**, and **11c** produce internal light emission **220a**, **220b**, and **220c**, respectively. Internal light emission **220c** exits the device without filtration to become external light emission **210c**. Internal light emission **220a** passes through color filter **140a** prior to exiting the device resulting in external light emission **210a**. Similarly, internal light emission **220b** passes through color filter **140b** prior to exiting the device resulting in external light emission **210b**. Color filters **140a** and **140b** are preferably organic layers deposited by lamination or spin coating methods known in the art. The color filters are preferably photo-patterable as is known in the art wherein the color filter materials are deposited over the entire display surface, exposed with a light source, and either the exposed or the unexposed regions are removed by use of a solvent. This method provides effective alignment accuracy to the desired pixel region. However, the present invention is not limited to this preferred case, and other ways of depositing and patterning the color filter material as are known in the art can be employed by one skilled in the art. Furthermore, additional black matrix structures (not shown) which absorb some portion of all visible light can optionally be disposed in the non-emitting regions between pixels to reduce ambient light reflection and improve display contrast as is known in the art.

[0020] The pixels are constructed over substrate **100**. Light can exit the device by passing through substrate **100** as shown. Such a configuration is known as a bottom emitting device. Substrate **100** should be constructed of a transparent

material such as glass or plastic. Alternately, the device can be constructed so that light exits the device in the direction opposite the substrate. Such a configuration is known as a top emitting device. The substrate can be selected from materials that are not transparent such as metals, or semiconductor materials like silicon wafers.

[0021] For the case of the bottom emitting device, as shown, first electrodes **110a**, **110b**, and **110c** are arranged to transmit light and are preferably constructed of a conductive transparent material such as indium tin oxide (ITO) or indium zinc oxide (IZO). Second electrode **130** is preferably constructed of a reflective conductive material such as aluminum, silver, magnesium silver alloy, or the like. These electrodes can be constructed of a single layer or of multiple layers in order to achieve the desired light absorption or reflection properties and conductivity properties. For the alternate case of a top emitting device, it is preferable that the second electrode is transparent and the first electrode is reflective. A top emitting device, color filters **140a** and **140b** would be disposed in the path of the light on the side of the second electrode. Although the first electrodes are shown as being arranged in the column direction and the second electrode is shown as being arranged in the row direction, the opposite arrangement is also possible.

[0022] FIG. 4 shows a top side view of pixels **11a**, **11b**, and **11c** according to the second embodiment of the present invention. Light emitting layer **123a** is provided for pixels **11a**, **11b**, and **11c** so as to be common between all pixels, and therefore does not require a precise alignment or patterning step. Light emitting layer **123c** is provided for pixel **11c** only, thus requiring a precise alignment or patterning step. In this manner, the number of precision aligned depositions required to form these three differently colored pixels is reduced from three to one. Light emitting layers **123a** and **123c** can be formed as previously described.

[0023] Light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between red and green, and produces light having spectral components corresponding to the desired colors of both pixel **11a** and pixel **11b**. Similarly, light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a blue color, and produces light having spectral components corresponding to the desired color of pixel **11c**. Although light emitting layers **123a** and **123c** are overlapped for pixel **11c**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired color of pixel **11c**. In order to achieve the red color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission, or in operative relationship, in pixel **11a** to absorb undesired spectral components for pixel **11a** and pass the desired spectral components corresponding to the desired red color. In order to achieve the green color desired for pixel **11b**, color filter **140b** is formed in the path of the light emission, or in operative relationship, in pixel **11b** to absorb undesired spectral components for pixel **11b** and pass the desired spectral components corresponding to the desired a green color. The blue color desired for pixel **11c** can be achieved with or without the use of a color filter.

[0024] Another alternate three pixel embodiment can be achieved by providing a first pixel emitting blue light, a second pixel emitting green light, and a third pixel emitting red light. In this alternate embodiment case, the first light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between blue and green, and produces light having spectral components corresponding to the desired colors of both pixel **11a** and pixel **11b**. Similarly, light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a red color, and produces light having spectral components corresponding to the desired color of pixel **11c**. Although light emitting layers **123a** and **123c** are overlapped for pixel **11c**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired colors of pixel **11c**. In order to achieve the blue color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission, or in operative relationship, in pixel **11a** to absorb undesired spectral components for pixel **11a** and pass the desired spectral components corresponding to the desired blue color. Color filter **140a** can be constructed, for example, to transmit blue light and absorb light having higher wavelengths. In order to achieve the green color desired for pixel **11b**, color filter **140b** can be constructed, for example, to transmit green light and absorb light having different wavelengths. The red color desired for pixel **11c** can be achieved with or without the use of a color filter.

[0025] FIG. 5 shows a cross sectional view of the device of FIG. 4 taken along line 5-5'. FIG. 5 shows that pixels **11a**, **11b**, and **11c** produce internal light emission **220a**, **220b**, and **220c**, respectively. Internal light emission **220c** exits the device without filtration to become external light emission **210c**. Internal light emission **220a** passes through color filter **140a** prior to exiting the device resulting in external light emission **210a**. Similarly, internal light emission **220b** passes through color filter **140b** prior to exiting the device resulting in external light emission **210b**. Color filters **140a** and **140b** are preferably organic layers as described previously.

[0026] The pixels are constructed over substrate **100**. Light can exit the device by passing through substrate **100** for the case of the bottom emitting device, as shown. First electrodes **110a**, **110b**, and **110c** are arranged to transmit light and are preferably constructed of a conductive transparent material such as indium tin oxide (ITO) or indium zinc oxide (IZO). Second electrode **130** is preferably constructed of a reflective conductive material such as previously described in order to achieve the desired light absorption or reflection properties and conductivity properties.

[0027] The above embodiments are described as providing three differently colored pixels. However, some advantage can be obtained according to alternate embodiments whereby four differently colored pixels are provided. In FIG. 6 for example, a multicolor display can be constructed according to the present invention by providing a first pixel **11a** emitting

red light, a second pixel **11c** emitting green light, a third pixel **11d** emitting blue light, and a fourth pixel **11b** emitting a color between that of the first and second pixels. As such, a common light emitting layer would be provided over the first, second and fourth pixels. FIG. 7 shows a top side view of pixels **11a**, **11b**, **11c**, and **11d** according to the third embodiment of the present invention. Light emitting layer **123a** is provided for pixels **11a**, **11b** and **11c** so as to be common between these pixels, and therefore requires a precise alignment or patterning step. Light emitting layer **123c** is provided for all pixels, and therefore does not require a precise alignment or patterning step. In this manner, the number of precision aligned depositions required to form these four differently colored pixels is reduced from four to one. Light emitting layers **123a** and **123c** can be formed as previously described.

[0028] Light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between red and green, and produces light having spectral components corresponding to the desired colors of pixels **11a**, **11b**, and **11c**. Similarly, light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a blue color, and produces light having spectral components corresponding to the desired color of pixel **11c**. Although light emitting layers **123a** and **123c** are overlapped for pixels **11a**, **11b**, and **11c**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired color of pixels **11a**, **11b**, and **11c**. In order to achieve the red color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission in pixel **11a** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired red color. In order to achieve the green color desired for pixel **11c**, color filter **140c** is formed in the path of the light emission in pixel **11c** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired green color. The desired color between red and green for pixel **11b** is achieved without the use of a color filter. The blue color desired for pixel **11c** can be achieved with or without the use of a color filter. A multicolor OLED display made in this manner can have higher power efficiency. The high efficiency unfiltered wide emission spectrum used in pixel **11b** can be used frequently to replace either the lower efficiency red or green pixels to produce within gamut colors, as is known in the art. Efficiency can be measured for example in candelas (cd) per ampere (A) of current. As such high efficiency light emission results in displays that consume less power, or in other words, have high power efficiency.

[0029] Another alternate four pixel embodiment can be achieved by providing a first pixel **11a** emitting blue light, a second pixel **11c** emitting green light, a third pixel **11d** emitting red light, and a fourth pixel **11b** emitting a color between that of the first and second pixels. Light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between blue and green, and produces light having spectral components corresponding to the desired colors of pixels **11a**, **11b**, and **11c**. Similarly, light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a red color, and produces light having spectral components corresponding to the desired color of pixel **11d**. Although light emitting layers **123a** and **123c** are overlapped for pixels **11a**, **11b**, and **11c**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired color of pixels **11a**, **11b**, and **11c**. In order to achieve the blue color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission in pixel **11a** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired blue color. In order to achieve the green color desired for pixel **11c**, color filter **140c** is formed in the path of the light emission in pixel **11c** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired green color. The desired color between blue and green for pixel **11b** is achieved without the use of a color filter. The red color desired for pixel **11d** can be achieved with or without the use of a color filter. A multicolor OLED display made in this manner can have higher power efficiency. The high efficiency unfiltered wide emission spectrum used in pixel **11b** can be used frequently to replace either the lower efficiency blue or green pixels to produce within gamut colors, as is known in the art.

[0030] FIG. 8 shows a cross sectional view of the device of FIG. 7 taken along line 8-8'. FIG. 8 shows that pixels **11a**, **11b**, **11c**, and **11d** produce internal light emission **220a**, **220b**, **220c**, and **220d**, respectively. Internal light emission **220b** and **220d** exit the device without filtration to become external light emission **210b** and **210d**, respectively. Internal light emission **220a** passes through color filter **140a** prior to exiting the device resulting in external light emission **210a**. Similarly, internal light emission **220c** passes through color filter **140c** prior to exiting the device resulting in external light emission **210c**. Color filters **140a** and **140c** are preferably organic layers as described previously.

[0031] The pixels are constructed over substrate 100. Light can exit the device by passing through substrate 100 for the case of the bottom emitting device, as shown. First electrodes **110a**, **110b**, **110c**, and **110d** are arranged to transmit light and are preferably constructed of a conductive transparent material such as previously described. Second electrode 130 is preferably constructed of a reflective conductive material such as previously described in order to achieve the desired light absorption or reflection properties and conductivity properties.

[0032] Yet another alternate four pixel embodiment can be achieved by providing a fourth pixel to the second embodiment of this invention. In this manner, the fourth pixel emits a color between that of the first and second pixels. As such, a common first light emitting layer would be provided over the first, second, third, and fourth pixels, while the second light emitting layer would be provided only over the third pixel. In this alternate embodiment case, the first and second pixels have color filters, while the third and fourth pixels have no color filters.

[0033] FIG. 9 shows an embodiment of a multicolor OLED display including five pixels that produce different colored light emission. For example, pixel **11a** preferably produces red light, pixel **11c** preferably produces green light, and pixel **11e** preferably produces blue light. Pixel **11b** preferably produces light having a color between that of the red light of pixel **11a** and the green light of pixel **11c**. Pixel **11d** preferably produces light having a color between that of the blue light of pixel **11e** and the green light of pixel **11c**. These pixels can be arranged in groups, such as pixel group **10**. Although it is shown that each pixel group includes each of the differently colored pixels, the present invention is not limited to this case. Instead, some colored pixels can be present in greater number than other colored pixels. For example, there can be twice as many red pixels as there are yellow pixels. As such, each pixel group does not have to contain a pixel having every color.

[0034] FIG. 10 shows a top side view of pixels **11a**, **11b**, **11c**, **11d**, and **11e** according to the fourth embodiment of the present invention. In a passive matrix configuration, these pixels can be addressed by providing a matrix of orthogonal electrodes such as first electrodes **110a**, **110b**, **110c**, **110d**, and **110e** and second electrode **130**. That is pixel **11a** is constructed from first electrode **110a** and second electrode **130**, pixel **11b** is constructed from first electrode **110b** and second electrode **130**, pixel **11c** is constructed from first electrode **110c** and second electrode **130**, pixel **11d** is constructed from first electrode **110d** and second electrode **130**, and pixel **11e** is constructed from first electrode **110e** and second electrode **130**. In this configuration, all pixels in a column share the same first electrode and all pixels in a row share the same second electrode. As such these pixels are arranged into a stripe pattern. However, the present invention is not limited to this arrangement and other arrangements such as delta pattern arrangements and quad arrangements can be applied by one skilled in the art. Furthermore, the present invention is not limited to the passive matrix configuration and an active matrix driving scheme can be applied by one skilled in the art.

[0035] According to the present invention, light emitting layer **123a** is provided for pixels **11a**, **11b**, and **11c** so as to be common between these pixels. This requires light emitting layer **123a** to be precisely aligned or patterned to these pixels. Light emitting layer **123c** is provided for all pixels, and therefore requires no precise alignment or patterning step. In this manner, the number of precision aligned depositions required to form these five differently colored pixels is reduced from five to one. Light emitting layers **123a** and **123c** can be formed as previously described. Light emitting layer **123a** can be continuously formed between pixels **11a**, **11b**, and **11c** as shown. This can be achieved, for example, by using a single opening in the shadow mask to deposit the entire layer. Such a continuous arrangement is preferred to reduce surface area allocated for alignment tolerances in the manufacturing process. To facilitate such a continuous arrangement, the pixels, which share the same light emitting layer, are preferably disposed to be adjacent to one and other. For example, pixel **11b** is adjacent to pixel **11a** and pixel **11c** as shown. The present invention, however, is not limited to this preferred embodiment and alternate embodiments where the light emitting layer is discontinuous between the two pixels or the two pixels are spaced apart are possible. Such alternate embodiments are still advantageous in that the number of precision aligned depositions is reduced.

[0036] Light emitting layer **123a** is preferably arranged to emit light having a spectrum corresponding to a color between red and green as described previously, and produces light having spectral components corresponding to the desired colors of pixels **11a**, **11b**, and **11c**. This can be achieved by forming a light emitting layer of materials that emit a wide spectrum of light in the red to green wavelengths. As such, this unfiltered spectra emission is preferably used for pixel **11b**. Light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a color between blue and green as described previously, and produces light having spectral components corresponding to the desired colors of pixels **11d** and **11e**. This can be achieved by forming a light emitting layer of materials that emit a wide spectrum of light in the blue to green wavelengths. As such, this unfiltered spectra emission is preferably used for pixel **11d**. Although light emitting layers **123a** and **123c** are overlapped for pixels **11a**, **11b**, and **11c**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired color of pixels **11a**, **11b**, and **11c**. In order to achieve the red color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission between the pixel and the viewer in pixel **11a** to absorb undesired spectral components for pixel **11a** and pass the desired spectral components corresponding to the desired red color. In order to achieve the green color desired for pixel **11c**, color filter **140c** is formed in the path of the light emission between the pixel and the viewer in pixel **11c** to absorb undesired spectral components corresponding to the desired green color. In order to achieve the blue color desired for pixel **11e**, color filter **140e** is formed in the path of the light emission between the pixel and the viewer in pixel **11e** to absorb undesired spectral components for pixel **11e** and pass the desired spectral components corresponding to the desired blue color. A multicolor OLED display made in this manner can have higher power efficiency. The high efficiency unfiltered wide emission spectrum used in pixel **11b** or pixel **11d** can be used frequently to replace either the lower efficiency red, blue or green pixels to produce within gamut colors, as is known in the art.

[0037] An alternate five pixel embodiment can be achieved whereby pixel **11a** produces blue light, pixel **11c** produces green light, and pixel **11e** produces red light. Pixel **11b** produces light having a color between that of the blue light of pixel **11a** and the green light of pixel **11c**. Pixel **11d** produces light having a color between that of the red light of pixel **11e** and the green light of pixel **11c**. Light emitting layer **123a** is preferably arranged to emit light having a spectrum

corresponding to a color between blue and green as described previously, and produces light having spectral components corresponding to the desired colors of pixels **11a**, **11b**, and **11c**. This can be achieved by forming a light emitting layer of materials that emit a wide spectrum of light in the blue to green wavelengths. As such, this unfiltered spectra emission is preferably used for pixel **11b**. Light emitting layer **123c** is preferably arranged to emit light having a spectrum corresponding to a color between red and green as described previously, and produces light having spectral components corresponding to the desired colors of pixels **11d** and **11e**. This can be achieved by forming a light emitting layer of materials that emit a wide spectrum of light in the red to green wavelengths. As such, this unfiltered spectra emission is preferably used for pixel **11d**. Although light emitting layers **123a** and **123c** are overlapped for pixels **11a**, **11b**, and **11c**, the combination of light emitting layers **123a** and **123c** is arranged so as to produce light having mostly spectral components corresponding to the desired color of pixels **11a**, **11b**, and **11c**. In order to achieve the blue color desired for pixel **11a**, color filter **140a** is formed in the path of the light emission between the pixel and the viewer in pixel **11a** to absorb undesired spectral components for pixel **11a** and pass the desired spectral components corresponding to the desired blue color. In order to achieve the green color desired for pixel **11c**, color filter **140c** is formed in the path of the light emission between the pixel and the viewer in pixel **11c** to absorb undesired spectral components for pixel **11c** and pass the desired spectral components corresponding to the desired green color. In order to achieve the red color desired for pixel **11e**, color filter **140e** is formed in the path of the light emission between the pixel and the viewer in pixel **11e** to absorb undesired spectral components for pixel **11e** and pass the desired spectral components corresponding to the desired red color.

[0038] Yet another alternate five pixel embodiment can be achieved by providing a fourth pixel and a fifth pixel to the second embodiment of this invention. In this manner, the fourth pixel emits a color between that of the first and second pixels, and the fifth pixel emits a color between that of the third and fifth pixels. As such, a common first light emitting layer would be provided over all pixels, while the second light emitting layer would be provided only over the third and fifth pixels. In this alternate embodiment case, the first, second, and third pixels have color filters, while the fourth and fifth pixels have no color filters.

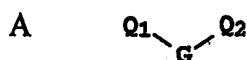
[0039] FIG. 11 shows a cross sectional view of the device of FIG. 10 taken along line 11-11'. FIG. 11 shows that pixels **11a**, **11b**, **11c**, **11d**, and **11e** produce internal light emission **220a**, **220b**, **220c**, **220d**, and **220e**, respectively. Internal light emission **220b** and **220d** exit the device without filtration to become external light emission **210b** and **210d**. Internal light emission **220a** passes through color filter **140a** prior to exiting the device resulting in external light emission **210a**. Internal light emission **220c** passes through color filter **140c** prior to exiting the device resulting in external light emission **210c**. Similarly, internal light emission **220e** passes through color filter **140e** prior to exiting the device resulting in external light emission **210e**. Color filters **140a**, **140c**, and **140e** are preferably organic layers as previously described.

