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(54) **RETARDATION PLATE, METHOD FOR MANUFACTURING THE RETARDATION PLATE, AND LIQUID CRYSTAL DISPLAY**

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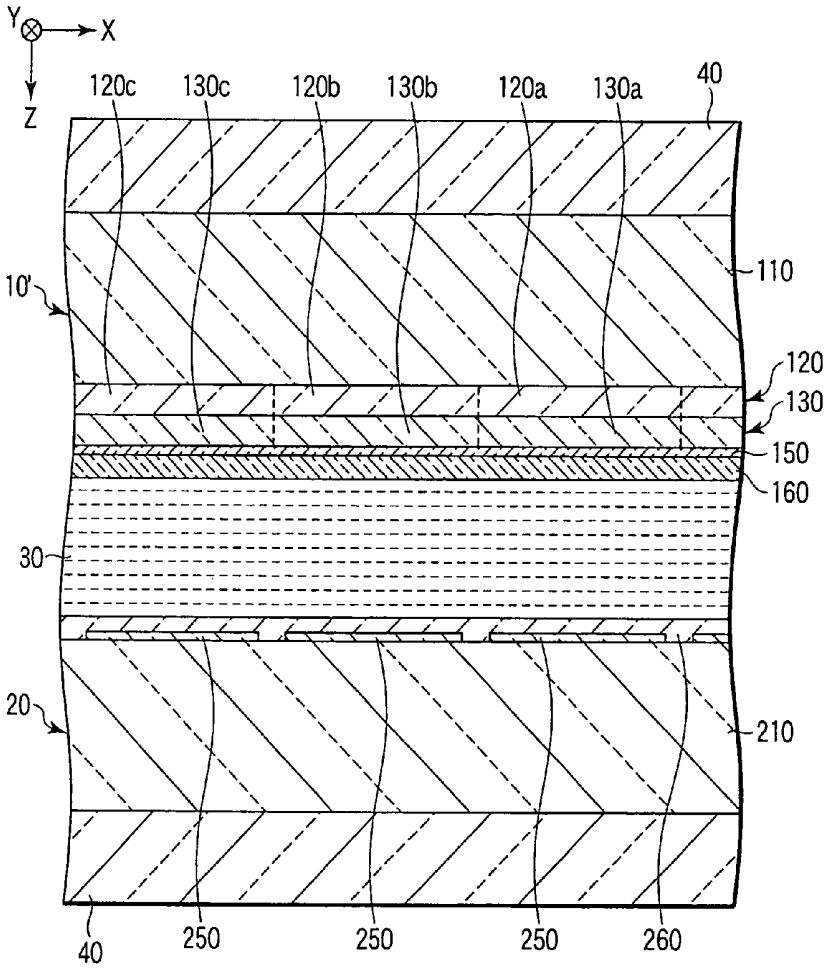
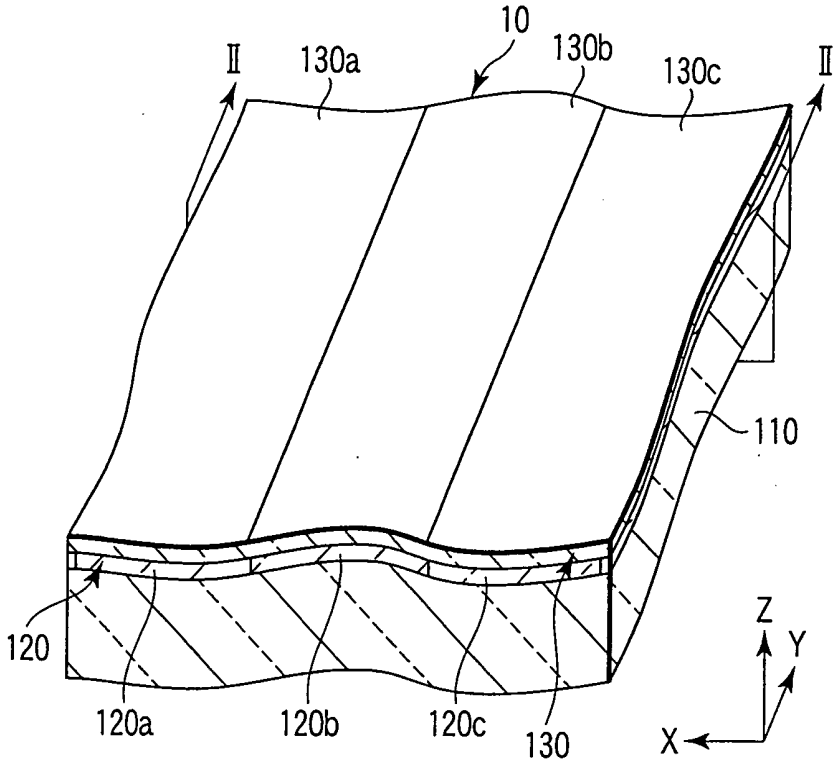
(57) **ABSTRACT**

A retardation plate includes a light transmissive planar body and a solidified liquid crystal layer which is a continuous film made from the same material supported by the planar body. The solidified liquid crystal layer comprises a plurality of regions in which a thickness direction refractive indices are lowest. The plurality of regions are arranged on the planar body, each region has a different in-plane retardation and different thickness direction retardation caused by the degree of orientational disorder of mesogens and anisotropy of orientational disorder of mesogens.

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130b
130c
II
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120
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120c
130
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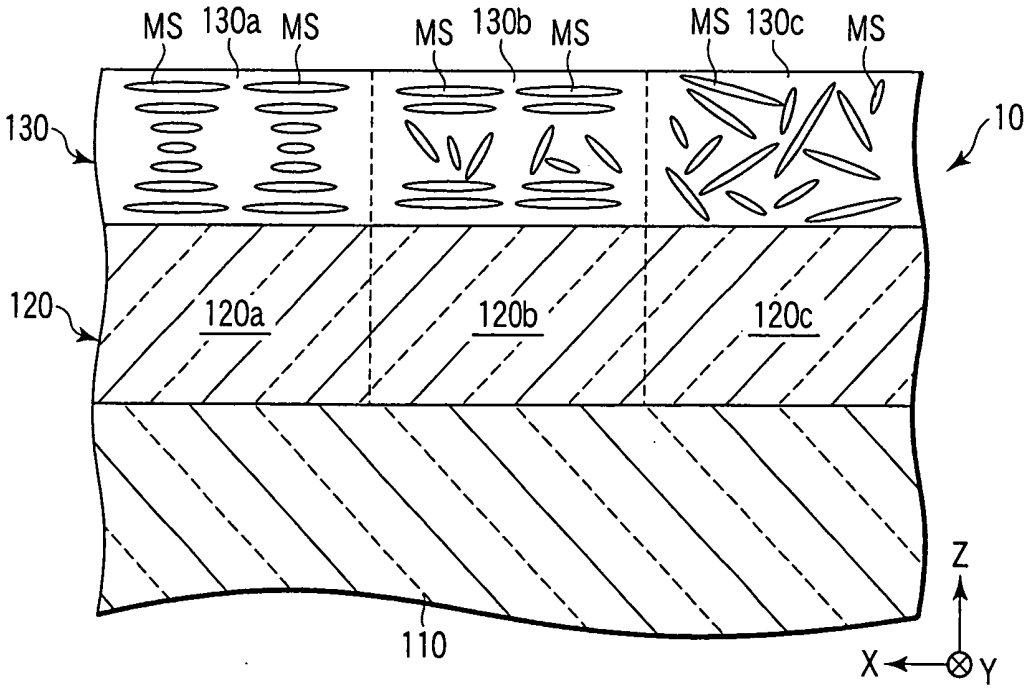
Y
X

FIG. 1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MS
130c
MS
130
10
120
120a
120b
120c
110
Z
X
Y

FIG. 2

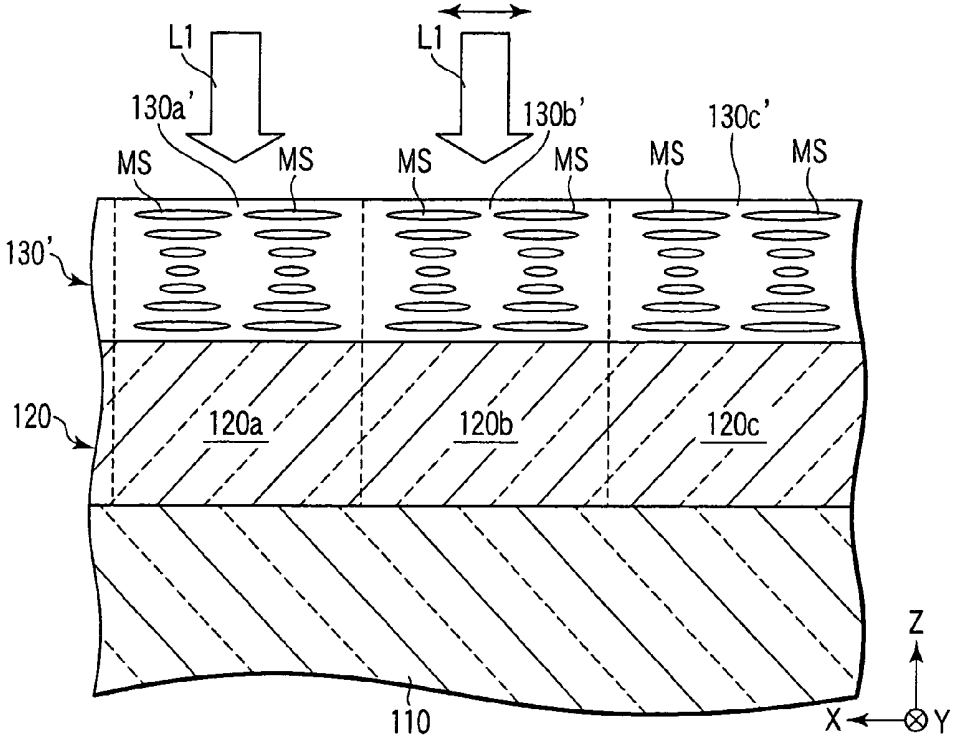

L1
L1
130a'
130b'
130c'
MS
MS
MS
MS
MS
MS
130'
120
120a
120b
120c
110
Z
X
Y

FIG. 3

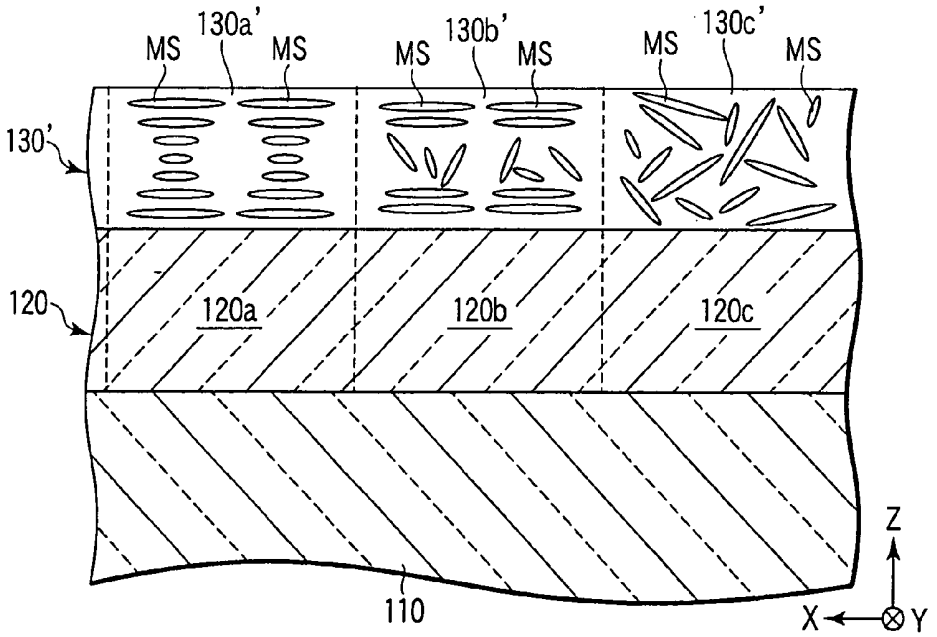
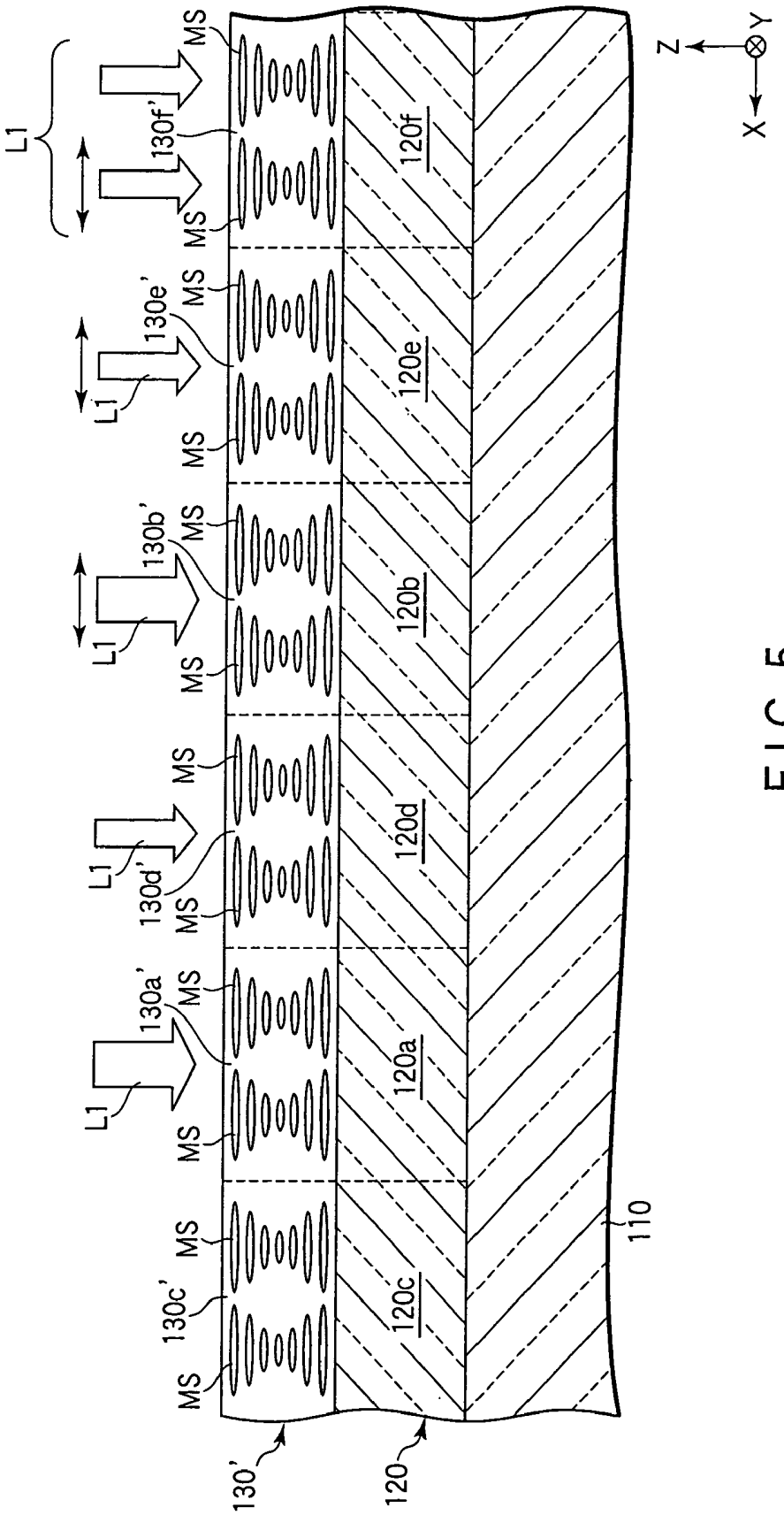

