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AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
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HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR,
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(54) Title: DEVICES CONTAINING A REMOTE PHOSPHOR PACKAGE WITH RED LINE EMITTING PHOSPHORS AND GREEN EMITTING QUANTUM DOTS

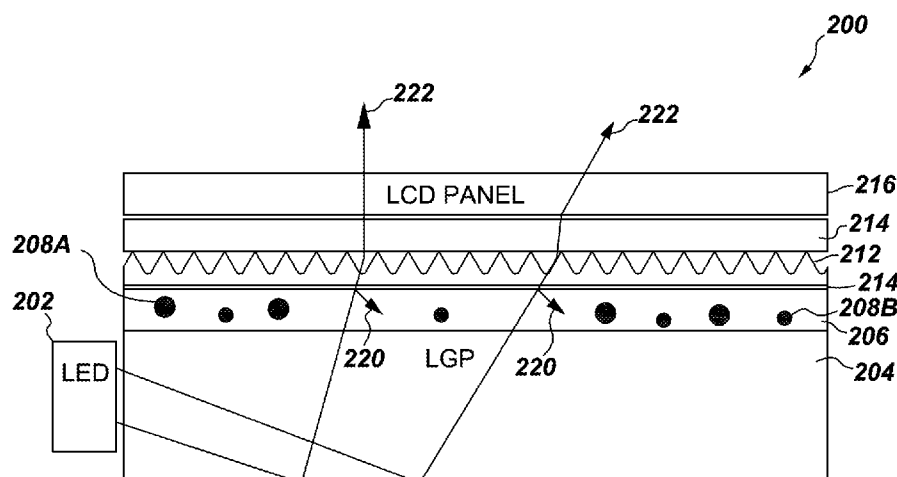


Fig. 2

(57) Abstract: A remote phosphor package according to the present invention includes a green emitting quantum dot material and a Mn⁴⁺ doped phosphor of Ax[MFy]:Mn⁴⁺ (formula I), dispersed in a host matrix, wherein A is Li, Na, K, Rb, Cs, or combinations thereof; M is Si, Ge, Sn, Ti, Zr, Al, Ga, In, Sc, Y, La, Nb, Ta, Bi, Gd, or combinations thereof; x is an absolute value of a charge of the [MFy] ion; and y is 5, 6 or 7.



DEVICES CONTAINING A REMOTE PHOSPHOR PACKAGE WITH RED LINE EMITTING PHOSPHORS AND GREEN EMITTING QUANTUM DOTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a non-provisional of and claims priority from U.S. provisional application, serial number 62/304572, filed March 7, 2016, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

[0002] Energy efficiency is a critical feature in the field of consumer electronics, and displays consume a large portion of device power. Display power consumption highly affects many features of electronic display devices, including battery requirements in mobile display applications, as well as device operating temperature and panel lifetime, especially in large display applications. In conventional display devices, a majority of the energy consumed by the device is dedicated to the display, particularly the display backlight unit. Conventional phosphors exhibit broad emission spectra, so a large amount of the light produced is filtered out by color filters to produce sharper color components. This broad spectrum filtering results in wasted light energy, decreased brightness, and higher display operating temperatures. Therefore, improvements in color gamut and brightness are desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1A illustrates a conventional liquid crystal display (LCD) with an edge lit backlight configuration.

[0004] FIG. 1B illustrates a direct lit backlight configuration for the conventional LCD.

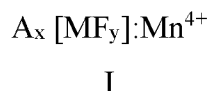
[0005] FIG. 2 illustrates a backlight unit or module 200 according to the present invention.

[0006] FIG. 3 illustrates backlight unit according to the present invention.

BRIEF DESCRIPTION

[0007] It has been discovered that backlight units including a remote phosphor package according to the present invention exhibit efficiency improvements over conventional display backlight units due to the efficient use of primary light, resulting in a reduction in wasted light

energy. The remote phosphor package includes a green emitting quantum dot material and a Mn^{4+} doped phosphor of formula I, dispersed in a host matrix



wherein

A is Li, Na, K, Rb, Cs, or combinations thereof;

M is Si, Ge, Sn, Ti, Zr, Al, Ga, In, Sc, Y, La, Nb, Ta, Bi, Gd, or combinations thereof;

x is an absolute value of a charge of the $[\text{MF}_y]$ ion; and

y is 5, 6 or 7.

