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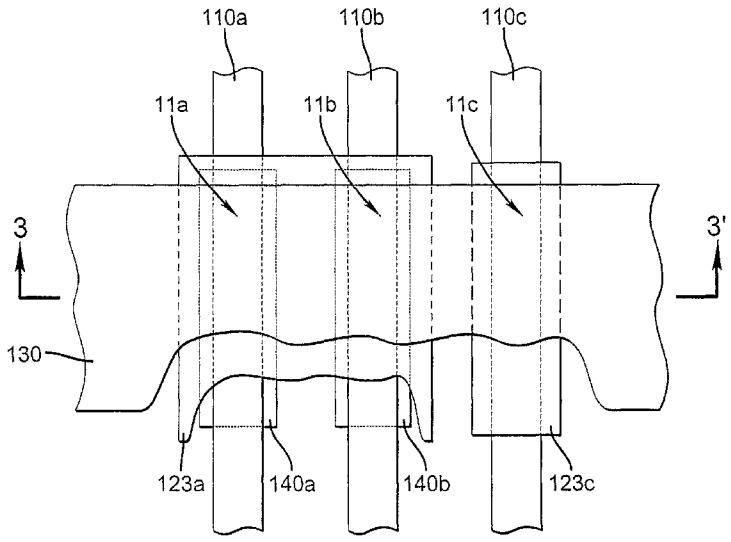
(54) **Title:** MULTICOLOR OLED DISPLAYS



(57) **Abstract:** An OLED display having at least first, second, and third differently colored pixels includes 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 third pixel wherein the first and second light emitting layers produce light having different spectra and the light produced by the first light emitting layer 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 first and second color filters in operative relationship with the first and second pixels.

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MULTICOLOR OLED DISPLAYS

FIELD OF INVENTION

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

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 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.

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.

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.

Other displays, such as described in U.S. Patent 6,693,611 or in U.S. Patent Application Publication 2002/0186214 A1, having additional pixels that emit white color or other 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 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.

One approach to constructing such displays having three 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 pattering 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.

Yet another approach for constructing displays, as is known in the art, is to use a broadband white emitting OLED combined with R, G, and B color filters. This method reduces the need for precisely aligning or patterning the OLED layers, and the color filters can be pre-patterned using conventional photolithography techniques. However, this method results in a display with higher power consumption because the color filters absorb a significant amount of the light.

SUMMARY OF THE INVENTION

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.

This object is achieved by an OLED display having at least first, second, and third differently colored pixels, comprising:

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 third pixel wherein the first and second light emitting layers produce light having different spectra and the light produced by the first light emitting layer 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

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

ADVANTAGES

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

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

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

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 multicolor OLED display having four differently colored pixels;

FIG. 5 shows a top side view of a pixel according to the second embodiment of the present invention;

FIG. 6 shows a cross section view of a group of pixels taken along the line 6-6' of FIG. 5;

FIG. 7 shows another multicolor OLED display having four differently colored pixels;

FIG. 8 shows a top side view of a pixel according to the third embodiment of the present invention; and

FIG. 9 shows a cross section view of a group of pixels taken along the line 9-9' of FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

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.

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.

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 pixel **11c** and also requires 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 two. 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.

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**. 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.

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**. 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.

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 photopatternable 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.

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.

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.

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. 4 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 **11b** emitting green light, a third pixel **11c** emitting blue light, and a fourth pixel

11d emitting a color different than that of the first, second, and third pixels. FIG. 5 shows a top side view of pixels **11a, 11b, 11c,** and **11d** according to the second embodiment of the present invention. The light emitting layer **123a** is provided for pixels **11a, 11b,** and **11d** so as to be common between these pixels, and therefore requires a precise alignment or patterning step. Light emitting layer **123c** is provided for pixels **11c** and **11d**, and also requires 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 two. Light emitting layers **123a** and **123c** can be formed as previously described.

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** and **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**. Light emitting layers **123a** and **123c** are overlapped for pixel **11d.** The combination of light emitting layers **123a** and **123c** in pixel **11d** is arranged so as to produce light having broadband spectral components corresponding to the desired color of pixel **11d**. The broadband emission is defined as a spectrum having emission throughout the visible wavelength range, and can be white in color. 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 **11b**, color filter **140b** is formed in the path of the light emission in pixel **11b** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired green color. The broadband white color desired for pixel **11d** 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 broadband emission spectrum used in pixel **11d** can be used more frequently, and the lower efficiency red, green, and blue pixels less frequently, to

produce colors containing much neutral content, 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.

FIG. 6 shows a cross sectional view of the device of FIG. 5 taken along line 6-6'. FIG. 6 shows that pixels **11a, 11b, 11c**, and **11d** produce internal light emission **220a, 220b, 220c**, and **220d**, respectively. Internal light emission **220c** and **220d** exit the device without filtration to become external light emission **210c** 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 **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.

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.

An alternate four pixel embodiment can be achieved by providing a first pixel **11a** emitting blue light, a second pixel **11b** emitting green light, a third pixel **11c** emitting red light, and a fourth pixel **11d** emitting a color different than that of the first, second, and third 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** and **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**. Light emitting layers **123a** and **123c** are overlapped for pixel **11d**. The combination of light emitting layers **123a** and **123c** is arranged so as to produce light having broadband spectral components corresponding to the desired

color of pixel **11d**. 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 **11b**, color filter **140b** is formed in the path of the light emission in pixel **11b** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired green color. The broadband white color desired for pixel **11d** is achieved without the use of a color filter. The red color desired for pixel **11c** can be achieved with or without the use of a color filter.

FIG. 7 shows an embodiment of a multicolor OLED display including four 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. Pixel **11d** preferably produces light having a color between that of the green light of pixel **11b** and the blue 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.

FIG. 8 shows a top side view of pixels **11a**, **11b**, **11c**, and **11d** according to the third 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**, and **110d** 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**, and pixel **11d** is constructed from first electrode **110d** 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.

According to the present invention, light emitting layer **123a** is provided for pixels **11a** and **11b** so as to be common between these pixels. This requires light emitting layer **123a** to be precisely aligned or patterned to these pixels. Similarly, light emitting layer **123c** is provided for pixels **11c** and **11d**, and also requires 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 two. Light emitting layers **123a** and **123c** can be formed as previously described. Light emitting layer **123a** 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. 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, pixels **11a** and **11b** are disposed adjacent to each other 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.

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** and **11b**. 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. 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 **11c** and **11d**. 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**. 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 **11b**, color filter **140b** is formed 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 green color. In order to achieve the blue 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 blue color. The wide blue-green color desired for pixel **11d** is achieved 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 **11d** 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.

An alternate four pixel embodiment can be achieved by providing a first pixel **11a** emitting blue light, a second pixel **11b** emitting green light, and a third pixel **11c** emitting red light. A fourth pixel **11d** preferably produces light having a color between that of the green light of pixel **11b** and the red 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, and produces light having spectral components corresponding to the desired colors of pixels **11a** and **11b**. Similarly, light emitting layer **123c** 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 **11c** and **11d**. 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 **11b**, color filter **140b** is formed in the path of the light emission in pixel **11b** to absorb undesired spectral components and pass the desired spectral components corresponding to the desired green color. In order to achieve the red 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 red color. The wide yellow-orange color desired for pixel **11d** is achieved 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 **11d** 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.

FIG. 9 shows a cross sectional view of the device of FIG. 8 taken along line 9-9'. FIG. 9 shows that pixels **11a**, **11b**, **11c**, and **11d** produce internal light emission **220a**, **220b**, **220c**, and **220d**, respectively. Internal light emission **220d** exits the device without filtration to become external light emission **210d**. Internal light emission **220a** passes through color filter **140a** prior to exiting the device resulting in external light emission **210a**. Internal light emission **220b** passes through color filter **140b** prior to exiting the device resulting in external light emission **210b**. Internal light emission **220c** passes through color filter **140c** prior to exiting the device resulting in external light emission **210c**. Color filters **140a**, **140b**, and **140c** are preferably organic layers as previously described.

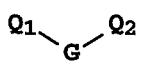
The pixels are constructed over substrate **100**. Light can exit the device by passing through substrate **100** for the case of the bottom emitting device, as shown. First electrodes **110a**, **110b**, **110c**, and **110d** are arranged to transmit light and are preferably constructed of a conductive 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.

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**, and **110d**. 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.

Although not always necessary, it is often useful that a hole-transporting layer **122** be formed and disposed over electrodes **110a**, **110b**, **110c**, and **110d**. 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.

A more preferred class of aromatic tertiary amines is those, which 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

A 

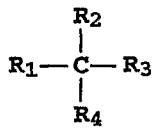
wherein:

Q_1 and Q_2 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.

In one embodiment, at least one of Q_1 or Q_2 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.

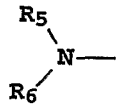
A useful class of triarylamines satisfying structural Formula A and containing two triarylamine moieties is represented by structural Formula B

B 

where:

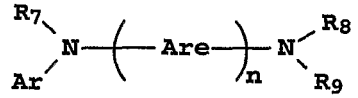
R_1 and R_2 each independently represent a hydrogen atom, an aryl group, or an alkyl group or R_1 and R_2 together represent the atoms completing a cycloalkyl group; and

R_3 and R_4 each independently represent an aryl group, which is in turn substituted with a diaryl substituted amino group, as indicated by structural Formula C

C 

wherein R_5 and R_6 are independently selected aryl groups. In one embodiment, at least one of R_5 or R_6 contains a polycyclic fused ring structure, e.g., a naphthalene.

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

D 

wherein:

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, R_7, R_8, and R_9 are independently selected aryl groups.

In a typical embodiment, at least one of Ar, R_7, R_8, and R_9 is a polycyclic fused ring structure, e.g., a naphthalene.