130a'
130b'
130c'
MS
MS
MS
MS
MS
MS
130'
120
120a
120b
120c
110
Z
X
Y

FIG. 4


L1
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MS
120f
130e'
120e
130b'
120b
130d'
120d
130a'
120a
130c'
120c
110
130'
120
Z
Y
X

FIG. 5

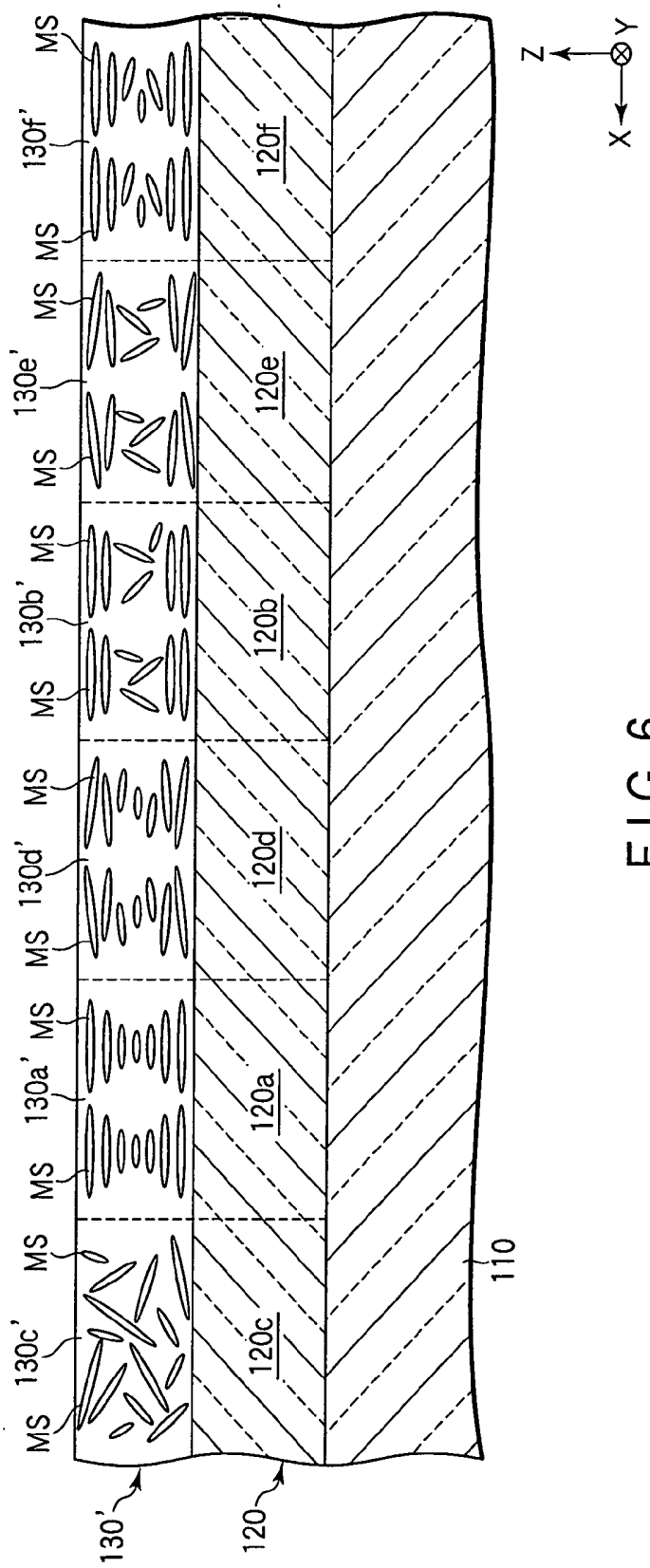

MS
130f'
120f
MS
MS
130e'
120e
MS
MS
130b'
120b
MS
MS
130d'
120d
MS
MS
130a'
120a
MS
MS
130c'
120c
MS
110
130'
120
Z
Y
X

FIG. 6

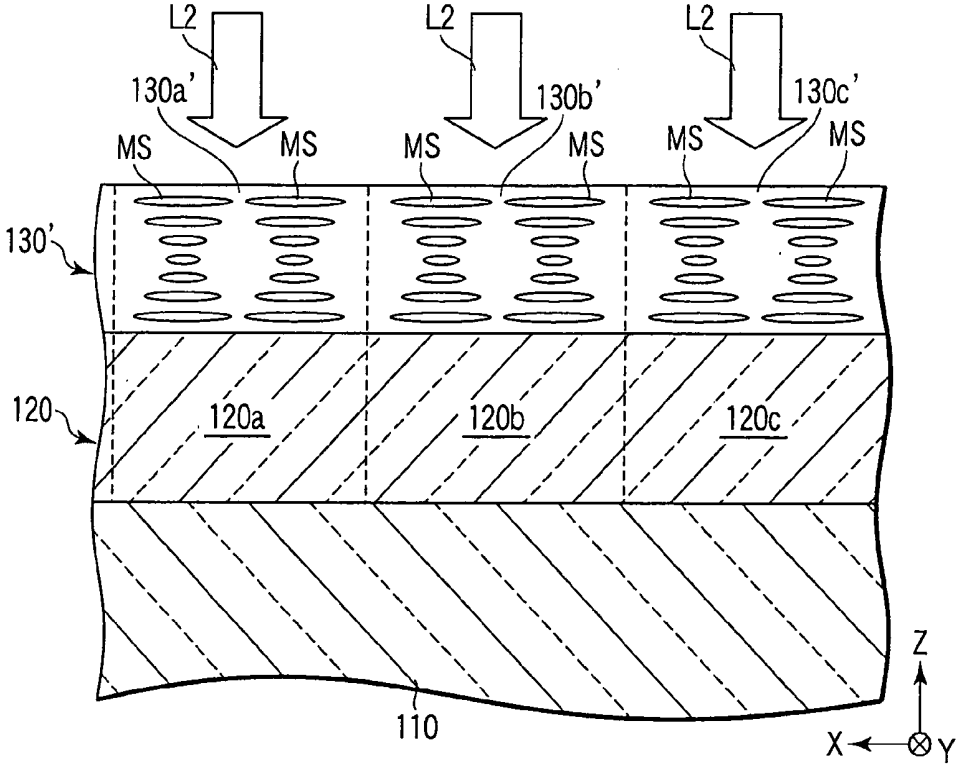

L2
L2
L2
130a'
130b'
130c'
MS
MS
MS
MS
MS
MS
130'
120
120a
120b
120c
110
Z
X
Y

FIG. 7

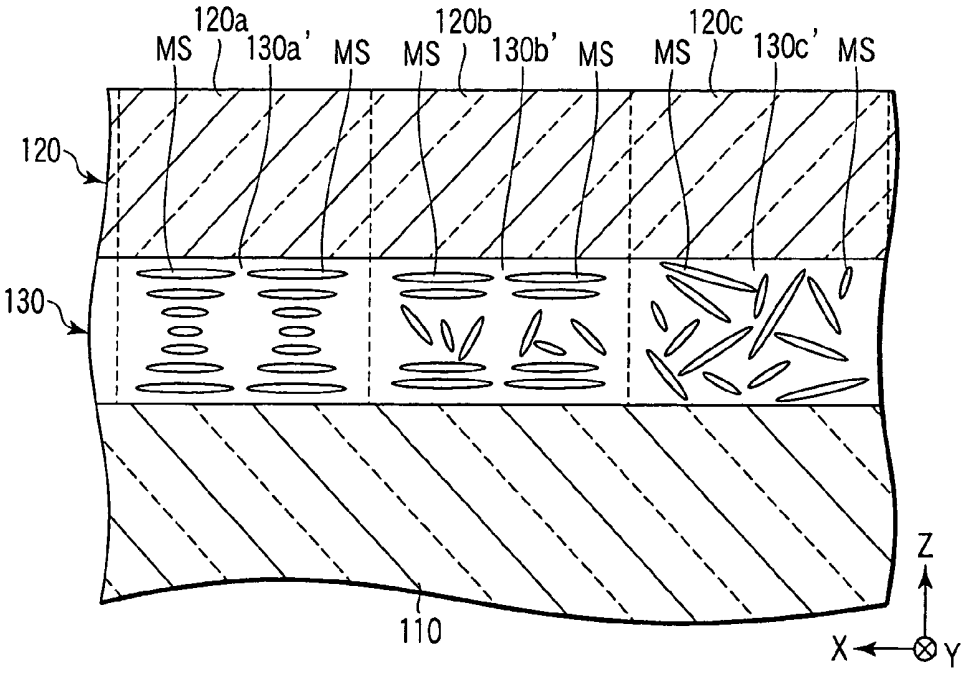

120a
120b
120c
MS
130a'
MS
MS
130b'
MS
MS
130c'
MS
120
130
110
Z
X
Y

FIG. 8

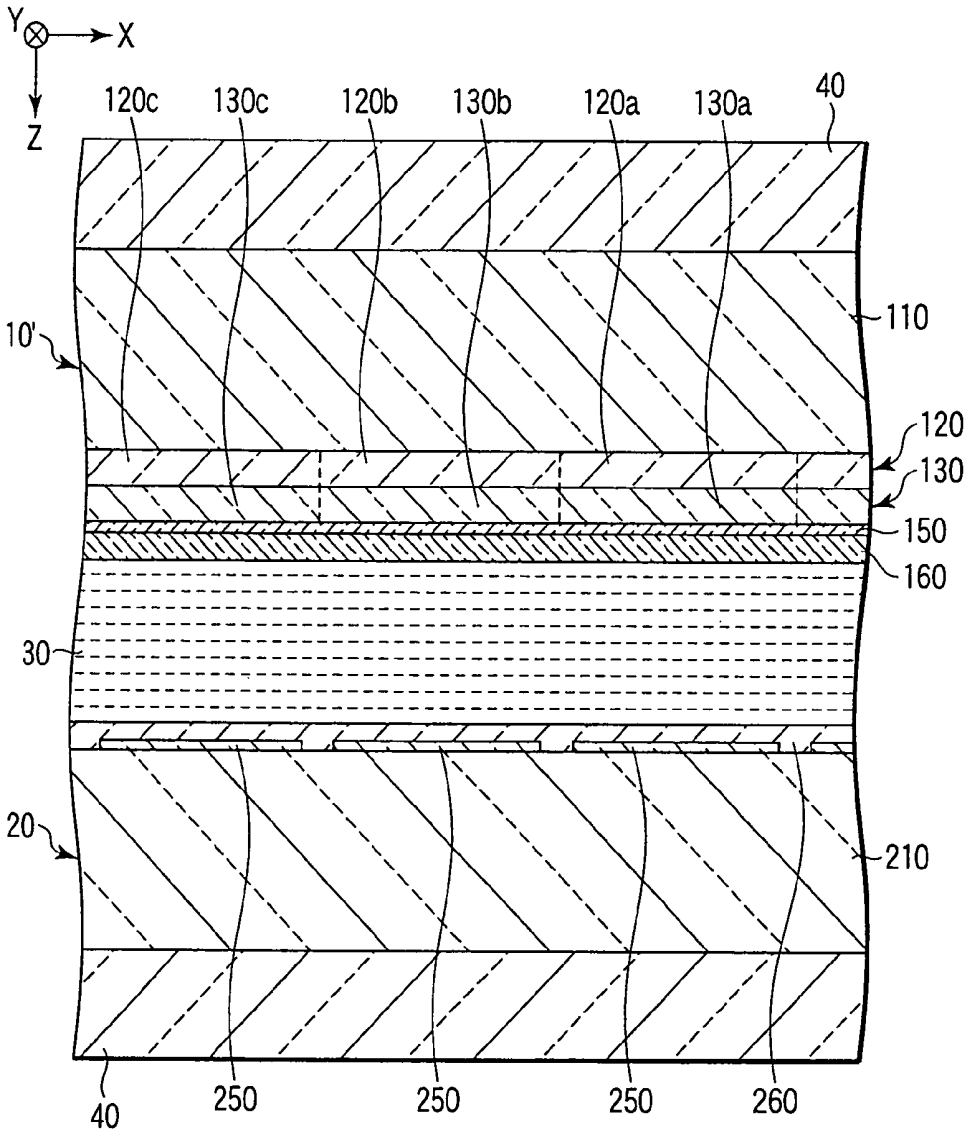

Y
X
Z
120c
130c
120b
130b
120a
130a
40
10'
110
120
130
150
160
30
20
210
40
250
250
250
260

FIG. 9

RETARDATION PLATE, METHOD FOR MANUFACTURING THE RETARDATION PLATE, AND LIQUID CRYSTAL DISPLAY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a Continuation Application of PCT Application No. PCT/JP2009/056174, filed Mar. 26, 2009, which was published under PCT Article 21(2) in Japanese.

[0002] This application is based upon and claims the benefit of priority from prior Japanese Patent Applications No. 2008-093498, filed Mar. 31, 2008; and No. 2008-164894, filed Jun. 24, 2008, the entire contents of both of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates to an optical technique that can be applied, for example, to a display such as liquid crystal display.

[0005] 2. Description of the Related Art

[0006] Liquid crystal displays have characteristics of thin-shaped, lightweight and low power consumption. Thus, in recent years, their application to mobile devices and stationary equipments such as television receivers increases rapidly.

[0007] In order to make it possible for a liquid crystal display to display a multi-colored image, a color filter is utilized. For example, in a transmissive or reflective liquid crystal display that can display a multi-colored image, a color filter including red, green and blue coloring layers is utilized in most cases. On the other hand, in a semi-transparent liquid crystal display that can display a multi-colored image, a color filter including red, green and blue coloring layers for transmissive display and red, green and blue coloring layers for reflective display is utilized in most cases.

[0008] Many liquid crystal displays include a retardation layers. For example, in a liquid crystal display of a television receiver, a retardation layer is utilized in combination with a linearly polarizing film in order to display an image that can be easily recognized regardless of the viewing direction. On the other hand, in a reflective or semi-transparent liquid crystal display, an absorption-type circularly polarizing plate including a quarter-wave plate or a combination of a quarter-wave plate and a half-wave plate as a retardation layer is utilized in order to achieve an excellent visibility under a high-luminance light source such as sun.

[0009] However, in spite of the fact that the red, green and blue pixels are different in wavelength range of display color from one another, the retardation of a retardation layer is usually even throughout its surface. For this reason, it is difficult to adopt optimal designs into all the pixels different in display color.

[0010] In addition, each of the retardation of a liquid crystal layer and the retardation of a retardation layer has wavelength dispersion. For this reason, when employing a design for sufficiently compensating the retardation of a liquid crystal cell using a retardation layer at pixels that display a certain color, the retardation layer may insufficiently compensate the retardation of a liquid crystal cell at pixels that display other colors.

