



(51) International Patent Classification:
C09K 19/36 (2006.01) *G02F 1/13* (2006.01)

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(21) International Application Number:
PCT/CN2010/070160

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(22) International Filing Date:
13 January 2010 (13.01.2010)

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
200910148980.9 16 June 2009 (16.06.2009) CN

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(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: LIQUID FLUORESCENT COMPOSITION AND LIGHT EMITTING DEVICE

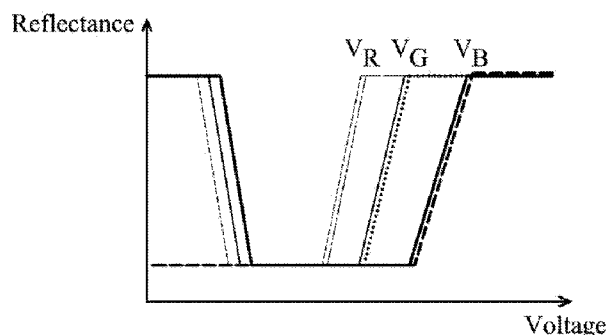


FIG. 1

(57) Abstract: The invention discloses a reflective liquid crystal material formulation, wherein a liquid crystal component of high dielectric anisotropy is employed to lower the driving voltage. By modulating the addition ratio of the high dielectric anisotropy components, reflective liquid crystal compositions of different reflective colors can be driven by a single driving voltage. The invention also provides a reflective bistable display using the above formulation.

LIQUID FLUORESCENT COMPOSITION AND LIGHT EMITTING DEVICE**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This Application claims priority of China Patent Application No. 200910148980.9, filed on June 16, 2009, the entirety of which is incorporated by reference herein.

5 BACKGROUND OF THE INVENTION**Field of the Invention**

[0002] The invention relates to a liquid crystal material and applications thereof, and more particularly to a reflective liquid crystal material formulation and single color, multi-color, or full color reflective bistable liquid crystal displays employing the same.

10 Description of the Related Art

[0003] Liquid crystal display (LCD) can include various liquid crystal materials such as twisted nematic (TN) liquid crystals, super twisted nematic (STN) liquid crystals, ferroelectric liquid crystals (FLC), or cholesteric liquid crystals.

[0004] Cholesteric liquid crystals, otherwise called chiral nematic liquid crystals, are generally prepared by mixing a twisted nematic liquid crystal with a chiral agent (chiral dopant). Due to the chiral agent, cholesteric liquid crystals exhibit higher twisting angular than that of twisted nematic liquid crystals and super twisted nematic liquid crystals. Cholesteric liquid crystals have several states, including a homeotropic state in which the direction of the liquid crystal molecules is approximately parallel to the substrate, and two stable states of a planar state and a focal conic state with no voltage applied. Cholesteric liquid crystals exhibit a bistable state characteristic, and the two stable states are stable in the absence of an electric field. In the planar state and the focal conic state, the image data can be kept displayed as a still image with no voltage applied, except for the switching of the planar state and the focal conic state.

[0005] In the other hand, since cholesteric liquid crystals can reflect the surrounding light and can be used in the absence of backlight source and polarizer, the liquid crystal display employing the same has lower power consumption than normal liquid crystal display. Since the reflectance of liquid crystal composition can be modified depending on desired reflective wavelengths, the requirement of a color display can be achieved in the absence of color filter. The detail driving means and optical characteristics of cholesteric liquid crystals are disclosed in US Pat. 5,251,048 and US 5,695,682.

[0006] The cholesteric liquid crystal is composed of optically active chiral agent and nematic liquid crystal, with helical pitch controlled by the ratio therebetween. The relationship between helical pitch P and amount of optically active chiral agent is:

[0007]
$$P=1/(HTP \cdot C)$$

5 [0008] In the above relational formula, C represents the weight concentration of chiral agent added to the liquid crystal composition and HTP helical twisting power, that is, the twisting and rotating ability of liquid crystal molecules. Therefore, the cholesteric liquid crystal with modifiable reflective wavelength can be obtained by adjusting the concentration of the chiral agent. The cholesteric liquid crystal composition with a higher concentration chiral
10 agent has a lower helical pitch and a shorter reflective wavelength (blue shift).

[0009] The driving voltage, however, increases in direct ratio with the increased concentration of the chiral agent, resulting in various driving voltage among the cholesteric liquid crystal. Fig. 1 is a graph plotting the reflectance of RGB cholesteric liquid crystal materials against driving voltage of RGB cholesteric liquid crystal materials. As shown in Fig.
15 1, the driving voltages of RGB cholesteric liquid crystal materials V_R , V_G and V_B are distinctively different (driving voltage of planar state represented by solid line, and driving voltage of focal conic state). Therefore, in a full-color display, there is necessary to provide three different driving voltages for driving red cholesteric liquid crystal material, green cholesteric liquid crystal material, and blue cholesteric liquid crystal material simultaneously.

20 [0010] There is, therefore, still a need for cholesteric liquid crystal materials with reduced driving voltage. Furthermore, the driving circuit design would be greatly simplified if cholesteric liquid crystal materials with different reflective wavelength are operated by a single driving voltage.

BRIEF SUMMARY OF THE INVENTION

25 [0011] An exemplary embodiment of a reflective liquid crystal material formulation, including at least two of (A) first liquid crystal component, (B) second liquid crystal component, and (C) third liquid crystal component, wherein

[0012] (A) the first liquid crystal component having a first reflective wavelength includes:

[0013] 100 parts by weight of a first liquid crystals host including 100% of a first
30 monomer; and

[0014] 3-10 parts by weight of a first chiral agent;

[0015] (B) the second liquid crystal component having a second reflective wavelength includes:

[0016] 100 parts by weight of a second liquid crystals host including 60-80% of a first monomer and 20-40% of a second monomer; and

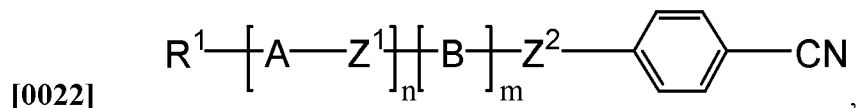
5 [0017] 3-10 parts by weight of a second chiral agent; and

[0018] (C) the third liquid crystal component having a third reflective wavelength includes:

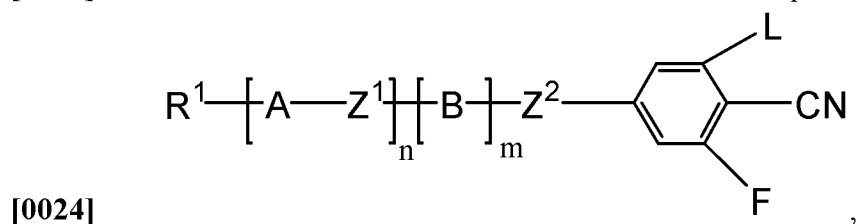
[0019] 100 parts by weight of a third liquid crystals host including 10-60% of a first monomer and 40-90% of a second monomer; and

[0020] 3-10 parts by weight of a third chiral agent,

10 [0021] wherein the first monomer includes a monomer represented by formula (I) of



[0023] and the second monomer includes a monomer represented by formula (III) of



[0025] wherein R^1 is independent and includes hydrogen, C_{1-15} straight or branched alkyl group, or C_{1-15} straight or branched alkenyl group; one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more $-\text{CH}_2-$ of the alkyl or alkenyl group is substituted

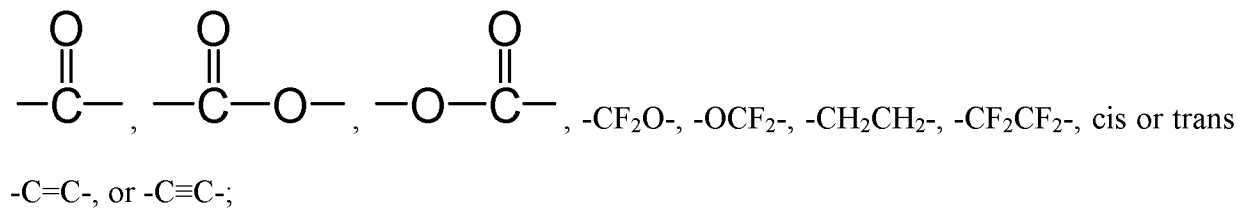
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optionally by $-\text{O}-$, $-\text{S}-$, $-\text{C}(=\text{O})-$, $-\text{C}(=\text{O})-\text{O}-$, or $-\text{O}-\text{C}(=\text{O})-$;

[0026] A and B are independent and selected from a group consisting of trans-1,4-cyclohexylene, and 1,4-phenylene; one or more $-\text{CH}_2-$ of A and B is substituted optionally by $-\text{O}-$, or $-\text{NH}-$; one or more $=\text{CH}-$ of A and B is substituted optionally by $=\text{N}-$; and one or more hydrogen atom of A and B is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group;

20

[0027] Z^1 and Z^2 are independent and, selected from a group consisting of $-\text{CH}_2-$, $-\text{O}-$, $-\text{S}-$,



[0028] n is 0 or an integral of 1-3, m is 0 or an integral of 1-3, and the sum of n and m is 1-3; and

5 [0029] L is hydrogen or fluorine.