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.

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 triarylamine, such as a triarylamine satisfying the Formula (B), in combination with a tetraaryldiamine, such as indicated by Formula (D). When a triarylamine 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:

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;

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);

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)amino]biphenyl (TNB);

4,4"-Bis[N-(1-naphthyl)-N-phenylamino]-p-terphenyl;

4,4'-Bis[N-(2-naphthyl)-N-phenylamino]biphenyl;

4,4'-Bis[N-(3-acenaphthenyl)-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;
4,4'-Bis[N-(8-fluoranthenyl)-N-phenylamino]biphenyl;
4,4'-Bis[N-(2-pyrenyl)-N-phenylamino]biphenyl;
4,4'-Bis[N-(2-naphthacenyl)-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;
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;
2,6-Bis[N,N-di(2-naphthyl)amino]fluorene; and
1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene.

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), polythiophenes, polypyrrole, polyaniline, and copolymers such as poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) also called PEDOT/PSS.

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. 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** 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 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.

The host and emitting materials can be small nonpolymeric molecules or polymeric materials including polyfluorenes 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.

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.

An important relationship for choosing a dye as a dopant is the value of the optical bandgap, which is defined 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.

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.

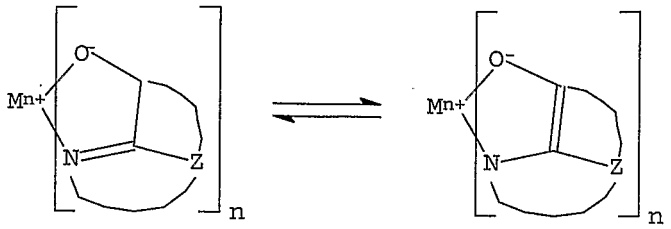
Other organic emissive materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, dialkoxy-polyphenylenevinylenes, poly-para-phenylene derivatives, and polyfluorene derivatives, as taught by Wolk, et al. in commonly assigned U.S. Patent 6,194,119 and references cited therein.

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, WO 01/39234 A2, WO 01/93642 A1, WO 02/074015 A2, WO 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.

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 00/70655 A2 and WO 01/93642 A1. Two examples of useful materials are bathocuproine (BCP) and bis(2-methyl-8-quinolinolato)(4-phenylphenolato)-Aluminum(III) (BAlQ). Metal complexes other than Balq 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,C^2)iridium(III) (Irppz) in an electron/exciton blocking layer.

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**

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.

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.

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.

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];

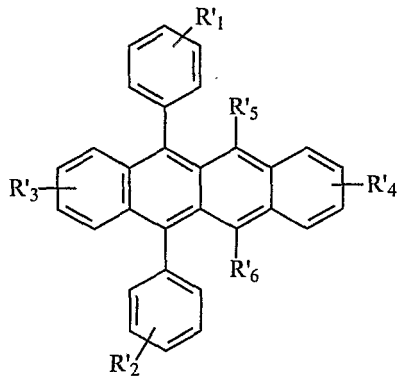
CO-6: Aluminum tris(5-methyloxine) [alias, tris(5-methyl-8-quinolinolato) aluminum(III)];

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

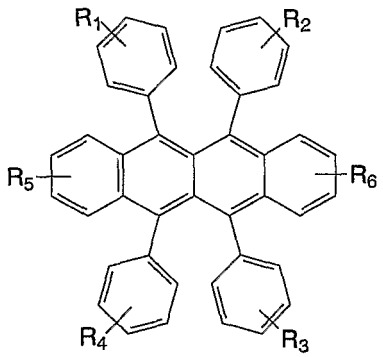
CO-8: Gallium oxine [alias, tris(8-quinolinolato)gallium(III)]; and

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

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



; or



wherein R_1- R_6 represent one or more substituents on each ring and where each substituent is individually selected from one of the following:

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;

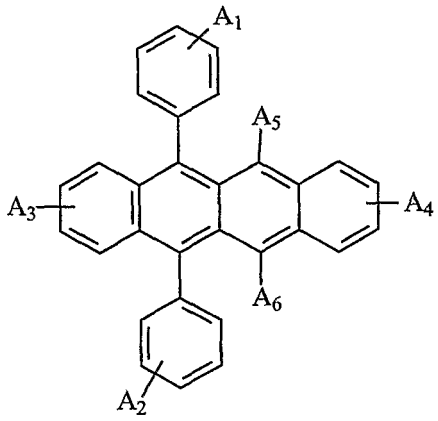
Category 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms such as thiazolyl, furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems, which are bonded via a single bond, or complete a fused heteroaromatic ring system;

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

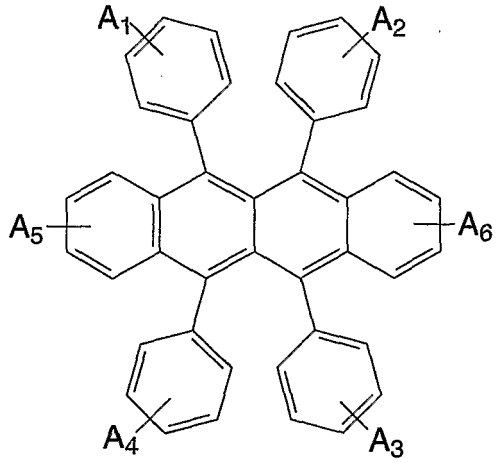
Category 6: fluoro, chloro, bromo or cyano.

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

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:



; or



wherein A_1-A_6 represent one or more substituents on each ring and where each substituent is individually selected from one of the following:

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;

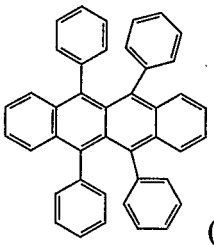
Category 3: hydrocarbon containing 4 to 24 carbon atoms, completing a fused aromatic ring or ring system;

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;

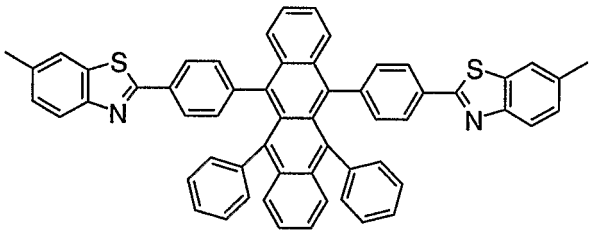
Category 5: alkoxylamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; or

Category 6: fluoro, chloro, bromo or cyano.

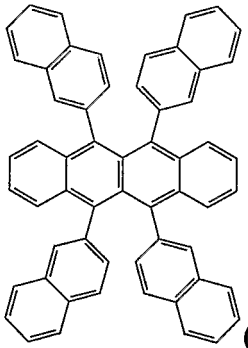
Examples of particularly useful yellow-orange dopants for use in light emitting layer **123a** include 5,6,11,12-tetraphenylnaphthacene (P3); 6,11-diphenyl-5,12-bis(4-(6-methyl-benzothiazol-2-yl)phenyl)naphthacene (P4); 5,6,11,12-tetra(2-naphthyl)naphthacene (P5); and compounds L49 and L50, the formulas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



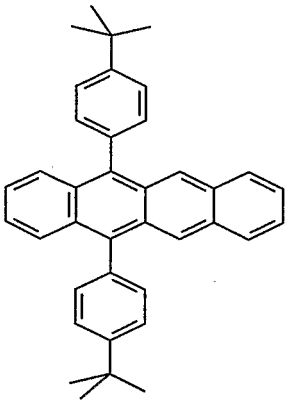
(P3);



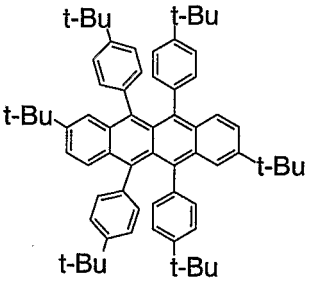
(P4);



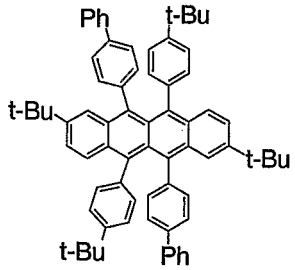
(P5);



(P6);



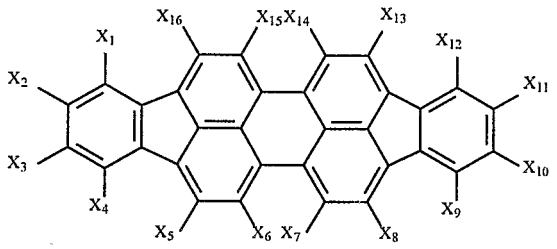
(L49);



(L50).

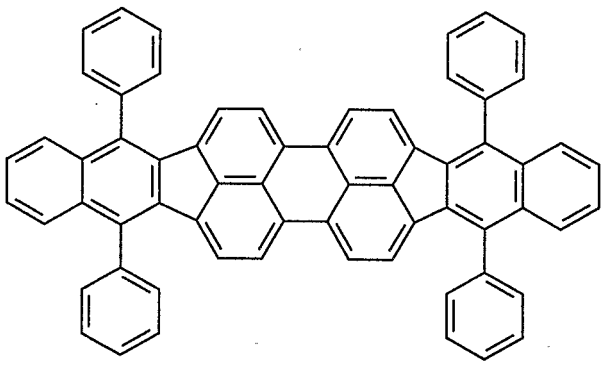
A suitable yellow-orange dopant can also be a mixture of compounds that would also be yellow-orange dopants individually.

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:



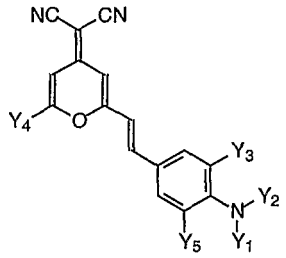
wherein X_1-X_{16} are independently selected as hydro or substituents that provide red luminescence.