[0040] The pixels are constructed over substrate **100**. Light can exit the device by passing through substrate **100** for the case of the bottom emitting device, as shown. First electrodes **110a**, **110b**, **110c**, **110d**, and **110e** are arranged to transmit light and are preferably constructed of a conductive transparent material such as previously described. Second electrode **130** is preferably constructed of a reflective conductive material such as previously described in order to achieve the desired light absorption or reflection properties and conductivity properties.

[0041] Although not always necessary, it is often useful that a hole-injecting layer (not shown) be formed and disposed over first electrodes **110a**, **110b**, **110c**, **110d**, and **110e**. The hole-injecting material can serve to improve the film formation property of subsequent organic layers and to facilitate injection of holes into the hole-transporting layer. Suitable materials for use in the hole-injecting layer include, but are not limited to, porphyrinic compounds as described in U.S. Patent 4,720,432, plasma-deposited fluorocarbon polymers as described in U.S. Patent 6,208,075, and inorganic oxides including vanadium oxide (VO_x), molybdenum oxide (MoO_x), and nickel oxide (NiO_x). Alternative hole-injecting materials reportedly useful in organic EL devices are described in EP 0 891 121 A1 and EP 1 029 909 A1.

[0042] Although not always necessary, it is often useful that a hole-transporting layer **122** be formed and disposed over electrodes **110a**, **110b**, **110c**, **110d**, and **110e**. Hole-transporting materials useful in hole-transporting layer **122** are well known to include compounds such as an aromatic tertiary amine, where the latter is understood to be a compound containing at least one trivalent nitrogen atom that is bonded only to carbon atoms, at least one of which is a member of an aromatic ring. In one form the aromatic tertiary amine can be an arylamine, such as a monoarylamine, diarylamine, triarylamine, or a polymeric arylamine. Exemplary monomeric triarylamines are illustrated by Klupfel, et al. in U.S. Patent 3,180,730. Other suitable triarylamines substituted with one or more vinyl radicals or at least one active hydrogen-containing group are disclosed by Brantley, et al. in U.S. Patents 3,567,450 and 3,658,520.

[0043] A more preferred class of aromatic tertiary amines is those that include at least two aromatic tertiary amine moieties as described in U.S. Patents 4,720,432 and 5,061,569. Such compounds include those represented by structural Formula A

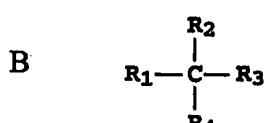


wherein:

Q₁ and Q₂ are independently selected aromatic tertiary amine moieties; and
G is a linking group such as an arylene, cycloalkylene, or alkylene group of a carbon to carbon bond.

5 [0044] In one embodiment, at least one of Q₁ or Q₂ contains a polycyclic fused ring structure, e.g., a naphthalene moiety. When G is an aryl group, it is conveniently a phenylene, biphenylene, or naphthalene moiety.
[0045] A useful class of triarylamines satisfying structural Formula A and containing two triarylamine moieties is represented by structural Formula B

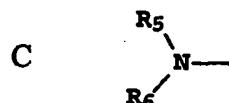
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where:

20 R₁ and R₂ each independently represent a hydrogen atom, an aryl group, or an alkyl group or R₁ and R₂ together represent the atoms completing a cycloalkyl group; and
R₃ and R₄ each independently represent an aryl group, which is in turn substituted with a diaryl substituted amino group, as indicated by structural Formula C

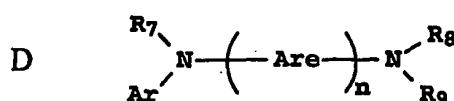
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30 wherein R₅ and R₆ are independently selected aryl groups. In one embodiment, at least one of R₅ or R₆ contains a polycyclic fused ring structure, e.g., a naphthalene.

35 [0046] Another class of aromatic tertiary amines is the tetraaryldiamines. Desirable tetraaryldiamines include two diarylamino groups, such as indicated by Formula C, linked through an arylene group. Useful tetraaryldiamines include those represented by Formula D

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wherein:

45 each Are is an independently selected arylene group, such as a phenylene or anthracene moiety;
n is an integer of from 1 to 4; and
Ar, R₇, R₈, and R₉ are independently selected aryl groups.

50 [0047] In a typical embodiment, at least one of Ar, R₇, R₈, and R₉ is a polycyclic fused ring structure, e.g., a naphthalene.

[0048] The various alkyl, alkylene, aryl, and arylene moieties of the foregoing structural Formulae A, B, C, D, can each in turn be substituted. Typical substituents include alkyl groups, alkoxy groups, aryl groups, aryloxy groups, and halides such as fluoride, chloride, and bromide. The various alkyl and alkylene moieties typically contain from 1 to about 6 carbon atoms. The cycloalkyl moieties can contain from 3 to about 10 carbon atoms, but typically contain five, six, or seven carbon atoms, e.g. cyclopentyl, cyclohexyl, and cycloheptyl ring structures. The aryl and arylene moieties are typically phenyl and phenylene moieties.

55 [0049] The hole-transporting layer in an OLED device can be formed of a single or a mixture of aromatic tertiary amine compounds. Specifically, one can employ a triaryamine, such as a triaryamine satisfying the Formula (B), in combination with a tetraaryldiamine, such as indicated by Formula (D). When a triaryamine is employed in combination with a

tetraaryldiamine, the latter is positioned as a layer interposed between the triarylamine and the electron injecting and transporting layer. Illustrative of useful aromatic tertiary amines are the following:

- 5 1,1-Bis(4-di-p-tolylaminophenyl)cyclohexane;
- 1,1-Bis(4-di-p-tolylaminophenyl)-4-phenylcyclohexane;
- 4,4'-Bis(diphenylamino)quaterphenyl;
- Bis(4-dimethylamino-2-methylphenyl)-phenylmethane;
- Tri(p-tolyl)amine;
- 10 4-(di-p-tolylamino)-4'-[4'-(di-p-tolylamino)-1-styryl]stilbene;
- N,N,N',N'-Tetra-p-tolyl-4,4'-diaminobiphenyl;
- N,N,N',N'-Tetraphenyl-4,4'-diaminobiphenyl;
- N-Phenylcarbazole;
- Poly(N-vinylcarbazole);
- 15 N,N'-di-1-naphthalenyl-N,N'-diphenyl-4,4'-diaminobiphenyl;
- 4,4'-Bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB);
- 4,4'-Bis[N-(1-naphthyl)-N-(2-naphthyl)ammo]biphenyl (TNB);
- 4,4"-Bis[N-(1-naphthyl)-N-phenylamino]-p-terphenyl;
- 4,4'-Bis[N-(2-naphthyl)-N-phenylamino]biphenyl;
- 20 4,4'-Bis[N-(3-acenaphthene)-N-phenylamino]biphenyl;
- 1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene;
- 4,4'-Bis[N-(9-anthryl)-N-phenylamino]biphenyl;
- 4,4"-Bis[N-(1-anthryl)-N-phenylamino]p-terphenyl;
- 4,4'-Bis[N-(2-phenanthryl)-N-phenylamino]biphenyl;
- 25 4,4'-Bis[N-(8-fluoranthene)-N-phenylamino]biphenyl;
- 4,4'-Bis[N-(2-pyrenyl)-N-phenylamino]biphenyl;
- 4,4'-Bis[N-(2-perylenyl)-N-phenylamino]biphenyl;
- 4,4'-Bis[N-(1-coronenyl)-N-phenylamino]biphenyl;
- 2,6-Bis(di-p-tolylamino)naphthalene;
- 30 2,6-Bis[di-(1-naphthyl)amino]naphthalene;
- 2,6-Bis[N-(1-naphthyl)-N-(2-naphthyl)amino]naphthalene;
- N,N,N',N'-Tetra(2-naphthyl)-4,4"-diamino-p-terphenyl;
- 4,4'-Bis {N-phenyl-N-[4-(1-naphthyl)-phenyl]amino}biphenyl;
- 4,4'-Bis[N-phenyl-N-(2-pyrenyl)amino]biphenyl;
- 35 2,6-Bis[N,N-di(2-naphthyl)amino]fluorene; and
- 1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene.

[0050] Another class of useful hole-transporting materials includes polycyclic aromatic compounds as described in EP 1 009 041. In addition, polymeric hole-transporting materials can be used such as poly(N-vinylcarbazole) (PVK), 40 polythiophenes, polypyrrole, polyaniline, and copolymers such as poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) also called PEDOT/PSS.

[0051] Light emitting layers **123a** and **123c** produce light in response to hole-electron recombination and are disposed over hole-transporting layer **122**, although hole-transporting layer **122** is not required for the practice of this invention. 45 Useful organic light emitting materials are well known. As more fully described in U.S. Patents 4,769,292 and 5,935,721, each of the light emitting layers of the organic EL element includes a luminescent or fluorescent material where electroluminescence is produced as a result of electron-hole pair recombination in this region. Although light emitting layers can be comprised of a single material, they more commonly include a host material doped with a guest compound or dopant where light emission comes primarily from the dopant. The practice of this invention concerns such host/dopant light emitting layers and OLED devices. Light emitting layer **123a** includes a first host, and light emitting layer **123c** 50 includes a second host. Any of the hosts can be the same material. Any of the hosts can comprise a single host material or a mixture of host materials. The dopant is selected to produce colored light having a particular spectrum. The dopant is typically chosen from highly fluorescent dyes, and is typically coated as 0.01 to 10% by weight into the host material. Light emitting layer **123a** includes a light emitting material of the first color, e.g. a yellow-orange or red-orange light emitting material. Light emitting layer **123c** includes a light emitting material of the second color, e.g. a blue or blue-green light emitting material. The practice of this invention is not restricted to this ordering of layers. For instance, light emitting layer **123a** can include a blue or blue-green light emitting material, and light emitting layer **123c** can include a red, red-orange, or yellow-orange light emitting material. The host materials in the light emitting layers can be an electron-transporting material, a hole-transporting material, or another material that supports hole-electron recombination. The 55

dopant is typically chosen from highly fluorescent dyes, but phosphorescent compounds, e.g., transition metal complexes as described in WO 98/55561, WO 00/18851, WO 00/57676, and WO 00/70655 are also useful.

[0052] The host and emitting materials can be small nonpolymeric molecules or polymeric materials including poly-fluorenes and polyvinylarylenes, e.g., poly(p-phenylenevinylene), PPV. When the host is a polymer, small molecule emitting materials can be molecularly dispersed into a polymeric host, or the emitting materials can be added by copolymerizing a minor constituent into a host polymer.

[0053] Desirable host materials are capable of forming a continuous film. The light emitting layer can contain more than one host material in order to improve the device's film morphology, electrical properties, light emission efficiency, and lifetime. The light emitting layer can contain a first host material that has effective hole-transporting properties, and a second host material that has effective electron-transporting properties.

[0054] An important relationship for choosing a dye as a dopant is the value of the optical bandgap, which is defined as the energy difference between the emissive excited state and the ground state of the molecule and is approximately equal to the energy difference between the lowest unoccupied molecular orbital and the highest occupied molecular orbital of the molecule. For efficient energy transfer from the host material to the dopant molecule, or to prevent back-transfer of energy from the dopant to the host, a necessary condition is that the band gap of the dopant be smaller than that of the host material.

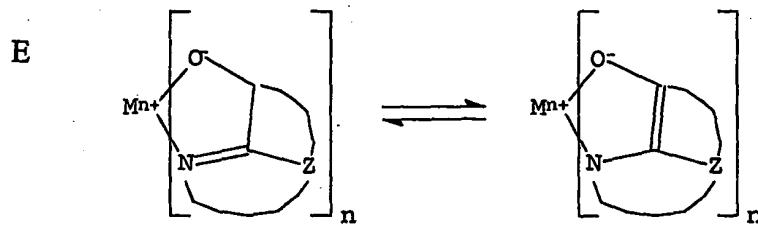
[0055] Host and emitting molecules known to be of use include, but are not limited to, those disclosed in U.S. Patents 4,768,292, 5,141,671, 5,150,006, 5,151,629, 5,294,870, 5,405,709, 5,484,922, 5,593,788, 5,645,948, 5,683,823, 5,755,999, 5,928,802, 5,935,720, 5,935,721, 6,020,078, and 6,534,199.

[0056] Other organic emissive materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, di-alkoxy-polyphenylenevinylenes, poly-para-phenylene derivatives, and polyfluorene derivatives, as taught by Wolk, et al. in commonly assigned U.S. Patent 6,194,119 and references cited therein.

[0057] Suitable host materials for phosphorescent emitters (including materials that emit from a triplet excited state, i.e. so-called "triplet emitters") should be selected so that the triplet exciton can be transferred efficiently from the host material to the phosphorescent material. For this transfer to occur, it is a highly desirable condition that the excited state energy of the phosphorescent material be lower than the difference in energy between the lowest triplet state and the ground state of the host. However, the band gap of the host should not be chosen so large as to cause an unacceptable increase in the drive voltage of the OLED. Suitable host materials are described in WO 00/70655 A2; 01/39234 A2; 01/93642 A1; 02/074015 A2; 02/15645 A1, and U.S. Patent Application Publication 2002/0117662 A1. Suitable hosts include certain aryl amines, triazoles, indoles and carbazole compounds. Examples of desirable hosts are 4,4'-N,N'-dicarbazole-biphenyl (CBP), 2,2'-dimethyl-4,4'-(N,N'-dicarbazole)-biphenyl, *m*-(N,N'-dicarbazole)benzene, and poly(N-vinylcarbazole), including their derivatives.

[0058] In addition to suitable hosts, an OLED device employing a phosphorescent material often requires at least one exciton- or hole-blocking layer to help confine the excitons or electron-hole recombination centers to the light emitting layer comprising the host and phosphorescent material. In one embodiment, such a blocking layer would be placed between a phosphorescent light emitting layer and the cathode, and in contact with the phosphorescent light emitting layer. The ionization potential of the blocking layer should be such that there is an energy barrier for hole migration from the host into the electron-transporting layer (or the metal-doped organic layer), while the electron affinity should be such that electrons pass more readily from the electron-transporting layer (or the metal-doped organic layer) into the light emitting layer comprising host and phosphorescent material. It is further desired, but not absolutely required, that the triplet energy of the blocking material be greater than that of the phosphorescent material. Suitable hole-blocking materials are described in WO 00/70655A2 and WO 01/93642 A1. Two examples of useful materials are bathocuproine (BCP) and bis(2-methyl-8-quinolinolato)(4-phenylphenolato)-Aluminum(III) (BAIQ). Metal complexes other than BAIQ are also known to block holes and excitons as described in U.S. Patent Application Publication 2003/0068528 A1. U.S. Patent Application Publication 2003/0175553 A1 describes the use of fac-tris(1-phenylpyrazolato-N,C²)iridium(III) (Irppz) in an electron/exciton blocking layer.

[0059] Light emitting layer 123a includes a host material, or mixture of hosts, and a light emitting material. In one embodiment, the host material is one or more electron-transporting materials or one or more tetracene derivatives. Electron-transporting materials useful as host materials including metal complexes of 8-hydroxyquinoline and similar derivatives (Formula E) constitute one class of host compounds useful in light emitting layer 123a



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wherein:

M represents a metal;

n is an integer of from 1 to 3; and

15 Z independently in each occurrence represents the atoms completing a nucleus having at least two fused aromatic rings.

20 [0060] From the foregoing it is apparent that the metal can be monovalent, divalent, or trivalent metal. The metal can, for example, be an alkali metal, such as lithium, sodium, or potassium; an alkaline earth metal, such as magnesium or calcium; or an earth metal, such as boron or aluminum. Generally, any monovalent, divalent, or trivalent metal known to be a useful chelating metal can be employed.

25 [0061] Z completes a heterocyclic nucleus containing at least two fused aromatic rings, at least one of which is an azole or azine ring. Additional rings, including both aliphatic and aromatic rings, can be fused with the two required rings, if required. To avoid adding molecular bulk without improving on function the number of ring atoms is typically maintained at 18 or less.

[0062] Illustrative of useful chelated oxinoid compounds are the following:

CO-1: Aluminum trisoxine [alias, tris(8-quinolinolato)aluminum(III)];

CO-2: Magnesium bisoxine [alias, bis(8-quinolinolato)magnesium(II)];

30 CO-3: Bis[benzo{f}-8-quinolinolato]zinc (II);

CO-4: Bis(2-methyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(2-methyl-8-quinolinolato) aluminum(III);

CO-5: Indium trisoxine [alias, tris(8-quinolinolato)indium];

CO-6: Aluminum tris(5-methyloxine) [alias, tris(5-methyl-8-quinolinolato) aluminum(III)];

CO-7: Lithium oxine [alias, (8-quinolinolato)lithium(I)];

35 CO-8: Gallium oxine [alias, tris(8-quinolinolato)gallium(III)]; and

CO-9: Zirconium oxine [alias, tetra(8-quinolinolato)zirconium(IV)].

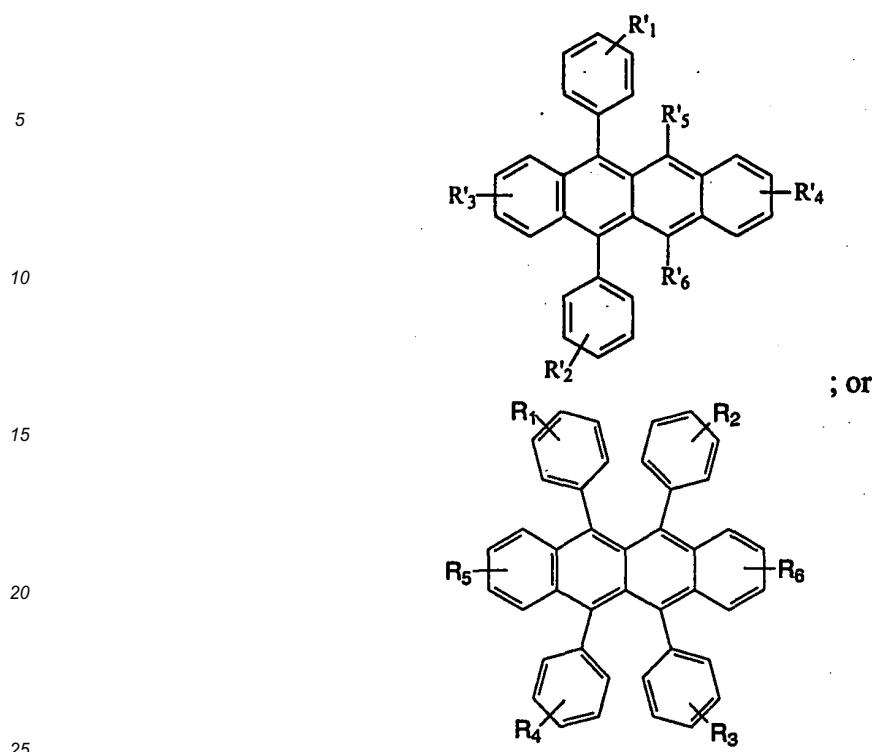
[0063] Examples of tetracene derivatives useful as hosts or co-hosts in light emitting layer 123a are:

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wherein R₁-R₆ represent one or more substituents on each ring and where each substituent is individually selected from one of the following:

30 Category 1: hydrogen, or alkyl of from 1 to 24 carbon atoms;
 Category 2: aryl or substituted aryl of from 5 to 20 carbon atoms;
 Category 3: hydrocarbon containing 4 to 24 carbon atoms, completing a fused aromatic ring or ring system;
 Category 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms such as thiazolyl, furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems, which are bonded via a single bond, or complete a fused heteroaromatic ring system;
 35 Category 5: alkoxyamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; or
 Category 6: fluoro, chloro, bromo or cyano.

