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Jang et al.

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(54) **OPTICAL SHEET ASSEMBLY AND LIQUID CRYSTAL DISPLAY APPARATUS HAVING THE SAME**

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(73) Assignee: **Samsung Electronics Co., Ltd.** (KR)

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(22) Filed: **Jul. 30, 2004**

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(30) **Foreign Application Priority Data**

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Jul. 31, 2003 (KR) 10-2003-0053266

(51) **Int. Cl.**
G02F 1/1335 (2006.01)

(52) **U.S. Cl.** **349/114**; 349/117; 349/119; 349/121

(58) **Field of Classification Search** 349/114
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0169801 A1 * 9/2004 Kabe et al. 349/114

* cited by examiner

Primary Examiner—Andrew Schechter
Assistant Examiner—Lucy Chien
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(57) **ABSTRACT**

A liquid crystal display panel includes a liquid crystal layer having a twist angle of ±10 degree. An upper polarizer is disposed over an upper substrate of the liquid crystal display panel, and includes an absorption axis forming at an angle of 47±10 degree in a clockwise direction with respect to a major axis. An upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer, and includes Δnd1 of 260±10 nm and a slow axis forming at an angle of 166±10 degree in the clockwise direction with respect to the absorption axis. An upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film, and includes Δnd2 of 140±10 nm and a slow axis forming at an angle of 111±10 degree in the clockwise direction with respect to the absorption axis. Therefore, the optical condition of the optical film assembly is optimized to improve an image display quality.

12 Claims, 20 Drawing Sheets

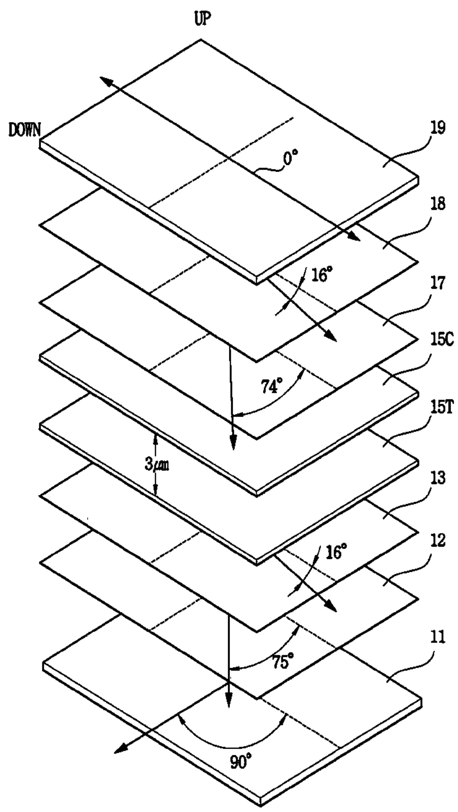


FIG. 1

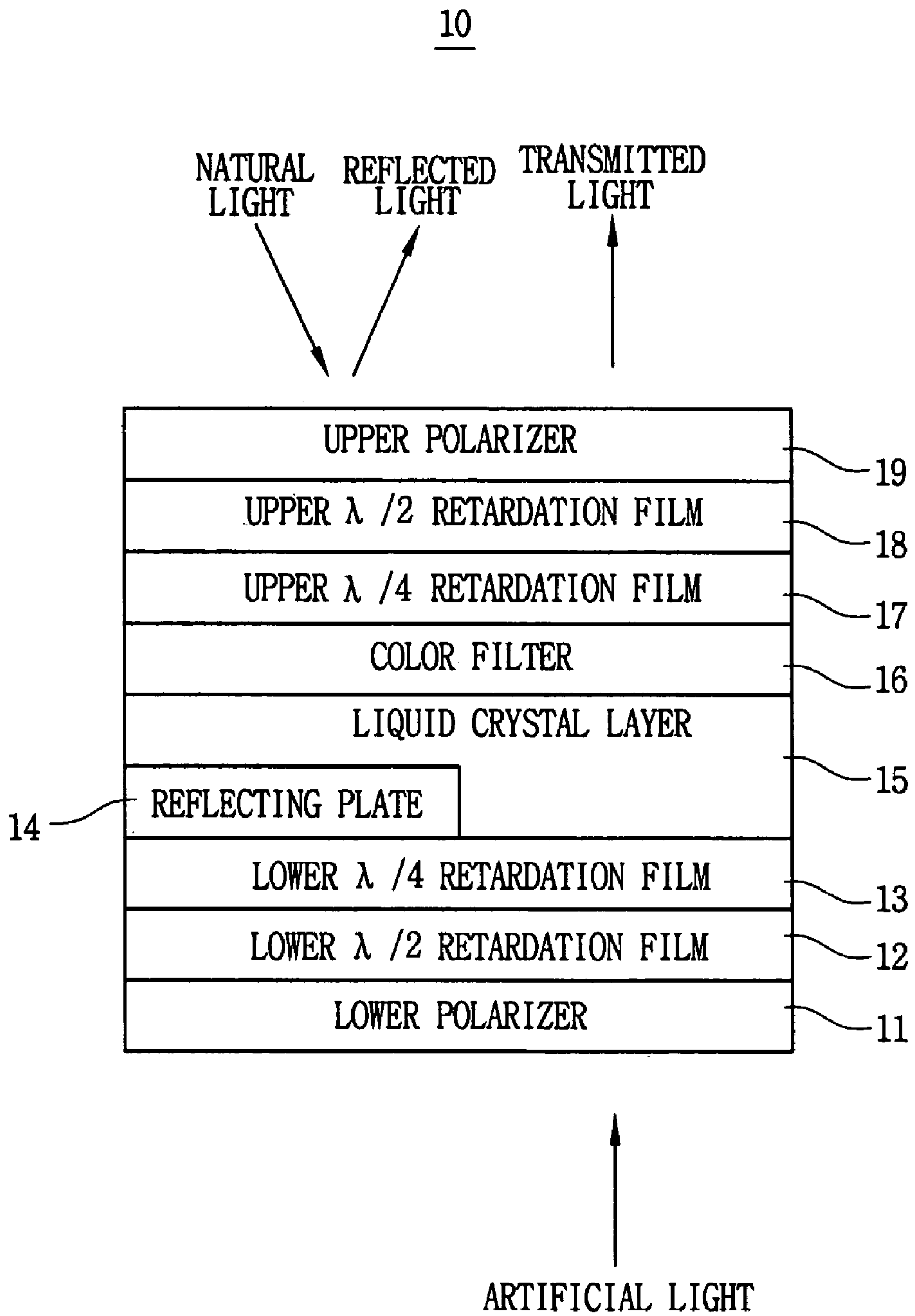
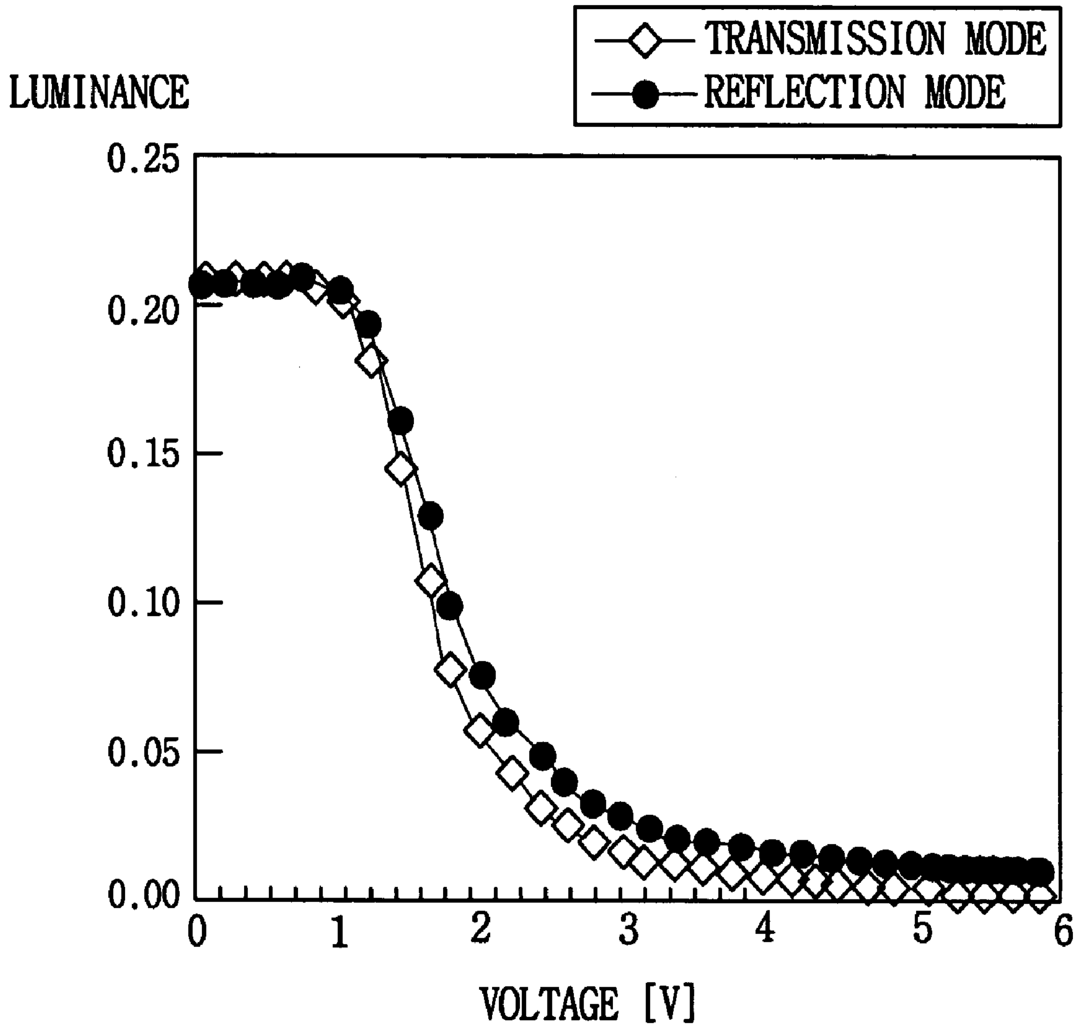

10
NATURAL LIGHT
REFLECTED LIGHT
TRANSMITTED LIGHT
UPPER POLARIZER
19
UPPER λ /2 RETARDATION FILM
18
UPPER λ /4 RETARDATION FILM
17
COLOR FILTER
16
LIQUID CRYSTAL LAYER
15
REFLECTING PLATE
14
LOWER λ /4 RETARDATION FILM
13
LOWER λ /2 RETARDATION FILM
12
LOWER POLARIZER
11
ARTIFICIAL LIGHT

FIG. 2


TRANSMISSION MODE
REFLECTION MODE
LUMINANCE
0.25
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0.10
0.05
0.00
0
1
2
3
4
5
6
VOLTAGE [V]

FIG. 3

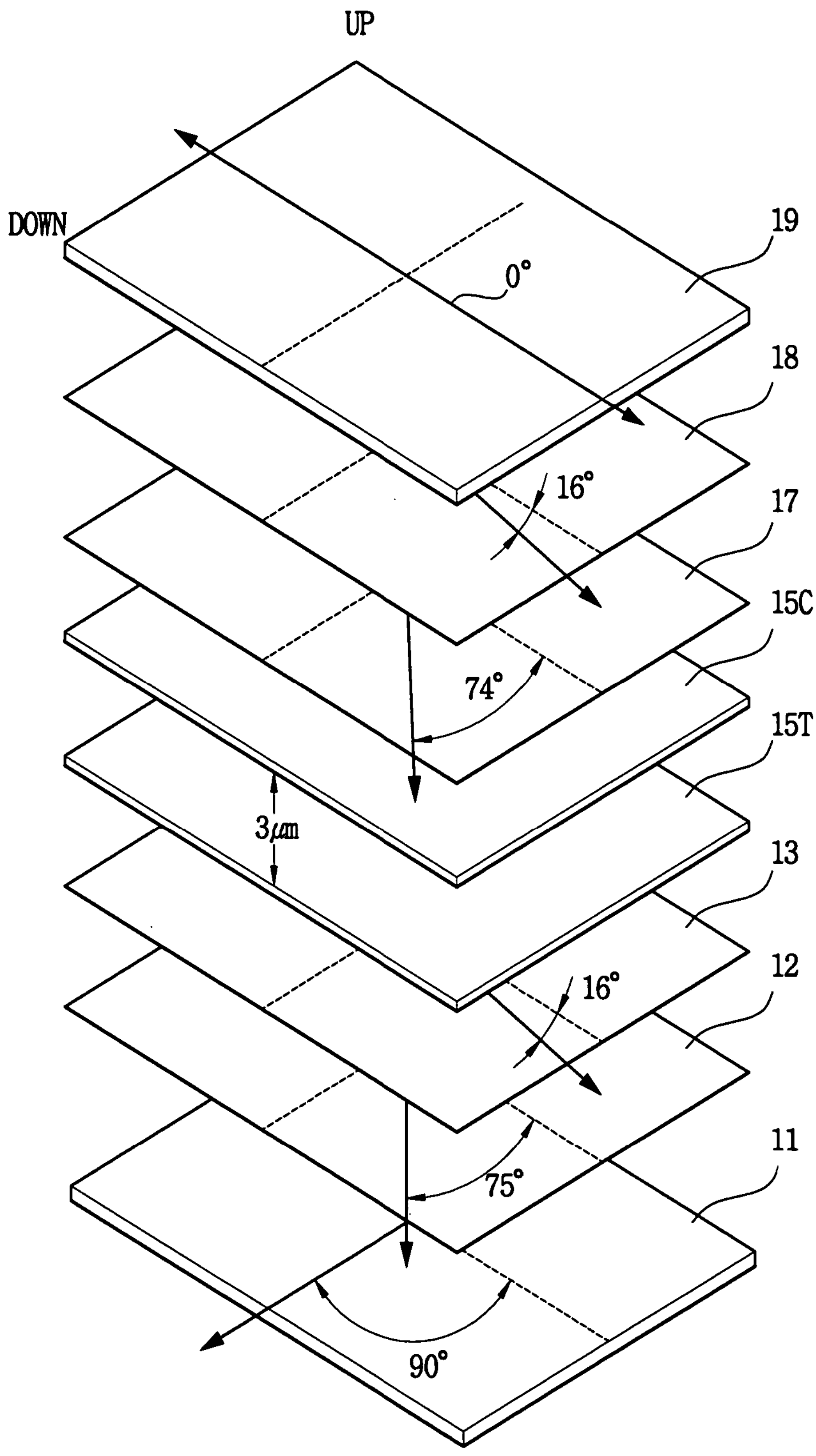
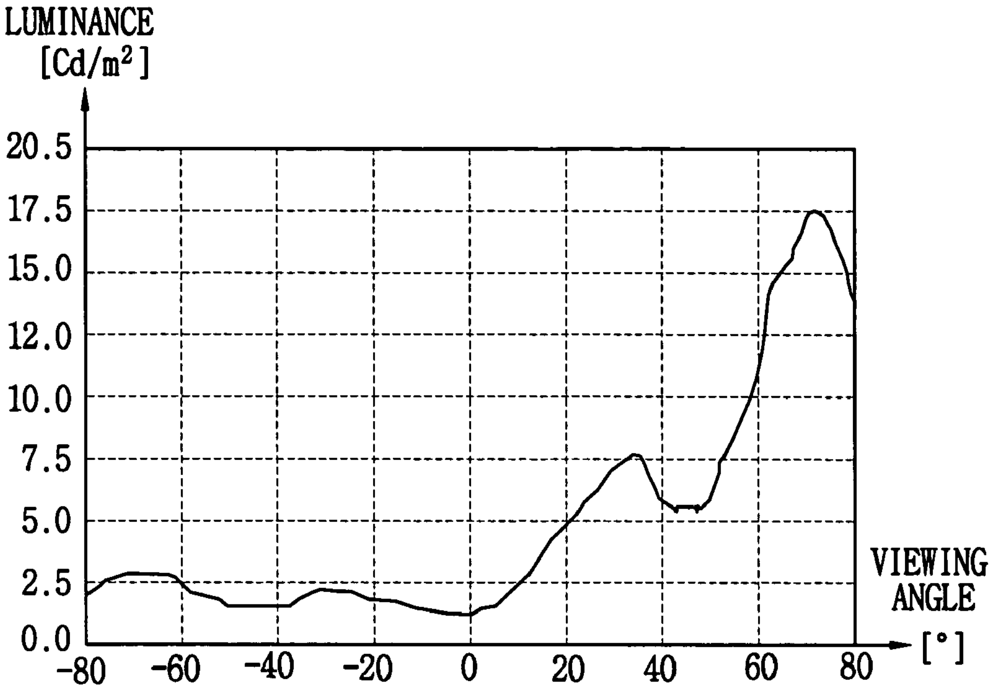


FIG. 4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15.0
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10.0
7.5
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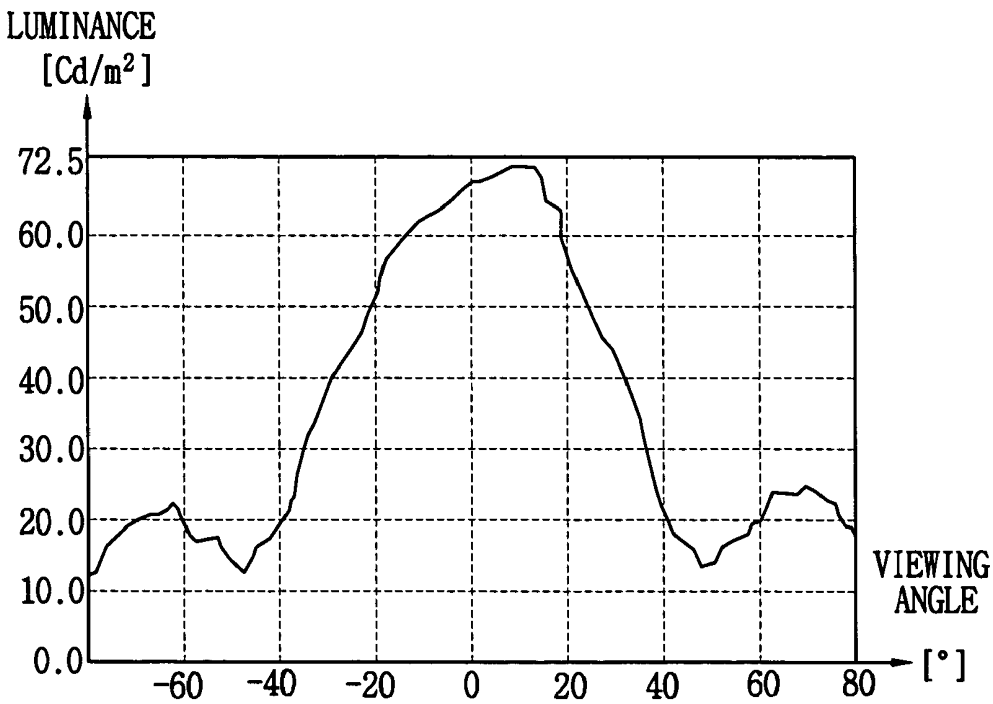
-60
-40
-20
0
20
40
60
80
VIEWING ANGLE
[°]