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)



TPDBP.

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

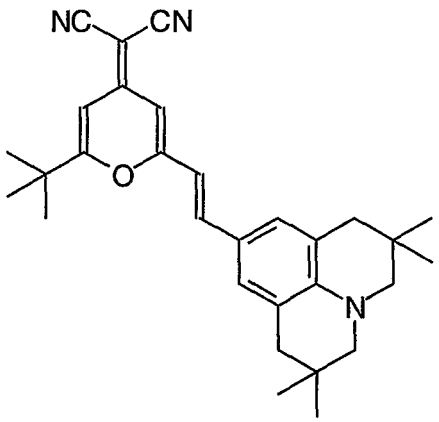


wherein:

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.

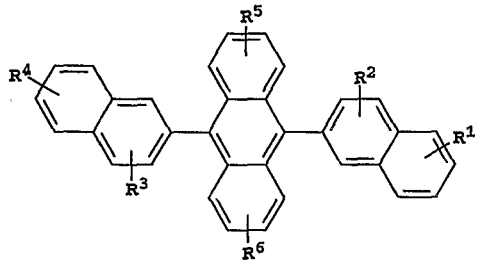
In a useful and convenient embodiment that provides red-orange luminescence, Y_1-Y_5 are selected independently from hydro, alkyl and aryl. A preferred DCM dopant is DCJTB shown below



DCJTB.

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

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**

F	

wherein:

R^1, R^2, R^3, R^4, R^5, and R^6 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;

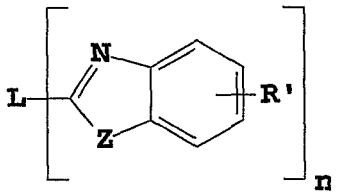
Group 3: carbon atoms from 4 to 24 necessary to complete a fused aromatic ring of anthracenyl; pyrenyl, or perylenyl;

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.

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

G 

wherein:

n is an integer of 3 to 8;

Z is O, NR or S;

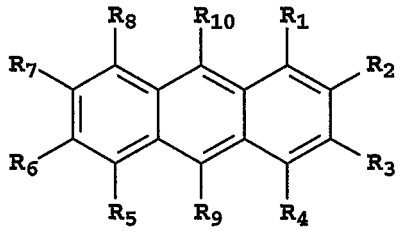
R' is hydrogen; alkyl of from 1 to 24 carbon atoms, for example, propyl, t-butyl, heptyl, and the like; aryl or hetero-atom substituted aryl of from 5 to 20 carbon atoms for example phenyl and naphthyl, furyl, thienyl, pyridyl, quinolinyl

and other heterocyclic systems; or halo such as chloro, fluoro; or atoms necessary to complete a fused aromatic ring; and

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

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

It has been found in commonly assigned U.S. Patent Application Serial No. 10/693,121 filed October 24, 2003 by Lelia Cosimbescu, et al., entitled "Electroluminescent Device With Anthracene Derivative Host", the disclosure of which is herein incorporated by reference, that 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 Formula (I) as a host material



(I)

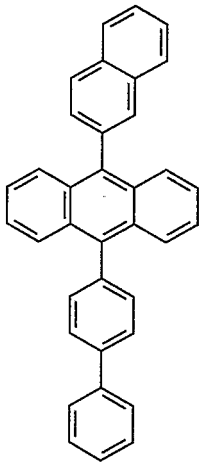
wherein:

R_1-R_8 are H; and

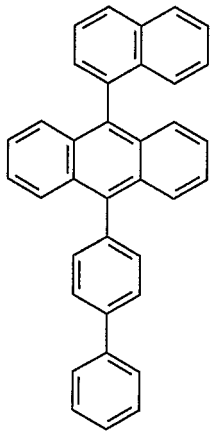
R_9 is a naphthyl group containing no fused rings with aliphatic carbon ring members; provided that R_9 and R_{10} are not the same, and are free of amines and sulfur compounds. Suitably, R_9 is a substituted naphthyl group with one or more further fused rings such that it forms a fused aromatic ring 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, R_9 is 2-naphthyl, or 1-naphthyl substituted or unsubstituted in the para position; and

R_{10} is a biphenyl group having no fused rings with aliphatic carbon ring members. Suitably R_{10} 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, R_{10} is 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.

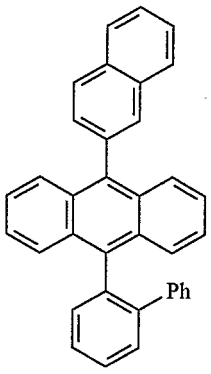
Some examples of useful mono-anthracene host materials for use in light emitting layer **123c** include:



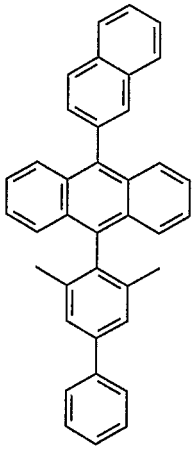
Host-1 ; Host-2



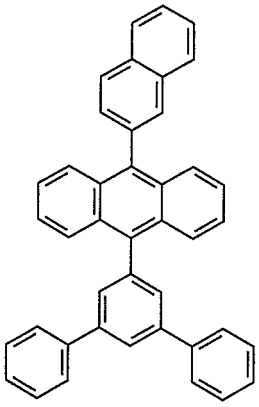
; Host-3



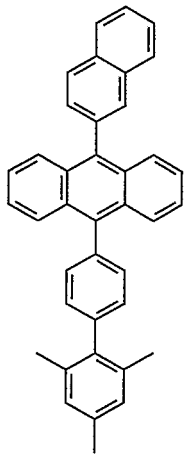
;



Host-4 ; Host-5



; Host-6



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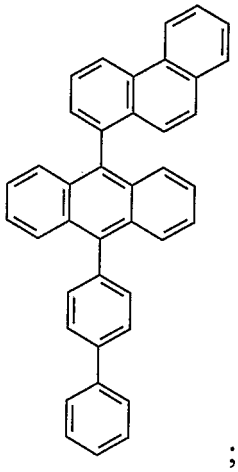
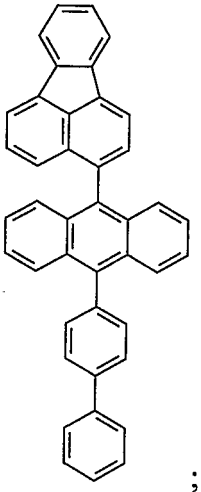
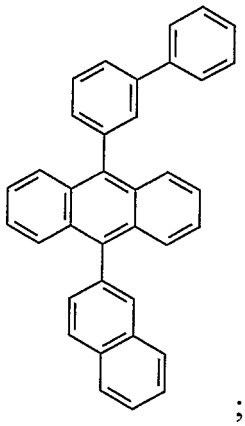
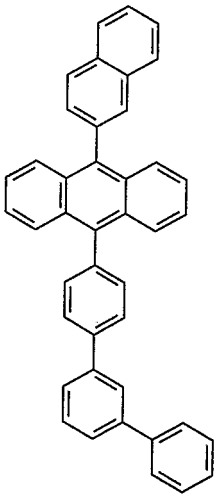
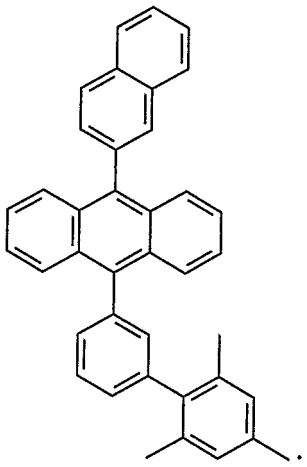
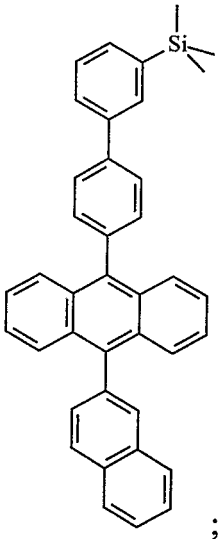
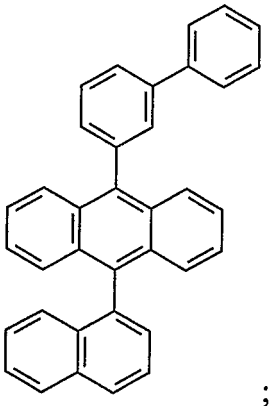
Host-7  ; Host-8  ; Host-9  ;

Host-10  ; Host-11  ;

Host-12  ; Host-13  ;