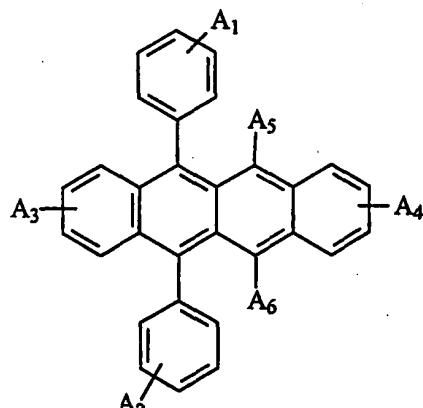
40 [0064] In a preferred embodiment, the host material can include a mixture of one or more tetracene derivatives, and one or more electron-transporting materials.

[0065] In the preferred embodiment, the light emitting material in light emitting layer **123a** has a peak emission in the yellow-orange portion of the visible spectrum, and can include a yellow-orange light emitting compound of the following structures:

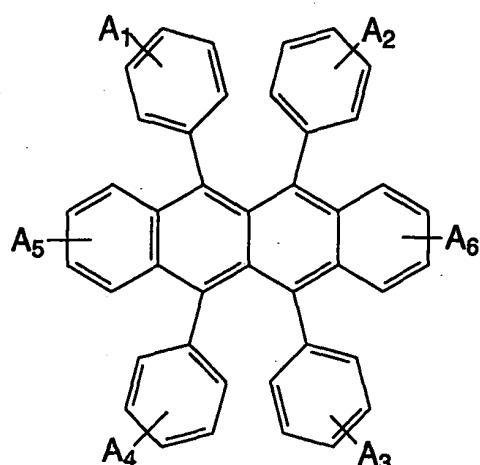
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or



wherein A₁-A₆ represent one or more substituents on each ring and where each substituent is individually selected from one of the following:

40 Category 1: hydrogen, or alkyl of from 1 to 24 carbon atoms;

Category 2: aryl or substituted aryl of from 5 to 20 carbon atoms;

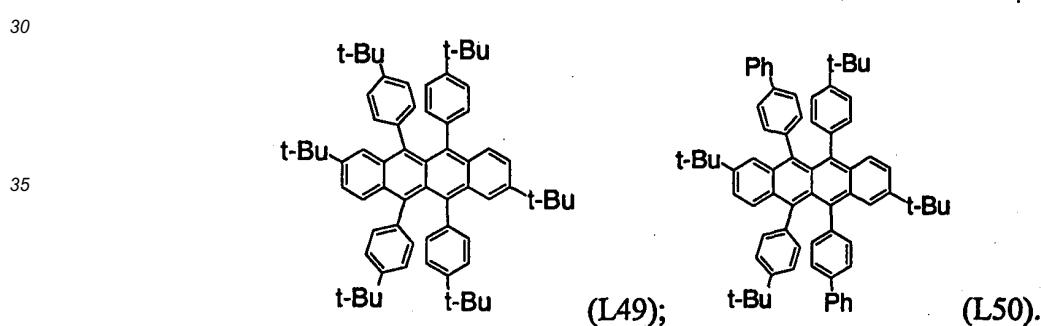
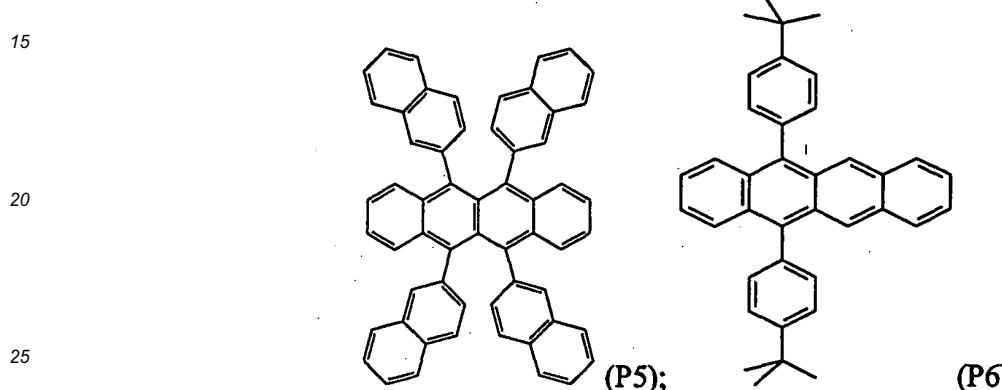
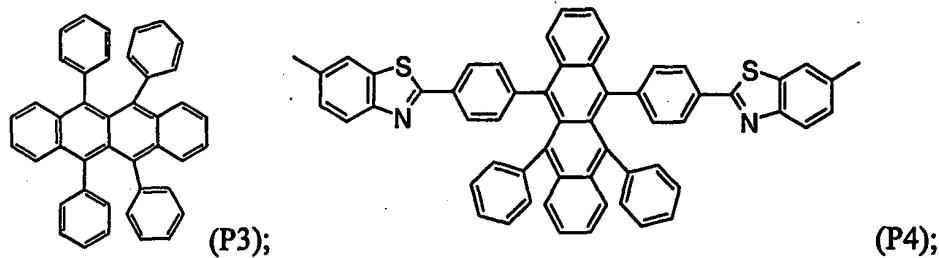
Category 3: hydrocarbon containing 4 to 24 carbon atoms, completing a fused aromatic ring or ring system;

45 Category 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms such as thiazolyl, furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems, which are bonded via a single bond, or complete a fused heteroaromatic ring system;

Category 5: alkoxyamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; or

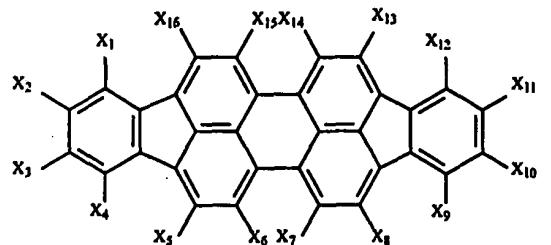
Category 6: fluoro, chloro, bromo or cyano.

50 [0066] Examples of particularly useful yellow-orange dopants for use in light emitting layer 123a include 5,6,11,12-tetraphenylnaphthacene (P3); 6,11-diphenyl-5,12-bis(4-(6-methyl-benzothiazol-2-yl)phenyl)naphthacene (P4); 5,6,11,12-tetra(2-naphthyl)naphthacene (P5); and compounds L49 and L50, the formulas of which are shown below:



[0067] A suitable yellow-orange dopant can also be a mixture of compounds that would also be yellow-orange dopants individually.

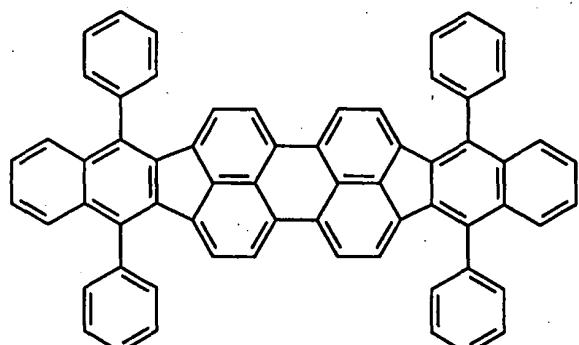
[0068] In another useful embodiment, the light emitting material in light emitting layer **123c** has a peak emission in the yellow-orange portion of the visible spectrum and contains yellow-orange light emitting materials and hosts as described above. In yet another useful embodiment, light emitting layer **123c** has a peak emission in the red portion of the visible spectrum, and can include a red or red-orange light emitting dopant. A suitable light emitting red or red-orange dopant can include a diindenoperylene compound of the following structure:



wherein X_1 - X_{16} are independently selected as hydro or substituents that provide red luminescence.

[0069] A particularly preferred diindenoperylene dopant is dibenzo $\{[f,f']-4,4'7,7'$ -tetraphenyl]diindeno-[1,2,3-*cd*:1',2',3'-*lm*]perylene (TPDBP, below)

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30 [0070] Other red or red-orange dopants useful in the present invention belong to the DCM class of dyes represented by

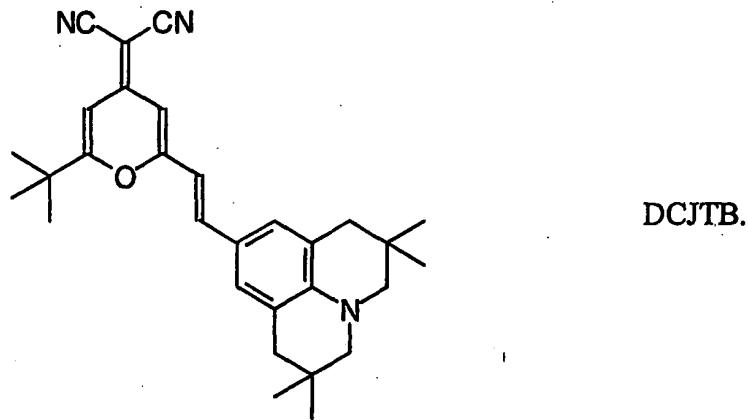


wherein:

45 Y_1 - Y_5 represent one or more groups independently selected from hydro, alkyl, substituted alkyl, aryl, or substituted aryl; and
 Y_1 - Y_5 independently include acyclic groups or are joined pairwise to form one or more fused rings, provided that Y_3 and Y_5 do not together form a fused ring.

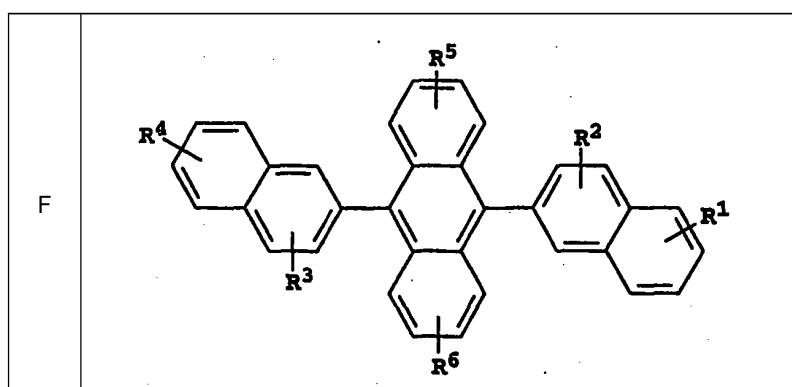
50 [0071] In a useful and convenient embodiment that provides red-orange luminescence, Y_1 - Y_5 are selected independently from hydro, alkyl and aryl. A preferred DCM dopant is DCJTB shown below.

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[0072] A useful red or red-orange dopant can also be a mixture of compounds that would also be red or red-orange dopants individually.

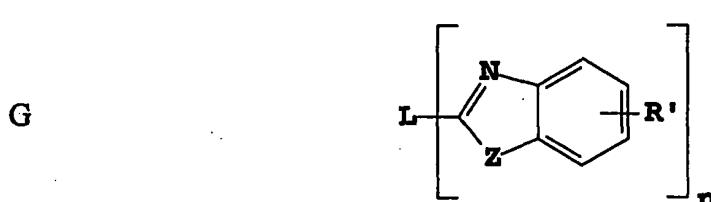
[0073] Light emitting layer **123c** includes a host material, or mixture of hosts, and a light emitting material. In the preferred embodiment, light emitting layer **123c** has a peak emission in the blue to blue-green portion of the visible spectrum. In one embodiment, the host material is one or more anthracene or mono-anthracene derivatives. Derivatives of 9,10-di-(2-naphthyl)anthracene (Formula F) constitute one class of hosts useful in light emitting layer **123c**



wherein:

40 R¹, R², R³, R⁴, R⁵, and R⁶ represent one or more substituents on each ring where each substituent is individually selected from the following groups: Group 1: hydrogen, or alkyl of from 1 to 24 carbon atoms; Group 2: aryl or substituted aryl of from 5 to 20 carbon atoms; Group 3: carbon atoms from 4 to 24 necessary to complete a fused aromatic ring of anthracenyl; pyrenyl, or perpyrenyl; Group 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms as necessary to complete a fused heteroaromatic ring of furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems; Group 5: alkoxylamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; and Group 6: fluorine, chlorine, bromine or cyano.

[0074] Benzazole derivatives (Formula G) constitute another class of hosts useful in light emitting layer **123c**



wherein:

n is an integer of 3 to 8;

Z is O, NR or S;

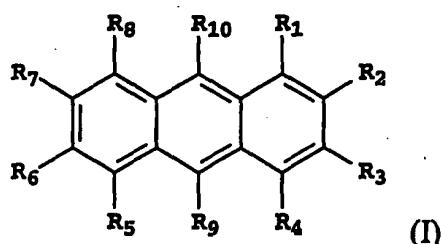
5 R' is hydrogen; alkyl of from 1 to 24 carbon atoms, for example, propyl, t-butyl, heptyl, and the like; aryl or hetero-atom substituted aryl of from 5 to 20 carbon atoms for example phenyl and naphthyl, furyl, thiienyl, pyridyl, quinolinyl and other heterocyclic systems; or halo such as chloro, fluoro; or atoms necessary to complete a fused aromatic ring; and

10 L is a linkage unit includes alkyl, aryl, substituted alkyl, or substituted aryl, which conjugately or unconjugately connects the multiple benzazoles together.

[0075] An example of a useful benzazole is 2,2', 2"- (1,3,5-phenylene)-tris[1-phenyl-1H-benzimidazole].

[0076] It has been found in commonly assigned U.S. Patent Application Serial No. 10/693,121 filed October 24, 2003 by Lelia Cosimescu, et al., entitled "Electroluminescent Device With Anthracene Derivative Host", the disclosure of 15 which is herein incorporated by reference, that

[0077] certain unsymmetrical anthracenes are extremely useful in OLED devices that exhibit high efficiencies. These compounds have been found to be particularly useful in blue light emitting layers of OLED devices that produce blue, blue-green, or green light. Blue or blue-green light emitting layer **123c** can include a mono-anthracene derivative of 20 Formula (I) as a host material



30 wherein:

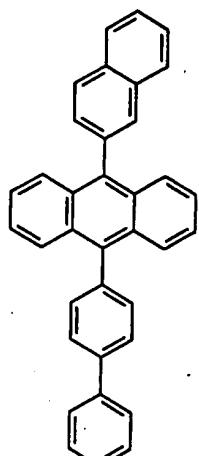
R₁-R₈ are H; and

R₉ is a naphthyl group containing no fused rings with aliphatic carbon ring members; provided that R₉ and R₁₀ are 35 not the same, and are free of amines and sulfur compounds. Suitably, R₉ is a substituted naphthyl group with one or more further fused rings such that it forms a fused aromatic ring system, including a phenanthryl, pyrenyl, fluoranthene, perylene, or substituted with one or more substituents including fluorine, cyano group, hydroxy, alkyl, alkoxy, aryloxy, aryl, a heterocyclic oxy group, carboxy, trimethylsilyl group, or an unsubstituted naphthyl group of two fused rings. Conveniently, R₉ is 2-naphthyl, or 1-naphthyl substituted or unsubstituted in the para position; and

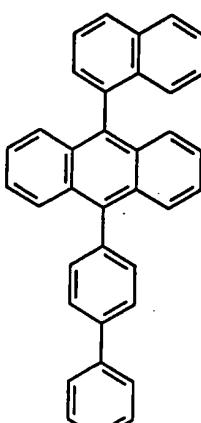
40 R₁₀ is a biphenyl group having no fused rings with aliphatic carbon ring members. Suitably R₁₀ is a substituted biphenyl group, such that it forms a fused aromatic ring system including but not limited to a naphthyl, phenanthryl, perylene, or substituted with one or more substituents including fluorine, cyano group, hydroxy, alkyl, alkoxy, aryloxy, aryl, a heterocyclic oxy group, carboxy, trimethylsilyl group, or an unsubstituted biphenyl group. Conveniently, R₁₀ is 45 4-biphenyl, 3-biphenyl unsubstituted or substituted with another phenyl ring without fused rings to form a terphenyl ring system, or 2-biphenyl. Particularly useful is 9-(2-naphthyl)-10-(4-biphenyl)anthracene.

