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(71) Applicant *(for all designated States except US)*: **Fuji Photo Film Co., Ltd.** [JP/JP]; 210 Nakanuma, Minami-Ashigara-shi, Kanagawa, 2500193 (JP).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **TAKEUCHI, Yosuke** [JP/JP]; c/o Fuji Photo Film Co., Ltd., 200 Onakazato, Fujinomiya-shi, Shizuoka, 4188666 (JP). **NAKAGAWA, Kenichi** [JP/JP]; c/o Fuji Photo Film Co., Ltd., 200 Onakazato, Fujinomiya-shi, Shizuoka, 4188666 (JP). **SATO, Masao** [JP/JP]; c/o Fuji Photo Film Co., Ltd., 210 Nakanuma, Minami-Ashigara-shi, Kanagawa, 2500193 (JP).

(74) Agents: **HIROTA, Koichi** et al.; HIROTA, NAGARE & ASSOCIATES 4th Floor, Shinjuku TR Bldg., 2-2-13, Yoyogi, Shibuya-ku, Tokyo 1510053 (JP).

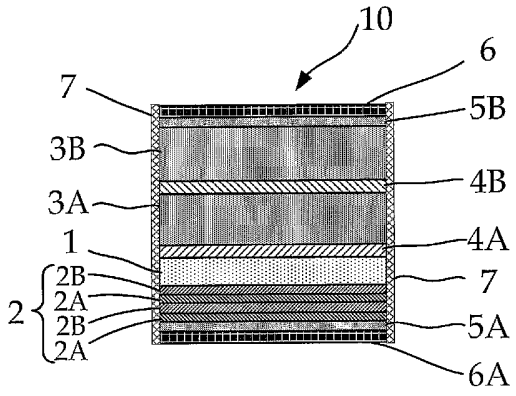
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(54) **Title:** OPTICAL COMPENSATORY ELEMENT AND METHOD FOR MANUFACTURING THEREOF, WAVE PLATE AND METHOD FOR MANUFACTURING THEREOF, LIQUID CRYSTAL DISPLAY AND LIQUID CRYSTAL PROJECTOR



(57) **Abstract:** It is an object of the present invention to provide the optical compensatory element and a method for manufacturing optical compensatory element having a sealing unit which seals the optical compensatory element body, and a wave plate and a method for manufacturing wave plate having a protective layer on the wave film, thereby being protected from outside air and capable of optically compensating a liquid crystal layer in black state more precisely and preventing light leakage at a wide range of viewing angles while having less aged deterioration. It is also an object of the present invention to provide a liquid crystal display and a liquid crystal projector with wide viewing angle, high contrast and high quality images owning to the optical compensatory element and the wave plate which are utilized therein.

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DESCRIPTION

OPTICAL COMPENSATORY ELEMENT AND METHOD FOR MANUFACTURING THEREOF, WAVE PLATE AND METHOD FOR MANUFACTURING THEREOF, LIQUID CRYSTAL DISPLAY AND LIQUID CRYSTAL PROJECTOR

Technical Field

The present invention relates to an optical compensatory element and method for manufacturing the optical compensatory element, a wave plate and method for manufacturing the wave plate, a liquid crystal display and a liquid crystal projector which retain the optical properties after long-term use.

Background Art

Development of liquid crystal displays is rapidly progressing and they are typically used in mobile phones, monitors for personal computers, television sets and liquid crystal projectors.

Such liquid crystal displays operate the liquid crystal and electrically control the light passing through the liquid crystal to show light and dark gradation on a screen to thereby display characters and images. Examples of liquid crystal operating mode are twisted nematic (TN) mode, vertical alignment (VA) mode, in-plane switching (IPS) mode, optically compensatory bend (OCB) mode and electrically controlled birefringence (ECB) mode.

TFT (Thin Film Transistor)-LCDs are generally known liquid crystal displays which mainly operates in TN mode. As the development of liquid crystal displays progressed, demand for higher contrast increased and liquid crystal displays of VA mode have been increasingly developed.

A liquid crystal display of TN mode contains two glass substrates, a nematic liquid crystal twisted by 90 degrees and encapsulated in between the glass substrates, and a pair of polarizing plates on the outside of the glass substrates arranged in cross nicol disposition. When no voltage is applied, linearly polarized light passes through the polarizing plate near polarizer, the plane of polarized light is then twisted by 90 degrees in the liquid crystal layer and passes through the polarizing plate near analyzer to display white. Upon application of sufficient voltage, the alignment direction of the liquid crystal becomes substantially perpendicular to the liquid crystal panel, linearly polarized light passing through the polarizing plate near polarizer passes through the liquid crystal layer without changing its optical polarization and reaches the polarizing plate near analyzer to thereby display black.

A liquid crystal display of VA mode contains two glass substrates, a nematic liquid crystal encapsulated in between the two glass substrates so as to be aligned vertically or aligned both vertically and obliquely, and a pair of polarizing plates on the outer side of the glass substrates arranged in cross nicol disposition. When no voltage is applied, linearly polarized light passes through the polarizing plate near polarizer and the liquid crystal layer without substantially changing its plane of polarization, and reaches a polarizing plate near analyzer so as to display black. Upon application of sufficient voltage, alignment direction of the liquid crystal changes to become parallel to the liquid crystal panel and is twisted by 90 degrees, linearly polarized light passes through the polarizing plate near polarizer, the plane of polarized light is twisted by 90 degrees in the liquid crystal layer and passes through the polarizing plate near analyzer so as to display white.

Such liquid crystal displays operated according to these display modes have problems such that decrease in contrast or tone reversal, in which light and dark

tones are reversely displayed, occurs due to light leakage when the display is viewed from oblique direction.

To improve above problems, optical compensatory films for avoiding the viewing angle dependency have been proposed. According to the technique, the phase difference of light passing through a liquid crystal layer in black state and the phase difference of an optically anisotropic layer are combined so as to optically compensate the liquid crystal layer in black state three-dimensionally to avoid light leakage at every angle.

The present applicant, for example, has proposed an optical compensatory film in Patent Literature 1. The optical compensatory film contains a support such as triacetate cellulose (TAC) film and an optical compensatory sheet which contains optically anisotropic layer disposed on the support, in which the optically anisotropic layer contains a compound containing a discotic structural unit and has optical anisotropy, the disc surface of the discotic structural unit is oblique to the surface of the support, the optically anisotropic layer is in a hybrid alignment where an angle formed between the disc surface of the discotic structural unit and the surface of the support varies in a thickness direction of the optically anisotropic layer and the support has a property of optically uniaxial negative optical indicatrix.

In the optical compensatory film, the discotic structural unit of the optically anisotropic layer is arrayed so as to form mirror symmetry with the liquid crystal layer in black state. Because of the optical property of the entire multilayered structure containing the support and the discotic structural unit, the liquid crystal layer in black state is optically compensated and prevention of light leakage at a wide range of viewing angles is possible.

This technique successfully reduces the viewing angle dependency of liquid

crystal displays and enlarges the viewing angle by using the optical compensatory film. However, large-screen liquid crystal monitors and liquid crystal projectors which enable to display in a large screen are attracting more demand and the large-screen liquid crystal monitors and liquid crystal projectors which exhibit less display quality deterioration such as color fading and color shift after long-term use are desired. Furthermore, liquid crystal projectors require a higher contrast because light entering a liquid crystal cell at various incident angles is integrated by the action of a projection lens, enlarged and projected onto a screen therein. The optical compensatory film must be further improved when used in these applications.

And another possible solution, a contrast ratio improving method for liquid crystal projector is disclosed in Patent Literature 2, for example. In the method, the liquid crystal projector contains an optical film having a liquid crystal layer in hybrid alignment as a liquid crystal cell, and two polarizing plates sandwiching the optical film in which the optical film contains a base film made of plastic film with substantially no birefringence, and the liquid crystal layer in hybrid alignment on or above the base film.

Even with this technique, however, the optically anisotropic layer contains organic materials such as polymerizable liquid crystal compounds and is formed by coating a coating solution for alignment layer containing organic polymer on the optical compensatory film and then coating a coating solution for optically anisotropic layer by a coating method, and the like. In the coating procedure, approximately 21% of acidic compounds such as oxygen, water, nitrogen oxide, sulfur oxide (sulfurous acid compound, for example), etc. contained in the air and molecules of various solvent gases generated in coating process are attached (absorbed) onto the alignment layer of the optically anisotropic layer because air is

filled in the layer of the optical compensatory film. As a result, attached elements become united with organic material and give out negative impact such as inducing oxidation reaction, etc. and the quality of the optically anisotropic layer and alignment layer are gradually deteriorated under aging phenomena and eventually the display quality of the optical compensatory element is deteriorated.

When used for liquid crystal projectors in particular, the oxidation reaction is accelerated by light irradiation and deterioration of blue channel is significant among red, green and blue channels thereby not only degrades contrast but also causes mismatch in color balance. An optical compensatory element which suppresses the oxidation reaction of organic materials which cause deterioration and has durability (light stability) with no aged deterioration is required. A corrective strategy, in which oxidation reaction is suppressed by forming a protective layer by coating of organic material or by vapor deposition of inorganic material on the layer of organic material, is known (Patent Literature 3 to 5 for reference).

In this case, gas barrier function in the direction of light passage and in normal-line direction of each layer may improve; however, the effect on implications of impurity contamination from edges of the optical compensatory element is not satisfactory and it is therefore insufficient for preventing aged deterioration of organic material part in the optical compensatory element.

Moreover, improvement on durability (light stability) of the wave plates by above strategy has not been reported. It is important for the strategy to be able to improve durability (light stability) of the wave plates dramatically and to give the protective layer a thickness required to improve the durability without impairing wave plate function.

[Patent Literature 1] Japanese Patent Application Laid-Open (JP-A) No. 08-50206

[Patent Literature 2] International Publication No. WO01/090808 brochure

[Patent Literature 3] JP-A No. 06-289227

[Patent Literature 4] JP-A No. 05-027114

[Patent Literature 5] JP-A No. 2001-091747

Disclosure of Invention

It is an object of the present invention to provide an optical compensatory element, a method for manufacturing optical compensatory element, an wave plate and a method for manufacturing wave plate which are capable of optically compensating a liquid crystal layer in black state more precisely and preventing light leakage at a wide range of viewing angles while having less aged deterioration. It is also an object of the present invention to provide a high-quality, long-lasting liquid crystal display and liquid crystal projector with wide viewing-angle and high contrast owning to the optical compensatory element and the wave plate which are utilized therein.

The measures of the present invention to settle above issues are as followings.

<1> An optical compensatory element comprising a sealing unit wherein the optical compensatory element is sealed by the sealing unit.

<2> The optical compensatory element as set forth in <1>, wherein the sealing unit comprises a holding member which holds the optical compensatory element and a sealing member which seals the periphery side of the optical compensatory element.

<3> The optical compensatory element as set forth in <1> and <2>, wherein the holding member is at least one of inorganic vapor-deposited film and glass.

<4> The optical compensatory element as set forth in <1> to <3>, wherein the optical compensatory element utilizes a twisted nematic liquid crystal device.

<5> The optical compensatory element as set forth in <1> to <4>, wherein the optical compensatory element is a viewing-angle widening film.

<6> The optical compensatory element as set forth in <1> to <5>, wherein the optical compensatory element comprises a first optically anisotropic layer formed of inorganic material and a second optically anisotropic layer formed of polymerizable liquid crystal compound on a support, wherein the first optically anisotropic layer is a periodic multilayered structure having a repeating unit and the repeating unit comprises plural layers having different refractive indices laminated in a regular order and the periodic multilayered structure as a whole exhibits a negative refractive index anisotropy, and wherein the second optically anisotropic layer is formed of polymerizable liquid crystal compound having a liquid crystal structure wherein the alignment angle of the liquid crystal structure is a hybrid alignment which varies in the thickness direction of the second optically anisotropic layer.

<7> The optical compensatory element as set forth in <6>, wherein the second optically anisotropic layer comprises two layers having different alignment direction.

<8> A method for manufacturing optical compensatory element comprising forming of an optical compensatory element by laminating optically anisotropic layers on a support, and sealing of an optical compensatory element wherein the optical compensatory element is sealed by a sealing unit under a deoxygenated atmosphere.

<9> The method for manufacturing an optical compensatory element as set

forth in <8>, wherein the optical compensatory element is sealed in the atmosphere further filled with an inactive gas.

<10> A wave plate comprising a protective layer on a wave film, wherein the protective layer comprises at least an inorganic layer containing an inorganic material.

<11> The wave plate as set forth in <10>, wherein the inorganic material is alumina.

<12> The wave plate as set forth in <10> and <11>, wherein the thickness of the protective layer is 0.05μm to 0.8μm.

<13> The wave plate as set forth in <10> to <12>, wherein the wave plate is utilized as an optical compensatory element for a twisted nematic liquid crystal device.

<14> The wave plate as set forth in <10> to <13>, wherein the wave film comprises at least an optically anisotropic layer formed of polymerizable liquid crystal compound comprising a liquid crystal structure.

<15> The wave plate as set forth in <14>, wherein the alignment angle of the liquid crystal structure in the optically anisotropic layer formed of polymerizable liquid crystal compound comprising the liquid crystal structure is a hybrid alignment which varies in the thickness direction of the optically anisotropic layer.

<16> The wave plate as set forth in <10> to <15>, wherein the wave plate is a viewing-angle widening film.

<17> The wave plate as set forth in <10> to <16>, wherein the wave plate comprises a first optically anisotropic layer formed of inorganic material and a second optically anisotropic layer formed of polymerizable liquid crystal compound on a support, wherein the first optically anisotropic layer is a periodic multilayered

structure having a repeating unit and the repeating unit comprises plural layers having different refractive indices laminated in a regular order and the periodic multilayered structure as a whole exhibits a negative refractive index anisotropy, and wherein the second optically anisotropic layer is formed of polymerizable liquid crystal compound having the liquid crystal structure wherein the alignment angle of the liquid crystal structure is the hybrid alignment which varies in the thickness direction of the second optically anisotropic layer.

<18> The wave plate as set forth in <17>, wherein the second optically anisotropic layer comprises two layers having different alignment direction.

<19> A method for manufacturing a wave plate comprising forming of a coated layer on a support by coating the polymerizable composition comprising a polymerizable liquid crystal compound having a liquid crystal structure, forming of an optically anisotropic layer by fixing the alignment angle of the liquid crystal structure by polymerization in a state of hybrid alignment which varies in the thickness direction of the coated layer, and forming of a protective layer comprising at least an inorganic layer containing an inorganic material on the optically anisotropic layer.

<20> The liquid crystal display comprising at least a pair of electrodes and a liquid crystal device comprising a liquid crystal molecule encapsulated in between the pair of electrodes, an optical compensatory element placed on one side or both sides of the liquid crystal device and a polarizing element facing the liquid crystal device and the optical compensatory element wherein the optical compensatory element is the optical compensatory element as set forth in <1> to <7>.

<21> A liquid crystal display comprising at least a pair of electrodes and a liquid crystal device comprising a liquid crystal structure encapsulated in between

the pair of electrodes, a wave plate placed on one side or both sides of the liquid crystal device and a polarizing element facing the liquid crystal device and the wave plate wherein the wave plate is the wave plate as set forth in <10> to <18>.

<22> A liquid crystal projector comprising a light source, a liquid crystal display wherein an illuminating light is irradiated from the light source and a projection optical system for forming an image on a screen from light optically modulated by the liquid crystal display wherein the liquid crystal display is the liquid crystal display as set forth in <20> and <21>.

Because the optical compensatory element according to the present invention contains a sealing unit by which the optical compensatory element is sealed, optically compensating a liquid crystal layer in black state more precisely, preventing light leakage at a wide range of viewing angles, and suppressing display quality deterioration for prolonged periods are possible.

The method for manufacturing optical compensatory element according to the present invention includes forming of an optical compensatory element by laminating optically anisotropic layers on a support and sealing of an optical compensatory element wherein the optical compensatory element is sealed under a deoxygenated atmosphere. Therefore it is possible to manufacture the optical compensatory element capable of optically compensating a liquid crystal layer in black state, preventing light leakage at a wide range of viewing angles, and retaining display quality.

And because the wave plate according to the present invention contains a protective layer having an inorganic layer containing an inorganic material, optically compensating a liquid crystal layer in black state more precisely, preventing light leakage at a wide range of viewing angles, and suppressing display quality

deterioration for prolonged periods are possible.

