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(54) **Method for determining the relative sizes of subpixels in a color organic light-emitting diode display with improved lifetime**

Verfahren zum Bestimmen der relativen Größe der Teilpixel in einer farbigen elektrolumineszierenden Diodenanzeige mit verlängerter Lebensdauer

Méthode pour déterminer la taille relative des sous-pixels dans un dispositif d'affichage de couleur à diode organique électroluminescent à durée de vie étenduée

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EP-A- 1 032 045
EP-A- 1 168 448
WO-A-01/99195
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Description

[0001] The present invention relates to a method of determining the relative sizes of subpixels in an OLED color display device while maximizing its useful lifetime.

[0002] Recent advances in flat panel display technology have included the advent of flat panel displays that are constructed using Organic Light Emitting Diodes. This flat panel display technology has many advantages over flat panel displays based on more popular liquid crystal display technology. Unlike liquid crystal displays that use the orientation of liquid crystal materials to modulate light from a large uniform backlight, OLED displays utilize materials that emit light. A full-color display is typically constructed by depositing three different materials that each emits a different color of light onto a substrate to create a full-color display, although they may also be constructed using a single emissive material and a color filter array. Depositing these separate light emissive elements in different spatial locations allows the construction of a full-color display when the light from the three primary colors are integrated by the human eye to allow the perception of a large gamut of colors from these few primary colors. During this deposition, equal areas of each of the three primary colors are commonly deposited onto the substrate.

[0003] Unfortunately, when equal area subpixels are used to construct a display using the OLED materials available today, the lifetime of the display is often limited by the lifetime of one of the OLED materials, typically blue. That is, when placed into a practical multicolor display, the time required for typical blue materials to deteriorate to produce half their original luminance is often only a fraction of the time required for typical green or red materials to deteriorate to the point that they produce half of their original luminance. For example, with one commonly available set of materials, the lifetime of the red emitting subpixels may be about 5.5 times as long as the lifetime of the blue emitting subpixels, and the lifetime of the green light emitting subpixels may be about 7 times as long as the lifetime of the blue light emitting subpixels, when each material set is driven at currents required to produce a standard color temperature display.

[0004] To maintain a well-balanced, full color display, it is important that the relative luminance of the three-colored materials be maintained throughout the lifetime of the display. If these relative luminance values change dramatically, images may have a serious color imbalance, and the user is likely to become dissatisfied with the display and consider the display to be at the end of its life. Some compensation can be made for the drop in blue efficiency over time by continually increasing the current density through the blue subpixels. However, it is known that increasing current densities tends to accelerate the luminance decay. Thus, the problem is actually worsened and the lifetime of the device before failure is shortened even more. Alternatively, one may reduce the luminance of the red and green to balance the blue, but this lowers the overall brightness of the display. Once the display becomes too dim, the user may also consider the display to be at the end of its useful lifetime, regardless of the relative luminance of the three colors. To maximize the useful lifetime of the display, it is important to maximize the time that the relative luminance of the three-color elements can be maintained while minimizing the loss of absolute luminance.

[0005] Flat panel displays with unequal areas of light emitting material have been discussed by Kim et al. in US Patent Application 2002/0014837, published February 7, 2002 (also published as EP 1 168 448 A2). Kim et al. discuss an OLED display in which the relative size of the red, green, and blue light emitting elements are adjusted based on the luminous efficiency of the color materials employed in an OLED display. It is commonly known that the available red OLED materials have significantly lower luminous efficiency than the existing green and blue OLED materials. Because of the lower efficiency of existing red OLED materials, if one wishes to maintain sub-pixels of equal size, the power per square area that must be provided to the low luminous efficiency material must be increased to obtain the desired light output. Using this criterion, Kim proposes an OLED display with twice as much red light emitting area as green and blue light emitting area. By creating displays with relatively larger areas of red emitting materials than green or blue materials, the relative power per square area can be somewhat equalized across the different colored materials. However, optimizing the display layout suggested by Kim et al., does not necessarily lead one to a design in which the lifetimes of the three materials are optimized.

[0006] US Patent 6,366,025 issued April 2, 2002 to Yamada discloses an OLED display with unequal light emitting element areas, wherein the area of the light emitting elements are adjusted with the goal of improving the lifetime of the OLED display. Yamada considers the emission efficiency of the material, the chromaticity of each of the emissive materials and the chromaticity of the target display when attempting to determine the aim light emissive element areas. However, Yamada fails to discuss other important characteristics of OLED materials that will affect device lifetime, such as the differences in the inherent luminance stability over time of different materials. Yamada further does not consider important optical characteristics of the target display design, each of which will influence the overall lifetime of OLED materials.

[0007] International application WO 01/99195 A1 describes a light-emitting device comprising two electroluminescent elements for emitting light of a first and second color, respectively. An active lifetime of the first element is greater than that of the second element. The document considers five different optimized operational regimes, one of which is characterized as equal perceived luminance, different voltage, different efficiency, and equal half-life.

[0008] A color display device having an organic EL element for each display pixel is also disclosed in EP 1 032 045

A2 (also cited as US 6,366,025 below).

[0009] Japanese patent application JP 2002208585 A1 discloses an organic electroluminescent display having laterally separated organic LEDs emitting different colors of light. The electroluminescent elements differ in width in order to optimize the light emitting efficiency and brightness, without a significant change in the driving voltages.

[0010] There is a need therefore for an improved arrangement of the light emitting elements in an OLED display that compensates for the differences in the relative efficiencies and relative luminance stability over time of the different color emitting materials that are used to construct the display, thereby providing a display with a truly longer lifetime.

[0011] The need is met according to the present invention by a method according to claim 1. In particular, the present invention provides a method of determining the relative sizes of subpixels in a OLED display device having a display pixel that includes a plurality of subpixels of different colors, wherein the subpixels are different in size, wherein the relative sizes (A_i) of the subpixels (i) are based on the emission efficiency of the subpixels, the chromaticity of a target display white point, and the relative luminance stability over time of the subpixels thereby protecting the subpixels whose emission efficiency is low from prematurely deteriorating, comprising the steps of:

a) measuring chromaticity coordinates for the subpixels (i);

b) selecting aim chromaticity coordinates (x_w, y_w) and luminance (Y_w) of a target display white point;

c) calculating a required luminance (Y_i) output from the display to create the selected target display white point for each subpixel (i) using the chromaticity coordinates of the subpixels, and the aim chromaticity coordinates and the luminance of the target display white point;

d) selecting an initial light emissive area (A_i) for each subpixel (i);

e) providing an optical transmission factor for each subpixel (i);

f) calculating an actual luminance (Y_i) for each subpixel using the initial areas (A_i) and optical transmission factors for the subpixel (i);

g) determining a functional relationship between current density (I_i) and luminance output for each subpixel (i);

h) calculating an aim current density (I_i) for each subpixel (i);

i) determining a functional relationship between current density (I_i) and a luminance stability over time (T_i) for each subpixel (i), wherein the luminance stability over time (T_i) is the time until the light-emitting element has lost half its original luminance;

j) calculating the time (T_i) representing the luminance stability over time for each subpixel (i) using the aim current density (I_i) and the luminance stability function; and

k) if the times (T_i) are unequal, modifying the light emissive areas (A_i) of the subpixels (i) by stacking multiple layers of light emitting materials of the same color, reducing the area (A_i) of the subpixel (i) with the larger time (T_i) and increasing the area (A_i) of the subpixel with the smaller time (T_i), and repeating steps h, j, and k until the times (T_i) are equal.

Fig. 1 is a schematic diagram showing a pixel having different sized subpixels as known in the prior art;
Fig. 2 is a flow chart of an iterative process used to determine relative subpixel areas according to the present invention;
Fig. 3 is a flow chart of an alternative process used to determine relative subpixel areas;
Fig. 4 is schematic cross-sectional diagram of a typical prior art organic light emitting display structure;
Fig. 5 is a schematic top view of a display pixel in an OLED display apparatus in which the largest subpixel is divided into more than one light emitting region;
Fig. 6 is a schematic illustration of an organic light emitting display structure in which the number of multiple stacked layers and the sizes of the subpixels are selected to optimize the lifetime of the final display;
Fig. 7 is a schematic diagram of an organic light emitting display structure in which the different colored layers are stacked on top of each other and the number of layers of each color are selected to optimize the lifetime of the final display;
Fig. 8 is a schematic diagram of an organic light emitting display structure in which one subpixel is provided on a

first layer and second and third subpixels are provided on a second layer and the relative sizes of the subpixels are selected to optimize the lifetime of the final display;

Fig. 9 is a graph useful in describing the present invention, showing the relationship between the luminance output and current density in OLED materials that emit red, green and blue light respectively; and

Fig. 10 is a graph useful in describing the present invention, showing the relationship between the material luminance stability over time and current density in OLED materials that emit red, green and blue light respectively.

[0012] The term "display device" is employed to designate a screen capable of electronically displaying video images or text. The term "pixel" is employed in its art-recognized usage to designate an element in a display device that can be addressed to form one part of a picture. The term "full color" is employed to describe multicolor display devices that are capable of forming color images. Generally red, green, and blue color primaries constitute the three primary colors from which all other colors can be generated by appropriately mixing these three primaries. It is recognized that a "full color" display may also be formed from more than three colors. The term "subpixel" is used in full color display devices and is employed to designate any portion of a pixel which can be independently addressable to emit a specific color. For example, a blue subpixel is that portion of a pixel which can be addressed to emit blue light. In a full-color display, a pixel generally comprises three primary-color subpixels, namely blue, green, and red. The term pixel or subpixel is generally used to designate the smallest addressable unit in a display device. Herein, the term light-emitting element is used interchangeably with the term subpixel.

[0013] The present invention is directed to a method of determining the relative sizes of subpixels in a full color OLED display in which the relative areas of the primary color, light emitting elements (subpixels) are adjusted to improve the useful lifetime of the display device. This invention is achieved by adjusting the relative overall areas of each of the subpixels on the display while taking into account the relative luminance stability over time, in addition to other factors such as the luminance efficiencies of the light emitting materials that make up the elements (subpixels) of the display to optimize the useful lifetime of the display. In the context used here, useful lifetime of the display refers to the number of hours in which the display can satisfy requirements such as display luminance output and/or white point stability.