[0030] In another exemplary embodiment of the invention, a reflective bistable liquid crystal display includes a first electrode layer; a second electrode layer; the above reflective liquid crystal material formulation disposed between the first electrode layer and the second electrode layer, wherein the liquid crystal components are isolated from each other, and the driving voltage difference of any two liquid crystal components is less than 4V.

[0031] A detailed description is given in the following embodiments with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The invention can be more fully understood by reading the subsequent detailed description and examples with reference to the accompanying drawings, wherein:

[0033] Fig. 1 is a graph plotting the reflectance against driving voltage of conventional RGB cholesteric liquid crystal materials.

[0034] Fig. 2 is a graph plotting the reflectance against driving voltage of RGB cholesteric liquid crystal materials as disclosed in an embodiment of the invention.

20 [0035] Figs. 3-5 are cross-sections of reflective bistable liquid crystal display according to the invention.

[0036] Fig. 6 shows the independent reflective spectrums of the red and blue liquid crystal components of Example 3.

[0037] Fig. 7 the reflective spectrum of the stacked device simultaneously including the red and blue liquid crystal components of Example 3.

DETAILED DESCRIPTION OF THE INVENTION

[0038] The invention provides a reflective liquid crystal material formulation with low driving voltage, wherein liquid crystal components with different reflective colors are modified by adding high dielectric anisotropy liquid crystal material in order to reduce driving voltage.

[0039] By adjusting the ratio between liquid crystal materials with different dielectric anisotropy, the cholesteric liquid crystal material formulation with different color liquid crystal components has a single driving voltage, referring to Fig. 2.

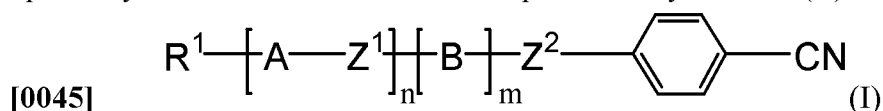
[0040] The cholesteric liquid crystal material of the invention can have a reflective wavelength in the range of visible light (380nm-800nm), and can be employed in single color or multi color liquid crystal display. The cholesteric liquid crystal components of the invention can have a helical pitch less than 1μm and of between 0.2-0.5μm. The cholesteric liquid crystal components of the invention are described as below in detail.

[0041] The liquid crystal materials of the invention can be generally divided into two groups, namely, first monomer with relatively low dielectric anisotropy (Group I), and second monomer with relatively high dielectric anisotropy (Group II).

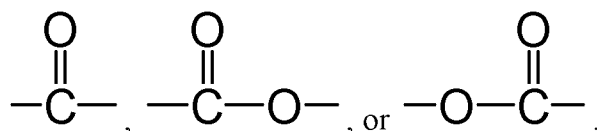
[0042] In an embodiment, the first monomer has a dielectric anisotropy, for example, less than 20, and the second monomer has a dielectric anisotropy, for example, more than 20.

[0043] In another embodiment, the first monomer has a dielectric anisotropy, for example, less than 15, and the second monomer has a dielectric anisotropy, for example, equal to or more than 15. Namely, one of the first and second monomers has a relatively low dielectric anisotropy, and the other has a relatively high dielectric anisotropy.

[0044] The first monomer at least includes a monomer represented by formula (I), and can optionally further include a monomer represented by formula (II).



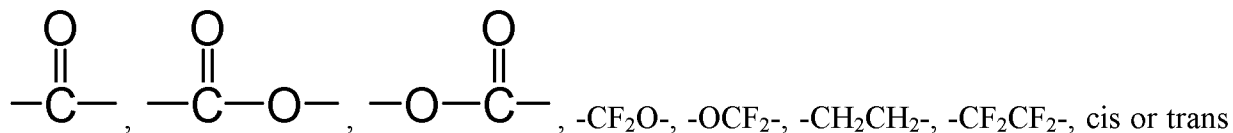
[0046] R^1 is independent and includes hydrogen, C_{1-15} straight or branched alkyl group, or C_{1-15} straight or branched alkenyl group; one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more $-CH_2-$ of the alkyl or alkenyl group is substituted optionally by $-O-$, $-S-$,



[0047] A and B are independent and selected from a group consisting of trans-1,4-cyclohexylene, and 1,4-phenylene; one or more $-CH_2-$ of A and B is substituted optionally by $-O-$, or $-NH-$; one or more $=CH-$ of A and B is substituted optionally by $=N-$; and one or more

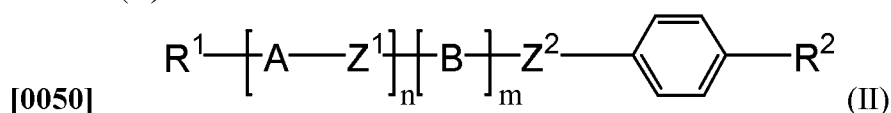
hydrogen atom of A and B is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group

[0048] Z^1 and Z^2 are independent and, selected from a group consisting of $-\text{CH}_2-$, $-\text{O}-$, $-\text{S}-$,

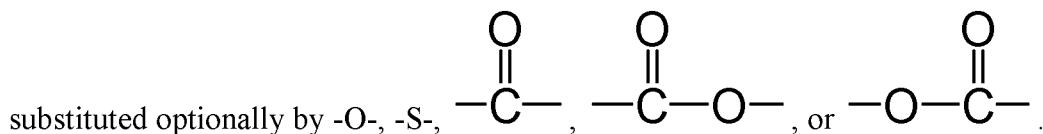


5 $-\text{C}=\text{C}-$, or $-\text{C}\equiv\text{C}-$; and n is 0 or an integral of 1-3, m is 0 or an integral of 1-3, and the sum of n and m is 1-3.

[0049] The first monomer can optionally further include a monomer represented by formula (II).



10 [0051] R^1 , A, B, Z^1 , Z^2 , n, and m are as previously defined; R^2 includes hydrogen, C_{1-15} straight or branched alkyl group, or C_{1-15} straight or branched alkenyl group, one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more $-\text{CH}_2-$ of the alkyl or alkenyl group is

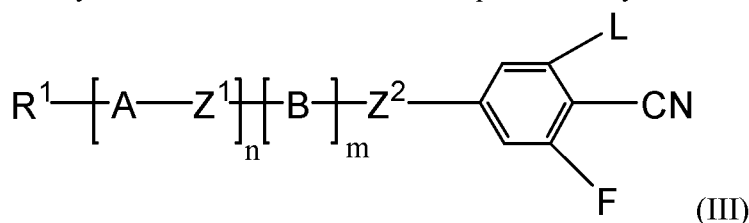


15 [0052] For the monomer represented by formula (II), since the terminal CN group of the monomer represented by formula (I) is replaced by R^2 group, the monomer represented by formula (II) has relatively low dielectric anisotropy in comparison with the monomer represented by formula (I). In general, the monomer represented by formula (I) has a dielectric anisotropy of between 5 to 20, and the monomer represented by formula (II) has a dielectric

20 anisotropy of between -5 to 5. The monomer represented by formula (II) employed in the liquid crystal material formulation is used to adjust the temperature range of liquid crystal phase and reduce the bulk viscosity of the liquid crystal material formulation. The first monomer can optionally include the monomer represented by formula (II). Alternatively, the first monomer consists of the monomer represented by formula (I).

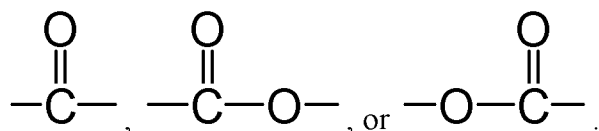
25 [0053] The second monomer at least includes the monomer represented by formula (III),

and can optionally further include a monomer represented by formula (IV).



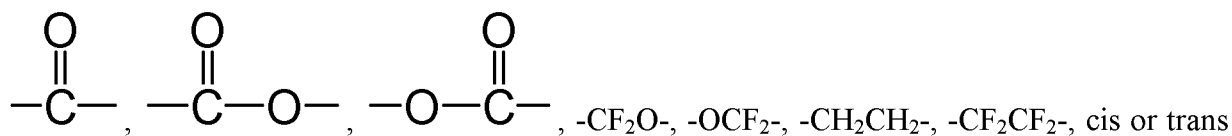
[0054]

[0055] R^1 is independent and includes hydrogen, C_{1-15} straight or branched alkyl group, or C_{1-15} straight or branched alkenyl group; one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more $-\text{CH}_2-$ of the alkyl or alkenyl group is substituted optionally by $-\text{O}-$, $-\text{S}-$,



[0056] A and B are independent and selected from a group consisting of trans-1,4-cyclohexylene, and 1,4-phenylene; one or more $-\text{CH}_2-$ of A and B is substituted optionally by $-\text{O}-$, or $-\text{NH}-$; one or more $=\text{CH}-$ of A and B is substituted optionally by $=\text{N}-$; and one or more hydrogen atom of A and B is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group.

[0057] Z^1 and Z^2 are independent and, selected from a group consisting of $-\text{CH}_2-$, $-\text{O}-$, $-\text{S}-$,

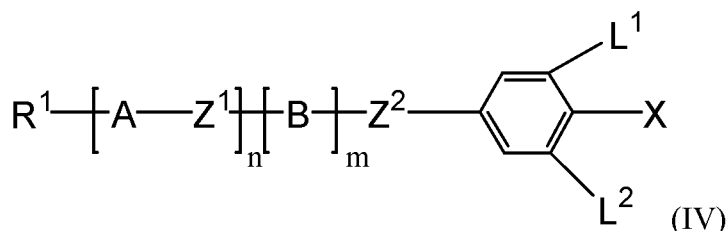


n is 0 or an integral of 1-3, m is 0 or an integral of 1-3, and the sum of n and m is 1-3; and L is hydrogen or fluorine.