DETAILED DESCRIPTION

[0008] FIG. 1A illustrates a conventional liquid crystal display (LCD) with an edge lit backlight configuration. LCD 100A includes a primary light source or backlight source 102, light guide panel 106, and a LCD panel 120. The LCD 100 uses the LCD panel 120 with control electronics and the backlight source 102 to produce color images. The backlight source 102 provides white light.

[0009] The liquid crystal display panel 120 includes color filters 122 arranged in subpixels, such as a red color filter, a green color filter, and a blue color filter. The red, green, and blue filters 122 transmit a light having a specific wavelength of white light incident from the backlight source 102. The filters 122 transmit wavelengths of light corresponding to the color of each filter, and absorb other wavelengths.

[0010] The LCD panel 120 also includes a front polarizer 118, a rear polarizer 114, a thin film transistor 126, and liquid crystal 116 as well as electrodes (not shown). The color filters 122 are positioned between the liquid crystal 116 and the front polarizer 118. The thin film transistor 126 is positioned between the liquid crystal 116 and the rear polarizer 114. Each pixel has a corresponding transistor or switch for controlling voltage applied to the liquid crystal 116. The front and rear polarizers 118 and 114 may be set at right angles. Normally, the LCD panel 120 is opaque. When a voltage is applied across the liquid crystal 116, the rod-shaped polymers align with the electric field and untwist such that the voltage controls the light output from the front polarizer 118. For example, when a voltage is applied to the liquid crystal 116, the liquid crystal 116 rotates so that there is a light output from the front polarizer 118.

[0011] Backlight source 102 includes one or more blue LEDs and yellow phosphor pumped by the blue LEDs to emit white light for LCD 100. The white light from the backlight source 102 travels toward light guide panel 106, through diffuser film 110 and prism 108 as well as double brightness enhanced film 124, which provides a uniform light backlight for the liquid crystal display panel 120. Alternatively, the backlight source 102 may include a white LED that provides white light to the light guide panel 106. The white LED may use a blue LED with broad spectrum yellow phosphor, or a blue LED with red and green phosphors.

[0012] FIG. 1B illustrates a direct lit backlight configuration for the conventional LCD. As shown, the main differences from the edge lit configuration 100B include different arrangement of a number of LEDs and absence of light guide panel 106. More specifically, the LEDs 102 are arranged to directly provide light to a diffuser plate 126, which is normally thicker than the diffuser film 110 and thus supports the diffuser film 110.

[0013] FIG. 2 illustrates a backlight unit or module 200 according to the present invention that includes light source 202, light guide panel 204, remote phosphor package 206, dichroic filter 210, and LCD panel 216. Backlight unit 200 may also optionally include a prism 212 and a double brightness enhanced film 214. The light source 202 is a blue emitting LED. To produce even lighting, blue light from the light source 202 first passes through light guide panel 204 which diffuses the blue light. The LCD panel 216 also includes color filters arranged in subpixels, a front polarizer, a rear polarizer, and liquid crystal as well as electrodes, similar to the LCD panel 120 for the conventional LCD 100. Generally, there is an air space between the LCD panel 216 and the double brightness enhanced film 214. The double brightness enhanced film 214 is a reflective polarizer film which increases efficiency by repeatedly reflecting any unpolarized light back, which would otherwise be absorbed by the LCD's rear polarizer. The double brightness enhanced film 214 is placed behind the liquid crystal display panel 216 without any other film in-between. The double brightness enhanced film 214 may be mounted with its transmission axis substantially parallel to the transmission axis of the rear polarizer. The double brightness enhanced film 214 helps recycle the white light 222 that would normally be absorbed by the rear polarizer (not shown) of the liquid crystal panel 216, and thus increases the brightness of the liquid crystal display panel 216.