[0014] The present invention can be employed in most OLED device configurations. These include very simple structures comprising a single anode and cathode to more complex devices, such as passive matrix displays comprised of orthogonal arrays of anodes and cathodes to form pixels, and active-matrix displays where each pixel is controlled independently, for example, with a thin film transistor (TFT). For example, the structure described in US 6,366,025 may be employed to form an active matrix electroluminescent display device having subpixels with relative sizes determined according to the present invention. Fig. 1 is a schematic diagram that shows a portion of a full color OLED display device **10** having an array of pixels **12**, each pixel **12** having subpixels **14** of different sizes as is known in the prior art. The subpixels **14** are labeled R, G, and B representing red, green and blue light emitting subpixels respectively.

[0015] Referring to Fig. 2, the relative sizes of the red, green, and blue subpixels in the display are determined according to the present invention by considering the chromaticity coordinates of the red, green and blue emissive subpixels; the aim white point and the luminance of the display; the fill factors of the red, green, and blue subpixels; the efficiency of the red, green, and blue subpixels; the optical transmission characteristics of the subpixels within the final display configuration; and the luminance stability over time of the red, green and blue emissive materials.

[0016] To calculate the relative sizes of the red, green and blue subpixels the chromaticity coordinates for the red, green, and blue emissive materials are first determined **24**. Next, the aim white point and luminance of the display device are selected **26.** The aim luminance required from each light emissive element is then calculated **28** from these values. If the display device is characterized using an additive color system, these values can be calculated using the following equations:

$$Y_r = \frac{y_r(x_w(-y_b + y_g) + x_g(y_b - y_w) + x_b(-y_g + y_w))Y_w}{(x_g y_b - x_r y_b - x_b y_g + x_r y_g + x_b y_r - x_g y_r)y_w} \quad (1)$$

$$Y_g = \frac{y_g(x_w(y_b - y_r) + x_b(y_r - y_w) + x_r(-y_b + y_w))Y_w}{(x_g y_b - x_r y_b - x_b y_g + x_r y_g + x_b y_r - x_g y_r)y_w} \quad (2)$$

$$Y_b = \frac{y_b(x_w(-y_g + y_r) + x_r(y_g - y_w) + x_g(-y_r + y_w))Y_w}{(x_g y_b - x_r y_b - x_b y_g + x_r y_g + x_b y_r - x_g y_r)y_w} \quad (3)$$

where: Y_w represents the luminance of the final display when the display is turned on to its maximum value; x_W and y_W represent the chromaticity coordinates of the desired display white point; Y_r, Y_g, and Y_b represent the luminance values that must be output from the display to create the selected aim white point and luminance when the red, green, or blue light emissive elements are all driven at their maximum value; x_r, x_g, and x_b represent the respective x chromaticity coordinates of the red, green, and blue light emissive materials; and y_r, y_g, and y_b represent the respective y chromaticity coordinates of the red, green, and blue light emissive materials.

[0017] An optical transmission factor is then determined 30 for each light emissive element (subpixel) in the display device. This optical transmission factor indicates the proportion of the luminance of each light emissive element that will be emitted by the display. The optical transmission factor may include factors such as absorptions that take place within a polarizer or other layers within the display device structure and reflections that occur at the interface between different optical layers within the display device structure. The luminance values for each of the color light emissive elements are then calculated 32 by multiplying the previously calculated luminance values by the inverse of this proportion to determine the aim luminance for each light emissive element before unwanted absorptions.

[0018] A fill factor for each light emissive element is then selected 34. This fill factor is the proportion of the total pixel area that will emit light of the red, green, or blue light emissive elements. The necessary surface luminance value for each color light emissive element is then calculated 36 by multiplying the luminance value determined in 32 by the fill factor.

[0019] Characteristic curves relating output luminance to input current density (see Fig. 9) are then entered 38 for the light emissive materials employed in each subpixel. For most OLED materials, this characteristic curve will be a linear function that allows the current density to be calculated as a function of luminance. These functions may be of the form:

$$I = (L - b)/a, \qquad (4)$$

where: I represents the current density required to drive each subpixel; L represents the surface luminance that was previously calculated; and a and b are constants that differ for each light emissive material. These functions are then used to calculate **40** the aim current density required to drive each subpixel to display the selected aim white point and luminance.

[0020] Characteristic curves relating current density to the luminance stability over time of the light emitting materials (see Fig. 10) are then determined **42** for the materials employed in each subpixel. For example, a power function of the form:

$$T = cI^d \qquad (5)$$

may be used to estimate the time until the light-emitting element has lost half its original luminance where T is the time and c and d are constants that are different for each different material. These characteristic curves are determined empirically by measuring the light output from test pixels that are produced using the processes that will be employed to manufacture the display device. These characteristic functions may then be used to calculate **44** the useful lifetime of the subpixel within the display device. Once these useful lifetime values are calculated for all three light emissive elements, a decision **46** is made based upon whether the useful lives are substantially equal (within a predetermined tolerance) for the three subpixels. If the useful lives are not equal, the fill factors for the three light emissive elements are modified **48** by stacking multiple layers of light emitting materials of the same color, reducing the area of the light emissive elements with the larger useful lives and increasing the area of the light emissive elements with the smaller useful lives. The calculations **36, 40,** and **44** are performed again with the altered light emissive element areas. If the values are equal to one another, the process is complete **50** and the aim fill factor for the display is used to determine the final relative subpixel sizes.

[0021] Referring to Fig. 3, the relative areas of the light emissive elements may be calculated directly for a display by specifying a target useful lifetime for the display. Assuming that the luminance of an OLED display device is linear with current, i.e., the luminance measured over area A_m doubles when the current applied to it doubles, one can calculate the relative subpixel sizes. This calculation may be performed by first providing **52** chromaticity coordinates for the light emissive elements. Then by selecting **54** the aim chromaticity coordinates and luminance of a target display white point, one calculates 56 the required luminance for the measurement area A_m for each light emissive element using the chromaticity coordinates of the light emissive materials used for the subpixels, the aim white point and luminance of the target display using equations 1, 2, and 3.

[0022] An aim optical transmission factor for each emissive primary is then selected **58** and the required luminance is calculated **60** by dividing the luminance by an optical transmission factor. One can then determine **62** a functional relationship between the current supplied to measurement area A_m of the material of a uniform test cell produced using

the processes that will be employed to manufacture the display device and the luminance measured over A_m of this same test cell for each of the emissive primaries.

[0023] Using this functional relationship, the required current per area A_m is calculated **64** for each emissive primary to produce the required luminance. One can then determine **66** a functional relationship between current density and the luminance stability over time of each light-emitting element by illuminating several test cells using different current densities and measuring the luminance decay of the element over time. Having these relationships, a target useful lifetime is specified **68**. The functional relationship between current density and luminance stability over time of the light-emitting element is used to calculate **70** the current density that will produce the selected useful lifetime for each emissive primary. Finally, an area fraction is calculated **72** for each emissive primary by dividing the required current per area A_m by the respective calculated current densities. One skilled in the art will note that the sum of area fractions for the emissive elements may be greater than can be physically produced (e.g. greater than a display fill factor that is determined by the manufacturing process used to make the display), indicating that it is impossible to build a single layer display that meets the target useful lifetime using the materials that are characterized for this computation.

[0024] There are numerous configurations of the organic layers wherein the present invention can be successfully practiced. A typical prior art structure is shown in Fig. 4 and is comprised of a substrate **122,** an anode layer **92,** a hole-injecting layer **124,** a hole-transporting layer **126,** a light-emitting layer **128**, an electron-transporting layer **130**, and a cathode layer 116. These layers are described in detail below. Note that the substrate may alternatively be located adjacent to the cathode, or the substrate may actually constitute the anode or cathode. The organic layers between the anode and cathode are conveniently referred to as the organic EL element. The total combined thickness of the organic layers is preferably less than 500 nm.

[0025] The OLED device is typically provided over a supporting substrate **122** where either the cathode or anode can be in contact with the substrate. The electrode in contact with the substrate is conveniently referred to as the bottom electrode. Conventionally, the bottom electrode is the anode, but this invention is not limited to that configuration. The substrate can either be light transmissive or opaque, depending on the intended direction of light emission. The light transmissive property is desirable for viewing the EL emission through the substrate. Transparent glass or plastic is commonly employed in such cases. For applications where the EL emission is viewed through the top electrode, the transmissive characteristic of the bottom support is immaterial, and therefore can be light transmissive, light absorbing or light reflective. Substrates for use in this case include, but are not limited to, glass, plastic, semiconductor materials, silicon, ceramics, and circuit board materials. Of course it is necessary to provide in these device configurations a light-transparent top electrode.

[0026] When EL emission is viewed through anode **92**, the anode should be transparent or substantially transparent to the emission of interest. Common transparent anode materials used in this invention are indium-tin oxide (ITO), indium-zinc oxide (IZO) and tin oxide, but other metal oxides can work including, but not limited to, aluminum- or indium-doped zinc oxide, magnesium-indium oxide, and nickel-tungsten oxide. In addition to these oxides, metal nitrides, such as gallium nitride, and metal selenides, such as zinc selenide, and metal sulfides, such as zinc sulfide, can be used as the anode. For applications where EL emission is viewed only through the cathode electrode, the transmissive characteristics of anode are immaterial and any conductive material can be used, transparent, opaque or reflective. Example conductors for this application include, but are not limited to, gold, iridium, molybdenum, palladium, and platinum. Typical anode materials, transmissive or otherwise, have a work function of 4.1 eV or greater. Desired anode materials are commonly deposited by any suitable means such as evaporation, sputtering, chemical vapor deposition, or electrochemical means. Anodes can be patterned using well-known photolithographic processes.

[0027] It is often useful to provide a hole-injecting layer **124** between anode 122 and hole-transporting layer **126.** 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 US 4,720,432, and plasma-deposited fluorocarbon polymers as described in US 6,208,075. Alternative hole-injecting materials reportedly useful in organic EL devices are described in EP 0 891 121 A1 and EP 1 029 909 A1.