FIG. 5


LUMINANCE
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50.0
40.0
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20.0
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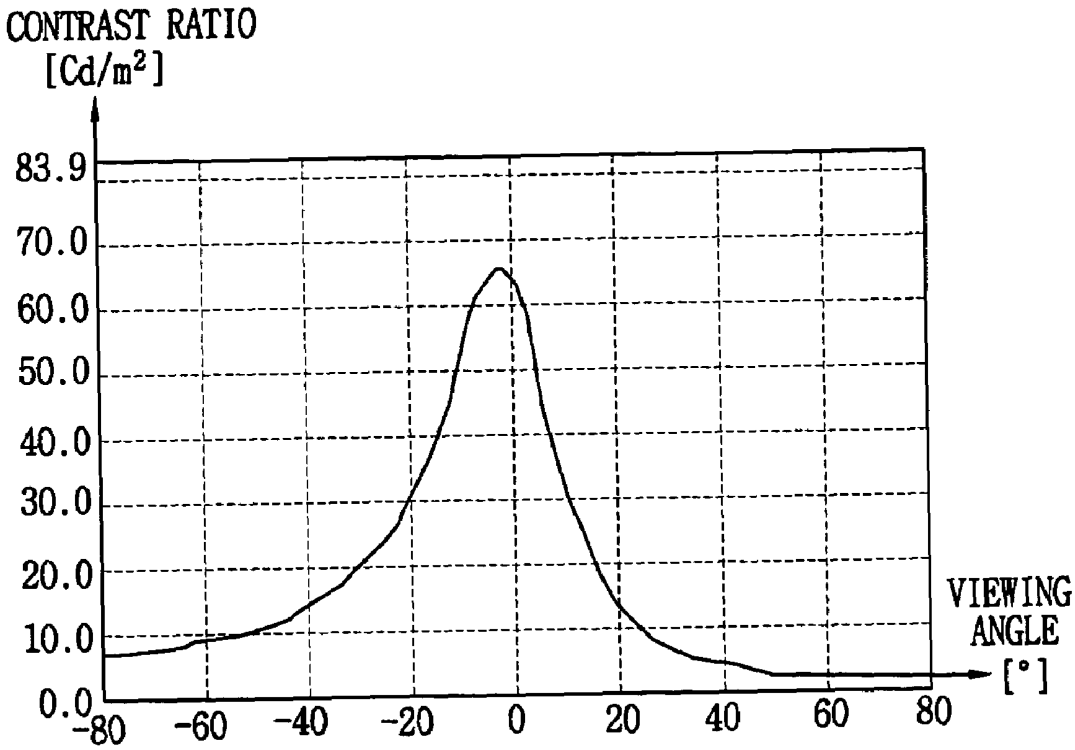
0
20
40
60
80
VIEWING ANGLE
[°]

FIG. 6


CONTRAST RATIO
[Cd/m2]
83.9
70.0
60.0
50.0
40.0
30.0
20.0
10.0
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-60
-40
-20
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20
40
60
80
VIEWING
ANGLE
[°]

FIG. 7

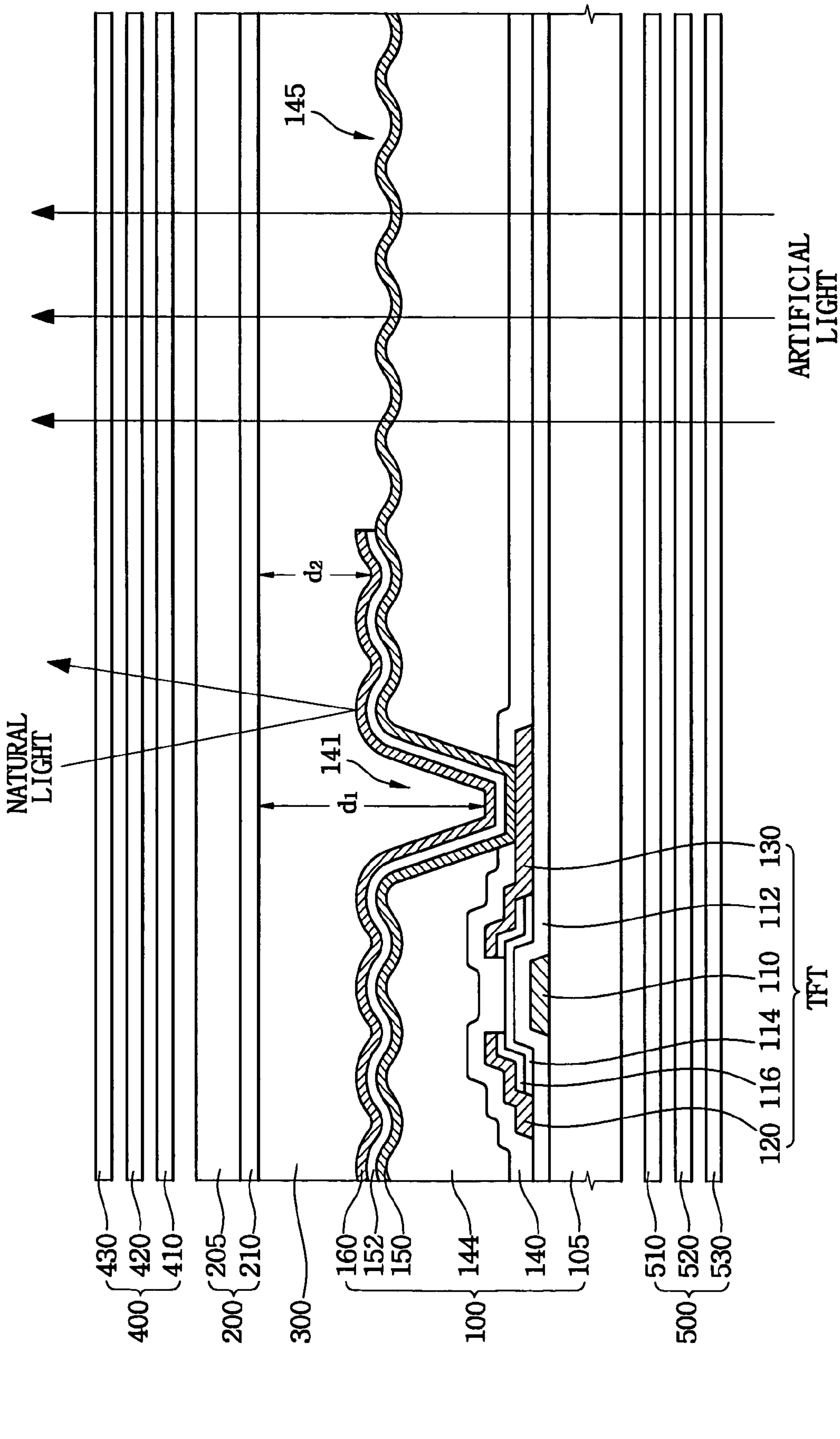

145
ARTIFICIAL LIGHT
NATURAL LIGHT
141
d_2
d_1
130
112
110
114
116
120
TFT
430
420
410
400
205
210
200
300
160
152
150
144
140
105
100
510
520
530
500

FIG. 8

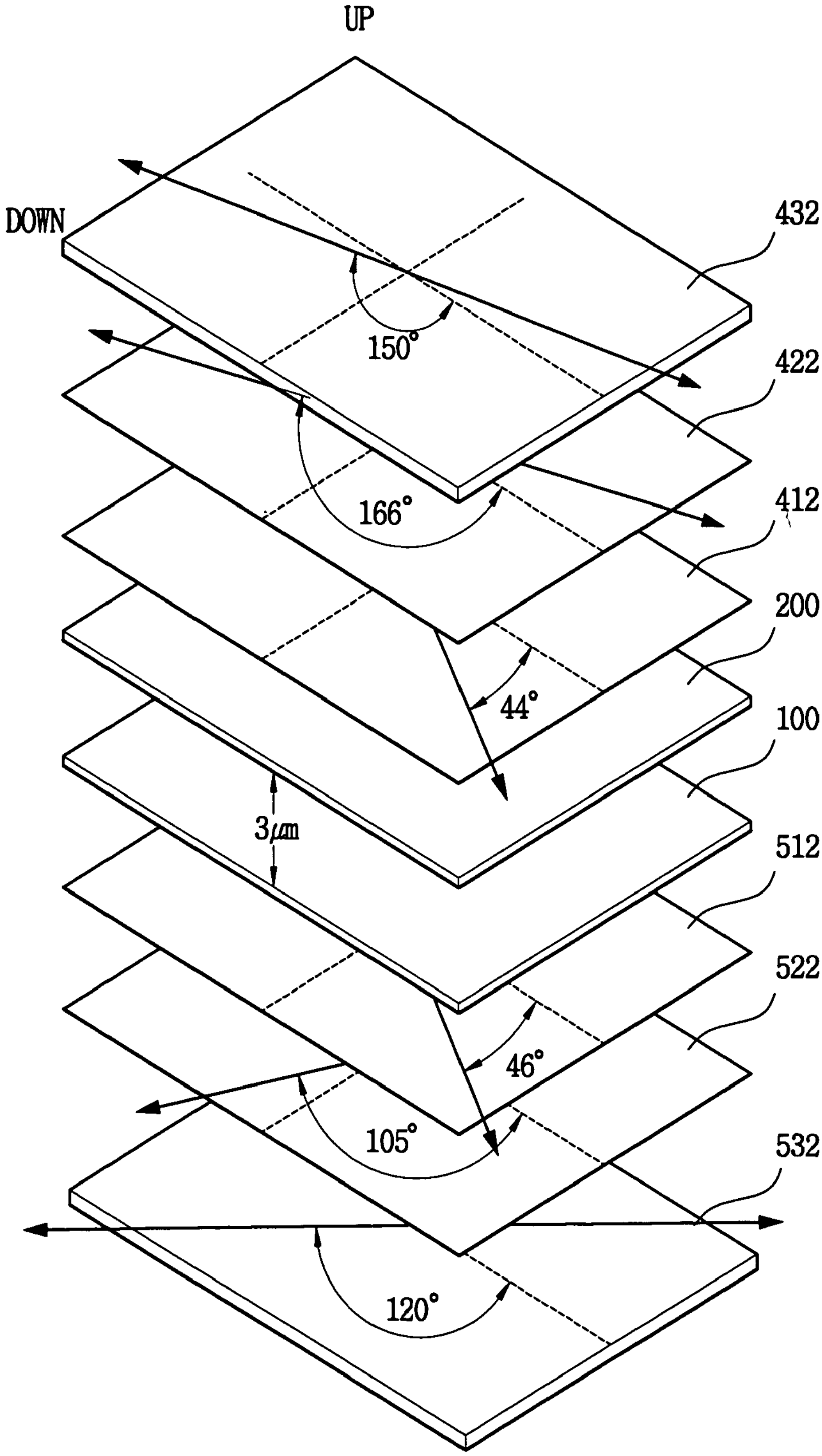


FIG. 9

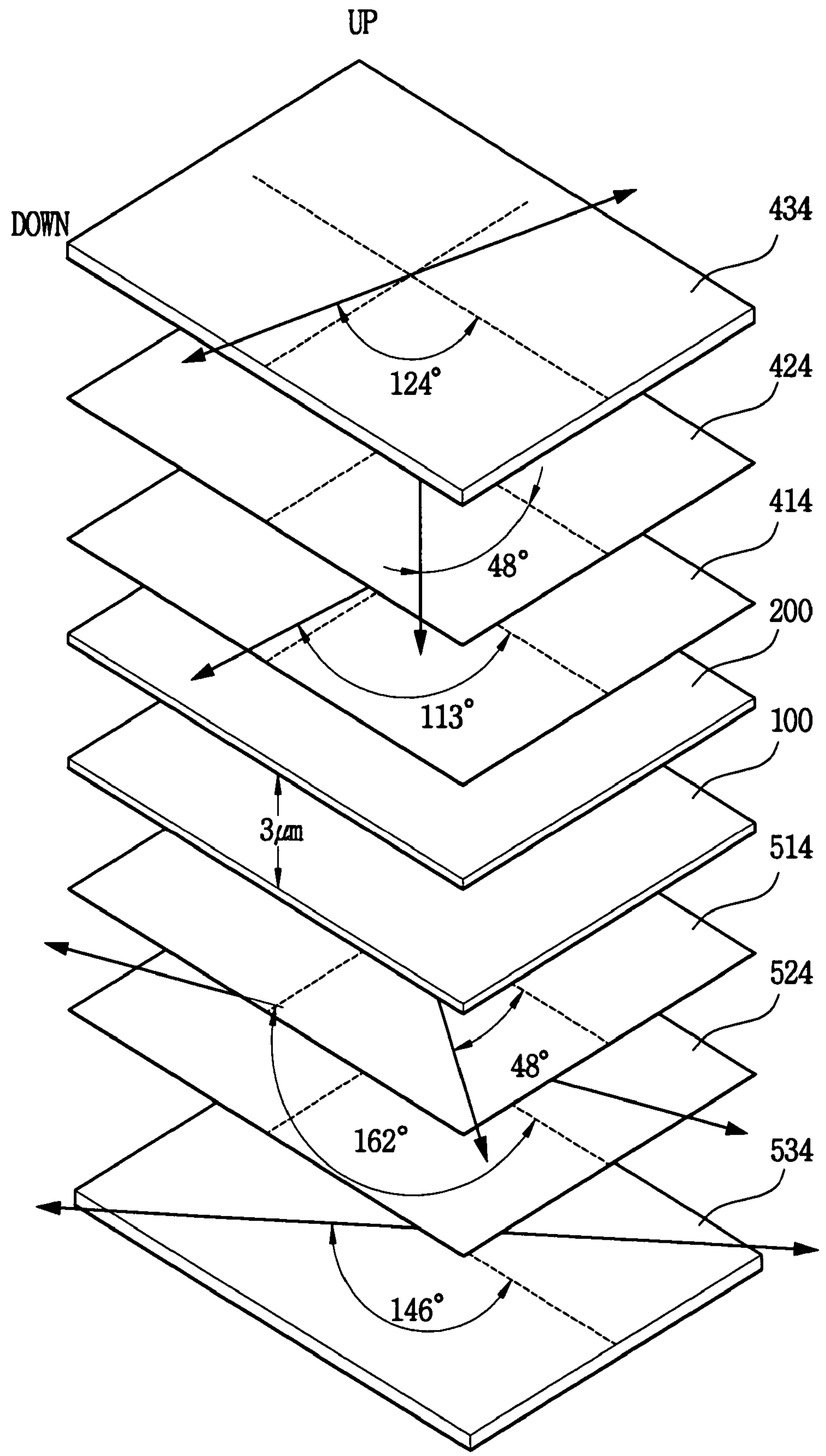


FIG. 10

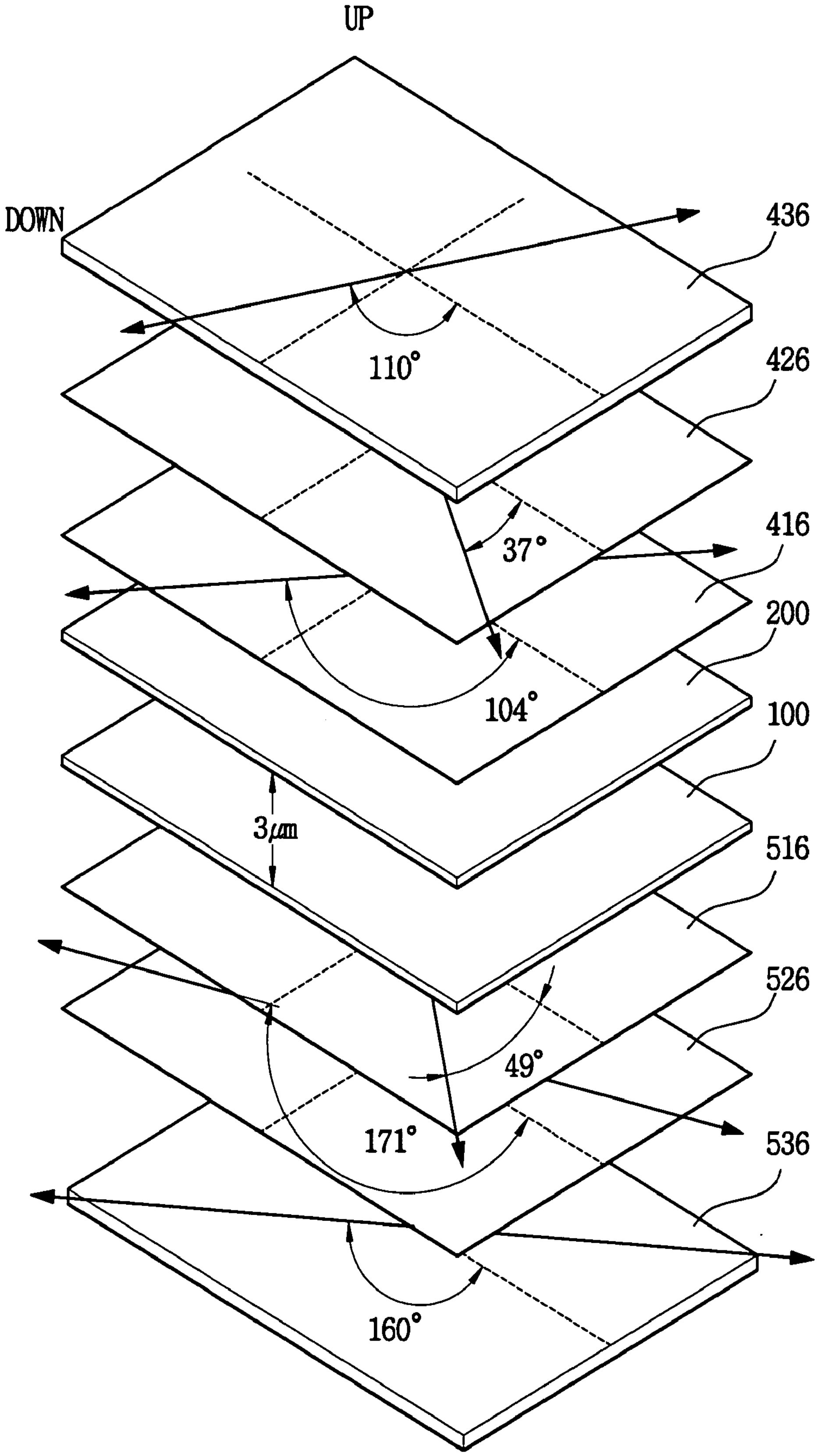

UP
DOWN
436
110°
426
37°
416
200
104°
100
3μm
100
516
526
49°
171°
536
160°

FIG. 11

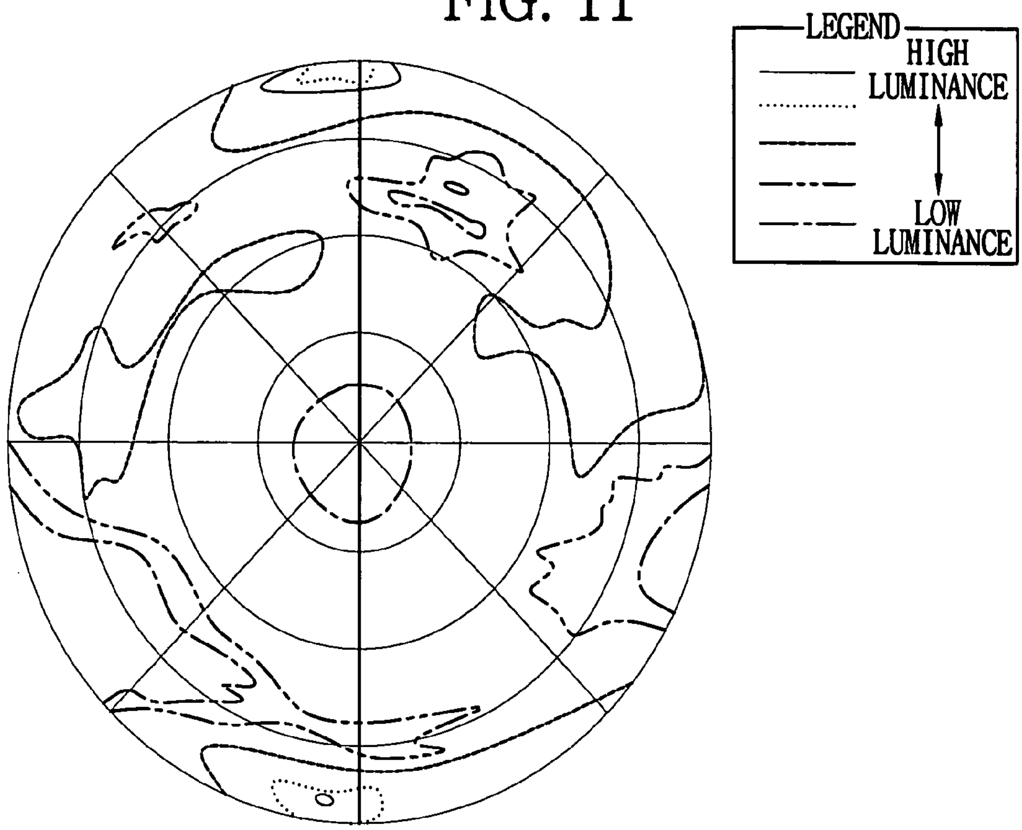

LEGEND
HIGH
LUMINANCE
LOW
LUMINANCE

FIG. 12

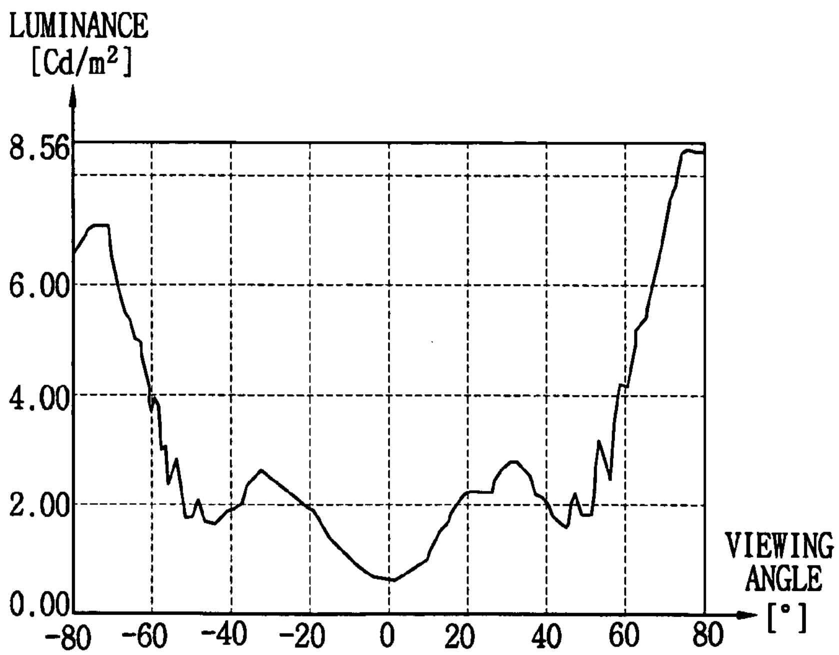

LUMINANCE
[Cd/m²]
8.56
6.00
4.00
2.00
0.00
-80
-60
-40
-20
0
20
40
60
80
VIEWING
ANGLE
[°]

