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(54) **LIQUID CRYSTAL DISPLAY WITH IN-CELL PHASE DIFFERENCE LAYER**

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(22) Filed: **Mar. 19, 2018**

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(51) **Int. Cl.**
G02F 1/137 (2006.01)
H01L 27/12 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02F 1/137*** (2013.01); ***G02F 1/1337*** (2013.01); ***G02F 1/1368*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC combination set(s) only.
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,796,704 B2 * 8/2014 Hatta H01L 27/3213 257/59
2013/0342793 A1 12/2013 Takeda et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2011075817 4/2011
JP 2015038598 2/2015
(Continued)

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(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

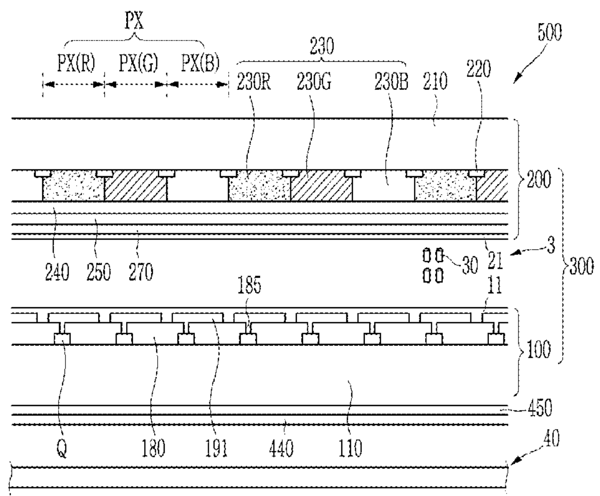
A liquid crystal display includes a lower substrate and an upper substrate facing each other, a liquid crystal layer disposed between the lower substrate and the upper substrate, a color conversion layer disposed on the liquid crystal layer, a first polarizing layer and a first phase difference layer disposed between the liquid crystal layer and the color conversion layer, and a second polarizing layer and a second phase difference layer disposed between a light source and the lower substrate, wherein the first phase difference layer has a refractive index satisfying Inequality 1 and the second phase difference layer has refractive indexes satisfying Inequality 2.

$$n_{x1} \geq n_{y1} \geq n_{z1} \quad \text{[Inequality 1]}$$

$$n_{x2} > n_{z2} > n_{y2} \quad \text{[Inequality 2]}$$

In Inequalities 1 and 2, n_{x1}, n_{x2}, n_{y1}, n_{y2}, n_{z1}, and n_{z2} are the same in the detailed description.

20 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

G02F 1/1335	(2006.01)
G02F 1/1337	(2006.01)
G02F 1/1362	(2006.01)
G02F 1/1368	(2006.01)

(52) **U.S. Cl.**

CPC .. ***G02F 1/133512*** (2013.01); ***G02F 1/133528*** (2013.01); ***G02F 1/136286*** (2013.01); ***H01L 27/124*** (2013.01); *G02F 1/133514* (2013.01); *G02F 2001/13712* (2013.01); *G02F 2001/133548* (2013.01); *G02F 2201/121* (2013.01); *G02F 2201/123* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0063418	A1*	3/2014	Zhao	G02F 1/133634 349/96
2015/0331278	A1*	11/2015	Araki	G02F 1/133617 349/61
2016/0131809	A1	5/2016	Takeda et al.	
2016/0291225	A1	10/2016	Sato et al.	
2016/0299371	A1	10/2016	Kim et al.	
2017/0031074	A1	2/2017	Kong et al.	

FOREIGN PATENT DOCUMENTS

JP	5915533	5/2016
JP	6027909	11/2016
KR	101065181	9/2011
KR	101450687	10/2014
KR	1020160089898	7/2016
KR	101662106	10/2016
KR	1020160120837	10/2016
KR	1020170001163	1/2017
KR	101705942	2/2017
KR	1020170013143	2/2017

* cited by examiner

FIG. 1

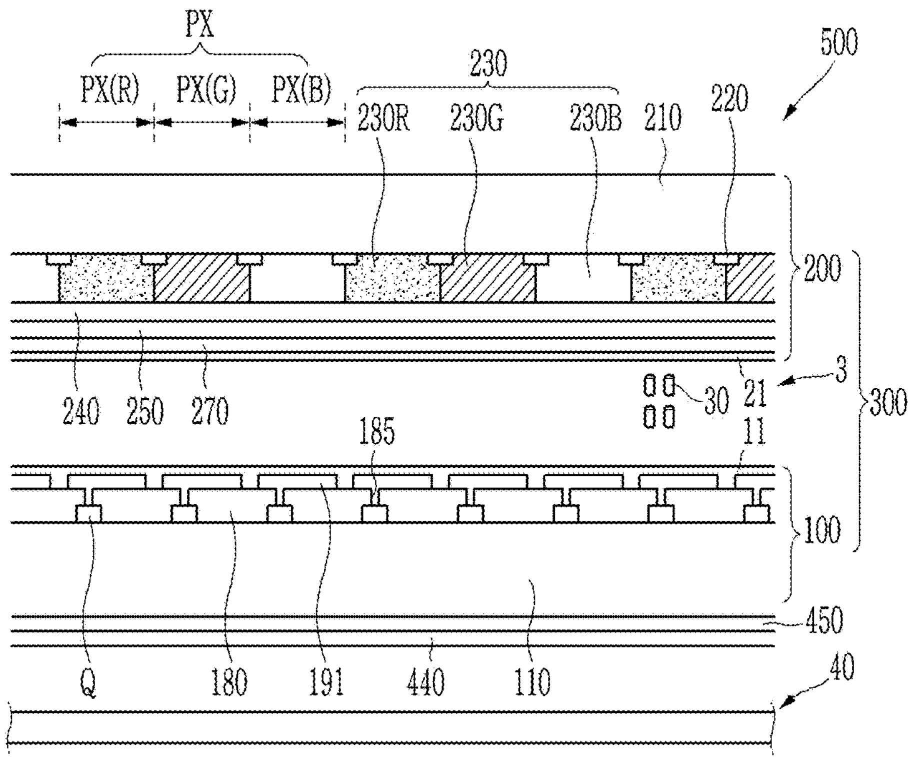

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FIG. 2

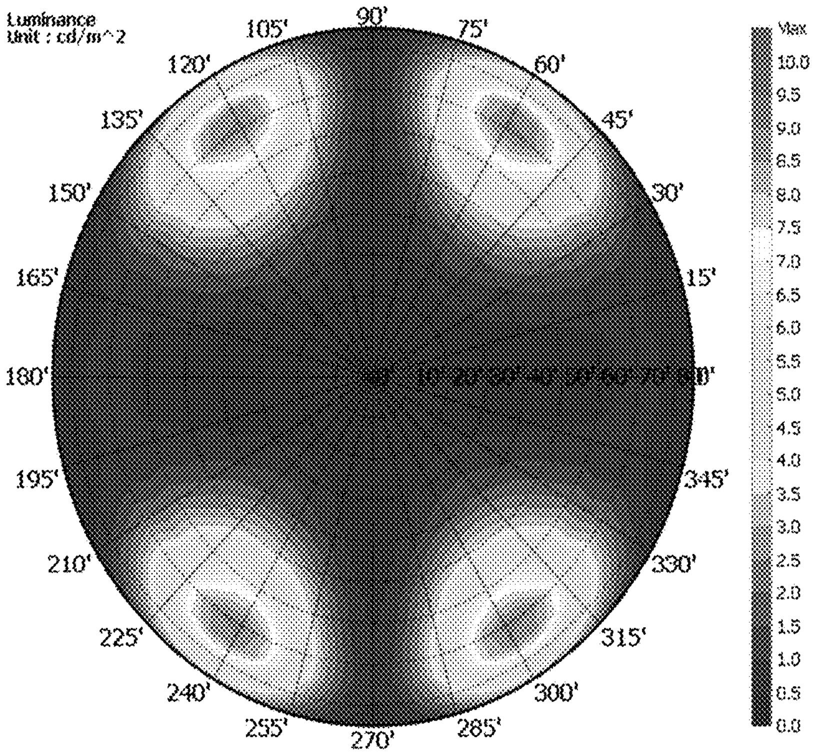

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FIG. 3

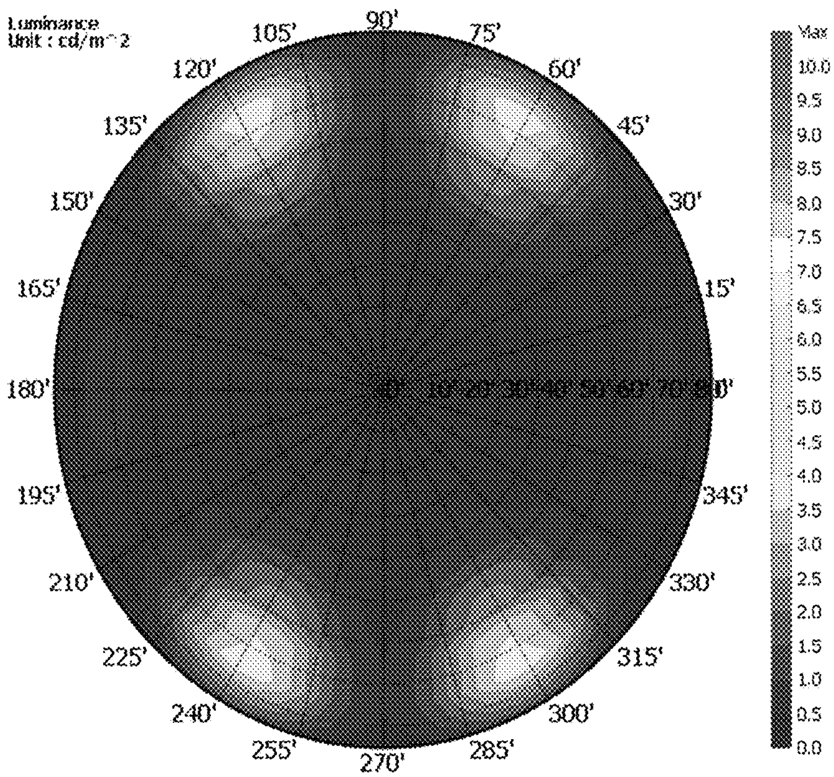
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FIG. 4