[0028] The hole-transporting layer **126** contains at least one hole-transporting compound 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 US 3,180,730. Other suitable triarylamines substituted with one or more vinyl radicals and/or comprising at least one active hydrogen containing group are disclosed by Brantley et al. in US 3,567,450 and 3,658,520.

[0029] A more preferred class of aromatic tertiary amines are those which include at least two aromatic tertiary amine moieties as described in U.S. Patent Nos. 4,720,432 and 5,061,569. The hole-transporting layer can be formed of a single or a mixture of aromatic tertiary amine compounds. 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)quadriphenyl
Bis(4-dimethylamino-2-methylphenyl)-phenylmethane
N,N,N-Trip-tolyl)amine
4-(di-p-tolylamino)-4'-[4(di-*p*-tolylamino)-styryl]stilbene
N,N,N',N'-Tetra-*p*-tolyl-4-4'-diaminobiphenyl
N,N,N',N'-Tetraphenyl-4,4'-diaminobiphenyl
N,N,N',N'-tetra-1-naphthyl-4,4'-diaminobiphenyl
N,N,N',N'-tetra-2-naphthyl-4,4'-diaminobiphenyl
N-Phenylcarbazole
4,4'-Bis[N-(1-naphthyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(1-naphthyl)-N-(2-naphthyl)amino]biphenyl
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)amine]fluorene
1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene

[0030] 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.

[0031] As more fully described in US 4,769,292 and 5,935,721, the light-emitting layer (LEL) **128** 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. The light-emitting layer can be comprised of a single material, but more commonly consists of a host material doped with a guest compound or compounds where light emission comes primarily from the dopant and can be of any color. The host materials in the light-emitting layer can be an electron-transporting material, as defined below, a hole-transporting material, as defined above, or another material or combination of materials that support hole-electron recombination. The dopant is usually 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. Dopants are typically coated as 0.01 to 10 % by weight into the host material. Polymeric materials such as polyfluorenes and polyvinylarylenes (e.g., poly(p-phenylenevinylene), PPV) can also be used as the host material. In this case, small molecule dopants can be molecularly dispersed into the polymeric host, or the dopant could be added by copolymerizing a minor constituent into the host polymer.

[0032] An important relationship for choosing a dye as a dopant is a comparison of the bandgap potential which is defined as the energy difference between the highest occupied molecular orbital and the lowest unoccupied molecular orbital of the molecule. For efficient energy transfer from the host to the dopant molecule, a necessary condition is that the band gap of the dopant is smaller than that of the host material.

[0033] Host and emitting molecules known to be of use include, but are not limited to, those disclosed in US 4,769,292; 5,141,671; 5,150,006; 5,151,629; 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; and 6,020,078.

[0034] Metal complexes of 8-hydroxyquinoline (oxine) and similar derivatives constitute one class of useful host com-

pounds capable of supporting electroluminescence. 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)]
CO-9: Zirconium oxine [alias, tetra(8-quinolinolato)zirconium(IV)]

[0035] Other classes of useful host materials include, but are not limited to: derivatives of anthracene, such as 9,10-di-(2-naphthyl)anthracene and derivatives thereof, distyrylarylene derivatives as described in US 5,121,029, and benzazole derivatives, for example, 2, 2', 2"-(1,3,5-phenylene)tris[1-phenyl-1H-benzimidazole].

[0036] Useful fluorescent dopants include, but are not limited to, derivatives of anthracene, tetracene, xanthene, perylene, rubrene, coumarin, rhodamine, quinacridone, dicyanomethylenepyran compounds, thiopyran compounds, polymethine compounds, pyrilium and thiapyrilium compounds, fluorene derivatives, periflanthene derivatives and carbostyryl compounds. Electron-Transporting Layer (ETL)

[0037] Preferred thin film-forming materials for use in forming the electron-transporting layer **130** of the organic EL elements of this invention 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, exhibit high levels of performance, and are readily fabricated in the form of thin films. Exemplary oxinoid compounds were listed previously.

[0038] Other electron-transporting materials include various butadiene derivatives as disclosed in US 4,356,429 and various heterocyclic optical brighteners as described in US 4,539,507. Benzazoles and triazines are also useful electron-transporting materials.

[0039] In some instances, layers **130** and **128** can optionally be collapsed into a single layer that serves the function of supporting both light emission and electron transport. These layers can be collapsed in both small molecule OLED systems and in polymeric OLED systems. For example, in polymeric systems, it is common to employ a hole-transporting layer such as PEDOT-PSS with a polymeric light-emitting layer such as PPV. In this system, PPV serves the function of supporting both light emission and electron transport.

[0040] When light emission is viewed solely through the anode, the cathode 116 used in this invention can be comprised of nearly any conductive material. Desirable materials have good film-forming properties to ensure good contact with the underlying organic layer, promote electron injection at low voltage, and have good luminance stability over time. Useful cathode materials often contain a low work function metal (<4.0 eV) or metal alloy. One preferred cathode material is comprised of a Mg:Ag alloy wherein the percentage of silver is in the range of 1 to 20 %, as described in US 4,885,221. Another suitable class of cathode materials includes bilayers comprising a thin electron-injection layer (EIL) in contact with the organic layer (e.g., ETL), which is capped with a thicker layer of a conductive metal. Here, the EIL preferably includes a low work function metal or metal salt, and if so, the thicker capping layer does not need to have a low work function. One such cathode is comprised of a thin layer of LiF followed by a thicker layer of A1 as described in US 5,677,572. Other useful cathode material sets include, but are not limited to, those disclosed in US 5,059,861; 5,059,862, and 6,140,763.

[0041] When light emission is viewed through the cathode, the cathode must be transparent or nearly transparent. For such applications, metals must be thin or one must use transparent conductive oxides, or a combination of these materials. Optically transparent cathodes have been described in more detail in US 4,885,211, US 5,247,190, JP 3,234,963, US 5,703,436, US 5,608,287, US 5,837,391, US 5,677,572, US 5,776,622, US 5,776,623, US 5,714,838, US 5,969,474, US 5,739,545, US 5,981,306, US 6,137,223, US 6,140,763, US 6,172,459, EP 1 076 368, and US 6,278,236. Cathode materials are typically deposited by evaporation, sputtering, or chemical vapor deposition. When needed, patterning can be achieved through many well known methods including, but not limited to, through-mask deposition, integral shadow masking as described in US 5,276,380 and EP 0 732 868, laser ablation, and selective chemical vapor deposition.

[0042] The organic materials mentioned above are suitably deposited through a vapor-phase method such as sublimation, but can be deposited from a fluid, for example, from a solvent with an optional binder to improve film formation. If the material is a polymer, solvent deposition is useful but other methods can be used, such as sputtering or thermal transfer from a donor sheet. The material to be deposited by sublimation can be vaporized from a sublimator "boat" often comprised of a tantalum material, e.g., as described in US 6,237,529, or can be first coated onto a donor sheet and then sublimed in closer proximity to the substrate. Layers with a mixture of materials can utilize separate sublimator boats or

the materials can be pre-mixed and coated from a single boat or donor sheet. Patterned deposition can be achieved using shadow masks, integral shadow masks (US 5,294,870), spatially-defined thermal dye transfer from a donor sheet (US 5,851,709 and 6,066,357) and inkjet method (US 6,066,357).

[0043] Most OLED devices are sensitive to moisture or oxygen, or both, so they are commonly sealed in an inert atmosphere such as nitrogen or argon, along with a desiccant such as alumina, bauxite, calcium sulfate, clays, silica gel, zeolites, alkaline metal oxides, alkaline earth metal oxides, sulfates, or metal halides and perchlorates. Methods for encapsulation and desiccation include, but are not limited to, those described in US 6,226,890. In addition, barrier layers such as SiOx, Teflon, and alternating inorganic/polymeric layers are known in the art for encapsulation.

[0044] OLED devices can employ various well-known optical effects in order to enhance its properties if desired. This includes optimizing layer thicknesses to yield maximum light transmission, providing dielectric mirror structures, replacing reflective electrodes with light-absorbing electrodes, providing anti glare or anti-reflection coatings over the display, providing a polarizing medium over the display, or providing colored, neutral density, or color conversion filters over the display. Filters, polarizers, and anti-glare or anti-reflection coatings may be specifically provided over the cover or as part of the cover.

[0045] In addition to the device architecture described above, each organic EL element may be comprised of a series of organic stacks as described in copending US Patent Application 10/077,270.

[0046] While this implementation has been described with respect to an OLED display constructed of different red, green, and blue light emitting materials, one skilled in the art will recognize that this same display configuration and process can be applied to the construction of an OLED display employing color filters. However, when employing color filters, the chromaticity coordinates of each color light emitting element and the luminance of each color of light emitting material as it contributes to the overall display luminance and chromaticity must be calculated by determining the spectral radiance of the light emitting materials across the visible spectrum, multiplying these spectra by the transmission of each of the color filter elements at each wavelength, and transforming the resulting spectral values to standardized luminance and chromaticity coordinates using standard CIE conventions.

[0047] Subpixels may be further divided into spatially distinct regions. Such an embodiment is shown in Fig. 5 where the subpixel with the largest area (for example the blue subpixel **14B**) is divided into two regions. In this example, the red subpixel **14R** and green subpixel **14G** are each composed of a single region. In this embodiment, the spatial pattern of the array of blue subpixels becomes visually less noticeable when viewing the display from a normal viewing distance, thereby improving the perceived quality of the display while providing improved lifetime according to the present invention.

[0048] Referring to Fig. 6, the relative areas of the subpixels are achieved by stacking multiple hole transport, light emitting and electron transport layers between the anode and cathode as described in US Patent Application 10/077,270. In other words, providing two stacks of blue light-emitting units effectively doubles the area of the blue subpixel. According to this embodiment, unequal numbers of light-emitting layers may be deposited for different subpixels, and may be further combined with unequal areas to achieve the relative subpixel areas calculated according to the present invention.

[0049] As shown in Fig. 6, multiple layers are deposited on a substrate **154** between the anode **156** and cathode **158.** In the preferred embodiment, a hole-injecting layer **160** will be deposited on the anode **156** followed by a hole transport layer **162.1**, a light emitting layer **164.1**, and an electron transport layer **166.1**. Next, a doped organic connector **168.1** is deposited. The doped organic connector **168.1** may be any material that provides efficient electron and hole injection into the adjacent organic light emitting units. Materials of this type are described in detail in US Patent Application 10/077,270.