[0011] Furthermore, in the case where a quarter-wave plate, which causes a retardation by a quarter of a wavelength ($\lambda/4$) at a center wavelength of green wavelength range, for example, about 550 nm, is combined with a linearly polarizing plate to be used as a circularly polarizing plate, even when the refractive index anisotropy, i.e., birefringence Δn of the quarter-wave plate is almost uniform throughout the wavelength range of visible rays, a retardation greater than $\lambda/4$ will be caused within a blue wavelength range having a center wavelength of, for example, about 450 nm. Also, a retardation smaller than $\lambda/4$ will be caused within a red wavelength range having a center wavelength of, for example, about 630 nm. Thus, when the circularly polarizing plate is irradiated with blue and red lights as natural lights, the transmitted light will be not a circularly polarized light but an elliptically polarized light. In fact, since the birefringence is greater on the short-wavelength's side of the visible range, i.e., within the blue wavelength range and is smaller on the long-wavelength's side of the visible range, i.e., within the red wavelength range, this problem is often more serious.

[0012] In view of this problem, a solidified liquid crystal layer containing a plurality of regions differing in thickness, that is, in retardation is proposed in, for example, JP-A 2005-24919 and JP-A 2006-85130.

[0013] Specifically, JP-A 2005-24919 describes that a color filter layer composed of red, green and blue coloring layers different in thickness is formed, and a solidified liquid crystal layer is formed on the color filter layer. The solidified liquid crystal layer is obtained by coating an alignment layer with a coating solution containing photo-polymerizing liquid crystal compound and irradiating the coated film with ultraviolet rays.

[0014] According to this method, due to the relief structure that the coloring layers produces on the surface of the color filter layer, a solidified liquid crystal layer thicker at a position of the thinner coloring layer and thinner at a position of the thicker coloring layer can be obtained. That is, a solidified liquid crystal layer different in thickness among pixels that displays different colors can be obtained. In other words, a solidified liquid crystal layer including regions that cause different retardations can be obtained.

[0015] JP-A 2006-85130 describes a semi-transparent liquid crystal display that includes a color filter layer and a solidified liquid crystal layer. In this liquid crystal display, each coloring layer of the color filter layer is thicker at the transmissive portions of pixels and thinner at the reflective portion of the pixels. That is, the surface of the color filter layer is provided with a relief structure. The solidified liquid crystal layer is obtained by forming a polyimide layer on the surface of the color filter layer provided with the relief structure, performing a rubbing process on the whole surface of the polyimide layer, coating the polyimide layer with ultraviolet-curing liquid crystal monomer, and irradiating the coated layer with ultraviolet rays. Alternatively, coating the surface of the color filter layer with a liquid crystal polymer and subjecting the whole of the coated film to a photo-alignment process obtain the solidified liquid crystal layer. The solidified liquid crystal layer thus obtained is thinner at the transmissive portions of pixels and thicker at the reflective portions of the pixels. That is, according to the method, a solidified liquid crystal layer that includes regions causing different retardations can be obtained.

[0016] However, according to the technique described in JP-A 2005-24919, it is necessary to accurately adjust the differences in thickness among the coloring layers. Similarly, according to the technique described in JP-A 2006-85130, it is necessary to accurately adjust the difference between the

thickness of the coloring layer at the reflective portion and the thickness of the coloring layer at the transmissive portion. For this reason, when the above-described techniques are employed, the design for the color filter layer is limited or the degree of difficulty in manufacturing the color filter layer increases. Therefore, in order to achieve the design thickness at each region of the solidified liquid crystal layer, it is necessary to consider various factors such as flowability of a coating solution and a shrinkage ratio of the coated film.

[0017] JP-A 2008-505369 (KOHYO) proposes a biaxial oriented film having periodically varying local birefringence. The film described therein is a short pitch cholesteric film, and develops additional in-plane anisotropy (Δn_{x-y}) in the negative C-type structure, due to the helical strain. More specifically, a drawing indicates the development of an index ellipsoid which satisfies $n_x \neq n_y \neq n_z$, wherein n_x and n_y are greater than n_z, and has biaxial negative C-type symmetry.

[0018] According to the description, the film is produced by, for example, irradiating the material with linearly polarized light, preferably linearly polarized UV light to induce the photoreaction of a photosensitive compound in a selected region of the material. In the film, the helical structure is uniform, but the birefringence varies locally throughout the helix.

BRIEF SUMMARY OF THE INVENTION

[0019] An object of the present invention is to make it possible to easily manufacture a retardation layer that includes a plurality of regions which are different in in-plane retardation and thickness direction retardation, and a retardation plate having this retardation layer.

[0020] According to a first aspect of the present invention, there is provided a retardation plate comprising a light transmissive planar body; and a solidified liquid crystal layer which is a continuous film made from the same material supported by the planar body, the solidified liquid crystal layer comprising a plurality of regions in each of which a thickness direction refractive index is the lowest, the plurality of regions being arranged on the planar body, the regions being different in in-plane retardation and thickness direction retardation caused by degree of orientational disorder of mesogens and anisotropy of orientational disorder of the mesogens.

[0021] According to a second aspect of the present invention, there is provided a liquid crystal display comprising the aforementioned retardation plate.

[0022] According to a third aspect of the present invention, there is provided a method of manufacturing a retardation plate, comprising forming a solidified liquid crystal layer on a light-transmissive planar body, the formation of the solidified liquid crystal layer comprising a film-forming step of forming a liquid crystal material layer on the planar body, the liquid crystal material layer comprising a photo-polymerizing or photo-crosslinking thermotropic liquid crystal compound and a chiral agent, and mesogens of the thermotropic liquid crystal compound forming a cholesteric alignment structure; an exposure step of irradiating at least two regions of the liquid crystal material layer with polarized light under different conditions and with unpolarized parallel light under different conditions, thereby polymerizing or crosslinking at least a portion of the thermotropic liquid crystal compound with different proportions and different degrees of anisotropy to produce a polymerized or crosslinked product; a developing step of heating thereafter the liquid crystal material layer to a temperature equal to or higher than a phase transition temperature at which the thermotropic liquid crystal compound is changed from a liquid crystal phase to an isotropic phase, thereby changing an orientation state of the mesogens of the unreacted thermotropic liquid crystal compound in the at least two regions; and a fixing step of polymerizing and/or crosslinking the unreacted compound with the orientation state of the mesogens kept changed.

[0023] According to a fourth aspect of the present invention, there is provided a method of manufacturing a retardation plate, comprising forming a solidified liquid crystal layer on a light-transmissive planar body, the formation of the solidified liquid crystal layer comprising a film-forming step of forming a liquid crystal material layer on the planar body, the liquid crystal material layer comprising a photo-polymerizing or photo-crosslinking thermotropic liquid crystal compound and a chiral agent, and mesogens of the thermotropic liquid crystal compound forming a cholesteric alignment structure; an exposure step of irradiating at least two regions of the liquid crystal material layer with linearly polarized light with at least extinction ratios thereof different from each other, thereby polymerizing or crosslinking at least a portion of the thermotropic liquid crystal compound with different proportions and different degrees of anisotropy to produce a polymerized or crosslinked product; a developing step of heating thereafter the liquid crystal material layer to a temperature equal to or higher than a phase transition temperature at which the thermotropic liquid crystal compound is changed from a liquid crystal phase to an isotropic phase, thereby changing an orientation state of the mesogens of the unreacted thermotropic liquid crystal compound in the at least two regions; and a fixing step of polymerizing and/or crosslinking the unreacted compound with the orientation state of the mesogens kept changed.

[0024] According to a fifth aspect of the present invention, there is provided a method of manufacturing a retardation plate, comprising forming a solidified liquid crystal layer on a light-transmissive planar body, the formation of the solidified liquid crystal layer comprising a film-forming step of forming a liquid crystal material layer on the planar body, the liquid crystal material layer containing a photo-polymerizing or photo-crosslinking thermotropic liquid crystal compound and a chiral agent, and mesogens of the thermotropic liquid crystal compound forming a cholesteric alignment structure; an exposure step of irradiating at least two regions of the liquid crystal material layer with elliptically polarized light with at least ellipticities thereof different from each other, thereby polymerizing or crosslinking at least a portion of the thermotropic liquid crystal compound with different proportions and different degrees of anisotropy to produce a polymerized or crosslinked product; a developing step of heating thereafter the liquid crystal material layer to a temperature equal to or higher than a phase transition temperature at which the thermotropic liquid crystal compound is changed from a liquid crystal phase to an isotropic phase, thereby changing an orientation state of the mesogens of the unreacted thermotropic liquid crystal compound in the at least two regions; and a fixing step of polymerizing and/or crosslinking the unreacted compound with the orientation state of the mesogens kept changed.

[0025] According to a sixth aspect of the present invention, there is provided a retardation plate comprising a light-transmissive planar body; and a solidified liquid crystal layer which is a continuous film made from the same material

supported by the planar body, the solidified liquid crystal layer comprising a plurality of regions in each of which a thickness direction refractive index is the lowest, the plurality of regions being arranged on the planar body, the regions being different in in-plane birefringence and thickness direction birefringence caused by degree of orientational disorder of mesogens and anisotropy of orientational disorder of the mesogens.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0026] FIG. **1** is a perspective view schematically showing a retardation plate according to an embodiment of the present invention;

[0027] FIG. **2** is a sectional view taken along the line II-II of the retardation plate shown in FIG. **1**;

[0028] FIG. **3** is a sectional view schematically showing one example of a method of forming a solidified liquid crystal layer;

[0029] FIG. **4** is a sectional view schematically showing one example of a method of forming a solidified liquid crystal layer;

[0030] FIG. **5** is a sectional view schematically showing another example of a method of forming a solidified liquid crystal layer;

[0031] FIG. **6** is a sectional view schematically showing another example of a method of forming a solidified liquid crystal layer;

[0032] FIG. **7** is a sectional view schematically showing a process following the process shown in FIG. **4**;

[0033] FIG. **8** is a sectional view schematically showing a retardation plate according to a modified example; and

[0034] FIG. **9** is an example of a liquid crystal display that can be manufactured using the retardation plate shown in FIGS. **1** and **2**.

DETAILED DESCRIPTION OF THE INVENTION

[0035] An embodiment of the present invention will be described below with reference to the accompanying drawings. Note that the same reference numerals in the drawings denote components that achieve the same or similar functions, and a repetitive explanation thereof will be omitted.

[0036] FIG. **1** is a perspective view schematically showing a retardation plate according to an embodiment of the present invention. FIG. **2** is a sectional view taken along the line II-II of the retardation plate shown in FIG. **1**.

[0037] The retardation plate **10** shown in FIGS. **1** and **2** includes a planar body **110**, a color filter layer **120** and a solidified liquid crystal layer **130**.

[0038] The planar body **110** has a light-transmitting property. The planar body **110** is, for example, a transparent substrate.

[0039] The color filter layer **120** is formed on the planar body **110**. The color filter layer **120** includes coloring layers **120***a* to **120***c* different in absorption spectrum from one another and adjacent to one another on the planar body **110**. For example, the light transmitted by the coloring layer **120***a* is shorter in wavelength than the light transmitted by the coloring layer **120***b*, and the light transmitted by the coloring layer **120***b* is shorter in wavelength than the light transmitted by the coloring layer **120***c*.

[0040] The color filter layer **120** may further include one or more coloring layer different in absorption spectrum from the coloring layer **120***a* to **120***c*. Here, as an example, it is supposed that the first coloring layer **120***a* is a blue coloring layer, the second coloring layer **120***b* is a green coloring layer, and the third coloring layer **120***c* is a red coloring layer.

[0041] Each of the coloring layers **120***a* to **120***c* has a band-like shape extending in the Y direction. The coloring layers **120***a* to **120***c* are alternately arranged in the X direction crossing the Y direction to form a stripe arrangement. Note that the X direction and the Y direction are directions parallel with the surface of the planar body **110** that face the color filter layer **120**. Note also that the Z direction to be referred later is a direction perpendicular to the X direction and the Y direction.

[0042] The coloring layers **120***a* to **120***c* may have other shapes. For example, each of the coloring layers **120***a* to **120***c* has a rectangular shape. In this case, the coloring layers **120***a* to **120***c* may form a square arrangement of a delta arrangement.

[0043] Each of the coloring layers **120***a* to **120***c* is made of, for example, a mixture containing a transparent resin and a pigment dispersed therein. Forming a patterned layer of a coloring composition that contains a pigment and a pigment carrier and curing the patterned layer can obtain each of the coloring layers **120***a* to **120***c*. The coloring composition will be described later.

[0044] The solidified liquid crystal layer **130** is a retardation layer, and is formed on the color filter layer **120**. The solidified liquid crystal layer **130** is a continuous film, and entirely covers one main surface of the color filter layer **120**.

[0045] The solidified liquid crystal layer **130** and the color filter layer **120** may be in contact with each other or not. In the latter case, an alignment layer may be interposed between the solidified liquid crystal layer **130** and the color filter layer **120**.

[0046] The solidified liquid crystal layer **130** includes a plurality of regions arranged in the direction parallel with the main surface. The plurality of regions each have birefringent anisotropy and the refractive index in the direction of the thickness (Z) is the lowest as compared with the refractive indices in the X- and Y-directions.

[0047] For example, the solidified liquid crystal layer **130** includes regions **130***a* to **130***c*. The regions **130***a* to **130***c* are adjacent to one another in a direction perpendicular to the Z direction.

[0048] Specifically, regions **130***a* to **130***c* face the coloring layer **120***a* to **120***c*, respectively. The regions **130***a* to **130***c* have almost the same shape.

[0049] The regions **130***a* to **130***c* are formed by polymerizing and/or crosslinking a thermotropic liquid crystal compound or composition. The regions **130***a* to **130***c* are equal in composition.

[0050] The regions **130***a*, **130***b*, and **130***c* are different in the in-plane retardation and the thickness direction retardation. The thickness direction retardation R_{th} [nm] is expressed by the following formula, wherein n_x is the maximum refractive index in the plane, n_y is the minimum refractive index in the plane, n_z is the refractive index in the normal direction, and d (μm) is the film thickness:

$$R_{th}=[(n_x-n_y)/2-n_z]\times d\times 1000$$

[0051] One of the reasons of the differences in in-plane retardation and in thickness direction retardation is that the thermotropic liquid crystal compound is polymerized or crosslinked in the state that these regions are different from one another in the degree of orientational disorder of

mesogens. For example, in a region having a lower degree of orientational disorder of mesogens, the in-plane retardation and thickness direction retardation are increased. In a region having a higher degree of orientational disorder of mesogens, on the other hand, the in-plane retardation and thickness direction retardation are decreased.

[0052] Moreover, the differences in in-plane retardation and in thickness direction retardation are caused by the polymerizing or crosslinking the thermotropic liquid crystal compound in the state that the degree of orientational disorder of mesogens is different depending on the in-plane azimuth, that is, in the state that the orientational disorder is anisotropic. In this case, the Nz factor of a certain region is different from those of other regions. In, for example, a region having a higher anisotropy of orientational disorder, the Nz factor of this region is less. On the other hand, in a region having a lower anisotropy of orientational disorder, the Nz factor of this region is greater.

[0053] Incidentally, the Nz constant a value obtained from $Nz=(n_x-n_z)/(n_x-n_y)$. n_x is a maximum refractive index in a plane, n_y is a minimum refractive index in the plane, and n_z is a refractive index in a normal direction.

[0054] Here, the expression "degree of orientational disorder" means the orientation state of mesogens MS in each of the regions adjacent in-plane direction. The orientation state of the mesogens MS may be uniform in the entire region or varied along the Z direction. For example, in one region, the orientation may be uniform near the upper surface, and disturbed near the lower surface. In this case, the "degree of orientational disorder" refers to an average of the degree of orientation in the direction of thickness. Similarly, with regard to the expression "orientational disorder anisotropy", the orientation state of the mesogens MS may be varied along the Z-direction and, in this case, "the degree of orientational disorder" also refers an average of the degrees of orientation in the direction of the thickness.