[0078] Some examples of useful mono-anthracene host materials for use in light emitting layer **123c** include:

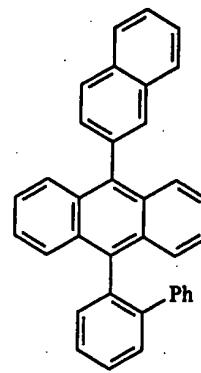
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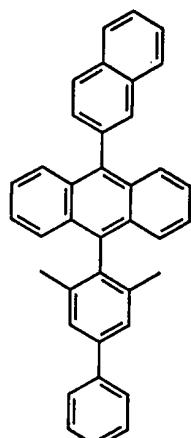
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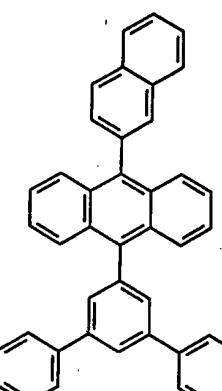
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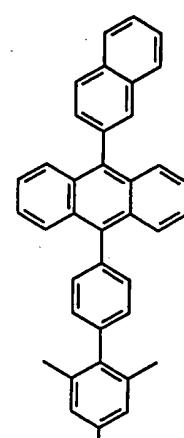
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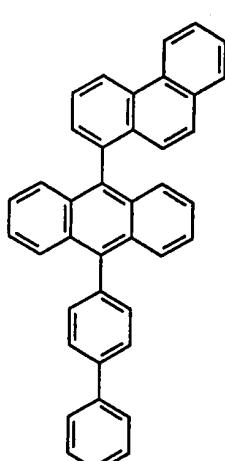
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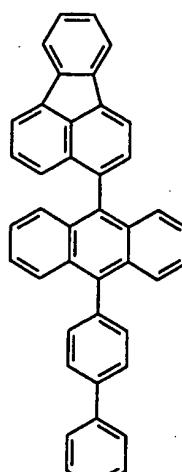
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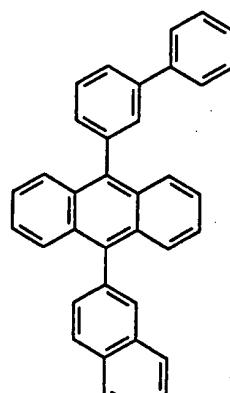
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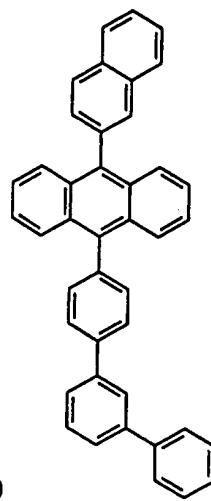
Host-7

; Host-8

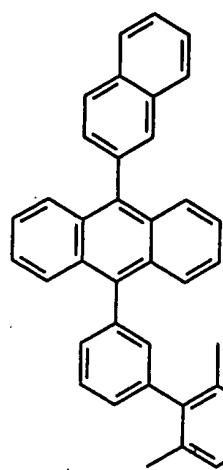
; Host-9

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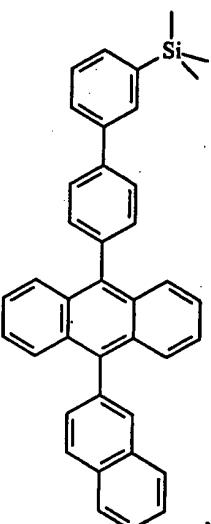


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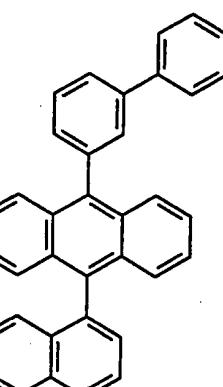
Host-10

; Host-11

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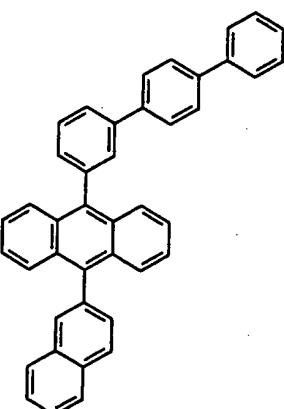
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Host-12

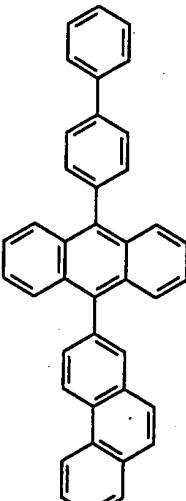
; Host-13

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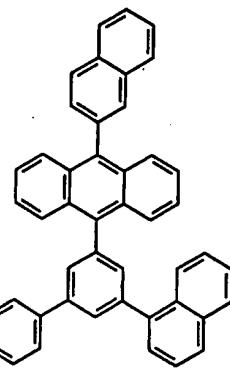
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Host-14

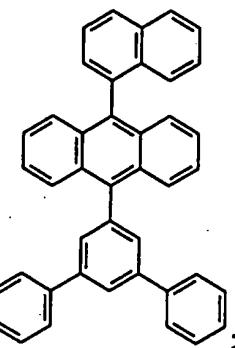
; Host-15

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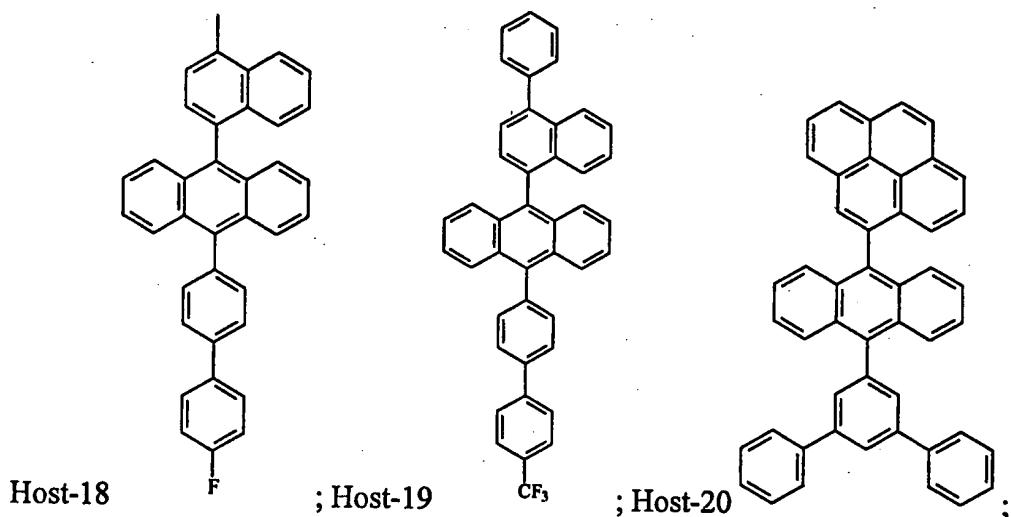
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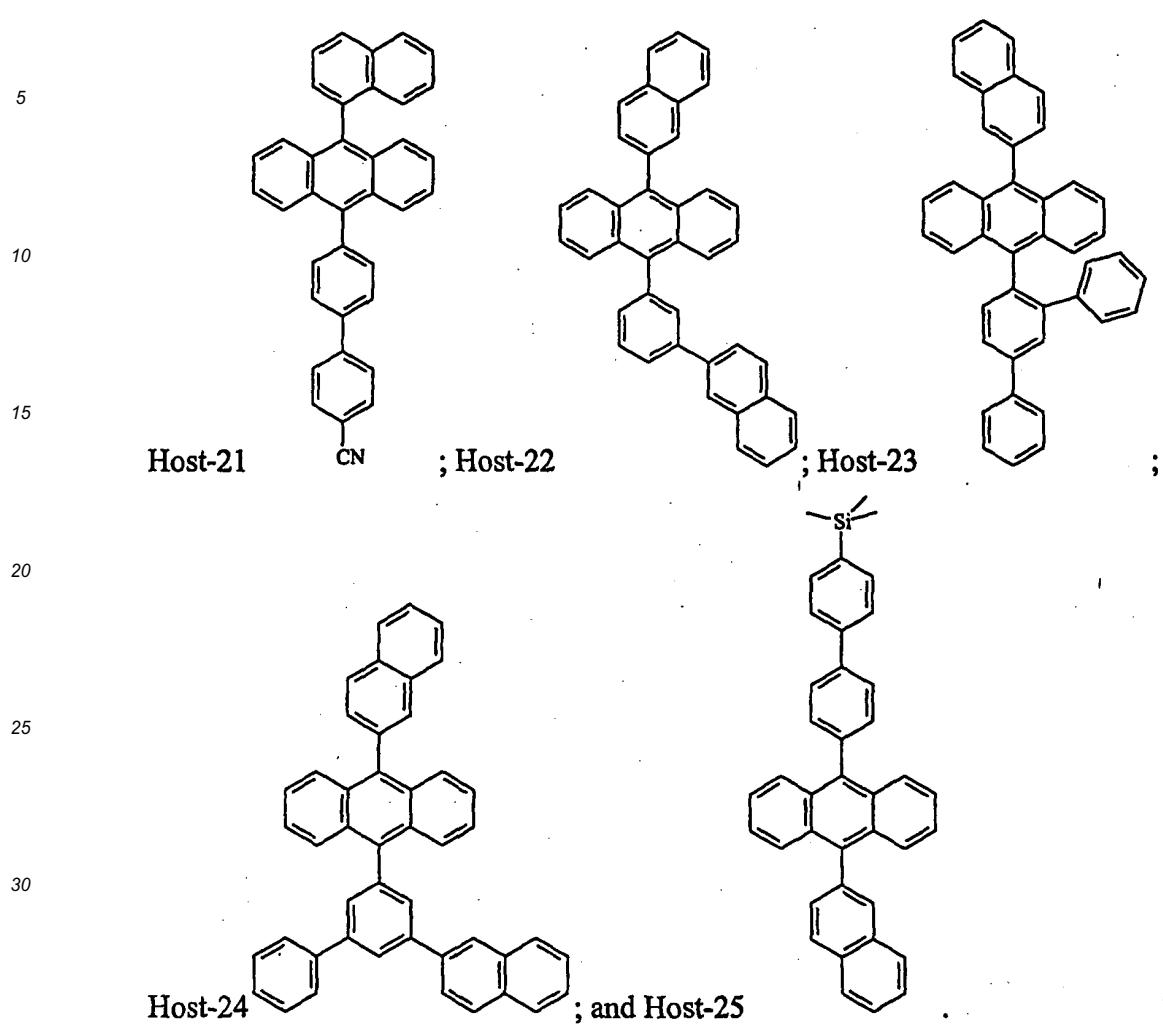
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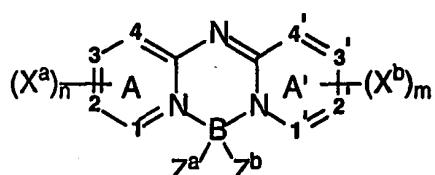
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[0079] Particularly useful is 9-(2-naphthyl)-10-(4-biphenyl)anthracene (Host-1).

[0080] In a preferred embodiment, the host material in light emitting layer 123c can include a mixture of one or more anthracene or mono-anthracene derivatives mentioned above, and one or more aromatic amine derivatives. The aromatic amine derivative in light emitting layer 123c can be any such amine that has hole-transporting properties, and can be selected from the same potential hole-transporting materials as in hole-transporting layer 122. Particularly useful is 4,4'-Bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB).

[0081] In the preferred embodiment, the light emitting material in light emitting layer 123c has a peak emission in the blue portion of the visible spectrum, and can include blue light emitting dopants including perylene or derivatives thereof, blue-emitting derivatives of distyrylbenzene or a distyrylbiphenyl that have one or more aryl amine substituents, or a compound of the structure



wherein:

A and A' represent independent azine ring systems corresponding to 6-membered aromatic ring systems containing

at least one nitrogen;

$(X^a)_n$ and $(X^b)_m$ represent one or more independently selected substituents and include acyclic substituents or are joined to form a ring fused to A or A';

m and n are independently 0 to 4;

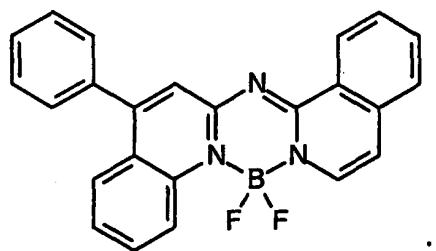
5 Z^a and Z^b are independently selected substituents;

10 1, 2, 3, 4, 1', 2', 3', and 4' are independently selected as either carbon or nitrogen atoms; and

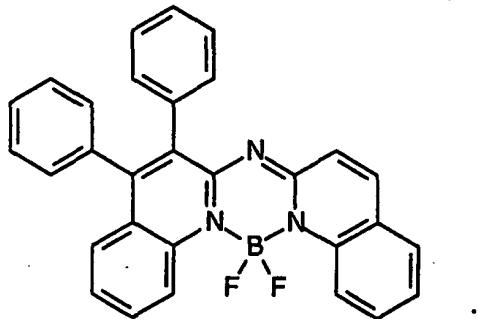
provided that X^a , X^b , Z^a , and Z^b , 1, 2, 3, 4, 1', 2', 3', and 4' are selected to provide blue luminescence.

[0082] Some examples of the above class of dopants include the following:

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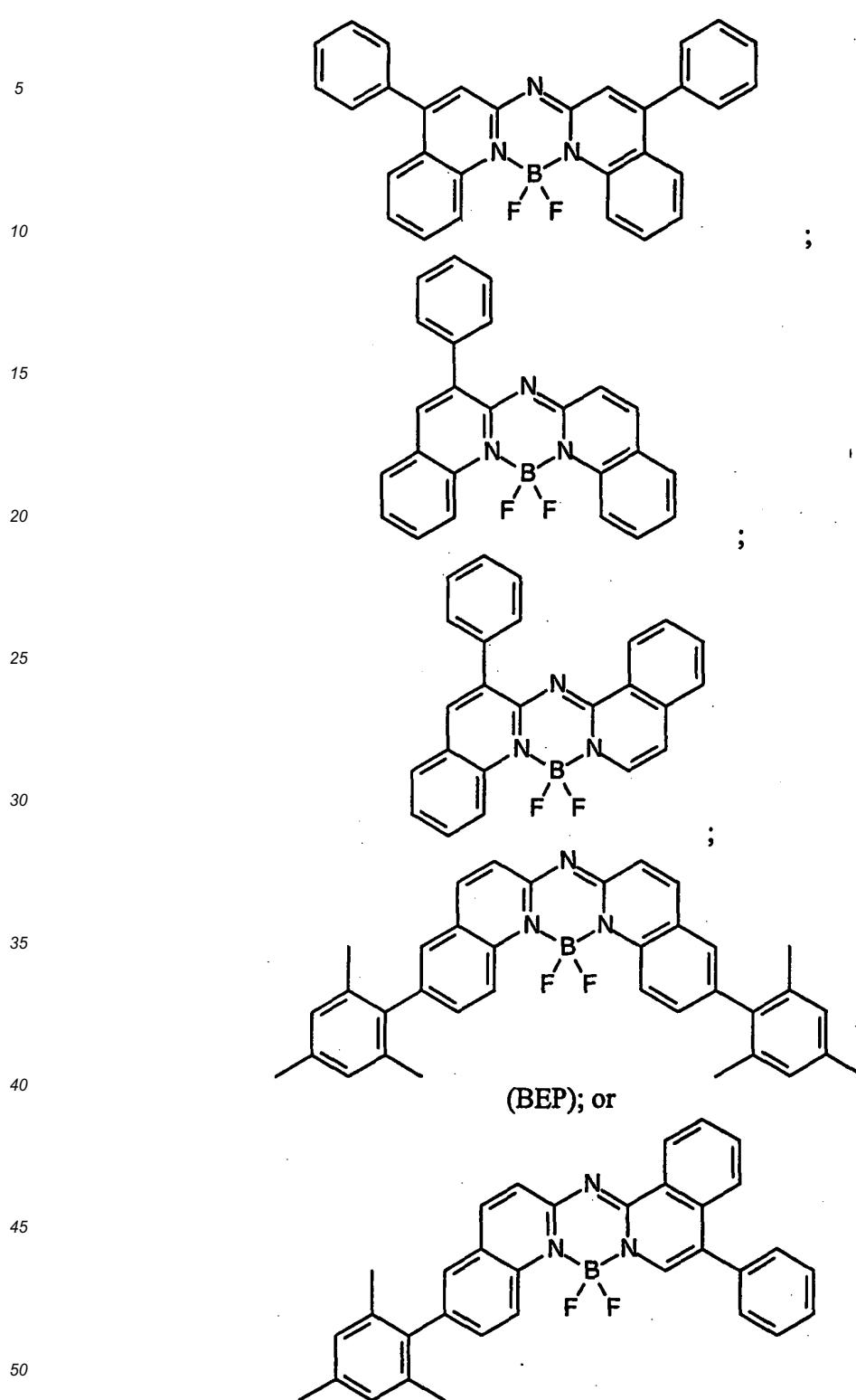
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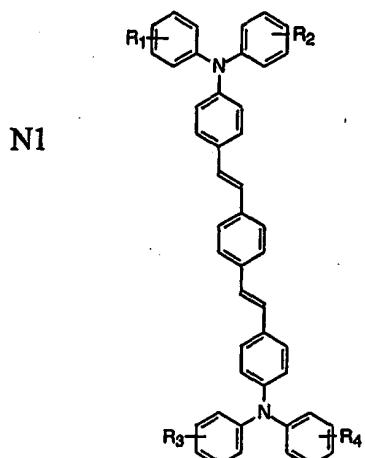


[0083] Preferred blue dopants are BEP and tetra-t-butylperylene (TBP). A useful blue dopant can also be a mixture of compounds that would also be blue dopants individually.

[0084] In another preferred embodiment, the light emitting material in light emitting layer **123c** has a peak emission in the blue-green portion of the visible spectrum, and can include blue-green emitting derivatives of such distyrylarenes as distyrylbenzene and distyrylbiphenyl, including compounds described in U.S. Patent 5,121,029. Among derivatives of distyrylarenes that provide blue or blue-green luminescence, particularly useful are those substituted with diaryl amino

groups, also known as distyrylamines. Examples include bis[2-[4-[N,N-diaryl amino]phenyl]vinyl]benzenes of the general structure N1 shown below:

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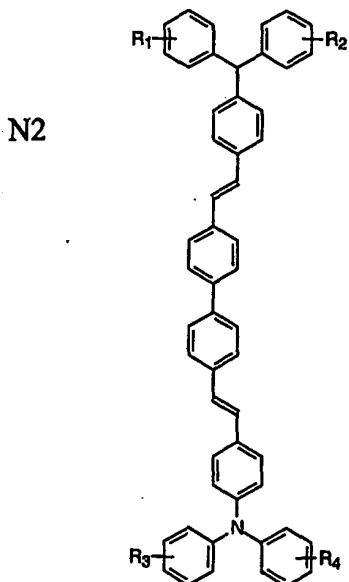
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and bis[2-[4-[N,N-diaryl amino]phenyl]vinyl]biphenyls of the general structure N2 shown below:

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[0085] In Formulas N1 and N2, R₁-R₄ can be the same or different, and individually represent one or more substituents such as alkyl, aryl, fused aryl, halo, or cyano. In a preferred embodiment, R₁-R₄ are individually alkyl groups, each containing from one to about ten carbon atoms. A particularly useful blue-green dopant of this class is 1,4-bis[2-[4-[N,N-di(p-tolyl)amino]phenyl]vinyl]benzene (BDTAPVB)

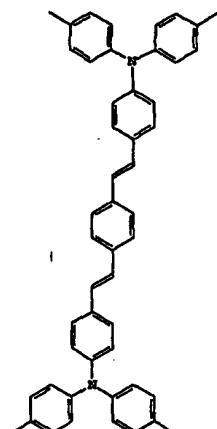
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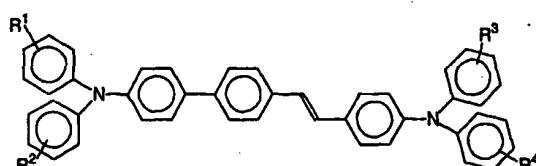
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[0086] In a useful embodiment of the invention, light emitting layer **123c** includes a blue-green dopant of Formula (3)

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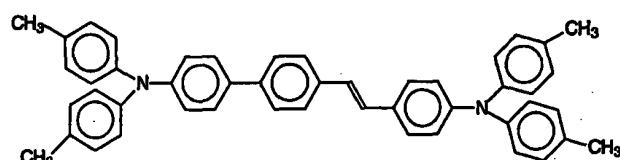
Formula (3)

30 wherein R¹ through R⁴ can be the same or different and individually represent hydrogen or one or more substituents, for example, alkyl groups, such as methyl groups, alkoxy groups, such as methoxy, aryl groups, such as phenyl, or aryloxy groups, such as phenoxy.