[0014] It will be appreciated by those skilled in the art that a backlight unit according to the present invention may vary in configuration. For example, a direct lit configuration may be used, similar to the direct lit configuration shown in FIG. 1B. The prism 212 may also be removed or

substituted by other brightness enhancement component in an alternative embodiment. The double brightness enhanced film 214 may be removed in another embodiment.

[0015] Unlike the conventional LCD 100, instead of using the red phosphor 110A and green phosphor 110B, remote phosphor package 206 includes particles 208A of a complex fluoride phosphor of formula I and particles 208B of a green quantum dot material. It is “remote” in the sense that the primary light source and the phosphor material are separate elements, and the phosphor material is not integrated with the primary light source as a single element. Primary light is emitted from the primary light source and is travels through one or more external media to radiationally couple the LED light source to the QD-phosphor material.

[0016] Red-emitting phosphors based on complex fluoride materials activated by Mn^{4+} , such as those described in US 7,358,542, US 7,497,973, and US 7,648,649, absorb blue light strongly, and efficiently emit between about 610 nanometers and 635 nanometers with little deep red/NIR emission. The complex fluoride phosphors of formula I have a host lattice containing a coordination center, surrounded by fluoride ions acting as ligands, and charge-compensated by counter ions (A) as necessary. For example, in $\text{K}_2[\text{SiF}_6]$, the coordination center is Si and the counter ion is K. Complex fluorides are occasionally represented as a combination of simple, binary fluorides but such a representation does not indicate the coordination number for the ligands around the coordination center. The square brackets (occasionally omitted for simplicity) indicate that the complex ion they encompass is a new chemical species, different from the simple fluoride ion. The Mn^{4+} dopant or activator acts as an additional coordination center, substituting a part of the coordination center, for example, Si, forming a luminescent center. The host lattice (including the counter ions) may further modify the excitation and emission properties of the activator ion.

[0017] The counter ion A in formula I is Li, Na, K, Rb, Cs, or combinations thereof, and y is 6. In certain embodiments, A is Na, K, Rb, or combinations thereof. The coordination center M in formula I is an element selected from the group consisting of Si, Ge, Ti, Zr, Hf, Sn, Al, Ga, In, Sc, Y, Bi, La, Gd, Nb, Ta, and combinations thereof. In certain embodiments, M is Si, Ge, Ti, or combinations thereof. Examples of the phosphors of formula I include $\text{K}_2[\text{SiF}_6]:\text{Mn}^{4+}$, $\text{K}_2[\text{TiF}_6]:\text{Mn}^{4+}$, $\text{K}_2[\text{SnF}_6]:\text{Mn}^{4+}$, $\text{Cs}_2[\text{TiF}_6]:\text{Mn}^{4+}$, $\text{Rb}_2[\text{TiF}_6]:\text{Mn}^{4+}$, $\text{Cs}_2[\text{SiF}_6]:\text{Mn}^{4+}$, $\text{Rb}_2[\text{SiF}_6]:\text{Mn}^{4+}$, $\text{Na}_2[\text{TiF}_6]:\text{Mn}^{4+}$, $\text{Na}_2[\text{ZrF}_6]:\text{Mn}^{4+}$, $\text{K}_3[\text{ZrF}_7]:\text{Mn}^{4+}$, $\text{K}_3[\text{BiF}_7]:\text{Mn}^{4+}$, $\text{K}_3[\text{YF}_7]:\text{Mn}^{4+}$, $\text{K}_3[\text{LaF}_7]:\text{Mn}^{4+}$, $\text{K}_3[\text{GdF}_7]:\text{Mn}^{4+}$, $\text{K}_3[\text{NbF}_7]:\text{Mn}^{4+}$, $\text{K}_3[\text{TaF}_7]:\text{Mn}^{4+}$. In certain embodiments, the phosphor of formula I is $\text{K}_2[\text{SiF}_6]:\text{Mn}^{4+}$.