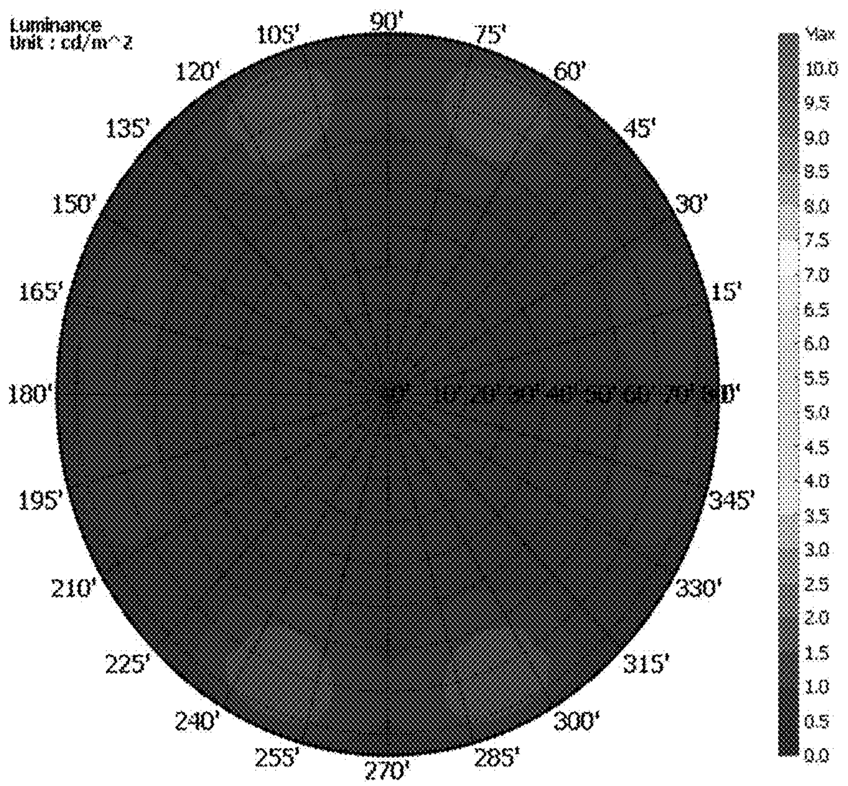
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FIG. 5

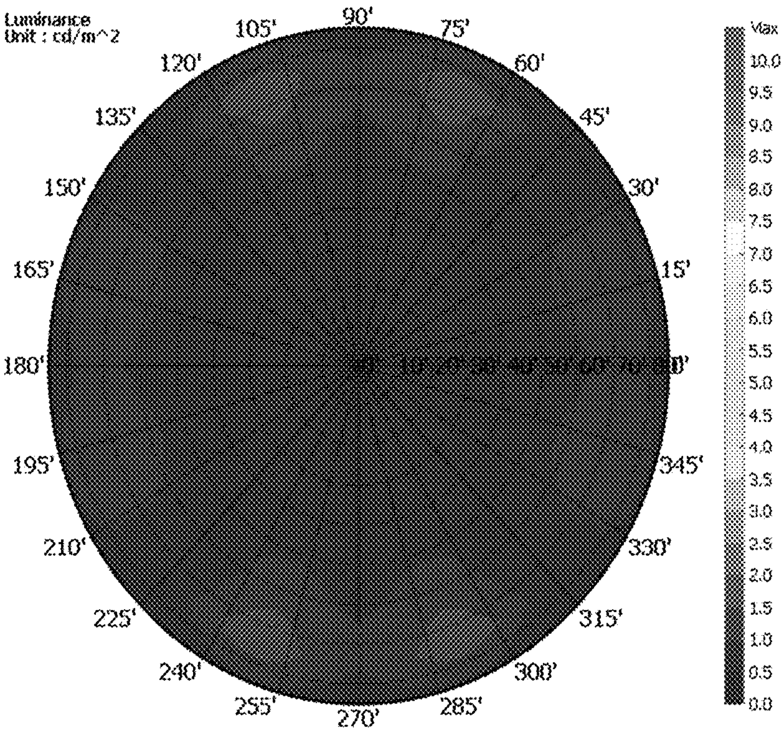
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FIG. 6

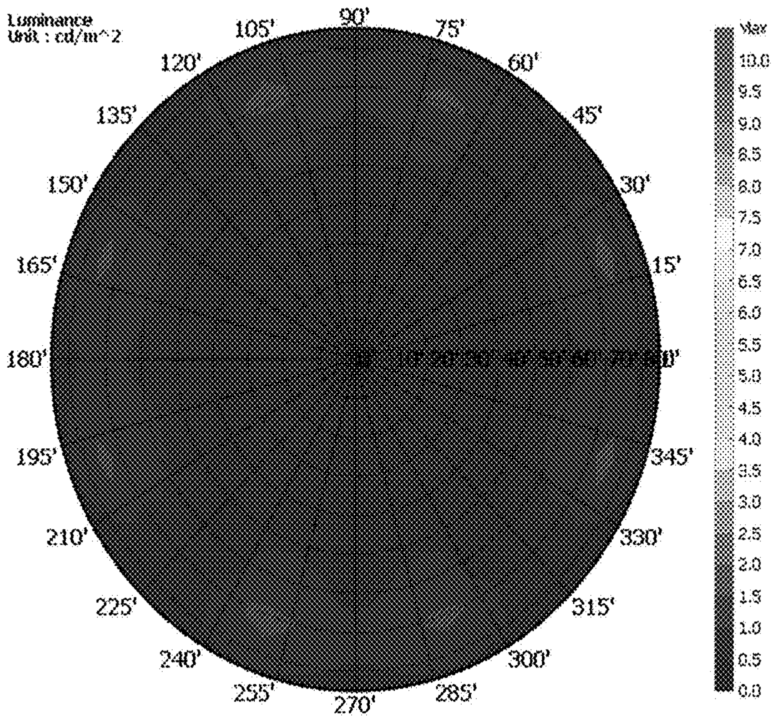
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FIG. 7

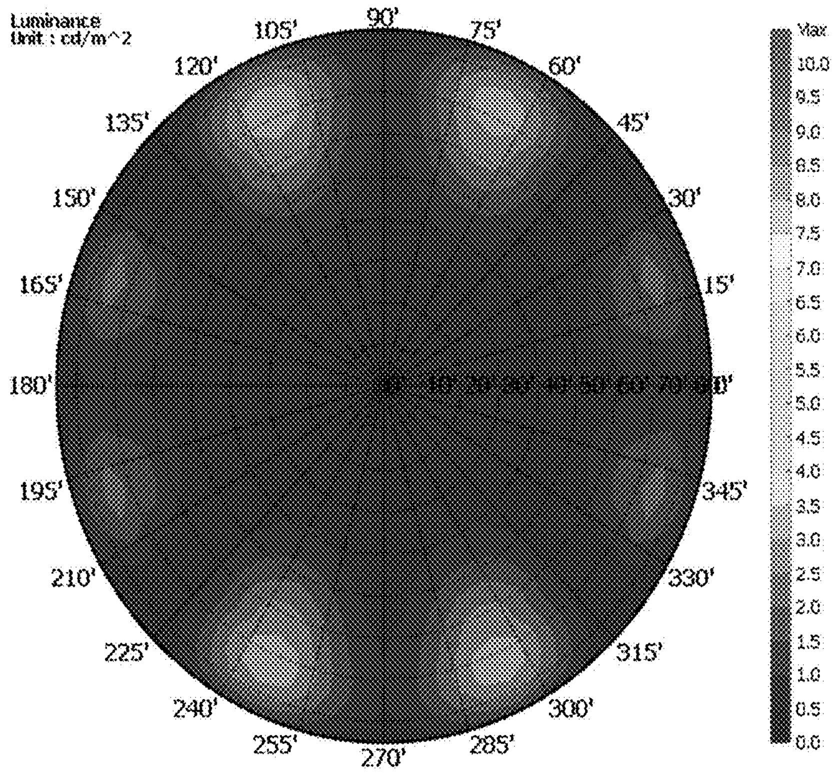
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FIG. 8

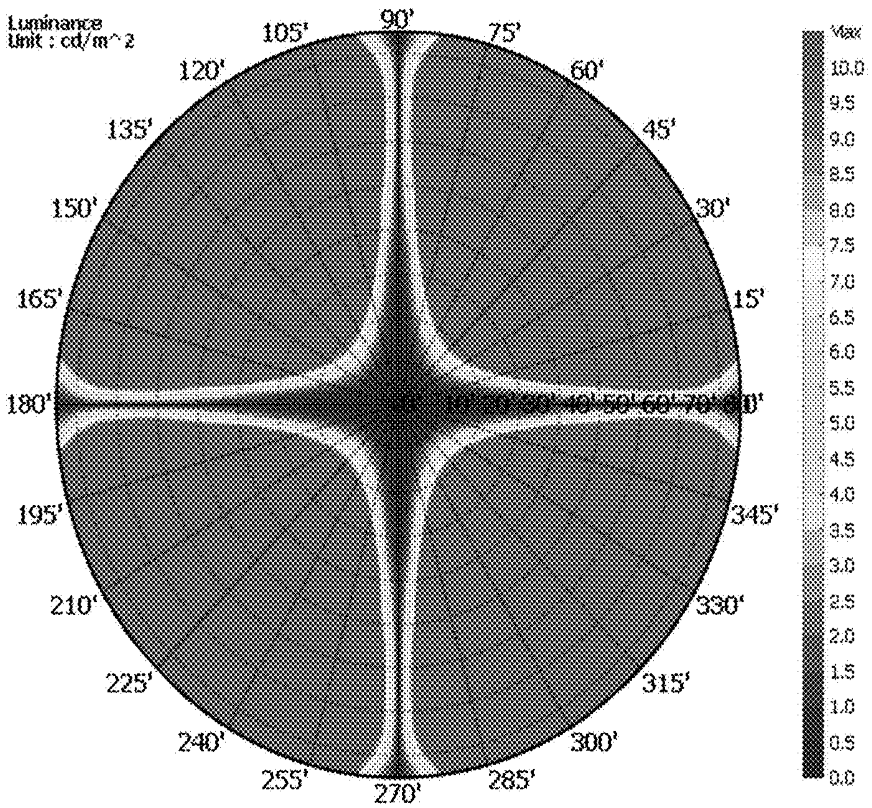
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FIG. 9

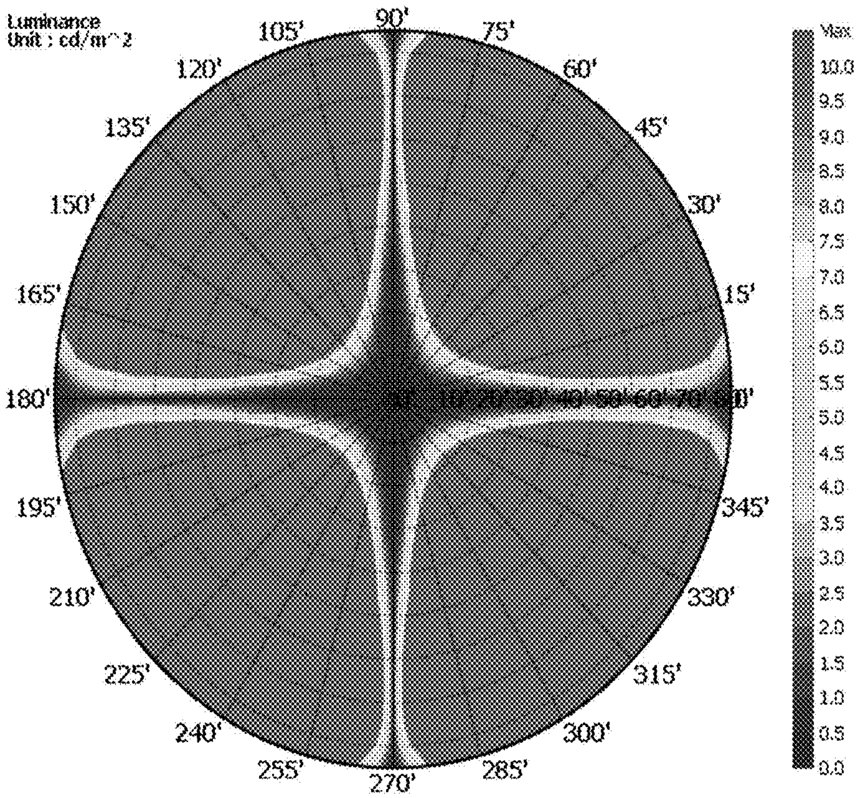
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FIG. 10