The method for manufacturing a wave plate according to the present invention makes the manufacturing possible by forming a coated layer on a support by coating the polymerizable composition containing a polymerizable liquid crystal compound having a liquid crystal structure, forming an optically anisotropic layer by fixing the alignment angle of the liquid crystal structure by polymerization in a state of hybrid alignment which varies in the thickness direction of the coated layer, and forming a protective layer having an inorganic layer containing an inorganic material on the optically anisotropic layer.

The liquid crystal display according to the present invention has at least a pair of electrodes and a liquid crystal device containing a liquid crystal molecule encapsulated in between the pair of electrodes, an optical compensatory element placed on one side or both sides of the liquid crystal device and a polarizing element facing the liquid crystal device and the optical compensatory element and further, the optical compensatory element and the wave plate are the optical compensatory element and the wave plate according to the present invention, thereby having wide viewing angle and high contrast for prolonged periods are possible.

Because the liquid crystal projector according to the present invention has a light source, a liquid crystal display wherein an illuminating light is irradiated from the light source and a projection optical system for forming an image on a screen from light optically modulated by the liquid crystal display and further, the liquid crystal display is the liquid crystal display according to the present invention, having wide viewing angle, high contrast and extended life are possible.

Brief Description of Drawings

FIG. 1 is a sectional view showing an example of the optical compensatory element of a first configuration.

FIG. 2 is a sectional view showing an example of the optical compensatory element of a second configuration.

FIG. 3 is a sectional view showing an example of the optical compensatory element of a third configuration.

FIG. 4 is a sectional view showing an example of the optical compensatory element of a fourth configuration.

FIG. 5 is a sectional view showing an example of the optical compensatory element of a fifth configuration.

FIG. 6 is a sectional view showing an example of the optical compensatory element of a sixth configuration.

FIG. 7 is a sectional view showing an example of the optical compensatory element of a seventh configuration.

FIG. 8 is a sectional view showing an example of the optical compensatory element of an eighth configuration.

FIG. 9 is a sectional view showing an example of the wave plate of a first configuration.

FIG. 10 is a sectional view showing an example of the wave plate of a second configuration.

FIG. 11 is a sectional view showing an example of the wave plate of a third configuration.

FIG. 12 is a sectional view showing an example of the wave plate of a fourth configuration.

FIG. 13 is a sectional view showing an example of the wave plate of a fifth

configuration.

FIG. 14 is a sectional view showing an example of the wave plate of a sixth configuration.

FIG. 15 is a sectional view showing an example of the wave plate of a seventh configuration.

FIG. 16 is a sectional view showing an example of the wave plate of an eighth configuration.

FIG. 17 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 18 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 19 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 20 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 21 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 22 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 23 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 24 is a schematic view showing an example of the liquid crystal display according to the present invention.

FIG. 25 is an outline view showing an example of a rear-projection liquid crystal projector.

FIG. 26 is a schematic diagram showing an example of a projection unit.

Best Mode for Carrying Out the Invention

(Optical Compensatory Element)

The optical compensatory element according to the present invention contains a sealing unit which seals the optical compensatory element, in particular, a support and a first optically anisotropic layer formed of inorganic material and a second optically anisotropic layer formed of polymerizable liquid crystal compound disposed on the support and also contains a holding member which holds the optical compensatory element and a sealing member which seals the periphery side of the optical compensatory element. The optical compensatory element contains other layers as necessary.

- Support -

The support is not particularly limited as long as it excels in transparency, exhibits 80% or more of light transmittance and gives uniform optical properties and may be selected accordingly. Examples include white sheet glass, blue sheet glass, quartz glass, alkali-free glass, sapphire glass and organic polymer film, and the like.

The organic polymer film is not particularly limited and may be selected accordingly. Examples include one or combination of two or more selected from polymers such as polyarylates, polyesters, polycarbonates, polyolefins, polyethers, polysulfines, polysulfones and polyether sulfones and cellulose esters.

Specific examples of organic polymer films include polycarbonate copolymers, polyester copolymers, polyester carbonate copolymers and polyarylate copolymers, of which polycarbonate copolymers are more preferred.

Preferred examples of polycarbonate copolymers are polycarbonate

copolymers having a fluorene skeleton, of which polycarbonate copolymers prepared by reacting a bisphenol with phosgene or a compound capable of forming a carbonic ester such as diphenyl carbonate are typically preferred for their excellent optical transparency, thermostability and productivity.

The content of the fluorene skeleton in the polycarbonate copolymer is preferably 1% by mole to 99% by mole. A repeating unit disclosed in International Publication No. WO00/26705 can be used as the polycarbonate copolymer.

Specific examples include triacetylcellulose, polyvinyl alcohol, polyimide, polyarylate, polyester, polycarbonate, polysulfones, polyether sulfones and plastic film such as epoxy resin.

The support is preferably glass derived from various inorganic materials or triacetylcellulose film for satisfactory smoothness of the surface.

The thickness of the support is not particularly limited and may be adjusted accordingly. It is preferably 0.1μm or more. The upper limit of the thickness is preferably 0.3mm to 3mm and more preferably 0.5mm to 1.5mm for easy handling in assembly and sufficient mechanical strength.

- First Optically Anisotropic Layer -

The structure of the first optically anisotropic layer is not particularly limited and may be selected accordingly as long as it is formed of inorganic material and the layer as a whole exhibits optical anisotropy. The first optically anisotropic layer preferably has a periodic multilayered structure containing a repeating unit (having a repeating structure), the repeating unit containing plural layers having different refractive indices laminated in a regular order in a direction normal to the support, in which the repeating unit has an optical thickness, i.e., a thickness of a repeating unit in a laminating direction of the periodic multilayered structure (hereinafter

referred to as "pitch of periodic structure"), of less than the wavelengths of visible light region.

The thickness of repeating units in a laminated direction of the periodic multilayered structure may differ from one another and it is possible to have different thickness depending on properties of light which passes through the first optically anisotropic layer.

The number of layers constituting one repeating unit is not particularly limited and may be selected accordingly as long as the layers are of two or more layers having different refractive indices. The repeating unit preferably contains two layers derived from two different inorganic materials, respectively.

The thickness of the respective layers constituting the periodic multilayered structure is not particularly limited and may be adjusted accordingly as long as it is less than the wavelength of visible light region. It is preferably $\lambda/100$ to $\lambda/5$, more preferably $\lambda/50$ to $\lambda/5$ and most preferably $\lambda/30$ to $\lambda/10$, wherein λ is the wavelength of visible light region.

The thickness of the respective layers constituting the periodic multilayered structure is preferably small so as to avoid optical interference among phases of laminated layers. Making thickness small, however, increases the number of film forming processes to obtain a required total thickness of the structure. An optimum thickness of the respective layers should be preferably determined according to materials, refractive indices, thickness ratio and total thickness of the respective layers in consideration of desired optical properties of the first optically anisotropic layer and of avoiding phase interference between the respective layers.

The pitch of periodic structure is not particularly limited and may be selected from visible light region accordingly as long as it is shorter than the wave length of

visible light region. The "visible light region" is defined as a wavelength region of 400 nm to 700 nm, unless otherwise specified. Accordingly, the pitch of periodic structure is preferably set within the range of 400nm to 700nm.

The retardation, Rth of the first optically anisotropic layer as represented by following Equation 1 is preferably 20nm to 300nm and more preferably 20nm to 200nm.

$$Rth = \{(nx+ny)/2-nz\} \times d \qquad \text{Equation 1}$$

In Equation 1, "nx", "ny" and "nz" are refractive indices in X, Y and Z axes direction in the first optically anisotropic layer respectively where X, Y and Z axes are orthogonal to one another, provided that the normal direction to the support is defined as Z axis; and "d" is the thickness of the first optically anisotropic layer.

The number of repeated structure in the periodic multilayered structure is not particularly limited and may be selected accordingly.

The thickness of the first optically anisotropic layer preferably satisfies the retardation Rth requirement and in particular, it is preferably 50 nm to 2,000 nm and more preferably 100 nm to 1,500 nm.

The material of the periodic multilayered structure constituting the first optically anisotropic layer is not particularly limited and may be selected accordingly. It is preferably selected according to a desired difference in refractive index Δn, since the phase difference caused by birefringence of the first optically anisotropic layer is determined by the product between the thickness "d" of the first optically anisotropic layer and the difference in refractive index Δn of respective layers constituting the repeated structure. More specifically, materials with high reflective indices are preferably selected from TiO_2, ZrO_2, and the like and materials with low reflective indices are selected from SiO_2, MgF_2, and the like accordingly.

The materials of the periodic multilayered structure are preferably selected from combinations of materials in which the difference in refractive index Δn between maximum and minimum refractive indices in the visible light region is 0.5 or more. It is preferably a combination of multiple materials selected from oxide layers and of these, a combination of SiO_2 layer having a refractive index "n" of 1.4870 to 1.5442 and TiO_2 layer having a refractive index "n" of 2.583 to 2.741 is particularly preferable.

If the difference in refractive index Δn is less than 0.5, the thickness "d" of the first optically anisotropic layer may be reduced so as to yield a desired phase difference in the first optically anisotropic layer to thereby increase the number of processes for laminating the repeating unit. Thus, the processability and productivity may be deteriorated.

The first optically anisotropic layer is equivalent to a medium having a uniform refractive index in a lamination direction of respective layers, namely, in the normal direction of the support. The first optically anisotropic layer as a whole exhibits anisotropy called a structural birefringence and has optical properties of uniaxial and non-inclined negative optical indicatrix. The first optically anisotropic layer has high smoothness and by appropriately setting the materials, thickness, number of layers and period of the pitch of periodic structure of the periodic multilayered structure, it is possible to have desired properties such as retardation easily and precisely.

The first optically anisotropic layer can function as an antireflective layer by appropriately setting the thickness of constitutional layers and thickness ratio thereof.

The measurement of retardation Rth is not particularly limited and may be

selected accordingly and it may be determined by using an ellipsometer (M-150, manufactured by JASCO Corporation), for example.

- Second Optically Anisotropic Layer -

The second optically anisotropic layer contains at least a polymerizable liquid crystal compound and may further contain other materials or configurations as necessary.

The polymerizable liquid crystal compound is not particularly limited and may be selected accordingly. The liquid crystal structure of the polymerizable liquid crystal compound, for example, is preferably a liquid crystal structure whose alignment can be fixed. And it is more preferably a rod-shaped, discotic or banana-shaped liquid crystal structure and most preferably a discotic liquid crystal structure.

The polymerizable liquid crystal compound may further contain other components as necessary.

The term "liquid crystal structure is aligned (or in alignment)" used herein means that average directions of specific axes in a liquid crystal structure contained in a microdomain in question substantially agree with each other when a specific axis of molecules constituting the liquid crystal derived from the molecular shape is set in a major axis direction in a rod-shaped molecule or in the direction normal to the plane in a plane molecule. When the liquid crystal structure is aligned, the angle formed between the average direction of specific axis of the liquid crystal structure in the microdomain in question and the lamination direction of the optical compensatory element (the normal direction at the interface between the second optically anisotropic layer and the support) is referred to as "alignment angle", and the component of the average direction of the specific axes projected onto the

interface is referred to as "alignment direction".

As the alignment, the liquid crystal structure preferably has an oblique alignment angle, namely, the alignment angle is preferably not parallel or perpendicular to a thickness direction of the second optically anisotropic layer. The liquid crystal structure is more preferably in a hybrid alignment in which the alignment angle successively varies in the thickness direction between the upper surface and lower surface of the second optically anisotropic layer.

The alignment angle in the hybrid alignment is preferably set so as to successively vary within the range of 20°±20° to 65°±25° from the alignment layer toward the air interface.

The alignment angle and alignment direction of the polymerizable liquid crystal compound, which determine the alignment thereof, are preferably set so as to form mirror symmetry with the liquid crystal layer in black state.

The alignment angle of the liquid crystal structure in the vicinity of alignment layer and in the vicinity of air interface, and average alignment angle in the second optically anisotropic layer are estimates determined by measuring retardations from multiple directions using an ellipsometer (M-150, manufactured by JASCO Corporation), assuming an optical indicatrix model from the measured retardations, and estimating the alignment angle based on the optical indicatrix model.

The alignment angle can be determined from retardations, for example, according to the procedure described in Design Concepts of Discotic Negative Birefringence Compensation Films SID98 DIGEST. The measurement directions of the retardation in determination of alignment angle are not particularly limited and may be selected accordingly. For example, a retardation in the direction normal

to the second optically anisotropic layer (Re0), a retardation in the direction at -40° from the normal direction (Re-40) and a retardation in the direction at +40° from normal direction (Re+40).

The Re0, Re-40 and Re+40 are determined by changing the observation angle to the respective directions, using the ellipsometer.

The polymerizable liquid crystal compound having a rod-shaped liquid crystal structure is not particularly limited and may be selected accordingly. Examples include a polymerizable liquid crystal compound capable of fixing alignment of the rod-shaped liquid crystal structure with the use of polymer binder and a polymerizable liquid crystal compound having a polymerizable group capable of fixing alignment of the liquid crystal structure as a result of polymerization. Among them, polymerizable liquid crystal compound having polymerizable group is preferred.

The rod-shaped liquid crystal structure is not particularly limited and may be selected accordingly. Examples include azomethines, azoxy compounds, cyanobiphenyl compounds, cyanophenyl esters, benzoic esters, cyclohexanecarboxylic acid phenyl esters, cyanophenylcyclohexanes, cyano-substituted phenylpyrimidines, alkoxy-substituted phenylpyrimidines, phenyldioxanes, tolanes and alkenylcyclohexylbenzonitriles.

Examples of polymerizable liquid crystal compound having a rod-shaped liquid crystal structure are polymeric liquid crystal compounds formed by polymerization of a rod-shaped liquid crystal compound having low-molecular polymerizable groups represented by following Structural Formula (1).

$Q^1 - L^1 - A^1 - L^3 - M - L^4 - A^2 - L^2 - Q^2$ Structural Formula (1)

In Structural Formula (1), each Q^1 and Q^2 represents a polymerizable group;

each L^1, L^2, L^3 and L^4 represents a single bond or a divalent linkage group, wherein at least one of L^2 and L^3 represents -O-CO-O-; each A^1 and A^2 represents a spacer group having two to twenty carbon atoms; and "M" represents a mesogenic group.

The polymerizable liquid crystal compound having a discotic liquid crystal structure is not particularly limited and may be selected accordingly. Examples include a polymerizable liquid crystal compound capable of fixing the alignment of discotic liquid crystal structure by the use of polymer binder and a polymerizable liquid crystal compound having a polymerizable group capable of fixing the alignment of discotic liquid crystal structure as a result of polymerization. Among them, polymerizable liquid crystal compound having polymerizable group is preferred.

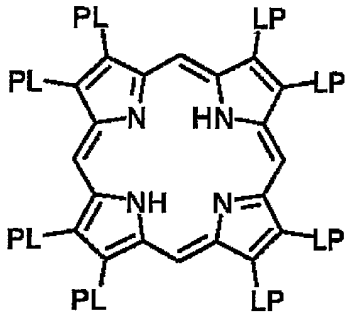
The structure of the polymerizable liquid crystal compound having the polymerizable group includes, for example, a structure having one or more linkage groups introduced between a discotic core and the polymerizable group. Specific suitable examples of polymerizable liquid crystal compound are compounds represented by following Structural Formula (2) as described in JP-A No. 08-050206.

D(-L-P)n Structural Formula (2)

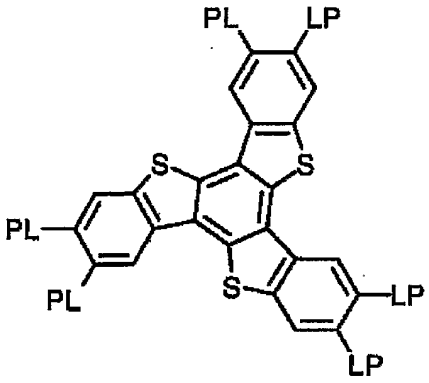
In Structural Formula (2), "D" represents a discotic core; "L" represents a divalent linkage group; "P" represents a polymerizable group; and "n" represents an integer of 4 to 12. Plural divalent linkage groups "L"s and plural polymerizable groups "P"s may be different from each other in combination, but these groups are preferably identical in their repetition. Two or more discotic cores "D"s may be used herein.