[0018] QD materials for use in the remote phosphor package include at least one population of QDs capable of emitting green light upon excitation by a blue light source. The QD wavelengths and concentrations can be adjusted to meet the optical performance required. Preferred QD characteristics include high quantum efficiency (e.g., about 90% or greater), continuous and tunable emission spectrum, and narrow and sharp spectral emission, e.g., less than 40 nm, 30 nm or less, or 20 nm or less full width at half max (FWHM).

[0019] The green emitting quantum dot material may include a group II-VI compound, a group III V compound, a group IV-IV compound, a group IV compound, a group I-III-VI₂ compound or a mixture thereof. Non-limiting examples of group II-VI compounds include CdSe, CdTe, CdS, ZnSe, ZnTe, ZnS, HgTe, HgS, HgSe, CdSeTe, CdSTe, ZnSeS, ZnSeTe, ZnSTe, HgSeS, HgSeTe, HgSTe, CdZnS, CdZnSe, CdZnTe, CdHgS, CdHgSe, CdHgTe, HgZnS, HgZnSe, HgZnTe, CdZnSeS, CdZnSeTe, CdZnSTe, CdHgSeS, CdHgSeTe, CdHgSTe, HgZnSeS, HgZnSeTe, HgZnSTe, or combinations thereof. Group III-V compounds may be selected from the group consisting of GaN, GaP, GaAs, AlN, AlP, AlAs, InN, InP, InAs, GaNP, GaNAs, GaPAs, AlNP, AlNAs, AlPAs, InNP, InNAs, InPAs, GaAlNP, GaAlNAs, GaAlPAs, GalnNP, GalnNAs, GalnPAs, InAlNP, InAlNAs, InAlPAs, and combinations thereof. Examples of group IV compounds include Si, Ge, SiC, and SiGe. Examples of group I-III-VI₂ chalcopyrite-type compounds include CuInS₂, CuInSe₂, CuGaS₂, CuGaSe₂, AgInS₂, AgInSe₂, AgGaS₂, AgGaSe₂ and combinations thereof.

[0020] QDs for use in the remote package may be a core/shell QD, including a core, at least one shell coated on the core, and an outer coating including one or more ligands, preferably organic polymeric ligands. Exemplary materials for preparing core-shell QDs include, but are not limited to, Si, Ge, Sn, Se, Te, B, C (including diamond), P, Co, Au, BN, BP, BAs, AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb, AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, ZnO, ZnS, ZnSe, ZnTe, CdS, CdSe, CdSeZn, CdTe, HgS, HgSe, HgTe, BeS, BeSe, BeTe, MgS, MgSe, MnS, MnSe, GeS, GeSe, GeTe, SnS, SnSe, SnTe, PbO, PbS, PbSe, PbTe, CuF, CuCl, CuBr, CuI, Si₃N₄, Ge₃N₄, Al₂O₃, (Al, Ga, In)₂(S, Se, Te)₃, Al₂CO, and appropriate combinations of two or more such materials. Exemplary core-shell QDs include, but are not limited to, CdSe/ZnS, CdSe/CdS, CdSe/CdS/ZnS, CdSeZn/CdS/ZnS, CdSeZn/ZnS, InP/ZnS, PbSe/PbS, PbSe/PbS, CdTe/CdS and CdTe/ZnS.

[0021] The QD materials typically include ligands conjugated to, cooperated with, associated with, or attached to their surface. In particular, the QDs may include a coating layer comprising

ligands to protect the QDs from environmental conditions including elevated temperatures, high intensity light, external gasses, and moisture, control aggregation, and allow for dispersion of the QDs in the matrix material.

[0022] In some embodiments, a remote phosphor package according to the present invention may contain a narrow green emitting phosphor material instead of or in addition to a quantum dot material. Examples of suitable green emitting phosphors include CdS:In, SrGa₂S₄:Eu, CaSO₄:Bi, SrS:Mn, ZnS:Eu, and CaGa₂S₄:Eu.