[0087] Particularly useful embodiments of the blue-green emissive dopants of light emitting layer **123c** are shown in Formula (4-1) through Formula (4-5)

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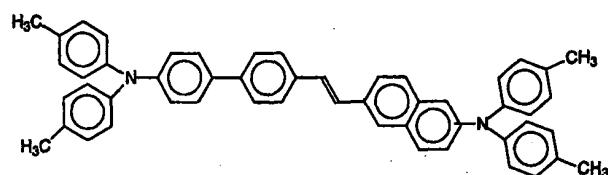
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Formula (4-1);

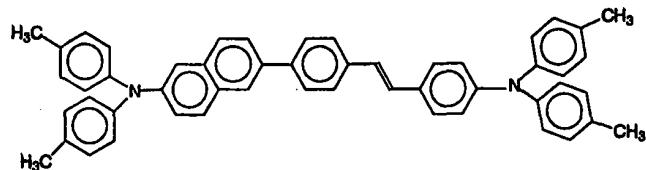
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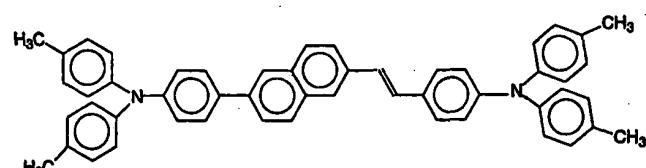


Formula (4-2);

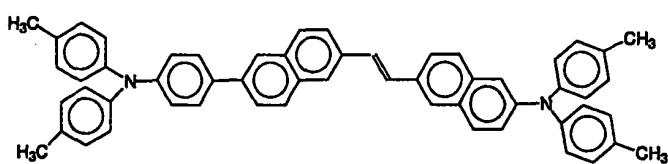
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Formula (4-3);



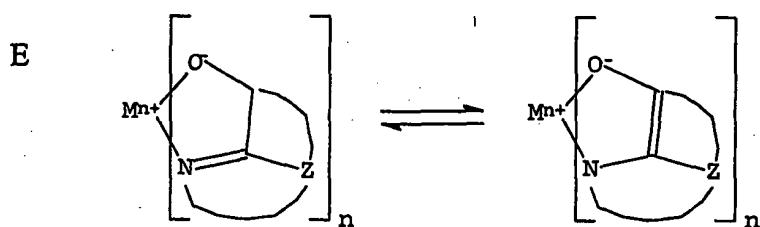
Formula (4-4); or



Formula (4-5).

[0088] In other embodiments of the invention, the light emitting material in light emitting layer **123a** has a peak emission in the blue or blue-green portion of the visible spectrum and contains blue or blue-green light emitting materials and hosts as described above.

[0089] Although not always necessary, it is often useful that an organic layer is formed over light emitting layers **123a** and **123c**, wherein the organic layer includes an electron-transporting material, e.g. electron-transporting layer **124**. Preferred electron-transporting materials for use in electron-transporting layer **124** are metal chelated oxinoid compounds, including chelates of oxine itself (also commonly referred to as 8-quinolinol or 8-hydroxyquinoline). Such compounds help to inject and transport electrons and both exhibit high levels of performance and are readily fabricated in the form of thin films. Exemplary of contemplated oxinoid compounds are those satisfying structural Formula E



wherein:

M represents a metal;

n is an integer of from 1 to 3; and

Z independently in each occurrence represents the atoms completing a nucleus having at least two fused aromatic

rings.

[0090] From the foregoing it is apparent that the metal can be a monovalent, divalent, or trivalent metal. The metal can, for example, be an alkali metal, such as lithium, sodium, or potassium; an alkaline earth metal, such as beryllium, magnesium or calcium; or an earth metal, such as boron or aluminum. Generally any monovalent, divalent, or trivalent metal known to be a useful chelating metal can be employed.

[0091] Z completes a heterocyclic nucleus containing at least two fused aromatic rings, at least one of which is an azole or azine ring. Additional rings, including both aliphatic and aromatic rings, can be fused with the two required rings, if required. To avoid adding molecular bulk without improving on function the number of ring atoms is typically maintained at 18 or less.

[0092] Illustrative of useful chelated oxinoid compounds are the following:

CO-1: Aluminum trisoxine [alias, tris(8-quinolinolato)aluminum(III)];
 CO-2: Magnesium bisoxine [alias, bis(8-quinolinolato)magnesium(II)];
 CO-3: Bis[benzo {f}-8-quinolinolato]zinc (II);
 CO-4: Bis(2-methyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(2-methyl-8-quinolinolato) aluminum(III);
 CO-5: Indium trisoxine [alias, tris(8-quinolinolato)indium];
 CO-6: Aluminum tris(5-methyloxine) [alias, tris(5-methyl-8-quinolinolato) aluminum(III)];
 CO-7: Lithium oxine [alias, (8-quinolinolato)lithium(I)];
 CO-8: Gallium oxine [alias, tris(8-quinolinolato)gallium(III)]; and
 CO-9: Zirconium oxine [alias, tetra(8-quinolinolato)zirconium(IV)].

[0093] Other electron-transporting materials include various butadiene derivatives as disclosed in U.S. Patent 4,356,429 and various heterocyclic optical brighteners as described in U.S. Patent 4,539,507. Benzazoles satisfying structural Formula G are also useful electron-transporting materials.

[0094] Other electron-transporting materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, poly-para-phenylene derivatives, polyfluorene derivatives, polythiophenes, polyacetylenes, and other conductive polymeric organic materials such as those listed in Handbook of Conductive Molecules and Polymers, Vols. 1-4, H.S. Nalwa, ed., John Wiley and Sons, Chichester (1997).

[0095] An electron-injecting layer (not shown) can also be present between the cathode and the electron-transporting layer. Examples of electron-injecting materials include alkali or alkaline earth metals, alkali halide salts, such as LiF mentioned above, or alkali or alkaline earth metal doped organic layers.

[0096] Desired organic materials for the hole-transporting layer 122, light emitting layers 123a and 123c, and electron-transporting layer 124 can be deposited and patterned by any one or more of several methods known in the art. For example, organic materials can be deposited by thermal evaporation from a heated source and pattern achieved by selectively blocking deposition by use of a shadow masking structure. Alternately, the materials can first be deposited onto a donor sheet, which is then placed in contact or in proximity to the display substrate and the materials can be selectively transferred by writing with a laser. Alternately, some materials can be dissolved in a solvent and then selectively deposited on the substrate in the desired location by placing droplets of the solution by drop ejecting apparatus such as an ink jet head.

[0097] The device can further include an encapsulation means (not shown) for preventing moisture from the environment from degrading the device as is known in the art. The encapsulation means can be a glass or metal cover hermetically sealed to the substrate or can be a thin film of moisture impermeable material coated over the pixels. The encapsulation means can further include a desiccant for absorbing moisture.

Examples

[0098] The invention and its advantages can be better appreciated by the following inventive and comparative examples. In the following, mixed compositions are described in terms of percentages or ratios by volume, as are commonly used in the art.

Example 1 (comparative)

[0099] A comparative OLED device was constructed in the following manner:

1. A clean glass substrate was vacuum-deposited with indium tin oxide (ITO) to form a transparent electrode of 85 nm thickness;
2. The above-prepared ITO surface was treated with a plasma oxygen etch, followed by plasma deposition of a 0.5

nm layer of a fluorocarbon polymer (CFx) as described in U.S. Patent 6,208,075;

3. The above-prepared substrate was further treated by vacuum-depositing a 240 nm layer of 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB) as a hole-transporting layer (HTL);

5. A coating of 30 nm thickness, composed of 97.5% NPB (as host) with 2.5% yellow-orange emitting dopant 5,11-bis(biphenyl-4-yl)-6,12-bis(4-tert-butylphenyl)-3,9-di-tert-butylnaphthacene (Formula L50) were co-evaporatively deposited onto the HTL layer to form a yellow-orange emitting first light emitting layer;

10. A coating of 45 nm thickness, composed of 92% 9-(2-naphthyl)-10-(4-biphenyl)anthracene (Host1), 7% NPB, and 1% tetra-t-butylperylene (TBP), was co-evaporatively deposited onto the above substrate to form a blue emitting second light emitting layer;

15. A 10 nm layer of tris(8-quinololato)aluminum (III) (ALQ) was vacuum-deposited onto the above substrate at a coating station that included a heated graphite boat source to form an electron-transporting layer;

7. A 100 nm cathode layer was deposited onto the electron-transporting layer. The cathode includes 0.5 nm of LiF as an electron injection layer followed by 100 nm of aluminum, to form a cathode layer; and

8. The device was then transferred to a dry box for encapsulation.

Example 2

[0100] Example 2 was prepared similar to Example 1, with the exception of the yellow-orange emitting layer, which included tBuDPN co-dopant (Formula P6). The yellow-orange emitting layer of Example 2 was composed of 78% NPB (as host) with 19.5% tBuDPN (Formula P6) and 2.5% of 5,11-bis(biphenyl-4-yl)-6,12-bis(4-tert-butylphenyl)-3,9-di-tert-butylnaphthacene (Formula L50).

[0101] The blue layer, ETL and cathode layers were the same. The device was then transferred to a dry box for encapsulation.

Example 3

[0102] Example 3 was prepared similar to Example 1, with the exception that the yellow-orange light emitting layer was not included, and the HTL layer was slightly thicker. The blue layer, ETL and cathode layers were the same. The device was then transferred to a dry box for encapsulation.

Example 4 (inventive)

[0103] Example 4 is an example of an OLED display device provided by this invention. The OLED devices of Examples 2 and 3 are combined into one OLED display device in Example 4 to make a multicolor RGB display according to this invention.

Table 1

| Examples | HTL NPB (nm) | Yellow-Orange EML (30 nm) | | | Blue EML (45 nm) | | | Performance | | |
|----------|--------------------|---------------------------|------|------|------------------|-------|-------|------------------------|------|------|
| | | NPB % | P6 % | L50% | Host1 % | NPB % | TBP % | Lum. Eff. (cd/A) | CIEx | CIEy |
| 1 | 240 | 97.5 | 0 | 2.5 | 92 | 7 | 1 | 12.0 | 0.32 | 0.32 |
| 2 | 240 | 78 | 19.5 | 2.5 | 92 | 7 | 1 | 16.5 | 0.43 | 0.41 |
| 3 | 300 | 0 | 0 | 0 | 92 | 7 | 1 | 5.2 | 0.14 | 0.17 |

[0104] Table 1 shows the device performance of Examples 1 to 3. It shows the device structure, luminance efficiency, and CIEx,y chromaticity. The first example is a typical white OLED with effective efficiency and desirable CIEx,y chromaticity. Example 2 is a yellowish-white OLED device with higher efficiency, and Example 3 is a blue OLED device, with the same blue EML as in Examples 1 and 2.

[0105] FIG. 12 shows the EL spectra of the devices of Examples 1 to 3. The EL spectrum of Example 1 shows a typical white OLED device, with yellow-orange and blue light emitting layers balanced in the appropriate ratios to give effective white emission. The CIEx,y chromaticity for this device was (0.32, 0.32). The EL spectrum of Example 2 shows a yellow-shifted 'white' OLED device, with CIEx,y chromaticity of (0.43, 0.41). The yellow-orange peak of device 2 has higher intensity than that of device 1, resulting in higher efficiency. The EL spectrum of Example 3 shows a blue OLED device. The blue peak of device 3 has higher intensity than that of devices 1 and 2. Devices 1, 2, and 3 all contain the

same blue light emitting layer.

Table 2

| Examples | Red | | | Green | | | Blue | | | RGB Power (mW) |
|----------|------------------|------|------|------------------|------|------|------------------|------|------|----------------|
| | Lum. Eff. (cd/A) | CIEx | CIEy | Lum. Eff. (cd/A) | CIEx | CIEy | Lum. Eff. (cd/A) | CIEx | CIEy | |
| 1 | 2.4 | 0.64 | 0.36 | 6.1 | 0.31 | 0.54 | 1.3 | 0.13 | 0.10 | 546 |
| 2 | 4.0 | 0.64 | 0.36 | 8.0 | 0.38 | 0.55 | 0.8 | 0.13 | 0.11 | 580 |
| 3 | n/a | | | | | | 5.2 | 0.14 | 0.17 | n/a |
| 4 | 4.0 | 0.64 | 0.36 | 8.0 | 0.38 | 0.55 | 5.2 | 0.14 | 0.17 | 314 |

[0106] Table 2 shows the simulated performance of Examples 1 to 4 in a multicolor three pixel RGB display. It shows the luminance efficiency and CIEx,y chromaticity for the red, green, and blue pixels using a typical set of LCD color filters (except for Example 3, which does not use color filters). In addition, it gives the predicted average power consumption (mW) for an RGB display at the panel luminance level of 180 cd/m², given a typical set of digital pictorial images. The power consumption calculation assumes a display size of 2.16" diagonal, a circular polarizer with 44% transmittance, and a typical set of LCD color filters. The first example is a typical white OLED with effective efficiency and desirable CIEx,y chromaticity, resulting in a power consumption of 546 mW. Although Example 2 has higher efficiency, it does not have effective white color resulting in higher power consumption. Example 4 combines the red and green pixels of Example 2 along with the blue pixel of Example 3, according to the first embodiment of this invention. Due to the unfiltered high efficiency blue pixel and the higher efficiency red and green pixels, the power consumption is much lower (and therefore the power efficiency is higher) than either Example 1 or 2. Further advantages in power efficiency would be obtained if a four pixel or five pixel multicolor OLED display were constructed according to other embodiments in the present invention. For instance, if a fourth unfiltered pixel were provided using the high efficiency yellow-orange emission from the device of Example 2 according to the third embodiment of this invention, then a further reduction in power consumption would be obtained.

PARTS LIST

[0107]

| | |
|------|-----------------------------|
| 10 | pixel group |
| 11a | pixel |
| 11b | pixel |
| 11c | pixel |
| 40 | 11d pixel |
| 11e | pixel |
| 100 | substrate |
| 110a | first electrode |
| 110b | first electrode |
| 45 | 110c first electrode |
| 110d | first electrode |
| 110e | first electrode |
| 122 | hole-transporting layer |
| 123a | light emitting layer |
| 50 | 123c light emitting layer |
| 124 | electron-transporting layer |
| 130 | second electrode |
| 140a | color filter |
| 140b | color filter |
| 55 | 140c color filter |
| 140e | color filter |
| 210a | external light emission |

210b external light emission
 210c external light emission
 210d external light emission
 210e external light emission
 5 220a internal light emission
 220b internal light emission
 220c internal light emission
 220d internal light emission
 220e internal light emission

10

Claims

1. An OLED display having at least first (11a), second (11b), and third (11c) differently colored pixels, comprising:

15 a) a first light emitting layer (123a) provided over a substrate (100) for the first (11a) and second (11b) pixels and a second light emitting layer (123c) provided over the substrate (100) for the first (11a), second (11b), and third (11c) pixels, wherein the first and second light emitting layers (123a), (123c) produce light having different spectra (220a), (220b), and wherein the light produced by overlapping the first and second light emitting layers (123a), (123c) has substantial spectral components corresponding to the light output (210a), (210b) desired for the first (11a) and second (11b) pixels, and the light produced by the second light emitting layer (123c) has substantial spectral components corresponding to the light output desired (210c) for the third pixel (11c); and
 20 b) first (140a) and second (140b) color filters in operative relationship with the first (11a) and second (11b) pixels; **characterized in that** the first light emitting layer (123a) is not provided over the third pixel (11c).

25 2. The OLED display according to claim 1 wherein the light spectrum produced by the first light emitting layer (123a) has substantial spectral components corresponding to yellow-orange light, and wherein the light spectrum produced by the second light emitting layer (123c) has substantial spectral components corresponding to blue light.

30 3. The OLED display according to claim 1 wherein the light spectrum produced by overlapping the first and second light emitting layers (123a), (123c) has substantial spectral components corresponding to yellow-orange light.

4. The OLED display according to claim 2 wherein the first color filter (140a) passes red light and absorbs light of other colors, and the second color filter (140b) passes green light and absorbs light of other colors.

35 5. The OLED display according to claim 1 wherein the light spectrum produced by the first light emitting layer (123a) has substantial spectral components corresponding to blue-green light, and wherein the light spectrum produced by the second light emitting layer (123c) has substantial spectral components corresponding to red light.

40 6. The OLED display according to claim 5 wherein the light spectrum produced by overlapping the first and second light emitting layers (123a), (123c) has substantial spectral components corresponding to blue-green light.

7. The OLED display according to claim 5 wherein the first color filter (140a) passes blue light and absorbs light of other colors, and the second color filter (140b) passes green light and absorbs light of other colors.