Specific examples of the discotic core "D" in Structural Formula (2) are discotic cores represented by following Structural Formulae (D1) to (D15):

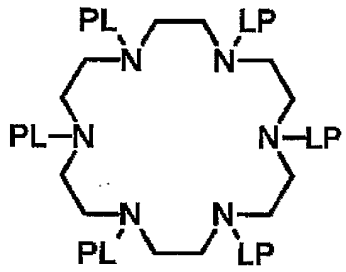
(D1)



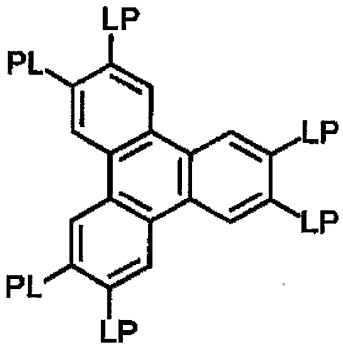
(D2)



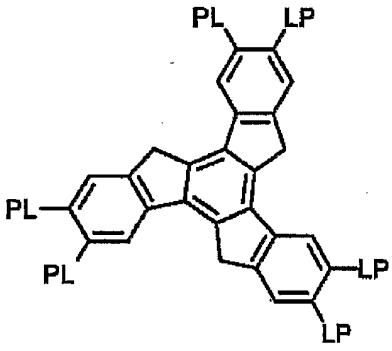
(D3)



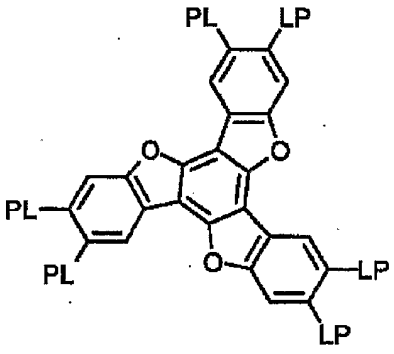
(D4)



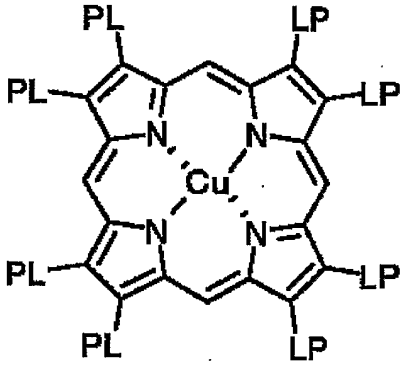
(D5)



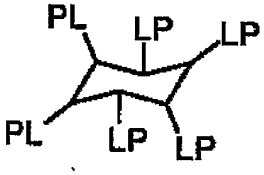
(D6)



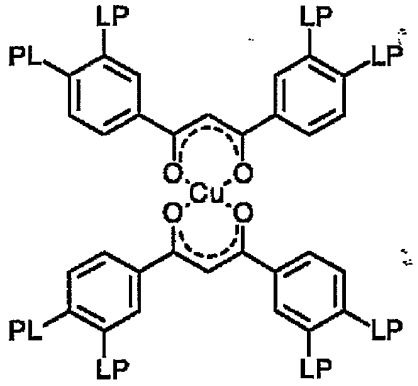
(D7)



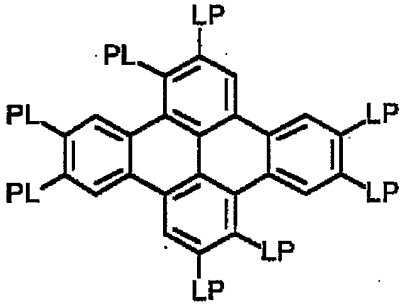
(D8)



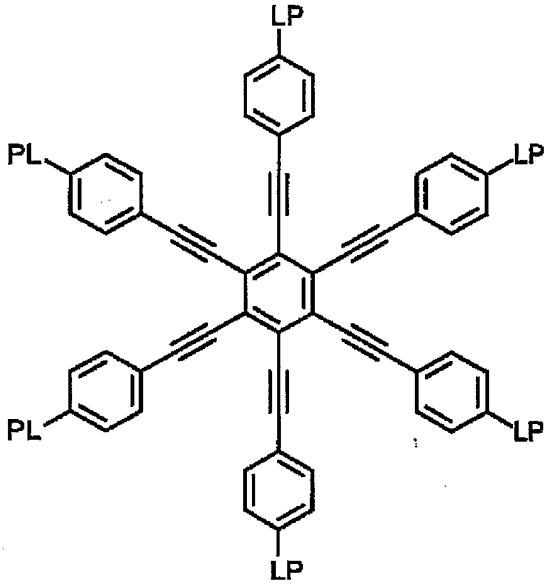
(D9)



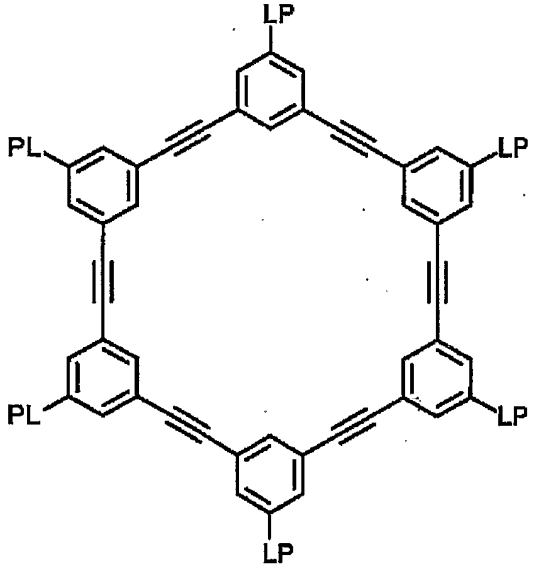
(D10)



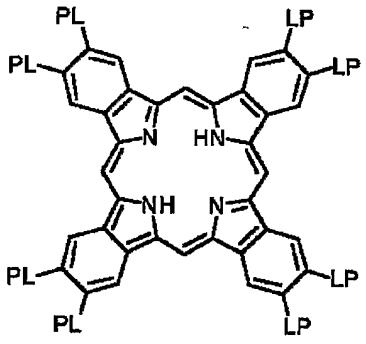
(D11)



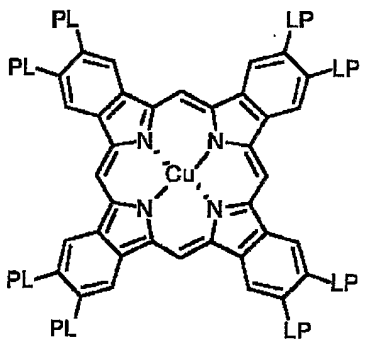
(D12)



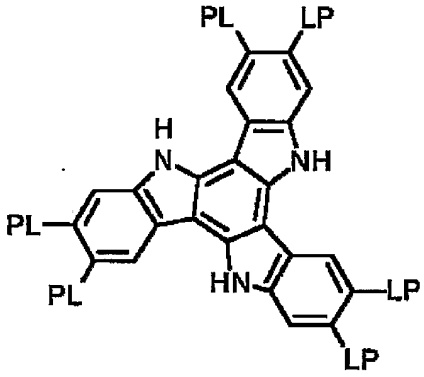
(D13)



(D14)



(D15)



The divalent linkage group "L" in Structural Formula (2) is not particularly limited and may be selected accordingly. Preferred examples thereof are an alkylene group, an alkenylene group, an arylene group, -CO-, -NH-, -O-, -S- and a combination of these groups, of which an alkylene group, an alkenylene group, an arylene group, -CO-, -NH-, -O-, -S- and a divalent linkage group having at least two of these divalent groups are more preferred. Among them, an alkylene group, an alkenylene group, an arylene group, -CO-, -O-, and a divalent linkage group having at least two of these divalent groups are specifically preferred.

The alkylene group preferably has one to twelve carbon atoms. The alkenylene group preferably has two to twelve carbon atoms. The arylene group preferably has six to ten carbon atoms. Each of alkylene group, alkenylene group and arylene group may have one or more substituents such as alkyl groups, halogen atoms, cyano groups, alkoxy groups and acyloxy groups.

Specific examples of divalent linkage group "L" are -AL-CO-O-AL-, -AL-CO-O-AL-O-, -AL-CO-O-AL-O-AL-, -AL-CO-O-AL-O-CO-, -CO-AR-O-AL-, -CO-AR-O-AL-O-, -CO-AR-O-AL-O-CO-, -CO-NH-AL-, -NH-AL-O-, -NH-AL-O-CO-, -O-AL-, -O-AL-O-, -O-AL-O-CO-, -O-AL-O-CO-NH-AL-, -O-AL-S-AL-, -O-CO-AL-AR-O-AL-O-CO-, -O-CO-AR-O-AL-CO-, -O-CO-AR-O-AL-O-CO-, -O-CO-AR-O-AL-O-AL-O-CO-, -O-CO-AR-O-AL-O-AL-O-AL-O-CO-, -S-AL-, -S-AL-O-, -S-AL-O-CO-, -S-AL-S-AL- and -S-AR-AL-.

In the specific examples of divalent linkage group "L", the left hand is bound to the discotic core "D", and the right hand is bound to the polymerizable group "P". The symbol "AL" represents an alkylene group or an alkenylene group; and "AR" represents an arylene group.

The polymerizable group "P" in Structural Formula (2) is not particularly limited and may be selected according to the type of polymerization reaction. Preferred examples thereof are an unsaturated polymerizable group and epoxy group of which an ethylenically unsaturated polymerizable group is more preferred. Specific examples of polymerizable group "P" are polymerizable groups represented by following Structural Formulae (P1) to (P18):

(P1) —CH=CH$_2$

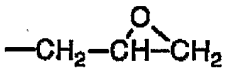
(P2) —C≡CH

(P3) —CH$_2$—C≡CH

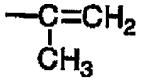
(P4) —NH$_2$

(P5) —SO$_3$H

(P6)



(P7)



(P8) —CH=CH—CH$_3$

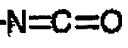
(P9) —N=C=S

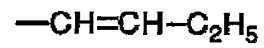
(P10) —SH

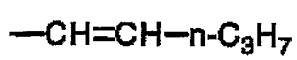
(P11) —CHO

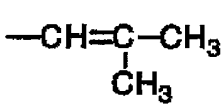
(P12) —OH

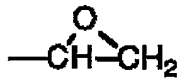
(P13) 

(P14) 

(P15) 

(P16) 

(P17) 

(P18) 

The polymerizable liquid crystal compounds thereof can be referenced, for example, in JP-A Nos. 09-104656, 11-92420, 2000-34251, 2000-44507, 2000-44517, and 2000-86589.

The other components the polymerizable liquid crystal compound may contain are not particularly limited and may be selected accordingly. Examples include a polymerization initiator for initiating the polymerization reaction of the polymerizable liquid crystal compound and a solvent for preparing a coating solution of the polymerizable liquid crystal compound.

The polymerization initiator is not particularly limited and may be selected accordingly. Suitable examples thereof are a thermal polymerization initiator for initiating a thermal polymerization reaction and a photopolymerization initiator for initiating a photopolymerization reaction of which the photopolymerization initiator is more preferred.

Specific examples of photopolymerization initiator are α-carbonyl compounds described in US Patent No. 2367661 and No. 2367670; acyloin ethers described in US Patent No. 2448828; α-hydrocarbon-substituted aromatic acyloin compounds described in US Patent No. 2722512; polynuclear quinone compounds described in US Patent No. 3046127 and No. 2951758; combinations of a triarylimidazole dimer and p-aminophenyl ketone described in US Patent No. 3549367; acridine and phenazine compounds described in JP-A No. 60-105667 and US Patent No. 4239850; and oxadiazole compounds described in US Patent No.

4212970.

The content of photopolymerization initiator in the polymerizable liquid crystal compound is not particularly limited and may be adjusted accordingly. For example, it is preferably 0.01% by mass to 20% by mass and more preferably 0.5% by mass to 5% by mass of solid content of the coating solution for the polymerizable liquid crystal compound.

Light irradiating means for use in the photopolymerization reaction is not particularly limited and may be selected accordingly. For example, it is preferably ultraviolet rays. The irradiation energy of light irradiating means is preferably 20mJ/cm^2 to 50mJ/cm^2 and more preferably 100mJ/cm^2 to 800mJ/cm^2.

The light irradiation may be carried out with heating to accelerate photopolymerization reaction.

The solvent is not particularly limited and may be selected accordingly and suitable examples thereof are organic solvents. Specific examples of organic solvents are amides such as N,N-dimethylformamide, N,N-dimethylacetamide and N-methylpyrrolidone; sulfoxides such as dimethyl sulfoxide (DMSO); heterocyclic compounds such as pyridine; hydrocarbons such as benzene and hexane; alkyl halides such as chloroform and dichloromethane; esters such as methyl acetate and butyl acetate; ketones such as acetone, methyl ethyl ketone and methyl isobutyl ketone; ketoesters such as methyl acetoacetate and ethyl acetoacetate; ethers such as tetrahydrofuran, 1,2-dimethoxyethane, diethylene glycol diethyl ether and dipropylene glycol dimethyl ether; and cellosolves such as methyl cellosolve, ethyl cellosolve and butyl cellosolve; of which amides, ethers and ketones are more preferred. Each of these organic solvents may be used alone or in combination.

The polymerization method for the polymerizable liquid crystal compound

is not particularly limited and may be selected accordingly. Examples include methods described in JP-A No. 08-27284 and No. 10-278123.

--Other Configuration--

The other components or configurations the second optically anisotropic layer may contain are not particularly limited and may be selected accordingly. Examples include an alignment layer for aligning the liquid crystal structure in the polymerizable liquid crystal compound. The polymerizable liquid crystal compound is preferably formed on or over the alignment layer typically by coating.

The alignment layer is not particularly limited and may be selected accordingly. Examples include a rubbed alignment layer containing an organic compound (preferably a polymer); an alignment layer having a micro groove; an alignment layer containing an organic compound such as ω-tricosanoic acid, dioctadecyldimethylammonium chloride or methyl stearate deposited according to Langmuir-Blodgett method (LB film); an alignment layer containing an inorganic compound deposited by oblique vapor deposition; and an alignment layer having an aligning function as a result of the application of electric field, magnetic field or light. Among them, rubbed alignment layer containing an organic compound is preferred.

The rubbing can be carried out by any procedure selected accordingly. For example, the surface of the film containing an organic compound is rubbed with paper or cloth several times in a certain direction.

The organic compound is not particularly limited and may be selected according to the alignment condition (particularly the alignment angle) of the liquid crystal structure. Examples include a polymer for an alignment layer which does not reduce the surface energy of the resulting alignment layer for horizontal alignment of the liquid crystal structure.

Preferred examples of polymer for an alignment layer for aligning the liquid crystal structure in a direction perpendicular to the direction of rubbing are modified polyvinyl alcohols (JP-A No. 2002-62427), acrylic copolymers (JP-A No. 2002-98836), polyimides and polyamic acid (JP-A No. 2002-268068).

The alignment layer preferably has a reactive group for improving adhesion with the polymerizable liquid crystal compound and the support. The reactive group is not particularly limited and may be selected accordingly. For example, a reactive group may be introduced into a side chain of a repeating unit of the polymer for an alignment layer or a cyclic group as a substituent may be introduced into the polymer for an alignment layer.

An alignment layer described in JP-A No. 09-152509 can be used as the alignment layer capable of forming a chemical bond with the polymerizable liquid crystal compound and the support by the action of the reactive group. The thickness of the alignment layer is not particularly limited and may be selected accordingly. It is preferably 0.01μm to 5μm and more preferably 0.02μm to 2μm.

-- Preparation of Second Optically Anisotropic Layer --

The method for preparing the second optically anisotropic layer is not limited and may be selected accordingly. For example, a method in which a coating solution containing the polymerizable liquid crystal compound having the liquid crystal structure, the polymerization initiator, and the like in the solvent is applied to the alignment layer.

The coating solution may be applied to the alignment layer according to any known procedures such as extrusion coating, direct gravure coating, reverse gravure coating, die coating or spin coating.

-Other Layers-

Other layers are not particularly limited and may be selected accordingly and examples include antireflective layer, anti-glare layer, antifouling layer and antistatic layer.

The material and structure of the antireflective layer are not particularly limited as long as they are capable of decreasing reflectance and increasing transmittance and may be selected accordingly and examples include known AR film (anti reflection coat film), and the like.