[0058] For the monomer represented by formula (III), since one or two hydrogen atoms bonded on the benzene ring of the monomer represented by formula (I) is replaced by fluorine atom, the monomer represented by formula (III) has relatively high dielectric anisotropy in comparison with the monomer represented by formula (I). In general, the monomer represented by formula (III) has a dielectric anisotropy of between 15 to 50, thereby increasing the dielectric anisotropy of the liquid crystal material formulation and reducing the driving

voltage of the liquid crystal material formulation.

[0059] The second monomer can optionally further include a monomer represented by formula (IV).



[0060]

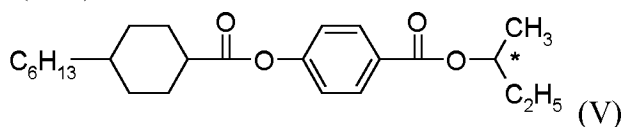
5 [0061] R^1 , A, B, Z^1 , Z^2 , n, and m are as previously defined; X is fluorine, $-\text{CF}_3$, and $-\text{OCF}_3$; and L^1 and L^2 are independent and includes hydrogen or fluorine.

[0062] For the monomer represented by formula (IV), since the terminal CN group of the monomer represented by formula (III) is replaced by X group (X is fluorine, $-\text{CF}$, or $-\text{OCF}_3$), the monomer represented by formula (IV) has relatively low dielectric anisotropy in comparison with the monomer represented by formula (III). In general, the monomer represented by formula (IV) has a dielectric anisotropy of between 5 to 20.

[0063] The monomers represented by formulas (I), (II), (III) and (IV) can be prepared by the methods known to those skilled in the art, such as, those described in US Patent Nos. 4229315, 4330426, 4422951, 4536321, 4576733, 4853152, and 5976404, the contents of which are hereby incorporated by reference.

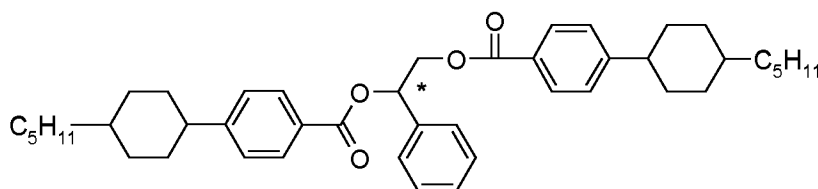
[0064] Generally, the cholesteric liquid crystal material seldom employs the monomer represented by formula (IV). Under some specific conditions, the characteristics (such as bulk viscosity, or driving time) of the liquid crystal material formulation can be modified by addition of the monomer represented by formula (IV).

20 [0065] In addition to the aforementioned liquid crystal monomers, the liquid crystal material component further includes, but not limited to, at least one of several chiral agents as below. The chiral agents can be commercially available and have structures represented by formula (V)-(VIII).



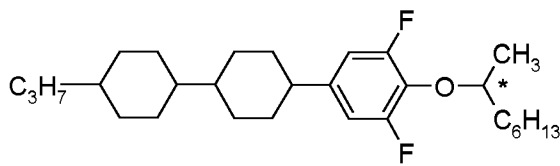
[0066]

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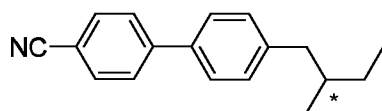
[0067]

(VI)



[0068]

(VII)

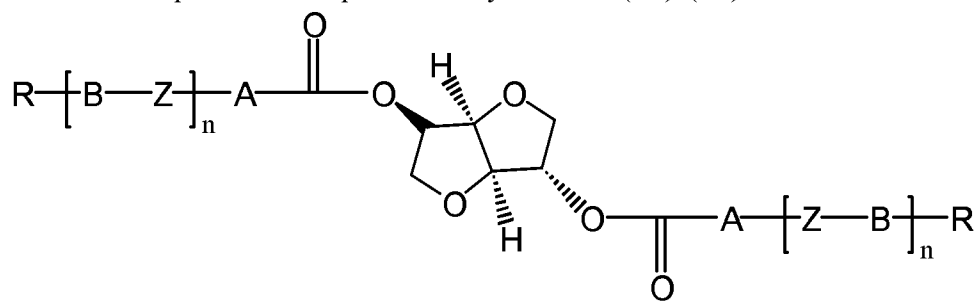


[0069]

(VIII)

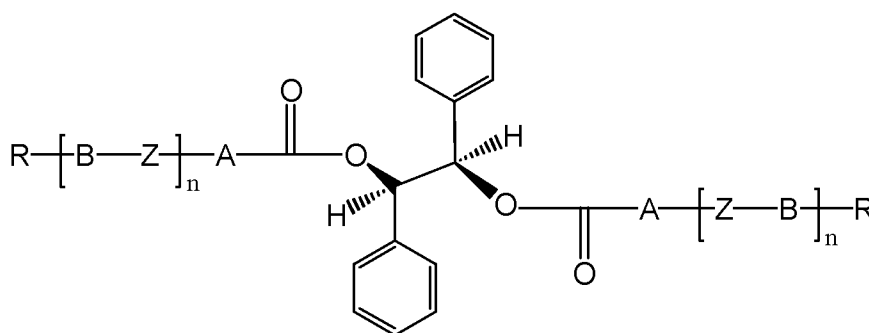
[0070] The chiral agents represented by formulas (V)- (VIII) can be prepared by the methods known to those skilled in the art, such as, those described in US Patent Nos. 4780240, 5114614, 5139698, EP0168043, and DE4322905, the contents of which are hereby incorporated by reference.

[0071] Other workable chiral agents can include the chiral agents disclosed in US6217792, V. Vill, F. Fischer, and J. Thiem, Zeitschrift Fur Naturforschung A., Journal of Physical Science, 43a(12), 1119-1125 (1988), GB2328207, US7052743, or US7150900B2, such as compounds having high helical twist power and represented by formula (IX)-(XI)



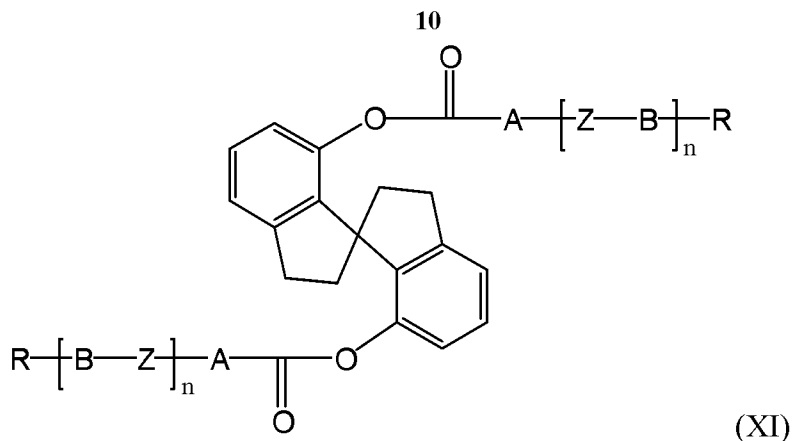
[0072]

(IX)

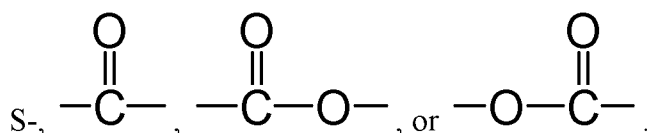


[0073]

(X)



[0075] R is independent and includes hydrogen, C₁₋₁₅ straight or branched alkyl group, or C₁₋₁₅ straight or branched alkenyl group; one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more -CH₂- of the alkyl or alkenyl group is substituted optionally by -O-, -



[0076] A and B are independent and selected from a group consisting of trans-1,4-cyclohexylene, and 1,4-phenylene; one or more -CH₂- of A and B is substituted optionally by -O-, or -NH-; one or more =CH- of A and B is substituted optionally by =N-; and one or more hydrogen atom of A and B is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group.

[0077] Z is independent and selected from a group consisting of -CH₂-, -O-, -S-, $\text{—}\overset{\text{O}}{\parallel}{\text{C}}\text{—}$,

$\text{—}\overset{\text{O}}{\parallel}{\text{C}}\text{—O—}$, $\text{—O—}\overset{\text{O}}{\parallel}{\text{C}}\text{—}$, -CF₂O-, -OCF₂-, -CH₂CH₂-, -CF₂CF₂-, cis or trans -C=C-, or -C≡C-; and n is independent and an integral of 1-2.

[0078] The reflective liquid crystal material formulation of the invention employs the second monomer with high dielectric anisotropy to reduce the driving voltage.

[0079] Due to the different ratio between the first monomer and second monomer, the liquid crystal components with different reflective colors can be operated by a single driving

voltage.

[0080] For example, in the case of a full-color liquid crystal display, the reflective liquid crystal material formulation of the invention includes:

[0081] (A) a first liquid crystal component having a first reflective wavelength (such as red light) includes:

[0082] 100 parts by weight of a first liquid crystals host including 100% of a first monomer; and

[0083] 3-10 parts by weight of a first chiral agent;

[0084] (B) second liquid crystal component having a second reflective wavelength (such as green light) includes:

[0085] 100 parts by weight of a second liquid crystals host including 60-80% of a first monomer and 20-40% of a second monomer; and

[0086] 3-10 parts by weight of a second chiral agent.