[0055] More specifically, the region **130***a* has the highest in-plane birefringence, while the smallest Nz coefficient. The region **130***c* has the smallest in-plane birefringence, while the highest Nz coefficient. The region **130***b* has the second highest in-plane birefringence and Nz coefficient.

[0056] At least one of the regions may be an optically uniaxial negative C-plate wherein the in-plane retardation is substantially zero.

[0057] In at least one of the regions, the axial direction giving the highest refractive index in the plane may be different from those in the other regions. For example, in the region **130***a*, the axis giving the highest refractive index in the plane is set in the X direction, while in the region **130***b*, the axis giving the highest refractive index in the plane is set in the direction forming an angle of 45 degrees with the X- and Y-directions.

[0058] As described above, the regions **130***a* to **130***c* are different in the degree of orientational disorder and/or in its anisotropy. In other words, the difference in the retardation of the regions in the retardation plate **10** of the present invention is mainly attributed to the difference in the birefringence. Therefore, it is not necessary to vary the thickness of the regions **130***a* to **130***c* with the intention of varying the retardation of the regions **130***a* to **130***c*. Depending on circumstances, the thicknesses of the regions **130***a* to **130***c* may be different from each other, but the formation of the solidified liquid crystal layer **130** is easier when the thicknesses of the regions **130***a* to **130***c* are equal.

[0059] As described above, the thicknesses of the regions **130***a* to **130***c* may be equal, thereby forming the solidified liquid crystal layer **130** as a continuous film. As a result, the solidified liquid crystal layer **130** is formed by a simplified process.

[0060] Further, the solidified liquid crystal layer **130** as a continuous film makes the mass transfer from the color filter layer **120** to the outside of the retardation plate **10** more difficult than the other patterned solidified liquid crystal layer **130** as a discontinuous film. Therefore, in the case where the retardation plate **10** that includes the solidified liquid crystal layer **130** as a continuous layer is used, for example, in a liquid crystal layer, it is possible to suppress the inclusion of impurities from the color filter layer **120** into the liquid crystal layer.

[0061] As described above, the in-plane retardation and the thickness direction retardation of the solidified liquid crystal layer **130** are varied among the regions by varying the degree of the orientational disorder and its anisotropy of the mesogen MS using, for example, the following method: the orientation of a liquid crystal including a rod-like shape mesogen is disordered so as to give a cholesteric orientation (anisotropically disordered cholesteric orientation) wherein the length direction of the mesogen is perpendicular to the Z direction, and the orientation in one direction is more disordered than in the other direction. In this case, each of the regions **130***a* to **130***c* is a complex of a positive A-plate and a negative C-plate which develop differences in the in-plane retardation and the thickness direction retardation corresponding to the degree of the orientational disorder and its anisotropy.

[0062] Next, materials and manufacturing methods of the retardation plate **10** will be described.

[0063] First, a light-transmissive planar body **110** is prepared. The planar body **110** is, typically, a light-transmitting substrate such as glass plate or resin plate. As a material of the glass plate, soda-lime glass, low-alkali borosilicate glass or non-alkali alumino borosilicate glass can be used, for example. As a material of the resin plate, polycarbonate, polymethyl methacrylate or polyethylene terephthalate may be used, for example. Also, the planar body **110** is not always hard but may be, for example, a light-transmissive film or sheet.

[0064] The planar body **110** may have a monolayer structure or a multi-layered structure. For example, in the case where the retardation plate **10** is a component of a liquid crystal display, a light-transmitting substrate on which a transparent electrode made of transparent conductor such as indium tin oxide or tin oxide may be used as the planar body **110**. Alternatively, as the planar body **110**, a light-transmitting substrate on which a circuit such as pixel circuit is formed may be used.

[0065] A color filter layer **120** is formed on the light-transmissive planar body **110** by, for example, the method shown below.

[0066] The color filter layer **120** is obtained, for example, by applying a coloring composition containing a pigment carrier and a pigment dispersed in the pigment carrier to form a given pattern, which is then cured, and these processes are repeated to form coloring layers **120***a* to **120***c* respectively.

[0067] As the pigment of the coloring composition, organic pigment and/or inorganic pigment can be used. The coloring composition may contain a single organic or inorganic pigment, or a plurality of organic pigments and/or inorganic pigments.

[0068] A pigment excellent in coloring property and heat-resisting property, in particular, thermal decomposition-resisting property is preferable, and normally, organic pigments are utilized. The following color index numbers are examples of the organic pigments that can be used in the coloring composition.

[0069] As an organic pigment of a red coloring composition, a red pigment such as C. I. Pigment Red 7, 14, 41, 48:2, 48:3, 48:4, 81:1, 81:2, 81:3, 81:4, 146, 168, 177, 178, 179, 184, 185, 187, 200, 202, 208, 210, 246, 254, 255, 264, 270, 272 or 279 can be used, for example. As an organic pigment of a red coloring composition, a mixture of a red pigment and a yellow pigment may be used. As the yellow pigment, C. I. Pigment Yellow 1, 2, 3, 4, 5, 6, 10, 12, 13, 14, 15, 16, 17, 18, 24, 31, 32, 34, 35, 35:1, 36, 36:1, 37, 37:1, 40, 42, 43, 53, 55, 60, 61, 62, 63, 65, 73, 74, 77, 81, 83, 93, 94, 95, 97, 98, 100, 101, 104, 106, 108, 109, 110, 113, 114, 115, 116, 117, 118, 119, 120, 123, 126, 127, 128, 129, 138, 147, 150, 151, 152, 153, 154, 155, 156, 161, 162, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 179, 180, 181, 182, 185, 187, 188, 193, 194, 199, 198, 213 or 214 can be used, for example.

[0070] As an organic pigment of a green coloring composition, a green pigment such as C. I. Pigment Green 7, 10, 36 or 37 can be used, for example. As an organic pigment of a green coloring composition, a mixture of a green pigment and a yellow pigment may be used. As the yellow pigment, the same pigments as that described for the red coloring composition can be used, for example.

[0071] As an organic pigment of a blue coloring composition, a blue pigment such as C. I. Pigment Blue 15, 15:1, 15:2, 15:3, 15:4, 15:6, 16, 22, 60 or 64 can be used, for example. As an organic pigment of a blue coloring composition, a mixture of a blue pigment and a purple pigment may be used. As the purple pigment, C. I. Pigment Violet 1, 19, 23, 27, 29, 30, 32, 37, 40, 42 or 50 can be used, for example.

[0072] As the inorganic pigment, metal oxide powders, metal sulfide powders, or metal powders such as yellow lead ore, zinc yellow, iron red (red oxide of iron (III)), cadmium red, ultramarine blue, chromic oxide green and cobalt green can be used, for example. The inorganic pigment can be used, for example, in combination with the organic pigment in order to achieve excellent application property, sensitivity and developing property while balancing chroma and lightness.

[0073] The coloring composition may further contain coloring components other than the pigment. For example, the coloring composition may contain dye if a sufficient thermal resistance can be achieved. In this case, the dye can be used for color matching.

[0074] Also, the pigment carrier contained in the above coloring composition is constituted of a transparent resin, its precursor or a mixture thereof. Examples of the transparent resin include thermoplastic resins, thermosetting resins and photosensitive resins, and examples of its precursor include polyfunctional monomers or oligomers which are cured by irradiating with rays to produce a resin. These compounds may be used either singly or in combinations of two or more. In this case, the transparent resins are those having a transmittance of 80% or higher and preferably 95% or higher throughout the entire wavelength range of 400 to 700 nm, which is the visible range.

[0075] In the coloring composition, the transparent resin is use at an amount of, for example, 30 to 700 parts by mass, preferably 60 to 450 parts by mass with respect to 100 parts by mass of the pigment. In the case where a mixture of the transparent resin and the precursor thereof is used as the pigment carrier, the transparent resin is used in the coloring composition at an amount of, for example, 20 to 400 parts by mass, preferably 50 to 250 parts by mass with respect to 100 parts by mass of the pigment. In this case, the precursor of the transparent resin is used in the coloring composition at an amount of, for example, 10 to 300 parts by mass, preferably 10 to 200 parts by mass with respect to 100 parts by mass of the pigment.

[0076] As the thermoplastic resin, butyral resins, styrene-maleic acid copolymers, chlorinated polyethylenes, polyvinyl chlorides, vinyl chloride-vinyl acetate copolymers, polyvinyl acetates, polyurethane resins, polyester resins, acrylic resins, alkyd resins, polystyrene resins, polyamide resins, rubber-based resins, cyclized rubber resins, celluloses, polybutadiens, polyethylenes, polypropylenes or polyimide resins can be used, for example.

[0077] As the thermosetting resin, epoxy resins, benzoguanamine resins, rosin-modified maleic resins, rosin-modified fumaric resins, melamine resins, urea resins or phenol resins can be used, for example.

[0078] As the photosensitive resin, resins obtained by causing the reaction of an acrylic compound, a methacrylic compound or cinnamic acid having a reactive substituent such as isocyanate group, aldehyde group and epoxy group with a linear polymer having a reactive substituent such as hydroxyl group, carboxyl group and amino group to introduce photo-crosslinking groups such as acryloyl groups, methacryloyl groups and stylyl groups into the linear polymer can be used, for example. Alternatively, resins obtained by half-esterifying a linear polymer including acid anhydride such as styrene-maleic anhydride copolymer and α-olefin-maleic anhydride copolymer using acrylic compounds or methacrylic compounds having hydroxyl group such as hydroxyalkyl acrylates and hydroxyalkyl methacrylates may be used.

[0079] As the monomers and/or oligomers, which are the precursor of the transparent resin, acrylic esters and methacrylic esters such as 2-hydroxyethyl acrylate, 2-hydroxyetyl methacrylate, 2-hydroxypropyl acrylate, 2-hydroxypropyl methacrylate, cycrohexyl acrylate, cycrohexyl methacrylate, polyethylene glycol diacrylate, polyethylene glycol dimethacrylate, pentaerythritol triacrylate, pentaerythritol trimethacrylate, trimethylolpropane triacrylate, trimethylolpropane trimethacrylate, dipentaerythritol hexaacrylate, dipentaerythritol hexamethacrylate, tricyclodecanyl acrylate, tricyclodecanyl methacrylate, melamine acrylate, melamine methacrylate, epoxy acrylate and epoxy methacrylate; acrylic acid, methacrylic acid, styrene, vinyl acetate, acrylamide, methacrylamide, N-hydroxymethyl acrylamide, N-hydroxymethyl methacrylamide or a mixture containing two or more of them can be used, for example.

[0080] In the case where the coloring composition is cured using light such as ultraviolet rays, for example, a photo-polymerization initiator is added to the coloring composition.

[0081] As the photo-polymerization initiator, acetophenone-based photo-polymerization initiator such as 4-phenoxydichloroacetophenone, 4-t-butyl-dichloroacetophenone, diethoxyacetophenone, 1-(4-isopropylphenyl)-2-hydroxy-2-methylpropane-1-one, 1-hydroxycyclohexylphenylketone, 2-methyl-1[4-(methylthio)phenyl]-2-morpholinopropane-1-one and 2-benzyl-2-dimethylamino-1-(4-morpholinophenyl)-butane-1-one; ben-

zoin-based photo-polymerization initiator such benzoin, benzoylbenzoate, methylbenzoylbenzoate, 4-phenylbenzophenone, hydroxybenzophenone, acrylated benzophenone and 4-benzoyl-4'-methyldiphenyl sulfide; thioxanthone-based photo-polymerization initiator such as thioxanthone, 2-chlorothioxanthone, 2-methyltioxanthone, isopropylthioxanthone and 2,4-diisopropylthioxanthone; triazine-based photo-polymerization initiator such as 2,4,6-trichloro-s-triazine, 2-phenyl-4,6-bis(trichloromethyl)-s-triazine, 2-(p-methoxyphenyl)-4,6-bis(trichloromethyl)-s-triazine, 2-(p-tolyl)-4,6-bis(trichloromethyl)-s-triazine, 2-piperonyl-4,6-bis(trichloromethyl)-s-triazine, 2,4-bis(trichloromethyl)-6-styryl-s-triaine, 2-(naphto-1-yl)-4,6-bis(trichloromethyl)-s-triazine, 2-(4-methoxy-naphto-1-yl)-4,6-bis(trichloromethyl)-s-triazine, 2,4-trichloromethyl-(piperonyl)-6-triazine and 2,4-trichloromethyl(4'-methoxystyryl)-6-triazine; borate-based photo-polymerization initiator; carbazole-based photo-polymerization initiator; imidazole-based photo-polymerization initiator; or a mixture containing two or more of them can be used, for example.

[0082] The photo-polymerization initiator is used in the coloring composition at an amount of, for example, 5 to 200 parts by mass, preferably 10 to 150 parts by mass with respect to 100 parts by mass of the pigment.

[0083] A sensitizer may be used together with the photo-polymerization initiator.

[0084] As the sensitizer, a compound such as α-acyloxy ester, acylphosphine oxide, methylphenyl glyoxylate, benzil, 9,10-phenanthrenequinone, camphor quinone, ethyl anthraquinone, 4,4'-diethyl isophthaloquinone, 3,3',4,4'-tetra(t-butylperoxycarbonyl)benzophenone and 4,4'-diehylamino benzophenone can be used.

[0085] The sensitizer is used at an amount of, for example, 0.1 to 60 parts by mass with respect to 100 parts by mass of the photo-polymerization initiator.

[0086] The coloring composition may further contain a chain transfer agent such as multi-functional thiol.

[0087] A multi-functional thiol is a compound having two or more thiol groups. As the multi-functional thiol, hexanedithiol, decanedithiol, 1,4-butanediol bisthiopropionate, 1,4-butanediol bisthioglycolate, ethylene glycol bisthioglycolate, ethylene glycol bisthiopropionate, trimethylolpropane tristhioglycolate, trimethylolpropane tristhiopropionate, trimethylolpropane tris(3-mercaptobutyrate), pentaerythritol tetrakisthioglycolate, pentaerythritol tetrakisthiopropionate, trimercaptopropionic tris(2-hydroxyethyl) isocyanurate, 1,4-dimethylmercaptobenzene, 2,4,6-trimercapto-s-triazine, 2-(N,N-dibutylamino)-4,6-dimercapto-s-triazine or a mixture containing two or more of them can be used, for example.

[0088] The multi-functional thiol is used in the coloring composition at an amount of, for example, 0.2 to 150 parts by mass, preferably 0.2 to 100 parts by mass with respect to 100 parts by mass of the pigment.

[0089] The coloring composition may further contain a solvent. When the solvent is used, the dispersibility of the pigment increases. As a result, the coloring composition can be easily applied to the planar body **110** at a dried thickness of, for example, 0.2 to 5 μm.

[0090] As the solvent, ketones such as methyl ethyl ketone, methyl amyl ketone, diethyl ketone, acetone, methyl isopropyl ketone, methyl isobutyl ketone and cyclohexanone; ether type solvents such as ethyl ether, dioxane, tetrahydrofuran, 1,2-dimethoxyethane, 1,2-diethoxyethane and dipropylene glycol dimethyl ether; ester type solvents such as methyl acetate, ethyl acetate, n-propyl acetate, isopropyl acetate and n-butyl acetate; cellosolve type solvents such as ethylene glycol monomethyl ether, ethylene glycol monoethyl ether and propylene glycol monomethyl ether acetate; alcohol type solvents such as methanol, ethanol, isopropanol, n-propanol, isobutanol, n-butanol and amyl alcohol; BTX type solvents such as benzene, toluene and xylene; and aliphatic hydrocarbon type solvents such as hexane, heptanes, octane and cyclohexane can be used, for example.