[0050] Over the doped organic connector **168.1**, another hole transport layer **162.2**, light emitting layer **164.2** and electron transport layer **166.2** is deposited. As many stacks (light emitting units) as required to achieve the desired lifetime characteristics may be fabricated by supplying muliple layers of doped organic connectors **168.1, 2 and 3**, hole transport layers **162.1, 2, 3,and 4,** light emitting layers **164.1, 2, 3 and 4,** and electron transport layers **166.1, 2, 3 and 4** as illustrated for the blue subpixel in Fig. 6. Fig 6, shows a device with a two unit stack for the red light emitting elements, a three unit stack for the green light emitting elements, and a four unit stack for the blue light emitting elements. After the appropriate number of stacked units are deposited, an electron injecting layer 169 is deposited on the entire stack, followed by the cathode **158.**

[0051] The order in size of the areas of the green, red, and blue emission regions and the number of layers of green, red, and blue emission regions are determined according to the method of the present invention described above. However, within this embodiment, if it is determined that the lifetime of the three light emitting elements are not equal, the relative sizes and/or the number of layers for the three subpixels are modified **48**, reducing the area of the materials with the larger values and increasing the area of the materials with the smaller values. It is also recognized that the optical transfer characteristics of each layer in the stack may be somewhat different and is to be taken into account when determining the relative areas.

[0052] A larger area for the light emitting material is provided within an RGB stacked OLED display of the type described in US 6,358,631. Herein, each subpixel in the stack is comprised of multiple light emitting units of substantially the same color as described in pending US Patent Application 10/077,270. This increases the overall area of the light emitting

material and reduces the current density per unit area. An embodiment is depicted in Fig. 7. This figure depicts a stacked OLED display as described in US 6,358,631 in which one of the light emitting layers is actually composed of two layers as described in Patent Application 10/077,270.

[0053] In the embodiment shown in Fig. 7, the differently colored subpixels are stacked on top of each other and include an anode **170** on which a hole injecting layer **172** is deposited. A hole transport layer **174.1**, light emitting layer **176.1**, and an electron transport layer **178.1** are then deposited onto this hole injecting layer **172**. A doped organic connector **180** is then deposited followed by a hole transport layer **174.2,** light emitting layer **176.2** and an electron transport layer **178.2.** An optional electron ejecting layer (not shown) may then be deposited. The cathode is then created through the deposition of a metallic layer **182** and an ITO layer **184.** Within this embodiment, the elements with numbers **172** through **184** compose a single addressable pixel element of a single color.

[0054] A second colored subpixel is then formed through the deposition of a hole injecting layer **186,** a hole transport layer **188**, a light emitting layer 190, an electron transport layer **192**, an optional electron injection layer (not shown), a metallic layer **194** and an ITO layer **196.** Finally, a third colored subpixel is formed through the deposition of a hole injecting layer **198,** a hole transport layer **200,** a light emitting layer **202**, an electron transport layer **204**, an optional electron injection layer (not shown), a metallic layer **206** and an ITO layer **208.**

[0055] The order of the areas of the green, red, and blue emission regions G, R, and B and the number of layers of green, red, and blue emission regions are determined based on the processes described above with reference to Fig. 2. The order of the subpixels in the stack needs to be taken into account because of the masking effects of the subpixels that may be positioned over a given subpixel. However, within this embodiment if it is determined that the lifetime of the three light emitting elements are not equal, the number of layers or the stacking order for the three subpixels are modified **48,** increasing the area of the materials with the smaller values and potentially reducing the area of the materials with the larger values.

[0056] Referring to Fig. 8, a larger area for the light emitting element with the shortest lifetime is provided within a stacked OLED display. In this embodiment, two subpixels (e.g. red and green) are stacked on top of a third subpixel (e.g. blue). A first subpixel is formed from an anode **210** on which a hole injecting layer **212** is deposited. A hole transport layer **214**, light emitting layer **216,** and an electron transport layer **218** are then deposited onto this hole injecting layer **212**. An optional electron ejecting layer (not shown) may then be deposited. The cathode is then created through the deposition of a metallic layer **220,240** and an ITO layer **222, 242.** The metallic layer **220,240** and ITO layer **222,242** also serve as an anode for the second and third subpixels. This first subpixel **224** provides the light for the shortest lifetime light emitting element (e.g. blue) and has substantially the same area as the combined areas of the second **226** and third **228** subpixels. This first subpixel may be composed of multiple areas that are treated as a single light emitting element or may be a single element as shown in Fig. 8. By separating the first subpixel into multiple areas, shorts or dark spots that are created in one half of the first subpixel can be precluded from growing into its neighboring areas.

[0057] A subpixel **226** is formed on top of this first subpixel **224**. This second subpixel **226** is formed by depositing a hole transport layer **230,** a light emitting layer **232** and an electron transport layer **234.** An optional electron ejecting layer (not shown) may then be deposited. The cathode is then created through the deposition of a metallic layer **236** and an ITO layer **238.**

[0058] A third subpixel **228** is also formed on top of the first subpixel **224.** This third subpixel **228** is formed from a hole transport layer **244**, a light emitting layer **246** and an electron transport layer **248**. An optional electron ejecting layer (not shown) may then be deposited. The cathode is then created through the deposition of a metallic layer **250** and an ITO layer **252.** It should also be noted that the relative areas of the second and third subpixels may not be equal depending on the relative areas calculated according to the present invention.

[0059] As stated before, the order in size of the areas of the first, second, and third subpixels are determined based on the process shown in Fig. 2 as described earlier. It should be recognized that this same embodiment may further be modified to contain multiple light emissive layers within the first, second, and/or third light emitting element as described above.

Example 1 (Inventive)

[0060] To further demonstrate the difference between the method described herein from the prior art, an example is provided. Within this example, it is assumed that the lifetime is defined as the number of hours required for any of the three color subpixels to decay to 50% of their original luminance. To utilize this method, it is important to establish the specific efficiencies and luminance stabilities over time of the materials from which the display is to be built as well as to establish the aim characteristics of a display.

[0061] In this example, it is assumed that a number of OLED test cells are available that have been prepared using the light emitting materials to be used in the display. These test cells are driven and configured as similarly to the final display as possible. The efficiencies and chromaticity coordinates for each test cell are determined by driving the test cell to a series of different current densities and measuring the luminance and chromaticity coordinate for each test cell.

The average performance of these test cells are calculated from the measured data to determine the efficiency of the red, green, and blue light emitting elements. Equations are then fit to this data to determine the efficiency curve for each material. Sample data sets and linear fits for an example family of light emitting elements are shown in Fig. 9. The linear fits shown in this figure can be described using the slopes and offsets for material efficiencies shown in Table 1 below.

[0062] The luminance stability over time of each light-emitting element may then be determined by selecting a subset of the test cells for each material and driving them with a single current density while measuring the luminance decay of the material over time. Once again, the average performance may be determined from a group of test cells that were prepared using the same light emissive materials and driven and configured as similarly to the final display as possible. A sample data set and power function fit to this data are shown in Fig. 10 for the same example family of light emitting materials. The multiplication and exponential factors for these equations that characterize luminance stability over time are shown in Table 1 below.

[0063] The remaining characteristics of the display and of the materials were likewise determined empirically. The remaining characteristics of the light emitting element are shown in Table 1 below. The display characteristics for this example are shown in Table 2 below.

[0064] Table 1 lists the important characteristics for the red, green, and blue light emitting elements to be used in constructing the final display. As shown in this table, the chromaticity coordinates, a characterization of the efficiency, luminance stability over time and optical transmission factor for each light-emitting element are included.

Table 1.

Characteristic	Red Light Emitting Material	Green Light Emitting Material	Blue Light Emitting Material
x chromaticity coordinate	0.6492	0.3118	0.1478
y chromaticity coordinate	0.3474	0.6196	0.1909
Slope for efficiency equation	16.82	70.33	28.03
Intercept for efficiency equation	0.0	0.0	0.0
Multiplication factor for the luminance stability equation	348006	116540	37234
Power for luminance stability equation	-1.4687	-1.6650	-1.3148
Optical transmission factor	0.5	0.5	0.5

[0065] Table 2 lists the luminance and chromaticity coordinates for the display. The aim fill factor (the proportion of the pixel area that will emit light in the final display) is also shown in Table 2.

Table 2.

Display Characteristic	Value
Luminance of 100% white	100 cd/sq m
x chromaticity coordinate for white	0.3128
y chromaticity coordinate for white	0.3292
Fill factor	0.60

[0066] Employing the data in Tables 1 and 2, and using the method of the present invention as described above, the relative proportions for the subpixels were calculated to be approximately, 0.125, 0.125, and 0.350 for the red, green, and blue light emitting elements respectively, where the total area of the pixel is 1. That is, the area ratio of red:green:blue light emitting elements is 1:1:2.8. In addition, the expected time for the red, green, and blue light emitting elements to produce half their initial luminance are 8285, 8203, and 8589 hours, respectively. This method provides a display lifetime of 8203 hours.

[0067] Using a conventional display of the prior art, one third of the total available display fill factor would be allocated to the red, green, and blue light emitting element. Using this conventional approach and the characteristics of the display and materials as shown in Tables 1 and 2, 20 percent of the light emitting area of each pixel in the final display would emit red, green, and blue light. Using the data in these tables and the equations shown within this disclosure, the time required for the red, green, and blue light emitting elements to produce half their initial luminance under the current drive

conditions would be 16523, 17941, and 4115 hours, respectively. Notice that within this prior art configuration, the lifetime of the display is 4115 hours when lifetime is defined as the time for any of the three color subpixels to decay to produce 50% of their initial luminance.

[0068] In this example, the method of Yamada in US 6,366,025 is used to determine the relative red, green, and blue areas. Yamada discusses the selection of individual light emitting element fill factors by determining the luminance ratios of the red, green and blue light emitting elements required to produce the desired white point. Then determining the emission efficiency ratio required to achieve a luminance of 1 and then dividing the luminance ratios by the maximum emission efficiency ratio.