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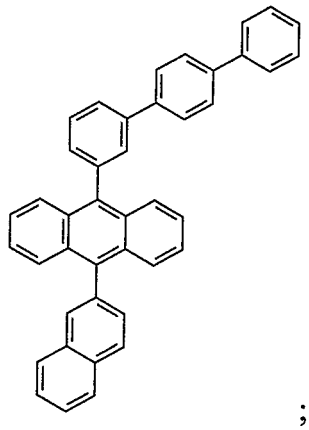
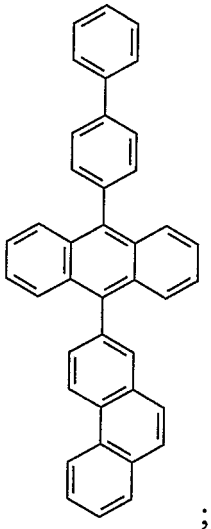
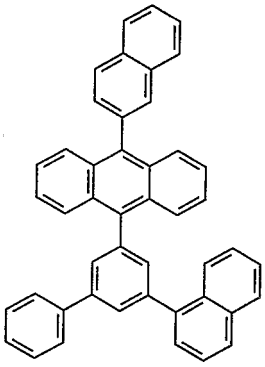
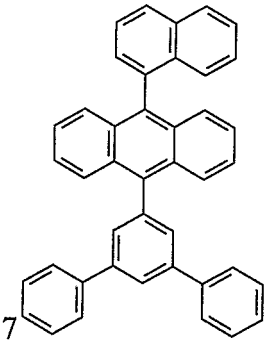
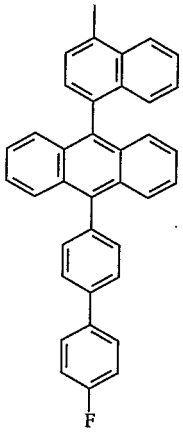
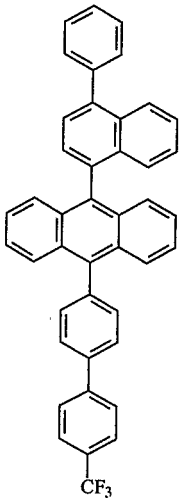
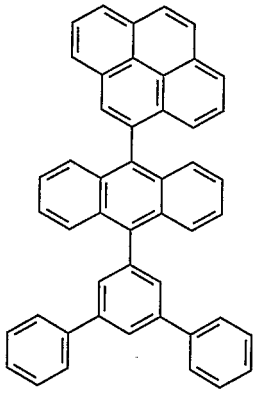
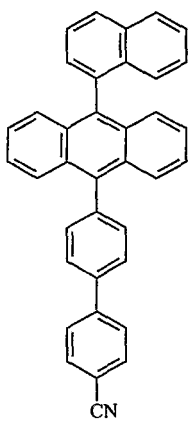
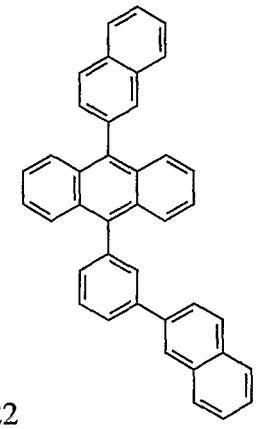
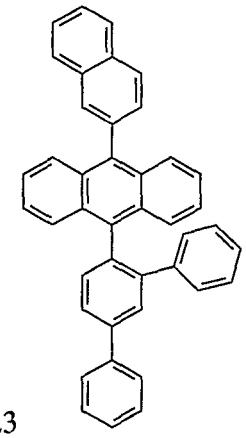
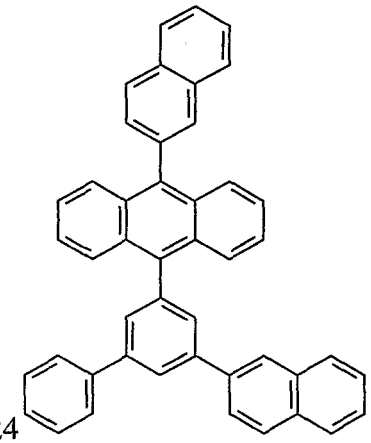
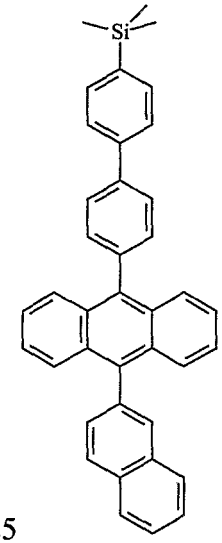
Host-14  ; Host-15  ;

Host-16  ; Host-17  ;

Host-18  ; Host-19  ; Host-20  ;

Host-21  ; Host-22  ; Host-23  ;

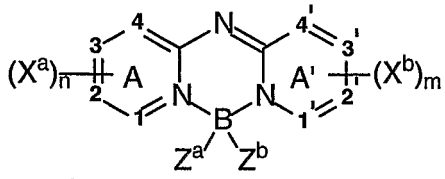
Host-24  ; and Host-25  .

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

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).

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';

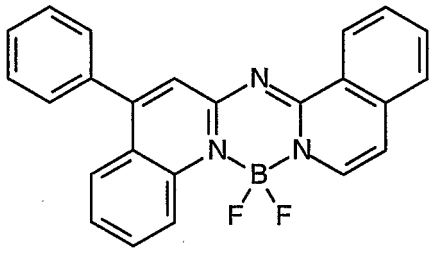
m and n are independently 0 to 4;

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

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.

Some examples of the above class of dopants include the following:



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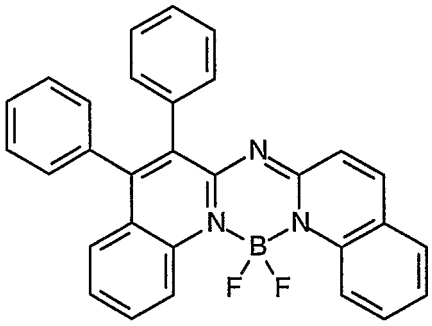

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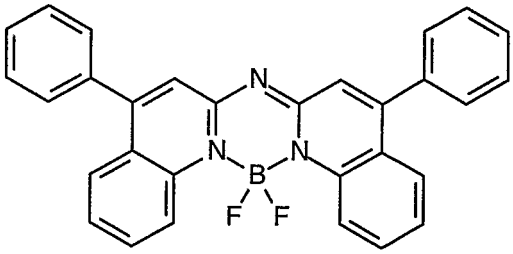
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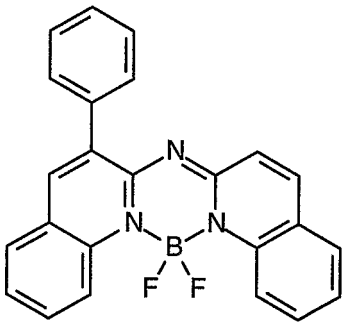
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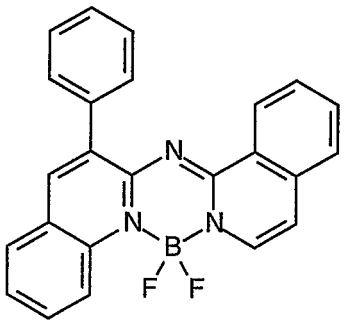
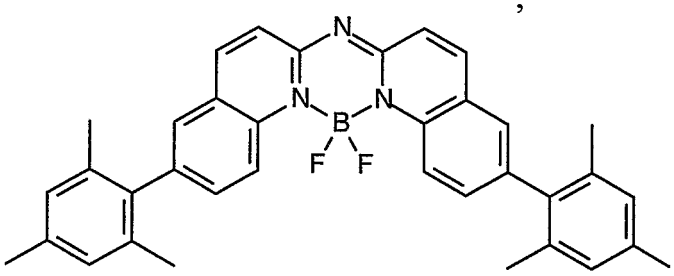
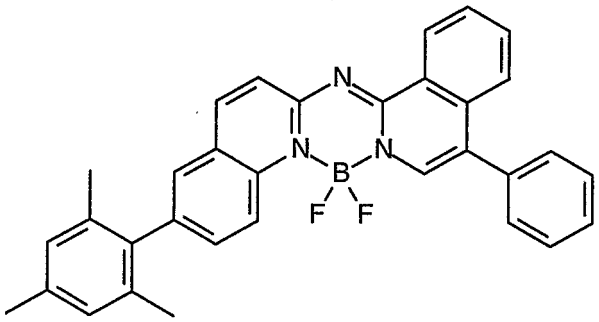

;

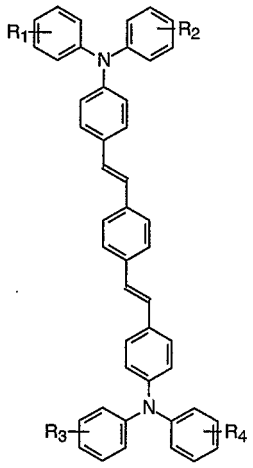

(BEP) ; or



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.

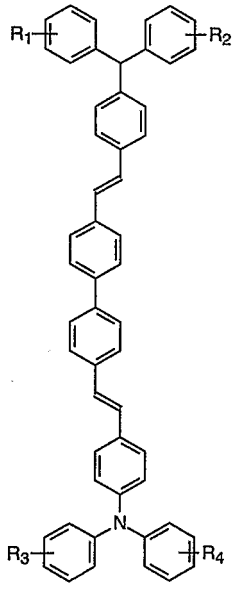
In another preferred embodiment, the light emitting material in light emitting layer **123c** has a peak emission in the blue-green portion of the visible spectrum, and can include blue-green emitting derivatives of such distyrylarenes as distyrylbenzene and distyrylbiphenyl, including compounds described in U.S. Patent 5,121,029. Among derivatives of distyrylarenes that provide blue or blue-green luminescence, particularly useful are those substituted with diarylamino groups, also known as distyrylamines. Examples include bis[2-[4-[N,N-diarylamino]phenyl]vinyl]-benzenes of the general structure N1 shown below:

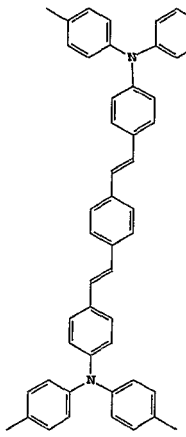
N1



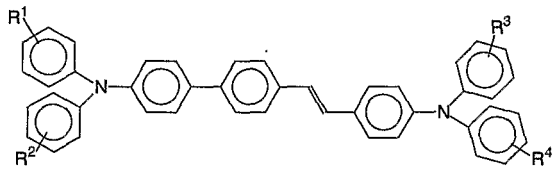
and bis[2-[4-[N,N-diarylamino]phenyl]vinyl]biphenyls of the general structure N2 shown below:

N2



In Formulas N1 and N2, R_1 - R_4 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, R_1-R_4 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)  .