[0087] (C) a third liquid crystal component having a third reflective wavelength includes:

[0088] 100 parts by weight of a third liquid crystals host including 10-60% of a first monomer and 40-90% of a second monomer; and

[0089] 3-10 parts by weight of a third chiral agent.

[0090] As shown in Fig.1, the relationship of RGB liquid crystal component driving voltages in a conventional liquid crystal formulation is $V_B > V_G > V_R$. In order to reduce the driving voltage, the second (green) liquid crystals host has 20-40% the second monomer with high dielectric anisotropy and the third (blue) liquid crystals host has 40-90% the second monomer with high dielectric anisotropy. Therefore, the cholesteric liquid crystal components with different reflective wavelengths have the same or similar driving voltage. In an embodiment, the first (red) liquid crystal host has a dielectric anisotropy less than 20 (such as 15-18), the second (green) liquid crystal host has a dielectric anisotropy of between 20-25, and the third (blue) liquid crystal host has a dielectric anisotropy of between. In this way, the driving voltage difference between two or more liquid crystal components with different reflective wavelengths can be less than 4V, more preferably less than 3V, and most preferably less than 1V.

[0091] It should be noted that the aforementioned liquid crystal components (A), (B), and (C) can respectively have the same or different first monomers and second monomers. Further,

the first , second , and third chiral agents can be selected from the compounds represented by formula (V)-(XI) or other known chiral agents.

[0092] As discussed above, the liquid crystal material formulation can include three liquid crystal components for full-color display. In addition, the liquid crystal material formulation of the invention can only include two liquid crystal components, such as crystal components (A) and (B), crystal components (A) and (C), or crystal components (B) and (C), for a color liquid crystal display, wherein the reflective wavelength difference between the two components has to be more than 50nm. Further, the reflective liquid crystal material formulation of the invention can be applied in a black-and-white binary liquid crystal display.

[0093] The following are intended to illustrate the invention more fully without limiting their scope, since numerous modifications and variations will be apparent to those skilled in this art.

[0094] A liquid crystal display employing the reflective liquid crystal material formulation in an exemplary embodiment of the invention is disclosed as below in detail.

[0095] The reflective bistable liquid crystal display of the invention can include at least two electrode layers, and the aforementioned reflective liquid crystal material formulation disposed between the two electrode layers, wherein the liquid crystal components are isolated from each other, and the driving voltage difference of any two liquid crystal components is less than 4V.

[0096] In an embodiment, the reflective liquid crystal material formulation of the invention can be applied in a color display with stacked multi-layers, as shown in Fig. 3. Particularly, the color display with stacked multi-layers can include three stacked light modulating layers 110, 120, and 130 respectively including red, green, and blue cholesteric liquid crystal components (such as the aforementioned liquid crystal components (A), (B), and (C)). Each light modulating layer is disposed between the two transparent electrodes 101 for forcing the cholesteric liquid crystal to present a planar state or a focal conic state. Suitable materials of the transparent electrodes 101 can be Indium tin oxide (ITO) or indium zinc oxide (IZO).

[0097] The liquid crystal component of the invention can be coated directly on the transparent electrodes to serve as light modulating layers. Otherwise, before coating, the liquid crystal component can be mixed with a prepolymer (such as monomers) in advance. After

polymerizing the prepolymer via irradiance or heat, phase separation has been observed during polymerization due to the reduction of the solubility among the prepolymer and the liquid crystal. Then, the liquid crystal (in microsphere form) is uniformly distributed among the polymer, obtaining a polymer dispersed cholesteric liquid crystal (PDChLC).

5 **[0098]** The substrate 100 can be a hard substrate, such as glass or quartz, or a flexible substrate for a flexible display. Suitable materials of the flexible substrate can be polyethylene naphthalate (PEN), polyethylene terephthalate (PET), polyamide, polymethylmethacrylate, polycarbonate, or polyurethane. Further, a light absorption layer 500 can be disposed under the substrate 100.

10 **[0099]** In another embodiment, the reflective liquid crystal material formulation of the invention is applied in a color display with a single layer, as shown in Fig.4. The display at least includes a bottom substrate 200 with a bottom electrode layer 201. Spacers 202 (such as polymer) are disposed on the bottom electrode layer 201 to define several isolated cavities. The red, green, and blue cholesteric liquid crystal components 210, 220, and 230 can be injected
15 into the cavities by ink-jet printing or vacuum injection molding. Next, a top electrode layer 30 is disposed on the spacers 202 to envelop the cavities. Further, a light absorption layer 500 can be disposed under the bottom substrate 200.

20 **[00100]** In yet another embodiment, the reflective liquid crystal material formulation of the invention is applied in a single color (black-and-white binary) display, as shown in Fig. 5. The display includes a top substrate 200 with a top electrode 201, a bottom substrate 300 with a bottom electrode 301, and a layer of polymer dispersed cholesteric liquid crystal (PDChLC) 400 disposed between the top electrode 201 and the bottom electrode 301. A light absorption layer 500 can be disposed under the bottom substrate 200. The polymer dispersed cholesteric liquid crystal (PDChLC) 400 includes simultaneously red, green, and blue cholesteric liquid
25 crystal 420R, 420G, and 420B uniformly distributed among a polymer matrix 410 such as acrylic resin or epoxy resin.

[00101] It should be noted that the red, green, and blue cholesteric liquid crystal components 420R, 420G, and 420B can be operated via the same voltage difference between the top and bottom electrodes, thereby providing a color liquid crystal display.

30 **[00102]** Although there are three types of reflective bistable liquid crystal displays, the practical applications of the invention are not limited by above. The related fabrication of

reflective bistable liquid crystal displays are also disclosed in US7382424, US7119859, US6570633, US6356323, US20060176257, and US20060119782.

[00103] The reflective bistable liquid crystal display of the invention can be implemented as a display device, such as a mobile phone, digital camera, PDA (personal data assistant), notebook computer, desktop computer, television, car display, or portable DVD player.

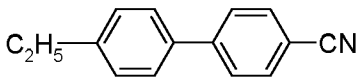
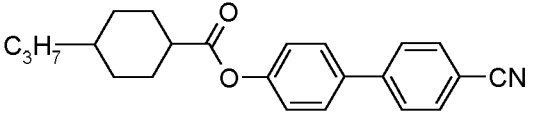
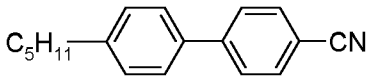
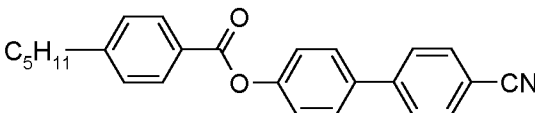
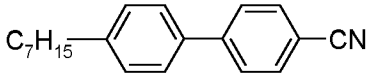
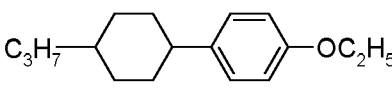
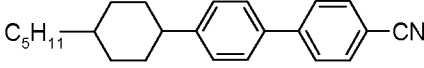
[00104] The following examples are intended to illustrate the invention more fully without limiting their scope, since numerous modifications and variations will be apparent to those skilled in this art. Unless specific definitions are provided, the symbol % disclosed as below represents weight percent.

[00105] Preparation Examples

[00106] The liquid crystal components disclosed in Examples and Comparative Examples are as discussed below in detail:

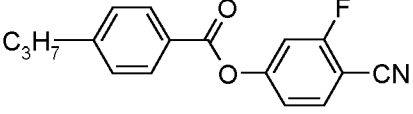
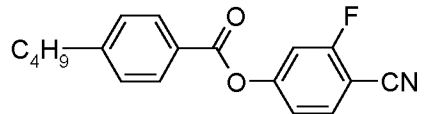
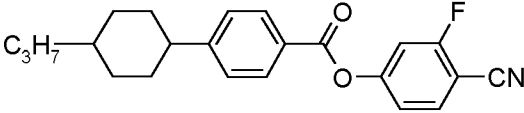
[00107] 1) BL087, sold by Merck GmbH, with a dielectric anisotropy of about 17.

[00108] 2) the components of the first monomer based formulation A (including compounds represented by formula (I) and formula (II)) has listed as following table:

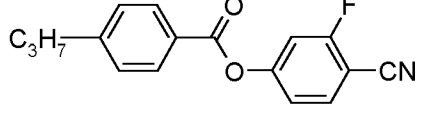
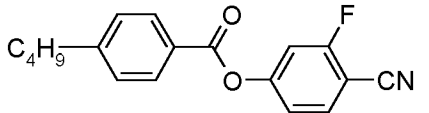
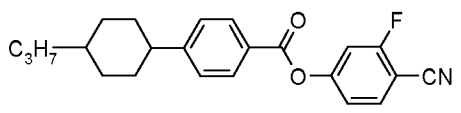
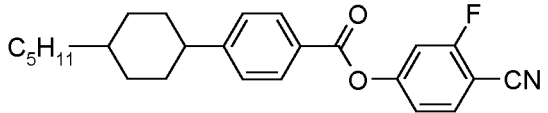
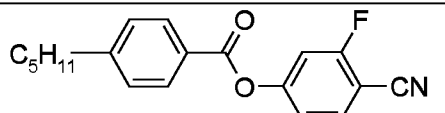
structure	%	structure	%
 , which can be obtained from US 4780242 and US 5114614.	12.6	 , which can be obtained from US 4780242 and US 5114614.	10.0
 , which can be obtained from US 4780242 and US 5114614.	31.9	 , which can be obtained from US 4576733.	6.2
 , which can be obtained from US 4780242 and US 5114614.	21.8	 , which can be obtained from US 6028655.	7.2
 , which can be obtained from US	10.3		

4330426 and US 5976404.