[0023] The remote phosphor package material additionally includes a matrix material in which the QD-phosphor material is embedded or otherwise disposed. Suitable matrix materials are transparent, non-yellowing, and chemically and optically compatible with the backlight unit components, including the QDs and any surrounding packaging materials or layers. Preferred matrix materials have low oxygen and moisture permeability, exhibit high photo- and chemical-stability, exhibit favorable refractive indices, and adhere to the barrier or other layers adjacent the QD phosphor material, thus providing an air-tight seal to protect the QD-phosphor material.

[0024] Examples of matrix materials for use in QD phosphor material of the present invention include epoxies, acrylates, norborene, polyethylene, poly(vinyl butyral):poly(vinyl acetate), polyurea, polyurethanes; silicones and silicone derivatives including, but not limited to, amino silicone (AMS), polyphenylmethyilsiloxane, polyphenylalkylsiloxane, polydiphenylsiloxane, polydialkylsiloxane, silsesquioxanes, fluorinated silicones, and vinyl and hydride substituted silicones; acrylic polymers and copolymers formed from monomers including, but not limited to, methylmethacrylate, butylmethacrylate, and laurylmethacrylate; styrene-based polymers such as polystyrene, amino polystyrene (APS), and poly(acrylonitrile ethylene styrene) (AES); polymers that are crosslinked with difunctional monomers, such as divinylbenzene; cross-linkers suitable for cross-linking ligand materials, epoxides which combine with ligand amines (e.g., APS or PEI ligand amines) to form epoxy polymers.

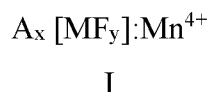
[0025] Referring to FIG. 3, backlight unit 300 according to the present invention includes backplane 2, light guide panel 4, LED light source 6, mounting bracket 8, and a remote phosphor package in the form of a strip 10, mounted in the backplane 2. The remote phosphor package 10 is mounted via mounting bracket 8 between light guide panel 4 and LED light source 6, whereby light emitting from the backlight source 6 is transmitted through composite material 10 and then enters the light guide plate 4. The backlight unit may further include a bottom reflector plate 14

arranged between light guide panel 4 and the backplane 2 and an optical film assembly 16 arranged above the light guide plate 4.

[0026] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS:

1. A backlight unit comprising a semiconductor light source and a remote phosphor package radiationally coupled to an LED light source; the remote phosphor package comprising a green emitting quantum dot material and a Mn^{4+} doped phosphor of formula I, dispersed in a host matrix,



wherein

A is Li, Na, K, Rb, Cs, or combinations thereof;

M is Si, Ge, Sn, Ti, Zr, Al, Ga, In, Sc, Y, La, Nb, Ta, Bi, Gd, or combinations thereof;

x is an absolute value of a charge of the $[\text{MF}_y]$ ion; and

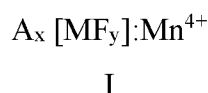
y is 5, 6 or 7.

2. A backlight unit according to claim 1, wherein the color stable Mn^{4+} doped phosphor is $\text{K}_2\text{SiF}_6:\text{Mn}^{4+}$.

3. A backlight unit according to claim 1, wherein the quantum dot material comprises CdSe.

4. A backlight unit according to claim 1, wherein the quantum dot material comprises InP.

5. A remote phosphor package comprising a green emitting quantum dot material and a Mn^{4+} doped phosphor of formula I, dispersed in a host matrix,



wherein

A is Li, Na, K, Rb, Cs, or combinations thereof;

M is Si, Ge, Sn, Ti, Zr, Al, Ga, In, Sc, Y, La, Nb, Ta, Bi, Gd, or combinations thereof;

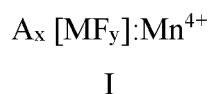
x is an absolute value of a charge of the $[\text{MF}_y]$ ion; and

y is 5, 6 or 7.

6. A remote phosphor package according to claim 5, wherein the color stable Mn^{4+} doped phosphor is $\text{K}_2\text{SiF}_6:\text{Mn}^{4+}$.