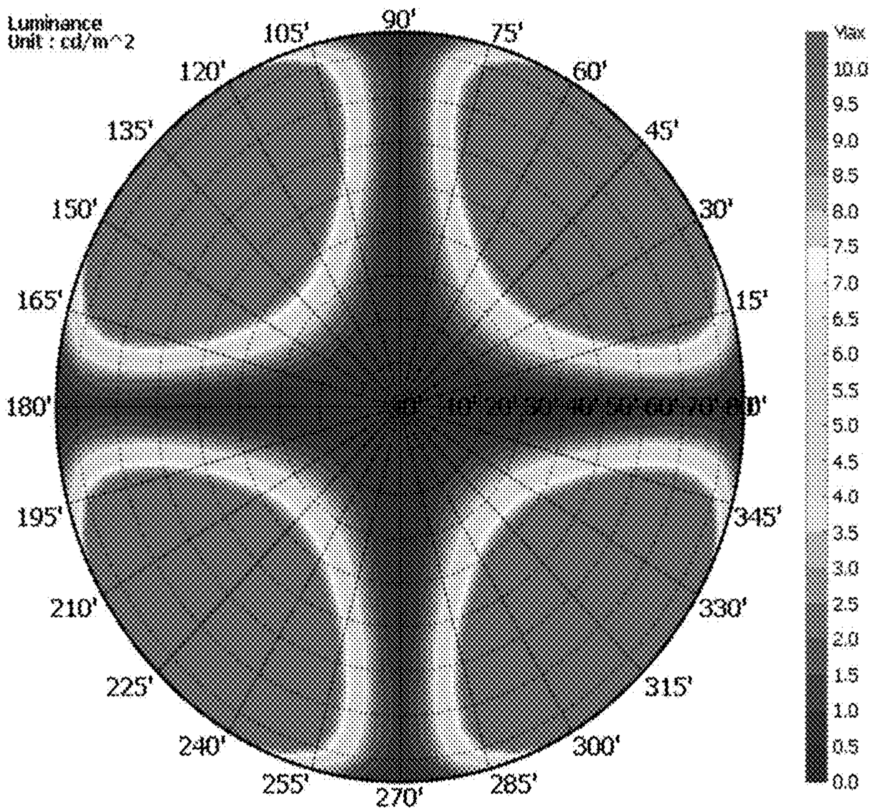
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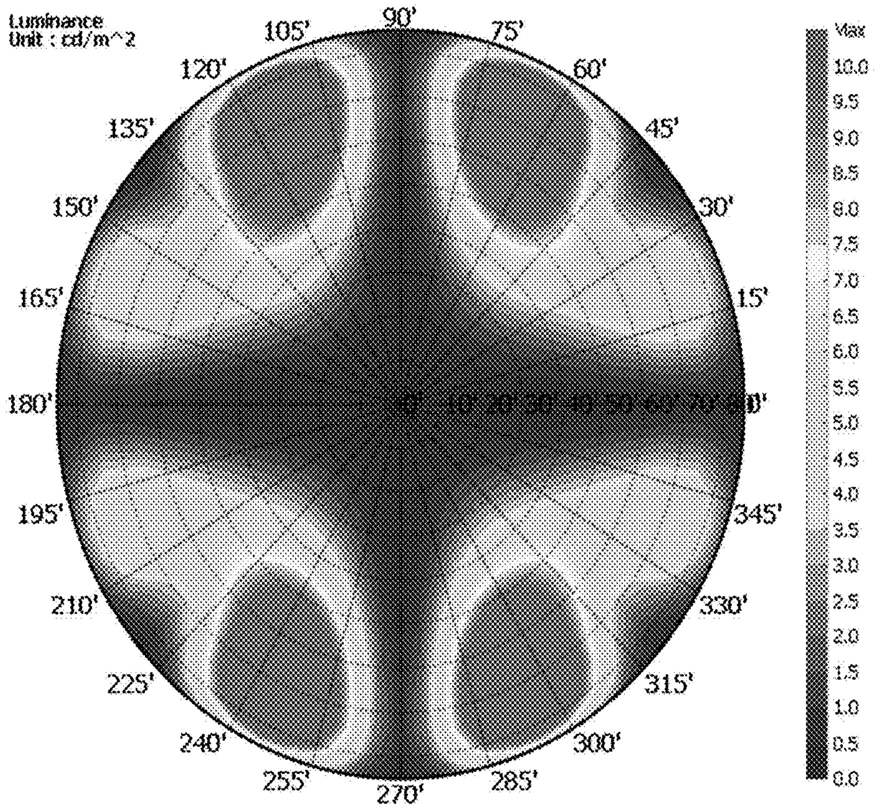
FIG. 11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LIQUID CRYSTAL DISPLAY WITH IN-CELL PHASE DIFFERENCE LAYER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Korean Patent Application No. 10-2017-0134030, filed on Oct. 16, 2017, and all the benefits accruing therefrom under 35 U.S.C. § 119, the content of which in its entirety is herein incorporated by reference.

BACKGROUND

1. Field

Embodiments of a liquid crystal display are disclosed.

2. Description of the Related Art

A liquid crystal display ("LCD") is one of the most widely used types of a flat panel display. The LCD generally includes two display panels formed with at least two field generating electrodes and a liquid crystal layer interposed therebetween, and liquid crystal molecules are rotated depending upon an electric field formed between the field generating electrodes to thereby vary light transmittance to display an image.

The LCD displays color by combining light from a light source with a color filter. However, a color filter absorbs a lot of light emitted from a light source, and thus lowers photo-efficiency.

SUMMARY

Recently, research on a photo-luminescent liquid crystal display ("LCD") displaying a color by using a light emitting element instead of a color filter has been made.

However, the photo-luminescent LCD may rarely adopt a conventional structure of disposing a polarizing plate on the light emitting element due to scattering characteristics of the light emitting element and the like. Accordingly, the photo-luminescent LCD may show a deteriorated contrast ratio and thus deteriorated display characteristics compared with an LCD using a color filter.

An embodiment provides an LCD capable of increasing a contrast ratio of a photo-luminescent LCD and thus improving display characteristics.

According to an embodiment, an LCD includes a lower substrate and an upper substrate facing each other, a liquid crystal layer between the lower substrate and the upper substrate, a color conversion layer on the liquid crystal layer, a first polarizing layer and a first phase difference layer between the liquid crystal layer and the color conversion layer, and a second polarizing layer and a second phase difference layer between a light source and the lower substrate, wherein the first phase difference layer has a refractive index satisfying Inequality 1 and the second phase difference layer has refractive indexes satisfying Inequality 2.

$$n_{x1} \geq n_{y1} \geq n_{z1} \quad \text{[Inequality 1]}$$

In Inequality 1,

n_{x1} denotes a refractive index at a slow axis of the first phase difference layer,

n_{y1} denotes a refractive index at a fast axis of the first phase difference layer, and

n_{z1} denotes a refractive index of the first phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof,

$$n_{x2} > n_{z2} > n_{y2} \quad \text{Inequality 2}$$

In Inequality 2,

n_{x2} denotes a refractive index at a slow axis of the second phase difference layer,

n_{y2} denotes a refractive index at a fast axis of the second phase difference layer, and

n_{z2} denotes a refractive index of the second phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof.

In an embodiment, the first phase difference layer may have a retardation satisfying Inequality 3.

$$230 \text{ nm} \leq R_{th1}(450 \text{ nm}) \leq 370 \text{ nm} \quad \text{Inequality 3}$$

In Inequality 3, R_{th1}(450 nm) denotes a thickness direction retardation of the first phase difference layer at a wavelength of 450 nanometers (nm).

In an embodiment, the first phase difference layer may have a retardation satisfying Inequality 4.

$$0 \text{ nm} \leq R_{in1}(450 \text{ nm}) \leq 20 \text{ nm} \quad \text{Inequality 4}$$

In Inequality 4, R_{in1}(450 nm) denotes an in-plane retardation of the first phase difference layer at the wavelength of 450 nm.

In an embodiment, the second phase difference layer may have a retardation satisfying Inequality 5.

$$110 \text{ nm} \leq R_{in2}(450 \text{ nm}) \leq 330 \text{ nm} \quad \text{Inequality 5}$$

In Inequality 5, R_{in2}(450 nm) denotes an in-plane retardation of the second phase difference layer at a wavelength of 450 nm.

In an embodiment, the second phase difference layer may have a retardation satisfying Inequality 6.

$$-60 \text{ nm} \leq R_{th2}(450 \text{ nm}) \leq 65 \text{ nm} \quad \text{Inequality 6}$$

In Inequality 6, R_{th2}(450 nm) denotes a thickness direction retardation of the second phase difference layer at a wavelength of 450 nm.

In an embodiment, the second phase difference layer may have a retardation satisfying Inequality 7.

$$-0.25 \leq R_{th2}(450 \text{ nm})/R_{in2}(450 \text{ nm}) \leq 0.25 \quad \text{Inequality 7}$$

In Inequality 7,

R_{in2}(450 nm) denotes an in-plane retardation of the second phase difference layer at a wavelength of 450 nm, and

R_{th2}(450 nm) denotes a thickness direction retardation of the second phase difference layer at the wavelength of 450 nm.

In an embodiment, the first phase difference layer may be disposed between the liquid crystal layer and the first polarizing layer.

In an embodiment, the second phase difference layer may be between the second polarizing layer and the lower substrate.

In an embodiment, the color conversion layer may include a light emitting element which receives a first visible light from the light source and emits a second visible light.

In an embodiment, the first visible light may be blue light and the second visible light may be one of blue light, green light, red light, and a combination thereof.

In an embodiment, the light emitting element may include at least one of a quantum dot and a phosphor.

In an embodiment, the liquid crystal layer may have negative dielectric anisotropy.

In an embodiment, the thickness direction retardation of the liquid crystal layer may have $-360\ nm \leq R_{th,cell} \leq -250$ nm.