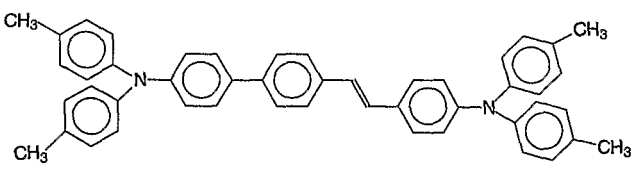
In a useful embodiment of the invention, light emitting layer **123c** includes a blue-green dopant of Formula (3)



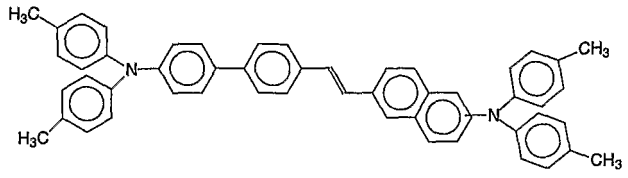
Formula (3)

wherein R^1 through R^4 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.

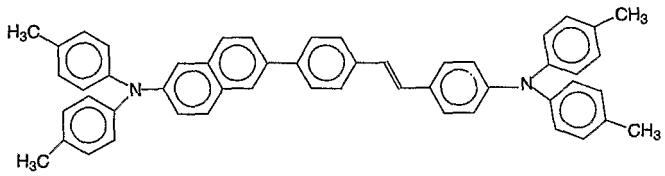
Particularly useful embodiments of the blue-green emissive dopants of light emitting layer **123c** are shown in Formula (4-1) through Formula (4-5)



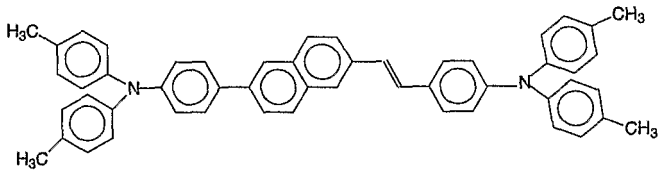
Formula (4-1);



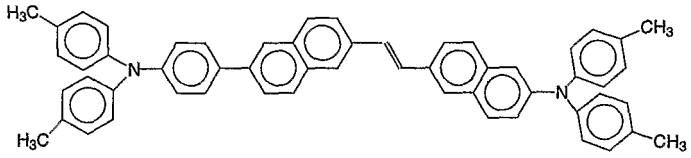
Formula (4-2);



Formula (4-3);



Formula (4-4); or



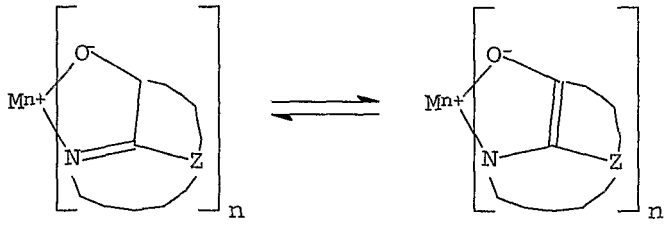
Formula (4-5).

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.

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

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.

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.

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.

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)].

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.

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).

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.

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.

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.

PARTS LIST

10	pixel group
11a	pixel
11b	pixel
11c	pixel
11d	pixel
100	substrate
110a	first electrode
110b	first electrode
110c	first electrode
110d	first electrode
122	hole-transporting layer
123a	light emitting layer
123c	light emitting layer
124	electron-transporting layer
130	second electrode
140a	color filter
140b	color filter
140c	color filter
210a	external light emission
210b	external light emission
210c	external light emission
210d	external light emission
220a	internal light emission
220b	internal light emission
220c	internal light emission
220d	internal light emission

CLAIMS:

1. An OLED display having at least first, second, and third differently colored pixels, comprising:

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 third pixel wherein the first and second light emitting layers produce light having different spectra and the light produced by the first light emitting layer 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

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

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

3. The OLED display according to claim 1 wherein no color filter is provided corresponding to the third pixel.

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

5. The OLED display according to claim 1 wherein the light spectrum produced by the first light emitting layer has substantial spectral components corresponding to blue-green light and wherein the light spectrum

produced by the second light emitting layer has substantial spectral components corresponding to red light.

6. The OLED display according to claim 5 wherein the first color filter passes blue light and absorbs light of other colors, and the second color filter passes green light and absorbs light of other colors.

7. The OLED display according to claim 1 wherein the first light emitting layer is continuous between the first and second pixels.

8. The OLED display according to claim 1 further including a fourth pixel such that the first and second light emitting layers overlap to produce light having a spectrum different than the first, second, and third pixels, 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 fourth pixel.

9. The OLED display according to claim 8 wherein the light spectrum produced by the first light emitting layer has substantial spectral components corresponding to yellow-orange light, and wherein the light spectrum produced by the second light emitting layer has substantial spectral components corresponding to blue light.

10. The OLED display according to claim 9 wherein the first color filter passes red light and absorbs light of other colors, and the second color filter passes green light and absorbs light of other colors.

11. The OLED display according to claim 8 wherein the light spectrum produced by overlapping the first and second light emitting layers has substantial spectral components corresponding to broadband white light.

12. The OLED display according to claim 8 wherein the fourth pixel is disposed adjacent to the second and third pixels, or wherein the fourth pixel is disposed adjacent to the first and third pixels.

13. The OLED display according to claim 8 wherein the first light emitting layer is continuous between the first, second, and fourth pixels, and the second light emitting layer is continuous between the third and fourth pixels.

14. The OLED display according to claim 1 wherein the second light emitting layer is provided over the substrate for a fourth pixel, and a third color filter provided in operative relationship to the third pixel wherein the light produced by the second light emitting layer has substantial spectral components corresponding to the light output desired for the third and fourth pixels.

15. The OLED display according to claim 14 wherein the light spectrum produced by the first light emitting layer has substantial spectral components corresponding to yellow-orange light and wherein the light spectrum produced by the second light emitting layer has substantial spectral components corresponding to blue-green light.

16. The OLED display according to claim 14 wherein the third color filter passes blue light and absorbs light of other colors.

17. The OLED display according to claim 5 wherein the second light emitting layer is provided over the substrate for a fourth pixel, and a third color filter is provided in operative relationship to the third pixel wherein the light produced by the second light emitting layer has substantial spectral components corresponding to the light output desired for the third and fourth pixels.

18. The OLED display according to claim 17 wherein the light spectrum produced by the first light emitting layer has substantial spectral components corresponding to blue-green light and wherein the light spectrum

produced by the second light emitting layer has substantial spectral components corresponding to yellow-orange light.

19. The OLED display according to claim 17 wherein the third color filter passes red light and absorbs light of other colors.