[0091] Further examples of the solvent further include terpene type hydrocarbon oils such as turpentine oil, D-limonene and pinene; paraffin type solvents such as mineral spirit, Swasol #310 (manufactured by Cosmo Matsuyama Oil Co. Ltd.), Solvesso #100 (Exxon Chemical Co., Ltd.); halogenated aliphatic hydrocarbon solvents such as carbon tetrachloride, chloroform, trichloroethylene and dichloromethane; halogenated aromatic hydrocarbon solvents such as chlorobenzene; and carbitol type solvents.

[0092] Also, a solvent such as aniline, triethylamine, pyridine, acetic acid, acetonitrile, carbon disulfide, tetrahydrofuran, N,N-dimethylformamide and N-methylpyrrolidone may be used. Among these compounds, ketones and cellosolve type solvents are preferable. These solvents may be used either singly or in combinations of two or more.

[0093] The solvent is used in the coloring composition at an amount of, for example, 800 to 4,000 parts by mass, preferably 1,000 to 2,500 parts by mass with respect to 100 parts by mass of the pigment.

[0094] The coloring composition can be manufactured, for example, by finely dispersing one or more pigment into the pigment carrier and the organic solvent together with the above-described photo-polymerization initiator as needed using a dispersing device such as three-roll mill, two-roll mill, sand mill, kneader and attritor. A coloring composition containing two or more pigments may be manufactured by preparing dispersions containing different pigments and mixing the dispersions together.

[0095] When dispersing the pigment into the pigment carrier and the solvent, a dispersion aid such as resin-type pigment-dispersing agent, surfactant and pigment derivative may be used. The dispersion aid increases the dispersibility of the pigment and suppresses the reaggregation of the dispersed pigment. Therefore, in the case of using a coloring composition prepared by dispersing a pigment into a pigment carrier and a solvent using a dispersion aid, a color filter excellent in transparency can be obtained.

[0096] The dispersion aid is used in the coloring composition at an amount of, for example, 0.1 to 40 parts by mass, preferably 0.1 to 30 parts by mass with respect to 100 parts by mass of the pigment.

[0097] The resin-type pigment-dispersing agent includes a pigment-affinitive moiety having a property of undergoing adsorption by the pigment and a moiety having a compatibility with the pigment carrier. The resin-type pigment-dispersing agent is adsorbed by the pigment so as to stabilize the dispersibility of the pigment in the pigment carrier.

[0098] As the resin-type pigment-dispersing agent, an oil-based dispersing agent such as polyurethane, polycarboxylate, e.g. polyacrylate, unsaturated polyamide, polycarboxylic acid, partial amine salt of polycarboxylic acid, ammonium polycarboxylate, alkylamine polycarboxylate, polysiloxane, long-chain polyaminoamide phosphate and hydroxyl group-

containing polycarboxylate, modified compounds thereof, amide produced through a reaction of poly(lower alkylene imine) with polyester having a free carboxyl group and a salt thereof; water-soluble resin or water-soluble macromolecular compound such as acrylic acid-styrene copolymer, methacrylic acid-styrene copolymer, acrylic acid-acrylate copolymer, acrylic acid-methacrylate copolymer, methacrylic acid-acrylate copolymer, methacrylic acid-methacrylate copolymer, styrene-maleic acid copolymer, polyvinyl alcohol and polyvinyl pyrrolidone; polyester; modified polyacrylate; ethylene oxide/propylene oxide adduct; phosphate; or a compound containing two or more of them can be used, for example.

[0099] As the surfactant, an anionic surfactant such as polyoxyethylene alkylether sulfate, dodecylbenzene sodium sulfonate, alkali salt of styrene-acrylic acid copolymer, alkylnaphthaline sodium sulfonate, alkyldiphenyl ether sodium disulfonate, monoethanol amine lauryl sulfate, triethanol amine lauryl sulfate, ammonium lauryl sulfate, monoethanol amine stearate, sodium stearate, sodium lauryl sulfate, monoethanol amine of styrene-acrylic acid copolymer and polyoxyethylene alkylether phosphate; a nonionic surfactant such as polyoxyethylene oleyl ether, polyoxyethylene lauryl ether, polyoxyethylene nonylphenyl ether, polyoxyethylene alkylether phosphate, polyoxyethylene sorbitan monostearate and polyethyleneglycol monolaurate; a cationic surfactant such as alkyl quaternary ammonium salt and an ethylene oxide adduct thereof; an amphoteric surfactant such as alkyl betaine, e.g. betaine alkyldimethyl aminoacetate and alkylimidazoline; and a mixture containing two or more of them can be used, for example.

[0100] The dye derivative is a compound produced by introducing a substituent into an organic dye. Although the dye derivative is similar in hue to the pigment used, the hue of the former may be different from that of the latter if the loading thereof is small. Note that the term "organic dye" includes aromatic polycyclic compounds exhibiting a light yellow color such as naphthalene-based compounds and anthraquinone-based compounds, which are generally not referred to as "dye", in addition to compounds generally referred to as "dye". As the dye derivative, those described in JP-A 63-305173, JP-B 57-15620, JP-B 59-40172, JP-B 63-17102 or JP-B 5-9469 can be used, for example. Especially, the dye derivatives having a basic group are highly effective in the dispersion of pigment. The coloring composition may contain a single dye derivative or a plurality of dye derivatives.

[0101] A storage-stability improver may be added to the coloring composition in order to improve the temporal stability of its viscosity. As the storage-stability improver, benzyltrimethyl chloride; quaternary ammonium chloride such as diethylhydroxy amine; organic acid such as lactic acid and oxalic acid; methyl ether of the organic acid; t-butyl pyrocatechol; organic phosphine such as tetraethyl phosphine and tetraphenyl phosphine; phosphite; or a mixture containing two or more of them can be used, for example.

[0102] The storage-stability improver is contained in the coloring composition at an amount of, for example, 0.1 to 10 parts by mass with respect to 100 parts by mass of the pigment.

[0103] To the coloring composition, an adhesion improver such as silane coupling agent may be added in order to improve the adhesion to the substrate.

[0104] As the silane coupling agent, vinyl silane such as vinyl tris(β-methoxyethoxy)silane, vinylethoxy silane and vinyltrimethoxy silane; acrylsilane and metacrylsilane such as γ-methacryloxypropyl trimethoxy silane; epoxy silane such as β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, β-(3,4-epoxycyclohexyl)methyltrimethoxy silane, β-(3,4-epoxycyclohexyl)ethyltriethoxy silane, β-(3,4-epoxycyclohexyl)methyltriethoxy silane, γ-glycidoxypropyl trimethoxy silane and γ-glycidoxypropyl triethoxy silane; amino silane such as N-β(aminoethyl) γ-aminopropyl trimethoxy silane, N-β(aminoethyl) γ-aminopropyl triethoxy silane, N-β(aminoethyl) γ-aminopropyl methyldiethoxy silane, γ-aminopropyl triethoxy silane, γ-aminopropyl trimethoxy silane, N-phenyl-γ-aminopropyl trimethoxy silane and N-phenyl-γ-aminopropyl triethoxy silane; thiosilane such as γ-mercaptopropyl trimethoxy silane and γ-mercaptopropyl triethoxy silane; or a mixture containing two or more of them can be used, for example.

[0105] The silane coupling agent is contained in the coloring composition at an amount of, for example, 0.01 to 100 parts by mass with respect to 100 parts by mass of the pigment.

[0106] The coloring composition can be prepared in the form of a gravure offset printing ink, a waterless offset printing ink, a silk screen printing ink, or a solvent developer-type or alkaline developer-type colored resist. The colored resist is the one that is obtained by dispersing dye in a composition containing a thermoplastic resin, thermosetting resin or photosensitive resin, a monomer, a photo-polymerization initiator and an organic solvent.

[0107] The pigment is used at an amount of, for example, 5 to 70 parts by mass, preferably 20 to 50 parts by mass with respect to 100 parts by mass of the total solid contents in the coloring composition. Note that a large part of the remainder of the solid contents in the coloring layer is the resin binder included in the pigment carrier.

[0108] Prior to using the coloring composition for forming a film, particles having a size of 5 μm or more, preferably 1 μm or more, more preferably 0.5 μm or more may be removed from the coloring composition using a refiner such as centrifugal separator, sintered filter and membrane filter.

[0109] Each of the coloring layers **120***a* to **120***c* can by formed, for example, by printing. According to printing, printing using the coloring composition and drying it thereafter can form each of the coloring layers **120***a* to **120***c*. Therefore, the printing method is low cost and excellent in mass productivity. Further, since the printing technique is improved in recent years, printing can form fine patterns having high dimension accuracy and high smoothness.

[0110] In the case where printing is used, the coloring composition should be designed to have a composition that would not cause the coloring composition to be dried and solidified on the printing plate or the blanket. Also, in the printing, it is important to optimize the flowability of the coloring composition in the printer. Therefore, a dispersing agent or an extender may be added to the coloring composition so as to adjust the viscosity thereof.

[0111] Each of the coloring layers **120***a* to **120***c* may be formed using photolithography. According to photolithography, the color filter layer **120** can be formed with higher accuracy as compared with the case where printing is utilized.

[0112] In this case, the coloring composition prepared as a solvent developer-type or alkaline developer-type colored resist is applied first to the planar body **110**. For this applica-

tion, an application method such as spray coating, spin coating, slit coating and roll coating is utilized. The coated film is formed to have a dried thickness of, for example, 0.2 to 10 μm.

[0113] Next, the coated film is dried. For example a vacuum drier, a convection oven, an IR oven or a hot plate is used for drying the coated film. Drying the coated film can be omitted.

[0114] Subsequently, the coated film is irradiated with ultraviolet rays via a photomask. That is, the coated film is subjected to a pattern exposure.

[0115] Then, the coated film is immersed in a solvent developer or an alkaline developer. Alternatively, the coated film is sprayed with the developer. Thus, soluble portions are removed from the coated film to obtain the coloring layer **120***a* as a resist pattern.

[0116] Further, by the same method as described above, the coloring layers **120***b* and **120***c* are formed in this order. Thus, the color filter layer **120** is obtained. Note that in this method, a heat treatment may be executed in order to promote the polymerization of the colored resists.

[0117] In the photolithography process, for example, an aqueous solution of sodium carbonate or sodium hydroxide can be used as the alkaline developer. Alternatively, a liquid containing an organic alkali such as dimethylbenzyl amine and triethanol amine may be used as the alkaline developer.

[0118] An additive such as defoaming agent or surfactant may be added to the developer. A shower developing method, a spray developing method, a dip developing method or a paddle developing method may be utilized for developing, for example.

[0119] In order to enhance the sensitivity to light exposure, the following process may be further executed. That is, after drying the first coated film of the colored resist, an alkaline-soluble resin, for example, polyvinyl alcohol or water-soluble acrylic resin is applied to the first coated film. After drying the second coated film, the above-described pattern exposure is performed. The second coated film prevents the polymerization in the first coated film from being inhibited by oxygen. Therefore, a higher sensitivity to light exposure can be achieved.

[0120] The color filter layer **120** may be formed by other methods. For example, it may be formed using an inkjet method, an electrodeposition method or a transfer method. In the case where the color filter layer **120** is formed using the inkjet method, each coloring layer is obtained, for example, by forming a light-shielding partition wall on the planar body **110** in advance and injecting an ink from a nozzle toward regions separated by the light-shielding partition wall. In the case where the color filter layer **120** is formed using the electrodeposition method, each coloring layer is obtained, for example, by forming a transparent conductive layer on the planar body **110** in advance and depositing the coloring composition on the transparent conductive film utilizing an electrophoresis of colloidal particles made of the coloring composition. In the case where the transfer method is used, the color filter layer **120** is formed on a surface of a releasable transfer base sheet in advance, and then the color filter layer **120** is transferred from the base sheet onto the planar body **110**.

[0121] Next, a method for manufacturing the solidified liquid crystal layer **130** will be described.

[0122] FIGS. **3** and **4** are sectional views schematically showing an example of a method of forming a solidified liquid crystal layer.

[0123] The solidified liquid crystal layer **130** is obtained, for example, by forming a liquid crystal material layer **130'** containing a photo-polymerizing or photo-crosslinking thermotropic liquid crystal material on the color filter layer **120** and subjecting the liquid crystal material layer **130'** to a pattern exposure and a heat treatment.

[0124] The liquid crystal material layer **130'** can be obtained, for example, by applying a coating solution, containing a thermotropic liquid crystal compound and a chiral agent, on the color filter layer **120** and drying the coated film, if necessary. In the liquid crystal material layer **130'**, the mesogens of the thermotropic liquid crystal compound form a cholesteric alignment structure.

[0125] As the thermotropic liquid crystal compound, alkyl cyanobiphenyl, alkoxy biphenyl, alkyl terphenyl, phenyl cyclohexane, biphenyl cyclohexane, phenyl bicyclohexane, pyrimidine, cyclohexane carboxylic acid ester, halogenated cyanophenol ester, alkyl benzoic acid ester, alkyl cyanotolane, dialkoxy tolane, alkyl alkoxy tolane, alkyl cyclohexyl tolane, alkyl bicyclohexane, cyclohexyl phenyl ethylene, alkyl cyclohexyl cyclohexene, alkyl benzaldehyde azine, alkenyl benzaldehyde azine, phenyl naphthalene, phenyl tetrahydronaphtalene, phenyl decahydronaphthalene, derivatives thereof, acrylates of the compounds, or methacrylates of the compounds can be used, for example.

[0126] The chiral agent is a low molecular weight compound having an optically active moiety, and typical examples thereof have a molecular weight of 1500 or less. The chiral agent is used for the purpose of inducing a helical structure in the positive uniaxial nematic regularity developed by a polymerizable liquid crystal material exhibiting nematic regularity. As long as the object is achieved, the type of the chiral agent is not particularly limited. The chiral agent may be any compound which mixes with the polymerizable liquid crystal material showing nematic regularity in a state of solution or melt, and induces a desired helical structure in the polymerizable liquid crystal material without impairing the liquid crystallinity of the material.

[0127] The chiral agent must have some chirality in its molecule, because it is used for inducing a helical structure in the liquid crystal. Accordingly, the chiral agent used herein is preferably, for example, a compound having one or more asymmetric carbons, a compound having an asymmetric point on the hetero atom such as a chiral amine or sulfoxide, or a compound having an optically active moiety with axial asymmetry, such as cumulene or binaphthol. Specific examples include commercially available chiral nematic liquid crystals such as Paliocolor LC 756 (manufactured by BASF), or a chiral dopant liquid crystal S-811 (manufactured by Merck Ltd.).

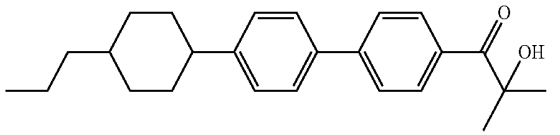
[0128] Since the solidified liquid crystal layer **130** of the present invention is required to have high transparency in the visible region, the chiral agent is added in an amount such that the helical pitch of the liquid crystal material layer **130'** is short and the wavelength of the selective reflection is about 400 nm or less. The specific content of the chiral agent may be 2 to 50 parts by weight based on the thermotropic liquid crystal compound, depending on the type of the thermotropic liquid crystal compound or the distortion inducing force of the chiral agent.