- Sealing Unit -

The sealing unit is not particularly limited as long as it is capable of sealing and satisfying optical properties and may be selected accordingly. Examples include holding structure which holds the optical compensatory element with a holding member and encapsulate periphery side, packing structure which packs the whole optical compensatory element with a sheet and containing structure which contains the optical compensatory element in a container in the form of cases and among them, holding structure which holds the optical compensatory element with a holding member in the form of plates is preferred.

Specifically, a holding member (a pair of plates, for example) which holds the optical compensatory element and a sealing member which seals the periphery side of the optical compensatory element is preferred.

The sealing unit seals the optical compensatory element and retain the clean condition with no impurities after molecule-like impurities such as water, oxygen, various solvent gases, and the like that are attached to the optical compensatory element are removed. Furthermore, by substituting with an inactive gas before sealing, high-quality condition can be retained for prolonged periods, oxidation reaction inside the optical compensatory element is suppressed as well as the color

degradation and contrast deterioration, and durability of the optical compensatory element is improved.

-- Holding Member —

The materials of holding member is not particularly limited as long as it has mechanical strength and sealing ability, excels in transparency and exhibits 80% or more of light transmittance which satisfies uniform optical properties and may be selected accordingly. Examples include inorganic and organic materials, and the like. Furthermore, in the case the support or each layer has stable antiweatherability, it may also function as plates.

Examples of inorganic material include glasses such as white sheet glass, blue sheet glass, quartz glass, sapphire glass, and the like.

Organic material is not particularly limited and may be selected accordingly. Examples of organic material include triacetylcellulose, polyvinyl alcohol, polyimide, polyarylate, polyester, polycarbonate, polysulfones, polyether sulfones and plastic film such as epoxy resin.

Thickness of the holding member is not particularly limited and may be adjusted accordingly. It is preferably 0.1μm or more. The upper limit of thickness is preferably 0.3mm to 3mm and more preferably 0.5mm to 1.5mm for easy handling in assembly and sufficient mechanical strength.

Size of the holding member is not particularly limited as long as it covers entire laminated optically anisotropic layer and may be adjusted accordingly. It is preferably equivalent to or larger than the optically anisotropic layer.

Form of the holding member is not particularly limited as long as it satisfies optical properties and may be selected accordingly. It is preferably a flat sheet with which the optical compensatory element can be further attached.

- Sealing Member -

The material of the sealing member is not particularly limited as long as it can retain sealing ability and may be selected accordingly. Examples include ultraviolet-curing type and thermo-curing type resin composition, one-component or two-component epoxy resin cement, solvent-type bond of synthetic rubber, metamorphic silicone resin bond, silanizing urethane resin bond, and the like and among them, ultraviolet-curing type and epoxy resin cement are preferable.

The place for sealing by the sealing member may be the side of the layer where contact with outside air should be blocked at least or the entire periphery side of the optical compensatory element held by the holding member for easier formation and type of usage.

Thickness of the sealing member is not particularly limited as long as it is capable of sealing and may be adjusted accordingly. It is preferably 0.1μm or more, more preferably 0.1mm to 1.1mm and most preferably 0.1mm to 0.7mm for easy coating and sufficient sealing ability.

The optical compensatory element is sealed by coating ultraviolet-curing type or epoxy resin cement on the periphery side of the optical compensatory element held by the holding member and curing.

The entire periphery side of the optical compensatory element is sealed by the sealing member to prevent the molecule-like impurities such as water, oxygen, various solvent gases, and the like from intruding.

(Method for Manufacturing Optical Compensatory Element)

The method for manufacturing optical compensatory element include forming of an optical compensatory element in which the optical compensatory element is formed by laminating the optically anisotropic layer on a support and

sealing of an optical compensatory element in which the optical compensatory element is sealed under a deoxygenated atmosphere by a sealing unit and further contains other steps as necessary.

- Forming of Optical Compensatory Element -

The forming procedure of the optical compensatory element body is described below, however, the present invention is not limited to the described procedure and the optical compensatory element prepared by different procedure may be used.

The forming steps of the optical compensatory element include first optically anisotropic layer forming, alignment layer forming, second optically anisotropic layer forming, heat treatment, second optically anisotropic layer polymerizing and curing, antireflective layer forming, sealing unit forming and other layer forming steps.

The respective layer-forming steps will be described in detail below.

- Forming of First Optically Anisotropic Layer -

The first optically anisotropic layer forming is not particularly limited and may be selected accordingly as long as resultant layer satisfies optical properties. For example, an optically anisotropic layer is formed by laminating plural layers having different refractive indices on or above the support in a regular order in a direction normal to the support and forming a periodic multilayered structure in which the plural layers are repeatedly laminated (a repeating unit is repeated).

Materials of the periodic multilayered structure is not particularly limited and may be selected accordingly as long as they are inorganic materials and are preferably used in combination of materials of high refractive indices or low refractive indices.

For materials having high refractive indices, TiO_2, ZrO_2, and the like are preferred and for materials having low refractive indices, SiO_2, MgF_2, and the like are preferred. These may be used alone or in combination.

Specifically, the materials of periodic multilayered structure are preferably selected from combination of materials in which the difference between maximum refractive index and minimum refractive index in visible light region is 0.5 or more, more preferably selected from combinations of plural materials suitably selected from oxides and of these, a combination of SiO_2 (refractive index, n = 1.4870 to 1.5442) and TiO_2 (refractive index, n = 2.583 to 2.741) is most preferable.

The number of layers constituting one repeating unit is not particularly limited as long as they are plural layers of different refractive indices. It is preferably plural layers formed of two types of inorganic materials and it is more preferably a periodic multilayered structure having dozens of layers formed by alternately depositing SiO_2 and TiO_2 on or above the support under reduced pressure using a sputtering apparatus.

An optical thickness of the repeating unit, i.e., the thickness of a repeating unit in a laminating direction of periodic multilayered structure is preferably formed as to be less than the wavelengths of visible light region. For example, when the wavelengths of visible light region is λ, it is preferably $\lambda/100$ to $\lambda/5$, more preferably $\lambda/50$ to $\lambda/5$ and most preferably $\lambda/30$ to $\lambda/10$.

The thickness of respective layers constituting the periodic multilayered structure is preferably thin; however, as the thickness is reduced, the number of laminating time is increased in order to obtain required total thickness. Therefore, the number of laminating time of respective layers should be determined to give each layer an optimum thickness by adjusting material, refractive index, thickness

ratio and total thickness while considering required optical properties of the first optically anisotropic layer and resultant coloring due to mutual interference of the layers. For instance, the total thickness of periodic multilayered structure is preferably adjusted from 400nm to 700nm.

The thickness of the first optically anisotropic layer is not particularly limited and may be adjusted accordingly and it is preferably 100μm to 1,500μm.

-- Forming of Alignment Layer --

In the alignment layer forming, a layer by which the alignment direction of the liquid crystal structure in the second optically anisotropic layer is determined is formed on or above the fist optically anisotropic layer.

The alignment layer is not particularly limited and may be selected accordingly and includes, for example, a rubbed alignment layer containing an organic compound (preferably a polymer); an alignment layer having a micro groove; an alignment layer containing an organic compound such as ω-tricosnoic acid, dioctadecyldimethylammonium chloride or methyl stearate, deposited according to Langmuir-Blodgett method (LB film); an alignment layer containing an inorganic compound deposited by oblique vapor deposition; and an alignment layer having an aligning function as a result of application of electric field, magnetic field or light. Among them, the rubbed alignment layer containing an organic compound is preferred.

The rubbing can be carried out by any procedure selected accordingly. For example, the surface of the film containing an organic compound is rubbed with paper or cloth several times in a certain direction.

The organic compound is not particularly limited and may be selected according to the alignment condition (particularly the alignment angle) of the liquid

crystal structure and includes, for example, a polymer for alignment layer which does not reduce the surface energy of resultant alignment layer for horizontal alignment of the liquid crystal structure.

The specific examples of polymer for alignment layer for aligning the liquid crystal structure in a direction perpendicular to the rubbing direction are modified polyvinyl alcohols, acrylic copolymers, polyimides, and polyamic acid. Of these, polyimides which excel in alignment properties are preferred.

The thickness of alignment layer is not particularly limited and may be adjusted accordingly. It is preferably 0.01μm to 5μm and more preferably 0.02μm to 2μm.

-- Forming of Second Optically Anisotropic Layer --

In the second optically anisotropic layer forming, an optically anisotropic layer using at least a polymerizable liquid crystal compound is formed on the alignment layer.

A solution of the polymerizable liquid crystal compound having liquid crystal structure is applied to the alignment layer to form a coated layer. The solution is applied by, for example, wire bar coating, gravure coating, micro gravure coating and dye coating. From the perspective of reducing uneven dryness by minimizing coated amount of wet solution, micro gravure coating and gravure coating are preferred, while from the perspective of uniform thickness in a lateral direction and uniform thickness in a longitudinal direction with time after being coated, rotating gravure coating is more preferred.

The polymerizable liquid crystal compound is not particularly limited and may be selected accordingly. For example, a polymerizable liquid crystal compound having a liquid crystal structure which is capable of fixing an alignment

condition is preferably used. And a polymerizable liquid crystal compound having a liquid crystal structure such as rod-shaped liquid crystal structure, discotic liquid crystal structure or banana-shaped liquid crystal structure is more preferable and a polymerizable liquid crystal compound having a discotic liquid crystal structure is most preferable.

The polymerizable liquid crystal compound may also include other components selected accordingly.

Examples of other components include a polymerization initiator for starting a polymerization reaction of the polymerizable liquid crystal compound and a solvent for preparing a coating solution for the polymerizable liquid crystal compound.

- Heat Treatment -

In the heat treatment, a second optically anisotropic layer is heated in order to equalize, mature and maintain the alignment.

The coated layer is heated at 60°C to 120°C to volatilize and dry the solvent. After drying the solvent, in order to mature the alignment of the polymerizable compound having liquid crystal structure, the heating temperature is controlled at a range of 85°C to 180°C or until the liquid crystal compound shows a ND layer and ultraviolet rays with an amount of energy enough to perform a curing reaction are irradiated to the polymerizable compound to polymerize and fix the polymerizable compound having liquid crystal structure to thereby yield an optically anisotropic layer.

-- Polymerizing/Curing of Second Optically Anisotropic Layer --

In the polymerizing and curing of the second optically anisotropic layer, the second optically anisotropic layer is polymerized and cured while keeping the

above-noted transition temperature.

The polymerization and curing of the second optically anisotropic layer with matured alignment is not particularly limited and may be selected accordingly as long as alignment of the liquid crystal layer can be fixed. For instance, a curing reaction of the second optically anisotropic layer is performed by irradiating active rays for photopolymerization. The active rays for photopolymerization can be suitably selected from electron beam, ultraviolet rays, visible beam and infrared rays (heat rays) accordingly. Typically, ultraviolet rays are preferred. Examples of light source for ultraviolet rays include low pressure mercury lamps (bactericidal lamp, fluorescent chemical lamp and blacklight lamp), high voltage discharge lamps (high-pressure mercury lamp and metal halide lamp), and short arc discharge lamps (ultra-high pressure mercury lamp, xenon lamp and mercury xenon lamp).

Examples of radical polymerization initiators for polymerization reaction of ethylene-unsaturated groups include azobis compounds, peroxides, hydro peroxides, redox catalysts such as potassium persulfate, ammonium persulfate, tert-butyl peroctoate, benzoyl peroxide, isopropyl percarbonate, 2, 4-dichlobenzoyl peroxide, methyl ethyl ketone peroxide, cumene hydroperoxide, dicumyl peroxide, azobis isobutylonitril, 2,2'-azobis (2-amidinopropane) hydrochroride or benzophenones, acetophenones, benzoins, and thioxanthenes. Details of these radical polymerization initiators are described in "Ultraviolet curable system" pp. 63-147, 1989 by General Technical Center (Japanese title: "Shigaisen-kouka system" by Sogo Gijutsu Center).

General examples of ultraviolet ray-activated cationic catalyst used for polymerization of a compound having epoxy groups include allyl diazonium salt

(hexafluorophosphate, tetrafluoroborate, and the like), diallyl iodonium salt, allylonium salt of VIa-groups (allyl sulfonium salt having anion such as PF_6, AsF_6, SbF_6, and the like).

When a curing reaction is performed using a radical reaction, to avoid delay in polymerization reaction due to the presence of oxygen in the air, irradiating the above-mentioned active rays in a nitrogen atmosphere is preferable because of shorter reaction time and smaller amount of light needed for curing reaction.

-- Forming of Antireflective Layer --

In the forming of antireflective layer, an antireflective layer is formed on or above the cured second optically anisotropic layer. For instance, when an inorganic material is used, an antireflective layer is formed on or above a second optically anisotropic layer by vapor deposition and when an organic material is used; an antireflective layer is formed by coating.

The deposition is not particularly limited and may be carried out by any method accordingly. The deposition is carried out, for example, by chemical vapor deposition (CVD) in which a sample is left in a gas atmosphere to form a layer on the surface of the sample by chemical reaction, and a physical vapor deposition (PVD) in which raw materials in a state of particles are physically attached to a sample to form a layer.

Among them, physical vapor deposition (PVD), in which a layer is physically prepared by sputtering under reduced pressure using a sputtering target formed of metal which is a material of the intermediate layer, is preferably used.

The coating can be performed by wire bar coating, gravure coating, micro gravure coating, and dye coating. From the perspective of reducing uneven dryness by minimizing the coated amount of wet solution, micro gravure coating

and gravure coating are preferred, while from the perspective of uniform thickness in a lateral direction and uniform thickness in a longitudinal direction with time after being coated, rotating gravure coating is more preferred.

-- Forming of Other Layers --

In the forming of other layers, another second optically anisotropic layer may be formed of which alignment direction differs from the second optically anisotropic layer previously formed. This is formed after each step for forming the first optically anisotropic layer, the alignment layer, the second optically anisotropic layer, heat treatment for polymerizing and curing of the second optically anisotropic layer is repeated at least once in this order.

Other layers may be arbitrarily formed on the antireflective layer after forming the antireflective layer. Examples include protective layer, anti-glare layer, antifouling layer and antistatic layer.

- Sealing of Optical Compensatory Element -

The sealing of the optical compensatory element is a step in which the optical compensatory element is sealed by a sealing unit under a deoxygenated atmosphere.

In particular, the optical compensatory element is held by a holding member, depressurized, deaired in a deoxygenated atmosphere, substituted with inactive gas and sealed.

First, using a holding member in the form of flat plate, the optical compensatory element is held so that the front and back surfaces of the optical compensatory element are being covered and the optical compensatory element and the holding member are closely attached.

Next, the optical compensatory element is heated at 25°C to 200°C or preferably at 25°C to 100°C and the work area is depressurized using general

vacuum apparatus or decompressor and then the optical compensatory element is deaired in a deoxygenated atmosphere. By this procedure, impurities inside the optical compensatory element, for example, acidic compounds such as water, oxygen, nitrogen oxide, sulfur oxide, and the like or molecules of various solvent gases generated from the manufacturing process of the optical compensatory element, are removed.

And it is filled with an inactive gas using gas substituting apparatus generally used. The inactive gas is not particularly limited as long as it is a compound that does not react with organic material of the optical compensatory element and may be selected accordingly. Examples include nitrogen gas, helium gas, argon gas, neon gas, and the like and among them, nitrogen gas is preferable. These inactive gases are preferably highly pure.

And the exposed side of the laminated body is then sealed with sealing material. When ultraviolet-curable sealing material is used, after sealing material is coated on the side and sealed, ultraviolet light is irradiated to the sealing material to cure. The wavelength region of approximately 300nm or less is preferably omitted from the light beam. If the light beam of above wavelength region is contained, it may facilitate decomposition or deterioration of the liquid crystal structure contained in the laminated body.

When one-component epoxy resin cement is used as sealing material, after the cement is coated and sealed, it is then heated at 100°C to 150°C for 30 minutes to 60 minutes to facilitate curing. When two-component epoxy resin cement is used, after mixed solution of two components is coated and sealed, curing is performed for a predetermined time.

By above procedures, the entire optical compensatory element is sealed,

oxidation reaction which occur inside laminated body, color degradation or contrast deterioration are suppressed and durability of the optical compensatory element is improved.

- Configuration of Optical Compensatory Element -

The optical compensatory element can have any configuration suitably selected accordingly. Preferred examples of configuration are the following first, second, third, fourth, fifth, sixth, seventh and eighth configurations.

(Optical Compensatory Element according to the First Configuration)

FIG. 1 is a sectional view schematically showing an optical compensatory element according to the first configuration of the present invention.