According to another embodiment, an LCD includes a first phase difference layer and a second phase difference layer, wherein one of the first phase difference layer and the second phase difference layer is inside an LCD panel and the other of the first phase difference layer and the second phase difference layer is outside of the LCD panel, the first phase difference layer has a refractive index satisfying Inequality 1, and the second phase difference layer has refractive indexes satisfying Inequality 2.

$$n_{x1} \geq n_{y1} \geq n_{z1} \quad \text{[Inequality 1]}$$

In Inequality 1,

n_{x1} denotes a refractive index at a slow axis of the first phase difference layer,

n_{y1} denotes a refractive index at a fast axis of the first phase difference layer, and

n_{z1} denotes a refractive index of the first phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof.

$$n_{x2} > n_{z2} > n_{y2} \quad \text{Inequality 2}$$

In Inequality 2,

n_{x2} denotes a refractive index at a slow axis of the second phase difference layer,

n_{y2} denotes a refractive index at a fast axis of the second phase difference layer, and

n_{z2} denotes a refractive index of the second phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof.

In an embodiment, the first phase difference layer may have a retardation satisfying Inequality 3 and the second phase difference layer may have a retardation satisfying Inequality 5.

$$230\ nm \leq R_{th1}(450\ nm) \leq 370\ nm \quad \text{Inequality 3}$$

$$110\ nm \leq R_{in2}(450\ nm) \leq 330\ nm \quad \text{Inequality 5}$$

In Inequality 3 or 5,

R_{th1}(450 nm) denotes a thickness direction retardation of the first phase difference layer at a wavelength of 450 nm, and

R_{in2}(450 nm) denotes an in-plane retardation of the second phase difference layer at the wavelength of 450 nm.

In an embodiment, the second phase difference layer may have a retardation satisfying Inequality 7.

$$-0.25 \leq R_{th2}(450\ nm)/R_{in2}(450\ nm) \leq 0.25 \quad \text{Inequality 7}$$

In Inequality 7,

R_{in2}(450 nm) denotes an in-plane retardation of the second phase difference layer at a wavelength of 450 nm, and

R_{th2}(450 nm) denotes a thickness direction retardation of the second phase difference layer at the wavelength of 450 nm.

In an embodiment, the LCD panel may include a lower substrate and an upper substrate facing each other, a liquid crystal layer between the lower substrate and the upper substrate, and a color conversion layer on the liquid crystal layer and including a light emitting element.

In an embodiment, the first phase difference layer may be under the color conversion layer in the LCD panel.

In an embodiment, the LCD may further include a first polarizing layer between the first phase difference layer and the color conversion layer.

In an embodiment, the second phase difference layer may be disposed outside the LCD panel and the LCD may further include a second polarizing layer on the second phase difference layer.

In an embodiment, a contrast ratio of the LCD may be increased and thus display characteristics may be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other embodiments, advantages and features of this disclosure will become more apparent by describing in further detail embodiments thereof with reference to the accompanying drawings, in which:

FIG. **1** is a schematic cross-sectional view of an embodiment of a liquid crystal display ("LCD");

FIG. **2** is a diagram showing a distribution of black luminance of the LCDs according to Example 3;

FIG. **3** is a diagram showing a distribution of black luminance of the LCDs according to Example 9;

FIG. **4** is a diagram showing a distribution of black luminance of the LCDs according to Example 16;

FIG. **5** is a diagram showing a distribution of black luminance of the LCDs according to Example 44;

FIG. **6** is a diagram showing a distribution of black luminance of the LCDs according to Example 49;

FIG. **7** is a diagram showing a distribution of black luminance of the LCDs according to Example 54;

FIG. **8** is a diagram showing a distribution of black luminance of the LCDs according to Comparative Example 1;

FIG. **9** is a diagram showing a distribution of black luminance of the LCDs according to Comparative Example 2;

FIG. **10** is a diagram showing a distribution of black luminance of the LCDs according to Comparative Example 3; and

FIG. **11** is a diagram showing a distribution of black luminance of the LCDs according to Comparative Example 4.

DETAILED DESCRIPTION

Hereinafter, example embodiments of the present disclosure will be described in detail so that a person skilled in the art would understand the same. This disclosure may, however, be embodied in many different forms and is not construed as limited to the example embodiments set forth herein.

In the drawings, the thickness of layers, films, panels, regions, etc., are exaggerated for clarity. Like reference numerals designate like elements throughout the specification. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present.

It will be understood that, although the terms "first," "second," "third" etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, "a first element," "component," "region," "layer" or "section" discussed below could be termed a second element, component, region, layer or section without departing from the teachings herein.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms, including "at least one," unless the content clearly indicates otherwise. "Or" means "and/or." As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

Furthermore, relative terms, such as "lower" or "bottom" and "upper" or "top," may be used herein to describe one element's relationship to another element as illustrated in the Figures. It will be understood that relative terms are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. In an embodiment, when the device in one of the figures is turned over, elements described as being on the "lower" side of other elements would then be oriented on "upper" sides of the other elements. The term "lower," can therefore, encompasses both an orientation of "lower" and "upper," depending on the particular orientation of the figure. Similarly, when the device in one of the figures is turned over, elements described as "below" or "beneath" other elements would then be oriented "above" the other elements. The terms "below" or "beneath" can, therefore, encompass both an orientation of above and below.

"About" or "approximately" as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). For example, "about" can mean within one or more standard deviations, or within +30%, 20%, 10%, 5% of the stated value.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the invention, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

Embodiments are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. In an embodiment, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the claims.

FIG. **1** is a schematic cross-sectional view of a liquid crystal display ("LCD") according to an embodiment.

Referring to FIG. **1**, an LCD **500** according to an embodiment includes a light source **40**, an LCD panel **300**, a lower polarizing layer **440**, and a lower phase difference layer **450**.

In an embodiment, the light source **40** may be a planar light source, a dot light source, or a line light source that supplies light with the LCD panel **300**, and may be, for example, disposed in form of an edge-type or a direct type. The light source **40** may include a light emitting region including a light emitting element, a reflector disposed under the light emitting region and reflecting light emitted from the light emitting region, a light guide that supplies the light emitted from the light emitting region toward an LCD panel and/or at least one optical sheet disposed on the light guide, but is not limited thereto.

In an embodiment, the light emitting element may be, for example, a fluorescent lamp or a light emitting diode ("LED"), and for example, may supply light in a visible ray region (hereinafter, referred to as 'visible light'), for example, blue light having high energy.

The LCD panel **300** includes a lower panel **100** disposed on the light source **40**, a upper panel **200** facing the lower panel **100**, and a liquid crystal layer **3** disposed between the lower panel **100** and the upper panel **200**.

The lower panel **100** includes a lower substrate **110**, a plurality of wires (not shown), a thin film transistor ("TFT") Q, a pixel electrode **191**, and an alignment layer **11**.

In an embodiment, the lower substrate **110** may be, for example, an insulation substrate such as a glass substrate or a polymer substrate, and the polymer substrate may include, for example, polyethylene terephthalate, polyethylene naphthalate, polycarbonate, polyacrylate, polyimide, or a combination thereof, but is not limited thereto.

A plurality of gate lines (not shown) that supplies a gate signal and a plurality of data lines (not shown) that supplies a data signal may be provided while crossing each other on the lower substrate **110**, and a plurality of pixels PX is arranged in a form of a matrix defined by the gate lines and the data lines. In an embodiment, the plurality of pixels PX may include a red pixel PX(R), a green pixel PX(G) and a blue pixel PX(B).

A plurality of TFTs Q is disposed on the lower substrate **110**. The TFTs Q may include a gate electrode (not shown) connected with the gate lines, a semiconductor (not shown) overlapping with the gate electrode, a gate insulating layer (not shown) disposed between the gate electrode and the semiconductor, a source electrode (not shown) connected with the data lines, and a source electrode and a drain electrode (not shown) facing the same in the center of the semiconductor. In FIG. **1**, each pixel PX includes one TFT Q, but is not limited thereto, and two or more TFTs may be disposed.

A protective layer **180** is disposed on the TFTs Q, and a contact hole **185** exposing the TFTs Q is defined in the protective layer **180**.

A pixel electrode **191** is disposed on the protective layer **180**. In an embodiment, the pixel electrode **191** may include a transparent conductor such as indium tin oxide ("ITO") or indium zinc oxide ("IZO"), and is electrically connected with the TFT Q through the contact hole **185**. The pixel electrode **191** may have a predetermined pattern.

An alignment layer **11** is disposed on the pixel electrode **191**.

The upper panel **200** includes an upper substrate **210**, a color conversion layer **230**, an upper polarizing layer **240**, an upper phase difference layer **250**, a common electrode **270**, and an alignment layer **21**.

In an embodiment, the upper substrate **210** may be, for example, an insulation substrate such as a glass substrate or a polymer substrate, and the polymer substrate may include, for example, polyethylene terephthalate, polyethylene naphthalate, polycarbonate, polyacrylate, polyimide, or a combination thereof, but is not limited thereto.

A light blocking member **220** that is referred to as a black matrix is disposed on one surface of the upper substrate **210**. The light blocking member **220** may block light leakage between the pixel electrodes **191**.

In addition, a color conversion layer **230** is disposed on one surface of the upper substrate **210**. The color conversion layer **230** receives light in a predetermined wavelength region and emits the same light or light in a different wavelength region to display colors. The color conversion layer **230** includes a photo-luminescent material that is stimulated by light and emits light by itself, that is a light emitting element. In an embodiment, the light emitting element may be, for example, at least one of a quantum dot and a phosphor.

In an embodiment, the light emitting element may emit light in the same wavelength region received from the light source **40** or light in a longer wavelength region, for example. In an embodiment, when the light source **40** supplies blue light, the light emitting element may emit blue light in the same wavelength region or emit light in a longer wavelength region than blue light, for example, red light or green light. In an embodiment, the light emitting element may emit light by combining at least two of blue light, red light, and green light.

In this way, high photo-conversion efficiency and low power consumption may be realized by including the color conversion layer **230** including a light emitting element. In addition, the color conversion layer **230** including the light emitting element may substantially reduce a light loss according to the absorption and thus increase photo-efficiency compared with a conventional color filter including a dye and/or a pigment and thus absorbing a considerable dose of light emitted from the light source **40** and showing low photo-efficiency. In addition, color purity may be increased by an inherent luminous color of the light emitting element. Furthermore, the light emitting element emits light scattering in all directions and may improve viewing angle characteristics.

FIG. **1** shows a red conversion layer **230**R including a red light emitting element emitting red light, a green conversion layer **230**G including a green light emitting element emitting green light, and a blue conversion layer **230**B including a blue light emitting element emitting blue light, but the present invention is not limited thereto. In an embodiment, the red conversion layer **230**R may emit light in a wavelength region ranging from greater than about 590 nanometers (nm) to less than or equal to about 700 nm, the green conversion layer **230**G may emit light in a wavelength region ranging from about 510 nm to about 590 nm, and the blue conversion layer **230**B may emit light in a wavelength region ranging from greater than or equal to about 380 nm to less than about 510 nm, for example. In an embodiment, the light emitting element may be a light emitting element emitting cyan light, a light emitting element emitting magenta light, and/or a light emitting element emitting yellow light or additionally include these light emitting elements. In an embodiment, when the light source **40** supplies blue light, the blue conversion layer **230**B passes the light supplied from the light source **40** without a separate light emitting element as it is and thus display blue, and herein, the blue conversion layer **230**B may be empty or include a transparent insulator, for example.