[0069] Within this example, equations 1, 2 and 3 are used to calculate the required red, green and blue luminance values to obtain the luminance and chromaticity coordinates shown in Table 2. The values are normalized by dividing each value by the maximum of the three values. This calculation produces luminance ratios of R:G:B = 0.62:1.0:0.69.

[0070] The emission efficiency is then calculated. For the material set described above, one can use the intercept and slope of the efficiency equation for each light emitting material to calculate the current density required to produce a luminance of 1. Performing these calculations, an emission efficiency ratio of R:G:B = 16.8:70.33:29.93 is obtained. Dividing the luminance ratios by the emission efficiency ratios produces R:G:B = 0.62/16.8:1.0/70.33:0.69/29.93 = 0.0369:0.0142:0.0231. Normalizing these values to provide a green value of 1, the relative areas of the red, green, and blue light emitting elements is R:G:B = 2.6:1.0:1.6, indicating that the red light emitting element should be 2.6 times the size of the green light emitting element, and the blue light emitting element should be 1.6 times the size of the green light emitting element.

[0071] The lifetime of a display with these pixel sizes may then be calculated using the method provided herein. Assuming that the total fill factor is constrained to 60 percent of the total pixel area and using the relative sizes calculated above, the fill factors to be used in this calculation are 0.3 for the red, 0.115 for the green and 0.185 for the blue subpixel. These results vary significantly from the relative areas calculated using the method of this invention. In this example, the time required for the three subpixels to produce half their initial luminance under the current drive conditions are 29972, 7140, and 3714 hours for the red, green, and blue subpixels, respectively. Notice that within this prior art configuration, the lifetime of the display is 3714 hours when lifetime is defined as the time for any of the three color subpixels to decay to produce 50% of their initial luminance.

[0072] In this example, the method of Kim et al. is used to determine the relative sizes of each subpixel. Kim et al discusses the selection of individual subpixel sizes based upon the luminance efficiency of the materials. Using this approach, the relative sizes would be determined based upon the ratios of the current density required to produce a luminance of 1. The relative areas of the red, green, and blue light emitting elements is achieved by dividing the emission efficiency of the material with the highest efficiency by the emission efficiency of each light emitting material, which indicates that the red light emitting element should be 4.18 times the size of the blue light emitting element and 2.51 times the size of the green light emitting element. This would indicate relative fill factors of 0.32 for the red, 0.078 for the green and 0.19 for the blue light emitting element. As with Yamada, the method of Kim teaches a very different ratio of subpixel areas. The time required for the red, green, and blue subpixels to produce half their initial luminance under the current drive conditions is 32,952, 3741, and 3847 hours, respectively. Notice that within this prior art configuration, the lifetime of the display is 3741 hours when lifetime is defined as the time for any of the three color subpixels to decay to produce 50% of their initial luminance.

[0073] Thus it can be readily seen the method of the present invention provides a substantial improvement in the useful lifetime of the display over the methods described in the prior art.

Claims

1. A method of determining the relative sizes of subpixels in a OLED display device having a display pixel that includes a plurality of subpixels of different colors, wherein the subpixels are different in size, wherein the relative sizes (Ai) of the subpixels (i) are based on the emission efficiency of the subpixels, the chromaticity of a target display white point, and the relative luminance stability over time of the subpixels thereby protecting the subpixels whose emission efficiency is low from prematurely deteriorating, comprising the steps of:

    a) measuring chromaticity coordinates for the subpixels (i);
    b) selecting aim chromaticity coordinates (x_w, y_w) and luminance (Y_w) of a target display white point;
    c) calculating a required luminance (Y_i) output from the display to create the selected target display white point for each subpixel (i) using the chromaticity coordinates of the subpixels, and the aim chromaticity coordinates and the luminance of the target display white point;
    d) selecting an initial light emissive area (A_i) for each subpixel (i);
    e) providing an optical transmission factor for each subpixel (i);

f) calculating an actual luminance (Y_i) for each subpixel using the initial areas (A_i) and optical transmission factors for the subpixel (i);
g) determining a functional relationship between current density (I_i) and luminance output for each subpixel (i);
h) calculating an aim current density (I_i) for each subpixel (i);
i) determining a functional relationship between current density (I_i) and a luminance stability over time (T_i) for each subpixel (i), wherein the luminance stability over time (T_i) is the time until the light-emitting element has lost half its original luminance;
j) calculating the time (T_i) representing the luminance stability over time for each subpixel (i) using the aim current density (I_i) and the luminance stability function; and
k) if the times (T_i) are unequal, modifying the light emissive areas (A_i) of the subpixels (i) by stacking multiple layers of light emitting materials of the same color, reducing the area (A_i) of the subpixel (i) with the larger time (T_i) and increasing the area (A_i) of the subpixel with the smaller time (T_i), and repeating steps h, j, and k until the times (T_i) are equal.

2. The method claimed in claim 1, wherein the relative sizes are determined according to the equation:

$$A_i = f(E_i, T_i, Y_i)$$

where A_i are the areas of the subpixels; E_i are the material efficiencies for the differently colored subpixels; T_i are the luminance stabilities over time for the differently colored subpixels; and Y_i are the luminances of the differently colored subpixels for a given target display white and the chromaticity coordinates of the subpixels.

3. The method claimed in claim 2, wherein the luminance stability for each of the materials over time are defined as:

$$T_i = cI^d$$

where c and d are constants and I is the current density through the subpixels.

Patentansprüche

1. Verfahren zum Bestimmen der relativen Größen von Subpixeln in einer OLED Anzeigevorrichtung, die einen Anzeigepixel enthaltend eine Mehrzahl von Subpixeln verschiedener Farben aufweist, wobei sich die Subpixel in der Größe unterscheiden, wobei die relative Größen (Ai) der Subpixel (i) auf einem Emissionswirkungsgrad der Subpixel, der Farbart eines Soll-Anzeigeweißpunkts, und der relativen Helligkeitsstabilität über der Zeit der Subpixel basieren, wodurch die Subpixel, deren Emissionswirkungsgrad gering ist, vor frühzeitiger Verschlechterung geschützt werden, wobei das Verfahren die Schritte aufweist:

a) Messen von Farbartkoordinaten der Subpixel (i);
b) Auswählen von gewünschten Farbartkoordinaten (x_w, y_w) und Helligkeit (Y_w) eines Soll-Anzeigeweißpunkts;
c) Berechnen einer benötigen Helligkeit (Y_i), die von der Anzeige ausgegeben wird, um den ausgewählten Soll-Anzeigeweißpunkt für jeden Subpixel (i) zu erzeugen unter Verwendung von Farbartkoordinaten des Subpixel, und den gewünschten Farbartkoordinaten und der Helligkeit des Soll-Anzeigeweißpunkts;
d) Auswählen eines anfänglichen lichtausstrahlenden Bereichs (A_i) für jeden Subpixel (i);
e) Bereitstellen eines optischen Lichtdurchlassgrads für jeden Subpixel (i);
f) Berechnen einer tatsächlichen Helligkeit (Y_i) für jeden Subpixel unter Verwendung der anfänglichen Bereiche (A_i) und der optischen Lichtdurchlassgrade für den Subpixel (i);
g) Bestimmen eines funktionalen Verhältnisses zwischen Stromdichte (I_i) und Helligkeitsausgabe für jeden Subpixel (i);
h) Berechnen einer gewünschten Stromdichte (I_i) für jeden Subpixel (i);
i) Bestimmen eines funktionalen Verhältnisses zwischen Stromdichte (I_i) und einer Helligkeitsstabilität über der Zeit (T_i) für jeden Subpixel (i), wobei die Helligkeitsstabilität über der Zeit (T_i) die Zeit ist, bis das lichtemittierende Element die Hälfte seiner ursprünglichen Helligkeit verloren hat;
j) Berechnen der Zeit (T_i), die die Helligkeitsstabilität über der Zeit für jeden Subpixel (i) repräsentiert, unter Verwendung der gewünschten Stromdichte (I_i) und der Helligkeitsstabilitätsfunktion; und

k) falls die Zeiten (T_i) ungleich sind, Modifzieren der lichtausstrahlenden Bereiche (I_i) der Subpixel (i) durch Stapeln mehrerer Schichten von lichtemittierendem Material derselben Farbe, Verringern des Bereichs (A_i) des Subpixels (i) mit der größeren Zeit (T_i) und Erhöhen des Bereichs (A_i) des Subpixels mit der geringeren Zeit (T_i), und Wiederholen der Schritte h, j und k bis die Zeiten (T_i) gleich ist.

2. Verfahren wie in Anspruch 1 beansprucht, bei dem die relativen Größen gemäß der folgenden Gleichung bestimmt werden:

$$A_i = f(E_i, T_i, Y_i),$$

wobei A_i die Bereiche der Subpixel sind, E_i die Materialwirkungsgrade für die Subpixel mit verschiedenen Farben sind; T_i die Helligkeitsstabilitäten über der Zeit für die Subpixel mit unterschiedlichen Farben sind; und Y_i die Helligkeiten der Subpixel mit unterschiedlichen Farben für ein gegebenes Soll-Anzeigeweiß und die Farbartkoordinaten der Subpixel sind.

3. Verfahren wie in Anspruch 2 beansprucht, bei dem die Helligkeitsstabilität für jedes der Materialien über der Zeit definiert ist als:

$$T_i = cI^d$$

wobei c und d Konstanten und I die Stromdichte durch die Subpixel sind.