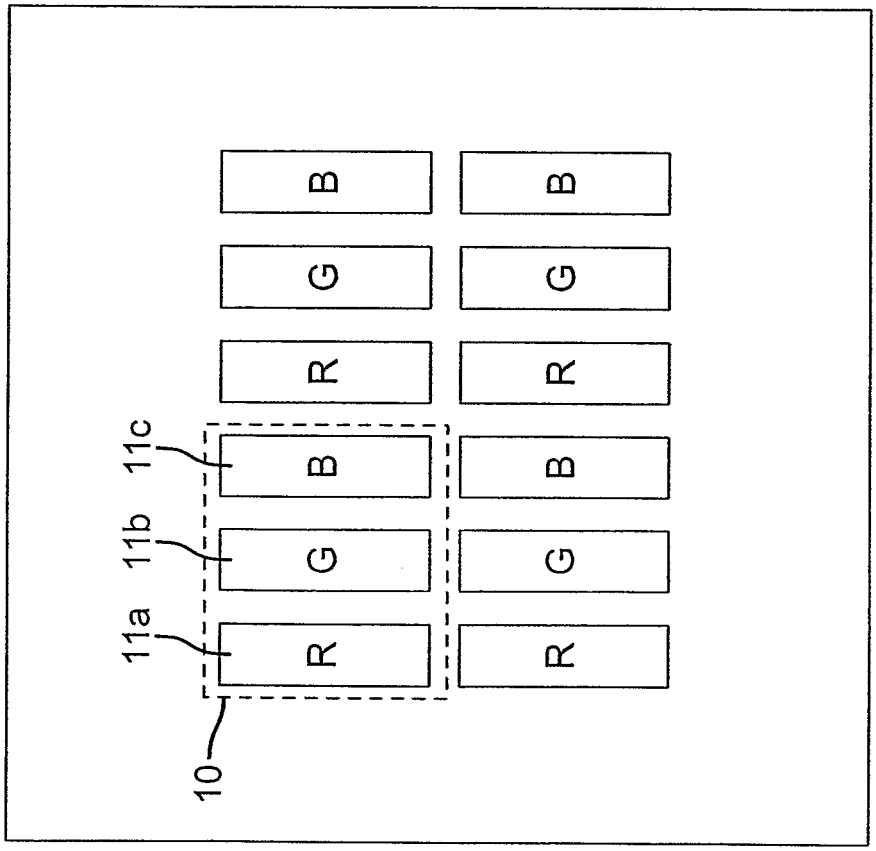


FIG. 1

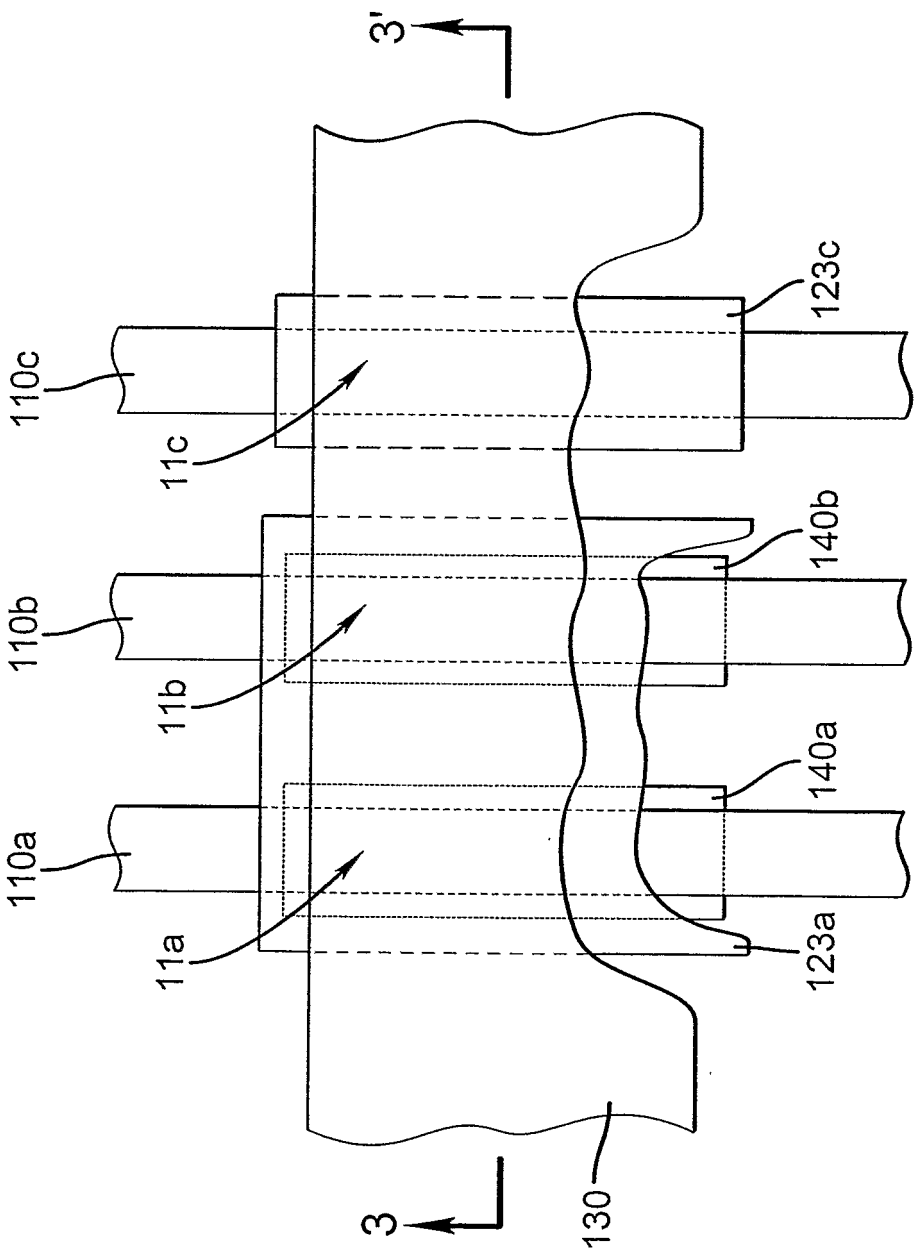


FIG. 2

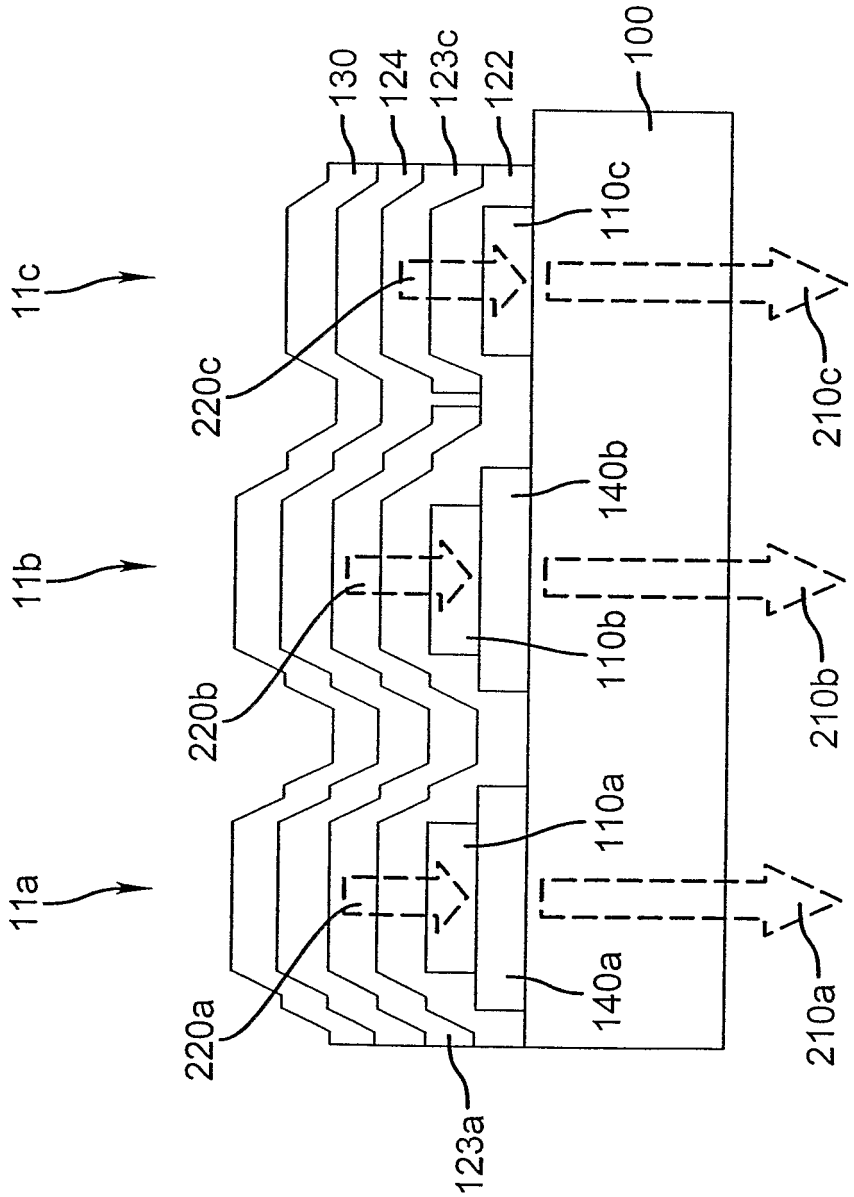

130
124
123c
122
100
11c
11b
11a
220c
220b
220a
110c
140b
110b
110a
140a
210c
210b
210a
123a