The light emitting element may be, for example, at least one of a phosphor and a quantum dot.

In an embodiment, the red conversion layer **230**R may include a red phosphor, for example, at least one of Y_2O_2S:Eu, YVO_4:Eu,Bi, Y_2O_2S:Eu,Bi, SrS:Eu, (Ca,Sr)S:Eu, SrY_2S_4:Eu, $CaLa_2S_4$:Ce, $(Sr,Ca,Ba)_3SiO_5$:Eu, $(Sr,Ca,Ba)_2SisN_8$:Eu, and $(Ca,Sr)_2AlSiN_3$:Eu. In an embodiment, the green conversion layer **230**G may include a green phosphor, for example, at least one of YBO_3:Ce,Tb, $BaMgAl_{10}O_{17}$:Eu,Mn, (Sr,Ca,Ba) $(Al,Ga)_2S_4$:Eu, ZnS:Cu,Al $Ca_8MgSiO_{44}Cl_2$:Eu,Mn, Ba_2SiO_4:Eu, $(Ba,Sr)_2SiO_4$:Eu, $Ba_2(Mg,Zn)Si_2O_7$:Eu, $(Ba,Sr)Al_2O_4$:Eu, $Sr_2Si_3O_8.2SrCl_2$:Eu, (Sr,Ca,Ba, $Mg)P_2O_7N_8$:Eu, Mn, $(Sr,Ca,Ba,Mg)_3P_2O_8$:Eu,Mn, $Ca_3Sc_2Si_3O_{12}$:Ce, $CaSc_2O_4$:Ce, b-SiAlON:Eu, $Ln_2Si_3O_3N_4$:Tb, and $(Sr,Ca,Ba)Si_2O_2N_2$:Eu.

In an embodiment, the red conversion layer **230** may include a quantum dot. The quantum dot may be a semiconductor nanocrystal in a general concept, and may have various shapes, for example, an isotropic semiconductor nanocrystal, a quantum rod, and a quantum plate. Herein, the quantum rod may indicate a quantum dot having an aspect ratio greater than about 1, for example, an aspect ratio greater than or equal to about 2, greater than or equal to about 3, or greater than or equal to about 5. In an embodiment, the quantum rod may have an aspect ratio of less than or equal to about 50, of less than or equal to about 30, or of less than or equal to about 20. In an embodiment, the quantum dot may have, for example, a particle diameter (an average largest particle diameter for a non-spherical shape) of about 1 nm to about 100 nm, for example, about 1 nm to about 80 nm, for example, about 1 nm to about 50 nm, for example, about 1 nm to about 20 nm.

The quantum dot may control a light emitting wavelength by changing a size and/or a composition. In an embodiment, the quantum dot may include a Group II-VI compound, a Group III-V compound, a Group IV-VI compound, a Group IV compound, or a combination thereof. The Group II-VI compound may include, for example, a binary element compound including CdSe, CdTe, ZnS, ZnSe, ZnTe, ZnO, HgS, HgSe, HgTe, MgSe, MgS, and a combination thereof; a ternary element compound including CdSeS, CdSeTe, CdSTe, ZnSeS, ZnSeTe, ZnSTe, HgSeS, HgSeTe, HgSTe, CdZnS, CdZnSe, CdZnTe, CdHgS, CdHgSe, CdHgTe, HgZnS, HgZnSe, HgZnTe, MgZnSe, MgZnS, and a combination thereof; and a quaternary element compound including HgZnTeS, CdZnSeS, CdZnSeTe, CdZnSTe, CdHgSeS, CdHgSeTe, CdHgSTe, HgZnSeS, HgZnSeTe, HgZnSTe, and a combination thereof. The Group III-V compound may include a binary element compound including GaN, GaP, GaAs, GaSb, AlN, AlP, AlAs, AlSb, InN, InP, InAs, InSb, and a combination thereof; a ternary element compound including GaNP, GaNAs, GaNSb, GaPAs, GaPSb, AlNP, AlNAs, AlNSb, AlPAs, AlPSb, InNP, InNAs, InNSb, InPAs, InPSb, GaAlNP, and a combination thereof; and a quaternary element compound including GaAlNAs, GaAlNSb, GaAlPAs, GaAlPSb, GaInNP, GaInNAs, GaInNSb, GaInPAs, GaInPSb, InAlNP, InAlNAs, InAlNSb, InAlPAs, InAlPSb, and a combination thereof. The Group IV-VI compound may include a binary element compound including SnS, SnSe, SnTe, PbS, PbSe, PbTe, and a combination thereof; a ternary element compound including SnSeS, SnSeTe, SnSTe, PbSeS, PbSeTe, PbSTe, SnPbS, SnPbSe, SnPbTe, and a combination thereof; and a quaternary element compound including SnPbSSe, SnPbSeTe, SnPbSTe, and a combination thereof. The Group IV compound may include a single-element compound including Si, Ge, and a combination thereof; and a binary element compound including SiC, SiGe, and a combination thereof.

The quantum dot may include the binary element compound, the ternary element compound, or the quaternary element compound in a substantially uniform concentration or partially different concentration distributions. The quantum dot may have a core-shell structure wherein one quantum dot surrounds another quantum dot. In an embodiment, the core and the shell of the quantum dot may have an interface, and an element of at least one of the core or the shell in the interface may have a concentration gradient wherein the concentration of the element(s) of the shell decreases toward the core, for example. In an embodiment, a material composition of the shell of the quantum dot has a higher energy bandgap than a material composition of the core of the quantum dot, and thereby the quantum dot may exhibit a quantum confinement effect, for example. The quantum dot may have one core of a quantum dot and multi-shells surrounding the core. The multi-shell structure has at least two shells wherein each shell may be a single composition, an alloy, or the one having a concentration gradient. In an embodiment, a shell of a multi-shell that is far from the core may have a higher energy bandgap than a shell that is near to the core, and thereby the quantum dot may exhibit a quantum confinement effect, for example.

In an embodiment, the quantum dot may have a quantum yield greater than or equal to about 10 percent (%), for example, greater than or equal to about 30%, greater than or equal to about 50%, greater than or equal to about 60%, greater than or equal to about 70%, or greater than or equal to about 90%, but is not limited thereto. The quantum dot has a relatively narrower spectrum. In an embodiment, the quantum dot may have a full width at half maximum ("FWHM") of a light emitting wavelength spectrum of less than or equal to about 45 nm, for example, less than or equal to about 40 nm, or less than or equal to about 30 nm.

The quantum dot may be included in the color conversion layer **230** in a form of a quantum dot-polymer composite wherein the quantum dot is dispersed in the polymer. The polymer may act as a matrix of the quantum dot-polymer composite, and the quantum dot is not particularly limited if it does not quench the quantum dot. In an embodiment, the polymer may include a transparent polymer, for example, polyvinylpyrrolidone, polystyrene, polyethylene, polypropylene, poly(methyl)acrylate, polymethylmethacrylate, polybutylmethacrylate ("PBMA"), a copolymer thereof, or a combination thereof, but is not limited thereto. The quantum dot-polymer composite may have one layer or a multi-layer.

The upper polarizing layer **240** is disposed on one surface of the color conversion layer **230**.

The upper polarizing layer **240** may be an in-cell polarizing layer inside the LCD panel **300** and may be disposed on a lower whole surface of the color conversion layer **230**. The upper polarizing layer **240** may be disposed under the color conversion layer **230** and supplies polarized light with the color conversion layer **230**.

In this way, since the upper polarizing layer **240** is disposed beneath the color conversion layer **230**, but a separate polarizing plate attached outside of the LCD panel **300** is not disposed, light emitted from the light emitting element of the color conversion layer **230** receives no influence by the polarizing plate outside of the LCD panel **300**, and resultantly, a contrast ratio may be improved. Specifically, the light emitting element of the color conversion layer **230** emits scattered light that polarizing light is broken, and accordingly, when a polarizing plate is disposed on the color conversion layer **230**, that is, where the scattered light passes, black luminance may be substantially increased, and thus a contrast ratio may be lowered. In addition, an effect of improving a viewing angle of an LCD may not be hindered by the scattered light emitted from the light emitting element of the color conversion layer **230** but maintained.

Accordingly, an in-cell polarizing layer used as the upper polarizing layer **240** may prevent discoloring or image distortion due to an influence of a polarizing plate attached to an outside of an LCD panel **300** on light emitted from the light emitting element but maintain inherent light emitting characteristics of the light emitting element and thus secure high color purity but reduce a light loss. In addition, the in-cell polarizing layer is a thin film having a thickness less than or equal to about 1 μm, and thus may reduce a thickness of an LCD.

The upper polarizing layer **240** may be a linear polarizer that converts light emitted from the light source **40** and passing through the liquid crystal layer **3** into linear polarized light.

In an embodiment, the upper polarizing layer **240** may include, for example, elongated polyvinyl alcohol ("PVA") according to a method of, for example, elongating a polyvinyl alcohol film, adsorbing iodine or a dichroic dye thereto, and borating and washing the same.

In an embodiment, the upper polarizing layer **240** may be a polarizing film prepared, for example, by mixing a polymer and a dichroic dye and melt blending the polymer with the dichroic dye to melt them at a temperature above the melting point of the polymer. In an embodiment, the polymer may include a hydrophobic polymer, for example, polyolefin.

In an embodiment, the upper polarizing layer **240** may be a wire grid polarizer. The wire grid polarizer has a structure that a plurality of metal wire is aligned in one direction, and accordingly, when incident light passes the wire grid polarizer, light parallel to a metal wire is absorbed or reflected, but light perpendicular therewith is transmitted and may form linear polarized light. Herein, the linear polarized light may be more efficiently provided when a wavelength of light is wider than a gap between the metal wires. The wire grid polarizer may be appropriately applied as the in-cell polarizing layer and also, is thin and thus may realize a thin LCD **500**.

The upper phase difference layer **250** is disposed on one surface of the upper polarizing layer **240**.

The upper phase difference layer **250** may be an in-cell phase difference layer inside the LCD panel **300**. In an embodiment, the upper phase difference layer **250** may contact the upper polarizing layer **240**, for example. In an embodiment, the upper phase difference layer **250** may be spaced apart from the upper polarizing layer **240** by disposing another layer therebetween, for example, an insulation layer (not shown) such as silicon oxide and nitrogen oxide.

When the upper phase difference layer **250** is combined with a lower phase difference layer **450** disposed outside of a lower panel **100** to adjust a retardation, a light leakage at the side before light reaches the color conversion layer **230** in a black mode may be reduced or prevented, an unnecessary light emission of the color conversion layer **230** in the black mode may be reduced, and accordingly, black luminance may be decreased, and thus a contrast ratio may be improved.