The optical compensatory element according to the first configuration has a first optically anisotropic layer on one surface of the support and two layers of the second optically anisotropic layer having different alignment directions on the other surface of the support. Specifically, with reference to FIG. 1, optical compensatory element 10 according to the first configuration has alignment layer 4A, second optically anisotropic layer 3A, alignment layer 4B, second optically anisotropic layer 3B and antireflective layer 5B disposed in this order on one surface of support 1 arranged so that the antireflective layer 5B constitutes an outermost surface. The optical compensatory element 10 further has first optically anisotropic layer 2 and antireflective layer 5A disposed in this order on the other surface of the support 1 arranged so that the antireflective layer 5A constitutes another outermost surface. The outermost surfaces of antireflective layers 5A and 5B are held by the holding members 6 and 6A and periphery sides are sealed by seal 7.

The first optically anisotropic layer 2 has a periodic multilayered structure containing TiO_2 layer 2A and SiO_2 layer 2B. The thickness of each layer is

approximately 15nm. The first optically anisotropic layer 2 may also serve as an antireflective layer by having a periodic multilayered structure.

The rubbing directions of alignment layers 4A and 4B preferably differ from each other by 90 degrees. By arranging these alignment layers 4A and 4B this way, it is possible for the alignment direction of liquid crystal structures contained in the polymerizable liquid crystal compounds of the second anisotropic layers 3A and 3B to differ from each other by 90 degrees.

(Optical Compensatory Element according to Second Configuration)

FIG. 2 is a sectional view schematically showing an optical compensatory element according to the second configuration of the present invention.

The optical compensatory element according to the second configuration has a first optically anisotropic layer and a second optically anisotropic layer disposed in this order on the support.

With reference to FIG. 2, optical compensatory element 20 according to the second configuration has first optically anisotropic layer 22, alignment layer 24, second optically anisotropic layer 23 and antireflective layer 25B disposed in this order on one surface of support 21 arranged so that the antireflective layer 25B constitutes an outermost surface and has an antireflective layer 25A on the other surface of the support 21. The outermost surfaces of antireflective layers 25A and 25B are held by the holding members 26 and 26A and periphery sides are sealed by seal 27.

The first optically anisotropic layer 22 may have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the first configuration.

Two layers of the optical compensatory element 20 according to the second

configuration can be used as laminate. In this case, rubbing directions of the alignment layers in the respective optical compensatory elements preferably differ from each other by 90 degrees.

Such an optical compensatory element having the respective layers disposed on one surface of the support, as in the optical compensatory element 20 according to the second configuration, can be generally satisfactorily handled and easily prepared, while these properties depend on the materials of the respective layers and combinations thereof.

(Optical Compensatory Element according to Third Configuration)

FIG. 3 is a sectional view schematically showing an optical compensatory element according to the third configuration of the present invention.

The optical compensatory element according to the third configuration has two second anisotropic layers having different alignment direction disposed on one surface of the support.

With reference to FIG. 3, optical compensatory element 30 according to the third configuration has first optically anisotropic layer 32, alignment layer 34A, second optically anisotropic layer 33A, alignment layer 34B, second optically anisotropic layer 33B and antireflective layer 35B disposed in this order on one surface of support 31 arranged so that the antireflective layer 35B constitutes an outermost surface, and has antireflective layer 35A on the other surface of the support 31. The outermost surfaces of antireflective layers 35A and 35B are held by the holding members 36 and 36A and periphery sides are sealed by seal 37.

The first optically anisotropic layer 32 can have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the first configuration.

The rubbing directions of the alignment layers 34A and 34B preferably differ from each other by 90 degrees. By arranging these alignment layers 34A and 34B this way, it is possible for the alignment directions of the liquid crystal structures in the polymerizable liquid crystal compounds of the second anisotropic layers 33A and 33B to differ from each other by 90 degrees.

(Optical Compensatory Element according to Fourth Configuration)

FIG. 4 is a sectional view schematically showing an optical compensatory element according to the fourth configuration of the present invention.

The optical compensatory element according to the fourth configuration has two second anisotropic layers having different alignment directions disposed with the interposition of the support.

With reference to FIG. 4, optical compensatory element 40 according to the fourth configuration has first optically anisotropic layer 42, alignment layer 44A, second optically anisotropic layer 43A and antireflective layer 45B disposed in this order on one surface of support 41 arranged so that the antireflective layer 45B constitutes an outermost surface, and has alignment layer 44B, second optically anisotropic layer 43B and antireflective layer 45A disposed in this order on the opposite surface of the support 41. The outermost surfaces of antireflective layers 45A and 45B are held by the holding members 46 and 46A and periphery sides are sealed by seal 47.

The first optically anisotropic layer 42 can have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the first configuration.

The rubbing directions of the alignment layers 44A and 44B preferably differ from each other by 90 degrees. By arranging these alignment layers 44A and 44B

this way, it is possible for alignment directions of the liquid crystal structures in the polymerizable liquid crystal compounds of the second anisotropic layers 43A and 43B to differ from each other by 90 degrees.

(Optical Compensatory Element according to Fifth Configuration)

FIG. 5 is a sectional view schematically showing an optical compensatory element according to the fifth configuration of the present invention.

The optical compensatory element according to the fifth configuration has the first optically anisotropic layer and the second anisotropic layer on at least one surface of the support.

With reference to FIG. 5, optical compensatory element 50 according to the fifth configuration has alignment layer 54, second optically anisotropic layer 53, first optically anisotropic layer 52 and antireflective layer 55B disposed in this order on one surface of support 51 arranged so that the antireflective layer 55B constitutes an outermost surface, and has antireflective layer 55A on the other surface of the support 51. The outermost surfaces of antireflective layers 55A and 55B are held by the holding members 56 and 56A and periphery sides are sealed by seal 57.

The first optically anisotropic layer 52 can have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the first configuration.

Two layers of the optical compensatory element 50 according to the fifth configuration can be used as laminate. In this case, rubbing directions of the alignment layers in the respective optical compensatory elements preferably differ from each other by 90 degrees.

(Optical Compensatory Element according to Sixth Configuration)

FIG. 6 is a sectional view schematically showing an optical compensatory

element according to the sixth configuration of the present invention.

The optical compensatory element according to the sixth configuration has two second optically anisotropic layers having different alignment directions. With reference to FIG. 6, optical compensatory element 60 according to the sixth configuration has alignment layer 64A, second optically anisotropic layer 63A, alignment layer 64B, second optically anisotropic layer 63B, first optically anisotropic layer 62, and antireflective layer 65B disposed in this order on one surface of support 61 arranged so that the antireflective layer 65B constitutes an outermost surface, and has antireflective layer 65A on the other surface of the support 61. The outermost surfaces of antireflective layers 65A and 65B are held by the holding members 66 and 66A and periphery sides are sealed by seal 67.

The first optically anisotropic layer 62 can have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the fist configuration.

The rubbing directions of the alignment layers 64A and 64B preferably differ from each other by 90 degrees. By arranging these alignment layers 64A and 64B this way, it is possible for the alignment direction of the liquid crystal structures contained in the polymerizable liquid crystal compounds of the second anisotropic layers 63A and 63B to differ from each other by 90 degrees.

(Optical Compensatory Element according to Seventh Configuration)

FIG. 7 is a sectional view schematically showing an optical compensatory element according to the seventh configuration of the present invention.

The optical compensatory element according to the seventh configuration has two second anisotropic layers having different alignment directions disposed with the interposition of the support.

With reference to FIG. 7, optical compensatory element 70 according to the seventh configuration has alignment layer 74A, second optically anisotropic layer 73A, first optically anisotropic layer 72, and antireflective layer 75B disposed in this order on one surface of support 71 arranged so that the antireflective layer 75B constitutes an outermost surface, and has alignment layer 74B, second optically anisotropic layer 73B, first optically anisotropic layer 72, and antireflective layer 75A disposed in this order on the other surface of the support 71 arranged so that the antireflective layer 75A constitutes another outermost surface. The outermost surfaces of antireflective layers 75A and 75B are held by the holding members 76 and 76A and periphery sides are sealed by seal 77.

The first optically anisotropic layer 72 can have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the first configuration. Having at least one layer of the first optically anisotropic layer 72 is satisfactory and one of the two first optically anisotropic layers 72 may be omitted.

The rubbing directions of the alignment layers 74A and 74B preferably differ from each other by 90 degrees. By arranging these alignment layers 74A and 74B in this way, it is possible for the alignment directions of the liquid crystal structures contained in the polymerizable liquid crystal compounds of the second anisotropic layers 73A and 73B to differ from each other by 90 degrees.

(Optical Compensatory Element according to Eighth Configuration)

FIG. 8 is a sectional view schematically showing an optical compensatory element according to the eighth configuration.

The optical compensatory element according to the eighth configuration has the first optically anisotropic layer on one surface of the support and the second

optically anisotropic layer on the other surface of the support.

With respect to FIG. 8, optical compensatory element 80 according to the eighth configuration has alignment layer 84, second optically anisotropic layer 83, and antireflective layer 85B disposed in this order on one surface of support 81, arranged so that the antireflective layer 85B constitutes an outermost surface, and has first optically anisotropic layer 82 and antireflective layer 85A disposed in this order on the other surface of the support 81, arranged so that the antireflective layer 85A constitutes another outermost surface. The outermost surfaces of antireflective layers 85A and 85B are held by the holding members 86 and 86A and periphery sides are sealed by seal 87.

The first optically anisotropic layer 82 can have a similar structure to that of the first optically anisotropic layer 2 in the optical compensatory element 10 according to the first configuration.

Two layers of the optical compensatory element 80 according to the eighth configuration can be used as laminate. In this case, rubbing directions of the alignment layers in the respective optical compensatory elements preferably differ from each other by 90 degrees.

In the optical compensatory elements, the optical properties of the first optically anisotropic layers 2, 22, 32, 42, 52, 62, 72 and 82 are determined depending on the pitch of periodic structure of the periodic multilayered structures containing inorganic materials. Therefore, these optical compensatory elements can avoid optical ununiformity such as variation in refractive index or reduced haze in the surface of a polymer film induced by residual stress when the polymer film is uniaxially stretched to yield predetermined optical properties. Thereby it is possible to achieve highly uniform optical properties in the surface of the first

optically anisotropic layer and to optically compensate the liquid crystal layer in black state more precisely.

It is possible to control in-plane thickness of the first optically anisotropic layers 2, 22, 32, 42, 52, 62, 72, and 82 to be in a range of several tens of nanometers, and having high smoothness and improving optical uniformity in the surfaces of the first optically anisotropic layers are possible. Thus the optical compensatory element can optically compensate the liquid crystal layer in black state more precisely and can reduce light leakage and prevent streaky unevenness.

In addition, the first optically anisotropic layers 2, 22, 32, 42, 52, 62, 72 and 82 do not swell or shrink even in use at high temperature and humidity over a long period of time.

Moreover, by holding each outermost surface of antireflective layers 5A, 25A, 35A, 45A, 55A, 65A, 75A, 85A, 5B, 25B, 35B, 45B, 55B, 65B, 75B and 85B with each holding member 6, 26, 36, 46, 56, 66, 76, 86, 6A, 26A, 36A, 46A, 56A, 66A, 76A and 86A, removing impurities attached to the laminated body by depressurizing and substituting with inactive gas, and sealing periphery sides of the laminated body with seals 7, 27, 37, 47, 57, 67, 77 and 87, sustaining clean condition and suppressing oxidation reaction are possible.

The above-mentioned optical compensatory elements as a whole can minimize changes in optical properties over a long period of time and their durability are remarkably improved.

In particular, the optical compensatory elements according to the first, second and third configurations have the first optically anisotropic layers 2, 22 and 32 on or above the supports 1, 21 and 31, and the in-plane thickness of these first optically anisotropic layers can be controlled within a range of dozen nanometers.

Thus, the first optically anisotropic layers 2, 22 and 32 can prevent unevenness in in-plane thickness with high degree of precision; therefore it is possible to have highly smooth surfaces. Since the second optically anisotropic layers 3, 23 and 33 are laminated on the first optically anisotropic layers 2, 22 and 32 having highly smooth surfaces, in-plane alignment failures of these second optically anisotropic layers can be prevented. The resultant optical compensatory elements can optically compensate the liquid crystal layer in black state more precisely and prevent light leakage at a wide viewing angle. By utilizing the optical compensatory element in large-screen liquid crystal monitors or liquid crystal projectors which require wide viewing angle, producing liquid crystal displays and liquid crystal projectors with high quality images and high contrast are possible.

(Liquid Crystal Display)

A liquid crystal display according to the present invention has at least a pair of electrodes and a liquid crystal device having liquid crystal molecules encapsulated in between the pair of electrodes, an optical compensatory element disposed on one or both surfaces of the liquid crystal device, a polarizing element facing the liquid crystal device and the optical compensatory element. It may also have other configurations accordingly and the optical compensatory element is the optical compensatory element according to the present invention.

The display mode of the liquid crystal device is not particularly limited and may be selected accordingly. Examples include TN (Twisted Nematic) mode, VA (Vertical Alignment) mode, IPS (In-Plane Switching) mode, OCB (Optically Compensatory Bend) mode and ECB (Electrically Controlled Birefringence) mode. Among them, TN mode is particularly preferable because of its high contrast ratio.

FIGS 17 through 20 are schematic block diagrams showing the liquid crystal

displays of the present invention.

To promote better understanding, in each schematic block diagram of the liquid crystal displays, light emitted from a light source enters from the bottom of the drawings and irradiated toward upper side. When the polarizing plate and/or the second optically anisotropic layer contains two components, the one that is present in the upper side of the drawings is called as "upper" component, and the one in the lower side of the drawings is called as "lower" component.

With reference to FIG. 17, liquid crystal display 100 has upper polarizing element 101 (analyzer) and lower polarizing element 116 (polarizer) which are a pair of polarizing elements wherein absorption axis 102 and 115 are substantially perpendicular to each other and are arranged in cross nicol disposition, optical compensatory element 108 disposed between the upper and lower polarizing elements 101 and 116, and liquid crystal device 114 (liquid crystal cell).

Polarization beam splitters such as Glan-Thompson prisms may be used as polarizing element facing the liquid crystal device 114 instead of upper and lower polarizing elements 101 and 116.

The liquid crystal device 114 has an upper substrate 109 and lower substrate 113 which are glass substrates and are placed opposite of each other, and nematic liquid crystal 111, for example, encapsulated in between these upper and lower substrates 109 and 113. The upper substrate 109 and the lower substrates 113 have components (not shown) such as pixel electrodes and circuit elements (thin-film transistors) on their surfaces facing each other. The upper substrate 109 and the lower substrate 113 further have upper and lower alignment layers (not shown), respectively, on their surfaces adjacent to the nematic liquid crystal 111. The surfaces of the alignment layers adjacent to the nematic liquid crystal 111 have been

rubbed for aligning the alignment directions of liquid crystal molecules. The rubbing direction, direction of grooves formed as a result of rubbing, of 110 and 112 in the upper and lower alignment layers are substantially perpendicular to each other in the case of a liquid crystal display of TN mode, for example.

FIG. 17 illustrates the alignment condition of liquid crystal molecules under a normal condition where no voltage is applied to the liquid crystal device 114. Liquid crystal molecules in the nematic liquid crystal 111 near the upper substrate 109 and the lower substrate 113 are arranged in directions substantially identical to the rubbing directions of 110 and 112 by the action of rubbing on the alignment layers (not shown). Since the rubbing directions of 110 and 112 are perpendicular to each other, the liquid crystal molecules in the nematic liquid crystal 111 are aligned so as to have major axes twisted by 90 degrees from the upper substrate 109 toward the lower substrate 113.

The optical transmittance of the polarizing elements arranged in cross nicol disposition is preferably 0.001% or less, provided that the optical transmittance of the polarizing elements arranged in parallel nicol disposition is defined as 100%.

Each upper polarizing element 101 (analyzer) and the lower polarizing element 116 (polarizer) has a polarizing film and other additional components as necessary.

The polarizing film is not particularly limited and may be selected accordingly. Examples include a film made from hydrophilic polymer which has adsorbed a dichroic material and has been subjected to stretching for alignment. Examples of hydrophilic polymer are polyvinyl alcohols, partially formalized polyvinyl alcohols and partially saponified products of ethylene-vinyl acetate copolymers. Examples of dichroic material are iodine and dichroic dyes such as azo

dyes, anthraquinone dyes and tetrazine dyes.