Revendications

1. Procédé de détermination des tailles relatives de sous-pixels dans un dispositif d'affichage à OLED ayant un pixel d'affichage qui inclut une pluralité de sous-pixels de différentes couleurs, dans lequel les sous-pixels sont différents en taille, dans lequel les tailles relatives (Ai) des sous-pixels (i) sont basées sur l'efficacité d'émission des sous-pixels, la chromaticité d'un point blanc d'affichage cible, et la stabilité relative de luminance dans le temps des sous-pixels, protégeant ainsi les sous-pixels dont l'efficacité d'émission est basse d'une détérioration prématurée, comprenant les étapes de :

a) mesure des coordonnées de chromaticité pour les sous-pixels (i) ;
b) sélection de coordonnées de chromaticité (x_w, y_w) cibles et d'une luminance d'un point blanc d'affichage cible ;
c) calcul d'une luminance (Y_i) requise délivrée en sortie de l'afficheur pour créer le point blanc d'affichage cible sélectionné pour chaque sous-pixel (i) en utilisant les coordonnées de chromaticité des sous-pixels, et les coordonnées de chromaticité cibles et la luminance du point blanc d'affichage cible ;
d) sélection d'une zone initiale (A_i) d'émission de lumière pour chaque sous-pixel (i) ;
e) prévision d'un facteur de transmission optique pour chaque sous-pixel (i) ;
f) calcul d'une luminance (Y_i) réelle pour chaque sous-pixel en utilisant les zones initiales (A_i) et les facteurs de transmission optique pour le sous-pixel (i) ;
g) détermination d'une relation fonctionnelle entre une densité de courant (I_i) et une sortie de luminance pour chaque sous-pixel (i) ;
h) calcul d'une densité de courant (I_i) cible pour chaque sous-pixel (i) ;
i) détermination d'une relation fonctionnelle entre une densité de courant (I_i) et une stabilité de luminance dans le temps (T_i) pour chaque sous-pixel (i), dans lequel la stabilité de luminance dans le temps (T_i) est le temps jusqu'à ce que l'élément d'émission de lumière ait perdu la moitié de sa luminance d'origine ;
j) calcul du temps (T_i) représentant la stabilité de luminance dans le temps pour chaque sous-pixel (i) en utilisant la densité de courant (I_i) cible et la fonction de stabilité de luminance ; et
k) si les temps (T_i) sont inégaux, modification des zones (A_i) d'émission de lumière des sous-pixels (i) en empilant des couches multiples de matériaux d'émission de lumière de la même couleur, en réduisant la zone (A_i) du sous-pixel (i) avec le temps (T_i) le plus grand et en augmentant la zone (A_i) du sous-pixel avec le temps

(T_i) le plus petit, et en répétant les étapes h, j et k jusqu'à ce que les temps (T_i) soient égaux.

2. Procédé selon la revendication 1, dans lequel les tailles relatives sont déterminées conformément à l'équation :

$$A_i = f(E_i, T_i, Y_i)$$

où A_i sont les zones des sous-pixels ; E_i sont les efficacités matérielles pour les sous-pixels différemment colorés ; T_i sont les stabilités de luminance dans le temps pour les sous-pixels différemment colorés ; et Y_i sont les luminances des sous-pixels différemment colorés pour un blanc d'affichage cible donné et les coordonnées de chromaticité des sous-pixels.

3. Procédé selon la revendication 2, dans lequel la stabilité de luminance pour chacun des matériaux dans le temps sont définies comme :

$$T_i = cI^d$$

où c et d sont des constantes et I est la densité de courant à travers les sous-pixels.

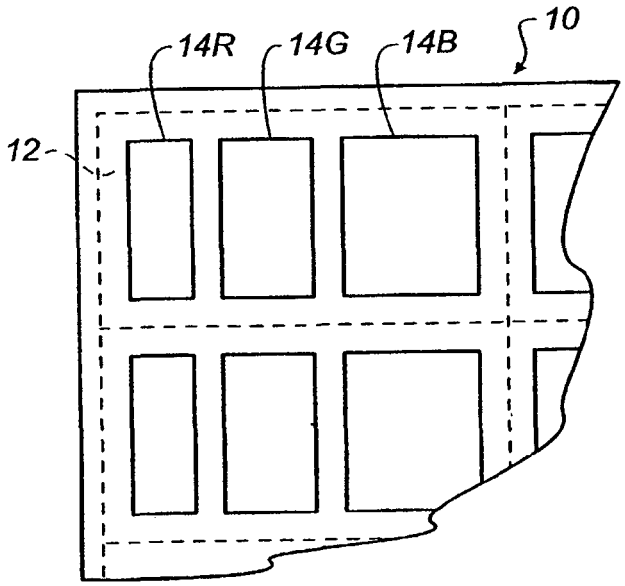


FIG. 1
(PRIOR ART)

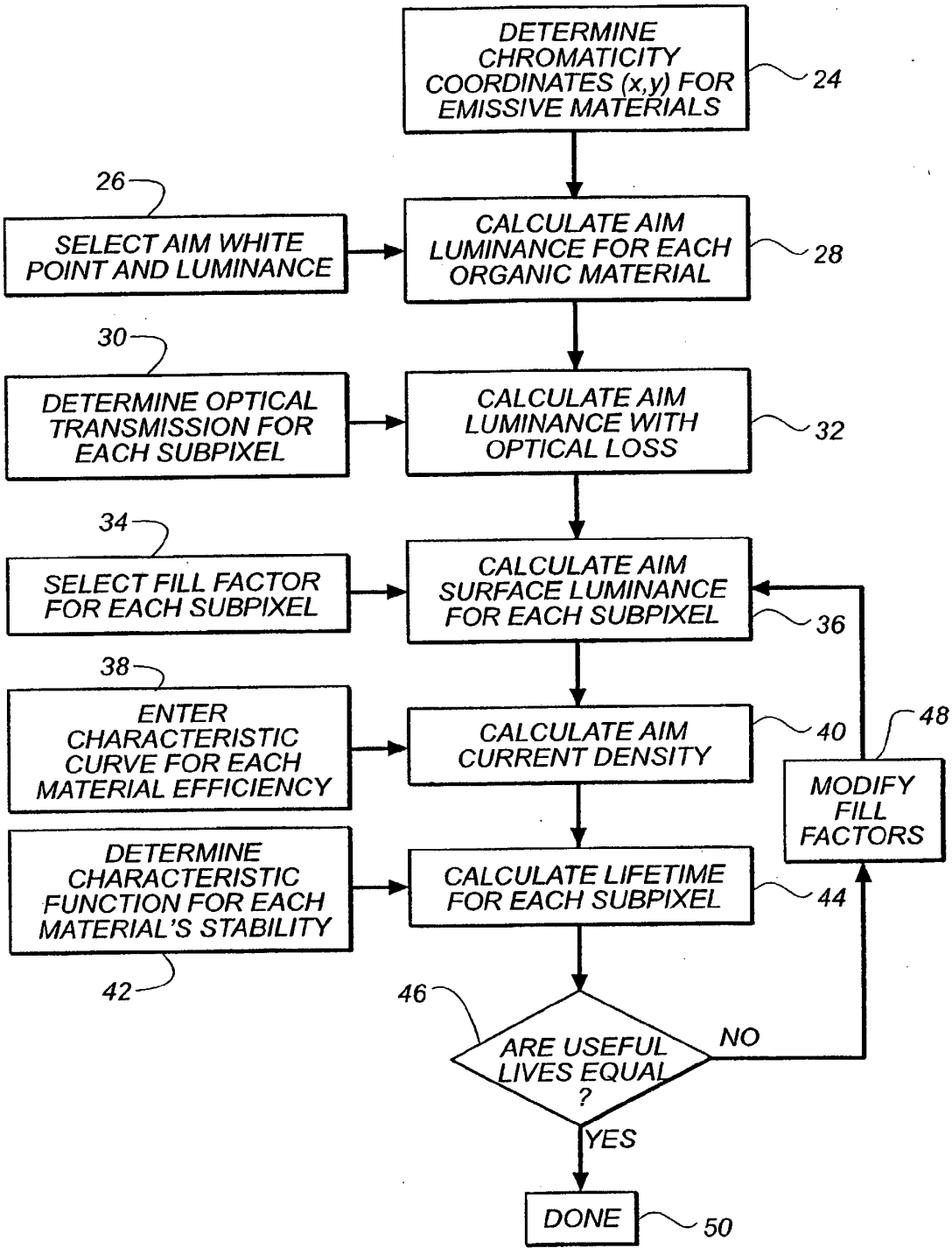

DETERMINE CHROMATICITY COORDINATES (x,y) FOR EMISSIVE MATERIALS
24
26
SELECT AIM WHITE POINT AND LUMINANCE
CALCULATE AIM LUMINANCE FOR EACH ORGANIC MATERIAL
28
30
DETERMINE OPTICAL TRANSMISSION FOR EACH SUBPIXEL
CALCULATE AIM LUMINANCE WITH OPTICAL LOSS
32
34
SELECT FILL FACTOR FOR EACH SUBPIXEL
CALCULATE AIM SURFACE LUMINANCE FOR EACH SUBPIXEL
36
38
ENTER CHARACTERISTIC CURVE FOR EACH MATERIAL EFFICIENCY
CALCULATE AIM CURRENT DENSITY
40
48
MODIFY FILL FACTORS
DETERMINE CHARACTERISTIC FUNCTION FOR EACH MATERIAL'S STABILITY
CALCULATE LIFETIME FOR EACH SUBPIXEL
44
42
46
ARE USEFUL LIVES EQUAL ?
NO
YES
DONE
50