[0129] The coating solution may contain a photo-polymerization initiator.

[0130] As the photo-polymerization initiator, dichroic photo-polymerization initiator may be used. Examples of the

photo-polymerization initiator include biphenylcyclohexane derivatives represented by the following chemical formula. Such a dichroic photo-polymerization initiator is desirable from the viewpoint that it tends to induce the immobilization of a thermotropic liquid crystal compound orientated in a specific direction in the plane in the exposure process which will be described later and a solidified liquid crystal layer **130** having large in-plane anisotropy is easily obtained.

(1)



[0131] The photo-polymerization initiator unnecessarily has dichroism. For example, as the photo-polymerization initiator, the same compounds (hereinafter referred to as "other photo-polymerization initiators") as those used for the above coloring composition may be used. Even if other photo-polymerization initiators are used without adding the dichroic photo-polymerization initiator to the coating solution, or any photo-polymerization initiator is not used, a retardation plate **10** according to this embodiment can be obtained. This reason is presumed that the photo-polymerizing or photo-crosslinking thermotropic liquid crystal material itself has anisotropy to photoreaction. The aforementioned other photo-polymerization initiators are desirable from the viewpoint that it tends to induce more exact immobilization in a small dose of light in the developing process which will be described later because it has high sensitivity and therefore, strong solidified liquid crystal layer **130** is easily obtained.

[0132] As the photo-polymerization initiator, any one of the above dichroic photo-polymerization initiators and the other photo-polymerization initiators or a mixture of two or more of these photo-polymerization initiators may be added. The content of the photo-polymerization initiator is preferably 0.1 to 30 parts by weight and more preferably 0.3 to 10 parts by weight based on 100 parts by weight of the liquid crystal compound in the coating solution.

[0133] A sensitizer may be used in combination with the photo-polymerization initiator. As the sensitizer, the same compounds as those used for the above coloring composition may be used. The sensitizer may be contained in an amount of 0.1 to 60 parts by weight based on 100 parts by weight of the photo-polymerization initiator.

[0134] A solvent may be added to the coating solution.

[0135] As the solvent, the same compounds as those used for the above coloring composition may be used. The solvent may be used in an amount of 100 to 3000 parts by weight and preferably 200 to 1000 parts by weight based on 100 parts by weight of the liquid crystal compound in the coating solution.

[0136] A thermal polymerization initiator, a polymerization inhibitor, a surfactant, a resin, a polyfunctional monomer and/or oligomer, a chain transfer agent and a storage-stability improver and an adhesion improver may be added to the coating solution in each appropriate amount.

[0137] As the thermal polymerization initiator, for example, peroxide initiators such as benzoyl peroxide (BPO), t-butylperoxy-2-ethylhexanate (PBO), di-t-butyl peroxide (PBD), t-butyl-peroxyisopropyl carbonate (PBI) and n-butyl-4,4'-bis(t-butylperoxy)varelate (PHV); and azo type initiators such as 2,2'-azobisisobutyronitrile, 2,2'-azobis(2-methylbutyronitrile), 1,1'-azobis(cyclohexane-1-carbonitrile), 2,2'-azobis(2-methylpropane), 2,2'-azobis(2-methylbutane), 2,2'-azobis(2-methylpentane), 2,2'-azobis(2,3-dimethylbutane), 2,2'-azobis(2-methylhexane), 2,2'-azobis(2,4-dimethylpentane), 2,2'-azobis(2,3,3-trimethylbutane), 2,2'-azobis(2,4,4-trimethylpentane), 3,3-azobis(3-methylpentane), 3,3'-azobis(3-methylhexane), 3,3'-azobis(3,4-dimethylpentane), 3,3'-azobis(3-ethylpentane), dimethyl-2,2'-azobis(2-methylpropionate), diethyl-2,2'-azobis(2-methylpropionate) and di-tert-butyl-2,2'-azobis(2-methylpropionate) may be used.

[0138] As the polymerization inhibitor, for example, phenol-based inhibitors such as 2,6-di-t-butyl-p-cresol, 3-t-butyl-4-hydroxyanisole, 2-t-butyl-4-hydroxyanisole, 2,2'-methylenebis(4-methyl-6-t-butylphenol), 2,2'-methylenebis(4-ethyl-6-t-butylphenol), 4,4'-butylidenebis(3-methyl-6-t-butylphenol), 4,4'-thiobis(3-methyl-6-t-butylphenol), styrenated phenol, styrenated p-cresol, 1,1,3-tris(2-methyl-4-hydroxy-5-t-butylphenyl)butane, tetrakis[methylene-3-(3',5'-di-1-butyl-4'-hydroxyphenyl)propionate]methane, octadecyl 3-(3,5-di-t-butyl-4-hydroxyphenylpropionate), 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxybenzyl) benzene, 2,2'-dihydroxy-3,3'-di(α-methylcyclohexyl)-5,5'-dimethyldiphenylmethane, 4,4'-methylenebis(2,6-di-t-butylphenol), tris(3,5-di-t-butyl-4-hydroxyphenyl) isocyanurate, 1,3,5-tris(3',5'-di-t-butyl-4-hydroxybenzoyl) isocyanurate, bis[2-methyl-4-(3-n-alkylthiopropionyloxy)-5-t-butylphenyl]sulfide, 1-oxy-3-methyl-isopropylbenzene, 2,5-di-t-butylhydroquinone, 2,2'-methylenebis(4-methyl-6-nonylphenol), alkylated bisphenol, 2,5-di-t-amylhydroquinone, polybutylated Bisphenol A, Bisphenol A, 2,6-di-t-butyl-p-ethylphenol, 2,6-bis(2'-hydroxy-3-t-butyl-5'-methyl-benzyl)-4-methylphenol, 1,3,5-tris(4-t-butyl-3-hydroxy-2,6-dimethylbenzyl)isocyanurate, terephthaloyl-di(2,6-dimethyl-4-t-butyl-3-hydroxybenzyl sulfide), 2,6-di-t-butylphenol, 2,6-di-t-butyl-α-dimethylamino-p-cresol, 2,2'-methylene-bis(4-methyl-6-cyclohexylphenol), triethylene glycol-bis[3-(3-t-butyl-5-methyl-4-hydroxyphenyl)propionate], hexamethylene glycol-bis(3,5-di-t-butyl-4-hydroxyphenyl)propionate, 3,5-di-t-butyl-4-hydroxytoluene, 6-(4-hydroxy-3,5-di-t-butylaniline)-2,4-bis(octylthio)-1,3,5-triazine, N,N'-hexamethylenebis(3,5-di-t-butyl-4-hydroxy-hydrocyamide), diethyl 3,5-di-t-butyl-4-hydroxybenzyl-phosphate, 2,4-dimethyl-6-t-butylphenol, 4,4'-methylenebis(2,6-di-t-butylphenol), 4,4'-thiobis(2-methyl-6-t-butylphenol), tris[β-(3,5-di-t-butyl-4-hydroxyphenyl) propionyl-oxyethyl] isocyanurate, 2,4,6-tributylphenol, glycol bis[3,3-bis(4'-hydroxy-3'-t-butylphenyl)-butylate], 4-hydroxymethyl-2,6-di-t-butylphenol and bis(3-methyl-4-hydroxy-5-t-butylbenzyl)sulfide can be used.

[0139] Also, as the polymerization inhibitor, amine-based inhibitors such as N-phenyl-N'-isopropyl-p-phenylenediamine, N-phenyl-N'-(1,3-dimethylbutyl)-p-phenylenediamine, N,N'-diphenyl-p-phenylenediamine, 2,2,4-trimethyl-1,2-dihydroquinoline polymer and diaryl-p-phenylenediamine; sulfur-based inhibitors such as dilauryl-thiodipropionate, distearyl-thiodipropionate and 2-mercaptobenzimidanol; and phosphorous-based inhibitors such as distearylpentaerythritol diphosphite can be used.

[0140] As the surfactant, resin, polyfunctional monomer and/or oligomer, chain transfer agent, storage-stability

improver and adhesion improver and the like, the same compounds as those used in the above coloring composition can be used.

[0141] For applying the coating solution, a printing method such as spin coating, slit coating, relief printing, screen printing, planographic printing, reverse printing and gravure printing; the printing method incorporated into an offset system; an inkjet method; or bar coat method can be used, for example.

[0142] The liquid crystal material layer **130'** is formed, for example, as a continuous layer having a uniform thickness. According to the method described above, the liquid crystal material layer **130'** can be formed as a continuous film having a uniform thickness as long as the surface to be coated is sufficiently flat.

[0143] Prior to the application of the coating solution, the surface of the color filter layer **120** may be subjected to an alignment process such as rubbing process. Alternatively, prior to the application of the coating solution, an alignment layer for regulating the orientation of the liquid crystal compound may be formed on the color filter layer **120**. Forming a transparent layer of resin such as polyimide on the color filter layer **120** and subjecting the transparent resin layer to an alignment process such as rubbing process can obtain the alignment layer, for example. The alignment layer may be formed using a photo-alignment technique.

[0144] In the liquid crystal material layer **130'**, the mesogen of the thermotropic liquid crystal compound is oriented to have a cholesteric structure. Depending on the case, a dichroic photo-polymerization initiator is orientated to exhibit a cholesteric structure together with the mesogens. Therefore, irradiation of the liquid crystal material layer **130'** with unpolarized light and polarized light achieves polymerization, i.e., crosslinking, with desired proportions and desired degrees of anisotropy. In other words, the thermotropic liquid crystal compound is heterogeneously polymerized or crosslinked.

[0145] The liquid crystal material layer **130'** obtained in the above manner is subjected to an exposure process. That is, as shown in FIG. **3**, a plurality of regions of the liquid crystal material layer **130'** are subjected to pattern exposure. Pattern exposure light L**1** is composed of a combination of polarized light and unpolarized parallel light, and the condition of the polarized light and the condition of the unpolarized parallel light differ with regions. Either of the polarized light and unpolarized parallel light may be applied first. Also, the light L**1** applied to some regions may be one light, and some regions may not be irradiated with any type of light.

[0146] The above description "difference in the condition of the irradiation with unpolarized parallel light" means that there is a difference in any one of exposure time, illuminance, emission line and the like or in combinations of these conditions. Usually, light is applied in such a manner that different irradiation energy, that is, a different exposure value of light is applied to each region. However, reciprocity natures are observed though depending on the type of material. In this case, it is not always necessary to use a different exposure value of light. For example, light may be applied to one region at high luminance for a short time and to another region at low luminance for a long time, with the result that the exposure values of light (illuminance×exposure time) of the both regions are equal to each other.

[0147] The condition of the polarized light irradiation includes the ellipticity and extinction ratio of the polarized light. The above description "difference in the irradiation with the polarized light" means that there is a difference in any one of the ellipticity and extinction of the polarized light or combinations of these conditions in addition to the conditions changed in the above irradiation with the unpolarized parallel light. Usually, light is applied in such a manner that a different exposure value of light is applied to each region. However, the condition of the polarized light is the same as that of the unpolarized parallel light in the point that it is not always necessary to use a different exposure value of light. Examples of the light to be used in the case of the irradiation with the polarized light include linearly polarized light and elliptically polarized light. Although the ellipticity and extinction ratio may be selected as the conditions which are to be changed as described above, it is simple to use linearly polarized light and to fix the extinction ratio, while changing other conditions.

[0148] The following descriptions will be furnished as to the case of using a different exposure value in each area and using linearly polarized light for the irradiation with the polarized light.

[0149] For example, on the liquid crystal material layer **130'**, the region **130***a*' corresponding to the region **130***a* is irradiated with a sufficient exposure value of unpolarized parallel light alone as the light L**1**. On the liquid crystal material layer **130'**, the region **130***b*' corresponding to the region **130***b* is irradiated with a sufficient exposure value of linearly polarized light as the light L**1**. On the liquid crystal material layer **130'**, no light is applied to the region **130***c*' corresponding to the region **130***c*.

[0150] In the liquid crystal material layer **130'**, the cholesteric orientation state formed by the mesogen is immobilized according to the type and exposure value of the irradiated light L**1**, whereby the thermotropic liquid crystal compound is polymerized or crosslinked. In the polymerized or crosslinked product of the thermotropic liquid crystal compound, the mesogenic groups lose their flowability, whereby the orientation variation in the subsequent process is prevented.

[0151] For example, in the region **130***a*' irradiated with a sufficient exposure value of unpolarized parallel light alone as the light L**1**, the cholesteric orientation state of the mesogen is immobilized with the state generally maintained. The content of the polymerized or crosslinked product of the thermotropic liquid crystal compound wherein the mesogenic groups are in the cholesteric orientation state is the highest, and the content of the unpolymerized and uncrosslinked thermotropic liquid crystal compound is the smallest.

[0152] In region **130***b*' irradiated with a sufficient exposure value of linearly polarized light alone as the light L**1**, mesogens orientated in a specific azimuth in the plane corresponding to the polarization axis among the mesogens forming a cholesteric alignment structure are immobilized while the orientation state is maintained. On the other hand, those orientated in other azimuths are not immobilized and still has flowability, though the state of the orientation is unchanged. In comparison with the region **130***a*', the polymerized and/or crosslinked product of the thermotropic liquid crystal compound having a immobilized orientation state is present, but the proportion is tilted toward those having mesogenic groups oriented in a specific direction. Therefore, as a whole, the content of the unpolymerized or uncrosslinked thermotropic liquid crystal compound is higher.

[0153] The light used in the exposure process is electromagnetic waves such as ultraviolet rays, visible rays and infrared rays. More specifically, ultraviolet rays including light having a wavelength of 180 to 400 nm are typically used.

[0154] The exposure process may be performed by any method as long as the above-described nonuniform polymerization or crosslinking can be caused.

[0155] For example, the exposure process may include exposure operations using photomasks having different patterns of the light shielding layers. For example, the region **130***a*' is selectively irradiated with a maximum exposure value of unpolarized parallel light as the light L**1** through a certain photomask, and the region **130***b*' is selectively irradiated with a maximum exposure value of linearly polarized light as the light L**1** through a photomask different from the above one.

[0156] Alternatively, the exposure process may include exposure of the region **130***a*' through a certain photomask, and exposure of the region **130***b*' through the same photomask. In this case, for example, the region **130***a*' is irradiated with a maximum exposure value of unpolarized parallel light as the light L**1** through a certain photomask. Using the photomask, the region **130***b* is irradiated with a maximum exposure value of linearly polarized light as the light L**1**.

[0157] Alternatively, operations such as an operation of scanning the liquid crystal material layer **130**' by a luminous flux instead of using a photomask may be performed.

[0158] Alternatively, the above-described methods may be combined. Irrespective of which method is used for the first exposure process, in the exposure process, the degree of polymerization or the degree of polymerization anisotropy of the thermotropic liquid crystal compound in the liquid crystal material layer **130**' is formed into a so-called "latent image".

[0159] After completing the exposure process, a developing process is performed. That is, the liquid crystal material layer **130**' is heated to a temperature equal to or higher than the phase transition temperature at which the thermotropic liquid crystal compound changes from a liquid crystal phase to an isotropic phase. As a result of the heating process, the "latent image" formed in the above-described exposure process develops as a change of the orientation state of the mesogen.

[0160] Details are as follows. The mesogen moiety of the thermotropic liquid crystal compound as an unreacted compound is not immobilized. Therefore, when the liquid crystal material layer **130**' is heated to the phase transition temperature or higher, the orientation of the mesogen of the unreacted compound is lowered. For example, the mesogen of the unreacted compound changes from the liquid crystal phase to the isotropic phase. On the other hand, the mesogen of the polymerized or crosslinked product of the thermotropic liquid crystal compound are immobilized.