The upper phase difference layer **250** may include a heat resistant polymer, a heat resistant liquid crystal, or a combination thereof. In an embodiment, the heat resistant polymer may include, for example, polymers having a glass transition temperature (Tg) greater than or equal to about 150 degrees Celsius (° C.), and may include, for example, polyimide, polyamic acid, polyamide, polycarbonate, cycloolefin, or a combination thereof, but is not limited thereto. In an embodiment, the heat resistant polymer may have a glass transition temperature (Tg) greater than or equal to about 180° C., for example, greater than or equal to about 200° C., greater than or equal to about 220° C., or greater than or equal to about 230° C. In an embodiment, the upper phase difference layer **250** may include a liquid crystal layer made of liquid crystals having positive or negative birefringence and may further include an alignment layer on one surface of the liquid crystal layer, for example.

In an embodiment, the upper phase difference layer **250** may be provided with a predetermined retardation by elongating a film made of a heat resistant polymer in a uniaxial or biaxial direction, for example. In an embodiment, the upper phase difference layer **250** may be endowed with a predetermined retardation to induce linear or surface alignment of a heat resistant polymer or a heat resistant liquid crystal during the drying, when the heat resistant polymer or the heat resistant liquid crystal is prepared as a solution and then, coated and dried, for example.

The common electrode **270** is disposed on one surface of the upper phase difference layer **250**. The common electrode **270** may include, for example, a transparent conductor such as ITO or IZO and disposed on a whole surface of the upper phase difference layer **250**. The common electrode **270** has a predetermined pattern.

The alignment layer **21** is coated on one surface of the common electrode **270**.

The liquid crystal layer **3** including a plurality of liquid crystals **30** is disposed between the lower panel **100** and the upper panel **200**. The liquid crystal **30** may have positive or negative dielectric anisotropy. In an embodiment, the liquid crystal **30** may have negative dielectric anisotropy, for example. In an embodiment, the liquid crystal **30** may be aligned in a substantially vertical direction to the surfaces of the substrates **110** and **210** when an electric field is not applied to the pixel electrode **191** and the common electrode **270**, for example. Therefore, the LCD **500** may realize a vertical alignment LCD. In an embodiment, the liquid crystal layer **30** may have a thickness direction retardation satisfying a range of about -360 nm$\leq R_{th,cell}\leq$about -250 nm, for example.

The lower polarizing layer **440** is attached to an outside of the lower panel **100**. The lower polarizing layer **440** may be a linear polarizer and polarizes light supplied from the light source **40** and supplies polarized light with the liquid crystal layer **3**.

In an embodiment, the lower polarizing layer **440** may include, for example, PVA according to a method of, for example, elongating a polyvinyl alcohol film, adsorbing iodine or a dichroic dye thereto, and treating it with a borate and washing the same.

In an embodiment, the lower polarizing layer **440** may be a polarizing film prepared, for example, by mixing a polymer and a dichroic dye and melt blending the polymer with the dichroic dye to melt them at a temperature above the melting point of the polymer. In an embodiment, the polymer may be a hydrophobic polymer, for example, polyolefin.

In an embodiment, the lower polarizing layer **240** may be a wire grid polarizer, for example. The wire grid polarizer is combined with the upper polarizing layer **240** to realize a thin LCD **500**.

The lower phase difference layer **450** may be attached to an outside of the lower panel **100** and may be disposed between the lower panel **100** and the lower polarizing layer **440**.

As described above, a contrast ratio may be improved by combining the upper phase difference layer **250** with the lower phase difference layer **450** to adjust a retardation, and thus reducing or preventing the light leakage at the side before light reaches the color conversion layer **230** in a black mode, and accordingly, reducing the unnecessary light emission of the color conversion layer **230** in a black mode and thus decreasing black luminance. The combination of the upper phase difference layer **250** with the lower phase difference layer **450** may be variously designed to reduce light leakage and increase a contrast ratio.

In an embodiment, the upper phase difference layer **250** may have a refractive index satisfying Inequality 1.

$$n_{x1}\geq n_{y1}\geq n_{z1}$$ <Inequality 1>

In Inequality 1,

n_{x1} denotes a refractive index of the upper phase difference layer **250** in a direction having a highest in-plane refractive index (hereinafter, referred to as a slow axis),

n_{y1} denotes a refractive index of the upper phase difference layer **250** in a direction having a lowest in-plane refractive index (hereinafter, referred to as a fast axis), and

n_{z1} denotes a refractive index of the upper phase difference layer **250** in a direction perpendicular to the slow axis and fast axis.

In Inequality 1, when n_{x1} and n_{y1} satisfy $n_{x1}>n_{y1}$, for example, the refractive index of n_{x1} may be greater than the refractive index of n_{y1} by about 0.02 or less, for example, by about 0.01 or less. By satisfying the ranges, the upper phase difference layer **250** may have a substantial in-plane isotropy.

When the upper phase difference layer **250** has the refractive index satisfying Inequality 1, a compensation function to reduce a viewing angle dependency may be performed.

In an embodiment, the upper phase difference layer **250** may, for example, have a refractive index satisfying Inequality 1-1.

$$n_{x1}=n_{y1}>n_{z1}$$ <Inequality 1-1>

Retardation of the upper phase difference layer **250** may be expressed as in-plane retardation (R_{in1}) and thickness direction retardation (R_{th1}). The in-plane retardation (R_{in1}) of the upper phase difference layer **250** is retardation generated in an in-plane direction of the upper phase difference layer **250** and may be expressed by $R_{in1}=(n_{x1}-n_{y1})d_1$. Herein, d_1 denotes a thickness of the upper phase difference layer **250**. The thickness direction retardation (R_{th1}) of the upper phase difference layer **250** is retardation generated in a thickness direction of the upper phase difference layer **250** and may be expressed by $R_{th1}=\{[(n_{x1}+n_{y1})/2]-n_{z1}\}d_1$.

The upper phase difference layer **250** may have in-plane retardation and thickness direction retardation within a predetermined range by changing the n_{x1}, n_{y1}, n_{z1}, and/or thickness (d_1).

In an embodiment, the upper phase difference layer **250** satisfying Inequality 1 may, for example, satisfy a thickness direction retardation (R_{th1}) of Inequality 3.

$$230\text{ nm}\leq R_{th1}(450\text{ nm})\leq 370\text{ nm}$$ <Inequality 3>

In Inequality 3,

R_{th1}(450 nm) denotes a thickness direction retardation of the upper phase difference layer at a wavelength of 450 nm.

Herein, the retardation is described based on 450 nm, but when a light emitting wavelength of the light source is changed, the reference wavelength may be changed and retardation may be also changed. In an embodiment, the retardation and the reference wavelength may be set to satisfy the relations: $0.51 \le \Delta_{BL}$(nm)$\le R_{th}(\Delta_{BL}) \le 0.82 \times \Delta_{BL}$ (nm) (Δ_{BL} (nm) is a maximum light emitting wavelength of a light source), for example, $0.53 \times \Delta_{BL}$ (nm)$\le R_{th}(\Delta_{BL}) \le 0.80 \times \Delta_{BL}$ (nm), $00.55 \times \Delta_{BL}$ (nm)$\le R_{th}(\Delta_{BL}) \le 0.78 \times \Delta_{BL}$ (nm), or $0.60 \times \Delta_{BL}$ (nm)$\le R_{th}(\Delta_{BL}) \le 0.74 \times \Delta_{BL}$ (nm), but is not limited thereto.

The upper phase difference layer **250** may, for example, have a thickness direction retardation satisfying Inequality 3a.

$$240\text{ nm} \le R_{th1}(450\text{ nm}) \le 360\text{ nm} \quad \text{<Inequality 3a>}$$

The upper phase difference layer **250** may, for example, have a thickness direction retardation satisfying Inequality 3b.

$$250\text{ nm} \le R_{th1}(450\text{ nm}) \le 350\text{ nm} \quad \text{<Inequality 3b>}$$

The upper phase difference layer **250** may, for example, have a thickness direction retardation satisfying Inequality 3c.

$$270\text{ nm} \le R_{th1}(450\text{ nm}) \le 330\text{ nm} \quad \text{<Inequality 3c>}$$

The upper phase difference layer **250** satisfies a thickness direction retardation within the range and accordingly, may decrease or offset the thickness direction retardation, thus reduce viewing angle dependency, and resultantly, effectively perform a compensation function.

In an embodiment, the upper phase difference layer **250** satisfying Inequality 1 may, for example, have an in-plane retardation (R_{in1}) satisfying Inequality 4.

$$0\text{ nm} \le R_{in1}(450\text{ nm}) \le 20\text{ nm} \quad \text{<Inequality 4>}$$

In Inequality 4,

R_{in1}(450 nm) denotes an in-plane retardation of the upper phase difference layer at a wavelength of 450 nm.

The upper phase difference layer **250** may, for example, have an in-plane retardation satisfying Inequality 4a.

$$0\text{ nm} \le R_{in1}(450\text{ nm}) \le 10\text{ nm} \quad \text{<Inequality 4a>}$$

The upper phase difference layer **250** may, for example, have an in-plane retardation satisfying Inequality 4b.

$$0\text{ nm} \le R_{in1}(450\text{ nm}) \le 5\text{ nm} \quad \text{<Inequality 4b>}$$

The upper phase difference layer **250** may, for example, have an in-plane retardation satisfying Inequality 4c.

$$0\text{ nm} \le R_{in1}(450\text{ nm}) \le 2\text{ nm} \quad \text{<Inequality 4c>}$$

When the upper phase difference layer **250** satisfies Inequality 1, the lower phase difference layer **450** may, for example, have a refractive index satisfying Inequality 2.

$$n_{x2} > n_{z2} > n_{y2} \quad \text{<Inequality 2>}$$

In Inequality 2,

n_{x2} denotes a refractive index at a slow axis of the lower phase difference layer **450**,

n_{y2} denotes a refractive index at a fast axis of the lower phase difference layer **450**, and

n_{z2} denotes a refractive index of the lower phase difference layer **450** in a direction perpendicular to the slow axis and fast axis.

The upper and lower phase difference layers **250** and **450** having the above refractive indexes are combined and thus perform an effective compensation function and accordingly, may effectively decrease a light leakage.

Retardation of the lower phase difference layer **450** may be expressed as an in-plane retardation (R_{in2}) and a thickness direction retardation (R_{th2}). The in-plane retardation (R_{in1}) of the lower phase difference layer **450** is retardation generated in an in-plane direction of the lower phase difference layer **450** and may be expressed by $R_{in2}=(n_{x2}-n_{y2})d_2$. The thickness direction retardation (R_{th2}) of the lower phase difference layer **450** is retardation generated in a thickness direction of the lower phase difference layer **450** and may be expressed by $R_{th2}=\{[(n_{x2}+n_{y2})/2]-n_{z2}\}d_2$. Herein, d_2 denotes a thickness of the lower phase difference layer **450**.

The lower phase difference layer **450** may have an in-plane retardation and a thickness direction retardation within a predetermined range by changing the n_{x2}, n_{y2}, n_{z2} and/or thickness (d_2).