The stretch alignment procedure can be carried out by using any device selected accordingly such as a lateral uniaxial tenter stretching machine in which the adsorption axis of the polarizing film is substantially perpendicular to longitudinal direction. The lateral uniaxial tenter stretching machine is advantageous for that it can avoid foreign matters entering during lamination.

A stretch alignment method described in JP-A No. 2002-131548 can be also employed for stretch alignment procedure.

The other components are not particularly limited and may be selected accordingly. Examples include transparent protective film, antireflective film and anti-glare film each disposed on or above one or both surfaces of the polarizing film.

Examples of upper and lower polarizing elements 101 and 116 include a polarizing plate having a transparent protective layer at least on one surface of the polarizing film, the one having polarizing film integrally on one surface of the liquid crystal device 114 as a support, and the like.

The material of the transparent protective film is not particularly limited and may be selected accordingly. Examples include cellulose esters such as cellulose acetate, cellulose acetate butyrate and cellulose propionate; polycarbonates; polyolefins; polystyrenes; and polyesters.

Suitable examples of the material of the transparent protective film are cellulose triacetate, polyolefins such as ZEONEX, ZEONOR (both manufactured by NIPPON ZEON CO., LTD.) and ARTON (manufactured by JSR Corporation).

Non-birefringent optical resin materials described in JP-A No. 08-110402 and No. 11-293116 are also usable.

The alignment axis (slow axis) of the transparent protective film may be

arranged in any direction; however, it is preferably in parallel with the longitudinal direction for easy and convenient operation. The angle formed between slow axis (alignment axis) of the transparent protective film and adsorption axis (stretching axis) of the polarizing film is not particularly limited and may be adjusted according to the purpose of the polarizing plate. When the polarizing film is prepared by using the lateral uniaxial tenter stretching machine, the slow axis (alignment axis) of the transparent protective film is in a direction substantially perpendicular to the adsorption axis (stretching axis) of the polarizing film.

The retardation of the transparent protective film is not particularly limited and may be selected accordingly and it is preferably, for example, 10nm or less and more preferably 5nm or less when measured by light having a wavelength of 632.8 nm.

The retardation of cellulose acetate, if used, is preferably less than 3nm and more preferably 2nm or less for minimizing the retardation variation with temperature and humidity in the environment.

The polarizing plate can be prepared by any method selected accordingly and it is preferably prepared by continuously laminating onto a long polarizing film fed as a roll so that the longitudinal directions correspond to each other.

The polarizing film and the polarizing plate are preferably fixed to the liquid crystal device for preventing misalignment of the optical axis and also preventing foreign matter such as dust from entering.

The antireflective layer is not particularly limited and may be selected accordingly. Examples include coated layer of fluorine-containing polymer and optical interference layer such as multilayered metal layer prepared by vapor deposition.

The upper and lower polarizing elements 101 and 116 preferably have optical properties and durability (short-term and long-time storage stability) equal to or higher than those of commercially available high-contrast product such as HLC2-5618 manufactured by Sanritz Corporation.

The optical compensatory element 108 is the optical compensatory element according to the present invention.

When the optical compensatory element is integrated into the liquid crystal display 100, the contrast ratio Vw/Vb in front of the liquid crystal display 100 is preferably 100:1 or more, more preferably 200:1 or more and most preferably 300:1 or more. The contrast ratio is the ratio of transmittance of the liquid crystal display 100 in white state "Vw" to the transmittance in black state "Vb".

The maximum transmittance in black state is preferably 10% or less and more preferably 5% or less of Vw in an azimuth direction inclined 60 degrees from the normal direction to the display surface of the liquid crystal display 100. By using the optical compensatory element having such properties, resultant liquid crystal display exhibits a high contrast and a wide viewing angle with no tone reversal.

To accurately compensate a liquid crystal device having a large residual twisted component, the liquid crystal display preferably does not optically quench in any direction and has an optical transmittance of 0.01% or more in all directions when the optical compensatory element is disposed between a pair of polarizing elements arranged in cross nicol disposition and the optical compensatory element is rotated in the normal direction to the optical compensatory element as a rotation axis.

The optical compensatory element 108 is disposed between upper polarizing

element 101 and liquid crystal device 114 and contains a first optically anisotropic layer 107, an upper second optically anisotropic layer 103 and a lower second optically anisotropic layer 105.

The respective optically anisotropic layers constituting the optical compensatory element 108 are arranged so that the angle formed between the rubbing direction 104 of an alignment layer in the upper second optically anisotropic layer 103 and rubbing direction 110 of an upper alignment layer in an upper substrate 109 of the liquid crystal device 114 is 180° and the angle formed between rubbing direction 106 of an alignment layer in the lower second optically anisotropic layer 105 and rubbing direction 112 of a lower alignment layer in the lower substrate 113 of the liquid crystal device 114 is 180°.

The rubbing directions in the alignment layers in the second optically anisotropic layer and in the substrate of the liquid crystal device may be exchanged. More specifically, the layers may be arranged so that the angle formed between the rubbing direction 106 of the alignment layer in the lower second optically anisotropic layer 105 and the rubbing direction 110 of the upper alignment layer in the upper substrate 109 of the liquid crystal device 114 is 180° and the angle formed between the rubbing direction 104 of the alignment layer in the upper second optically anisotropic layer 103 and the rubbing direction 112 of the lower alignment layer in the lower substrate 113 of the liquid crystal device 114 is 180°.

The first optically anisotropic layer 107 is preferably arranged to be near the liquid crystal device 114.

FIG. 18 schematically illustrates the arrangement of liquid crystal molecules in a liquid crystal display of TN mode in black state, i.e., when a voltage is applied to the liquid crystal device 114. Upon application of a voltage to the liquid crystal

device 114, the liquid crystal molecules change in their arrangement so that the liquid crystal molecules stand up with their major axes perpendicular to the incident plane of light. Ideally, all the liquid crystal molecules in the liquid crystal device 114 are in parallel with the incident plane of light upon application of a voltage. In actuality, however, the major axis of liquid crystal molecules in the liquid crystal device 114 gradually stand up from the upper substrate 109 and the lower substrate 113 toward the center part of the liquid crystal device 114, as shown in FIG. 18. Thus, major axis of the liquid crystal molecules near interfaces of the upper substrate 109 and of the lower substrate 113 are not parallel with but oblique or inclined to the incident plane of light upon application of a voltage. These liquid crystal molecules being inclined to the incident plane of light fail to display black and cause light leakage at some viewing angles.

In addition, nematic liquid crystal molecules used in liquid crystal display of TN mode are generally rod-shaped and exhibit optically positive uniaxial properties. Accordingly, when the liquid crystal display 100 is viewed from an oblique direction, with the liquid crystal molecules at the center part of the liquid crystal device 114 standing up completely, birefringence occurs and the liquid crystal device fails to display black and cause light leakage at some viewing angles.

The birefringence caused by the alignment of the liquid crystal molecules in the liquid crystal device 114 in the vicinity of the upper substrate 109 and of the lower substrate 113 in black state can be optically compensated by allowing the alignment of the liquid crystal molecules in the second optically anisotropic layers 103 and 105 to be mirror symmetry. In addition, the birefringence caused by liquid crystal molecules at the center part of the liquid crystal device 114 can be optically compensated by arranging the first optically anisotropic layer 107 having optical

properties of uniaxial and non-inclined negative optical indicatrix. Thus, the liquid crystal device 114 in black state as a whole can be optically compensated three-dimensionally to thereby prevent light leakage in a wide range of viewing angles.

The optical compensatory element 108 may be placed below the liquid crystal device 114, as shown in FIG. 19, or may be placed above or below the liquid crystal device 114 as optical compensatory elements 108a and 108b, as shown in FIG. 20. When the optical compensatory elements 108a and 108b are placed above and below the optical crystal element 114, one of first optically anisotropic layers 107a and 107b may be omitted. When both of the first optically anisotropic layers 107a and 107b are used, the retardation is defined as a total of the retardations of these layers.

It is possible for the optical compensatory element 108 to have the upper substrate 109 and the lower substrate 113 of the liquid crystal device 114 as the substrate (not shown) equipped to the optical compensatory element 108. In this case, the first optically anisotropic layers 107a and 107b shown in FIG. 20 are directly formed on the upper substrate 109 and the lower substrate 113, respectively.

(Wave Plate)

The wave plate of the present invention contains a protective layer having at least an inorganic layer containing an inorganic material on a wave film and further contains other layers as necessary.

In particular, the wave plate contains a support and a wave film and a protective layer on the support and other layers selected accordingly.

Preferred examples of the wave film include first optically anisotropic layer and second optically anisotropic layer.

- Support -

The support is not particularly limited as long as it excels in transparency, exhibits 80% or more of light transmittance and gives uniform optical properties and may be selected accordingly. Examples include the same support as used for the optical compensatory element of the present invention.

Thickness of the support is not particularly limited and may be adjusted accordingly. It is preferably 0.1μm or more and the upper limit is preferably 0.3mm to 3mm and more preferably 0.5mm to 1.5mm for easy handling in assembly and appropriate mechanical strength.

- First Optically Anisotropic Layer -

The composition of the first optically anisotropic layer is not particularly limited as long as it is optically anisotropic and may be selected accordingly. The first optically anisotropic layer as used for the optical compensatory element of the present invention may be used, for example.

- Second Optically Anisotropic Layer -

The composition of the second optically anisotropic layer is not particularly limited as long as it contains polymerizable compounds and may be selected accordingly. The same second optically anisotropic layer as used for the optical compensatory element of the present invention may be used, for example.

- Protective Layer -

The protective layer protects the second optically anisotropic layer formed of organic material from degradation caused by oxidation reaction, suppresses secular changes such as contrast degradation of the second optically anisotropic layer and improves durability.

The composition of the protective layer is not particularly limited and may

be selected accordingly. Examples include single or multiple layer of the same material or multiple layer of two of more of different material.

The material of the protective layer is not particularly limited and may be selected accordingly as long as it has mechanical strength and sealing ability (gas barrier), excels in transparency, exhibits 80% or more of light transmittance and satisfies uniform optical properties. Examples include inorganic materials and organic materials combined with inorganic materials. Of these, inorganic material is preferable for appropriate mechanical strength and excellent durability.

The inorganic material is not limited and may be selected accordingly. Examples include materials such as glass, sapphire glass, alumina, silica, and the like.

Of these examples, alumina is preferable because it has no permeability to oxygen gas, and the like and may be easily laminated. These may be used alone or in combination.

The organic material is not particularly limited and may be selected accordingly. Examples include plastic films such as polyvinyl alcohol, polyvinyl chloride, and the like. These may be used alone or in combination.

The thickness of the protective layer may be adjusted accordingly and it is preferably 0.05μm to 0.8μm and more preferably 0.05μm to 0.4μm for better function. If the thickness is less than 0.05μm, it may lack mechanical strength, impair sealing ability and exhibit poor durability. If it is more than 0.8μm, optical properties may be deteriorated and may result in contrast degradation.

Since the protective layer can suppress the degradation of the optically anisotropic layer caused by permeable gas, it is preferably placed on at least one surface of the wave plate and more preferably on both sides of the plate. In this

case, when the support is formed of a glass, and the like, the support also serves as a protective layer and gas permeation from both sides can be suppressed even when protective layer is formed only on one side.

The size of the protective layer is not particularly limited as long as it covers entire laminated optically anisotropic layer and may be selected accordingly. It is preferably the same size or larger than the wave plate, for example.

Other layers are not particularly limited and may be selected accordingly. Examples include antireflective layer, anti-glare layer, antifouling layer, antistatic layer, and the like.

The antireflective layer functions to decrease reflectance and increase transmittance. The material of the antireflective layer is not particularly limited and may be selected accordingly. Examples include known AR film (anti reflection coat film), and the like.

These layers are preferably disposed on outermost layer of the wave plate, which is a boundary face of the wave plate and air for better function.

- Method for Manufacturing Wave Plate -

The method for manufacturing a wave plate according to the present invention is not particularly limited and may be selected accordingly. Examples include first optically anisotropic layer forming, alignment layer forming, second optically anisotropic layer forming, heat treatment, second optically anisotropic layer polymerizing and curing, protective layer forming and other layer forming.

Each layer forming steps will be described in detail below.

-- Forming of First Optically Anisotropic Layer --

The first optically anisotropic layer forming is not particularly limited and may be selected accordingly as long as resultant layer satisfies optical properties.

For example, an optically anisotropic layer is formed by laminating plural layers having different refractive indices on or above the support in a regular order in a direction normal to the support and forming a periodic multilayered structure in which plural layers are repeatedly laminated (a repeating unit is repeated).

Materials of the periodic multilayered structure is not particularly limited and may be selected accordingly as long as they are inorganic materials and are preferably used in combination of materials having high refractive indices or low refractive indices.

For materials having high refractive indices, TiO_2, ZrO_2, and the like are preferred, and for materials having low refractive indices, SiO_2, MgF_2, and the like are preferred. These may be used alone or in combination.

Specifically, the materials of periodic multilayered structure are preferably selected from combination of materials of which the difference between maximum refractive index and minimum refractive index in visible light region is 0.5 or more, more preferably selected from combinations of plural materials suitably selected from oxides and of these, a combination of SiO_2 (refractive index, n = 1.4870 to 1.5442) and TiO_2 (refractive index, n = 2.583 to 2.741) is most preferable.

The number of layers constituting one repeating unit is not particularly limited as long as they are plural layers of different refractive indices. It is preferably plural layers formed of two types of inorganic materials and more preferably a periodic multilayered structure having dozens of layers formed by alternately depositing SiO_2 and TiO_2 on or above the support under reduced pressure using a sputtering apparatus.

An optical thickness of the repeating unit, i.e., the thickness of a repeating unit in a laminating direction of periodic multilayered structure is preferably formed

as to be less than the wavelengths of visible light region. For example, when the wavelengths of visible light region is λ, it is preferably λ/100 to λ/5, more preferably λ/50 to λ/5 and most preferably λ/30 to λ/10. The thickness of respective layers constituting periodic multilayered structure is preferably thin; however, as the thickness is reduced, the number of laminating times is increased in order to obtain required total thickness. Therefore, the number of laminating times of respective layers should be determined to give each layer an optimum thickness by adjusting material, refractive index, thickness ratio and total thickness while considering required optical properties of the first optically anisotropic layer and resultant coloring due to mutual interference of the layers. For instance, the total thickness of periodic multilayered structure is preferably adjusted from 400nm to 700nm.

The thickness of the first optically anisotropic layer is not particularly limited and may be adjusted accordingly and it is preferably 100μm to 1,500μm.

-- Forming of Alignment Layer --

In the alignment layer forming, a layer by which the alignment direction of the liquid crystal structure in the second optically anisotropic layer is determined is formed on or above the first optically anisotropic layer.

The alignment layer is not particularly limited and may be selected accordingly and includes, for example, a rubbed alignment layer containing an organic compound (preferably a polymer); an alignment layer having a micro groove; an alignment layer containing an organic compound such as ω-tricosnoic acid, dioctadecyldimethylammonium chloride or methyl stearate, deposited according to Langmuir-Blodgett method (LB film); an alignment layer made up of an inorganic compound deposited by oblique vapor deposition; and an alignment layer having an aligning function as a result of application of electric field, magnetic field

or light. Among them, the rubbed alignment layer containing an organic compound is preferred.

The rubbing can be carried out by any procedure selected accordingly. For example, the surface of the film made up of an organic compound is rubbed with paper or cloth several times in a certain direction.

The organic compound is not particularly limited and may be selected according to the alignment condition (particularly the alignment angle) of the liquid crystal structure and includes, for example, a polymer for alignment layer which does not reduce the surface energy of resultant alignment layer for horizontal alignment of the liquid crystal structure.

The specific examples of polymer for alignment layer for aligning the liquid crystal structure in a direction perpendicular to the rubbing direction are modified polyvinyl alcohols, acrylic copolymers, polyimides and polyamic acid. Of these, polyimides which excel in alignment properties are more preferred.

The thickness of alignment layer is not particularly limited and may be adjusted accordingly. It is preferably 0.01μm to 5μm and more preferably 0.02μm to 2μm.

-- Forming of Second Optically Anisotropic Layer --

In the second optically anisotropic layer forming, an optically anisotropic layer using at least a polymerizable liquid crystal compound is formed on the alignment layer.