FIG. 13

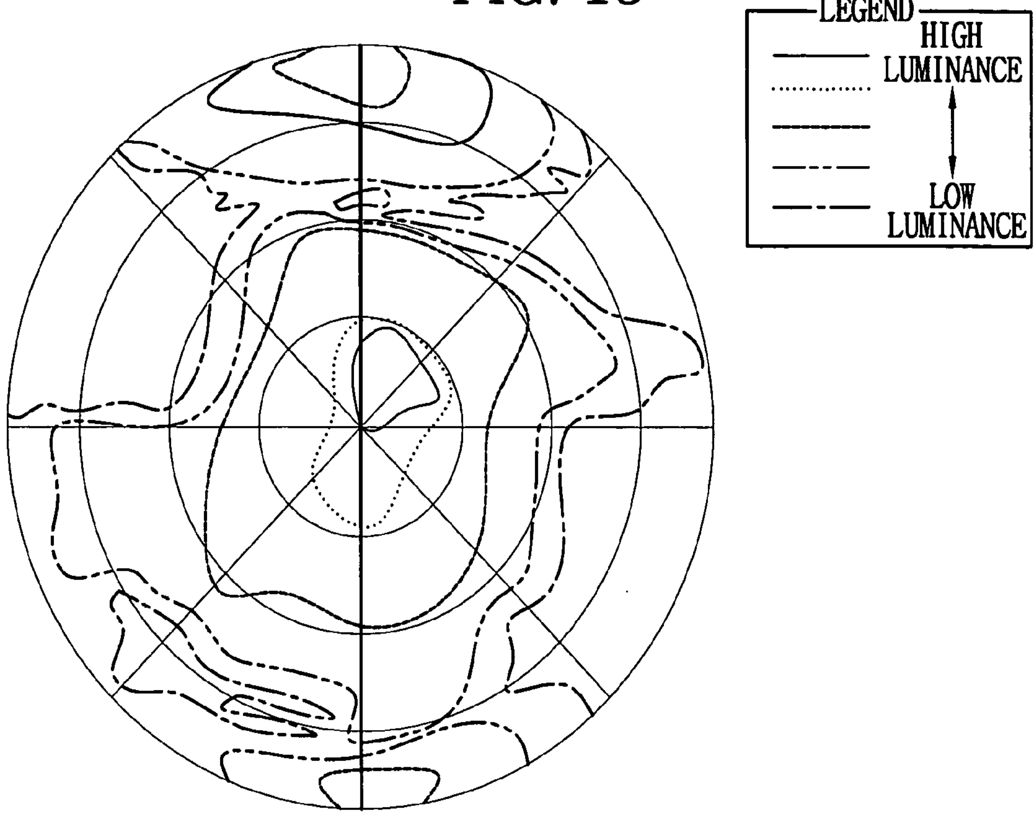
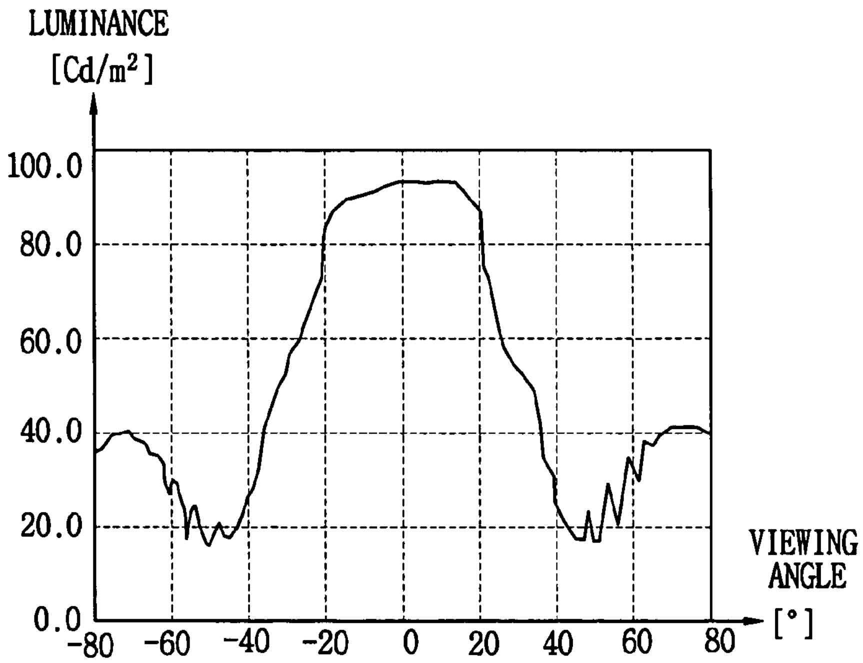

LEGEND
HIGH
LUMINANCE
LOW
LUMINANCE

FIG. 14


LUMINANCE
[Cd/m²]
100.0
80.0
60.0
40.0
20.0
0.0
-80
-60
-40
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0
20
40
60
80
VIEWING
ANGLE
[°]

FIG. 15

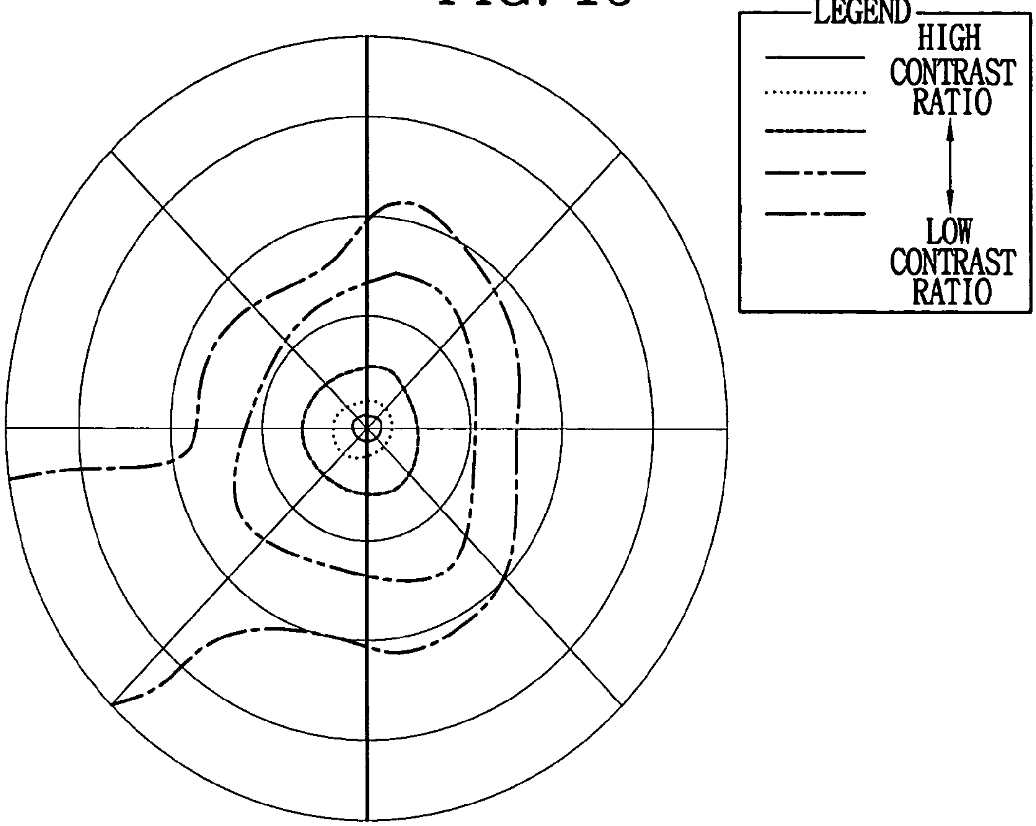

LEGEND
HIGH CONTRAST RATIO
LOW CONTRAST RATIO

FIG. 16

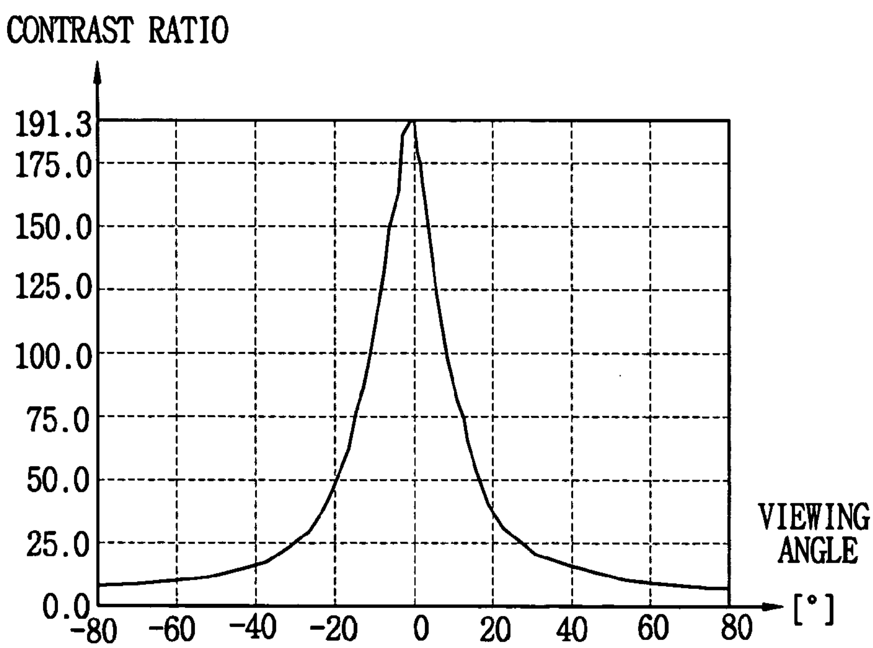

CONTRAST RATIO
191.3
175.0
150.0
125.0
100.0
75.0
50.0
25.0
0.0
-80
-60
-40
-20
0
20
40
60
80
VIEWING ANGLE
[°]

FIG. 17

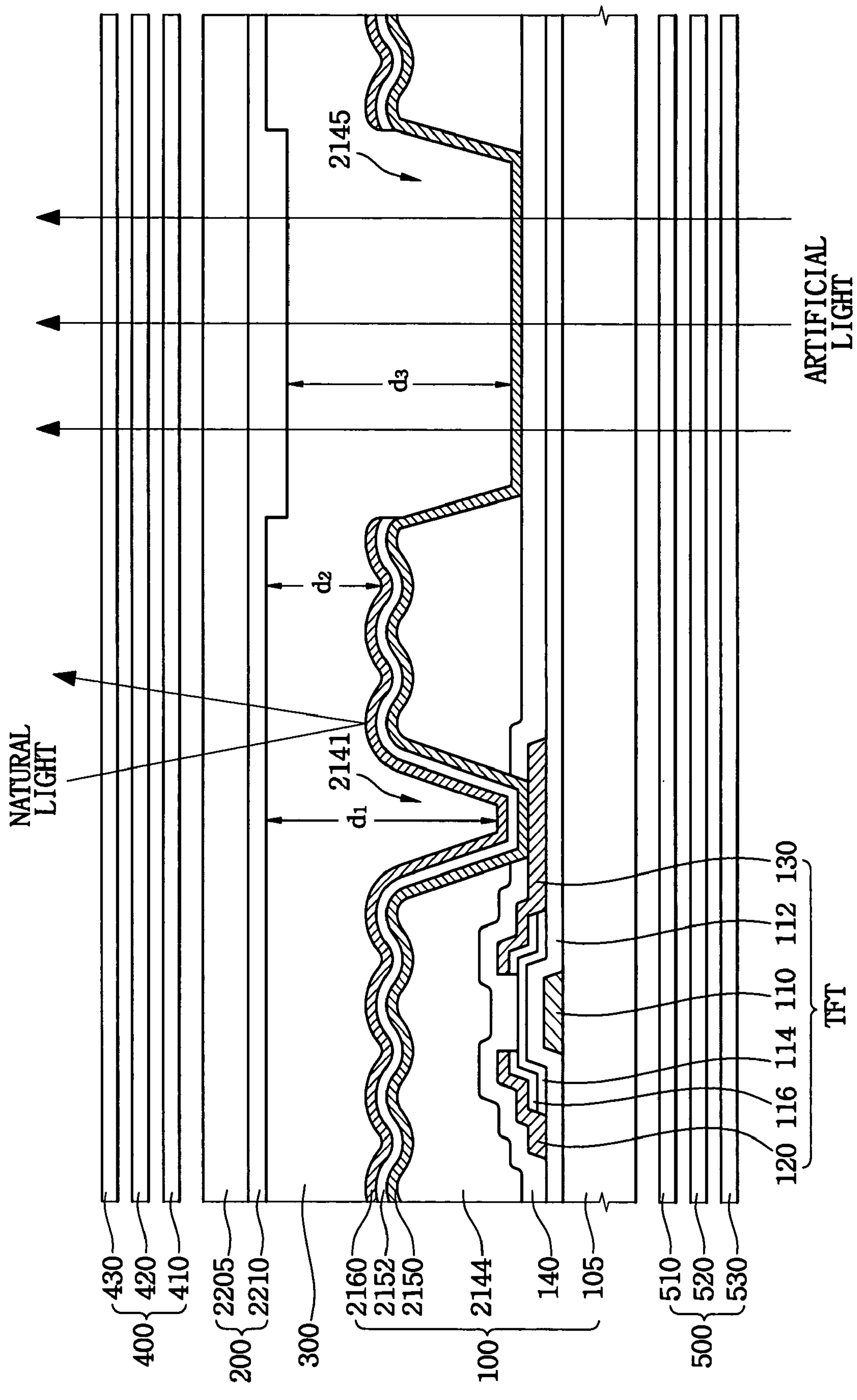

2145
ARTIFICIAL LIGHT
d3
d2
NATURAL LIGHT
2141
d1
130
112
110
114
116
120
TFT
430
420
410
400
2205
2210
200
300
2160
2152
2150
2144
140
105
100
510
520
530
500