45 8. An OLED display having at least first (11a), second (11b), and third (11c) differently colored pixels, comprising:

50 a) a first light emitting layer (123a) provided over a substrate (100) for the first (11a), second (11b), and third (11c) pixels and a second light emitting layer (123c) provided over the substrate (100) for the third pixel (11c) wherein the first and second light emitting layers (123a), (123c) produce light having different spectra (220a), (220b), and wherein the light produced by overlapping the first and second light emitting layers (123a), (123c) has substantial spectral components corresponding to the light output desired (210c) for the third pixel (11c); and
 55 b) first (140a) and second (140b) color filters in operative relationship with the first (11a) and second (11b) pixels; **characterized in that** the second light emitting layer (123c) is not provided over the first (11a) and second (11b) pixels.

9. The OLED display according to claim 1 wherein the first and second light emitting layers (123a), (123c) are provided over the substrate (100) for a fourth pixel, and wherein the light produced by overlapping the first and second light

emitting layers (123a), (123c) has substantial spectral components corresponding to the light output desired for the first, second, and fourth pixels.

5 10. The OLED display according to claim 8 wherein the first light emitting layer (123a) is provided over the substrate (100) for a fourth pixel, and wherein the light produced by the first light emitting layer (123a) has substantial spectral components corresponding to the light output desired for the first, second, and fourth pixels.

10 11. The OLED display according to claim 10 wherein the second light emitting layer (123c) is provided over the substrate (100) for a fifth pixel, and wherein the light produced by the second light emitting layer (123c) has substantial spectral components corresponding to the light output desired for the third and fifth pixels.

Patentansprüche

15 1. OLED-Display mit mindestens ersten (11a), zweiten (11b), und dritten (11c) unterschiedlich gefärbten Pixeln, umfassend:

20 a) eine erste Licht emittierende Schicht (123a), die über einem Substrat (100) für die ersten (11a) und zweiten (11b) Pixel vorgesehen ist, und eine zweite Licht emittierende Schicht (123c), die über einem Substrat (100) für die ersten (11a), zweiten (11b) und dritten (11c) Pixel vorgesehen ist, wobei die ersten und zweiten Licht emittierenden Schichten (123a), (123c) Licht mit unterschiedlichen Spektren (220a), (220b) erzeugen, und wobei das durch Überlappen der ersten und zweiten Licht emittierenden Schichten (123a), (123c) erzeugte Licht wesentliche spektrale Komponenten entsprechend der für die ersten (11a) und zweiten (11b) Pixel gewünschten Lichtleistung (210a), (210b) hat, und das durch die zweite Licht emittierende Schicht (123c) erzeugte Licht wesentliche spektrale Komponenten entsprechend der für das dritte Pixel (11c) gewünschten Lichtleistung (210c) hat; und

25 b) erste (140a) und zweite (140b) Farbfilter in Wirkbeziehung zu den ersten (11a) und zweiten (11b) Pixeln; **dadurch gekennzeichnet, dass** die erste Licht emittierende Schicht (123a) nicht über dem dritten Pixel (11a) vorgesehen ist.

30 2. OLED-Display nach Anspruch 1, wobei das durch die erste Licht emittierende Schicht (123a) erzeugte Lichtspektrum wesentliche spektrale Komponenten entsprechend dem gelb-orangen Licht hat, und wobei das durch die zweite Licht emittierende Schicht (123c) erzeugte Lichtspektrum wesentliche spektrale Komponenten entsprechend dem blauen Licht hat.

35 3. OLED-Display nach Anspruch 1, wobei das durch Überlappen der ersten und zweiten Licht emittierenden Schichten (123a), (123c) erzeugte Lichtspektrum wesentliche spektrale Komponenten entsprechend dem gelb-orangen Licht hat.

40 4. OLED-Display nach Anspruch 2, wobei der erste Farbfilter (140a) rotes Licht durchlässt und Licht von anderen Farben absorbiert, und der zweite Farbfilter (140b) grünes Licht durchlässt und Licht von anderen Farben absorbiert.

45 5. OLED-Display nach Anspruch 1, wobei das durch die erste Licht emittierende Schicht (123a) erzeugte Lichtspektrum wesentliche spektrale Komponenten entsprechend dem blau-grünen Licht hat, und wobei das durch die zweite Licht emittierende Schicht (123c) erzeugte Lichtspektrum wesentliche spektrale Komponenten entsprechend dem roten Licht hat.

50 6. OLED-Display nach Anspruch 5, wobei das durch Überlappen der ersten und zweiten Licht emittierenden Schichten (123a), (123c) erzeugte Lichtspektrum wesentliche spektrale Komponenten entsprechend dem blau-grünen Licht hat.

7. OLED-Display nach Anspruch 5, wobei der erste Farbfilter (140a) blaues Licht durchlässt und Licht von anderen Farben absorbiert, und der zweite Farbfilter (140b) grünes Licht durchlässt und Licht von anderen Farben absorbiert.

55 8. OLED-Display mit mindestens ersten (11a), zweiten (11b) und dritten (11c) unterschiedlich gefärbten Pixeln, umfassend:

a) eine erste Licht emittierende Schicht (123a), die über einem Substrat (100) für die ersten (11a), zweiten

(11b) und dritten (11c) Pixel vorgesehen ist, und eine zweite Licht emittierende Schicht (123c), die über dem Substrat (100) für das dritte Pixel (11c) vorgesehen ist, wobei die ersten und zweiten Licht emittierenden Schichten (123a), (123c) Licht mit unterschiedlichen Spektren (220a), (220b) erzeugen, und wobei das durch Überlappen der ersten und zweiten Licht emittierenden Schichten (123a), (123c) erzeugte Licht wesentliche spektrale Komponenten entsprechend der für das dritte Pixel (11c) gewünschten Lichtleistung (210c) hat; und b) erste (140a) und zweite (140b) Farbfilter in Wirkbeziehung zu den ersten (11a) und zweiten (11b) Pixeln; **dadurch gekennzeichnet, dass** die zweite Licht emittierende Schicht (123c) nicht über den ersten (11a) und zweiten (11b) Pixeln vorgesehen ist.

5 9. OLED-Display nach Anspruch 1, wobei die ersten und zweiten Licht emittierende Schichten (123a), (123c) über dem Substrat (100) für ein vieres Pixel vorgesehen sind, und wobei das durch Überlappen der ersten und zweiten Licht emittierenden Schichten (123a), (123c) erzeugte Licht wesentliche spektrale Komponenten entsprechend der für die ersten, zweiten und vierten Pixel gewünschten Lichtleistung hat.

10 15 10. OLED-Display nach Anspruch 8, wobei die erste Licht emittierende Schicht (123a) über dem Substrat (100) für ein vieres Pixel vorgesehen ist, und wobei das durch die erste Licht emittierende Schicht (123a) erzeugte Licht wesentliche spektrale Komponenten entsprechend der für die ersten, zweiten und vierten Pixel gewünschten Lichtleistung hat.

20 25 11. OLED-Display nach Anspruch 10, wobei die zweite Licht emittierende Schicht (123c) über dem Substrat (100) für ein fünftes Pixel vorgesehen ist, und wobei das durch die zweite Licht emittierende Schicht (123c) erzeugte Licht wesentliche spektrale Komponenten entsprechend der für die dritten und fünften Pixel gewünschten Lichtleistung hat.

30 25 **Revendications**

1. Dispositif d'affichage OLED comportant au moins des premier (11a), deuxième (11b) et troisième (11c) pixels de couleur différente, comprenant :

35 30 a) une première couche émettrice de lumière (123a) prévue au-dessus d'un substrat (100) pour les premier (11a) et deuxième (11b) pixels et une seconde couche émettrice de lumière (123c) prévue au-dessus du substrat (100) pour les premier (11a), deuxième (11b) et troisième (11c) pixels, dans lequel les première et seconde couches émettrices de lumière (123a), (123c) produisent de la lumière ayant des spectres différents (220a), (220b), et dans lequel la lumière produite par chevauchement des première et seconde couches émettrices de lumière (123a), (123c) a sensiblement des composantes spectrales correspondant à la sortie de lumière (210a), (210b) souhaitée pour les premier (11a) et deuxième (11b) pixels, et la lumière produite par la seconde couche émettrice de lumière (123c) a sensiblement des composantes spectrales correspondant à la sortie de lumière (210c) souhaitée pour le troisième pixel (11c) ; et

40 35 b) des premier (140a) et second (140b) filtres colorés en relation de fonctionnement avec les premier (11a) et deuxième (11b) pixels ;
caractérisé en ce que la première couche émettrice de lumière (123a) n'est pas prévue au-dessus du troisième pixel (11c).

45 40 2. Dispositif d'affichage OLED selon la revendication 1, dans lequel le spectre de lumière produit par la première couche émettrice de lumière (123a) a sensiblement des composantes spectrales correspondant à la lumière jaune orangé, et dans lequel le spectre de lumière produit par la seconde couche émettrice de lumière (123c) a sensiblement des composantes spectrales correspondant à la lumière bleue.

50 45 3. Dispositif d'affichage OLED selon la revendication 1, dans lequel le spectre de lumière produit par chevauchement des première et seconde couches émettrices de lumière (123a), (123c) a sensiblement des composantes spectrales correspondant à la lumière jaune orangé.

55 50 4. Dispositif d'affichage OLED selon la revendication 2, dans lequel le premier filtre coloré (140a) laisse passer la lumière rouge et absorbe la lumière d'autres couleurs, et le second filtre coloré (140b) laisse passer la lumière verte et absorbe la lumière d'autres couleurs.

5. Dispositif d'affichage OLED selon la revendication 1, dans lequel le spectre de lumière produit par la première

couche émettrice de lumière (123a) a sensiblement des composantes spectrales correspondant à la lumière bleu vert, et dans lequel le spectre de lumière produit par la seconde couche émettrice de lumière (123c) a sensiblement des composantes spectrales correspondant à la lumière rouge.

5 6. Dispositif d'affichage OLED selon la revendication 5, dans lequel le spectre de lumière produit par chevauchement des première et seconde couches émettrices de lumière (123a), (123c) a sensiblement des composantes spectrales correspondant à la lumière bleu vert.

10 7. Dispositif d'affichage OLED selon la revendication 5, dans lequel le premier filtre coloré (140a) laisse passer la lumière bleue et absorbe la lumière d'autres couleurs, et le second filtre coloré (140b) laisse passer la lumière verte et absorbe la lumière d'autres couleurs.

15 8. Dispositif d'affichage OLED ayant au moins des premier (11a), deuxième (11b) et troisième (11c) pixels de couleur différente, comprenant :

15 a) une première couche émettrice de lumière (123a) prévue au-dessus d'un substrat (100) pour les premier (11a), deuxième (11b) et troisième (11c) pixels, et une seconde couche émettrice de lumière (123c) prévue au-dessus du substrat (100) pour le troisième (11c) pixel, dans lequel les première et seconde couches émettrices de lumière (123a), (123c) produisent de la lumière ayant des spectres différents (220a), (220b), et dans lequel la lumière produite par chevauchement des première et seconde couches émettrices de lumière (123a), (123c) a sensiblement des composantes spectrales correspondant à la sortie de lumière (210c) souhaitée pour le troisième pixel (11c) ; et

20 b) des premier (140a) et second (140b) filtres colorés en relation de fonctionnement avec les premier (11a) et deuxième (11b) pixels ;

25 **caractérisé en ce que** la seconde couche émettrice de lumière (123c) n'est pas prévue au-dessus des premier (11a) et deuxième (11b) pixels.

30 9. Dispositif d'affichage OLED selon la revendication 1, dans lequel les première et seconde couches émettrices de lumière (123a), (123c) sont prévues au-dessus du substrat (100) pour un quatrième pixel, et dans lequel la lumière produite par chevauchement des première et seconde couches émettrices de lumière (123a), (123c) a sensiblement des composantes spectrales correspondant à la sortie de lumière souhaitée pour les premier, deuxième et quatrième pixels.

35 10. Dispositif d'affichage OLED selon la revendication 8, dans lequel la première couche émettrice de lumière (123a) est prévue au-dessus du substrat (100) pour un quatrième pixel, et dans lequel la lumière produite par la première couche émettrice de lumière (123a) a sensiblement des composantes spectrales correspondant à la sortie de lumière souhaitée pour les premier, deuxième et quatrième pixels.

40 11. Dispositif d'affichage OLED selon la revendication 10, dans lequel la seconde couche émettrice de lumière (123c) est prévue au-dessus du substrat (100) pour un cinquième pixel, et dans lequel la lumière produite par la seconde couche émettrice de lumière (123c) a sensiblement des composantes spectrales correspondant à la sortie de lumière souhaitée pour les troisième et cinquième pixels.

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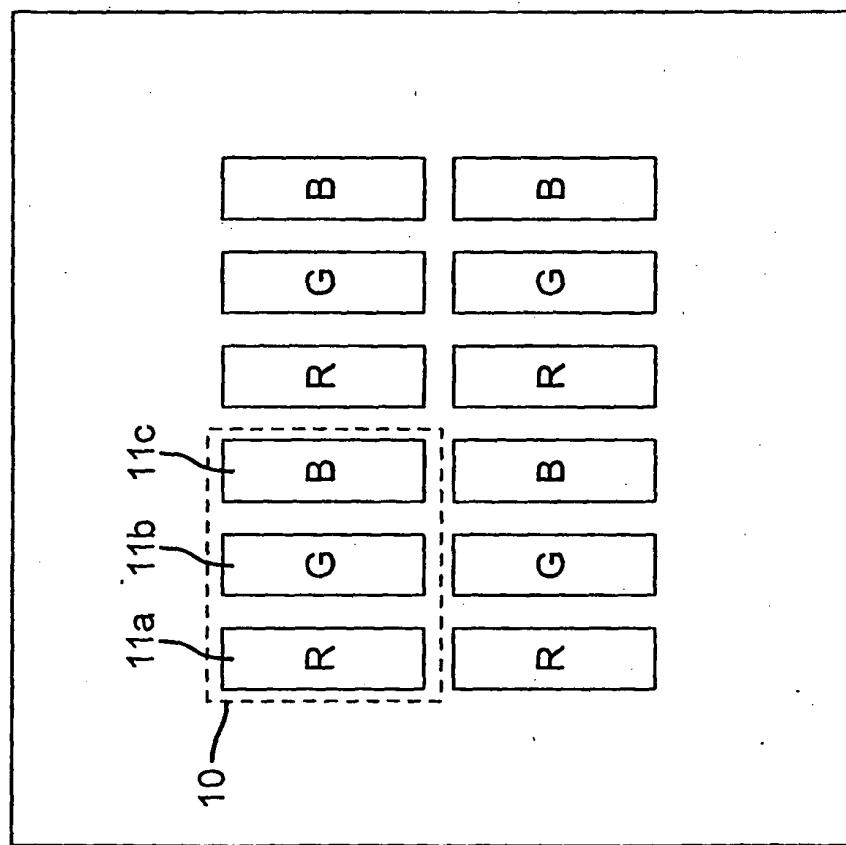