The lower phase difference layer **450** satisfying Inequality 2 may, for example, have an in-plane retardation satisfying Inequality 5.

$$110\text{ nm} \le R_{in2}(450\text{ nm}) \le 330\text{ nm} \quad \text{Inequality 5}$$

In Inequality 5,

R_{in2}(450 nm) denotes an in-plane retardation of the lower phase difference layer **450** at a wavelength of 450 nm.

As the in-plane retardation of the lower phase difference layer **450** satisfies Inequality 5, the retardations of the upper phase difference layer **250** and the lower phase difference layer **450** may be combined to effectively reduce viewing angle dependency and further increase a compensation function.

The lower phase difference layer **450** may, for example, have an in-plane retardation satisfying Inequality 5a.

$$120\text{ nm} \le R_{in2}(450\text{ nm}) \le 320\text{ nm} \quad \text{<Inequality 5a>}$$

The lower phase difference layer **450** may, for example, have an in-plane retardation satisfying Inequality 5b.

$$150\text{ nm} \le R_{in2}(450\text{ nm}) \le 300\text{ nm} \quad \text{<Inequality 5b>}$$

The lower phase difference layer **450** may, for example, have an in-plane retardation satisfying Inequality 5c.

$$180\text{ nm} \le R_{in2}(450\text{ nm}) \le 270\text{ nm} \quad \text{<Inequality 5c>}$$

The lower phase difference layer **450** satisfying Inequality 2 may, for example, have a thickness direction retardation satisfying Inequality 6.

$$-60\text{ nm} \le R_{th2}(450\text{ nm}) \le 65\text{ nm} \quad \text{<Inequality 6>}$$

In Inequality 6,

R_{th2}(450 nm) denotes a thickness direction retardation of the lower phase difference layer at a wavelength of 450 nm.

The lower phase difference layer **450** may, for example, have a thickness direction retardation satisfying Inequality 6a.

$$-50\text{ nm} \le R_{th2}(450\text{ nm}) \le 50\text{ nm} \quad \text{<Inequality 6a>}$$

The lower phase difference layer **450** may, for example, have a thickness direction retardation satisfying Inequality 6b.

$$-40\text{ nm} \le R_{th2}(450\text{ nm}) \le 40\text{ nm} \quad \text{<Inequality 6b>}$$

The lower phase difference layer **450** may, for example, have retardation satisfying Inequality 7.

$$-0.25 \le R_{th2}(450\text{ nm})/R_{in2}(450\text{ nm}) \le 0.25 \quad \text{<Inequality 7>}$$

The lower phase difference layer **450** may, for example, have retardation satisfying Inequality 7a.

$-0.22 \leq R_{th2}(450\text{ nm})/R_{in2}(450\text{ nm}) \leq 0.22$ <Inequality 7a>

The lower phase difference layer **450** may, for example, have retardation satisfying Inequality 7b.

$-0.20 \leq R_{th2}(450\text{ nm})/R_{in2}(450\text{ nm}) \leq 0.20$ Inequality 7b

The lower phase difference layer **450** may, for example, have retardation satisfying Inequality 7c.

$-0.15 \leq R_{th2}(450\text{ nm})/R_{in2}(450\text{ nm}) \leq 0.15$ <Inequality 7c>

The lower phase difference layer **450** may, for example, have retardation satisfying Inequality 7d.

$-0.10 \leq R_{th2}(450\text{ nm})/R_{in2}(450\text{ nm}) \leq 0.10$ <Inequality 7d>

The lower phase difference layer **450** may, for example, have retardation satisfying Inequality 7e.

$-0.05 \leq R_{th2}(450\text{ nm})/R_{in2}(450\text{ nm}) \leq 0.05$ <Inequality 7e>

According to the embodiment, the LCD displays a color by using a color conversion layer including a light emitting element, and thus may increase photo-efficiency and improve color characteristics.

In addition, light characteristics and viewing angle characteristics of the color conversion layer including a light emitting element may be secured, and thus display characteristics may be improved by introducing the upper polarizing layer and the upper phase difference layer inside the LCD panel **300** but omitting a polarizer and a phase difference film outside an upper substrate to prevent deterioration of the light characteristics and the color characteristics by the polarizer and the phase difference film disposed outside the upper substrate.

In addition, the upper polarizing layer and the upper phase difference layer are provided to be thin and thus may realize a thin LCD.

In addition, the phase difference layer having the refractive index of Inequality 1 and the phase difference layer having the refractive index of Inequality 2 may be combined to adjust an overall retardation and thus to reduce or prevent a light leakage at the side before light reaches a color conversion layer in a black mode, and accordingly, to reduce unnecessary light emission of the color conversion layer in the black mode, thus decrease black luminance, and resultantly, improve a contrast ratio.

In an embodiment, the upper phase difference layer having the refractive index of Inequality 1 and the lower phase difference layer having the refractive indexes of Inequality 2 are exemplarily illustrated but not limited thereto, and the lower phase difference layer having the refractive index of Inequality 1 and the upper phase difference layer having the refractive index of Inequality 2 may be combined, for example.

Hereinafter, the embodiments are illustrated in more detail with reference to examples. However, these examples are exemplary, and the present disclosure is not limited thereto.

<Optical Simulation>

An LCD is manufactured to have the following structure, and an optical simulation is performed.

The optical simulation is performed by using a Techwiz program (Sanayi System Co., Ltd.) to obtain a black luminance distribution at a wavelength of 450 nm and at an azimuthal angle of about 0° to about 360° and a tilt angle of about 0° to about 90° and calculate its average.

Examples 1 to 54

An optical simulation about an LCD including an upper substrate (glass); an upper polarizing layer; an upper phase difference layer; a homeotropic liquid crystal layer; a lower substrate (glass); a lower phase difference layer; a lower polarizing layer; and a blue light source disposed in order from the examiner is performed. Input variables of each layer are as follows:

Refractive indexes of the upper and lower substrates (glass): 1.5,

Thicknesses of the upper and lower substrates (glass): 500 μm,

Transmittance of the upper and lower polarizing layers: 42.45%,

Degrees of polarization of the upper and lower polarizing layers: 99.99%,

Refractive indexes ne and no of the vertical alignment liquid crystal layer: ne=1.6163 and no=1.4956,

Average refractive index of the upper phase difference layer: 1.60,

nx-nz of the upper phase difference layer: 0.052,

Average refractive index of the lower phase difference layer: 1.65,

nx-nz of the lower phase difference layer: 0.0026,

Blue light source: 450 nm short wavelength light source

The optical simulation is performed at various ranges satisfying the following optical conditions.

Vertical alignment liquid crystal layer: R_{th}=−295 nm,

Upper phase difference layer: $n_{x1} \geq n_{y1} > n_{z1}$, R_{in1}=0 nm-20 nm, R_{th1}=230 nm to 370 nm, and

Lower phase difference layer: $n_{x2} > n_{z2} > n_{y2}$, R_{in2}=110 nm to 330 nm, R_{th2}=−60 nm to 65 nm

Comparative Example 1

An optical simulation about an LCD having the same structure as Examples except for including neither the upper phase difference layer nor the lower phase difference layer is performed.

Comparative Example 2

An optical simulation about an LCD having the same structure as Examples except for not including the upper phase difference layer is performed.

Comparative Example 3

An optical simulation about an LCD having the same structure as Examples except for not including the lower phase difference layer is performed.

Comparative Example 4

An optical simulation about an LCD having the same structure as Examples except for not including the upper phase difference layer and changing an optical condition of the lower phase difference layer as follows is performed.

Lower phase difference layer: $n_{x2} \neq n_{y2} > n_{z2}$, R_{in2}=65 nm, R_{th2}=250 nm

<Evaluation>

The optical simulation results are shown as a black luminance distribution and an average black luminance at a wavelength of 450 nm at an azimuth ranging from 0° to 360° and a tilt angle ranging from 0° to 90°.

A sum of the black luminances at all the azimuths and tilt angles tends to be proportional to a dose of light reaching a color conversion layer, and accordingly, as the sum of the black luminances is smaller, the dose of light emitted by the color conversion layer is decreased, and thus the black luminance becomes lower. Accordingly, as the black luminance is lower, an LCD is expected to have the higher contrast ratio.

An average black luminance may be obtained by averaging all the black luminances at all the azimuths and all the tilt angles. As the average black luminance is lower, an LCD is expected to have the higher contrast ratio.

Table 1 shows average black luminances of the LCDs according to Examples and Comparative Examples, and FIGS. **2** to **11** show a black luminance distribution of the LCDs according to Examples 3, 9, 16, 44, 49, and 54 and Comparative Examples 1 to 4.

FIG. **2** is a diagram showing a black luminance distribution of the LCDs according to Example 3, FIG. **3** is a diagram showing a black luminance distribution of the LCDs according to Example 9, FIG. **4** is a diagram showing a black luminance distribution of the LCDs according to Example 16, FIG. **5** is a diagram showing a black luminance distribution of the LCDs according to Example 44, FIG. **6** is a diagram showing a black luminance distribution of the LCDs according to Example 49, FIG. **7** is a diagram showing a black luminance distribution of the LCDs according to Example 54, FIG. **8** is a diagram showing a black luminance distribution of the LCDs according to Comparative Example 1, FIG. **9** is a diagram showing a black luminance distribution of the LCDs according to Comparative Example 2, FIG. **10** is a diagram showing a black luminance distribution of the LCDs according to Comparative Example 3, and FIG. **11** is a diagram showing a black luminance distribution of the LCDs according to Comparative Example 4.