FIG. 18

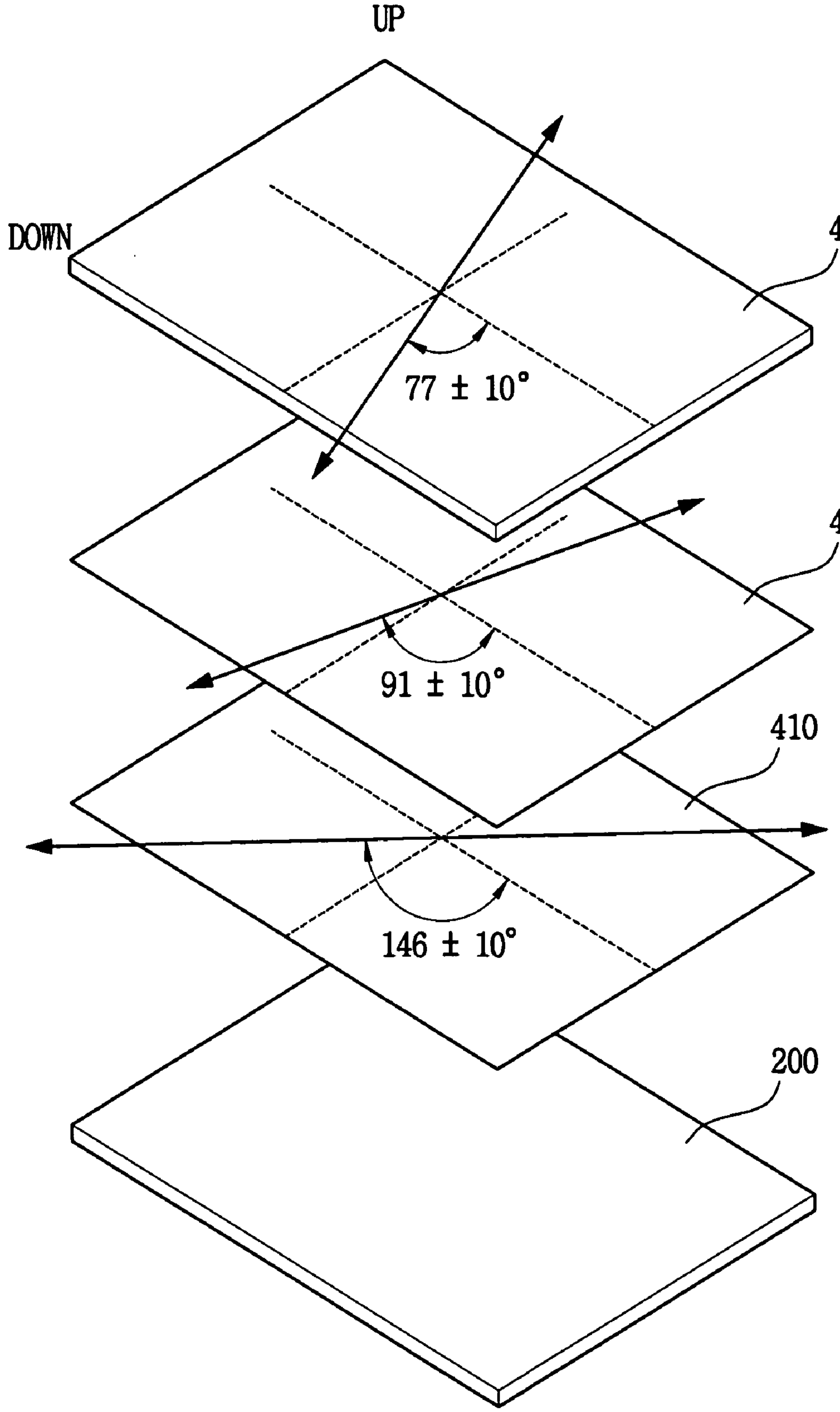


FIG. 19

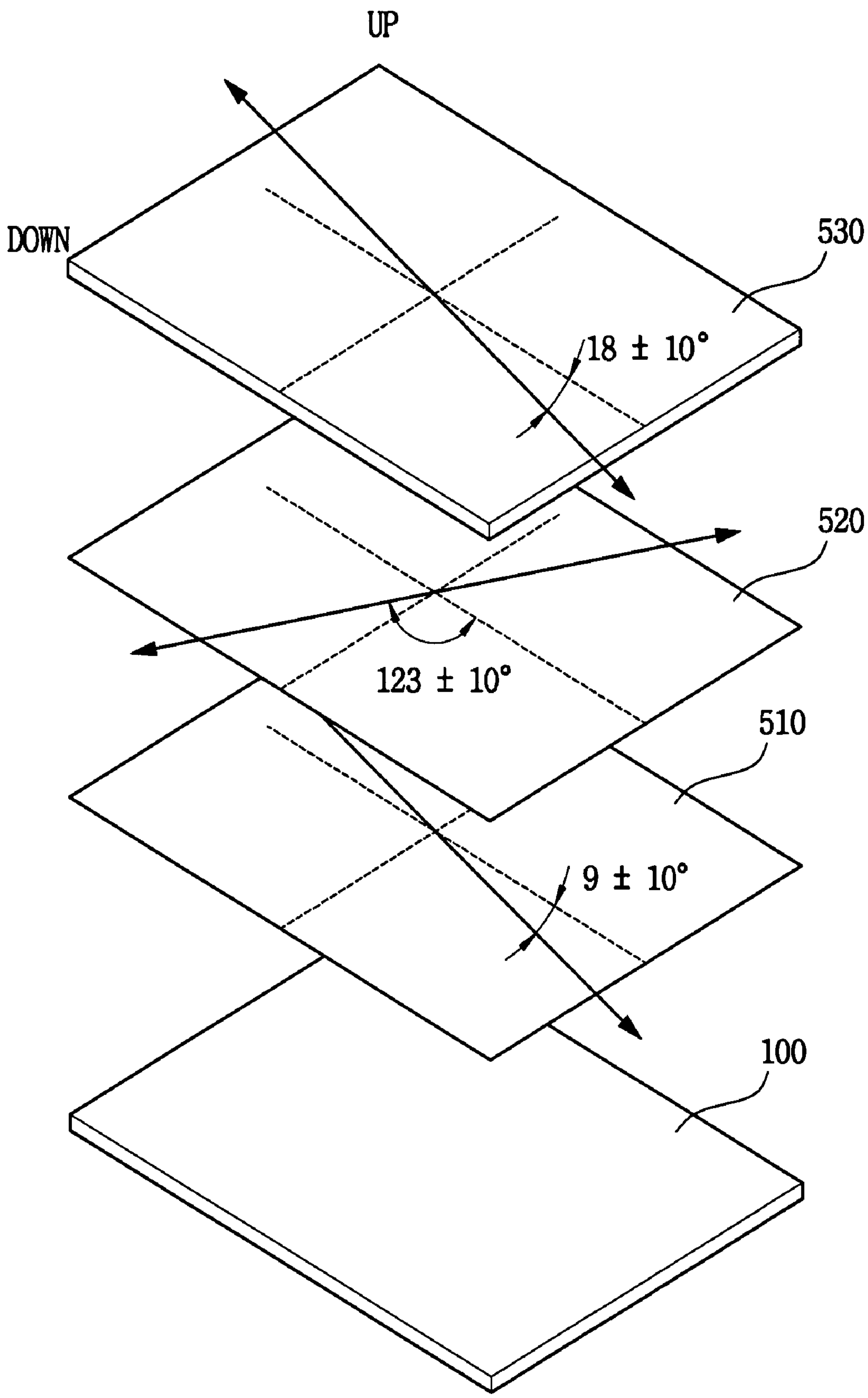


FIG. 20

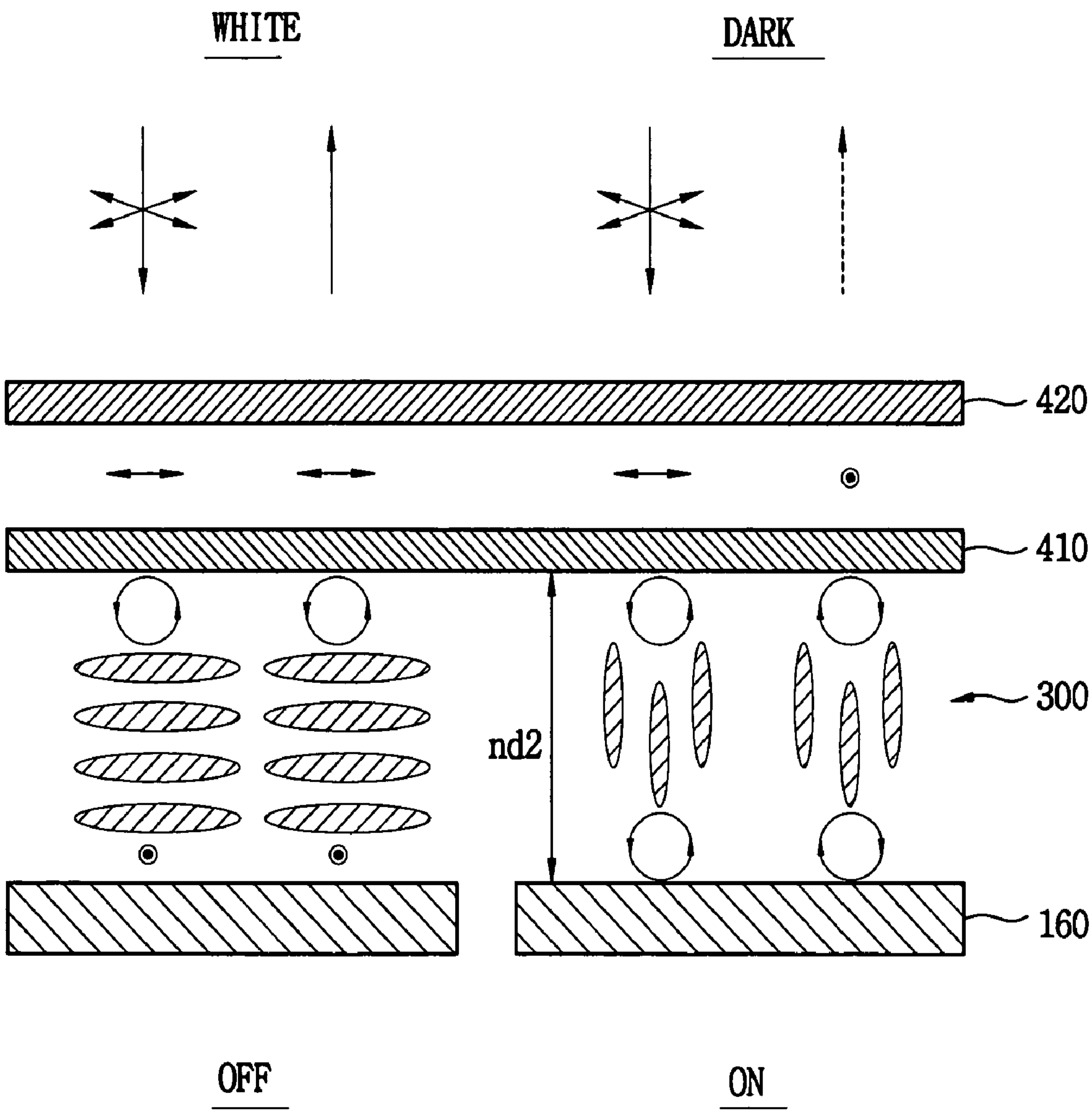


FIG. 21

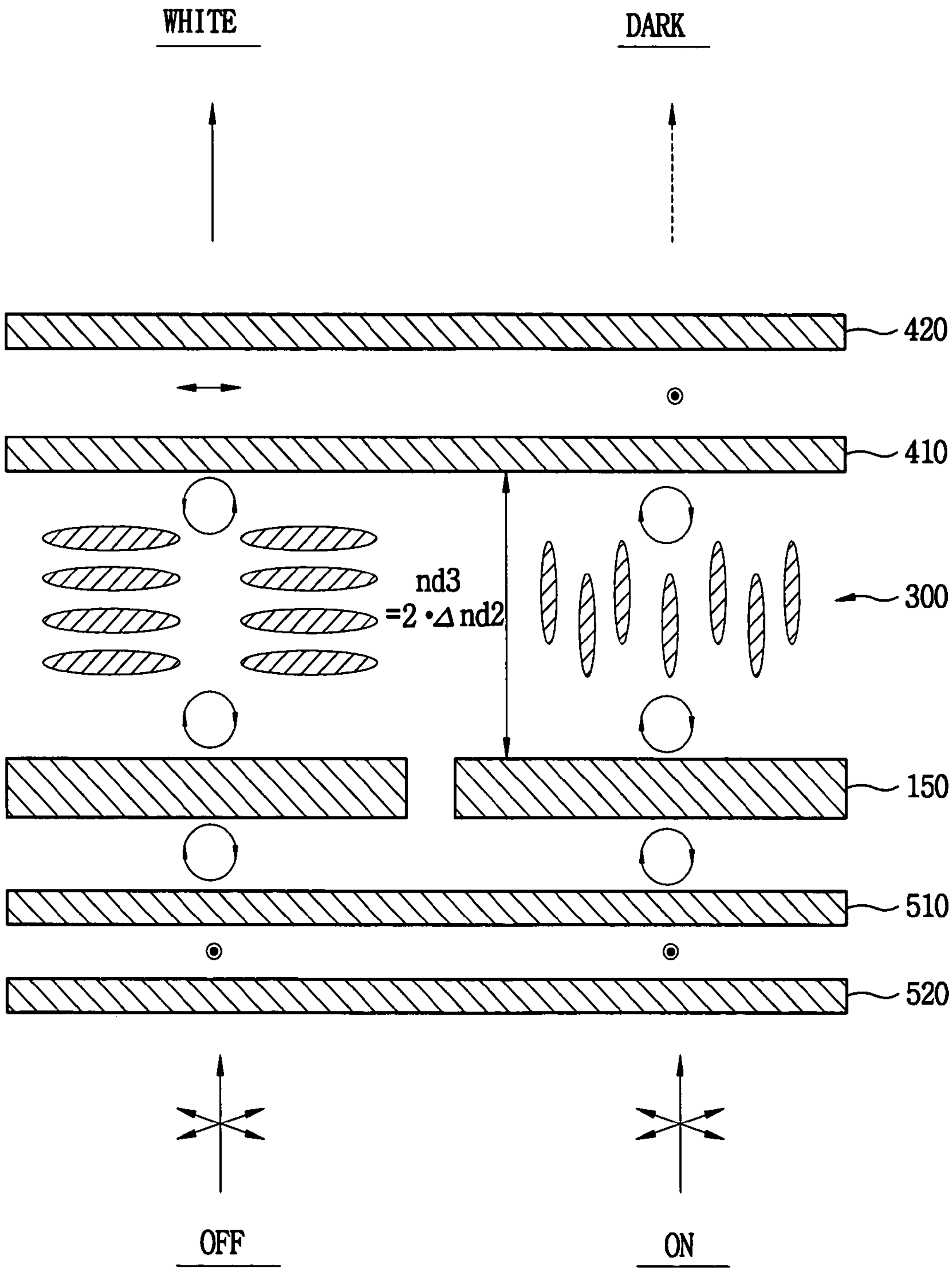


FIG. 22

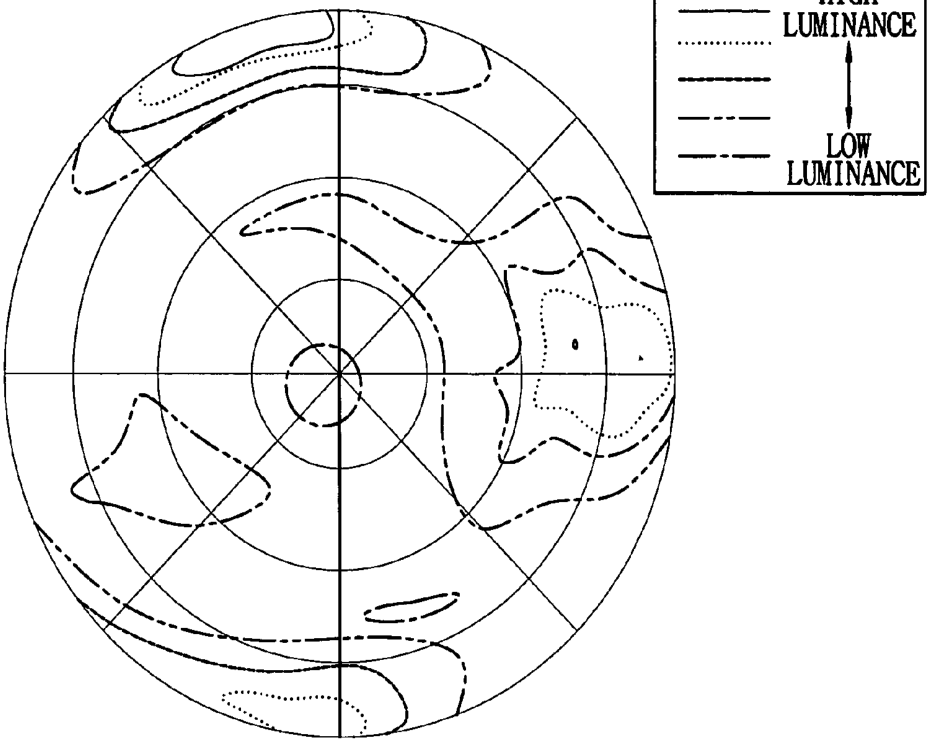

LEGEND
HIGH
LUMINANCE
LOW
LUMINANCE

FIG. 23

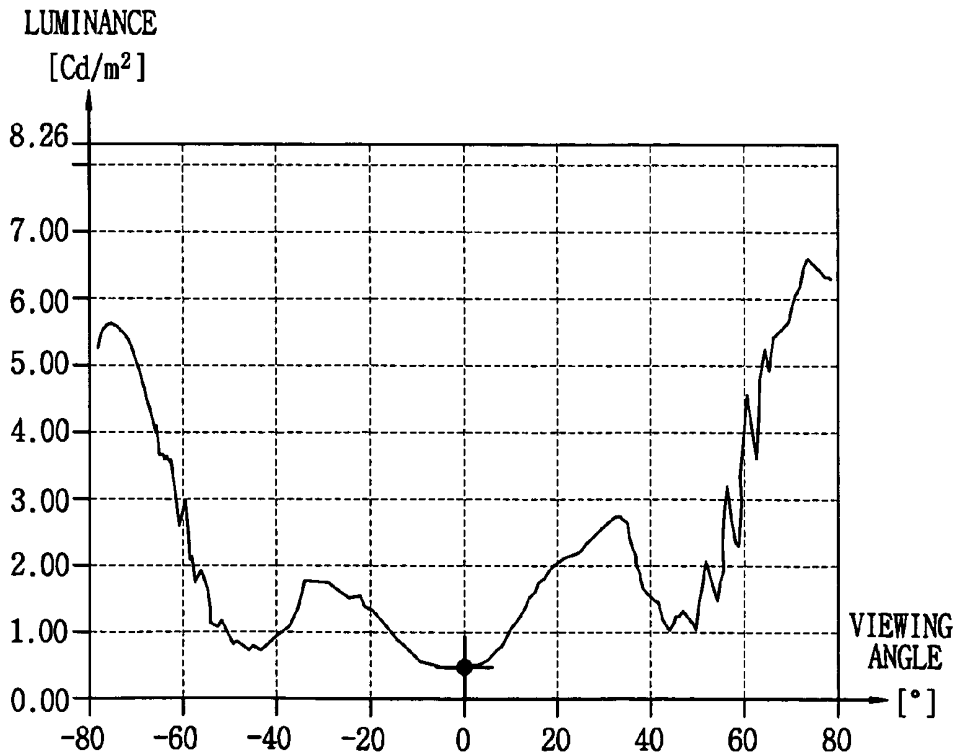

LUMINANCE
[Cd/m2]
8.26
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
VIEWING
ANGLE
[°]
-80
-60
-40
-20
0
20
40
60
80

FIG. 24

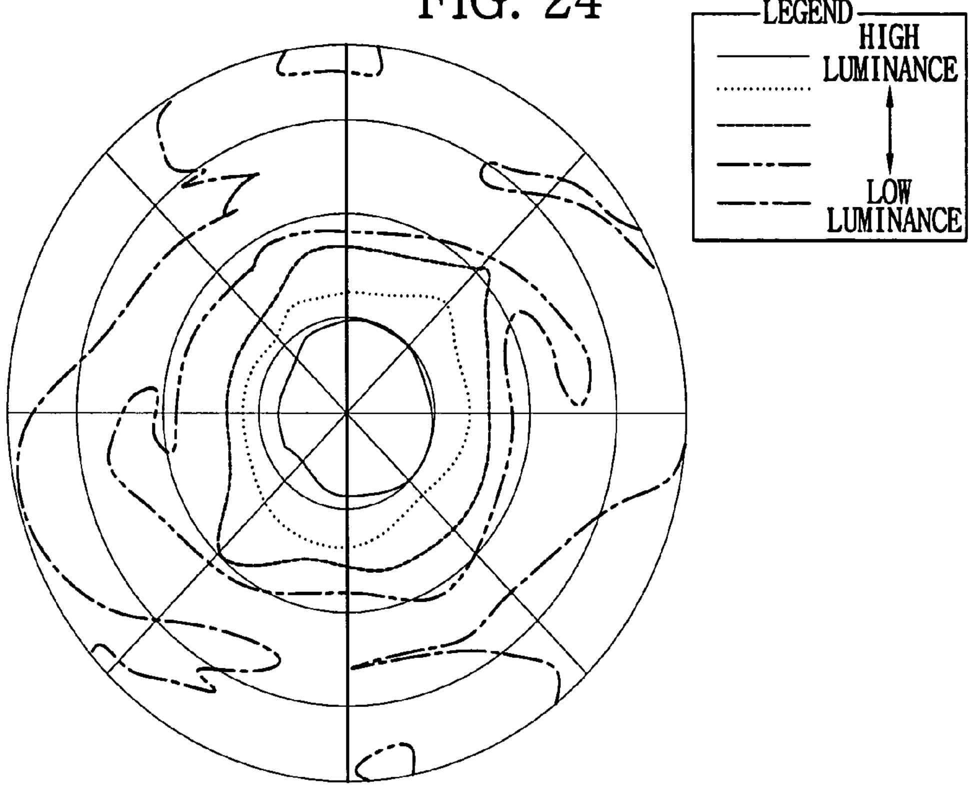

LEGEND
HIGH
LUMINANCE
LOW
LUMINANCE

FIG. 25

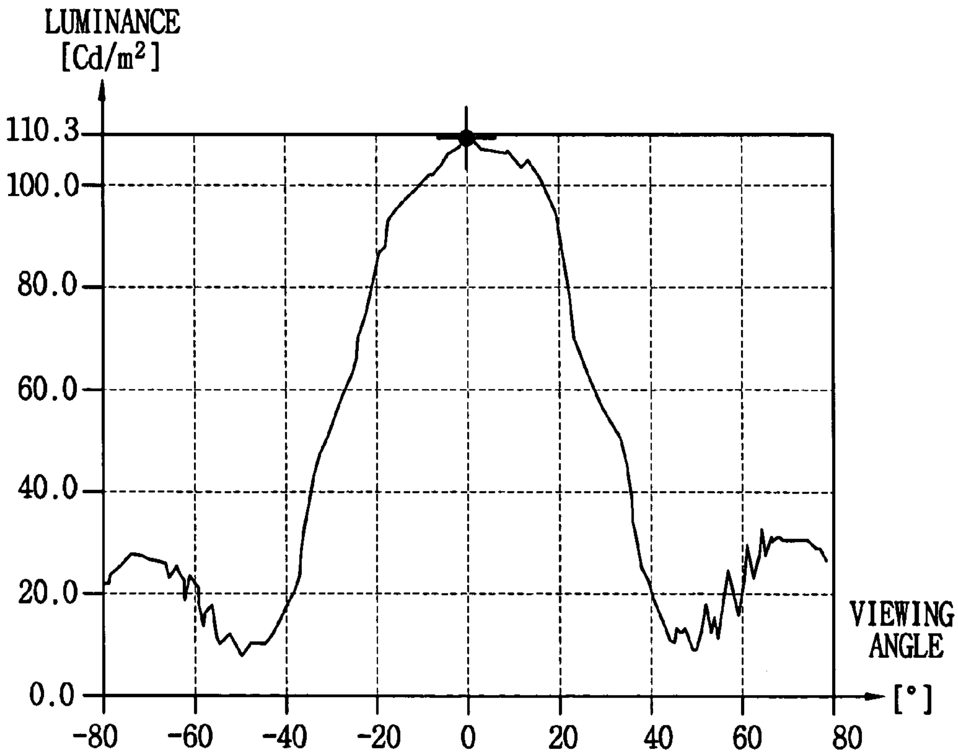

LUMINANCE
[Cd/m²]
110.3
100.0
80.0
60.0
40.0
20.0
0.0
-80
-60
-40
-20
0
20
40
60
80
VIEWING
ANGLE
[°]