FIG. 1

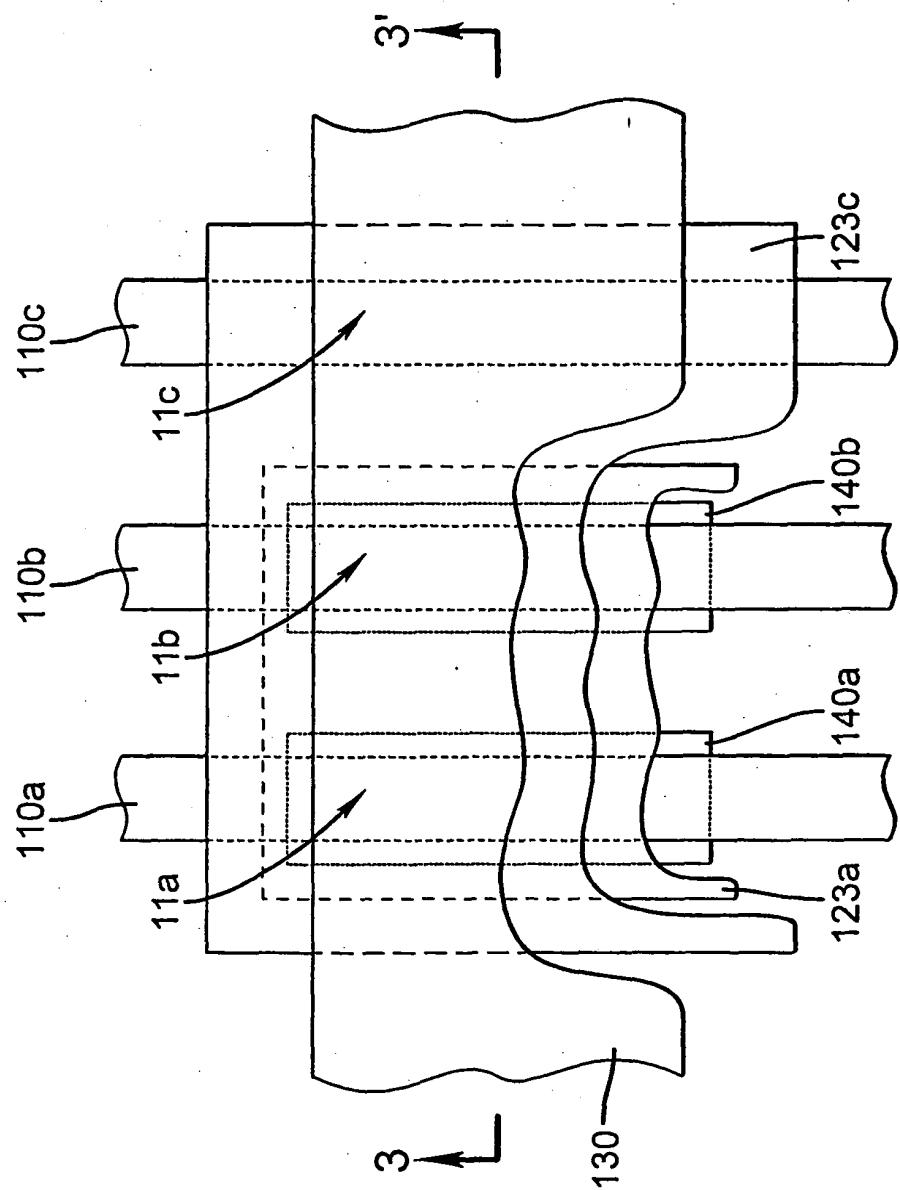


FIG. 2

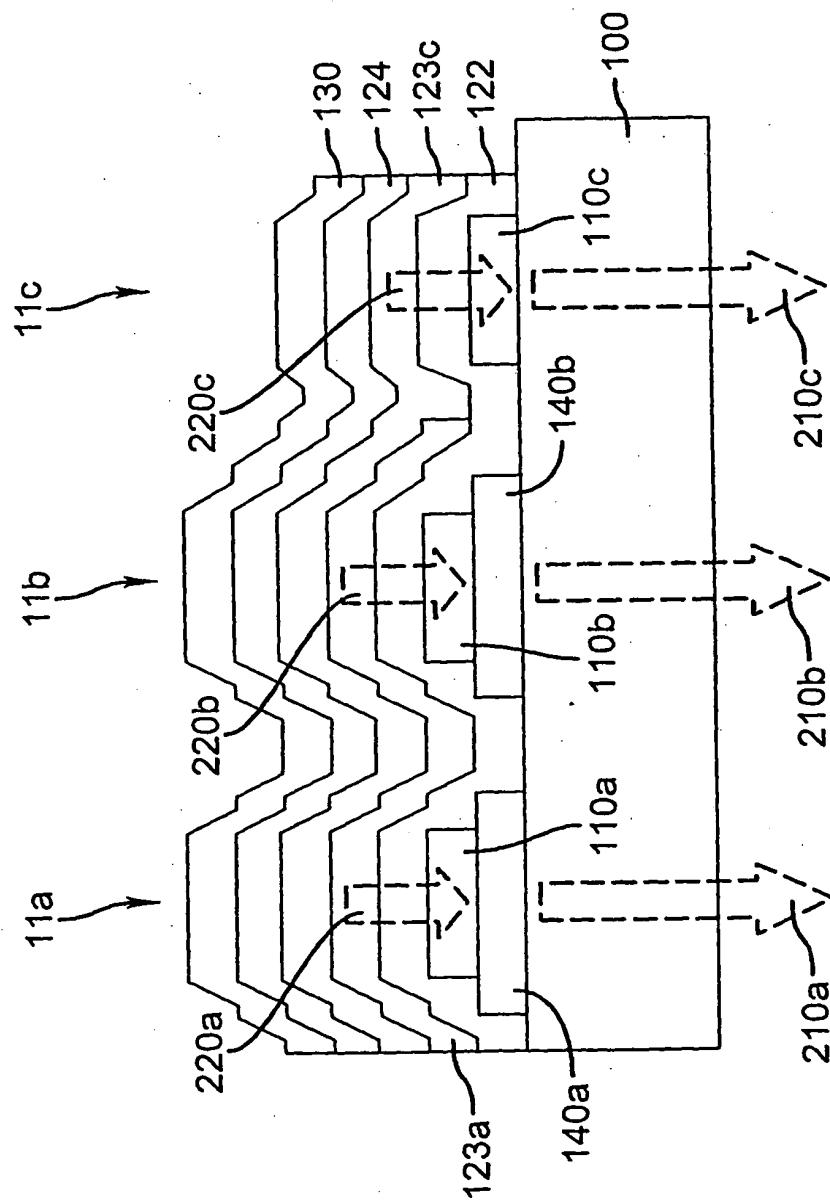


FIG. 3

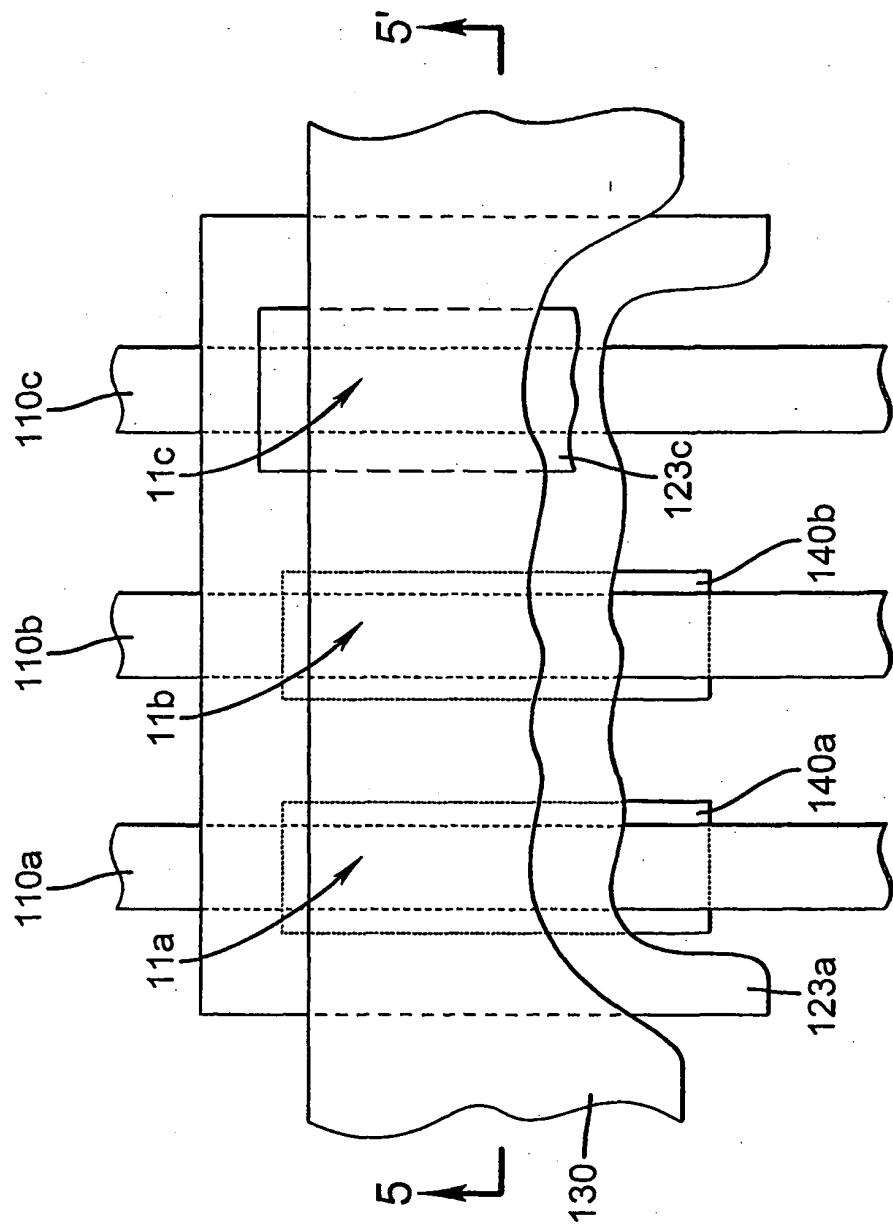


FIG. 4

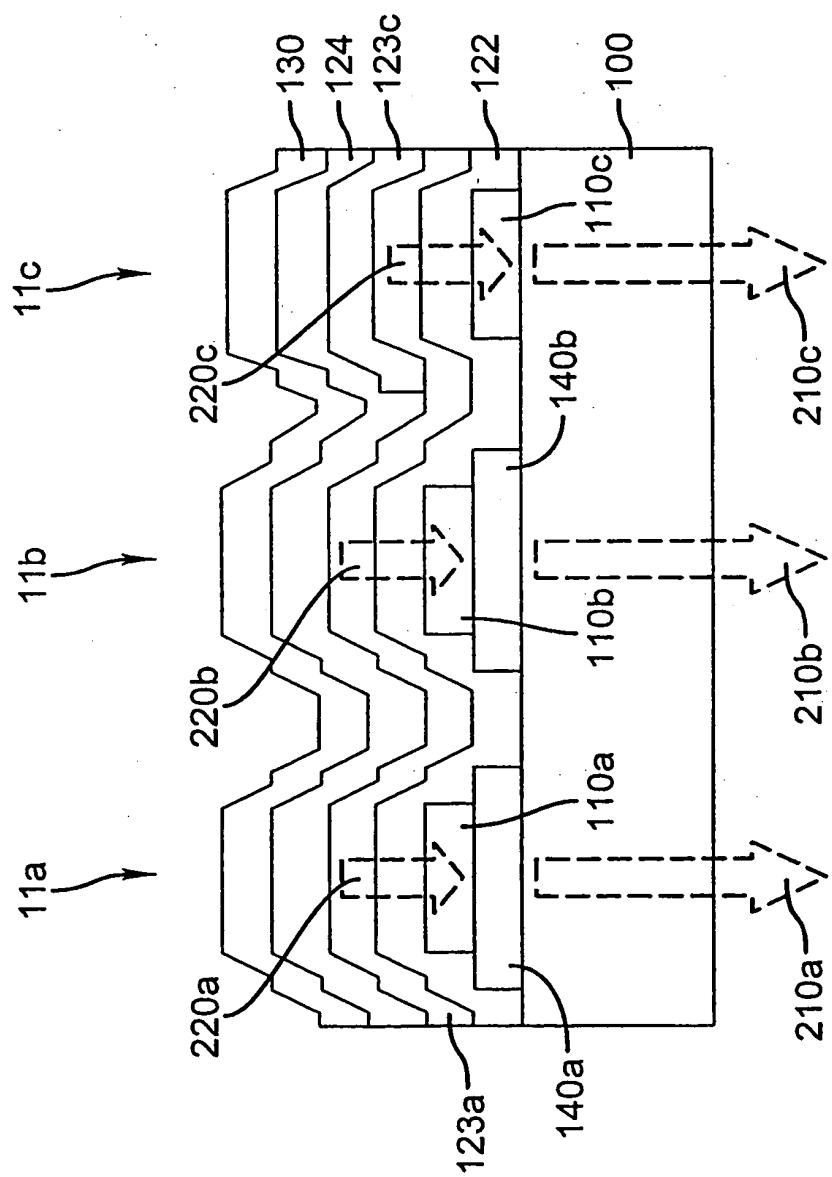


FIG. 5

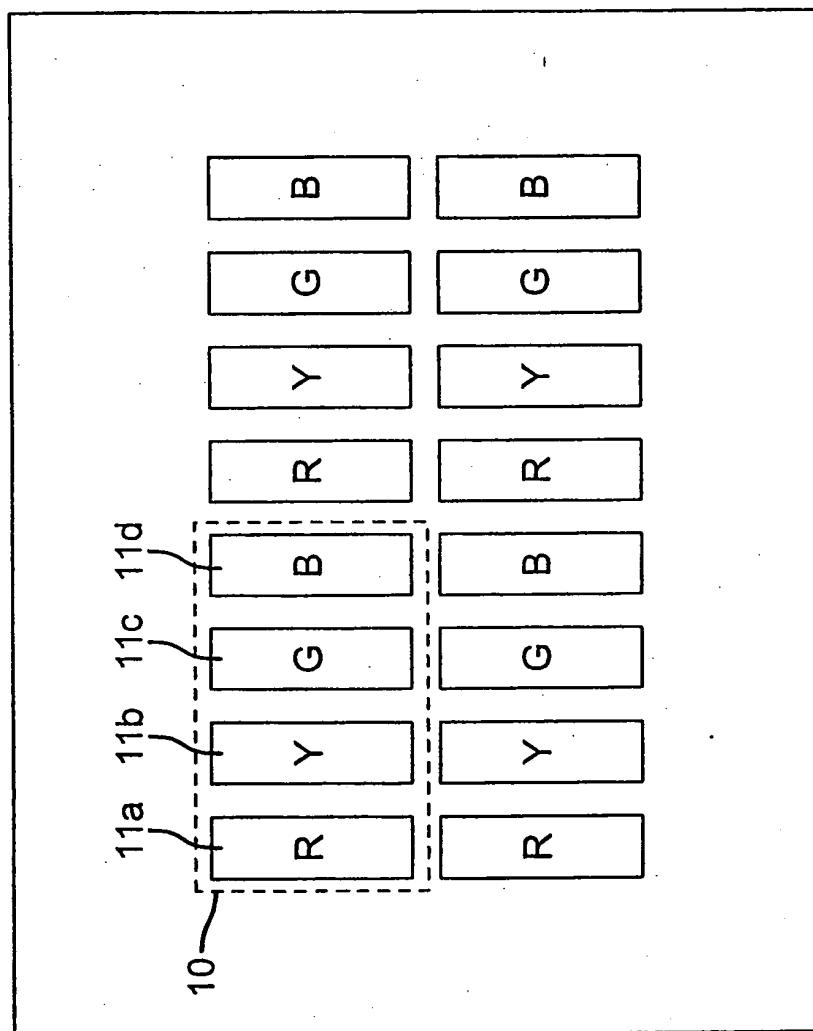


FIG. 6

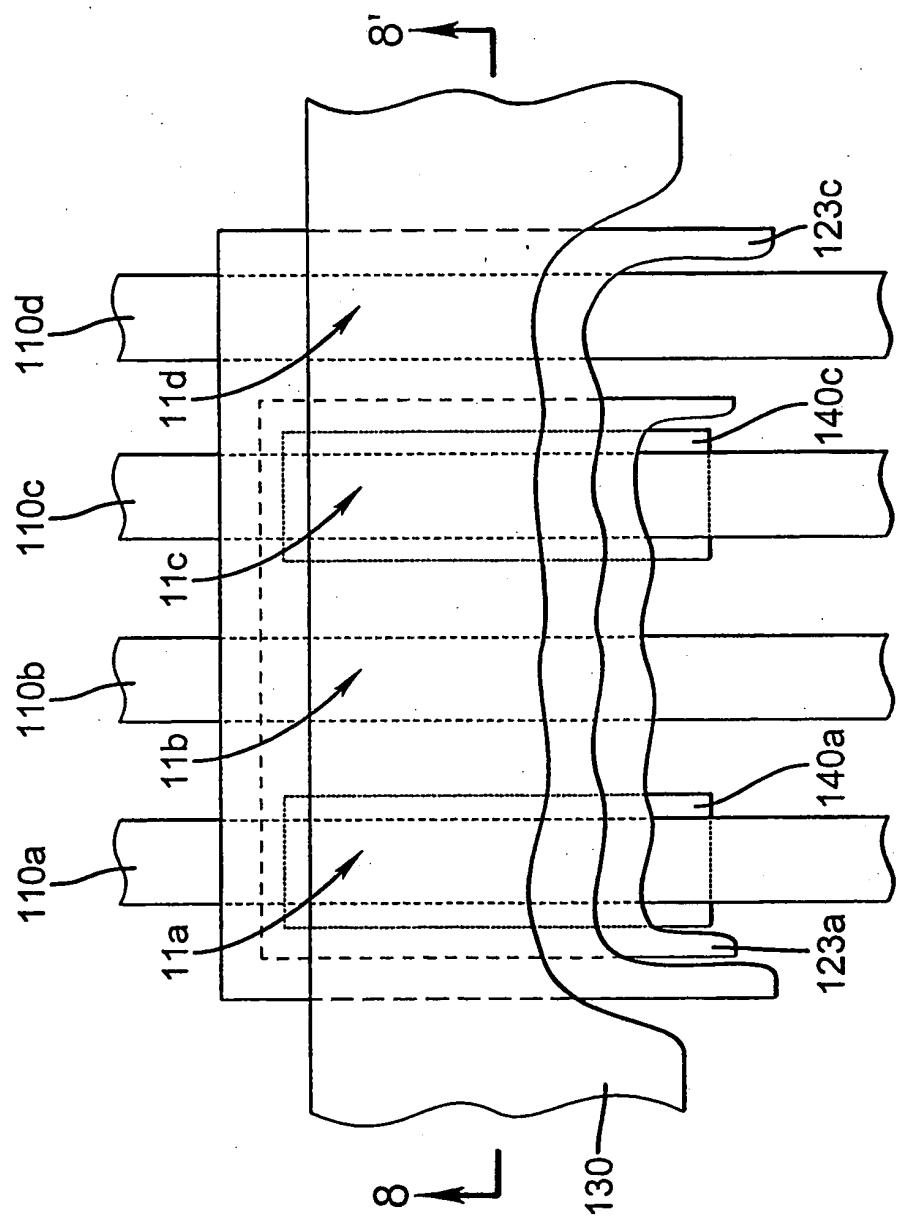


FIG. 7

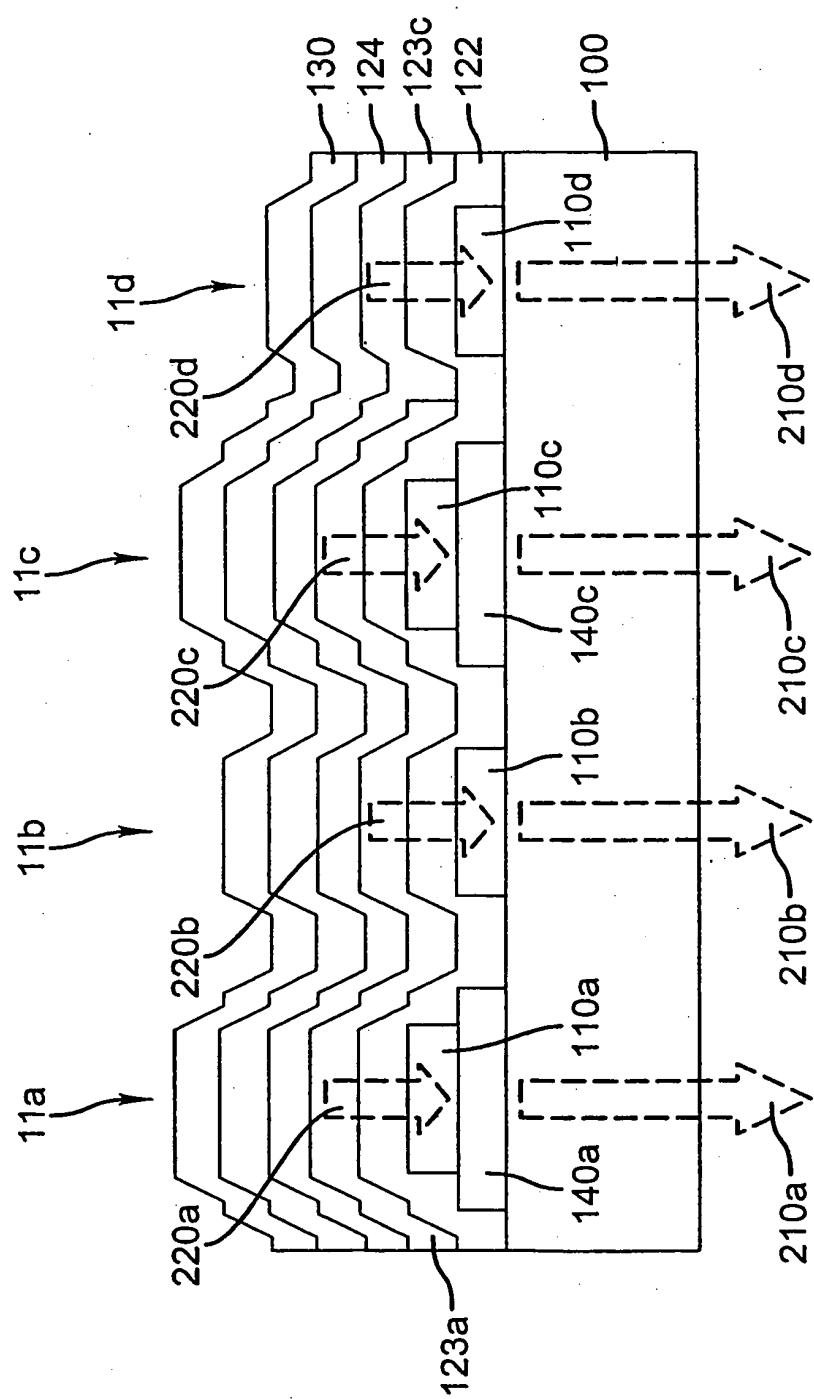


FIG. 8

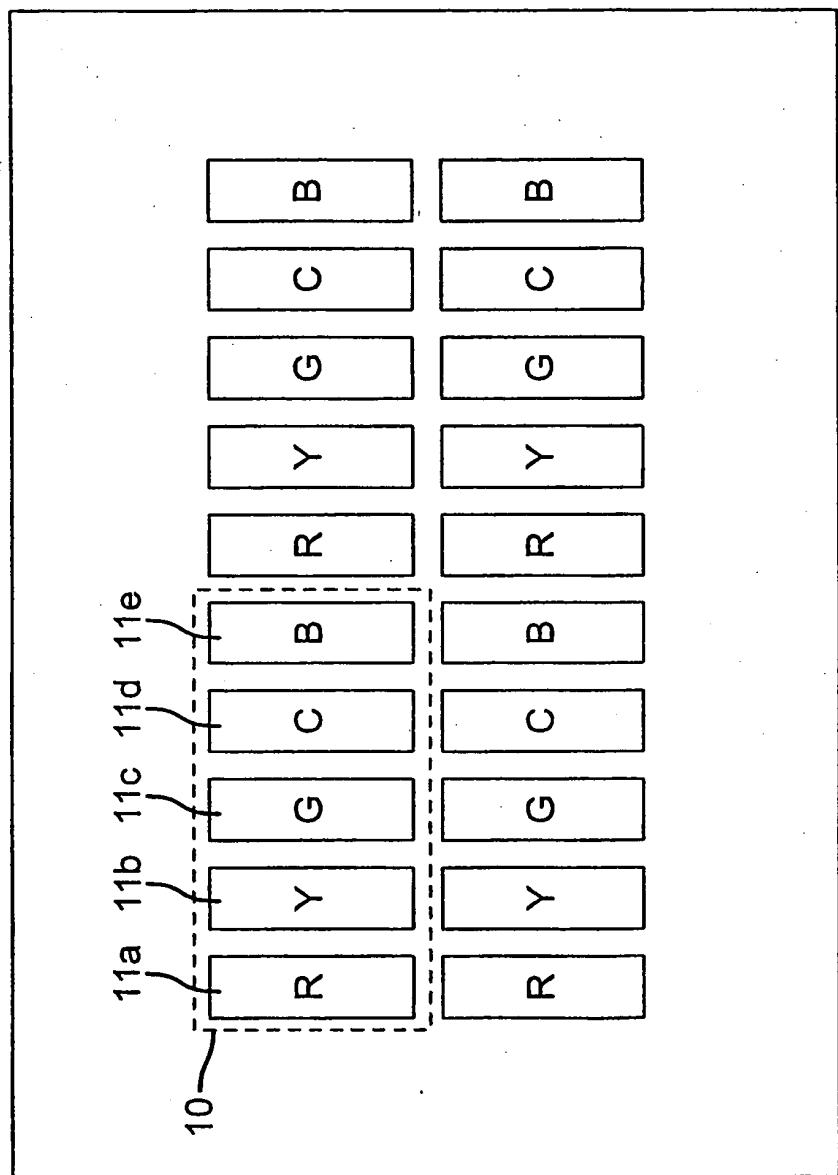


FIG. 9

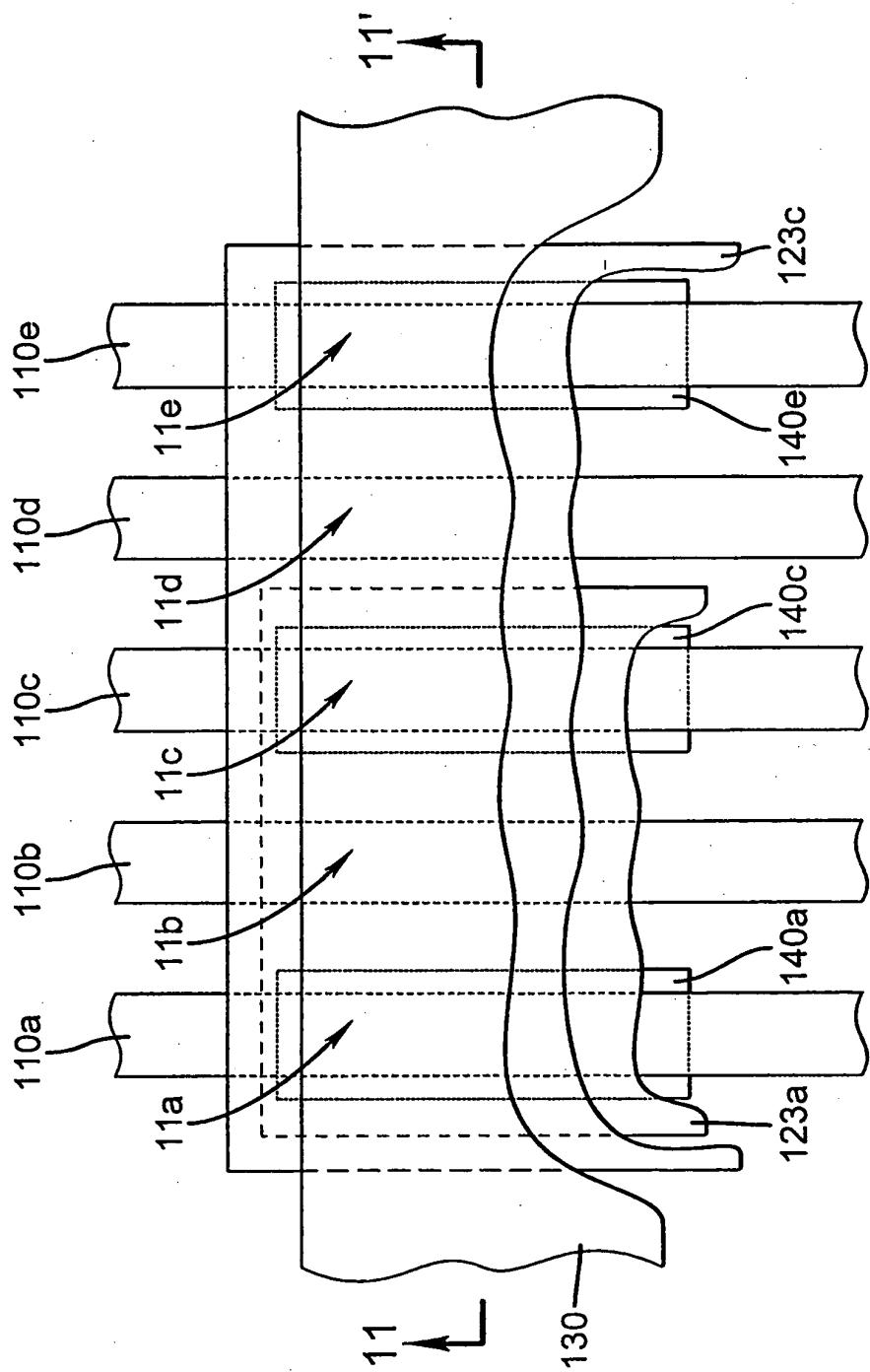


FIG. 10

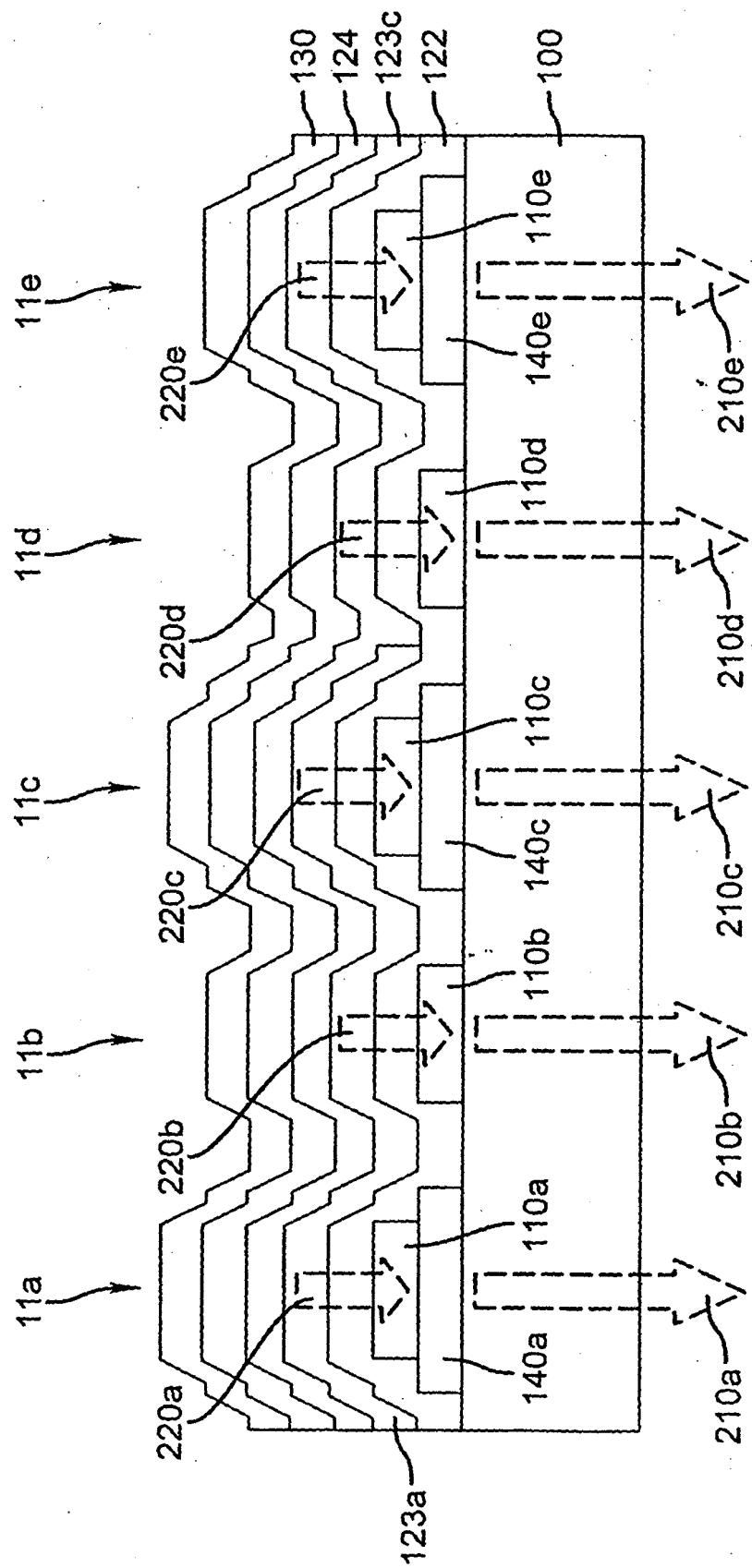


FIG. 11

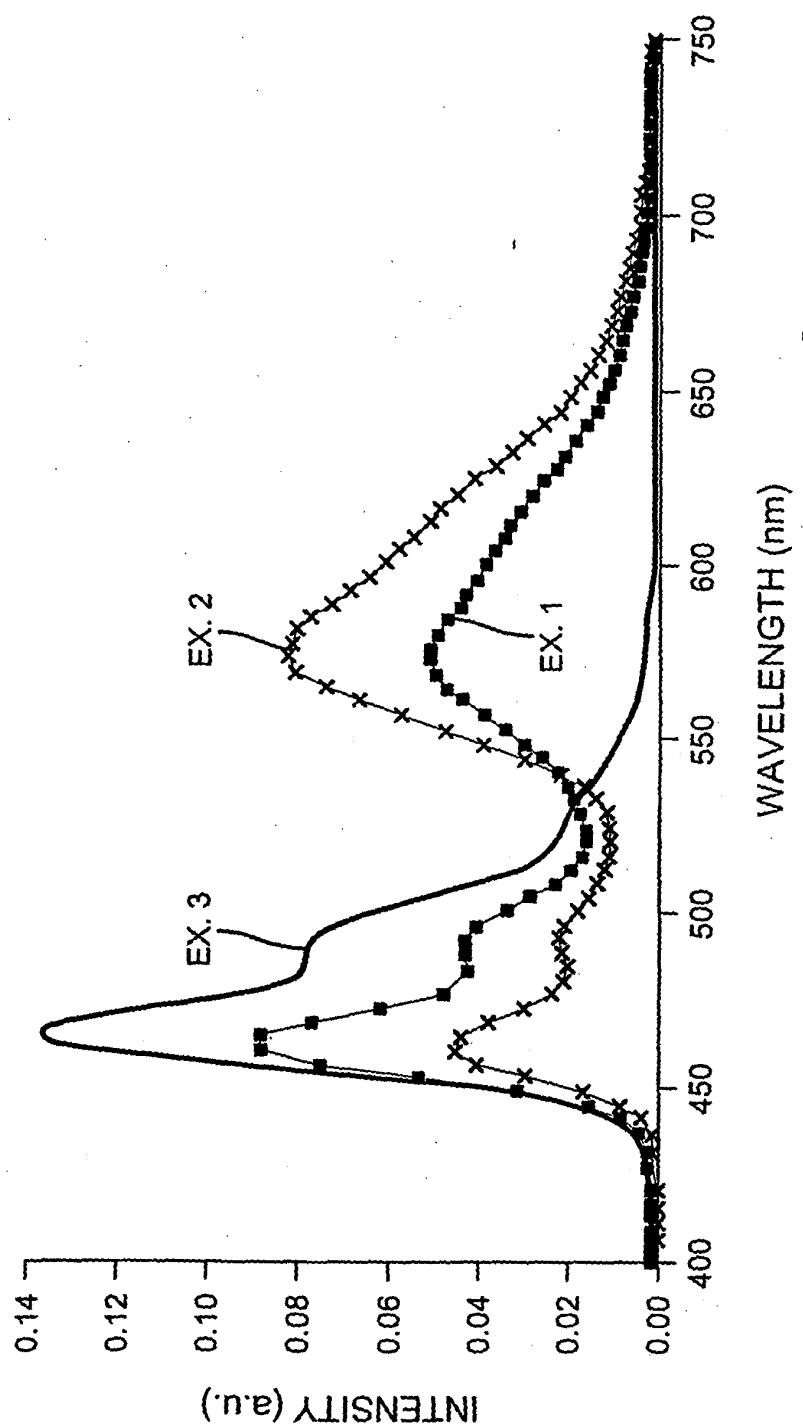


FIG. 12

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 5276380 A [0002]
- US 5550066 A [0002]
- US 20010043043 A1 [0003]
- US 6693611 B [0006] [0007]
- US 4720432 A [0041] [0043]
- US 6208075 B [0041] [0100]
- EP 0891121 A1 [0041]
- EP 1029909 A1 [0041]
- US 3180730 A, Klupfel [0042]
- US 3567450 A, Brantley [0042]
- US 3658520 A [0042]
- US 5061569 A [0043]
- EP 1009041 A [0050]
- US 4769292 A [0051]
- US 5935721 A [0051] [0055]
- WO 9855561 A [0051]
- WO 0018851 A [0051]
- WO 0057676 A [0051]
- WO 0070655 A [0051]
- US 4768292 A [0055]
- US 5141671 A [0055]
- US 5150006 A [0055]
- US 5151629 A [0055]
- US 5294870 A [0055]
- US 5405709 A [0055]
- US 5484922 A [0055]