TABLE 1

	Upper phase difference layer		Lower phase difference layer			Average black	Percentage (%) relative to Com-
	R_{in1} (nm)	R_{th1} (nm)	R_{in2} (nm)	R_{th2} (nm)	R_{th2}/R_{in2}	luminance (cd/m^2)	parative Example 4
Comparative Example 1	—	—	—	—		101.392	3111%
Comparative Example 2	—	—	230	0	0.00	94.681	2905%
Comparative Example 3	0	300	—	—	—	9.054	278%
Comparative Example 4	—	—	65	250	3.85	3.259	100%
Example 1	0	240	120	0	0.00	2.417	74%
Example 2	0	240	140	0	0.00	1.662	51%
Example 3	0	240	160	0	0.00	1.471	45%
Example 4	0	240	180	0	0.00	1.867	57%
Example 5	0	240	200	0	0.00	2.808	86%
Example 6	0	260	120	0	0.00	2.062	63%
Example 7	0	260	140	0	0.00	1.154	35%
Example 8	0	260	160	0	0.00	0.662	20%
Example 9	0	260	180	0	0.00	0.625	19%
Example 10	0	260	200	0	0.00	1.044	32%
Example 11	0	260	220	0	0.00	1.889	58%
Example 12	0	280	120	0	0.00	2.733	84%
Example 13	0	280	140	0	0.00	1.681	52%
Example 14	0	280	160	0	0.00	0.894	27%
Example 15	0	280	180	0	0.00	0.429	13%
Example 16	0	280	200	0	0.00	0.328	10%
Example 17	0	280	220	0	0.00	0.595	18%
Example 18	0	280	240	0	0.00	1.212	37%
Example 19	0	280	260	0	0.00	2.130	65%
Example 20	0	300	160	0	0.00	2.197	67%
Example 21	0	300	180	0	0.00	1.287	40%
Example 22	0	300	200	0	0.00	0.652	20%
Example 23	0	300	220	0	0.00	0.334	10%
Example 24	0	300	240	0	0.00	0.359	11%
Example 25	0	300	260	0	0.00	0.726	22%
Example 26	0	300	280	0	0.00	1.408	43%
Example 27	0	300	300	0	0.00	2.344	72%
Example 28	0	320	200	0	0.00	2.020	62%
Example 29	0	320	220	0	0.00	1.116	34%
Example 30	0	320	240	0	0.00	0.545	17%
Example 31	0	320	260	0	0.00	0.356	11%
Example 32	0	320	280	0	0.00	0.562	17%
Example 33	0	320	300	0	0.00	1.146	35%
Example 34	0	320	320	0	0.00	2.072	64%
Example 35	0	340	240	0	0.00	1.784	55%
Example 36	0	340	260	0	0.00	1.043	32%
Example 37	0	340	280	0	0.00	0.769	24%
Example 38	0	340	300	0	0.00	0.996	31%
Example 39	0	340	320	0	0.00	1.708	52%
Example 40	0	360	260	0	0.00	2.744	84%
Example 41	0	360	280	0	0.00	2.028	62%
Example 42	0	360	300	0	0.00	1.929	59%
Example 43	0	360	320	0	0.00	2.453	75%
Example 44	0	250	150	25	0.17	0.314	10%
Example 45	0	275	190	7.5	0.04	0.311	10%
Example 46	0	300	230	−50	−0.22	1.772	54%
Example 47	0	300	230	−30	−0.13	0.843	26%
Example 48	0	300	230	−10	−0.04	0.368	11%
Example 49	0	300	230	0	0.00	0.303	9%
Example 50	0	300	230	10	0.04	0.357	11%
Example 51	0	300	230	30	0.13	0.819	25%
Example 52	0	300	230	50	0.22	1.751	54%
Example 53	0	325	270	20	0.07	0.319	10%
Example 54	0	350	295	50	0.17	0.529	16%

Referring to Table 1 and FIGS. **2** to **11**, the LCDs according to Examples maintain a low black luminance at all the azimuths and tilt angles and in addition, a low average black luminance compared with the LCDs according to Comparative Examples 1 to 4. Accordingly, the LCDs according to Examples show an improved contrast ratio compared with the LCDs according to Comparative Examples 1 to 4.

While this disclosure has been described in connection with what is presently considered to be practical example embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. A liquid crystal display, comprising:

a lower substrate and an upper substrate facing each other,

a liquid crystal layer between the lower substrate and the upper substrate,

a color conversion layer on the liquid crystal layer,

a first polarizing layer and a first phase difference layer between the liquid crystal layer and the color conversion layer, and

a second polarizing layer and a second phase difference layer between a light source and the lower substrate,

wherein the first phase difference layer has a refractive index satisfying Inequality 1 and

the second phase difference layer has refractive indexes satisfying Inequality 2:

$nx1 \geq ny1 > nz1$ <Inequality 1>

wherein, in Inequality 1,

nx1 denotes a refractive index at a slow axis of the first phase difference layer,

ny1 denotes a refractive index at a fast axis of the first phase difference layer, and

nz1 denotes a refractive index of the first phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof,

$$nx2>nz2>ny2 \quad \text{<Inequality 2>}$$

wherein, in Inequality 2,

nx2 denotes a refractive index at a slow axis of the second phase difference layer,

ny2 denotes a refractive index at a fast axis of the second phase difference layer, and

nz2 denotes a refractive index of the second phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof.

2. The liquid crystal display of claim **1**, wherein the first phase difference layer has a retardation satisfying Inequality 3:

$$230\text{ nm}\le Rth1(450\text{ nm})\le 370\text{ nm} \quad \text{<Inequality 3>}$$

wherein, in Inequality 3,

Rth1(450 nm) denotes a thickness direction retardation of the first phase difference layer at a wavelength of 450 nanometers.

3. The liquid crystal display of claim **2**, wherein the first phase difference layer has a retardation satisfying Inequality 4:

$$0\text{ nm}\le R_{in1}(450\text{ nm})\le 20\text{ nm} \quad \text{<Inequality 4>}$$

wherein, in Inequality 4,

Rin1(450 nm) denotes an in-plane retardation of the first phase difference layer at the wavelength of 450 nanometers.

4. The liquid crystal display of claim **1**, wherein the second phase difference layer has a retardation satisfying Inequality 5:

$$110\text{ nm}\le Rin2(450\text{ nm})\le 330\text{ nm} \quad \text{<Inequality 5>}$$

wherein, in Inequality 5,

Rin2(450 nm) denotes an in-plane retardation of the second phase difference layer at a wavelength of 450 nanometers.

5. The liquid crystal display of claim **4**, wherein the second phase difference layer has a retardation satisfying Inequality 6:

$$-60\text{ nm}\le Rth2(450\text{ nm})\le 65\text{ nm} \quad \text{<Inequality 6>}$$

wherein, in Inequality 6,

Rth2(450 nm) denotes a thickness direction retardation of the second phase difference layer at the wavelength of 450 nanometers.

6. The liquid crystal display of claim **1**, wherein the second phase difference layer has a retardation satisfying Inequality 7:

$$-0.25\le Rth2(450\text{ nm})/Rin2(450\text{ nm})\le 0.25 \quad \text{<Inequality 7>}$$

wherein, in Inequality 7,

Rin2(450 nm) denotes an in-plane retardation of the second phase difference layer at a wavelength of 450 nanometers, and

Rth2(450 nm) denotes a thickness direction retardation of the second phase difference layer at the wavelength of 450 nanometers.

7. The liquid crystal display of claim **1**, wherein the first phase difference layer is disposed between the liquid crystal layer and the first polarizing layer.

8. The liquid crystal display of claim **1**, wherein the second phase difference layer is disposed between the second polarizing layer and the lower substrate.

9. The liquid crystal display of claim **1**, wherein the color conversion layer includes a light emitting element which receives a first visible light from the light source and emits a second visible light.

10. The liquid crystal display of claim **9**, wherein the first visible light is blue light and

the second visible light is one of blue light, green light, red light, and a combination thereof.

11. The liquid crystal display of claim **9**, wherein the light emitting element includes at least one of a quantum dot and a phosphor.

12. The liquid crystal display of claim **1**, wherein the liquid crystal layer has negative dielectric anisotropy.

13. The liquid crystal display of claim **1**, wherein the thickness direction retardation of the liquid crystal layer satisfies −360 nm≤Rth,cell≤−250 nm.

14. A liquid crystal display comprising

a first phase difference layer and a second phase difference layer, and

a liquid crystal display panel including a lower substrate and an upper substrate facing each other and a liquid crystal layer between the lower substrate and the upper substrate,

wherein one of the first phase difference layer and the second phase difference layer is disposed between the liquid crystal layer and the upper substrate, and

a remaining one of the first phase difference layer and the second phase difference layer is disposed at a location other than between the lower substrate and the upper substrate,

the first phase difference layer has a refractive index satisfying Inequality 1, and

the second phase difference layer has refractive indexes satisfying Inequality 2:

$$nx1\ge ny1>nz1 \quad \text{<Inequality 1>}$$

wherein, in Inequality 1,

nx1 denotes a refractive index at a slow axis of the first phase difference layer,

ny1 denotes a refractive index at a fast axis of the first phase difference layer, and

nz1 denotes a refractive index of the first phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof,

$$nx2>nz2>ny2 \quad \text{<Inequality 2>}$$

wherein, in Inequality 2,

nx2 denotes a refractive index at a slow axis of the second phase difference layer,

ny2 denotes a refractive index at a fast axis of the second phase difference layer, and

nz2 denotes a refractive index of the second phase difference layer in a direction perpendicular to the slow axis and the fast axis thereof.

15. The liquid crystal display of claim **14**, wherein the first phase difference layer has a retardation satisfying Inequality 3 and the second phase difference layer has a retardation satisfying Inequality 5:

$$230\text{ nm}\le Rth1(450\text{ nm})\le 370\text{ nm} \quad \text{<Inequality 3>}$$

$$110\text{ nm}\le Rin2(450\text{ nm})\le 330\text{ nm} \quad \text{<Inequality 5>}$$

wherein, in Inequality 3 or 5,

Rth1(450 nm) denotes a thickness direction retardation of the first phase difference layer at a wavelength of 450 nanometers, and

Rin2(450 nm) denotes an in-plane retardation of the second phase difference layer at the wavelength of 450 nanometers.

16. The liquid crystal display of claim **14**, wherein the second phase difference layer has a retardation satisfying Inequality 7:

$$-0.25 \leq Rth2(450\ \text{nm})/Rin2(450\ \text{nm}) \leq 0.25 \qquad \text{<Inequality 7>}$$

wherein, in Inequality 7,

Rin2(450 nm) denotes an in-plane retardation of the second phase difference layer at a wavelength of 450 nanometers, and

Rth2(450 nm) denotes a thickness direction retardation of the second phase difference layer at the wavelength of 450 nanometers.

17. The liquid crystal display of claim **14**, wherein the liquid crystal display panel further comprises

a color conversion layer on the liquid crystal layer and including a light emitting element.

18. The liquid crystal display of claim **17**, wherein the first phase difference layer is under the color conversion layer in the liquid crystal display panel.

19. The liquid crystal display of claim **18**, further comprising a first polarizing layer between the first phase difference layer and the color conversion layer.

20. The liquid crystal display of claim **19**, wherein the second phase difference layer is disposed outside the liquid crystal display panel which is the location other than between the lower substrate and the upper substrate, and

the liquid crystal display further includes a second polarizing layer on the second phase difference layer.

* * * * *

专利名称(译)	具有单元内相位差层的液晶显示器		
公开(公告)号	US10303029	公开(公告)日	2019-05-28
申请号	US15/925439	申请日	2018-03-19
[标]申请(专利权)人(译)	三星电子株式会社		
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IPC分类号	G02F1/137 G02F1/1335 H01L27/12 G02F1/1368 G02F1/1337 G02F1/1362		
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代理机构(译)	康托科尔伯恩LLP		
优先权	1020170134030 2017-10-16 KR		
其他公开文献	US20190113782A1		
外部链接	Espacenet		

摘要(译)

液晶显示器包括彼此面对的下基板和上基板，设置在下基板和上基板之间的液晶层，设置在液晶层上的颜色转换层，第一偏振层和第一相差层设置在液晶层和颜色转换层之间，第二偏振层和第二相差层设置在光源和下基板之间，其中第一相差层具有满足不等式1和第二相差的折射率相位差层具有满足不等式2的折射率。 名词的 X1 的≥N的 Y1 的≥N的 Z1 20032003 [不平等1] 名词的 X2 > N 的 Z2 > N 的 Y2 20032003 [不平等2] 在不等式1和2中，n x1 ，n x2 ，n y1 ，n y2 ，n z1 和n z2 在详细描述中是相同的。