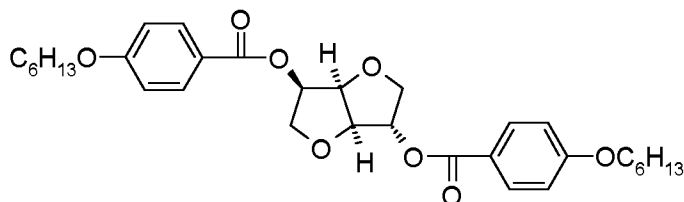
[00109] 3) the components of the second monomer based formulation X (including compounds represented by formula (III)) has listed as following table:

structure	%	structure	%
 , which can be obtained from US4576733.	40	 , which can be obtained from US4576733.	40
 , which can be obtained from US5976404 and US 6028655.	20		

[00110] 4) the components of the second monomer based formulation Y (including compounds represented by formula (III)) has listed as following table:

structure	%	structure	%
 , which can be obtained from US 4576733.	30	 , which can be obtained from US 4576733.	10
 , which can be obtained from US 5976404 and US 6028655.	20	 , which can be obtained from US 5976404 and US 6028655.	10
 , which can be obtained from US 4576733.	30		

[00111] The chiral agent (Z) including compounds represented by formula (IX) has a structure as below:



[00112]

[00113] The chiral agent (Z) including compounds represented by formula (IX) can be obtained from US6217792.

[00114] The process for preparing nematic liquid crystal and cholesteric liquid crystal includes the following steps: mixing components according to the specific ratio, heating the mixture over the temperature of the clearing point, and cooling.

[00115] The dielectric anisotropy of the reflective liquid crystal material formulation is measured by LCAS (manufactured and sold by LC-Version). The reflective spectrum of the liquid crystal material is measured by UV/VIS spectrophotometer. The reflective spectrum and V-R curve of the display employing the reflective liquid crystal material formulation is measured by DMS-803 (manufactured and sold by Autronic Melchers).

[00116] Comparative Example 1

[00117] In Comparative Example 1, the color liquid crystal material formulation employs the first monomer based formulation A and the chiral agent (Z). The following table shows the ratio between the first monomer A and the chiral agent Z and the driving voltage of the respective red, green, and blue cholesteric liquid crystal components of the material formulation.

	$\lambda_{\max}$	first monomer A (%)	chiral agent Z (%)	driving voltage(V)
Red	670	95.6	4.4	23.2
Green	540	94.6	5.4	27.6
blue	440	93.2	6.8	33.1

[00118] As shown in the above table, the driving voltages increases depending on the amount of chiral agent added. Therefore, due to the driving voltage difference of the red, green,

and blue cholesteric liquid crystal components of about 4-5V, the display employing the reflective liquid crystal material formulation should be operated by three different driving voltages.

[00119] Example 1

- 5 **[00120]** In Example 1, the color liquid crystal material formulation employs the first monomer based formulation A and the second monomer formulation X. The following table shows the ratio between the monomer and the chiral agent and the driving voltage of the respective red, green, and blue cholesteric liquid crystal components of the material formulation.

	$\lambda_{\max}$	first monomer A (%)	second monomer X(%)	chiral agent Z (%)	driving voltage(V)
Red	670	95.6	0	4.4	23.2
Green	540	74.6	20.4	5.1	23.6
blue	440	43.8	50.2	6.0	23.8

- 10 **[00121]** As shown in the above table, after the addition of the second monomer formulation X, the driving voltage of each red, green, and blue cholesteric liquid crystal component is reduced and the driving voltage difference of the red, green, and blue cholesteric liquid crystal components is reduced to less than 1V. Therefore, the display employing the reflective liquid crystal material formulation can be operated by a single driving voltage.

15 **[00122]** Comparative Example 2

[00123] In Comparative Example 2, the color liquid crystal material formulation employs the liquid crystal BL087 and the chiral agent (Z). The following table shows the ratio between the liquid crystal BL087 and the chiral agent Z and the driving voltage of the respective red, green, and blue cholesteric liquid crystal components of the material formulation.

	$\lambda_{\max}$	BL087 (%)	chiral agent Z (%)	driving voltage
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Red	650	95.5	4.5	22.8
Green	530	94.4	5.6	27.3
blue	480	93.8	6.2	29.2

[00124] The driving voltage measurement results of Comparative Example 2 are similar to that of the Comparative Example 1. The driving voltages increases depending on the amount of chiral agent added. Therefore, the display employing the reflective liquid crystal material formulation should be operated by three different driving voltages.

5 **[00125]** Example 2

[00126] In Example 2, the color liquid crystal material formulation employs the liquid crystal BL087 and the second monomer formulation X. The following table shows the ratio between the monomer and the chiral agent and the driving voltage of the respective red, green, and blue cholesteric liquid crystal components of the material formulation.

10

	$\lambda_{\max}$	BL087 (%)	second monomer X(%)	chiral agent Z (%)	driving voltage(V)
Red	650	95.5	0	4.5	22.8
Green	530	64.5	30.4	5.1	22.7
blue	460	38.7	55.7	5.6	22.4

[00127] Similar to Example 1, the driving voltage of each red, green, and blue cholesteric liquid crystal component disclosed in Example 2 is reduced and the driving voltage difference of the red, green, and blue cholesteric liquid crystal components is reduced to less than 1V. Therefore, the display employing the reflective liquid crystal material formulation can be operated by a single driving voltage.

15

[00128] Example 3

[00129] In Example 3, the color liquid crystal material formulation employs the liquid crystal BL087 and the second monomer formulation Y. The following table shows the ratio between the monomer and the chiral agent and the driving voltage of the respective red, green,

and blue cholesteric liquid crystal components of the material formulation.

	$\lambda_{\max}$	BL087 (%)	second monomer Y(%)	chiral agent Z (%)	driving voltage
Red	650	95.5	0	4.5	22.8
Green	530	58.8	36.3	4.9	23.1
blue	450	21.7	72.6	5.7	23.3

[00130] Likewise, the driving voltage of each red, green, and blue cholesteric liquid crystal component disclosed in Example 3 is reduced and the driving voltage difference of the red, green, and blue cholesteric liquid crystal components is reduced to less than 1V.

5 **[00131]** Example 4

[00132] Two liquid crystal cell (respectively including two transparent substrates and electrodes formed thereon) were provided, and the red and blue liquid crystal component disclosed in Example 3 were respectively injected into the two liquid crystal cells. Fig. 6 shown the independent reflective spectrums thereof.

10 **[00133]** After overlapping the two liquid crystal cell, the reflective spectrum of the stacked device during 25V to 30V was measured. As shown in Fig. 7, the cholesteric liquid crystal components with different reflective colors can be operated by a single driving voltage.

[00134] While the invention has been described by way of example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. To the
15 contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

CLAIMS

1. A reflective liquid crystal material formulation, comprising at least two of (A) first liquid crystal component, (B) second liquid crystal component, and (C) third liquid crystal component,

5 wherein

(A) the first liquid crystal component having a first reflective wavelength comprises:

100 parts by weight of a first liquid crystals host comprising 100% of a first monomer;

and

3-10 parts by weight of a first chiral agent;

10 (B) the second liquid crystal component having a second reflective wavelength comprises:

100 parts by weight of a second liquid crystals host comprising 60-80% of a first monomer and 20-40% of a second monomer; and

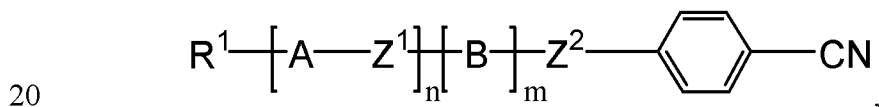
3-10 parts by weight of a second chiral agent; and

15 (C) the third liquid crystal component having a third reflective wavelength comprises:

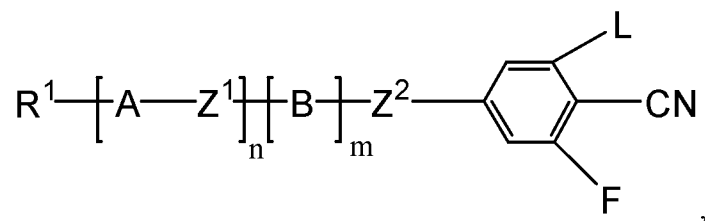
100 parts by weight of a third liquid crystals host comprising 10-60% of a first monomer and 40-90% of a second monomer; and

3-10 parts by weight of a third chiral agent,

wherein the first monomer comprises a monomer represented by formula (I) of



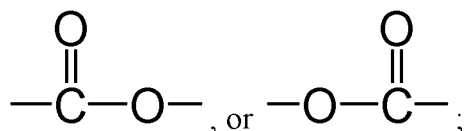
and the second monomer comprises a monomer represented by formula (III) of



wherein R^1 is independent and comprises hydrogen, C_{1-15} straight or branched alkyl group, or C_{1-15} straight or branched alkenyl group; one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more $-\text{CH}_2-$ of the