[0161] Accordingly, as shown in FIG. **4**, in the region **130***a*' irradiated with a sufficient exposure value of unpolarized parallel light alone as the light L**1**, the orientation state of the mesogen MS is hardly changed by the heat treatment. The orientation state is immobilized with the cholesteric orientation maintained. As a result of this, a negative C-plate is obtained.

[0162] The orientation of the mesogen MS orientated in a specific azimuth in the plane corresponding to the polarization axis in region **130***b*' irradiated with a sufficient exposure value of linearly polarized light as the light L**1** is kept in a immobilized state whereas the mesogen MS orientated in other azimuths are disordered. That is, anisotropic orientational disorder arises. As a result of this, the region **130***b*' develops a biaxiality composed of a positive A-plate and a negative C-plate, and thus having both of the in-plane retardation and the thickness direction retardation. In the region **130***c*', to which no light is applied before heating, the orientation structure of the mesogen MS disappears upon heat treatment. As shown in the figure, in the region **130***c*', the cholesteric orientation of the mesogen MS is almost completely disordered to give an isotropic phase.

[0163] The exposure value of linearly polarized light, the exposure value of unpolarized parallel light, the ratio of exposure values of linearly polarized light and unpolarized parallel light and the like are changed to perform the exposure process, and then, the developing process is performed, thereby enabling optional control of the orientation state of the mesogens MS in each of the plurality of regions of the liquid crystal material layer **130**'. One example of these process will be described with reference to FIGS. **5** and **6**.

[0164] FIG. **5** shows the liquid crystal material layer **130**' containing the regions **130***a*' to **130***f*'. As described above, the regions **130***a*' to **130***c*' are irradiated with different types of the light L**1**, and the regions **130***d*' to **130***f*' are also irradiated with different types of the light L**1**.

[0165] The region **130***c*' is not irradiated with the light L**1**, and the region **130***a*' is irradiated with a sufficient exposure value of unpolarized parallel light as the light L**1**. The region **130***d*' is irradiated with unpolarized parallel light as the light L**1** with a smaller exposure value than the region **130***a'*.

[0166] The region **130***b*' is irradiated with a sufficient exposure value of linearly polarized light as the light L**1**, and the region **130***e*' is irradiated with linearly polarized light as the light L**1** with a smaller exposure value than the region **130***b*'. Further, the region **130***f*' is irradiated with unpolarized parallel light and linearly polarized light as the light L**1** with smaller exposure values than the regions **130***a*' and **130***b*', respectively.

[0167] The sufficient exposure value of the unpolarized parallel light refers to an exposure value by which the major portion of the thermotropic liquid crystal compound is substantially polymerized or crosslinked. Even if the light is applied with an exposure value over the sufficient exposure value, no difference is found in the orientation state in the subsequent first heat treatment process. The sufficient exposure value of the linearly polarized light refers to an exposure value by which the anisotropy of the polymerizing or crosslinking the thermotropic liquid crystal compound is maximized. In principle, when the quenching ratio of the linearly polarized light is infinite, even if the light is applied with an exposure value over the sufficient exposure value, no difference is found in the orientation state in the subsequent first heat treatment process.

[0168] In general cases, the quenching ratio of linearly polarized light is finite, and the in-plane retardation gradually decreases when the light is continuously applied with an exposure value over the sufficient exposure value. When the exposure value is in such a range, the thickness direction retardation cannot be controlled. The present invention requires the differences in the in-plane retardation and the thickness direction retardation, and thus does not use the exposure value in the above range.

[0169] A specific value cannot be given for the sufficient exposure value because it markedly varies depending on the type of the thermotropic liquid crystal compound, the type

and amount of the photo-polymerization initiator, the presence or absence, type, and amount of other additives, and the type and intensity of the irradiated light. In typical cases, a sufficient exposure value is about 200 mJ/cm^2 to 1000 mJ/cm^2. For example, when a luminous flux of 20 mW/cm^2 is used, sufficient exposure is achieved with irradiation for about 10 to 100 seconds.

[0170] If the above-described sufficient exposure value is not reached, the exposure value is insufficient, but the degree of immobilization of the orientation by the light is not necessarily proportional to the exposure value. The immobilization often markedly proceeds with a small exposure value. For example, even if the exposure value is half the sufficient exposure value, over half of the orientation is immobilized. In order to achieve a significant difference from the region irradiated with a sufficient exposure value, the desirable exposure value may be markedly smaller than the sufficient exposure value. More specifically, an insufficient exposure value is about 2 mJ/cm^2 to 180 mJ/cm^2. For example, when a luminous flux of 20 mW/cm^2 is used, the exposure is insufficient when the irradiation time is about 0.1 to 9 seconds.

[0171] FIG. **6** shows the result of the above-described heating process performed after the completion of the exposure process through the irradiation of the light L**1**.

[0172] In the region **130***d*' which has been irradiated with an insufficient exposure value of unpolarized parallel light as the light L**1**, the orientation of the uncured component, which remains due to the insufficient exposure value, is disordered to give a poorly orientated state. A negative C-plate is obtained owing to the irradiation with the unpolarized parallel light, but the thickness direction retardation is smaller than that in the region **130***a*.

[0173] In region **130***e*' irradiated with insufficient and linearly polarized light as light L**1**, the in-plane retardation and thickness direction retardation are both less than those of region **130***b*'. However, biaxiality composed of a positive A-plate and a negative C-plate is exhibited in the same manner as in the region **130***b*'.

[0174] In the region **130***f*' which has been irradiated with an insufficient exposure value of linearly polarized light and an insufficient exposure value of unpolarized parallel light as the light L**1**, the nature of the orientation varies depending on the exposure value ratio between the linearly polarized light and unpolarized parallel light, and the total exposure value. More specifically, the nature of the orientation obtained in the region **130***a*' and the nature of the orientation obtained in the region **130***b*' are developed, whereby biaxiality composed of an A-plate and a negative C-plate is exhibited. However, the in-plane retardation of this area **130***f*' is less than that of area **130***b*'. In other words, The Nz coefficient is greater than in the region **130***b*'.

[0175] The exposure process may be performed by the above-described method. When a halftone mask is used in the exposure process, the exposure values of the linearly polarized light and unpolarized parallel light applied to the respective regions may be controlled as desired. The halftone mask has a light shielding layer at a position corresponding to a specific region, and a semi-transmissive layer at a position corresponding to another region. Instead of the halftone mask, a gray-tone mask or a wavelength-limiting mask may be used. The gray-tone mask has the same structure as that of the halftone mask except that the semitransparent layer is omitted, and it includes a plurality of slits in the light-shielding layer in width equal to or smaller than the resolution of the light-exposure apparatus. The light-limiting mask includes portions different in wavelength range of light allowed to pass through.

[0176] As explained about the region **130***f*', the desired biaxiality is obtained through the appropriate selection of the exposure value ratio between linearly polarized light and unpolarized parallel light and their total exposure value. That is, the Nz coefficient may be freely established.

[0177] The same effect is obtained not only in the case of using a combination of the linearly polarized light and unpolarized parallel light but also in the case of irradiating linearly polarized lights differing in extinction ratio. When, for example, linearly polarized light having an extinction ratio of 2:1 is irradiated, this almost corresponds to the case where the irradiation value of linearly polarized light (infinite extinction ratio) is equal to the irradiation value of unpolarized parallel light. When linearly polarized light having an extinction ratio greater than 2:1 is irradiated, this corresponds to the case where the irradiation value of linearly polarized light is greater than the irradiation value of unpolarized parallel light.

[0178] The same effect is also obtained not only in the case of using a combination of the linearly polarized light and unpolarized parallel light, but also in the case of irradiating elliptically polarized light differing in ellipticity. For example, when elliptically polarized light having an ellipticity of 2 is irradiated, this corresponds to the case where the irradiation value of linearly polarized light having an infinite extinction ratio is almost equal to the irradiation value of unpolarized parallel light. Also, elliptically polarized light having an ellipticity of greater than 2 is irradiated, this corresponds to the case where the irradiation value of linearly polarized light is greater than the irradiation value of unpolarized parallel light.

[0179] Furthermore, light L**1** may be obtained by combining the above approaches. For example, the linearly polarized light differing in extinction ratio may be combined with the unpolarized parallel light, or the elliptically polarized light differing in ellipticity may be combined with the unpolarized parallel light to make each combination light L**1**.

[0180] In the process of irradiation with linearly polarized light or elliptically polarized light, the axial direction of the polarized light applied to at least one region may be different from that of the polarized light applied to other region. As a result of this, in the subsequent developing process, the axial direction in the plane in which the refractive index reaches peak is different from that of the other region, corresponding to the azimuth of polarization axis of the linearly or elliptically polarized light.

[0181] As shown in FIG. **4**, after different orientation states are established in the respective regions, a fixing process is performed to polymerize and/or crosslink unreacted compounds, with the orientation state of the mesogen of the unreacted compound maintained.

[0182] For example, as shown in FIG. **7**, light L**2** is applied over the entire liquid crystal material layer **130'**, with the liquid crystal material layer **130'** kept at a temperature higher than the phase transition temperature at which the thermotropic liquid crystal compound changes from an isotropic phase to a liquid crystal phase.

[0183] The liquid crystal material layer **130'** is irradiated with the light L**2** with an exposure value sufficient for causing the polymerization and/or crosslinking reaction of almost all of the unreacted compound. As a result of this, the unreacted compound is polymerized or crosslinked, and the mesogen

having a changed orientation state is immobilized. In this manner, the solidified liquid crystal layer **130** is obtained.

[0184] In a liquid crystal compound, the first phase transition temperature at which the compound changes from an isotropic phase to a liquid crystal phase is lower than the second phase transition temperature at which the compound changes from a liquid crystal phase to an isotropic phase. Therefore, in a particular case, the temperature of the liquid crystal material layer **130'** in the fixing process may be lower than the heating temperature in the developing process. In normal cases, in consideration of convenience, the temperature of the liquid crystal material layer **130'** in the fixing process is equal to or higher than the first phase transition temperature.

[0185] The light L**2** may be polarized light, but unpolarized light is usually preferred from the viewpoint of convenience.

[0186] In the fixing process, the entire surface of the liquid crystal material layer **130'** may be irradiated with a uniform exposure value. In this case, the use of a photomask having a fine pattern is not necessary. As a result of this, the process is simplified.

[0187] The fixing process may be performed by another methods.

[0188] For example, when the unreacted compound, or the thermotropic liquid crystal compound is a material which is polymerized and/or crosslinked by heating to a polymerization and/or crosslinking temperature higher than the first phase transition temperature, heating process may be performed in place of applying light. More specifically, in place of applying light, the liquid crystal material layer **130'** is heated to a temperature equal to or higher than the polymerization and/or crosslinking temperature, thereby polymerizing and/or crosslinking the unreacted compound. As a result of this, the solidified liquid crystal layer **130** is obtained. The heating temperature in the developing process is, for example, equal to or higher than the first phase transition temperature, and below the polymerization and/or crosslinking temperature.

[0189] Alternatively, in the fixing process, the irradiation with light and heating may be performed out sequentially. Such a combination of light and heat can progress the polymerizing and/or crosslinking the unreacted compound more exactly. As a result of this, the solidified liquid crystal layer **130** has a greater strength.

[0190] In the case where, for example, the unreacted compound is a material which is polymerized and/or crosslinked by heating it to a certain temperature, the heating temperature in the developing process may be equal to or higher than the polymerization temperature and/or crosslinking temperature of the compound. That is, the developing process and the fixing process may be performed simultaneously. However, in this case, the occurrence of orientational disorder and the polymerization and/or crosslinking progress at the same time. Therefore, the production conditions affect the optical characteristics of the solidified liquid crystal layer **130** relatively greatly.

[0191] As described with reference to FIGS. **3** and **4**, a retardation pattern is formed without a wet process in the retardation plate of the present invention. In order to form the pattern by a wet process, a liquid such as a solvent or an aqueous alkaline solution, which has the capability to dissolve the liquid crystal material layer is used. For example, the liquid crystal material layer is dipped in this liquid or the liquid is sprayed on the liquid crystal material layer by a spray or the like to remove an uncured part, thereby forming a pattern. In such a wet process, the conditions of the process have a significantly large influence on the optical characteristics of a final product. For this reason, according to the method including a wet process, deviations of the optical properties from the target values prone to occur.

[0192] On the other hand, in the method of the present invention, no wet process is performed in the first exposure process or later. Therefore, it is possible to prevent the deviation of the refractive index anisotropy from the target value due to the wet process.

[0193] Note that the refractive index anisotropy and the exposure value in the exposure process are not always in a proportional relation. However, under the conditions in which materials and the exposure values are unchanged, the reproducibility of the refractive index anisotropy is high. Therefore, the conditions, for example, an exposure value necessary for achieving certain refractive index anisotropy can be found out easily, and a stable manufacture can be done easily.

[0194] Various modifications can be made to the retardation plate **10** described with reference to FIGS. **1** to **4** and **7**, i.e., a panel substrate.

[0195] In the retardation plate **10**, the solidified liquid crystal layer **130** includes the regions **130***a* to **130***c* different in refractive index anisotropy. The solidified liquid crystal layer **130** may further include one or more regions different in refractive index anisotropy from the regions **130***a* to **130***c*. For example, in a semi-transparent liquid crystal display, each of the red, green and blue pixels includes a transmissive portion and a reflective portion. The transmissive portion and the reflective portion need to be designed separately. Therefore, each of the portions of the solidified liquid crystal layer **130** that correspond to the red, green and blue pixels may include two or more regions different in refractive index anisotropy from each other.

[0196] Also, the color filter layer **120** may include black partition walls besides the aforementioned coloring layers. The black partition walls are formed in such a manner as to divide coloring layers **120***a* to **120***c* from one another.

[0197] The color filter layer **120** may be omitted from the retardation plate **10**. For example, in a liquid crystal display, one of the substrates may include both a color filter layer and a retardation layer. Alternatively, it is possible that one substrate of a liquid crystal display includes a color filter layer and the other substrate includes a retardation layer. In the latter case, it is not necessary that the retardation plate **10** includes the color filter layer **120**. However, in the case where the retardation plate **10** includes both the color filter layer **120** and the solidified liquid crystal layer **130**, an alignment between the color filter layer **120** and the solidified is unnecessary when bonding them together.

[0198] The solidified liquid crystal layer **130** may be interposed between the planar body **110** and the color filter layer **120**.

[0199] FIG. **8** is a sectional view schematically showing a retardation plate according to a modified example. This retardation plate **10** is the same as the retardation plate **10** described with reference to FIGS. **1** to **4** except that the solidified liquid crystal layer **130** is interposed between the planar body **110** and the color filter layer **120**.

[0200] In the case where such a structure is employed, for example, in a liquid crystal display including the retardation plate **10**, the solidified liquid crystal layer **130** does not suppress the inclusion of impurities from the color filter layer **120**

into the liquid crystal layer. However, in the case where this structure is employed, there is no possibility that the color filter layer **120** is subjected to the exposure process and the heat treatment process for forming the solidified liquid crystal layer **130**. Therefore, in the case where such a structure is employed, deteriorations of the color filter layer **120** due to the light in the above exposure process and by the heat in the above developing process and fixing process are less prone to occur as compared with the case where the structure shown in FIGS. **1** and **2** is employed.