A solution of the polymerizable liquid crystal compound having liquid crystal structure is applied to the alignment layer to form a coated layer. The solution is applied by, for example, wire bar coating, gravure coating, micro gravure coating and dye coating. From the perspective of reducing uneven dryness by

minimizing coated amount of wet solution, micro gravure coating and gravure coating are preferred, while from the perspective of uniform thickness in a lateral direction and uniform thickness in a longitudinal direction with time after being coated, rotating gravure coating is more preferred.

The polymerizable liquid crystal compound is not particularly limited and may be selected accordingly. For example, a polymerizable liquid crystal compound having a liquid crystal structure which is capable of fixing an alignment condition is preferably used. And a polymerizable liquid crystal compound having a liquid crystal structure such as rod-shaped liquid crystal structure, discotic liquid crystal structure or banana-shaped liquid crystal structure is more preferable and a polymerizable liquid crystal compound having a discotic liquid crystal structure is most preferable.

The polymerizable liquid crystal compound may also include other components selected accordingly.

Examples of other components include a polymerization initiator for starting a polymerization reaction of the polymerizable liquid crystal compound and a solvent for preparing a coating solution for the polymerizable liquid crystal compound.

-- Heat Treatment --

In the heat treatment, a second optically anisotropic layer is heated in order to equalize, mature and maintain the alignment.

The coated layer is heated at 60°C to 120°C to volatilize and dry the solvent. After drying the solvent, in order to mature the alignment of the polymerizable compound having liquid crystal structure, the heating temperature is controlled at a range of 85°C to 180°C or until the liquid crystal compound shows a ND layer and

ultraviolet rays with an amount of energy enough to perform a curing reaction are irradiated to the polymerizable compound to polymerize and fix the polymerizable compound having liquid crystal structure to thereby yield an optically anisotropic layer.

-- Polymerizing/Curing of Second Optically Anisotropic Layer --

In the polymerizing and curing of the second optically anisotropic layer, the second optically anisotropic layer is polymerized and cured while keeping the above-noted transition temperature.

The polymerization and curing of the second optically anisotropic layer with matured alignment is not particularly limited and may be selected accordingly as long as alignment of the liquid crystal layer can be fixed. For instance, a curing reaction of the second optically anisotropic layer is performed by irradiating active rays for photopolymerization. The active rays for photopolymerization can be suitably selected from electron beam, ultraviolet rays, visible beam and infrared rays (heat rays) accordingly. Typically, ultraviolet rays are preferred. Examples of light source for ultraviolet rays include low pressure mercury lamps (bactericidal lamp, fluorescent chemical lamp and blacklight lamp), high voltage discharge lamps (high-pressure mercury lamp and metal halide lamp) and short arc discharge lamps (ultra-high pressure mercury lamp, xenon lamp and mercury xenon lamp).

Examples of radical polymerization initiators for polymerization reaction of ethylene-unsaturated groups include azobis compounds, peroxides, hydro peroxides, redox catalysts such as potassium persulfate, ammonium persulfate, tert-butyl peroctoate, benzoyl peroxide, isopropyl percarbonate, 2, 4-dichlobenzoyl peroxide, methyl ethyl ketone peroxide, cumene hydroperoxide, dicumyl peroxide, azobis isobutylonitril, 2,2'-azobis (2-amidinopropane) hydrochroride or benzophenones,

acetophenones, benzoins and thioxanthenes. Details of these radical polymerization initiators are described in "Ultraviolet curable system" pp. 63-147, 1989 by General Technical Center (Japanese title: "Shigaisen-kouka system" by Sogo Gijutsu Center).

General examples of ultraviolet ray-activated cationic catalyst used for polymerization of a compound having epoxy groups include allyl diazonium salt (hexafluorophosphate, tetrafluoroborate, and the like), diallyl iodonium salt, allylonium salt of VIa-groups (allyl sulfonium salt having anion such as PF_6, AsF_6, SbF_6, and the like).

When a curing reaction is performed using a radical reaction, to avoid delay in polymerization reaction due to the presence of oxygen in the air, irradiating the above-mentioned active rays in a nitrogen atmosphere is preferable because of shorter reaction time and smaller amount of light needed for curing reaction.

-- Forming of Protective Layer --

The protective layer forming is a step for forming a protective layer and is not particularly limited and may be selected accordingly. For instance, it is preferred that in the polymerizing and curing of second optically anisotropic layer, the second optically anisotropic layer is first polymerized and cured to fix the alignment of the liquid crystal layer and then a protective layer is laminated on the second optically anisotropic layer. The protective layer blocks oxidation reaction of the second optically anisotropic layer formed of organic material to improve durability and it is preferably laminated on the second optically anisotropic layer.

The method for forming the protective layer is not particularly limited and may be selected accordingly. When organic material is used, for example, a preferred method is that a solution for forming protective layer is prepared and

coated on the second optically anisotropic layer for lamination.

The coating method is not particularly limited and examples include extrusion coating, direct gravure coating, reverse gravure coating, dye coating and spin-coating.

When inorganic material is used, the protective layer is preferably formed, for example, by a deposition method in which a material is deposited for lamination.

The deposition method is not particularly limited and may be selected accordingly. Examples of deposition method include chemical vapor deposition (CVD) in which a sample is left in a gas material atmosphere to form a thin layer on the surface of the sample by chemical reaction, and physical vapor deposition (PVD) in which raw materials in a state of particles are attached to the surface of the sample by vapor deposition or sputtering to form a thin layer.

Among them, physical vapor deposition in which a layer is physically prepared by sputtering under reduced pressure using a sputtering target formed of metal which is a material of the protective layer is more preferred.

-- Forming of Antireflective Layer --

In the forming of antireflective layer, an antireflective layer is formed on or above the cured second optically anisotropic layer. For instance, when an inorganic material is used, an antireflective layer is formed on or above a second optically anisotropic layer by vapor deposition and when an organic material is used; an antireflective layer is formed by coating.

The deposition is not particularly limited and may be carried out by any method accordingly. The deposition is carried out, for example, by chemical vapor deposition (CVD) in which a sample is left in a gas atmosphere to form a layer on the surface of the sample by chemical reaction and physical vapor deposition (PVD) in

which raw materials in a state of particles are physically attached to the sample to form a layer.

Among them, physical vapor deposition (PVD), in which a layer is physically prepared by sputtering under reduced pressure using a sputtering target formed of metal which is a material of the antireflective layer, is preferably used.

The coating method is not particularly limited and may be selected accordingly. The coating may be performed by wire bar coating, gravure coating, micro gravure coating and dye coating, for example. From the perspective of reducing uneven dryness by minimizing the coated amount of a wet solution, micro gravure coating and gravure coating are preferred, while from the perspective of uniform thickness in a lateral direction and uniform thickness in a longitudinal direction with time after being coated, rotating gravure coating is more preferred.

-- Forming of Other Layers --

In the forming of other layers, another second optically anisotropic layer may be formed of which alignment direction differs from the second optically anisotropic layer previously formed. This is formed after each step for forming the first optically anisotropic layer, the alignment layer, the second optically anisotropic layer and heat treatment for polymerizing and curing of the second optically anisotropic layer is repeated at least once in this order.

Other layers may be arbitrarily formed on the antireflective layer after forming the antireflective layer. Examples include anti-glare layer, antifouling layer and antistatic layer.

-- Configuration of Wave Plate --

The wave plate can have any configuration suitably selected accordingly. Preferred examples of configuration are the following first, second, third, fourth,

fifth, sixth, seventh and eighth configurations. The same layers as used for the optical compensatory element are given the same codes and the explanations are omitted.

(Wave Plate according to First Configuration)

FIG. 9 is a sectional view schematically showing a wave plate according to the first configuration of the present invention.

The wave plate according to the first configuration has a first optically anisotropic layer on one surface of the support and two layers of the second optically anisotropic layer having different alignment directions on the other surface of the support. Specifically, with reference to FIG. 9, wave plate 210 according to the first configuration has alignment layer 4A, second optically anisotropic layer 3A, alignment layer 4B, second optically anisotropic layer 3B, protective layer 6P and antireflective layer 5B disposed in this order on one surface of support 1 arranged so that the antireflective layer 5B constitutes an outermost surface. The wave plate 210 further has first optically anisotropic layer 2 and antireflective layer 5A laminated in this order on the other surface of the support 1 arranged so that the antireflective layer 5A constitutes another outermost surface.

The protective layer 6P is laminated on the second optically anisotropic layers 3B for improving durability of the second optically anisotropic layers 3A and 3B.

The first optically anisotropic layer 2 has a periodic multilayered structure containing TiO_2 layer 2A and SiO_2 layer 2B. The thickness of each layer is approximately 15nm. The first optically anisotropic layer 2 may also serve as an antireflective layer by having a periodic multilayered structure.

The rubbing directions of alignment layers 4A and 4B preferably differ from

each other by 90 degrees. By arranging these alignment layers 4A and 4B this way, it is possible for the alignment direction of liquid crystal molecules contained in the polymerizable liquid crystal compounds of the second anisotropic layers 3A and 3B to differ from each other by 90 degrees.

(Wave Plate according to Second Configuration)

FIG. 10 is a sectional view schematically showing a wave plate according to the second configuration of the present invention.

The wave plate according to the second configuration has a first optically anisotropic layer and a second optically anisotropic layer laminated in this order on the support.

With reference to FIG. 10, wave plate 220 according to the second configuration has first optically anisotropic layer 22, alignment layer 24, second optically anisotropic layer 23, protective layer 26P and antireflective layer 25B laminated in this order on one surface of support 21 arranged so that the antireflective layer 25B constitutes an outermost surface and has an antireflective layer 25A on the other surface of the support 21.

The protective layer 26P is laminated on the second optically anisotropic layer 23 for improving durability of the second optically anisotropic layer 23.

The first optically anisotropic layer 22 may have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration.

Two layers of the wave plate 220 according to the second configuration can be used as laminate. In this case, rubbing directions of the alignment layers in the respective wave plates preferably differ from each other by 90 degrees.

Such a wave plate having the respective layers disposed on one surface of

the support, as in the wave plate 220 according to the second configuration, can be generally satisfactorily handled and easily prepared, while these properties depend on the materials of the respective layers and combinations thereof.

(Wave Plate according to Third Configuration)

FIG. 11 is a sectional view schematically showing a wave plate according to the third configuration of the present invention.

The wave plate according to the third configuration has two second anisotropic layers having different alignment direction disposed on one surface of the support.

With reference to FIG. 11, wave plate 230 according to the third configuration has first optically anisotropic layer 32, alignment layer 34A, second optically anisotropic layer 33A, alignment layer 34B, second optically anisotropic layer 33B, protective layer 36P and antireflective layer 35B laminated in this order on one surface of support 31 arranged so that the antireflective layer 35B constitutes an outermost surface, and has antireflective layer 35A on the other surface of the support 31.

The protective layer 36P is laminated on the second optically anisotropic layers 33B for improving durability of the second optically anisotropic layers 33A and 33B.

The first optically anisotropic layer 32 can have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration.

The rubbing directions of the alignment layers 34A and 34B preferably differ from each other by 90 degrees. By arranging these alignment layers 34A and 34B this way, it is possible for the alignment directions of the liquid crystal structures in

the polymerizable liquid crystal compounds of the second anisotropic layers 33A and 33B to differ from each other by 90 degrees.

(Wave Plate according to Fourth Configuration)

FIG. 12 is a sectional view schematically showing a wave plate according to the fourth configuration of the present invention.

The wave plate according to the fourth configuration has two second anisotropic layers having different alignment directions disposed with the interposition of the support.

With reference to FIG. 12, wave plate 240 according to the fourth configuration has first optically anisotropic layer 42, alignment layer 44A, second optically anisotropic layer 43A, protective layer 46P and antireflective layer 45B laminated in this order on one surface of support 41 arranged so that the antireflective layer 45B constitutes an outermost surface, and has alignment layer 44B, second optically anisotropic layer 43B, protective layer 46PA and antireflective layer 45A laminated in this order on the other surface of the support 41.

The protective layers 46P and 46PA are laminated on each second optically anisotropic layer 43A and 43B for improving durability of the second optically anisotropic layers 43A and 43B.

The first optically anisotropic layer 42 can have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration.

The rubbing directions of the alignment layers 44A and 44B preferably differ from each other by 90 degrees. By arranging these alignment layers 44A and 44B this way, it is possible for alignment directions of the liquid crystal structures in the polymerizable liquid crystal compounds of the second anisotropic layers 43A and

43B to differ from each other by 90 degrees.

(Wave Plate according to Fifth Configuration)

FIG. 13 is a sectional view schematically showing a wave plate according to the fifth configuration of the present invention.

The wave plate according to the fifth configuration has the first optically anisotropic layer and the second anisotropic layer on at least one surface of the support.

With reference to FIG. 13, wave plate 250 according to the fifth configuration has alignment layer 54, second optically anisotropic layer 53, protective layer 56P, first optically anisotropic layer 52 and antireflective layer 55B laminated in this order on one surface of support 51 arranged so that the antireflective layer 55B constitutes an outermost surface, and has antireflective layer 55A on the other surface of the support 51.

The protective layer 56P is laminated on the second optically anisotropic layer 53 for improving durability of the second optically anisotropic layer 53.

The first optically anisotropic layer 52 can have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration.

Two layers of the wave plate 250 according to the fifth configuration can be used as laminate. In this case, rubbing directions of the alignment layers in the respective wave plates preferably differ from each other by 90 degrees.

(Wave Plate according to Sixth Configuration)

FIG. 14 is a sectional view schematically showing a wave plate according to the sixth configuration of the present invention.

The wave plate according to the sixth configuration has two second optically

anisotropic layers having different alignment directions. With reference to FIG. 14, wave plate 260 according to the sixth configuration has alignment layer 64A, second optically anisotropic layer 63A, alignment layer 64B, second optically anisotropic layer 63B, protective layer 66P, first optically anisotropic layer 62 and antireflective layer 65B laminated in this order on one surface of support 61 arranged so that the antireflective layer 65B constitutes an outermost surface, and has antireflective layer 65A on the other surface of the support 61.

The protective layer 66P is laminated on the second optically anisotropic layer 63B for improving durability of the second optically anisotropic layer 63B.

The first optically anisotropic layer 62 can have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration.

The rubbing directions of the alignment layers 64A and 64B preferably differ from each other by 90 degrees. By arranging these alignment layers 64A and 64B this way, it is possible for the alignment direction of the liquid crystal structures contained in the polymerizable liquid crystal compounds of the second anisotropic layers 63A and 63B to differ from each other by 90 degrees.

(Wave Plate according to Seventh Configuration)

FIG. 15 is a sectional view schematically showing a wave plate according to the seventh configuration of the present invention.

The wave plate according to the seventh configuration has two second anisotropic layers having different alignment directions disposed with the interposition of the support.

With reference to FIG. 15, wave plate 270 according to the seventh configuration has alignment layer 74A, second optically anisotropic layer 73A,

protective layer 76P, first optically anisotropic layer 72 and antireflective layer 75B laminated in this order on one surface of support 71 arranged so that the antireflective layer 75B constitutes an outermost surface, and has alignment layer 74B, second optically anisotropic layer 73B, protective layer 76PA, first optically anisotropic layer 72, and antireflective layer 75A laminated in this order on the other surface of the support 71 arranged so that the antireflective layer 75A constitutes another outermost surface.

The protective layers 76P and 76PA are laminated on the second optically anisotropic layers 73A and 73B for improving durability of the second optically anisotropic layers 73A and 73B.

The first optically anisotropic layer 72 can have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration. Having at least one layer of the first optically anisotropic layer 72 is satisfactory and one of the two first optically anisotropic layers 72 may be omitted.

The rubbing directions of the alignment layers 74A and 74B preferably differ from each other by 90 degrees. By arranging these alignment layers 74A and 74B this way, it is possible for the alignment directions of the liquid crystal structures contained in the polymerizable liquid crystal compounds of the second anisotropic layers 73A and 73B to differ from each other by 90 degrees.

(Wave Plate according to Eighth Configuration)

FIG. 16 is a sectional view schematically showing a wave plate according to the eighth configuration.

The wave plate according to the eighth configuration has the first optically anisotropic layer on one surface of the support and the second optically anisotropic layer on the other surface of the support.

With respect to FIG. 16, wave plate 280 according to the eighth configuration has alignment layer 84, second optically anisotropic layer 83, protective layer 86P and antireflective layer 85B laminated in this order on one surface of support 81 arranged so that the antireflective layer 85B constitutes an outermost surface, and has first optically anisotropic layer 82 and antireflective layer 85A laminated in this order on the other surface of the support 81 arranged so that the antireflective layer 85A constitutes another outermost surface.