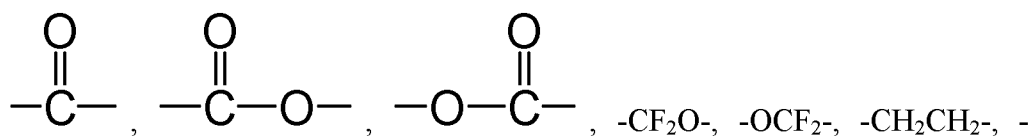
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alkyl or alkenyl group is substituted optionally by -O-, -S-, $\text{—}\overset{\text{O}}{\underset{\text{||}}{\text{C}}}\text{—}$,



A and B are independent and selected from a group consisting of trans-1,4-cyclohexylene, and 1,4-phenylene; one or more -CH₂- of A and B is substituted optionally by -O-, or -NH-; one or more =CH- of A and B is substituted optionally by =N-; and one or more hydrogen atom of A and B is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group;

Z¹ and Z² are independent and, selected from a group consisting of -CH₂-, -O-, -S-,



CF₂CF₂-, cis or trans -C=C-, or -C≡C-;

n is 0 or an integral of 1-3, m is 0 or an integral of 1-3, and the sum of n and m is 1-3;

and

L is hydrogen or fluorine.

2. The reflective liquid crystal material formulation as claimed in claim 1, wherein the first liquid crystals host has a dielectric anisotropy of less than 20, the second liquid crystals host has a dielectric anisotropy of between 20-25, and the third liquid crystals host has dielectric anisotropy of between 30-45.

3. The reflective liquid crystal material formulation as claimed in claim 1, wherein the difference between any two of the first reflective wavelength, the second reflective wavelength, and the third reflective wavelength is more than 50nm.

4. The reflective liquid crystal material formulation as claimed in claim 1, wherein the first reflective wavelength corresponds to a wavelength of red light, the second reflective wavelength corresponds to a wavelength of green light, and the third reflective wavelength corresponds to a wavelength of blue light.

5. The reflective liquid crystal material formulation as claimed in claim 4, wherein the reflective liquid crystal material formulation comprises (A) first liquid crystal component and (B) second liquid crystal component.

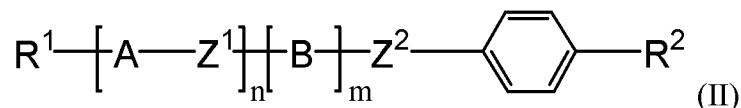
6. The reflective liquid crystal material formulation as claimed in claim 4, wherein the reflective liquid crystal material formulation comprises (A) first liquid crystal component and (C) third liquid crystal component.

7. The reflective liquid crystal material formulation as claimed in claim 4, wherein the reflective liquid crystal material formulation comprises (B) second liquid crystal component and (C) third liquid crystal component.

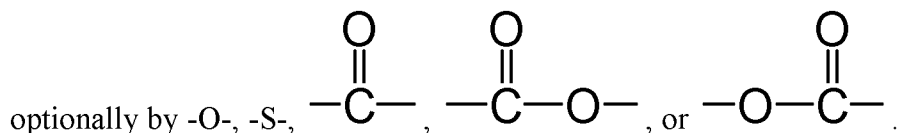
8. The reflective liquid crystal material formulation as claimed in claim 4, wherein the reflective liquid crystal material formulation comprises (A) first liquid crystal component, (B) second liquid crystal component and (C) third liquid crystal component.

9. The reflective liquid crystal material formulation as claimed in claim 4, wherein (A) the first liquid crystal component, (B) the second liquid crystal component, and (C) the third liquid crystal component are dispersed in a polymer.

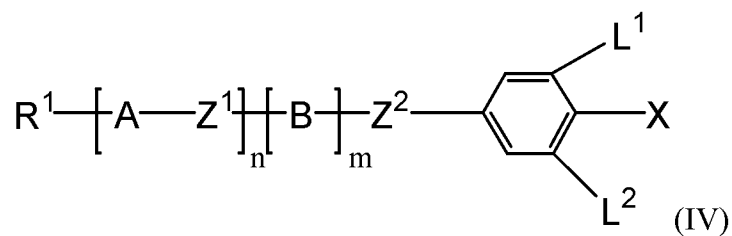
10. The reflective liquid crystal material formulation as claimed in claim 1, wherein the first monomer further comprises a monomer represented by formula (II) of :



wherein R^1 , A, B, Z^1 , Z^2 , n, and m are as previously defined; R^2 comprises hydrogen, C_{1-15} straight or branched alkyl group, or C_{1-15} straight or branched alkenyl group, one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more $-CH_2-$ of the alkyl or alkenyl group is substituted

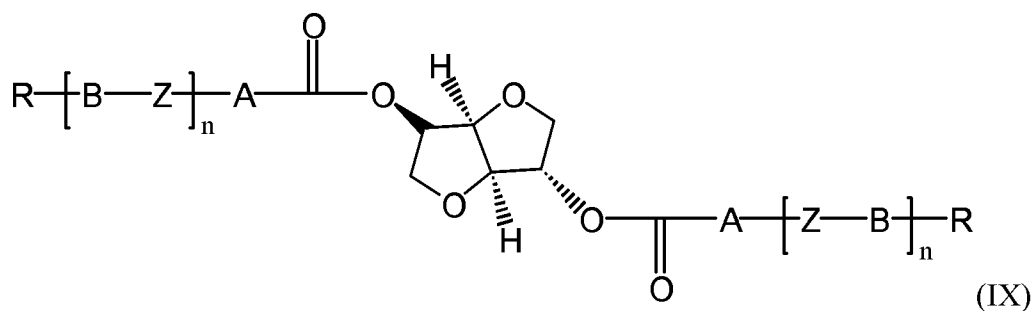
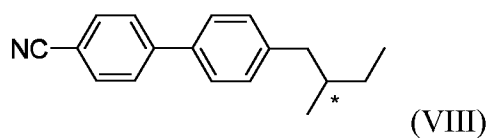
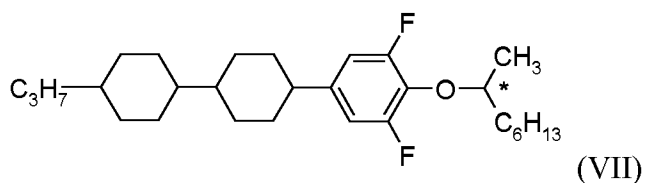
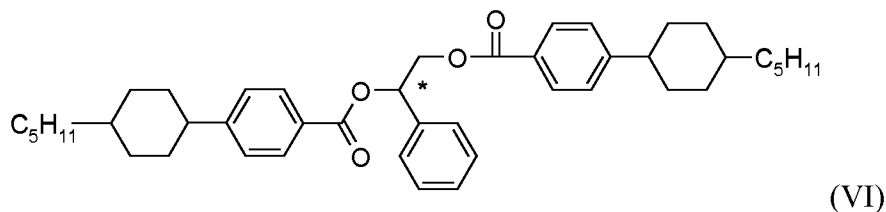
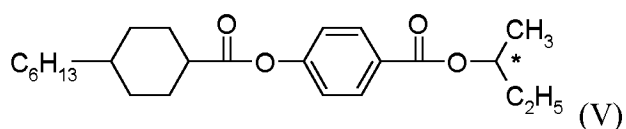


11. The reflective liquid crystal material formulation as claimed in claim 1, wherein the second monomer further comprises a monomer represented by formula (IV) of :

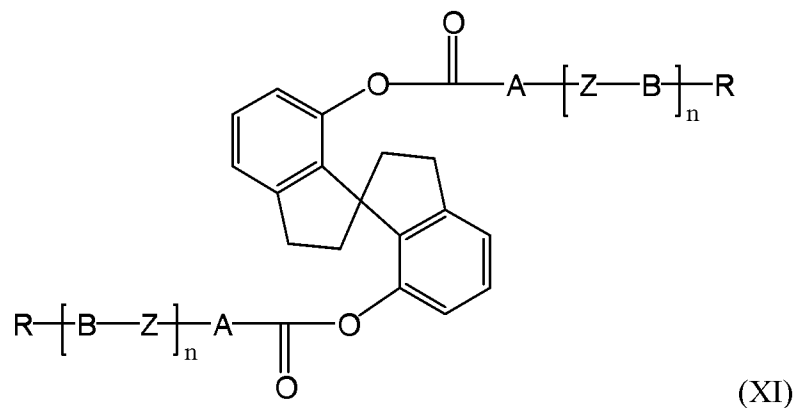
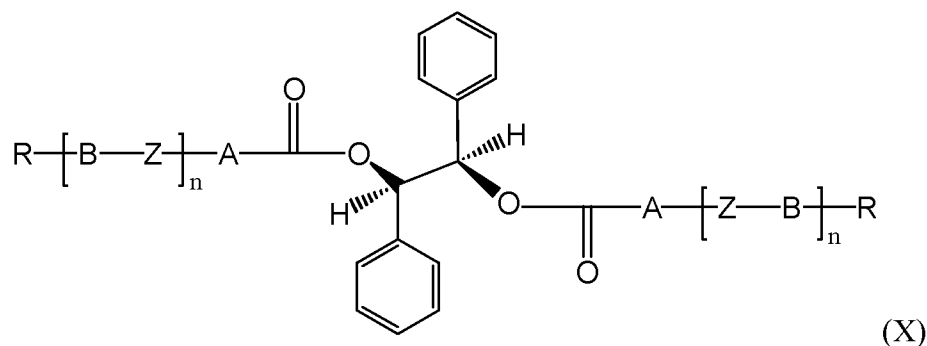


wherein R¹, A, B, Z¹, Z², n, and m are as previously defined; X is fluorine, -CF₃, and -OCF₃; and L¹ and L² are independent and comprises hydrogen or fluorine.