FIG. 2

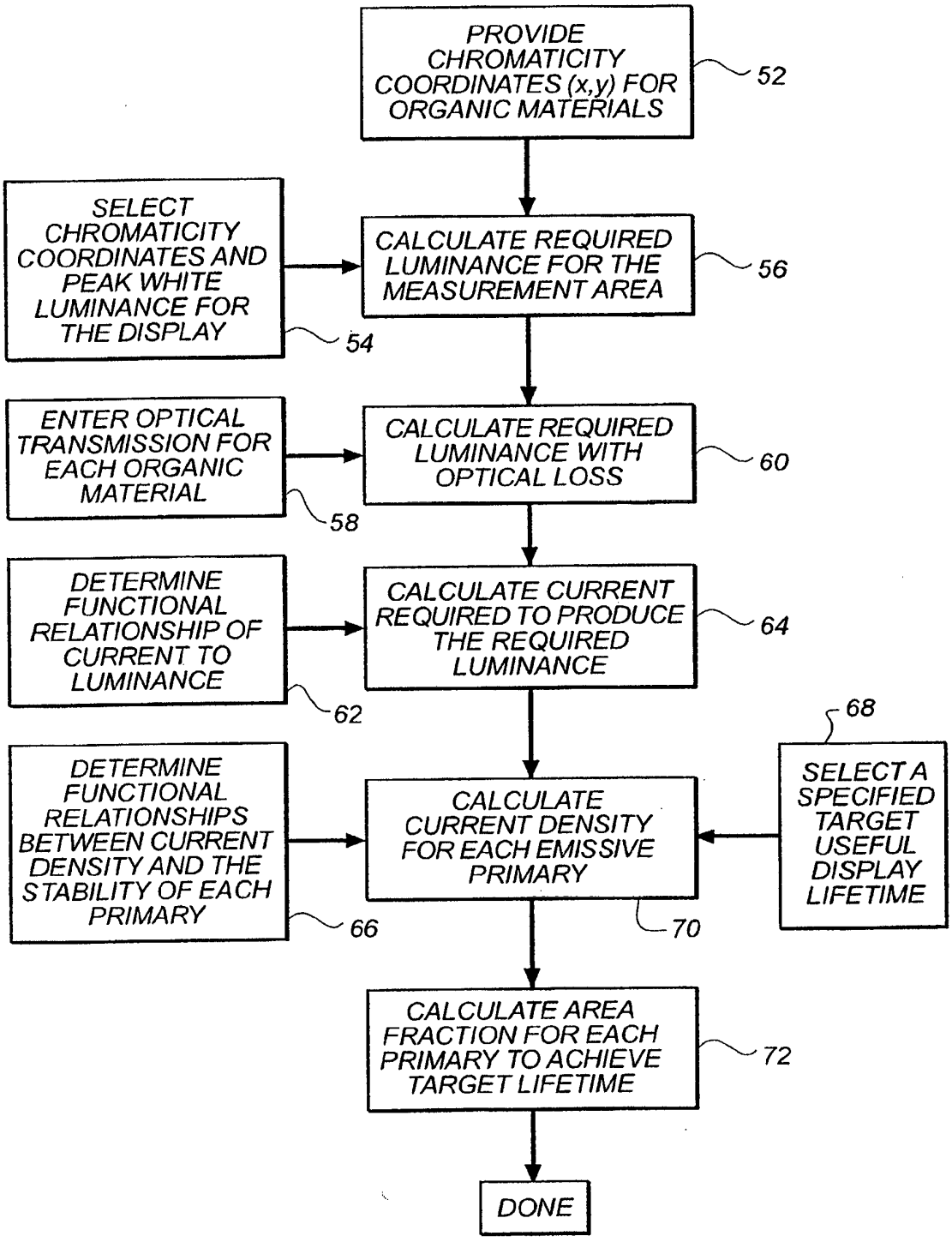

PROVIDE CHROMATICITY COORDINATES (x,y) FOR ORGANIC MATERIALS
52
SELECT CHROMATICITY COORDINATES AND PEAK WHITE LUMINANCE FOR THE DISPLAY
54
CALCULATE REQUIRED LUMINANCE FOR THE MEASUREMENT AREA
56
ENTER OPTICAL TRANSMISSION FOR EACH ORGANIC MATERIAL
58
CALCULATE REQUIRED LUMINANCE WITH OPTICAL LOSS
60
DETERMINE FUNCTIONAL RELATIONSHIP OF CURRENT TO LUMINANCE
62
CALCULATE CURRENT REQUIRED TO PRODUCE THE REQUIRED LUMINANCE
64
68
SELECT A SPECIFIED TARGET USEFUL DISPLAY LIFETIME
DETERMINE FUNCTIONAL RELATIONSHIPS BETWEEN CURRENT DENSITY AND THE STABILITY OF EACH PRIMARY
66
CALCULATE CURRENT DENSITY FOR EACH EMISSIVE PRIMARY
70
CALCULATE AREA FRACTION FOR EACH PRIMARY TO ACHIEVE TARGET LIFETIME
72
DONE

FIG. 3

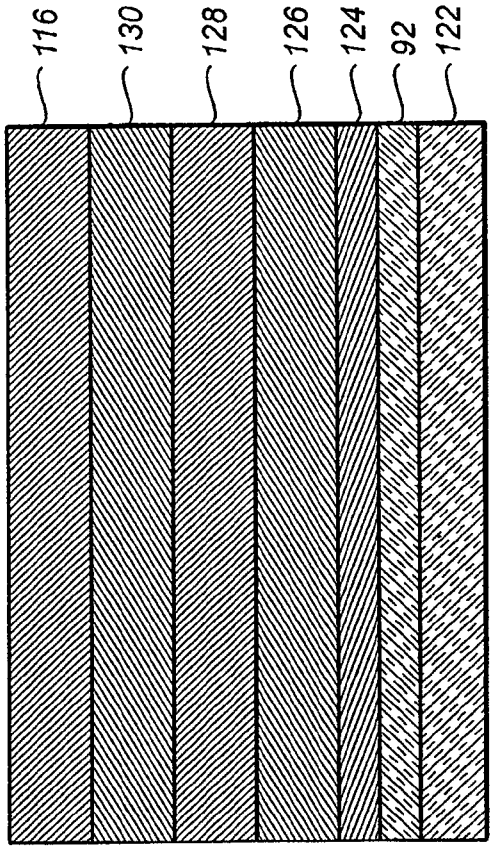


FIG. 4
(PRIOR ART)

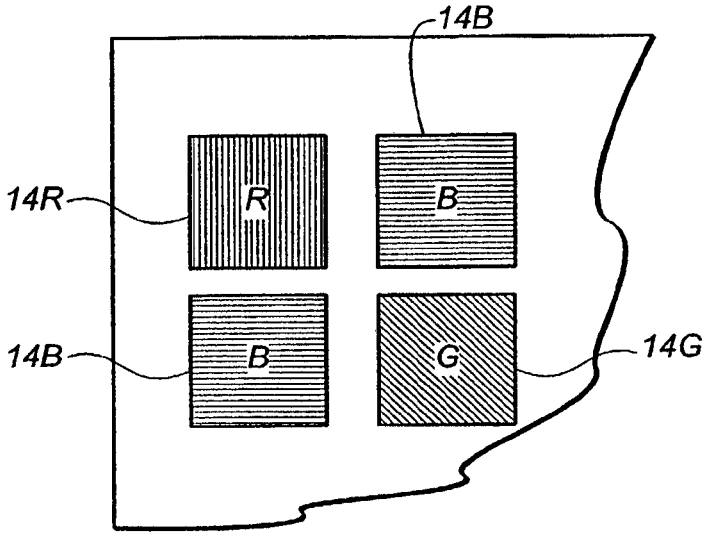


FIG. 5

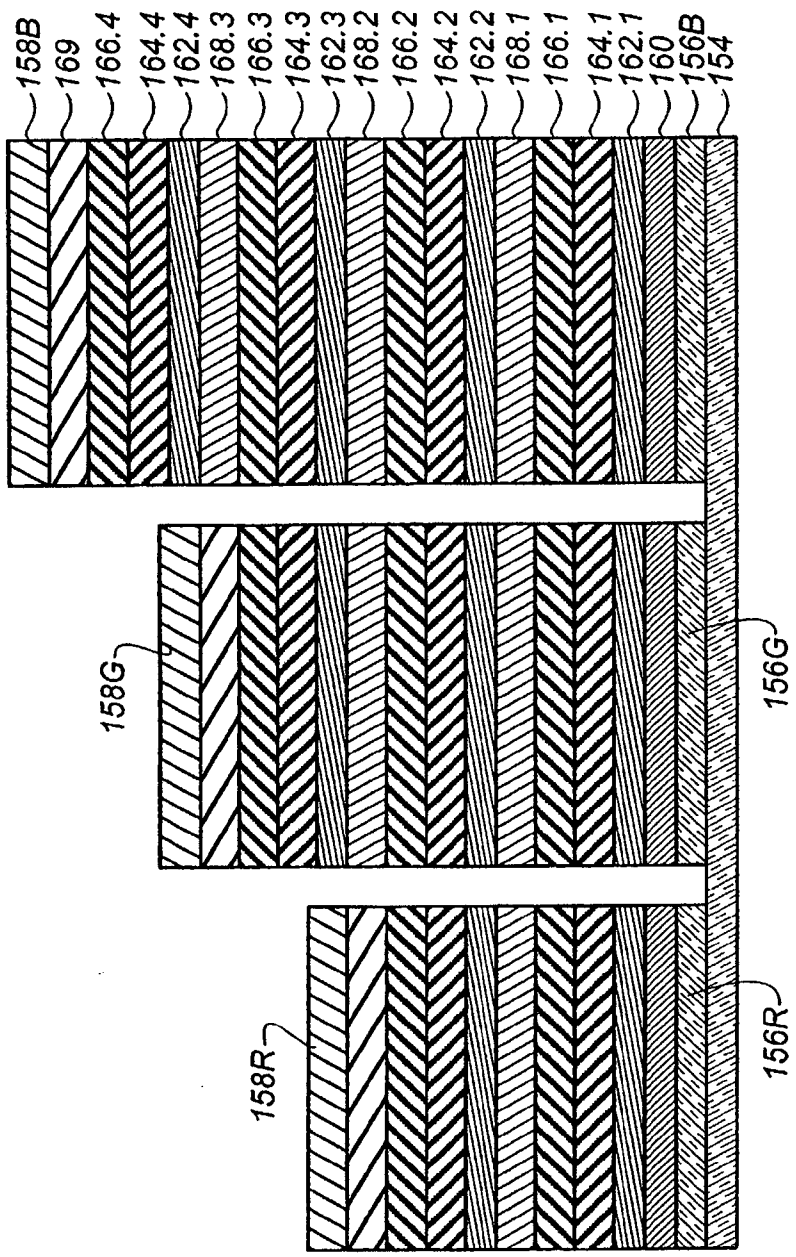

158B
169
166.4
164.4
162.4
168.3
166.3
164.3
162.3
168.2
166.2
164.2
162.2
168.1
166.1
164.1
162.1
160
156B
154
158G
156G
158R
156R