- US 5593788 A [0055]
- US 5645948 A [0055]
- US 5683823 A [0055]
- US 5755999 A [0055]
- US 5928802 A [0055]
- US 5935720 A [0055]
- US 6020078 A [0055]
- US 6534199 B [0055]
- US 6194119 B [0056]
- WO 0070655 A2 [0057] [0058]
- WO 0139234 A2 [0057]
- WO 0193642 A1 [0057] [0058]
- WO 02074015 A2 [0057]
- WO 0215645 A1 [0057]
- US 20020117662 A1 [0057]
- US 20030068528 A1 [0058]
- US 20030175553 A1 [0058]
- US 69312103 A, Lelia Cosimescu [0077]
- US 5121029 A [0085]
- US 4356429 A [0094]
- US 4539507 A [0094]

Non-patent literature cited in the description

- Handbook of Conductive Molecules and Polymers.
John Wiley and Sons, 1997, vol. 1-4 [0095]

| | | | |
|----------------|---|---------|------------|
| 专利名称(译) | OLED多色显示器 | | |
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| [标]申请(专利权)人(译) | 伊斯曼柯达公司 | | |
| 申请(专利权)人(译) | 伊士曼柯达公司 | | |
| 当前申请(专利权)人(译) | 全球OLED科技有限责任公司 | | |
| [标]发明人 | SPINDLER JEFFREY PAUL | | |
| 发明人 | SPINDLER, JEFFREY PAUL | | |
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摘要(译)

具有至少第一，第二和第三不同颜色像素的OLED显示器包括设置在用于第一和第二像素的基板上的第一发光层和设置在用于第一，第二和第三像素的基板上的第二发光层其中第一和第二发光层产生具有不同光谱的光，并且其中通过重叠第一和第二发光层产生的光具有与第一和第二像素所需的光输出相对应的基本光谱分量，并且产生的光通过第二发光层具有与第三像素所需的光输出相对应的实质光谱分量;第一和第二滤色器与第一和第二像素有关。