12. The reflective liquid crystal material formulation as claimed in claim 1, wherein the
5 first chiral agent, the second chiral agent, and the third chiral agent are independent and
selected from a group consisting of compounds represented by formula (V)-(XI) :

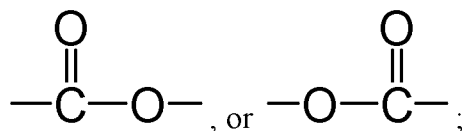


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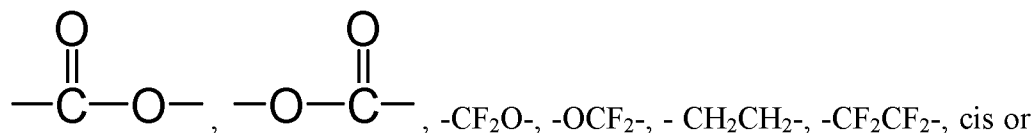
wherein, R is independent and comprises hydrogen, C₁₋₁₅ straight or branched alkyl group, or C₁₋₁₅ straight or branched alkenyl group; one or more hydrogen atom bonded to the alkyl or alkenyl group is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group; and one or more -CH₂- of the

alkyl or alkenyl group is substituted optionally by -O-, -S-, $\text{--}\overset{\text{O}}{\parallel}{\text{C}}\text{--}$,



A and B are independent and selected from a group consisting of trans-1,4-cyclohexylene, and 1,4-phenylene; one or more -CH₂- of A and B is substituted optionally by -O-, or -NH-; one or more =CH- of A and B is substituted optionally by =N-; and one or more hydrogen atom of A and B is substituted optionally by a halogen atom, cyano group, or perfluoromethyl group;

Z is independent and selected from a group consisting of $-\text{CH}_2-$, $-\text{O}-$, $-\text{S}-$, $-\text{C}(=\text{O})-$,



trans $-\text{C}=\text{C}-$, or $-\text{C}\equiv\text{C}-$; and n is independent and an integral of 1-2.

13. A reflective bistable liquid crystal display, comprising:

a first electrode layer;

a second electrode layer;

the reflective liquid crystal material formulation as claimed in claim 1 disposed between the first electrode layer and the second electrode layer,

wherein the liquid crystal components are isolated from each other, and the driving

voltage difference of any two liquid crystal components is less than 4V.

14. The reflective bistable liquid crystal display as claimed in claim 13, wherein the liquid crystal components are isolated from each other by spacers.

15. The reflective bistable liquid crystal display as claimed in claim 13, further comprising at least a third electrode layer disposed between the first electrode layer and the second electrode layer, isolating the liquid crystal components.

16. The reflective bistable liquid crystal display as claimed in claim 13, wherein the liquid crystal components are dispersed in a polymer.

17. The reflective bistable liquid crystal display as claimed in claim 13, wherein the reflective bistable liquid crystal display is a black-and-white binary display.

18. The reflective bistable liquid crystal display as claimed in claim 13, wherein the reflective bistable liquid crystal display is a color display.

19. The reflective bistable liquid crystal display as claimed in claim 13, wherein the reflective bistable liquid crystal display is a full-color display.