FIG. 26

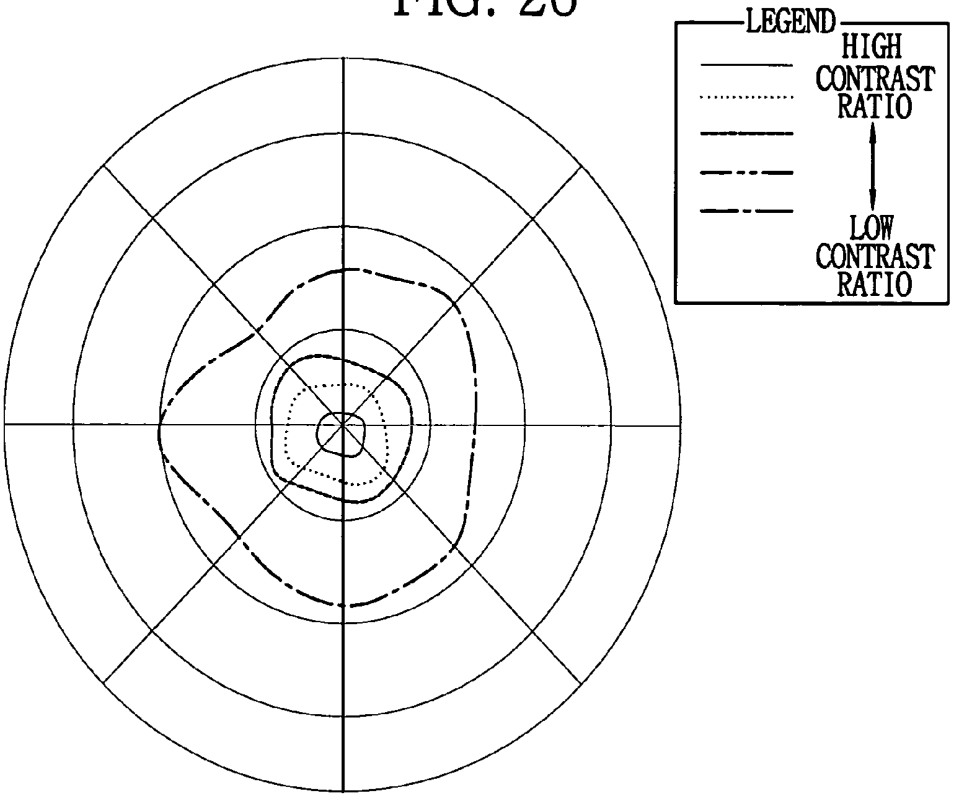
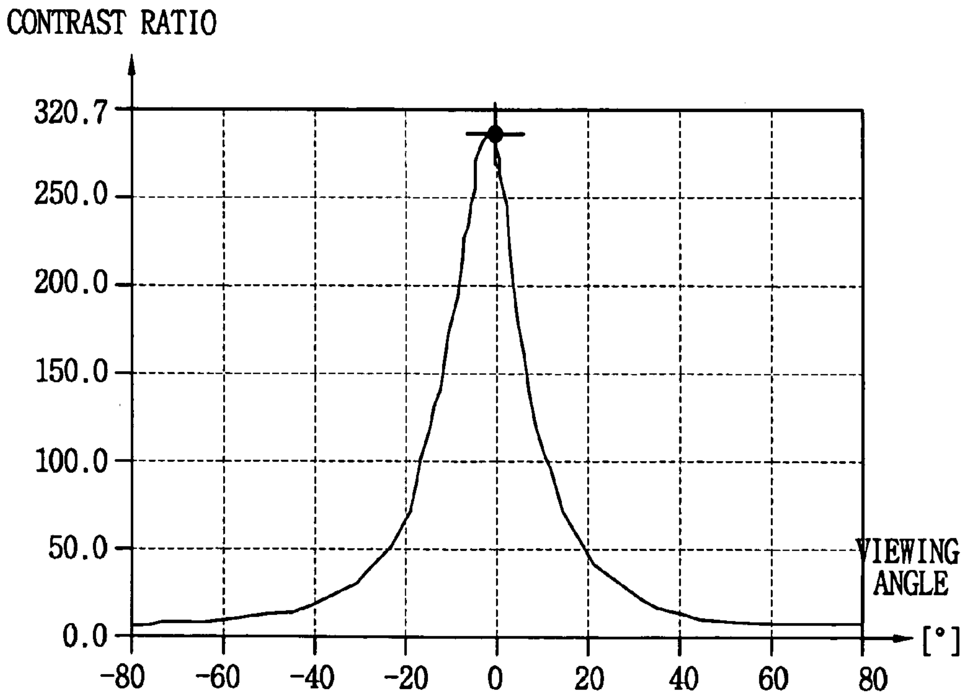

LEGEND
HIGH
CONTRAST
RATIO
LOW
CONTRAST
RATIO

FIG. 27


CONTRAST RATIO
320.7
250.0
200.0
150.0
100.0
50.0
0.0
-80
-60
-40
-20
0
20
40
60
80
VIEWING
ANGLE
[°]

OPTICAL SHEET ASSEMBLY AND LIQUID CRYSTAL DISPLAY APPARATUS HAVING THE SAME

CROSS-REFERENCE OF RELATED APPLICATIONS

The present application claims priority from Korean Patent Application No. 2003-53264, filed on Jul. 31, 2003 and Korean Patent Application No. 2003-53266, filed on Jul. 31, 2003, the disclosure of which is hereby incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical sheet assembly and a liquid crystal display apparatus having the optical sheet assembly. More particularly, the present invention relates to an optical sheet assembly capable of optimizing optical condition and a liquid crystal display (LCD) apparatus having the optical sheet assembly.

2. Description of the Related Art

A reflective type LCD apparatus, in general, displays an image using a natural light that is provided from an exterior to the reflective type LCD apparatus so that an amount of the natural light decreases in a dark place, thereby deteriorating an image display quality.

A transmissive type LCD apparatus displays the image using an artificial light that is generated from a light source, for example, such as a backlight to display the image having a good quality in the dark place. A power consumption of the transmissive type LCD apparatus, however, is greater than that of the reflective type LCD apparatus. Therefore, a size of a portable display apparatus having a battery may be increased.

A transmissive-reflective type LCD apparatus includes a reflection mode and a transmission mode to display the image having good quality using the artificial light in the dark place. The transmissive-reflective type LCD apparatus also displays the image using the natural light in a bright place so that a power consumption of the transmissive-reflective type LCD apparatus is decreased.

The optical condition of the transmissive-reflective type LCD apparatus is determined by the reflection mode so that the transmission mode of the optical condition is designed with respect to a black color. Therefore, a light transmittance of the transmission mode of the transmissive-reflective type LCD apparatus is decreased so that the light transmittance of the transmission mode of the transmissive-reflective type LCD apparatus may be a half of that of the transmissive type LCD apparatus.

BRIEF SUMMARY OF THE INVENTION

The present invention provides an optical film assembly capable of optimizing an optical condition to improve a light transmittance, a contrast ratio and a viewing angle.

The present invention also provides a liquid crystal display (LCD) apparatus having the optical film assembly.

The optical film assembly for a liquid crystal display panel in accordance with an aspect of the present invention includes an upper polarizer, an upper $\lambda/2$ retardation film and an upper $\lambda/4$ retardation film. The liquid crystal display panel includes a liquid crystal layer having a twist angle of about −10 degree to about +10 degree. The upper polarizer is disposed over an upper substrate of the liquid crystal display panel. The upper polarizer includes an absorption axis forming about 37 degree to about 57 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal is disposed adjacent to the upper substrate. The upper $\lambda/2$ retardation film is disposed between the upper substrate and the upper polarizer. The upper $\lambda/2$ retardation film includes a first optical characteristics $\Delta n d1$ of about 250 nm to about 270 nm. A slow axis of the upper $\lambda/2$ retardation film forms at an angle of about 156 degree to about 176 degree in the clockwise direction with respect to the absorption axis. The upper $\lambda/4$ retardation film is disposed between the upper substrate and the upper $\lambda/2$ retardation film. The upper $\lambda/4$ retardation film includes a second optical characteristics $\Delta n d2$ of about 130 nm to about 150 nm. A slow axis of the upper $\lambda/4$ retardation film forms at an angle of about 101 degree to about 121 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', '$d1$' and '$d2$' denote an anisotropy of a refractive index, a thickness of the upper $\lambda/2$ retardation film and a thickness of the upper $\lambda/4$ retardation film, respectively.

The optical film assembly for a liquid crystal display panel in accordance with another aspect of the present invention includes a lower polarizer, a lower $\lambda/2$ retardation film and a lower $\lambda/4$ retardation film. The liquid crystal display panel includes a liquid crystal layer having a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under a lower substrate of the liquid crystal display panel. The lower polarizer includes an absorption axis forming at an angle of about 38 degree to about 58 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal is disposed adjacent to the lower substrate. The lower $\lambda/2$ retardation film is disposed between the lower substrate and the lower polarizer. The lower $\lambda/2$ retardation film includes a first optical characteristics $\Delta n d1$ of about 260 nm to about 280 nm. The slow axis of the lower $\lambda/2$ retardation film forms at an angle of about 65 degree to about 85 degree in the clockwise direction with respect to the absorption axis. The lower $\lambda/4$ retardation film is disposed between the lower substrate and the lower $\lambda/2$ retardation film. The lower $\lambda/4$ retardation film includes a second optical characteristics $\Delta n d2$ of about 120 nm to about 140 nm. A slow axis of the lower $\lambda/4$ retardation film forms at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', '$d1$' and '$d2$' denote an anisotropy of a refractive index, a thickness of the lower $\lambda/2$ retardation film and a thickness of the lower $\lambda/4$ retardation film, respectively.

The optical film assembly for a liquid crystal display panel in accordance with still another aspect of the present invention includes a lower polarizer, a lower $\lambda/2$ retardation film and a lower $\lambda/4$ retardation film. The liquid crystal display panel includes a liquid crystal layer having a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under a lower substrate of the liquid crystal display panel. The lower polarizer includes an absorption axis forming at an angle of about 122 degree to about 142 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal is disposed adjacent to the lower substrate. The lower $\lambda/2$ retardation film is disposed between the lower substrate and the lower polarizer. The lower $\lambda/2$ retardation film includes a first optical characteristics $\Delta n d1$ of about 260 nm to about 280 nm. A slow axis of the lower $\lambda/2$ retardation film forms at an angle of about 95 degree to about 115 degree in the clockwise direction with respect to the absorption axis. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 161 degree to about 181 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The optical film assembly for a liquid crystal display panel in accordance with still another aspect of the present invention includes an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes a liquid crystal layer having a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The upper polarizer is disposed over an upper substrate of the liquid crystal display panel, the upper polarizer including an absorption axis forming at an angle of about 67 degree to about 87 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd**1** of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 81 degree to about 101 degree in the clockwise direction with respect to the horizontal direction. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 136 degree to about 156 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The optical film assembly for a liquid crystal display panel in accordance with still another aspect of the present invention includes a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes a liquid crystal layer having a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under a lower substrate of the liquid crystal display panel. The lower polarizer includes an absorption axis forming at an angle of about 8 degree to about 28 degree in a clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 113 degree to about 133 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The optical film assembly for a liquid crystal display panel in accordance with still another aspect of the present invention includes a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes a liquid crystal layer having a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under a lower substrate of the liquid crystal display panel. The lower polarizer includes an absorption axis forming at an angle of about 152 degree to about 172 degree in a clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 47 degree to about 67 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 120 nm to about 140 nm, a slow axis of the lower λ/4 retardation film forming at an angle of about 161 degree to about 181 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with an aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about −10 degree to about +10 degree. The upper polarizer is disposed over the upper substrate. The upper polarizer includes an absorption axis forming at an angle of about 37 degree to about 57 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal is disposed adjacent to the upper substrate. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd**1** of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 156 degree to about 176 degree in the clockwise direction with respect to the absorption axis. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 101 degree to about 121 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 38 degree to about 58 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal is disposed adjacent to the lower substrate. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 65 degree to about 85 degree in the clockwise direction with respect to the absorption axis. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 132 degree to about 152 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal is disposed adjacent to the lower substrate. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 95 degree to about 115 degree in the clockwise direction with respect to the absorption axis. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 161 degree to about 181 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The upper polarizer is disposed over the upper substrate. The upper polarizer includes an absorption axis forming at an angle of about 67 degree to about 87 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd**1** of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 81 degree to about 101 degree in the clockwise direction with respect to the horizontal direction. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 136 degree to about 156 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 8 degree to about 28 degree in a clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 113 degree to about 133 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 152 degree to about 172 degree in a clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd1 of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 47 degree to about 67 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd2 of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 161 degree to about 181 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd1' and 'd2' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film, a lower λ/4 retardation film, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about −10 degree to about +10 degree. The lower polarizer is disposed under the lower substrate. The lower polarizer includes a first absorption axis forming at an angle of about 8 degree to about 28 degree in a clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd1 of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 113 degree to about 133 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd2 of about 120 nm to about 140 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the horizontal direction. The upper polarizer is disposed over the upper substrate of the liquid crystal display panel. The upper polarizer includes a second absorption axis forming at an angle of about 67 degree to about 87 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The upper λ/2 retardation film disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a third optical characteristics Δnd3 of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 81 degree to about 101 degree in the clockwise direction with respect to the horizontal direction. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a fourth optical characteristics Δnd4 of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 136 degree to about 156 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd1', 'd2', 'd3' and 'd4' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film, a thickness of the lower λ/4 retardation film, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about 62 degree to about 82 degree. The upper polarizer is disposed over the upper substrate. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd1 of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 6 degree to about 26 degree in a clockwise direction with respect to an absorption axis of the upper polarizer. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd2 of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 64 degree to about 84 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd1' and 'd2' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about 50 degree to about 70 degree. The upper polarizer is disposed over the upper substrate. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd1 of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 94 degree to about 114 degree in a clockwise direction with respect to an absorption axis of the upper polarizer. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd2 of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 159 degree to about 179 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd1' and 'd2' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about 50 degree to about 70 degree. The upper polarizer is disposed over the upper substrate. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd1 of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at angle of about 97 degree to about 117 degree in a clockwise direction with respect to an absorption axis of the upper polarizer. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 164 degree to about 184 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about 50 degree to about 70 degree. The upper polarizer is disposed over the upper substrate. The upper polarizer includes an absorption axis forming at an angle of about 100 degree to about 120 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd**1** of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 27 degree to about 47 degree in the clockwise direction with respect to the horizontal direction. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 94 degree to about 114 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel including an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 230 degree to about 310 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about 62 degree to about 82 degree. The upper polarizer is disposed over the upper substrate. The upper polarizer includes an absorption axis forming at an angle of about 140 degree to about 160 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd**1** of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 156 degree to about 176 degree in the clockwise direction with respect to the horizontal direction. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 34 degree to about 54 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, an upper polarizer, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about 50 degree to about 70 degree. The upper polarizer is disposed over the upper substrate. The upper polarizer includes an absorption axis forming at an angle of about 114 degree to about 134 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The upper λ/2 retardation film is disposed between the upper substrate and the upper polarizer. The upper λ/2 retardation film includes a first optical characteristics Δnd**1** of about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film forms at an angle of about 38 degree to about 58 degree in the clockwise direction with respect to the horizontal direction. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. The upper λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film forms at an angle of about 103 degree to about 123 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film, a lower λ/4 retardation film, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about 62 degree to about 82 degree. The lower polarizer is disposed under the lower substrate. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 135 nm to about 155 nm. The upper λ/2 retardation film is disposed over the upper substrate. A slow axis of the upper λ/2 retardation film forms at an angle of about 155 degree to about 175 degree in a clockwise direction with respect to an absorption axis of the lower polarizer. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. A slow axis of the upper λ/4 retardation film forms at an angle of about 96 degree to about 116 degree in the clockwise direction with respect to the absorption axis of the lower polarizer. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film, a lower λ/4 retardation film, an upper λ/2 retardation film and an upper λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about 50 degree to about 70 degree. The lower polarizer is disposed under the lower substrate. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. The upper λ/2 retardation film is disposed over the upper substrate. A slow axis of the upper λ/2 retardation film forms at an angle of about 28 degree to about 48 degree in a clockwise direction with respect to an absorption axis of the lower polarizer. The upper λ/4 retardation film is disposed between the upper substrate and the upper λ/2 retardation film. A slow axis of the upper λ/4 retardation film forms at an angle of about 94 degree to about 114 degree in the clockwise direction with respect to the absorption axis of the lower polarizer. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about 50 degree to about 70 degree. The lower polarizer is disposed under the lower substrate. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 1 degree to about 21 degree in a clockwise direction with respect to an absorption axis of the lower polarizer. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 59 degree to about 79 degree in the clockwise direction with respect to the absorption axis. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 230 degree to about 310 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about 62 degree to about 82 degree. The lower polarizer is disposed over the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 110 degree to about 130 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 95 degree to about 115 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 135 nm to about 155 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 36 degree to about 56 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about 50 degree to about 70 degree. The lower polarizer is disposed over the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 136 degree to about 156 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 152 degree to about 172 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 38 degree to about 58 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The liquid crystal display apparatus in accordance with still another aspect of the present invention includes a liquid crystal display panel, a lower polarizer, a lower λ/2 retardation film and a lower λ/4 retardation film. The liquid crystal display panel includes an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a viewing angle of about 170 degree to about 250 degree in a clock direction with respect to a horizontal direction of the liquid crystal display panel and a twist angle of about 50 degree to about 70 degree. The lower polarizer is disposed over the lower substrate. The lower polarizer includes an absorption axis forming at an angle of about 150 degree to about 170 degree in the clockwise direction with respect to the horizontal direction of the liquid crystal display panel. The lower λ/2 retardation film is disposed between the lower substrate and the lower polarizer. The lower λ/2 retardation film includes a first optical characteristics Δnd**1** of about 260 nm to about 280 nm. A slow axis of the lower λ/2 retardation film forms at an angle of about 161 degree to about 181 degree in the clockwise direction with respect to the horizontal direction. The lower λ/4 retardation film is disposed between the lower substrate and the lower λ/2 retardation film. The lower λ/4 retardation film includes a second optical characteristics Δnd**2** of about 130 nm to about 150 nm. A slow axis of the lower λ/4 retardation film forms at an angle of about 39 degree to about 59 degree in the clockwise direction with respect to the horizontal direction. Here, 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

The LCD apparatus includes a reflective type LCD apparatus, a transmissive type LCD apparatus or a transmissive-reflective type LCD apparatus having a multi-cell gap.

Therefore, the optical conditions of the optical film assembly and the LCD apparatus are optimized to improve the light transmittance, the contrast ratio and the viewing angle of the LCD apparatus. In addition, the viewing angle is uniformized.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the accompanying drawings, in which:

FIG. **1** is a cross-sectional view showing a transmissive-reflective type liquid crystal display (LCD) apparatus in accordance with an exemplary embodiment of the present invention;

FIG. **2** is a graph showing a relationship between a luminance and a voltage applied to the LCD apparatus shown in FIG. **1**;

FIG. **3** is an exploded perspective view showing a transmissive-reflective type LCD apparatus in accordance with an exemplary embodiment of the present invention;

FIG. **4** is a graph showing a relationship between a luminance and a viewing angle when the LCD apparatus shown in FIG. **3** displays black color;

FIG. **5** is a graph showing a relationship between a luminance and a viewing angle when the LCD apparatus shown in FIG. **3** displays white color;

FIG. **6** is a graph showing a relationship between a contrast ratio and a viewing angle of the LCD apparatus shown in FIG. **3**;

FIG. **7** is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;

FIG. **8** is an exploded perspective view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;

FIG. **9** is an exploded perspective view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;

FIG. **10** is an exploded perspective view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;

FIGS. **11** and **12** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays black color;

FIGS. **13** and **14** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays white color;

FIGS. **15** and **16** are graphs showing a relationship between a contrast ratio and a viewing angle of an LCD apparatus in accordance with another exemplary embodiment of the present invention;

FIG. **17** is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;

FIG. **18** is an exploded perspective view showing an upper optical film assembly of the LCD apparatus shown in FIG. **17**;

FIG. **19** is an exploded perspective view showing a lower optical film assembly of the LCD apparatus shown in FIG. **17**;

FIG. **20** is a cross-sectional view showing a reflection mode of the LCD apparatus shown in FIG. **17**;

FIG. **21** is a cross-sectional view showing a transmission mode of the LCD apparatus shown in FIG. **17**;

FIGS. **22** and **23** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays black color;

FIGS. **24** and **25** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays white color; and

FIGS. **26** and **27** are graphs showing a relationship between a contrast ratio and a viewing angle of an LCD apparatus in accordance with another exemplary embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be understood that the exemplary embodiments of the present invention described below may be varied modified in many different ways without departing from the inventive principles disclosed herein, and the scope of the present invention is therefore not limited to these particular following embodiments. Rather, these embodiments are provided so that this disclosure will be through and complete, and will fully convey the concept of the invention to those skilled in the art by way of example and not of limitation.