FIG. 6

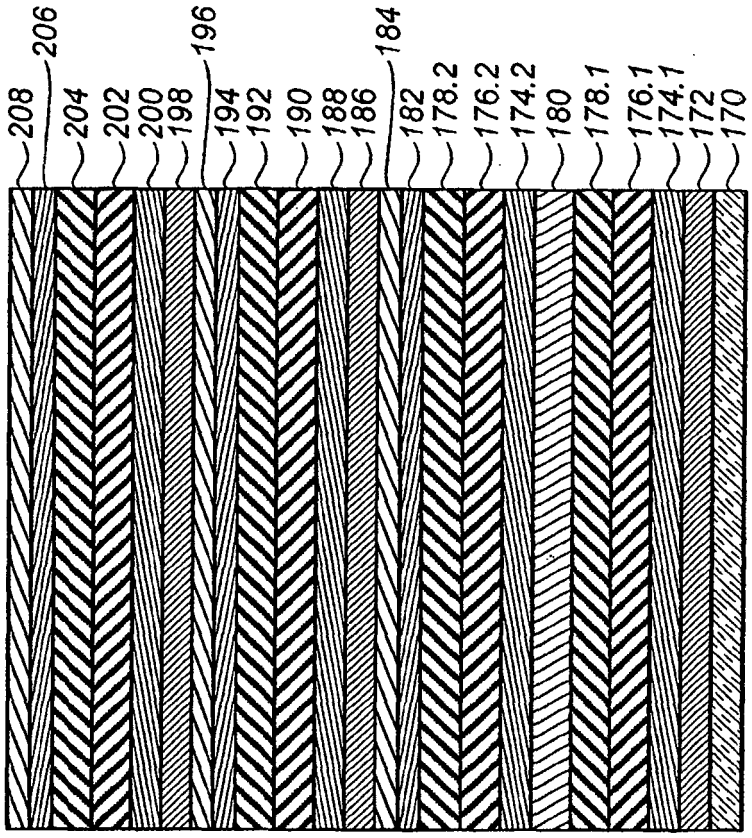
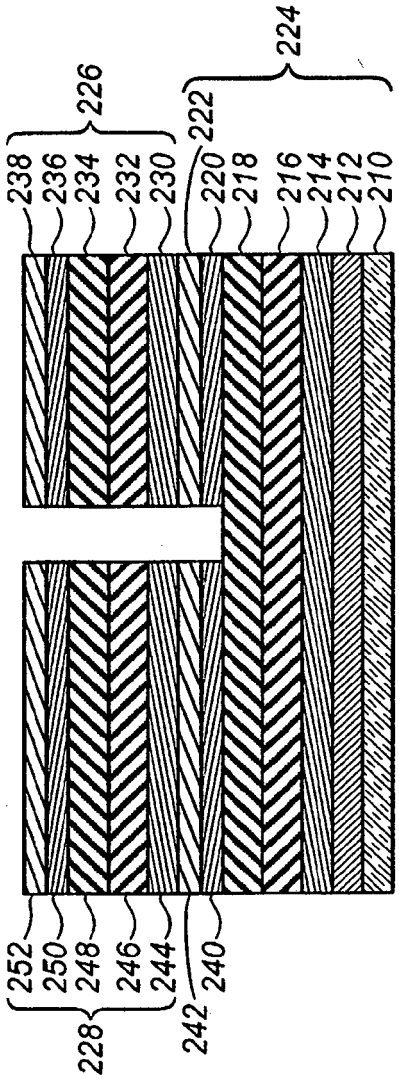

208
206
204
202
200
198
196
194
192
190
188
186
184
182
178.2
176.2
174.2
180
178.1
176.1
174.1
172
170

FIG. 7


224
226
222
238
236
234
232
230
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218
216
214
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252
250
248
246
244
240
228
242

FIG. 8

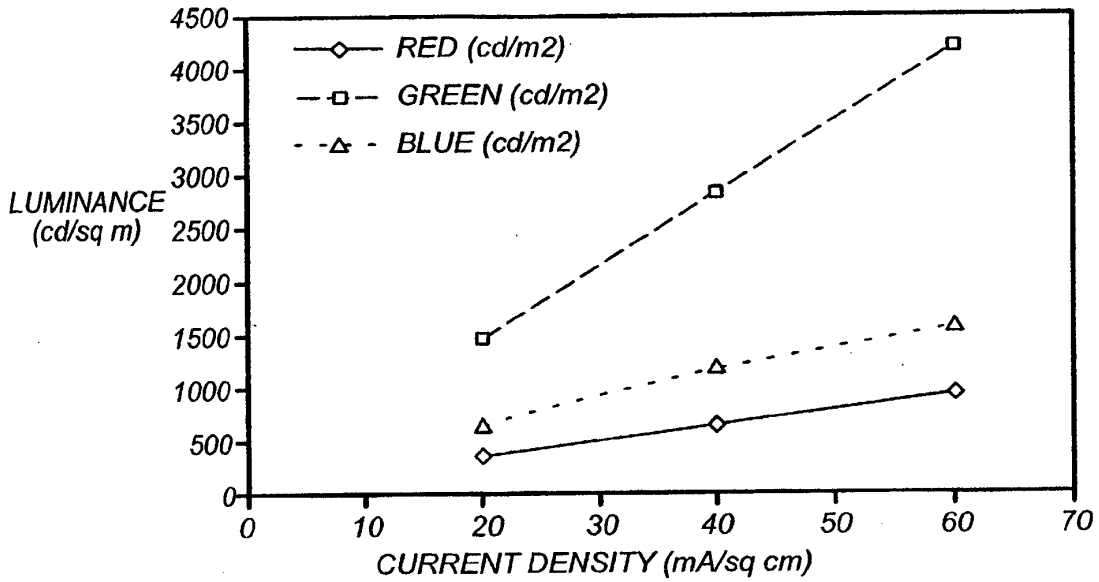
RED (cd/m2)
GREEN (cd/m2)
BLUE (cd/m2)
LUMINANCE (cd/sq m)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
CURRENT DENSITY (mA/sq cm)

FIG. 9

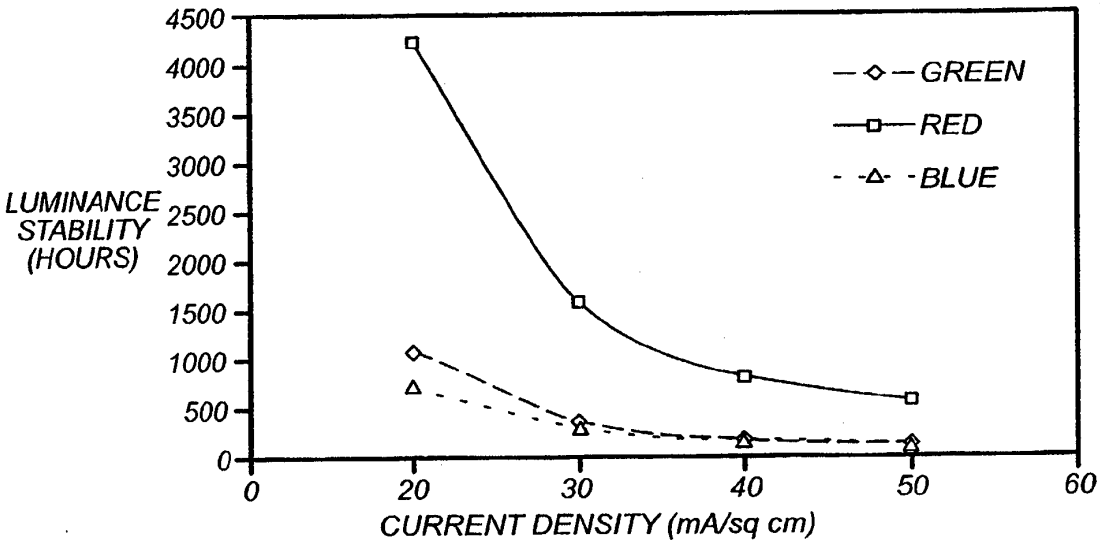
GREEN
RED
BLUE
LUMINANCE STABILITY (HOURS)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
30
40
50
60
CURRENT DENSITY (mA/sq cm)

FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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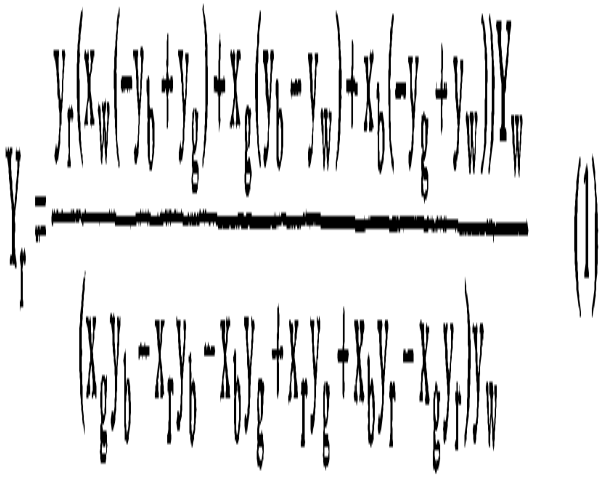
专利名称(译)	用于确定具有改善的寿命的彩色有机发光二极管显示器中的子像素的相对尺寸的方法		
公开(公告)号	EP1391918B1	公开(公告)日	2015-04-22
申请号	EP2003077495	申请日	2003-08-08
[标]申请(专利权)人(译)	伊斯曼柯达公司		
申请(专利权)人(译)	伊士曼柯达公司		
当前申请(专利权)人(译)	全球OLED科技有限责任公司		
[标]发明人	ARNOLD ANDREW D MILLER MICHAEL E MURDOCH MICHAEL J		
发明人	ARNOLD, ANDREW D. MILLER, MICHAEL E. MURDOCH, MICHAEL J.		
IPC分类号	H01L51/56 H01L27/32 G09G3/32 H05B33/12 H01L51/50 H01L51/52 H05B33/14		
CPC分类号	H01L51/5278 G09G3/3208 G09G3/3216 G09G3/3225 G09G2300/0452 G09G2320/043 G09G2320/048 H01L27/3213 H01L27/3218		
优先权	10/224239 2002-08-20 US		
其他公开文献	EP1391918A3 EP1391918A2		
外部链接	Espacenet		

摘要(译)

一种改进的OLED彩色显示装置，其中显示像素具有不同颜色的多个子像素，其中子像素的面积基于发光元件的发射效率和目标显示白点的色度而不同，从而保护发射效率低的子像素过早劣化，其中改进包括子像素的相对尺寸进一步基于子像素随时间的相对亮度稳定性，从而进一步延长显示器的使用寿命。