[0201] Also, when this structure is adopted, the solidified liquid crystal layer **130** can be formed on the planar body **110**. Therefore, the solidified liquid crystal layer **130** having performance according to the design can be obtained more easily as compared with the case of forming the solidified liquid crystal layer **130** on the color filter layer **120** which is scarcely formed as a perfect plane.

[0202] Typically, the solidified liquid crystal layer **130** has a uniform thickness. However, in particular cases, the regions **130***a* to **130***c* of the solidified liquid crystal layer **130** can be different in thickness from one another.

[0203] Any of the aforementioned retardation plates **10** may be used in various applications. For example, the retardation plate **10** may be utilized for display technologies typified by liquid display technologies.

[0204] FIG. **9** is a sectional view schematically showing an example of a liquid crystal display that can be manufactured using the retardation plate shown in FIGS. **1** and **2**.

[0205] The liquid crystal display shown in FIG. **9** is a transmissive liquid crystal display employing an active matrix driving method. The liquid crystal display includes a color filter substrate **10'**, an array substrate **20**, a liquid crystal layer **30**, a pair of polarizing plates **40**, and a backlight (not shown).

[0206] The color filter substrate **10'** includes the retardation plate **10** described above, a counter electrode **150**, and an alignment layer **160**.

[0207] The counter electrode **150** is formed on the solidified liquid crystal layer **130**. It is a continuous film extending over the display area. The counter electrode **150** is made of the above-described transparent conductor, for example.

[0208] The alignment layer **160** covers the counter electrode **150**. Forming a transparent layer of resin such as polyimide on the counter electrode **150** and subjecting the transparent resin layer to an alignment process such as rubbing process can obtain the alignment layer **160**, for example. The alignment layer **160** may be formed using a photo-alignment technique.

[0209] The array substrate **20** includes a substrate **210** facing the alignment layer **160**. The substrate **210** is a light-transmitting substrate such as glass plate or resin plate.

[0210] On the surface of the substrate **210** facing the alignment layer **160**, pixel circuits (not shown), scanning lines (not shown), signal lines (not shown), and pixel electrodes **250** are arranged. The pixel circuits each includes a switching device such as thin-film transistor and are arranged in a matrix on the substrate. The scanning lines are arranged correspondingly with the rows of the pixel circuits. The operation of each pixel circuit is controlled by a scanning signal supplied via the scanning line. The signal lines are arranged correspondingly with the columns of the pixel circuits. Each pixel electrode **250** is connected to the signal line via the pixel circuit. Each pixel electrode **250** faces one of the coloring layers **120***a* to **120***c*.

[0211] The pixel electrodes **250** are covered with an alignment layer **260**. Forming a transparent layer of resin such as polyimide on the pixel electrode **250** and subjecting the transparent resin layer to an alignment process such as rubbing process can obtain the alignment layer **260**, for example. The alignment layer **260** may be formed using a photo-alignment technique.

[0212] The color filter substrate **10'** and the array substrate **20** are bonded together via a frame-shaped adhesive layer (not shown). The color filter substrate **10'**, the array substrate **20** and the adhesive layer form a hollow structure.

[0213] The liquid crystal layer **30** is made of a liquid crystal compound or a liquid crystal composition.

[0214] The liquid crystal compound or the liquid crystal composition has flowability and fills the space enclosed with the color filter substrate **10'**, the array substrate **20** and the adhesive layer. The color filer substrate **10'**, the array substrate **20**, the adhesive layer and the liquid crystal layer **30** form a liquid crystal cell.

[0215] The polarizing plates **40** are adhered to the main surfaces of the liquid crystal cell. The polarizing plates **40** are arranged such that their transmission axes intersect orthogonally, for example.

[0216] In the liquid crystal display, the regions **130***a* to **130***c* of the solidified liquid crystal layer **130** are almost equal in thickness to one another and are different in refractive index anisotropy from one another. Accordingly, it is possible to optimize the refractive index anisotropy of each of the regions **130***a* to **130***c* so as to achieve an ideal optical compensation for each of red, green and blue colors.

[0217] As described above, the retardation plate **10** can be used in a transmissive liquid crystal display employing an active matrix driving method. The retardation plate **10** can be used in other displays.

[0218] For example, the retardation plate **10** may be used in a semi-transparent liquid crystal display or a reflective liquid crystal display. Also, driving methods other than an active matrix driving method such as passive matrix driving method may be employed in the liquid crystal display. Alternatively, the retardation plate **10** may be used in displays other than liquid crystal displays such as organic electroluminescent display.

[0219] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A retardation plate comprising:

a light transmissive planar body; and

a solidified liquid crystal layer which is a continuous film made from the same material supported by the planar body, the solidified liquid crystal layer comprising a plurality of regions in each of which a thickness direction refractive index is the lowest, the plurality of regions being arranged on the planar body, the regions being different in in-plane retardation and thickness direction retardation caused by degree of orientational disorder of mesogens and anisotropy of orientational disorder of the mesogens.

2. The retardation plate according to claim 1, wherein a number of the regions in the solidified liquid crystal layer is 3 or more.

3. The retardation plate according to claim 1, wherein in at least one region of the solidified liquid crystal layer, an N_z coefficient represented by the formula (1) is different from that of another region:

$$Nz=(n_x-n_z)/(n_x-n_y) \quad \text{formula (1)}$$

where n_x is a maximum refractive index in the plane, n_y is a minimum refractive index in the plane, and n_z is a refractive index in a normal direction.

4. The retardation plate according to claim 2, wherein any one of the first to third regions substantially has no in-plane retardation.

5. The retardation plate according to claim 2, wherein at least one of the first to third regions is different from other regions in an axial direction in which a refractive index in the plane is the highest.

6. The retardation plate according to claim 2, further comprising a region having substantially no refractive index anisotropy.

7. The retardation plate according to claim 1, wherein the solidified liquid crystal layer has a uniform thickness.

8. The retardation plate according to claim 1, wherein the solidified liquid crystal layer is formed by polymerizing and/or crosslinking a thermotropic liquid crystal compound or composition in a state of an anisotropically disordered cholesteric alignment.

9. The retardation plate according to claim 2, further comprising a color filter layer which is interposed between the planar body and the solidified liquid crystal layer, or faces the planar body with the solidified liquid crystal layer interposed therebetween, the color filter layer comprising first to third coloring layers having different absorption spectra and facing the first to third regions, respectively.

10. The retardation plate according to claim 9, wherein the in-plane retardation of the solidified liquid crystal layer is the smallest in the first region and the greatest in the third region, and the Nz coefficient of the solidified liquid crystal layer is the greatest in the first region and the smallest in the third region, and

a wavelength of light transmissible through the color filter layer is the shortest in the first coloring layer, and the longest in the third coloring layer.

11. A liquid crystal display comprising the retardation plate according to claim 1.

12. A method of manufacturing a retardation plate, comprising forming a solidified liquid crystal layer on a light-transmissive planar body, the formation of the solidified liquid crystal layer comprising:

a film-forming step of forming a liquid crystal material layer on the planar body, the liquid crystal material layer comprising a photo-polymerizing or photo-crosslinking thermotropic liquid crystal compound and a chiral agent, and mesogens of the thermotropic liquid crystal compound forming a cholesteric alignment structure;

an exposure step of irradiating at least two regions of the liquid crystal material layer with polarized light under different conditions and with unpolarized parallel light under different conditions, thereby polymerizing or crosslinking at least a portion of the thermotropic liquid crystal compound with different proportions and different degrees of anisotropy to produce a polymerized or crosslinked product;

a developing step of heating thereafter the liquid crystal material layer to a temperature equal to or higher than a phase transition temperature at which the thermotropic liquid crystal compound is changed from a liquid crystal phase to an isotropic phase, thereby changing an orientation state of the mesogens of the unreacted thermotropic liquid crystal compound in the at least two regions; and

a fixing step of polymerizing and/or crosslinking the unreacted compound with the orientation state of the mesogens kept changed.

13. The manufacturing method according to claim 12, wherein the irradiation of unpolarized parallel light is performed before the irradiation of polarized light in the exposure step.

14. The manufacturing method according to claim 12, wherein the irradiation of polarized light is performed by irradiating with linearly polarized light in the exposure step.

15. The manufacturing method according to claim 12, wherein the irradiation of polarized light is performed by irradiating with elliptically polarized light in the exposure step.

16. A method of manufacturing a retardation plate, comprising forming a solidified liquid crystal layer on a light-transmissive planar body, the formation of the solidified liquid crystal layer comprising:

a film-forming step of forming a liquid crystal material layer on the planar body, the liquid crystal material layer comprising a photo-polymerizing or photo-crosslinking thermotropic liquid crystal compound and a chiral agent, and mesogens of the thermotropic liquid crystal compound forming a cholesteric alignment structure;

an exposure step of irradiating at least two regions of the liquid crystal material layer with linearly polarized light with at least extinction ratios thereof different from each other, thereby polymerizing or crosslinking at least a portion of the thermotropic liquid crystal compound with different proportions and different degrees of anisotropy to produce a polymerized or crosslinked product;

a developing step of heating thereafter the liquid crystal material layer to a temperature equal to or higher than a phase transition temperature at which the thermotropic liquid crystal compound is changed from a liquid crystal phase to an isotropic phase, thereby changing an orientation state of the mesogens of the unreacted thermotropic liquid crystal compound in the at least two regions; and

a fixing step of polymerizing and/or crosslinking the unreacted compound with the orientation state of the mesogens kept changed.

17. A method of manufacturing a retardation plate, comprising forming a solidified liquid crystal layer on a light-transmissive planar body, the formation of the solidified liquid crystal layer comprising:

a film-forming step of forming a liquid crystal material layer on the planar body, the liquid crystal material layer containing a photo-polymerizing or photo-crosslinking thermotropic liquid crystal compound and a chiral agent, and mesogens of the thermotropic liquid crystal compound forming a cholesteric alignment structure;

an exposure step of irradiating at least two regions of the liquid crystal material layer with elliptically polarized light with at least ellipticities thereof different from each other, thereby polymerizing or crosslinking at least a portion of the thermotropic liquid crystal compound with different proportions and different degrees of anisotropy to produce a polymerized or crosslinked product;

a developing step of heating thereafter the liquid crystal material layer to a temperature equal to or higher than a phase transition temperature at which the thermotropic liquid crystal compound is changed from a liquid crystal phase to an isotropic phase, thereby changing an orientation state of the mesogens of the unreacted thermotropic liquid crystal compound in the at least two regions; and

a fixing step of polymerizing and/or crosslinking the unreacted compound with the orientation state of the mesogens kept changed.

18. The manufacturing method according to claim **12**, wherein in the exposure step, irradiating with linearly polarized light or elliptically polarized light is performed such that an azimuth of polarization axis in at least one of the regions is different from that in the another region.

19. The manufacturing method according to claim **12**, wherein in the exposure step, a region which comprises the thermotropic liquid crystal compound or composition as an unreacted compound and does not comprise the polymerized or crosslinked product is formed by irradiating neither with the polarized light nor with the unpolarized parallel light,

in this region,

the orientation of the mesogens of the unreacted thermotropic liquid crystal compound disappears in the developing step, by heating the liquid crystal material layer to the temperature equal to or higher than the phase transition temperature at which the thermotropic liquid crystal compound is changed from the liquid crystal phase to the isotropic phase, and

the unreacted compound is polymerized and/or crosslinked in the fixing step maintaining the disappearance of the orientation of the mesogens.

20. The manufacturing method according to claim **12**, wherein in the film-forming step, the liquid crystal material layer is formed as a continuous film having a uniform thickness.

21. The manufacturing method according to claim **12**, wherein in the fixing step, the polymerizing and/or crosslinking the unreacted compound reaction is induced by light irradiation.

22. The manufacturing method according to claim **12**, wherein the thermotropic liquid crystal compound is a material which is polymerized and/or crosslinked by heating to a polymerizing and/or crosslinking temperature higher than the phase transition temperature,

in the developing step, the orientation state of the mesogen groups is changed by heating the liquid crystal material layer at a temperature lower than the polymerization and/or crosslinking temperature, and

in the fixing step, the unpolymerized and uncrosslinked thermotropic liquid crystal compound is polymerized and/or crosslinked by heating the liquid crystal material layer to a temperature equal to or higher than the polymerization and/or crosslinking temperature.

23. The manufacturing method according to claim **22**, wherein the heating in the developing step is performed by raising a temperature of the planar body continuously from a temperature in the exposure step to a temperature in the fixing step.

24. The manufacturing method according to claim **12**, further comprising forming a color filter layer on the planar body before the solidified liquid crystal layer is formed, wherein that the solidified liquid crystal layer is formed on the color filter directly or with another layer interposed therebetween.

25. The manufacturing method according to claim **12**, further comprising forming a color filter layer on the solidified liquid crystal layer after the solidified liquid crystal layer is formed, wherein that the color filter layer is formed on the solidified liquid crystal layer directly or with another layer interposed therebetween.

26. A retardation plate comprising:

a light-transmissive planar body; and

a solidified liquid crystal layer which is a continuous film made from the same material supported by the planar body, the solidified liquid crystal layer comprising a plurality of regions in each of which a thickness direction refractive index is the lowest, the plurality of regions being arranged on the planar body, the regions being different in in-plane birefringence and thickness direction birefringence caused by degree of orientational disorder of mesogens and anisotropy of orientational disorder of the mesogens.

27. The retardation plate according to claim **26**, wherein that a number of the regions in the solidified liquid crystal layer is 3 or more.

28. The retardation plate according to claim **26**, wherein in at least one region of the solidified liquid crystal layer, an N_z coefficient represented by the formula (1) is different from that of another region:

$$Nz=(n_x-n_z)/(n_x-n_y) \quad \text{formula (1)}$$

where n_x is a maximum refractive index in the plane, n_y is a minimum refractive index in the plane, and n_z is a refractive index in a normal direction.

29. The retardation plate according to claim **27**, wherein any one of the first to third regions substantially has no in-plane retardation.

30. The retardation plate according to claim **27**, wherein at least one of the first to third regions is different from other regions in an axial direction in which a refractive index in the plane is the highest.

31. The retardation plate according to claim **26**, further comprising a region having substantially no refractive index anisotropy.

32. The retardation plate according to claim **26**, wherein the solidified liquid crystal layer has a uniform thickness.

33. The retardation plate according to claim **26**, wherein the solidified liquid crystal layer is formed by polymerizing and/or crosslinking a thermotropic liquid crystal compound or composition in a state of an anisotropically disordered cholesteric alignment.

34. The retardation plate according to claim **27**, further comprising a color filter layer which is interposed between the planar body and the solidified liquid crystal layer, or faces the planar body with the solidified liquid crystal layer interposed therebetween, the color filter layer comprising first to third coloring layers having different absorption spectra and facing the first to third regions, respectively.

35. The retardation plate according to claim **34**, wherein the in-plane retardation of the solidified liquid crystal layer is the smallest in the first region and the greatest in the third region, and the Nz coefficient of the solidified liquid crystal layer is the greatest in the first region and the smallest in the third region, and

a wavelength of light transmissible through the color filter layer is the shortest in the first coloring layer, and the longest in the third coloring layer.

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摘要(译)

延迟板包括透光平面体和固化液晶层，该固化液晶层是由由平面体支撑的相同材料制成的连续膜。固化的液晶层包括多个厚度方向折射率最低的区域。多个区域布置在平面体上，每个区域具有不同的面内延迟和不同厚度方向的延迟，这是由介晶的取向紊乱程度和介晶的取向紊乱的各向异性引起的。