Hereinafter, the present invention will be described in detail with reference to the accompanying drawings.

FIG. **1** is a cross-sectional view showing a transmissive-reflective type liquid crystal display (LCD) apparatus in accordance with an exemplary embodiment of the present invention.

Referring to FIG. **1**, the transmissive-reflective type LCD apparatus **10** includes a lower polarizer **11**, a lower λ/2 retardation film **12** disposed on the lower polarizer **11**, a lower λ/4 retardation film **13** disposed on the lower λ/2 retardation film **12**, a reflecting plate **14** disposed on the lower λ/4 retardation film **13**, a liquid crystal layer **15** disposed on the reflecting plate **14**, a color filter **16** disposed on the liquid crystal layer **15**, an upper λ/4 retardation film **17** disposed on the color filter **16**, an upper λ/2 retardation film **18** disposed on the upper λ/4 retardation film **17** and an upper polarizer **19** disposed on the upper λ/2 retardation film **18**. When a linearly polarized light passes through the retardation films **12**, **13**, **17** and **18**, the linearly polarized light may be converted into an elliptically polarized light or a circularly polarized light. Also, when the elliptically polarized light or the circularly polarized light passes through the retardation films **12**, **13**, **17** and **18**, the elliptically polarized light or the circularly polarized light may be converted into the linearly polarized light. In addition, when the linearly polarized light passes through the retardation films **12**, **13**, **17** and **18**, the direction of the linearly polarized light may be changed. In particular, when the linearly polarized light passes through the λ/2 retardation films **12** and **18**, the direction of the linearly polarized light is changed. In addition, when the linearly polarized light and the circularly polarized light pass through the λ/4 retardation films **13** and **17**, the linearly polarized light and the circularly polarized light are converted into the circularly polarized light and the linearly polarized light, respectively.

In a transmission mode, an artificial light passes through the lower polarizer **11**, the lower λ/2 retardation film **12**, the lower λ/4 retardation film **13**, the liquid crystal layer **15**, the color filter **16**, the upper λ/4 retardation film **17**, the upper λ/2 retardation film **18** and the upper polarizer **19**, in sequence, to display the image.

In a reflection mode, a natural light passes through the upper polarizer **19**, the upper λ/2 retardation film **18**, the upper λ/4 retardation film **17**, the color filter **16** and the liquid crystal layer **15**, in sequence, so that the natural light that passes through the liquid crystal layer **15** is reflected from the reflecting plate **14**. The reflected light passes through the liquid crystal layer **15**, the color filter **16**, the upper λ/4 retardation film **17**, the upper λ/2 retardation film **18** and the upper polarizer **19**, in sequence, to display the image.

FIG. **2** is a graph showing a relationship between a luminance and a voltage applied to the LCD apparatus shown in FIG. **1**.

Referring to FIG. **2**, when the LCD apparatus includes a normally white mode and a low voltage is applied to the LCD apparatus, the LCD apparatus displays white color. When the LCD apparatus includes the normally white mode and a high voltage that is higher than a driving voltage of the liquid crystal layer **15** is applied to the LCD apparatus, the LCD apparatus displays black color. A shape of a curve showing a relationship between a voltage applied to the LCD apparatus and a luminance of the transmission mode is substantially similar to that of a curve showing a relationship between the voltage applied to the LCD apparatus and a luminance of the reflection mode.

FIG. **3** is an exploded perspective view showing a transmissive-reflective type LCD apparatus in accordance with an exemplary embodiment of the present invention. A reference direction of an LCD panel of the LCD apparatus is a horizontal direction with respect to the LCD panel. A reference wavelength of a light is about 550 nm.

Referring to FIG. **3**, the liquid crystal layer **15** (shown in FIG. **1**) is disposed between an array substrate **15**T and a color filter substrate **15**C. An anisotropy Δn of a reflective index of the liquid crystal layer **15** is about 0.078 ZSM5342 with reference to a light having a wavelength of about 589 nm. The 'ZSM5342' is a unit of the anisotropy Δn of the reflective index. A thickness d**1** of the liquid crystal layer **15** is about 3.0 μm. A twist angle of the liquid crystal layer **15** is about 72 degree. A viewing angle of the liquid crystal layer **15** is about 8 degree. A direction of a major axis of a liquid crystal of the liquid crystal layer **15**, and the liquid crystal is disposed adjacent to the lower substrate may be the reference direction. The upper λ/4 retardation film **17** is disposed on the color filter substrate **15**C. A second optical characteristics Δnd**2** of the upper λ/4 retardation film **17** is about 140 nm with reference to a reference light whose wavelength is about 550 nm. A slow axis of the upper λ/4 retardation film **17** forms at an angle of about 74 degree with respect to the reference direction in a clockwise direction. A velocity of the light that passes through the upper λ/4 retardation film **17** along the slow axis is slower than that of the light that passes through the upper λ/4 retardation film **17** along a fast axis. The upper λ/2 retardation film **18** is disposed on the upper λ/4 retardation film **17**. A third optical characteristics Δnd**3** of the upper λ/2 retardation film **18** is about 260 nm with reference to the reference light whose wavelength is about 550 nm. A slow axis of the upper λ/2 retardation film **18** forms at an angle of about 156 degree to about 176 degree with respect to the reference direction in a clockwise direction. The upper polarizer **19** is disposed on the upper λ/2 retardation film **18**. An absorption axis of the upper polarizer **19** forms at an angle of about 140 degree to about 160 degree with respect to the reference direction of the LCD panel in the clockwise direction.

The lower λ/4 retardation film **13** is disposed under the array substrate **15**T. A fourth optical characteristics Δnd**4** of the lower λ/4 retardation film **13** is about 145 nm with respect to the reference wavelength. A slow axis of the lower λ/4 retardation film **13** forms at an angle of about 46 degree with respect to the reference direction in the clockwise direction. The lower λ/2 retardation film **12** is disposed under the lower λ/4 retardation film **13**. A fifth optical characteristics Δnd**5** of the lower λ/2 retardation film **12** is about 270 nm with respect to the reference wavelength. A slow axis of the lower λ/2 retardation film **12** forms at an angle of about 105 degree with respect to the reference direction in the clockwise direction. The lower polarizer **11** is disposed under the lower λ/2 retardation film **12**. An absorption axis of the lower polarizer **11** forms at an angle of about 120 degree with respect to the reference direction in the clockwise direction.

FIG. **4** is a graph showing a relationship between a luminance and a viewing angle when the LCD apparatus shown in FIG. **3** displays black color. FIG. **5** is a graph showing a relationship between a luminance and a viewing angle when the LCD apparatus shown in FIG. **3** displays white color. FIG. **6** is a graph showing a relationship between a contrast ratio and a viewing angle of the LCD apparatus shown in FIG. **3**.

Referring to FIG. **4**, the black color is displayed in a direction at an angle of about 90 degree with respect to the reference direction in the clockwise direction. The black color is not displayed in a direction at an angle of about 90 degree with respect to the reference direction in a counter-clockwise direction. In particular, the white color having a luminance of about 17.5 [Cd/m^3] is displayed in a direction at an angle of about 60 degree to about 80 degree with respect to the reference direction in the counter-clockwise direction.

Referring to FIG. **5**, the white color is displayed in a direction substantially perpendicular to the reference direction.

Referring to FIG. **6**, an image having high contrast ratio is displayed at an angle of about 90 degree with respect to the reference direction so that a contrast ratio of an upper portion of the LCD panel is different from that of a lower portion of the LCD panel.

Therefore, the display quality of the transmissive-reflective LCD apparatus having a unit cell-gap may be deteriorated.

FIG. **7** is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention. The LCD apparatus includes a transmissive-reflective LCD apparatus having a unit cell-gap and a top indium tin oxide (ITO) type.

Referring to FIG. **7**, the LCD apparatus includes an array substrate **100**, a color filter substrate **200**, a liquid crystal layer **300**, an upper optical film assembly **400** and a lower optical film assembly **500**. The liquid crystal layer **300** is disposed between the array substrate **100** and the color filter substrate **200**. The upper optical film assembly **400** is disposed on the color filter substrate **200**. The lower optical film assembly **500** is disposed under the array substrate **100**.

The array substrate **100** includes a first transparent plate **105**, a switching element that includes a thin film transistor (TFT), a passivation layer **140** and an organic insulating layer **144**. The switching element is formed on the first transparent plate **105**. The switching element includes a gate electrode **110**, a gate insulating layer **112** that is formed on the first transparent plate **105** having the gate electrode **110**, a semiconductor layer **114**, an ohmic contact layer **116**, a source electrode **120** and a drain electrode **130**. The passivation layer **140** is formed on the first transparent plate **105** having the switching element. The passivation layer **140** includes a first opening, through which the drain electrode **130** is partially exposed. The organic insulating layer **144** is formed on the passivation layer **140**. The organic insulating layer **144** has a second opening, through which the drain electrode **130** is partially exposed. The second opening is disposed on the first opening. The first and second openings form a first contact hole **141**. Convex and concave portions may be formed on the organic insulating layer **144** to improve a reflective index of a reflecting plate **160**.

The array substrate **100** further includes a pixel electrode **150**, an insulating interlayer **152** and the reflecting plate **160**. The pixel electrode **150** is electrically connected to the drain electrode **130** through the first contact hole **141**. The switching element is formed on a portion of the pixel electrode **130**, which corresponds to the switching element. The reflecting plate **160** is formed on the insulating interlayer **152**. The array substrate **100** further includes a reflection region and a transmission window **145**. The reflecting plate **160** is disposed in the reflection region. The reflecting plate **160** defines the transmission window **145**.

The pixel electrode **150** includes a transparent conductive material, for example, such as indium tin oxide (ITO), tin oxide (TO), indium zinc oxide (IZO), zinc oxide (ZO), etc. A capacitor line is formed at a position spaced apart from the switching element to form a storage capacitor (Cst, not shown). The capacitor line is disposed under the pixel electrode **150**.

The reflecting plate **160** is formed on the insulating interlayer **152** corresponding to the reflection region. The reflecting plate **160** is electrically insulated from the pixel electrode **150** by the insulating interlayer **152**. Alternatively, a portion of the insulating interlayer **152** is removed so that the reflecting plate **160** is electrically connected to the pixel electrode **150**. In addition, the insulating interlayer **152** may be omitted, and a conductive layer (not shown) may be disposed between the reflecting plate **160** and the pixel electrode **150**.

The color filter substrate **200** includes a second transparent plate **205**, a black matrix (not shown), a color filter **210** and an overcoating layer (not shown). The black matrix is formed on the second transparent plate **205** to define red (R), green (G) and blue (B) pixel regions. The color filter **210** is formed in the red (R), green (G) and the blue (B) pixel regions. The overcoating layer is coated on the second transparent plate **205** having the black matrix and the color filter **210** to protect the black matrix and the color filter **210**. Alternatively, portions of the color filter **210** may be overlapped with one another to form the black matrix. A common electrode (not shown) may also be formed on the overcoating layer.

The liquid crystal layer **300** is formed between the array substrate **100** and the color filter substrate **200**. A liquid crystal of the liquid crystal layer **300** varies an arrangement in response to an electric field applied between the pixel electrode **150** of the array substrate **100** and the common electrode of the color filter substrate **200**, and thus a light transmittance of a natural light that passes through the color filter substrate **200** or an artificial light that passes through the transmission window **145** may be changed. A direction of a major axis of a liquid crystal of the liquid crystal layer **300**, which is disposed adjacent to the lower substrate, may be the reference direction.

The liquid crystal layer **300** may have a homogeneous alignment mode. When the liquid crystal layer **300** has the homogeneous alignment mode, a twist angle of the liquid crystal layer **300** is about 0 degree.

The array substrate **100** may include a first alignment layer (not shown) so that the first alignment layer is rubbed in a first rubbing direction that is in substantially parallel with a horizontal direction. The color filter substrate **200** may also include a second alignment layer (not shown) so that the second alignment layer is rubbed in a second rubbing direction that is in substantially opposite to the first rubbing direction. Alternatively, the second alignment layer may be rubbed in a second rubbing direction that is in substantially parallel with the horizontal direction, and the first alignment layer may be rubbed in a first rubbing direction that is in substantially opposite to the second rubbing direction.

In this exemplary embodiment, the array substrate **100** includes the pixel electrode **150**, and the color filter substrate **200** includes the common electrode. Alternatively, the LCD apparatus may include a coplanar electrode (CE) mode, for example, such as an in-plane switching (IPS) mode, a fringe field switching (FFS) mode, etc., so that the color filter substrate **200** includes the common electrode.

In this exemplary embodiment, the LCD apparatus includes the transmissive-reflective LCD apparatus. Alternatively, the LCD apparatus may include a reflective type LCD apparatus having a switching element, a pixel electrode that is electrically connected to a drain electrode of the switching element and a reflecting plate that is formed on the pixel electrode to reflect the natural light.

In this exemplary embodiment, the LCD apparatus includes the top indium tin oxide (ITO) type. Alternatively, the LCD apparatus may include a bottom ITO type. A pixel electrode of the bottom ITO type LCD apparatus is formed under the organic insulating layer.

The upper optical film assembly **400** includes an upper $\lambda/4$ retardation film **410** disposed on the color filter substrate **200**, an upper $\lambda/2$ retardation film **420** disposed on the upper $\lambda/4$ retardation film **420** and an upper polarizer **430** disposed on the upper $\lambda/2$ retardation film **420**. The lower optical film assembly **500** includes a lower $\lambda/4$ retardation film **510** disposed under the array substrate **100**, a lower $\lambda/2$ retardation film disposed under the lower λ/4 retardation film and a lower polarizer **530** disposed under the lower λ/2 retardation film **520**.

A reference direction is in substantially parallel with the horizontal direction. A reference wavelength of the LCD apparatus is about 550 nm. A velocity of a light that passes through a retardation film along a slow axis is slower than that of a light that passes through the retardation film along a fast axis.

FIG. **8** is an exploded perspective view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention. Referring to FIG. **8** in which the same reference numerals denote the same elements as in FIG. **3**, and thus any further detailed descriptions concerning the same elements will be omitted. A reference direction is in substantially parallel with a horizontal direction of an LCD panel of the LCD apparatus.

Referring to FIG. **8**, the liquid crystal layer is disposed between an array substrate **100** and a color filter substrate **200**. An anisotropy Δn of a reflective index of the liquid crystal layer is about 0.078 ZSM5342 with reference to a light having a wavelength of about 589 nm. The 'ZSM5342' is a unit of the anisotropy Δn of the reflective index. A thickness d**1** of the liquid crystal layer **15** is about 3.0 μm. A twist angle of the liquid crystal layer is about 72 degree. A viewing angle of the liquid crystal layer is about 12 degree.

The upper λ/4 retardation film **412** is disposed on the color filter substrate **200**. A second optical characteristics Δnd**2** of the upper λ/4 retardation film **412** is about 130 nm to about 150 nm with reference to a reference light whose wavelength is about 550 nm. A slow axis of the upper λ/4 retardation film **412** forms at an angle of about 34 degree to about 54 degree with respect to the reference direction in a clockwise direction.

The upper λ/2 retardation film **422** is disposed on the upper λ/4 retardation film **412**. A third optical characteristics Δnd**3** of the upper λ/2 retardation film **422** is about 250 nm to about 270 nm with reference to the reference light whose wavelength is about 550 nm. A slow axis of the upper λ/2 retardation film **422** forms at an angle of about 156 degree to about 176 degree with respect to the reference direction in a clockwise direction.

The upper polarizer **432** is disposed on the upper λ/2 retardation film **422**. An absorption axis of the upper polarizer **432** forms at an angle of about 140 degree to about 160 degree with respect to the reference direction of the LCD panel in the clockwise direction.

The lower λ/4 retardation film **512** is disposed under the array substrate **100**. A fourth optical characteristics Δnd**4** of the lower λ/4 retardation film **512** is about 135 nm to about 155 nm with respect to the reference wavelength. A slow axis of the lower λ/4 retardation film **512** forms at an angle of about 36 degree to about 56 degree with respect to the reference direction in the clockwise direction.

The lower λ/2 retardation film **522** is disposed under the lower λ/4 retardation film **512**. A fifth optical characteristics Δnd**5** of the lower λ/2 retardation film **522** is about 260 nm to about 280 nm with respect to the reference wavelength. A slow axis of the lower λ/2 retardation film **522** forms at an angle of about 95 degree to about 115 degree with respect to the reference direction in the clockwise direction.

The lower polarizer **532** is disposed under the lower λ/2 retardation film **522**. An absorption axis of the lower polarizer **532** forms at an angle of about 110 degree to about 130 degree with respect to the reference direction in the clockwise direction.

In another exemplary embodiment, a slow axis of a lower λ/4 retardation film may form at an angle of about 124 degree to about 144 degree with respect to the reference direction in the clockwise direction. A slow axis of a lower λ/2 retardation film may form at an angle of about 65 degree to about 85 degree with respect to the reference direction in the clockwise direction. An absorption axis of a lower polarizer may form at an angle of about 50 degree to about 70 degree with respect to the reference direction in the clockwise direction.

A light transmittance of the LCD apparatus in this exemplary embodiment is about 0.2373, and a contrast ratio of a transmission mode of the LCD apparatus in this exemplary embodiment is about 911. The light transmittance of the LCD apparatus in this exemplary embodiment is increased by about 20% than that of the LCD apparatus shown in FIG. **3**. The contrast ratio of the transmission mode of the LCD apparatus in this exemplary embodiment is substantially the same as that of the LCD apparatus shown in FIG. **3**.

A light reflectivity of the LCD apparatus in this exemplary embodiment is about 8%, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A contrast ratio of the reflection mode of the LCD apparatus in this exemplary embodiment is about 30, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A light reflectivity of an integrating sphere of the LCD apparatus in this exemplary embodiment is about 5%, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A contrast ratio of the integrating sphere of the LCD apparatus in this exemplary embodiment is about 10, and is substantially the same as that of the LCD apparatus shown in FIG. **3**.

A luminance viewed in front of the LCD panel in this exemplary embodiment is about 70 [Cd/m^3]. A luminance viewed in front of the LCD panel shown in FIG. **3** is about 55 [Cd/m^3]. The luminance viewed in front of the LCD panel in this exemplary embodiment is increased by about 25% than that of the LCD panel shown in FIG. **3**. A contrast ratio viewed in front of the LCD panel in this exemplary embodiment is about 110. A contrast ratio viewed in front of the LCD panel shown in FIG. **3** is about 80. The contrast ratio viewed in front of the LCD panel in this exemplary embodiment is increased by about 12% than that of the LCD panel shown in FIG. **3**. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel in this exemplary embodiment are about 28, 28, 52 and 22, respectively. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel shown in FIG. **3** are about 21, 36, 22 and 38, respectively. Therefore, the viewing angles are increased.

FIG. **9** is an exploded perspective view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention. Referring to FIG. **9** in which the same reference numerals denote the same elements in FIG. **3**, and thus any further detailed descriptions concerning the same elements will be omitted. A reference direction is in substantially parallel with a horizontal direction of an LCD panel of the LCD apparatus.

Referring to FIG. **9**, the liquid crystal layer is disposed between an array substrate **100** and a color filter substrate **200**. An anisotropy Δn of a reflective index of the liquid crystal layer is about 0.078 ZSM5342 with reference to a light having a wavelength of about 589 nm. The 'ZSM5342' is a unit of the anisotropy Δn of the reflective index. A thickness d**1** of the liquid crystal layer is about 3.0 μm. A twist angle of the liquid crystal layer is about 60 degree. A viewing angle of the liquid crystal layer is about 10 degree.