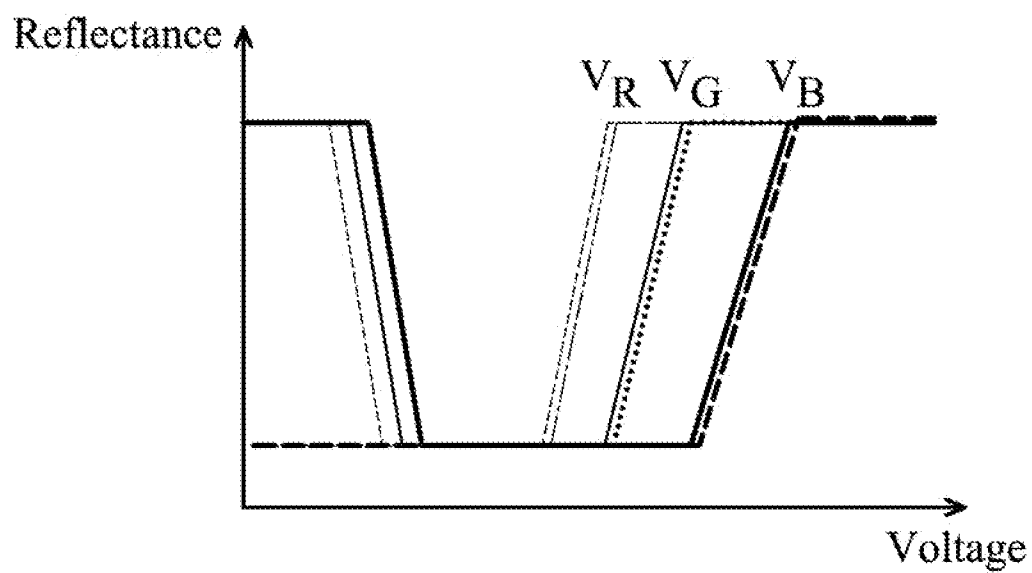


FIG. 1

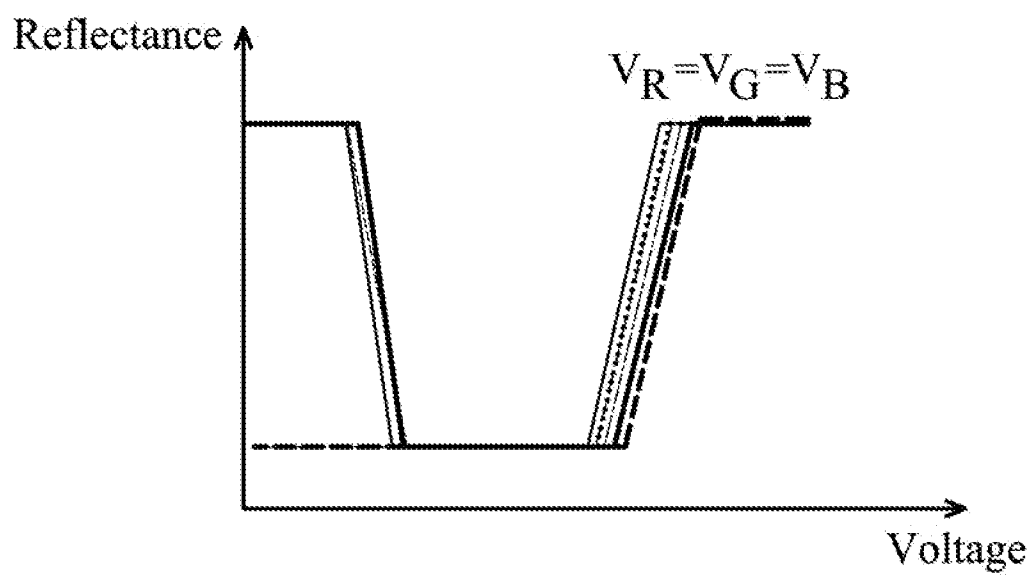


FIG. 2

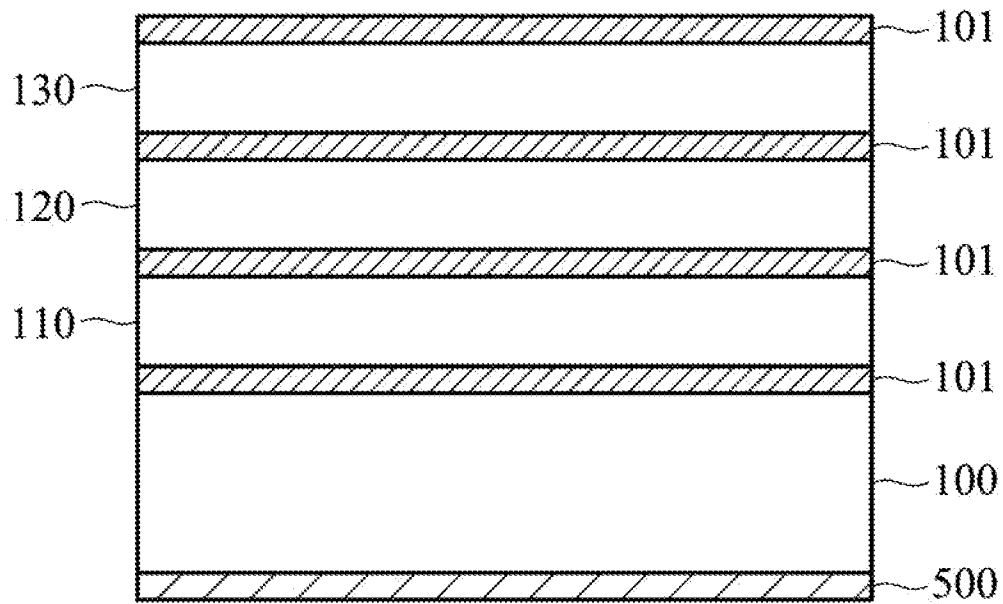


FIG. 3

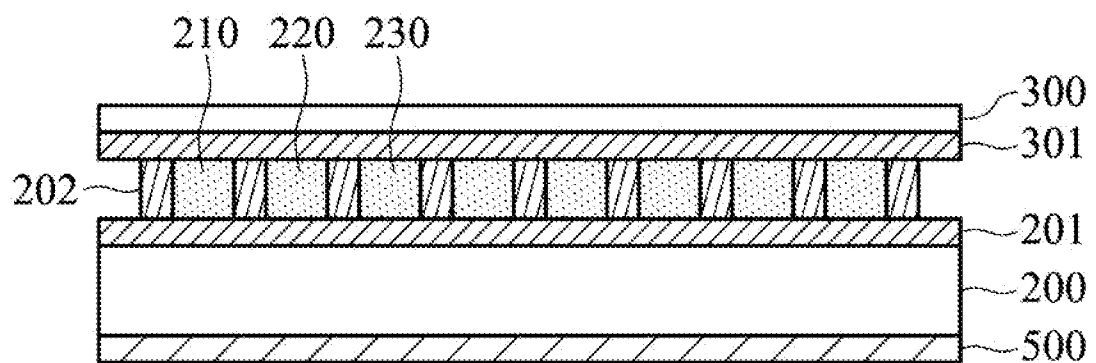


FIG. 4

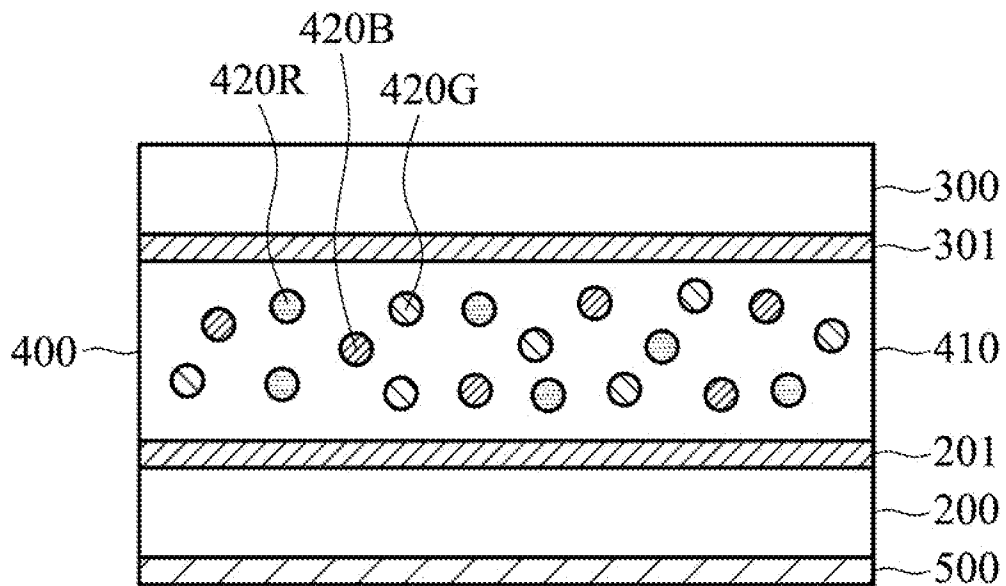


FIG. 5

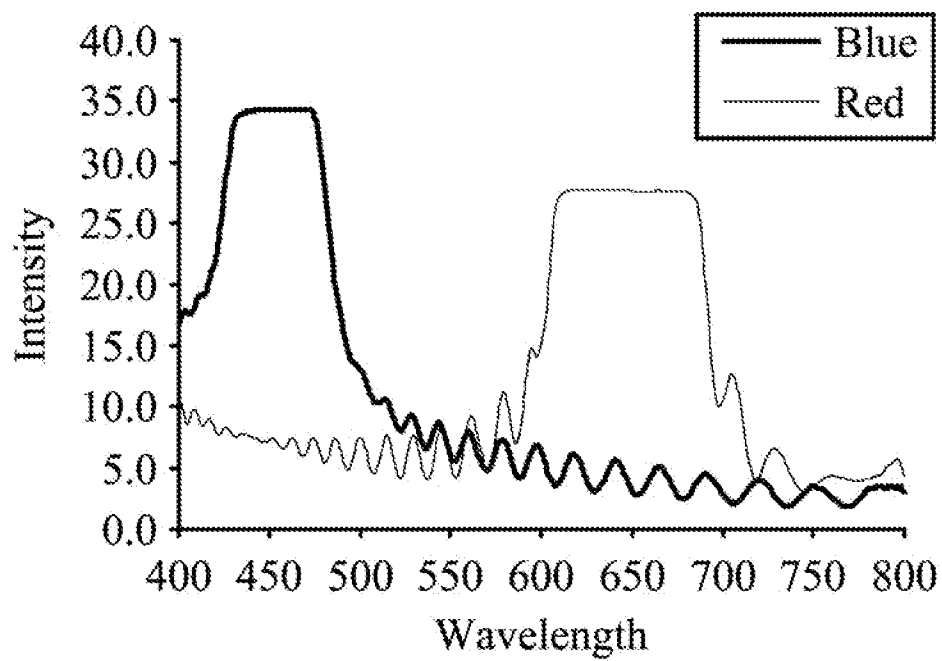


FIG. 6

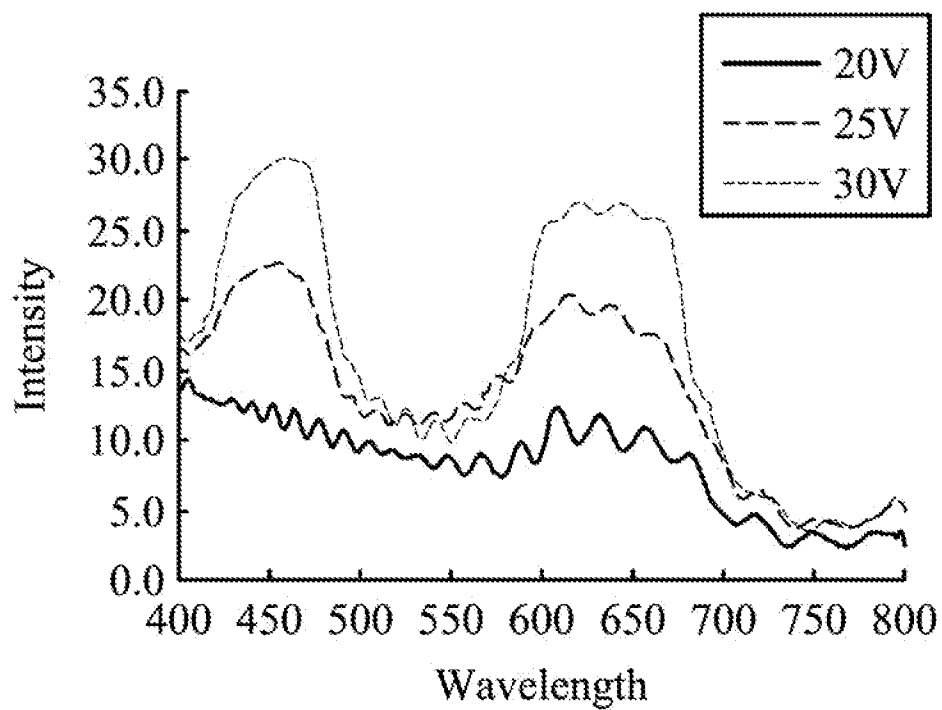


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/070160

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:C09K19,G02F1/13

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

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

CNPAT,CNKI,WPI,EPODOC: LIQUIDCRYSTAL+,LIQUID W
CRYSTAL+,LC,+,NITRILE,+,CYAN+,CYANIDE,CN,REFLECTIVE,ADMIXTURE?,MIXTURE?,COMPOSITION?,VOLTAGE,FIRST
4W (LIQUIDCRYSTAL+ OR (LIQUID W CRYSTAL+) OR LC)
STN: search base on general formula(I),(III)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US2007/0278449 A1(FUJI FILM CO LTD) 06 Dec. 2007(06.12.2007) See claim 1,paragraphs[0032-0040],[0047],[0058-0059],[0077]-[0080]	1-19
A	WO97/03146 A1(MERCK PATENT GMBH) 30 Jan. 1997(30.01.1997) See claims 1,6	1-19

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&”document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 07 Apr. 2010 (07.04.2010)	Date of mailing of the international search report 22 Apr. 2010 (22.04.2010)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer QU, Zaidan Telephone No. (86-10)62084552

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2010/070160

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN1153807 A(CHISSO CORP) 09 Jul. 1997(09.07.1997) See claims 1-10,pages 7-27	1-19
A	CN101144944 A(YOUDA PHOTOELECTRIC CO LTD) 19 Mar. 2008(19.03.2008) See pages 10-13	1-19

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2010/070160

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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CN101144944 A	19.03.2008	None	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/070160

CLASSIFICATION OF SUBJECT MATTER:

C09K 19/36 (2006.01) i

G02F 1/13 (2006.01) i

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