7. A device comprising an LED light source radiationally coupled to a remote phosphor package according to claim 5.

8. A backlight unit comprising a device according to claim 7.
9. An electronic device comprising a backlight unit according to claim 8.
10. A device comprising a semiconductor light source radiationally coupled to a green emitting quantum material and a Mn^{4+} doped phosphor of formula I,



the green emitting quantum dot material comprising a group II-VI compound, a group III-V compound, a group IV compound, a group I-III-VI₂ compound or a mixture thereof;

wherein

A is Li, Na, K, Rb, Cs, or combinations thereof;

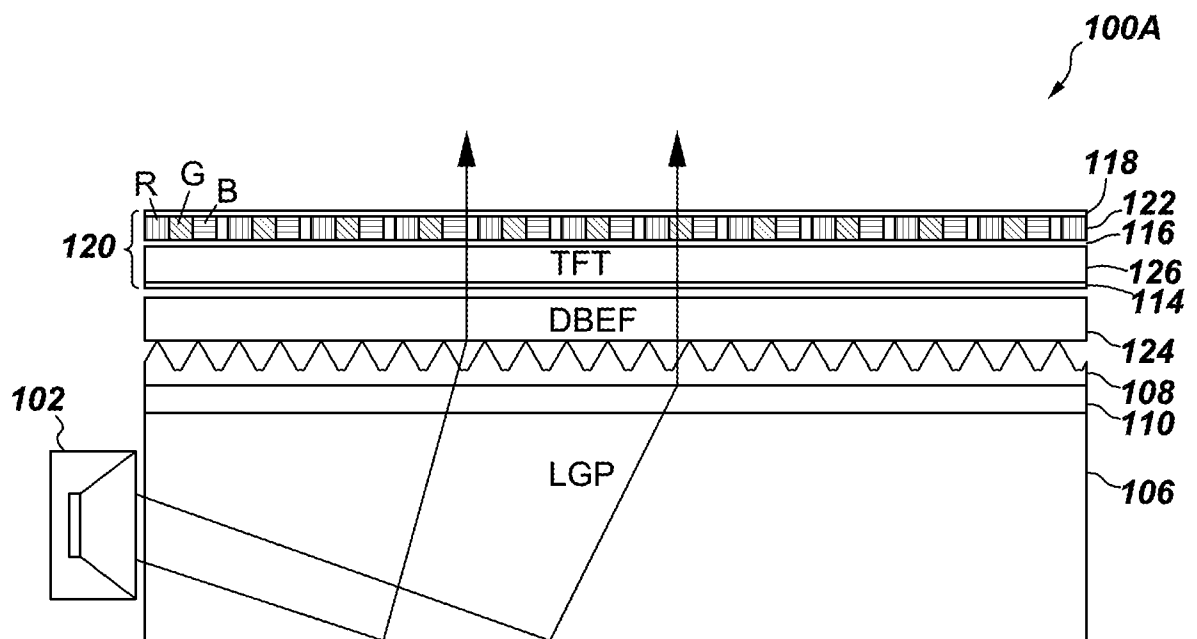
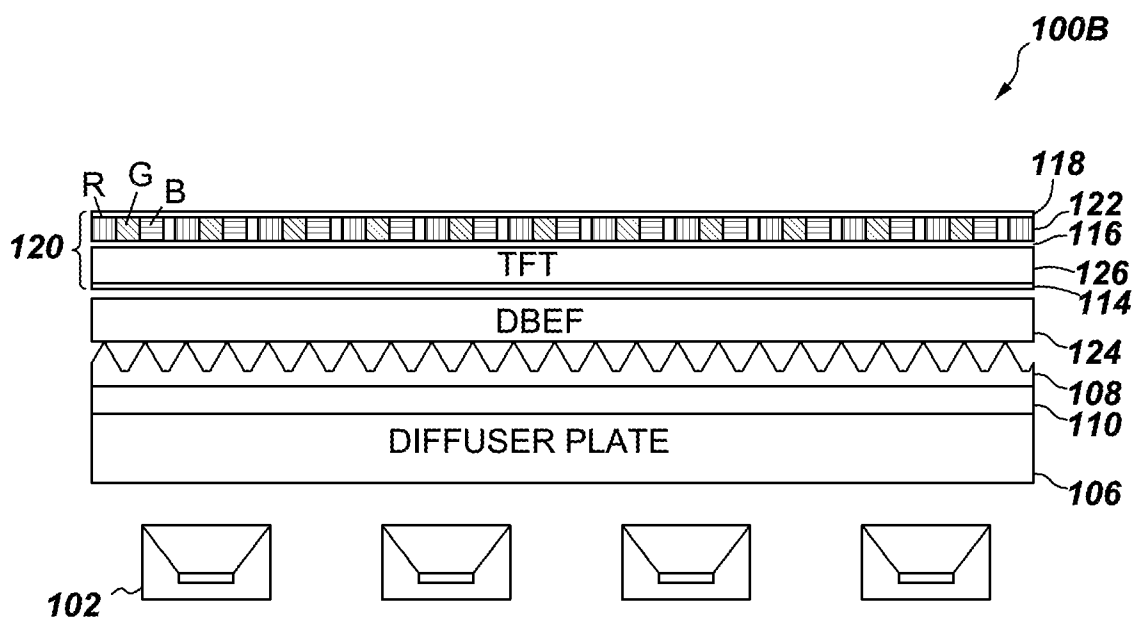
M is Si, Ge, Sn, Ti, Zr, Al, Ga, In, Sc, Y, La, Nb, Ta, Bi, Gd, or combinations thereof;