The upper λ/4 retardation film **414** is disposed on the color filter substrate **200**. A second optical characteristics Δnd**2** of the upper λ/4 retardation film **414** is about 130 nm to about 150 nm with reference to a reference light whose wavelength is about 550 nm. A slow axis of the upper λ/4 retardation film **414** forms at an angle of about 103 degree to about 123 degree with respect to the reference direction in a clockwise direction.

The upper λ/2 retardation film **424** is disposed on the upper λ/4 retardation film **414**. A third optical characteristics Δnd**3** of the upper λ/2 retardation film **424** is about 250 nm to about 270 nm with reference to the reference light whose wavelength is about 550 nm. A slow axis of the upper λ/2 retardation film **424** forms at an angle of about 38 degree to about 58 degree with respect to the reference direction in a clockwise direction.

The upper polarizer **434** is disposed on the upper λ/2 retardation film **424**. An absorption axis of the upper polarizer **434** forms at an angle of about 114 degree to about 134 degree with respect to the reference direction of the LCD panel in the clockwise direction.

The lower λ/4 retardation film **514** is disposed under the array substrate **100**. A fourth optical characteristics Δnd**4** of the lower λ/4 retardation film **514** is about 120 nm to about 140 nm with respect to the reference wavelength. A slow axis of the lower λ/4 retardation film **514** forms at an angle of about 38 degree to about 58 degree with respect to the reference direction in the clockwise direction.

The lower λ/2 retardation film **524** is disposed under the lower λ/4 retardation film **514**. A fifth optical characteristics Δnd**5** of the lower λ/2 retardation film **524** is about 260 nm to about 280 nm with respect to the reference wavelength. A slow axis of the lower λ/2 retardation film **524** forms at an angle of about 152 degree to about 172 degree with respect to the reference direction in the clockwise direction.

The lower polarizer **534** is disposed under the lower λ/2 retardation film **524**. An absorption axis of the lower polarizer **534** forms at an angle of about 136 degree to about 156 degree with respect to the reference direction in the clockwise direction.

In another exemplary embodiment, a slow axis of a lower λ/4 retardation film may form at an angle of about 122 degree to about 142 degree with respect to the reference direction in the clockwise direction. A slow axis of a lower λ/2 retardation film may be form at an angle of about 8 degree to about 28 degree with respect to the reference direction in the clockwise direction. An absorption axis of a lower polarizer may be form at an angle of about 24 degree to about 44 degree with respect to the reference direction in the clockwise direction.

A light transmittance of the LCD apparatus in this exemplary embodiment is about 0.2838, and a contrast ratio of a transmission mode of the LCD apparatus in this exemplary embodiment is about 2247. The light transmittance of the LCD apparatus in this exemplary embodiment is increased by about 250% than that of the LCD apparatus shown in FIG. **3**. The contrast ratio of the transmission mode of the LCD apparatus in this exemplary embodiment is substantially the same as that of the LCD apparatus shown in FIG. **3**.

A light reflectivity of the LCD apparatus in this exemplary embodiment is about 8%, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A contrast ratio of the reflection mode of the LCD apparatus in this exemplary embodiment is about 30, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A light reflectivity of an integrating sphere of the LCD apparatus in this exemplary embodiment is about 5%, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A contrast ratio of the integrating sphere of the LCD apparatus in this exemplary embodiment is about 10, and is substantially the same as that of the LCD apparatus shown in FIG. **3**.

A luminance viewed in front of the LCD panel in this exemplary embodiment is about 85 [Cd/m^3]. A luminance viewed in front of the LCD panel shown in FIG. **3** is about 55 [Cd/m^3]. The luminance viewed in front of the LCD panel in this exemplary embodiment is increased by about 54% than that of the LCD panel shown in FIG. **3**. A contrast ratio viewed in front of the LCD panel in this exemplary embodiment is about 150. A contrast ratio viewed in front of the LCD panel shown in FIG. **3** is about 80. The contrast ratio viewed in front of the LCD panel in this exemplary embodiment is increased by about 180% than that of the LCD panel shown in FIG. **3**. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel in this exemplary embodiment are about 44, 42, 36 and 40, respectively. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel shown in FIG. **3** are about 21, 36, 22 and 38, respectively. Therefore, the viewing angles are increased.

FIG. **10** is an exploded perspective view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention. Referring to FIG. **10** in which the same reference numerals denote the same elements in FIG. **3**, and thus any further detailed descriptions concerning the same elements will be omitted. A reference direction is in substantially parallel with a horizontal direction of an LCD panel of the LCD apparatus.

Referring to FIG. **10**, the liquid crystal layer is disposed between an array substrate **100** and a color filter substrate **200**. An anisotropy Δn of a reflective index of the liquid crystal layer is about 0.078 ZSM5342 with reference to a light having a wavelength of about 589 nm. The 'ZSM5342' is a unit of the anisotropy Δn of the reflective index. A thickness d**1** of the liquid crystal layer is about 3.0 μm. A twist angle of the liquid crystal layer is about 60 degree. A viewing angle of the liquid crystal layer is about 10 degree.

The upper λ/4 retardation film **416** is disposed on the color filter substrate **200**. A second optical characteristics Δnd**2** of the upper λ/4 retardation film **416** is about 130 nm to about 150 nm with reference to a reference light whose wavelength is about 550 nm. A slow axis of the upper λ/4 retardation film **416** forms at an angle of about 94 degree to about 114 degree with respect to the reference direction in a clockwise direction.

The upper λ/2 retardation film **426** is disposed on the upper λ/4 retardation film **416**. A third optical characteristics Δnd**3** of the upper λ/2 retardation film **426** is about 250 nm to about 270 nm with reference to the reference light whose wavelength is about 550 nm. A slow axis of the upper λ/2 retardation film **426** forms at an angle of about 27 degree to about 47 degree with respect to the reference direction in a clockwise direction.

The upper polarizer **436** is disposed on the upper λ/2 retardation film **426**. An absorption axis of the upper polarizer **436** forms at an angle of about 100 degree to about 120 degree with respect to the reference direction of the LCD panel in the clockwise direction.

The lower λ/4 retardation film **516** is disposed under the array substrate **100**. A fourth optical characteristics Δnd**4** of the lower λ/4 retardation film **516** is about 120 nm to about 140 nm with respect to the reference wavelength. A slow axis of the lower λ/4 retardation film **516** forms at an angle of about 39 degree to about 59 degree with respect to the reference direction in the clockwise direction.

The lower λ/2 retardation film **526** is disposed under the lower λ/4 retardation film **516**. A fifth optical characteristics Δnd**5** of the lower λ/2 retardation film **526** is about 260 nm to about 280 nm with respect to the reference wavelength. A slow axis of the lower λ/2 retardation film **526** forms at an angle of about 161 degree to about 181 degree with respect to the reference direction in the clockwise direction.

The lower polarizer **536** is disposed under the lower λ/2 retardation film **526**. An absorption axis of the lower polarizer **536** forms at an angle of about 150 degree to about 170 degree with respect to the reference direction in the clockwise direction.

In another exemplary embodiment, a slow axis of a lower λ/4 retardation film may form at an angle of about 121 degree to about 141 degree with respect to the reference direction in the clockwise direction. A slow axis of a lower λ/2 retardation film may form at an angle of about −1 degree to about 19 degree with respect to the reference direction in the clockwise direction. An absorption axis of a lower polarizer may form at an angle of about 10 degree to about 30 degree with respect to the reference direction in the clockwise direction.

A light transmittance of the LCD apparatus in this exemplary embodiment is about 0.2658, and a contrast ratio of a transmission mode of the LCD apparatus in this exemplary embodiment is about 4158. The light transmittance of the LCD apparatus in this exemplary embodiment is increased by about 35% than that of the LCD apparatus shown in FIG. **3**. The contrast ratio of the transmission mode of the LCD apparatus in this exemplary embodiment is increased by about 460% than that of the LCD apparatus shown in FIG. **3**.

A light reflectivity of the LCD apparatus in this exemplary embodiment is about 8%, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A contrast ratio of the reflection mode of the LCD apparatus in this exemplary embodiment is about 30, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A light reflectivity of an integrating sphere of the LCD apparatus in this exemplary embodiment is about 5%, and is substantially the same as that of the LCD apparatus shown in FIG. **3**. A contrast ratio of the integrating sphere of the LCD apparatus in this exemplary embodiment is about 10, and is substantially the same as that of the LCD apparatus shown in FIG. **3**.

A luminance viewed in front of the LCD panel in this exemplary embodiment is about 77 [Cd/m^3]. A luminance viewed in front of the LCD panel shown in FIG. **3** is about 55 [Cd/m^3]. The luminance viewed in front of the LCD panel in this exemplary embodiment is increased by about 40% than that of the LCD panel shown in FIG. **3**. A contrast ratio viewed in front of the LCD panel in this exemplary embodiment is about 190. A contrast ratio viewed in front of the LCD panel shown in FIG. **3** is about 80. The contrast ratio viewed in front of the LCD panel in this exemplary embodiment is increased by about 230% than that of the LCD panel shown in FIG. **3**. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel in this exemplary embodiment are about 44, 42, 36 and 40, respectively. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel shown in FIG. **3** are about 21, 36, 22 and 38, respectively. Therefore, the viewing angles are increased.

FIGS. **11** and **12** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays black color. Radius shown in FIG. **11** represents the viewing angle of an LCD panel of the LCD apparatus. A reference direction is in substantially parallel with a horizontal direction of the LCD panel.

A luminance of a portion of the LCD panel, which corresponds to a viewing angle between about 60 degree and about 80 degree in a direction of about 90 degree in a counter-clockwise direction, is increased. Also, a luminance of a portion of the LCD panel, which corresponds to a viewing angle of about 80 degree in a direction of about 90 degree in a clockwise direction, is increased. A luminance of remaining portion of the LCD panel is decreased to display the black color. In particular, a viewing angle viewed in front of the LCD panel is about 0.5 [Cd/m^3] so that an image display quality of the LCD panel is improved.

FIGS. **13** and **14** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays white color.

Referring to FIGS. **13** and **14**, a luminance of a portion of the LCD panel, which corresponds to a viewing angle of about 0 degree to about 30 degree, is increased. A luminance viewed in front of the LCD panel is about 11 [Cd/m^3].

FIGS. **15** and **16** are graphs showing a relationship between a contrast ratio and a viewing angle of an LCD apparatus in accordance with another exemplary embodiment of the present invention. Radius shown in FIG. **15** represents the viewing angle of the LCD panel.

Referring to FIGS. **15** and **16**, a contrast ratio of the LCD panel corresponding to a central portion is higher than that of the LCD panel corresponding to a peripheral portion to improve the image display quality of the LCD apparatus.

According to this exemplary embodiment, optical condition of the LCD apparatus is optimized so that the light transmittance and the contrast ratio of the LCD apparatus are improved. In addition, the distribution of the viewing angle and the contrast ratio of the LCD apparatus are uniformized so that a color reproductivity and the image display quality are improved.

Furthermore, the light transmittance of the LCD apparatus is increased by about 40% to about 50%, and the contrast ratio viewed in front of the LCD panel is increased by about 200%.

FIG. **17** is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention. Referring to FIG. **17** in which the same reference numerals denote the same elements in FIG. **7**, and thus any further detailed descriptions concerning the same elements will be omitted. A reference direction is in substantially parallel with a horizontal direction of an LCD panel of the LCD apparatus.

Referring to FIG. **17**, the LCD apparatus includes an array substrate **100**, a color filter substrate **200**, a liquid crystal layer **300**, an upper optical film assembly **400** and a lower optical film assembly **500**. The liquid crystal layer **300** is disposed between the array substrate **100** and the color filter substrate **200**. The upper optical film assembly **400** is disposed on the color filter substrate **200**. The lower optical film assembly **500** is disposed under the array substrate **100**.

The array substrate **100** includes a first transparent plate **105**, a switching element that includes a thin film transistor (TFT), a passivation layer **140** and an organic insulating layer **2144**, a pixel electrode **2150**, an insulating interlayer **2152** and a reflecting plate **2160**. The switching element is formed on the first transparent plate **105**. The switching element includes a gate electrode **110**, a gate insulating layer **112** that is formed on the first transparent plate **105** having the gate electrode **110**, a semiconductor layer **114**, an ohmic contact layer **116**, a source electrode **120** and a drain electrode **130**. The passivation layer **140** is formed on the first transparent plate **105** having the switching element. The passivation layer **140** includes a first opening, through which the drain electrode **130** is partially exposed. The organic insulating layer **2144** is formed on the passivation layer **140**. The organic insulating layer **2144** has a second opening, through which the drain electrode **130** is partially exposed. The second opening is disposed on the first opening. The first and second openings form a first contact hole **2141**. Convex and concave portions may be formed on the organic insulating layer **2144** to improve a reflective index of a reflecting plate **2160**. The pixel electrode **2150** is electrically connected to the drain electrode **130** through the first contact hole **2141**. The switching element is formed on a portion of the pixel electrode **130**, which corresponds to the switching element. The reflecting plate **2160** is formed on the insulating interlayer **2152**. The array substrate **100** further includes a reflection region and a transmission window **2145**. The reflecting plate **2160** is disposed in the reflection region. The reflecting plate **2160** defines the transmission window **2145**.

The color filter substrate **200** includes a second transparent plate **2205**, a black matrix (not shown), a color filter **2210** and an overcoating layer (not shown). The black matrix is formed on the second transparent plate **2205** to define red (R), green (G) and blue (B) pixel regions. The color filter **2210** is formed in the red (R), green (G) and the blue (B) pixel regions. The overcoating layer is coated on the second transparent plate **2205** having the black matrix and the color filter **2210** to protect the black matrix and the color filter **2210**. A common electrode (not shown) may also be formed on the overcoating layer.

A viewing angle of the liquid crystal layer **300** is about 170 degree to about 250 degree. A twist angle of the liquid crystal layer **300** is about −10 degree to about +10 degree. The liquid crystal layer **300** is formed between the array substrate **100** and the color filter substrate **200**. A liquid crystal of the liquid crystal layer **300** varies an arrangement in response to an electric field applied between the pixel electrode **2150** of the array substrate **100** and the common electrode of the color filter substrate **200**, and thus a light transmittance of a natural light that passes through the color filter substrate **200** or an artificial light that passes through the transmission window **2145** may be changed.

A first thickness d**1** of a portion of the liquid crystal layer **300** in the reflection region corresponding to the contact hole **2141**, a second thickness d**2** of a portion of the liquid crystal layer **300** in a remaining reflection region, and a third thickness d**3** of a portion of the liquid crystal layer **300** corresponding to the transmission window are different from one another. The first thickness d**1** is thicker than the second thickness d**2**. The third thickness d**3** is thicker than the first thickness d**1**.

An anisotropy Δn of a refractive index multiplied by a thickness is equal to an optical characteristics **66** nd. A first optical characteristics Δnd**1** corresponds to the portion of the liquid crystal layer **300** in the reflection region corresponding to the contact hole **2141**. A second optical characteristics Δnd**2** corresponds to the portion of the liquid crystal layer **300** in the remaining reflection region. A third optical characteristics Δnd**3** corresponds to the portion of the liquid crystal layer **300** corresponding to the transmission window.

The second thickness d**2** may be no more than 1.7 μm. The third thickness d**3** may be no less than 3.3 μm. The first to third thicknesses d**1**, d**2** and d**3** may be determined by the liquid crystal of the liquid crystal layer **300**, the upper optical film assembly **400** and the lower optical film assembly **500**.

The liquid crystal layer **300** has a homogeneous alignment mode. When the liquid crystal layer **300** has the homogeneous alignment mode, a twist angle of the liquid crystal layer **300** is about 0 degree.

The array substrate **100** may include a first alignment layer (not shown) so that the first alignment layer is rubbed in a first rubbing direction that is in substantially parallel with a horizontal direction. The color filter substrate **200** may also include a second alignment layer (not shown) so that the second alignment layer is rubbed in a second rubbing direction that is in substantially opposite to the first rubbing direction. Alternatively, the second alignment layer may be rubbed in a second rubbing direction that is in substantially parallel with the horizontal direction, and the first alignment layer may be rubbed in a first rubbing direction that is in substantially opposite to the second rubbing direction.

In this exemplary embodiment, the array substrate **100** includes the pixel electrode **150**, and the color filter substrate **200** includes the common electrode. Alternatively, the LCD apparatus may include a coplanar electrode (CE) mode, for example, such as an in-plane switching (IPS) mode, a fringe field switching (FFS) mod, etc., so that the color filter substrate **200** includes the common electrode.

The upper optical film assembly **400** includes an upper λ/4 retardation film **410** disposed on the color filter substrate **200**, an upper λ/2 retardation film **420** disposed on the upper λ/4 retardation film **420** and an upper polarizer **430** disposed on the upper λ/2 retardation film **420**. The lower optical film assembly **500** includes a lower λ/4 retardation film **510** disposed under the array substrate **100**, a lower λ/2 retardation film **520** disposed under the lower λ/4 retardation film **510** and a lower polarizer **530** disposed under the lower λ/2 retardation film **520**.

FIG. **18** is an exploded perspective view showing an upper optical film assembly of the LCD apparatus shown in FIG. **17**. A reference direction is in substantially parallel with a horizontal direction of an LCD panel of the LCD apparatus. A reference wavelength of a light is about 550 nm.

Referring to FIG. **18**, the upper λ/4 retardation film **410** is disposed on the color filter substrate **200**. The fourth optical characteristics Δnd**4** of the upper λ/4 retardation film **410** is about 130 nm to about 150 nm. A slow axis of the upper λ/4 retardation film **410** forms at an angle of about 136 degree to about 156 degree with respect to the reference direction in a clockwise direction.

The upper λ/2 retardation film **420** is disposed on the upper λ/4 retardation film **410**. The fifth optical characteristics Δnd**5** of the upper λ/2 retardation film **420** is about 250 nm to about 270 nm. A slow axis of the upper λ/2 retardation film **420** forms at an angle of about 81 degree to about 101 degree with respect to the reference direction in a clockwise direction.

The upper polarizer **430** is disposed on the upper λ/2 retardation film **420**. An absorption axis of the upper polarizer **430** forms at an angle of about 67 degree to about 87 degree with respect to the reference direction of the LCD panel in the clockwise direction.

FIG. **19** is an exploded perspective view showing a lower optical film assembly of the LCD apparatus shown in FIG. **17**.

The lower λ/4 retardation film **510** is disposed under the array substrate **100**. A sixth optical characteristics Δnd**6** of the lower λ/4 retardation film **510** is about 120 nm to about 140 nm with respect to the reference wavelength. A slow axis of the lower λ/4 retardation film **510** forms at an angle of about −1 degree to about +19 degree with respect to the reference direction in the clockwise direction.

The lower λ/2 retardation film **520** is disposed under the lower λ/4 retardation film **516**. A seventh optical characteristics Δnd**7** of the lower λ/2 retardation film **520** is about 260 nm to about 280 nm with respect to the reference wavelength. A slow axis of the lower λ/2 retardation film **520** forms at an angle of about 113 degree to about 133 degree with respect to the reference direction in the clockwise direction.

The lower polarizer **530** is disposed under the lower λ/2 retardation film **520**. An absorption axis of the lower polarizer **530** forms at an angle of about 8 degree to about 28 degree with respect to the reference direction in the clockwise direction.

In another exemplary embodiment, a slow axis of a lower λ/4 retardation film may form at an angle of about 161 degree to about 181 degree with respect to the reference direction in the clockwise direction. A slow axis of a lower λ/2 retardation film may form at an angle of about 47 degree to about 67 degree with respect to the reference direction in the clockwise direction. An absorption axis of a lower polarizer may form at an angle of about 152 degree to about 172 degree with respect to the reference direction in the clockwise direction.

Alternatively, the second and third thicknesses d**2** and d**3** may be substantially equal to each other.

The LCD apparatus may also include a reflective type LCD apparatus having a switching element, a pixel electrode that is electrically connected to a drain electrode of the switching element and a reflecting plate that is formed on the pixel electrode to reflect the natural light.

The LCD apparatus may also include a bottom ITO type. A pixel electrode of the bottom ITO typed LCD apparatus is formed under the organic insulating layer.