FIG. 3

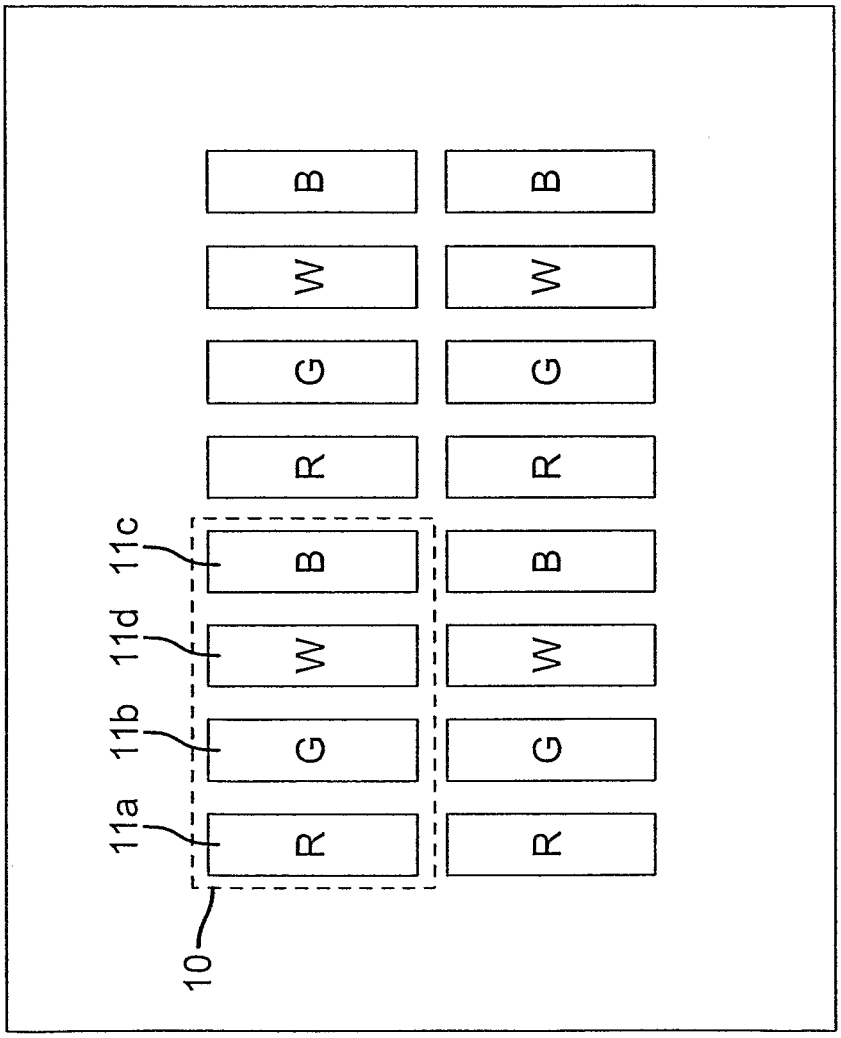


FIG. 4

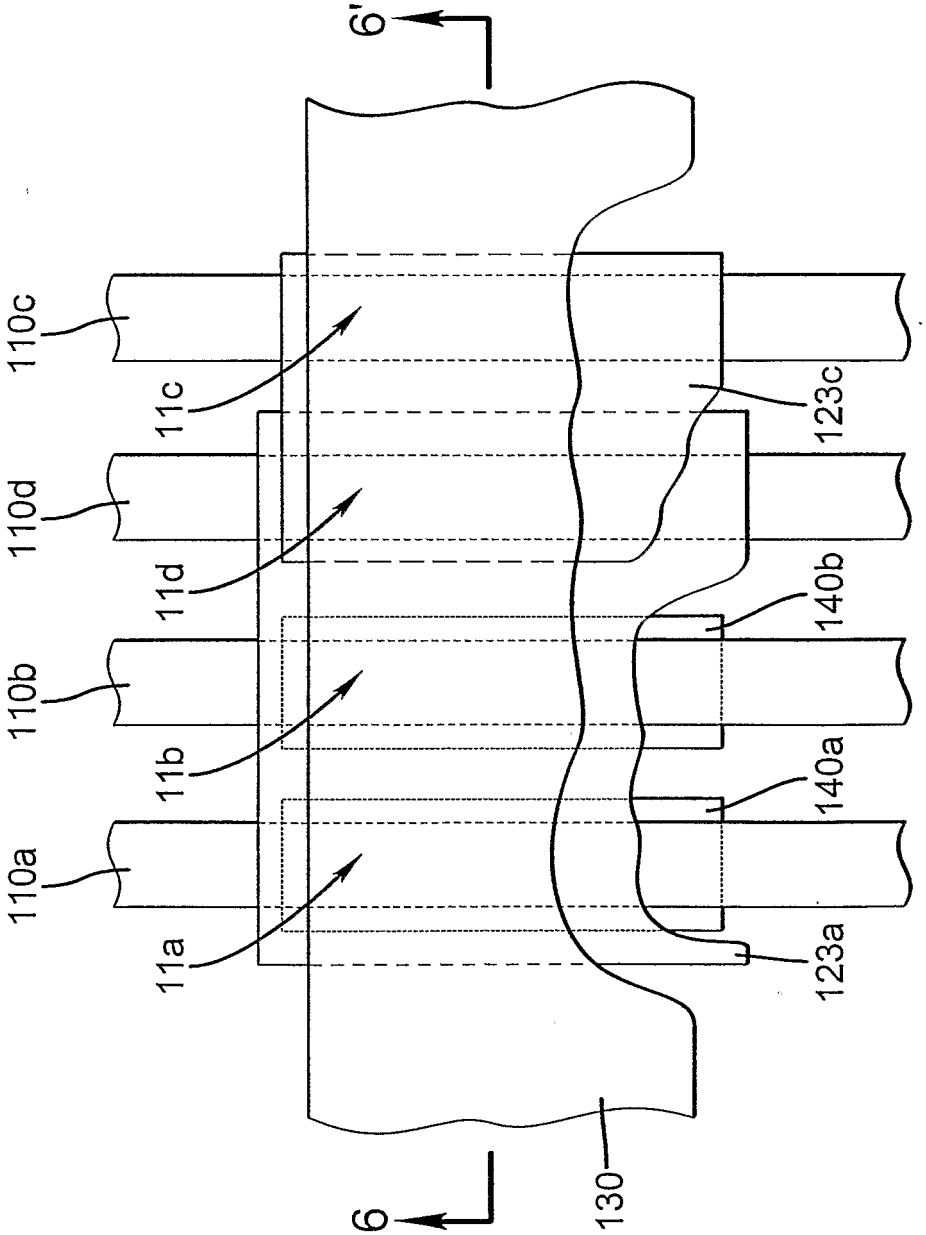


FIG. 5

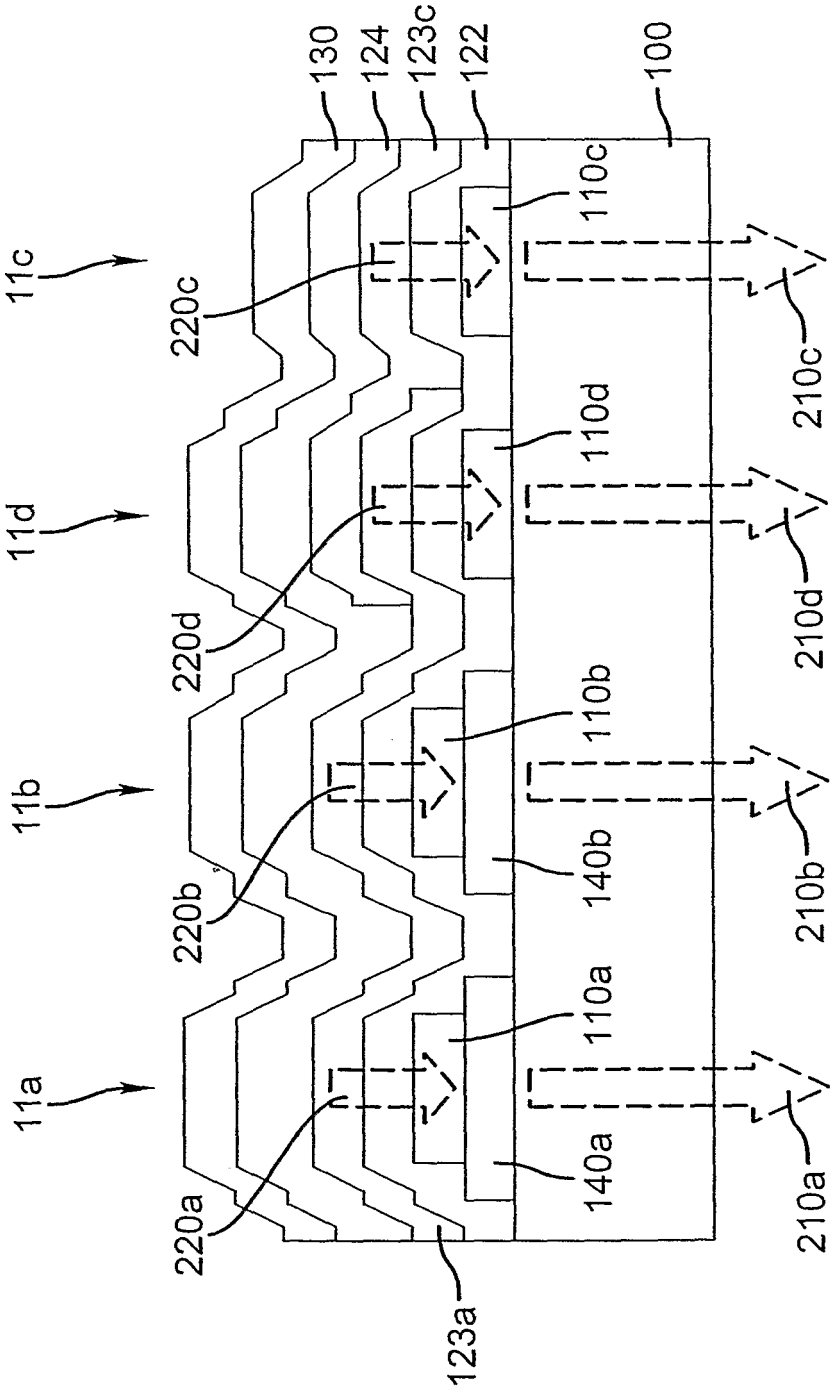

130
124
123c
122
100
11c
11d
11b
11a
220c
220d
220b
220a
110c
110d
110b
110a
140b
140a
210c
210d
210b
210a
123a