x is an absolute value of a charge of the $[\text{MF}_y]$ ion; and

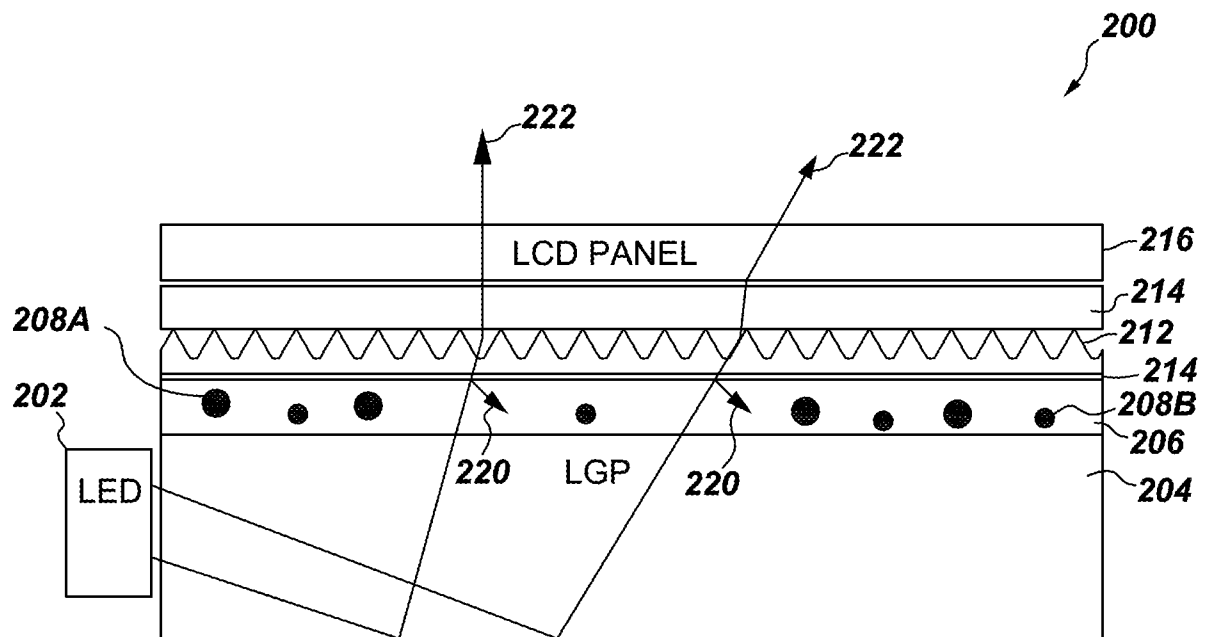
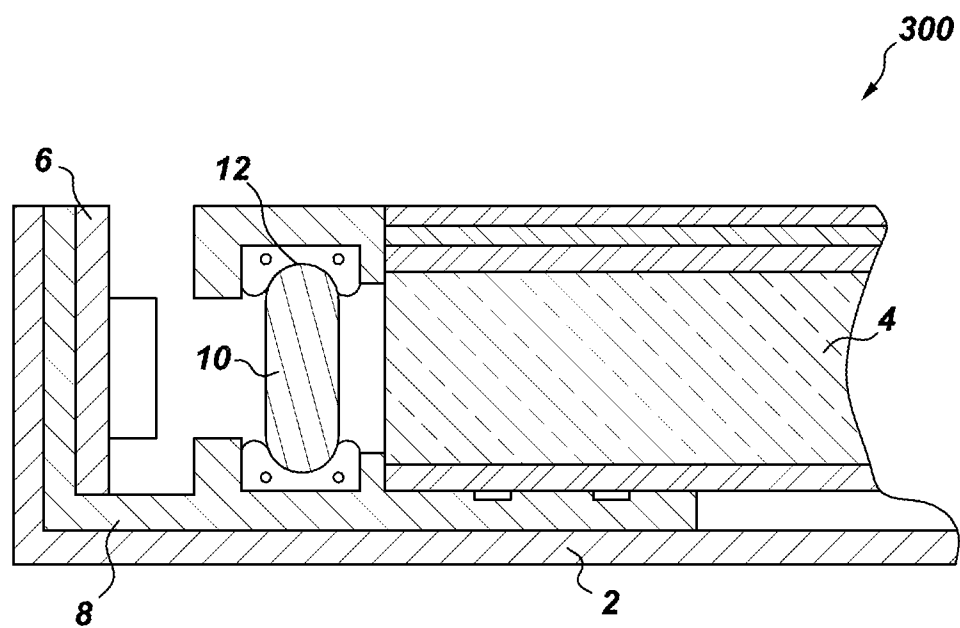
y is 5, 6 or 7.

11. A device according to claim 10, wherein the color stable Mn^{4+} doped phosphor is $\text{K}_2\text{SiF}_6:\text{Mn}^{4+}$.
12. A device according to claim 10, wherein the quantum dot material comprises CdSe.
13. A device according to claim 10, wherein the quantum dot material comprises InP.
14. A backlight unit comprising a device according to claim 10.
15. An electronic device comprising a backlight unit according to claim 14.

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**Fig. 1A****Fig. 1B**

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*Fig. 2**Fig. 3*

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/027209

A. CLASSIFICATION OF SUBJECT MATTER
INV. C09K11/61
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C09K

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/093776 A1 (SETLUR ANANT ACHYUT [US] ET AL) 31 March 2016 (2016-03-31) claims 1-22 -----	1-15
X	US 2016/312114 A1 (MURPHY JAMES EDWARD [US] ET AL) 27 October 2016 (2016-10-27) paragraphs [0047] - [0072]; claims 1-20 -----	1-15
X	WO 2016/186636 A1 (GEN ELECTRIC [US]) 24 November 2016 (2016-11-24) paragraph [0036]; claims 1-19 -----	1-15
A	US 2013/335677 A1 (YOU CHENHUA [US]) 19 December 2013 (2013-12-19) claims 1-20 -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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14/12/2017

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Kövecs, Monika

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/027209

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016093776 A1	31-03-2016	NONE	
US 2016312114 A1	27-10-2016	NONE	
WO 2016186636 A1	24-11-2016	TW 201708502 A WO 2016186636 A1	01-03-2017 24-11-2016
US 2013335677 A1	19-12-2013	NONE	