FIG. **20** is a cross-sectional view showing a reflection mode of the LCD apparatus shown in FIG. **17**. FIG. **21** is a cross-sectional view showing a transmission mode of the LCD apparatus shown in FIG. **17**. The LCD apparatus includes the liquid crystal layer **300** having a normally white mode. When an electric field is not applied to the liquid crystal layer **300** having the normally white mode, the LCD apparatus displays white color.

Referring to FIG. **20**, when the electric field is not applied to the liquid crystal layer **300** in the reflection mode, the liquid crystal of the liquid crystal layer **300** is horizontally aligned. The natural light that is provided from an exterior to the liquid crystal layer **300** passes through the upper polarizer **420** so that the natural light is converted into a linearly polarized light. The linearly polarized light passes through the upper λ/4 retardation film **410** so that the linearly polarized light is converted into a left circularly polarized light. Alternatively, the linearly polarized light passes through the upper λ/4 retardation film **410** so that the linearly polarized light may be converted into a right circularly polarized light.

The left circularly polarized light passes through the liquid crystal layer **300** so that a phase of the left circularly polarized light is delayed by λ/4 to form a linearly polarized light. The optical characteristics of the liquid crystal layer **300** corresponding to the reflection mode are represented by the reference numeral Δnd**2**. The linearly polarized light that passes through the liquid crystal layer **300** is reflected from the reflecting plate **160**. The reflecting plate may include an aluminum-neodymium (Al—Nd) alloy. The reflected light passes through the liquid crystal layer **300** so that a phase of the reflected light is delayed by λ/4 to form a left circularly polarized light.

The left circularly polarized light that is formed from the reflected light passes through the upper λ/4 retardation film **410** so that the left circularly polarized light is converted into a linearly polarized light. The linearly polarized light passes through the upper polarizer **420** so that the white color is displayed.

When the electric field is applied to the liquid crystal layer **300** in the reflection mode, the liquid crystal of the liquid crystal layer **300** is vertically aligned. The natural light that is provided from the exterior to the LCD apparatus passes through the upper polarizer **420** so that the natural light is converted into a linearly polarized light. The linearly polarized light passes through the upper λ/4 retardation film **410** so that the linearly polarized light is converted into a left circularly polarized light.

The left circularly polarized light passes through the liquid crystal layer **300**, and the left circularly polarized light remains unchanged. The left circularly polarized light that passes through the liquid crystal layer **300** is reflected from the reflecting plate **160** so that the left circularly polarized light is converted into a right circularly polarized light. The right circularly polarized light passes through the liquid crystal layer **300**, and the right circularly polarized light remains unchanged. The right circularly polarized light passes through the upper λ/4 retardation film **410** so that the right circularly polarized light is converted into a linearly polarized light. The linearly polarized light is blocked by the upper polarizer to display black color.

Referring to FIG. **21**, when the electric field is not applied to the liquid crystal layer **300** in the transmission mode, the liquid crystal of the liquid crystal layer **300** is horizontally aligned. The artificial light generated from a backlight assembly passes through the lower polarizer **520** so that the artificial light is converted into a linearly polarized light. The linearly polarized light passes through the lower λ/4 retardation film **510** so that the linearly polarized light is converted into a right circularly polarized light. The right circularly polarized light passes through the pixel electrode that is transparent so that the right circularly polarized light remains unchanged. The second optical characteristics Δnd**2** of the liquid crystal layer **300** corresponding to the reflection region is about a half of the third optical characteristics Δnd**3** of the liquid crystal layer **300** corresponding to the transmission window **2145**.

The right circularly polarized light that passes through the liquid crystal layer **300** so that a phase of the right circularly polarized light is delayed by λ/2 to form a right circularly polarized light. The right circularly polarized light passes through the upper λ/4 retardation film **410** so that the right circularly polarized light is converted into a linearly polarized light. The linearly polarized light passes through the upper polarizer **420** to display the white color.

When the electric field is applied to the liquid crystal layer **300** in the transmission mode, the liquid crystal of the liquid crystal layer **300** is vertically aligned. The artificial light generated from the backlight assembly passes through the lower polarizer **520** so that the artificial light is converted into a linearly polarized light. The linearly polarized light passes through the lower λ/4 retardation film **510** so that the linearly polarized light is converted into a right circularly polarized light. The right circularly polarized light passes through the pixel electrode **150** so that the right circularly polarized light remains unchanged.

The right circularly polarized light that passes through the pixel electrode **150** passes through the liquid crystal layer **300** so that the right circularly polarized light remains unchanged.

The right circularly polarized light that passes through the liquid crystal layer **300** passes through the upper λ/4 retardation film **410** so that the right circularly polarized light is converted into a linearly polarized light. The linearly polarized light is blocked by the upper polarizer **420** to display the black color.

FIGS. **22** and **23** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays black color. Radius shown in FIG. **22** represents the viewing angle of an LCD panel of the LCD apparatus. A reference direction is in substantially parallel with a horizontal direction of the LCD panel.

Referring to FIGS. **22** and **23**, a luminance of a portion of the LCD panel, which corresponds to a viewing angle between about 60 degree and about 80 degree in a direction at an angle of about 90 degree to about 120 degree in a counter-clockwise direction, is increased. Also, a luminance of a portion of the LCD panel, which corresponds to a viewing angle of about 40 degree to about 80 degree in a direction in substantially parallel with the reference direction, is increased. In addition, a luminance of a portion of the LCD panel, which corresponds to a viewing angle of about 80 degree in a direction at an angle of about 90 degree to about 120 degree in a clockwise direction, is increased. A luminance of remaining portion of the LCD panel is decreased to display the black color. In particular, a viewing angle viewed in front of the LCD panel is about 0.5 [Cd/m^3] so that an image display quality of the LCD panel is improved.

FIGS. **24** and **25** are graphs showing a relationship between a luminance and a viewing angle when an LCD apparatus in accordance with another exemplary embodiment of the present invention displays white color. Radius shown in FIG. **24** represents the viewing angle of an LCD panel of the LCD apparatus.

Referring to FIGS. **24** and **25**, a luminance of a portion of the LCD panel, which corresponds to a viewing angle of about 0 degree to about 30 degree, is increased. A luminance viewed in front of the LCD panel is about 11 [Cd/m^3].

FIGS. **26** and **27** are graphs showing a relationship between a contrast ratio and a viewing angle of an LCD apparatus in accordance with another exemplary embodiment of the present invention. Radius shown in FIG. **26** represents the viewing angle of the LCD panel.

Referring to FIGS. **26** and **27**, a contrast ratio of the LCD panel corresponding to a central portion is higher than that of the LCD panel corresponding to a peripheral portion to improve the image display quality of the LCD apparatus.

Hereinafter, the LCD apparatus having the optical film assembly shown in FIGS. **18** and **19** is compared with the LCD apparatus having the optical film assembly shown in FIG. **8**.

The optical film assembly shown in FIG. **8** includes the upper λ/4 retardation film **412**, the upper λ/2 retardation film **422**, the upper polarizer **432**, the lower λ/4 retardation film **512**, the lower λ/2 retardation film **522** and the lower polarizer **532**. The second optical characteristics Δnd**2** of the upper λ/4 retardation film **412** may be about 140 nm, and the slow axis of the upper λ/4 retardation film **412** may form at an angle of about 44 degree with respect to the reference direction in the clockwise direction. The third optical characteristics Δnd**3** of the upper λ/2 retardation film **422** may be about 260 nm, and the slow axis of the upper λ/2 retardation film **422** may form at an angle of about 166 degree with respect to the reference direction in the clockwise direction. The absorption axis of the upper polarizer **432** may form at an angle of about 150 degree with respect to the reference direction of the LCD panel in the clockwise direction. The fourth optical characteristics Δnd**4** of the lower λ/4 retardation film **512** may be about 145 nm with respect to the reference wavelength, and the slow axis of the lower λ/4 retardation film **512** may form at an angle of about 46 degree with respect to the reference direction in the clockwise direction. The fifth optical characteristics Δnd**5** of the lower λ/2 retardation film **522** may be about 270 nm, and the slow axis of the lower λ/2 retardation film **522** may form at an angle of about 105 degree with respect to the reference direction in the clockwise direction. The absorption axis of the lower polarizer **532** may form at an angle of about 120 degree with respect to the reference direction in the clockwise direction.

The optical film assembly shown in FIGS. **18** and **19** includes the upper λ/4 retardation film **410**, the upper λ/2 retardation film **420**, the upper polarizer **430**, the lower λ/4 retardation film **510**, the lower λ/2 retardation film **520** and the lower polarizer **530**. The fourth optical characteristics Δnd**4** of the upper λ/4 retardation film **410** may be about 140 nm, and the slow axis of the upper λ/4 retardation film **410** may form at an angle of about 146 degree with respect to the reference direction in the clockwise direction. The fifth optical characteristics Δnd**5** of the upper λ/2 retardation film **420** may be about 260 nm, and the slow axis of the upper λ/2 retardation film **420** may form at an angle of about 91 degree with respect to the reference direction in the clockwise direction. The absorption axis of the upper polarizer **430** may form at an angle of about 77 degree with respect to the reference direction of the LCD panel in the clockwise direction. The sixth optical characteristics Δnd**6** of the lower λ/4 retardation film **510** may be about 130 nm with respect to the reference wavelength, and the slow axis of the lower λ/4 retardation film **510** may form at an angle of about 9 degree with respect to the reference direction in the clockwise direction. The seventh optical characteristics Δnd**7** of the lower λ/2 retardation film **520** may be about 270 nm, and the slow axis of the lower λ/2 retardation film **520** may form at an angle of about 123 degree with respect to the reference direction in the clockwise direction. The absorption axis of the lower polarizer **530** may form at an angle of about 18 degree with respect to the reference direction in the clockwise direction.

A light reflectivity of the LCD apparatus having the optical film assembly shown in FIG. **8** is about 8%, and is substantially the same as that of the LCD apparatus having the optical film assembly shown in FIGS. **18** and **19**. A contrast ratio of the reflection mode of the LCD apparatus having the optical film assembly shown in FIG. **8** is about 30, and is substantially the same as that of the LCD apparatus having the optical film assembly shown in FIGS. **18** and **19**. A light reflectivity of an integrating sphere of the LCD apparatus having the optical film assembly shown in FIG. **8** is about 5%, and is substantially the same as that of the LCD apparatus having the optical film assembly shown in FIGS. **18** and **19**. A contrast ratio of the integrating sphere of the LCD apparatus having the optical film assembly shown in FIG. **8** is about 10, and is substantially the same as that of the LCD apparatus having the optical film assembly shown in FIGS. **18** and **19**.

A luminance viewed in front of the LCD panel having the optical film assembly shown in FIG. **8** is about 70 [Cd/m^3]. A luminance viewed in front of the LCD panel having the optical film assembly shown in FIGS. **18** and **19** is about 180 [Cd/m^3]. The luminance viewed in front of the LCD panel having the optical film assembly shown in FIGS. **18** and **19** is increased by about 260% than that of the LCD panel having the optical film assembly shown in FIG. **8**. A contrast ratio viewed in front of the LCD panel having the optical film assembly shown in FIG. **8** is about 110. A contrast ratio viewed in front of the LCD panel having the optical film assembly shown in FIGS. **18** and **19** is about 250. The contrast ratio viewed in front of the LCD panel having the optical film assembly shown in FIGS. **18** and **19** is increased by about 230% than that of the LCD panel having the optical film assembly shown in FIG. **8**. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel having the optical film assembly shown in FIG. **8** are about 28, 28, 52 and 22, respectively. Viewing angles of an upper portion, a lower portion, a left portion and a right portion of the LCD panel shown in FIGS. **18** and **19** are about 50, 50, 50 and 48, respectively. Therefore, the viewing angles are increased.

According to the present invention, the optical conditions of the upper and lower optical film assembly are optimized so that the light transmittance, the contrast ratio and the viewing angle of the LCD apparatus are improved.

The LCD apparatus includes a reflective type LCD apparatus, a transmissive type LCD apparatus or a transmissive-reflective LCD apparatus. In the transmissive-reflective LCD apparatus, the thickness of the liquid crystal layer corresponding to the reflection region is different from that of the liquid crystal layer corresponding to the transmission window. Alternatively, the thickness of the liquid crystal layer corresponding to the reflection region may be substantially the same as that of the liquid crystal layer corresponding to the transmission window.

This invention has been described with reference to the exemplary embodiments. It is evident, however, that many alternative modifications and variations will be apparent to those having skill in the art in light of the foregoing description. Accordingly, the present invention embraces all such alternative modifications and variations as fall within the spirit and scope of the appended claims.

What is claimed is:

1. An optical film assembly for a liquid crystal display panel including a liquid crystal layer having a twist angle of about −10 degree to about +10 degree, the optical film assembly comprising:

an upper polarizer disposed over an upper substrate of the liquid crystal display panel, the upper polarizer including an absorption axis forming at an angle of about 37 degree to about 57 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal being disposed adjacent to the upper substrate;

an upper λ/2 retardation film disposed between the upper substrate and the upper polarizer, the upper λ/2 retardation film including a first optical characteristics Δnd**1** of about 250 nm to about 270 nm, a slow axis of the upper λ/2 retardation film forming at an angle of about 156 degree to about 176 degree in the clockwise direction with respect to the absorption axis; and

an upper λ/4 retardation film disposed between the upper substrate and the upper λ/2 retardation film, the upper λ/4 retardation film including a second optical characteristics Δnd**2** of about 130 nm to about 150 nm, a slow axis of the upper λ/4 retardation film forming at an angle of about 101 degree to about 121 degree in the clockwise direction with respect to the absorption axis,

wherein 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

2. An optical film assembly for a liquid crystal display panel including a liquid crystal layer having a twist angle of about −10 degree to about +10 degree, the optical film assembly comprising:

a lower polarizer disposed under a lower substrate of the liquid crystal display panel, the lower polarizer including an absorption axis forming at an angle of about 38 degree to about 58 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal being disposed adjacent to the lower substrate;

a lower λ/2 retardation film disposed between the lower substrate and the lower polarizer, the lower λ/2 retardation film including a first optical characteristics Δnd**1** of about 260 nm to about 280 nm, a slow axis of the lower λ/2 retardation film forming at an angle of about 65 degree to about 85 degree in the clockwise direction with respect to the absorption axis; and

a lower λ/4 retardation film disposed between the lower substrate and the lower λ/2 retardation film, the lower λ/4 retardation film including a second optical characteristics Δnd**2** of about 120 nm to about 140 nm, a slow axis of the lower λ/4 retardation film forming at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the absorption axis,

wherein 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

3. A liquid crystal display apparatus comprising:

a liquid crystal display panel including an upper substrate, a lower substrate corresponding to the upper substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about −10 degree to about +10 degree;

an upper polarizer disposed over the upper substrate, the upper polarizer including an absorption axis forming at an angle of about 37 degree to about 57 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal being disposed adjacent to the upper substrate;

an upper λ/2 retardation film disposed between the upper substrate and the upper polarizer, the upper λ/2 retardation film including a first optical characteristics Δnd**1** of about 250 nm to about 270 nm, a slow axis of the upper λ/2 retardation film forming at an angle of about 156 degree to about 176 degree in the clockwise direction with respect to the absorption axis; and

an upper λ/4 retardation film disposed between the upper substrate and the upper λ/2 retardation film, the upper λ/4 retardation film including a second optical characteristics Δnd**2** of about 130 nm to about 150 nm, a slow axis of the upper λ/4 retardation film forming at an angle of about 101 degree to about 121 degree in the clockwise direction with respect to the absorption axis, wherein 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the upper λ/2 retardation film and a thickness of the upper λ/4 retardation film, respectively.

4. The liquid crystal display apparatus of claim **3**, wherein the liquid crystal layer comprises a homogeneous alignment mode.

5. The liquid crystal display apparatus of claim **3**, wherein the lower substrate comprises a switching element, a pixel electrode electrically connected to a drain electrode of the switching element and a reflecting plate formed on the pixel electrode to reflect an artificial light.

6. The liquid crystal display apparatus of claim **3**, wherein the lower substrate comprises a switching element, a pixel electrode electrically connected to a drain electrode of the switching element, a reflection region where a natural light is reflected from and a transmission window where an artificial light passes through.

7. The liquid crystal display apparatus of claim **6**, wherein the liquid crystal layer comprises a first thickness corresponding to the reflection region and a second thickness corresponding to the transmission window, and the first thickness is different from the second thickness.

8. A liquid crystal display apparatus comprising:

a liquid crystal display panel including an upper substrate, a lower substrate and a liquid crystal layer disposed between the upper and lower substrates to have a twist angle of about −10 degree to about +10 degree;

a lower polarizer disposed under the lower substrate, the lower polarizer including an absorption axis forming at an angle of about 38 degree to about 58 degree in a clockwise direction with respect to a major axis of a liquid crystal of the liquid crystal layer, and the liquid crystal being disposed adjacent to the lower substrate;

a lower λ/2 retardation film disposed between the lower substrate and the lower polarizer, the lower λ/2 retardation film including a first optical characteristics Δnd**1** of about 260 nm to about 280 nm, a slow axis of the lower λ/2 retardation film forming at an angle of about 65 degree to about 85 degree in the clockwise direction with respect to the absorption axis; and

a lower λ/4 retardation film disposed between the lower substrate and the lower λ/2 retardation film, the lower λ/4 retardation film including a second optical characteristics Δnd**2** of about 120 nm to about 140 nm, a slow axis of the lower λ/4 retardation film forming at an angle of about −1 degree to about 19 degree in the clockwise direction with respect to the absorption axis,

wherein 'Δn', 'd**1**' and 'd**2**' denote an anisotropy of a refractive index, a thickness of the lower λ/2 retardation film and a thickness of the lower λ/4 retardation film, respectively.

9. The liquid crystal display apparatus of claim **8**, wherein the liquid crystal layer comprises a homogeneous alignment mode.

10. The liquid crystal display apparatus of claim **8**, wherein the lower substrate comprises a switching element, a pixel electrode electrically connected to a drain electrode of the switching element and a reflecting plate formed on the pixel electrode to reflect an artificial light.

11. The liquid crystal display apparatus of claim **8**, wherein the lower substrate comprises a switching element, a pixel electrode electrically connected to a drain electrode of the switching element, a reflection region where a natural light is reflected from and a transmission window where an artificial light passes through.

12. The liquid crystal display apparatus of claim **11**, wherein the liquid crystal layer comprises a first thickness corresponding to the reflection region and a second thickness corresponding to the transmission window, and the first thickness is different from the second thickness.

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专利名称(译)	光学片组件和具有该光学片组件的液晶显示装置		
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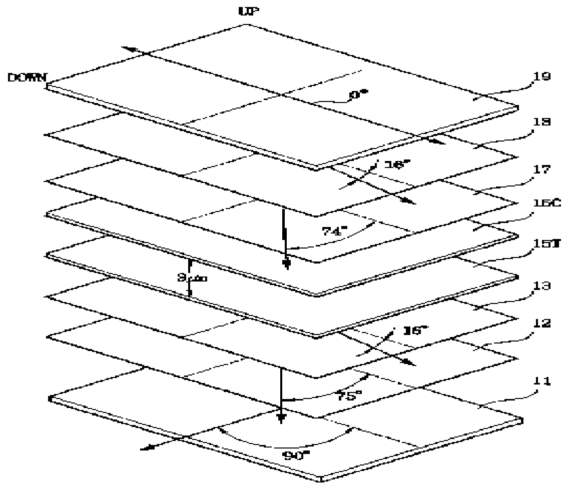
摘要(译)

液晶显示面板包括扭曲角为±10度的液晶层。上偏振器设置在液晶显示面板的上基板上，并包括相对于长轴在顺时针方向上以47±10度的角度形成的吸收轴。上λ/ 2延迟膜设置在上基板和上偏振器之间，并且包括260±10nm的Δnd1和相对于吸收轴在顺时针方向上以166±10度的角度形成的慢轴。上部λ/ 4延迟膜设置在上基板和上部λ/ 2延迟膜之间，并且包括140±10nm的Δnd2和相对于顺时针方向以111±10度的角度形成的慢轴。吸收轴。因此，优化光学膜组件的光学条件以改善图像显示质量。



UP
DOWN
19
0°
18
16°
17
15C
74°
15T
13
12
16°
75°
11
90°