FIG. 6

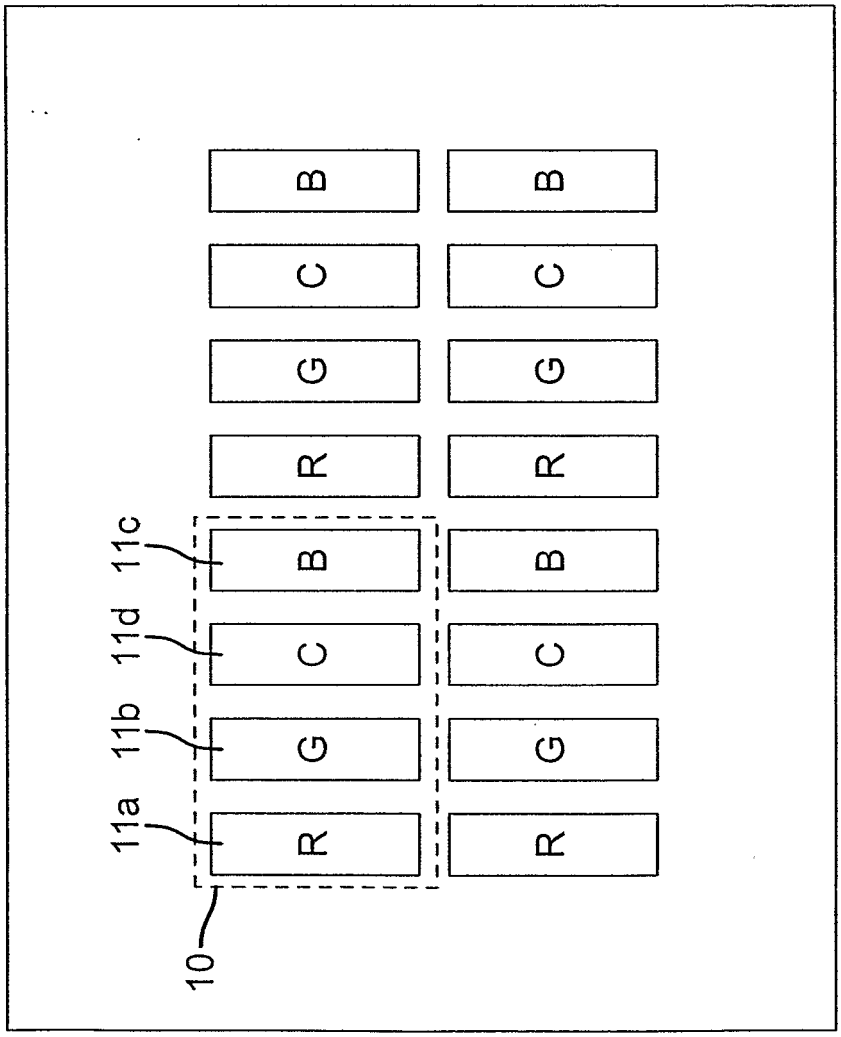


FIG. 7

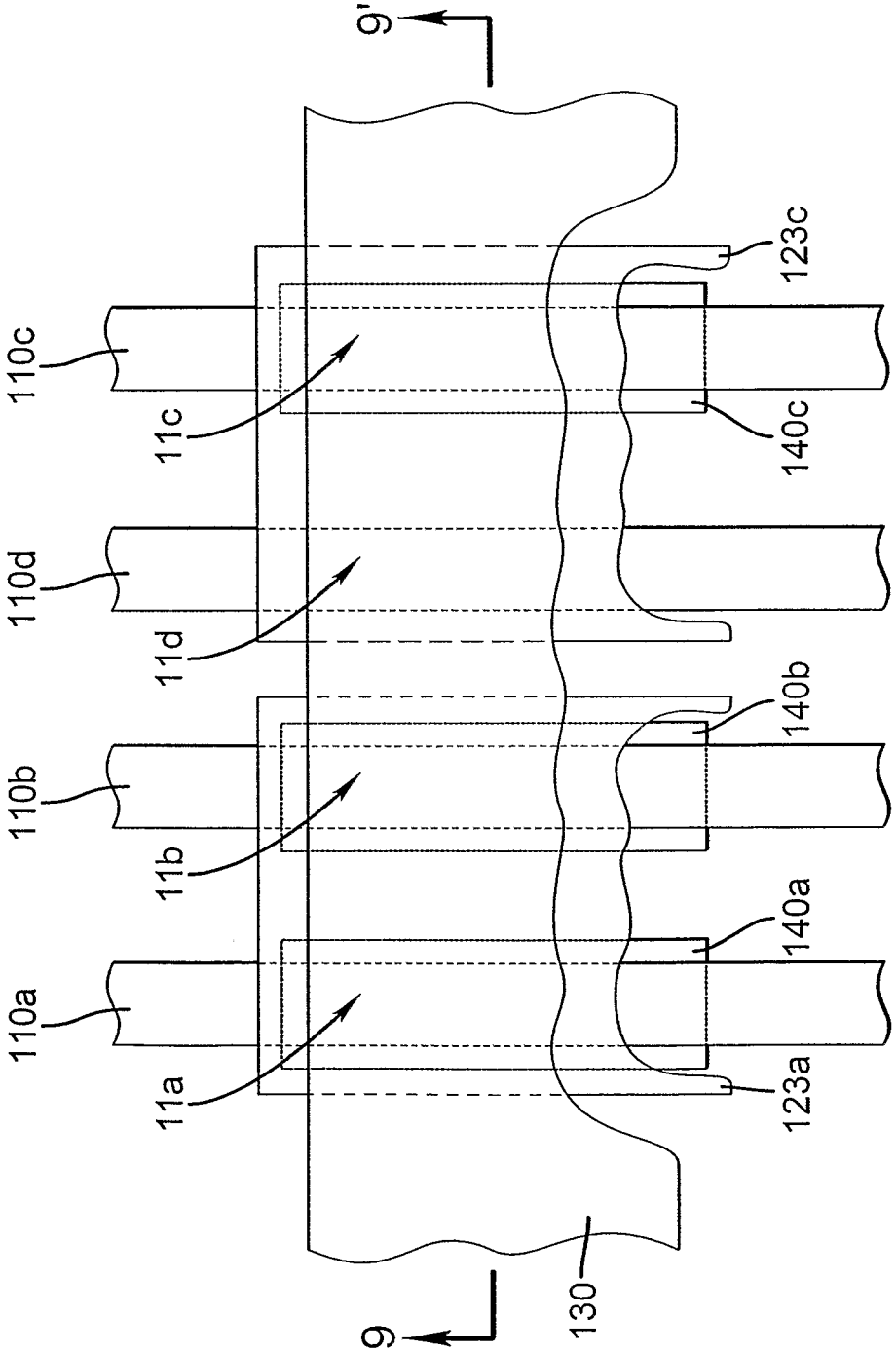

9'
9
110c
110d
110b
110a
11c
11d
11b
11a
123c
140c
140b
140a
123a
130

FIG. 8

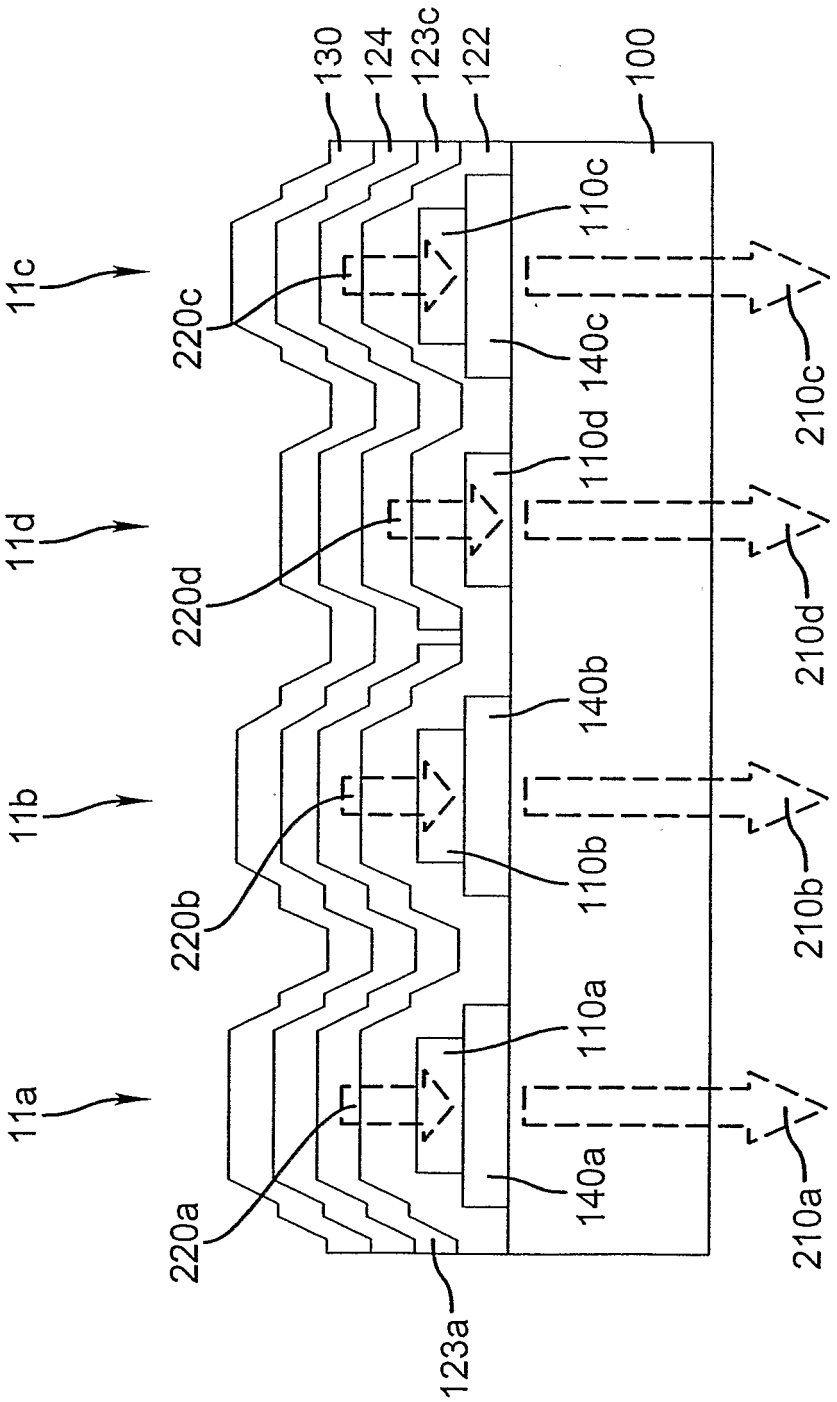

130
124
123c
122
100
11c
11d
11b
11a
220c
220d
220b
220a
110c
140c
110d
140b
110b
110a
140a
210c
210d
210b
210a
123a

FIG. 9

专利名称(译)	多色OLED显示屏		
公开(公告)号	EP1875510A2	公开(公告)日	2008-01-09
申请号	EP2006751301	申请日	2006-04-19
[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		
IPC分类号	H01L27/32		
CPC分类号	C09K11/06 C09K2211/1007 C09K2211/1011 C09K2211/1014 C09K2211/1029 C09K2211/1033 C09K2211/1037 C09K2211/1044 C09K2211/107 C09K2211/1088 H01L27/3213 H01L27/322 H01L51/0021 H01L51/0051 H01L51/0052 H01L51/0059 H01L51/0062 H01L51/0081 H01L51/0094 H01L51/5036 H05B33/14		
优先权	11/113484 2005-04-25 US 11/315827 2005-12-22 US 11/113915 2005-04-25 US		
其他公开文献	EP1875510B1		
外部链接	Espacenet		

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三像素的基板上的第二发光层，其中第一和第二像素发光层产生具有不同光谱的光，并且由第一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实质光谱分量，并且由第二发光层产生的光具有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，第一和第二滤色器与第一和第二像素有关。