The protective layer 86P is laminated on the second optically anisotropic layer 83 for improving durability of the second optically anisotropic layer 83.

The first optically anisotropic layer 82 can have a structure similar to that of the first optically anisotropic layer 2 in the wave plate 210 according to the first configuration.

Two layers of the wave plate 280 according to the eighth configuration can be used as laminate. In this case, rubbing directions of the alignment layers in the respective wave plates preferably differ from each other by 90 degrees.

In the wave plates, the optical properties of the first optically anisotropic layers 2, 22, 32, 42, 52, 62, 72 and 82 are determined depending on the pitch of periodic structure of the periodic multilayered structures containing inorganic materials. Therefore, these wave plates can avoid optical ununiformity such as variation in refractive index or reduced haze in the surface of a polymer film induced by residual stress when the polymer film is uniaxially stretched to yield predetermined optical properties. Thereby it is possible to achieve highly uniform optical properties in the surface of the first optically anisotropic layer and optically compensate the liquid crystal layer in black state more precisely.

It is possible to control in-plane thickness of the first optically anisotropic

layers 2, 22, 32, 42, 52, 62, 72, and 82 to be in a range of several tens of nanometers, and having high smoothness and improving optical uniformity in the surfaces of the first optically anisotropic layers are possible. Thus wave plates can optically compensate the liquid crystal layer in black state more precisely and can reduce light leakage and prevent streaky unevenness.

In addition, the first optically anisotropic layers 2, 22, 32, 42, 52, 62, 72 and 82 do not swell or shrink even in use at high temperature and humidity over a long period of time.

Moreover, because the protective layers 6P, 26P, 36P, 46P, 46PA, 56P, 66P, 76P, 76PA and 86P are laminated on the surface of the second optically anisotropic layers 3, 23, 33A, 33B, 43, 53, 63A, 63B, 73 and 83, suppressing oxidation reaction of the second optically anisotropic layers is possible.

The above-mentioned wave plates as a whole can minimize changes in optical properties over a long period of time and their durability are remarkably improved. In addition, for each above-mentioned embodiment, an embodiment omitting the first optically anisotropic layer for simplification may be possible, however, the wave plate of the present invention exhibits the same durability in these simplified embodiment as long as it is being held by the protective layers 6P, 26P, 36P, 46P, 46PA, 56P, 66P, 76P, 76PA and 86P.

In particular, the wave plates according to the first, second and third configurations have the first optically anisotropic layers 2, 22 and 32 on or above the supports 1, 21 and 31, and the in-plane thickness of these first optically anisotropic layers can be controlled within the range of dozen nanometers. Thus, the first optically anisotropic layers 2, 22 and 32 can prevent unevenness in in-plane thickness with high degree of precision; therefore it is possible to have highly smooth surfaces.

Since the second optically anisotropic layers 3, 23 and 33 are laminated on the first optically anisotropic layers 2, 22 and 32 having highly smooth surfaces, in-plane alignment failures of these second optically anisotropic layers can be prevented. The resultant wave plates can optically compensate the liquid crystal layer in black state more precisely and prevent light leakage at a wide viewing angle. By utilizing the wave plate in large-screen liquid crystal monitors or liquid crystal projectors which require wide viewing angle, producing liquid crystal displays and liquid crystal projectors with high quality images and high contrast are possible.

(Liquid Crystal Display)

The liquid crystal display according to the present invention has at least a pair of electrodes and a liquid crystal device having liquid crystal structures encapsulated in between the pair of electrodes, a wave plate disposed on one or both surfaces of the liquid crystal device, a polarizing element facing the liquid crystal device and the wave plate. It may also contain other configurations accordingly and the wave plate is the wave plate according to the present invention.

The display mode of the liquid crystal device is not particularly limited and may be selected accordingly. Examples include TN (Twisted Nematic) mode, VA (Vertical Alignment) mode, IPS (In-Plane Switching) mode, OCB (Optically Compensatory Bend) mode and ECB (Electrically Controlled Birefringence) mode. Among them, TN mode is particularly preferable because of its high contrast ratio.

FIGS 21 through 24 are schematic block diagrams showing the liquid crystal displays of the present invention.

To promote better understanding, similar to each schematic block diagram of the liquid crystal displays using the optical compensatory element of the present invention, light emitted from a light source enters from the bottom of the drawings

and irradiated toward upper side. When the polarizing plate and/or the second optically anisotropic layer contains two components, the one that is present in the upper side of the drawings is called as "upper" component, and the one in the lower side of the drawings is called as "lower" component.

With reference to FIG. 21, liquid crystal display 100 has upper polarizing element 101 (analyzer) and lower polarizing element 116 (polarizer) which are a pair of polarizing elements wherein absorption axis 102 and 115 are substantially perpendicular to each other and are arranged in cross nicol disposition, wave plate 208 disposed between the upper and lower polarizing elements 101 and 116, and liquid crystal device 114 (liquid crystal cell).

Polarization beam splitters such as Glan-Thompson prisms may be arranged as polarizing element facing the liquid crystal device 114 instead of upper and lower polarizing elements 101 and 116.

The liquid crystal device 114 has an upper substrate 109 and lower substrate 113 which are glass substrates and are placed opposite of each other, and nematic liquid crystal 111, for example, encapsulated in between these upper and lower substrates 109 and 113. The upper substrate 109 and the lower substrates 113 have components (not shown) such as pixel electrodes and circuit elements (thin-film transistors) on their surfaces facing each other. The upper substrate 109 and the lower substrate 113 further have upper and lower alignment layers (not shown) respectively on their surfaces adjacent to the nematic liquid crystal 111. The surfaces of the alignment layers adjacent to the nematic liquid crystal 111 have been rubbed for aligning the alignment directions of liquid crystal molecules. The rubbing direction, direction of grooves formed as a result of rubbing, of 110 and 112 in the upper and lower alignment layers are substantially perpendicular to each

other in the case of a liquid crystal display of TN mode, for example.

FIG. 21 illustrates the alignment condition of liquid crystal molecules under a normal condition where no voltage is applied to the liquid crystal device 114. Liquid crystal molecules in the nematic liquid crystal 111 near the upper substrate 109 and the lower substrate 113 are arranged in directions substantially identical to the rubbing directions of 110 and 112 by the action of rubbing on the alignment layers (not shown). Since the rubbing directions of 110 and 112 are perpendicular to each other, the liquid crystal molecules in the nematic liquid crystal 111 are aligned so as to have major axes twisted by 90 degrees from the upper substrate 109 toward the lower substrate 113.

The optical transmittance of the polarizing elements arranged in cross nicol disposition is preferably 0.001% or less, provided that the optical transmittance of the polarizing elements arranged in parallel nicol disposition is defined as 100%.

Each upper polarizing element 101 (analyzer) and the lower polarizing element 116 (polarizer) has a polarizing film and other additional components as necessary.

The polarizing film is not particularly limited and may be selected accordingly. Examples include a film made from hydrophilic polymer which has adsorbed a dichroic material and has been subjected to stretching for alignment. Examples of hydrophilic polymer are polyvinyl alcohols, partially formalized polyvinyl alcohols and partially saponified products of ethylene-vinyl acetate copolymers. Examples of dichroic material are iodine and dichroic dyes such as azo dyes, anthraquinone dyes and tetrazine dyes.

The stretch alignment procedure can be carried out by using any device selected accordingly such as a lateral uniaxial tenter stretching machine in which the

adsorption axis of the polarizing film is substantially perpendicular to longitudinal direction. The lateral uniaxial tenter stretching machine is advantageous for that it can avoid foreign matters entering during lamination.

A stretch alignment method described in JP-A No. 2002-131548 can be also employed for stretch alignment procedure.

Other components are not particularly limited and may be selected accordingly. Examples include transparent protective layer, antireflective layer and anti-glare layer each disposed on or above one or both surfaces of the polarizing film.

Examples of upper and lower polarizing elements 101 and 116 include a polarizing plate having a transparent protective layer at least on one surface of the polarizing film, the one having polarizing film integrally on one surface of the wave plate 208 as a support, and the like.

The material for transparent protective layer is not particularly limited and may be selected accordingly. Examples include cellulose esters such as cellulose acetate, cellulose acetate butyrate and cellulose propionate; polycarbonates; polyolefins; polystyrenes; and polyesters.

Suitable examples of material of transparent protective layer are cellulose triacetate, polyolefins such as ZEONEX, ZEONOR (both manufactured by NIPPON ZEON CO., LTD.) and ARTON (manufactured by JSR Corporation).

Non-birefringent optical resin materials described in JP-A No. 08-110402 and No. 11-293116 are also usable.

The alignment axis (slow axis) of the transparent protective layer may be arranged in any direction; however, it is preferably in parallel with the longitudinal direction for easy and convenient operation. The angle formed between slow axis

(alignment axis) of transparent protective layer and adsorption axis (stretching axis) of the polarizing film is not particularly limited and may be adjusted according to the purpose of polarizing plates. When the polarizing film is prepared by using the lateral uniaxial tenter stretching machine, the slow axis (alignment axis) of transparent protective layer is in a direction substantially perpendicular to the adsorption axis (stretching axis) of the polarizing film.

The retardation of the transparent protective layer is not particularly limited and may be selected accordingly and it is preferably, for example, 10nm or less and more preferably 5nm or less when measured by light having a wavelength of 632.8nm.

The retardation of the cellulose acetate, if used, is preferably less than 3nm and more preferably 2nm or less for minimizing the retardation variation with temperature and humidity in the environment.

The polarizing plate can be prepared by any method selected accordingly and it is preferably prepared by continuously laminating onto a long polarizing film fed as a roll so that the longitudinal directions meet each other.

The polarizing film and the polarizing plate are preferably fixed to the wave plate for preventing misalignment of the optical axis and also preventing foreign matter such as dust from entering.

The antireflective layer is not particularly limited and may be selected accordingly. Examples include coated layer of fluorine-containing polymer and optical interference layer such as multilayered metal layer prepared by vapor deposition.

The upper and lower polarizing elements 101 and 116 preferably have optical properties and durability (short-term and long-term storage stability) equal to

or higher than those of commercially available high-contrast product such as HLC2-5618 manufactured by Sanritz Corporation.

The wave plate 208 is the wave plate according to the present invention.

When the wave plate is integrated into the liquid crystal display 100, the contrast ratio Vw/Vb in front of the liquid crystal display 100 is preferably 100:1 or more, more preferably 200:1 or more and most preferably 300:1 or more. The contrast ratio is the ratio of transmittance of the liquid crystal display 100 in white state, "Vw" to the transmittance in black state, "Vb".

The maximum transmittance in black state is preferably 10% or less and more preferably 5% or less of Vw in an azimuth direction inclined 60 degrees from the normal direction to the display surface of the liquid crystal display 100. By using the wave plate having such properties, the liquid crystal display exhibits high contrast and wide viewing angles with no tone reversal.

To accurately compensate a liquid crystal device having a large residual twisted component, the liquid crystal display preferably does not optically quench in any direction and has an optical transmittance of 0.01% or more in all directions when the wave plate is disposed between a pair of polarizing elements arranged in cross nicol disposition and the wave plate is rotated in the normal direction to the wave plate as a rotation axis.

The wave plate 208 is disposed between upper polarizing element 101 and liquid crystal device 114 and contains a first optically anisotropic layer 107, an upper second optically anisotropic layer 103 and a lower second optically anisotropic layer 105.

The respective optically anisotropic layers constituting the wave plate 208 are arranged so that the angle formed between the rubbing direction 104 of an

alignment layer in the upper second optically anisotropic layer 103 and rubbing direction 110 of an upper alignment layer in the upper substrate 109 of the liquid crystal device 114 is 180° and the angle formed between rubbing direction 106 of an alignment layer in the lower second optically anisotropic layer 105 and rubbing direction 112 of a lower alignment layer in the lower substrate 113 of the liquid crystal device 114 is 180°.

The rubbing directions in the alignment layers in the second optically anisotropic layer and in the substrate of the liquid crystal device may be exchanged. More specifically, the layers may be arranged so that the angle formed between the rubbing direction 106 of the alignment layer in the lower second optically anisotropic layer 105 and the rubbing direction 110 of the upper alignment layer in the upper substrate 109 of the liquid crystal device 114 is 180° and the angle formed between the rubbing direction 104 of the alignment layer in the upper second optically anisotropic layer 103 and the rubbing direction 112 of the lower alignment layer in the lower substrate 113 of the liquid crystal device 114 is 180°.

The first optically anisotropic layer 107 is preferably arranged to be near the liquid crystal device 114.

FIG. 22 schematically illustrates the arrangement of liquid crystal molecules in a liquid crystal display of TN mode in black state, i.e., when a voltage is applied to the liquid crystal device 114. Upon application of a voltage to the liquid crystal device 114, the liquid crystal molecules change in their arrangement so that the liquid crystal molecules stand up with their major axes perpendicular to the incident plane of light. Ideally, all the liquid crystal molecules in the liquid crystal device 114 are in parallel with the incident plane of light upon application of a voltage. In actuality, however, the major axis of liquid crystal molecules in the liquid crystal

device 114 gradually stand up from the upper substrate 109 and the lower substrate 113 toward the center part of the liquid crystal device 114, as shown in FIG. 22. Thus, major axis of the liquid crystal molecules near interfaces of the upper substrate 109 and the lower substrate 113 are not in parallel with but oblique or inclined to the incident plane of light upon application of a voltage. These liquid crystal molecules being inclined to the incident plane of light fail to display black and cause light leakage at some viewing angles.

In addition, nematic liquid crystal molecules used in liquid crystal display of TN mode are generally rod-shaped and exhibit optically positive uniaxial properties. Accordingly, when the liquid crystal display 100 is viewed from an oblique direction, with the liquid crystal molecules at the center part of the liquid crystal device 114 standing up completely, birefringence occurs and the liquid crystal device fails to display black and cause light leakage at some viewing angles.

The birefringence caused by the alignment of the liquid crystal molecules in the liquid crystal device 114 in the vicinity of the upper substrate 109 and of the lower substrate 113 in black state can be optically compensated by allowing the alignment of the liquid crystal molecules in the second optically anisotropic layers 103 and 105 to be mirror symmetry. In addition, the birefringence caused by liquid crystal molecules at the center part of the liquid crystal device 114 can be optically compensated by arranging the first optically anisotropic layer 107 having optical properties of uniaxial and non-inclined negative optical indicatrix. Thus, the liquid crystal device 114 in black state as a whole can be optically compensated three-dimensionally to thereby prevent light leakage in a wide range of viewing angles.

The wave plate 208 may be placed below the liquid crystal device 114, as

shown in FIG. 23 or may be placed above or below the liquid crystal device 114 as wave plates 208a and 208b, as shown in FIG. 24. When the wave plates 108a and 108b are disposed above and below the optical crystal element 114, one of first optically anisotropic layers 107a and 107b may be omitted. When both of the first optically anisotropic layers 107a and 107b are disposed, the retardation is defined as a total of the retardations of these layers.

It is possible for the wave plate 208 to have the upper substrate 109 and the lower substrate 113 of the liquid crystal device 114 as substrates (not shown) equipped to the wave plate 208. In this case, the first optically anisotropic layers 107a and 107b shown in FIG. 24 are directly formed on the upper substrate 109 and the lower substrate 113, respectively.

(Liquid Crystal Projector)

The liquid crystal projector according to the present invention is so configured that light from a light source is applied to a liquid crystal display to allow the liquid crystal display to optically modulate the light, and the modulated light is allowed to form an image on a screen by the action of a projection optical system so as to display the image, in which the liquid crystal display is the liquid crystal display of the present invention.

The type of the liquid crystal projector is not particularly limited and may be selected accordingly. Examples include a screen-projection front projector and a rear-projection television set. The type of the liquid crystal display used for the liquid crystal projector is not particularly limited and may be selected accordingly. Preferred examples thereof include a transmission liquid crystal display and a reflective liquid crystal display.

FIG. 25 is an outside view schematically illustrating a rear-projection liquid

crystal projector.

With reference to FIG. 25, liquid crystal projector 200 has a diffusional transmittance screen 203 in front of housing 202. An image projected to the rear of the screen 203 is viewed from the front of the screen 203. Housing 202 houses a projection unit 300, and an image projected by the projection unit 300 is reflected by mirrors 206 and 207 to form an image on the rear side of the screen 203. Housing 202 of the liquid crystal projector 200 also houses other components (not shown) such as tuner circuit and circuit units for reproducing video and voice signals.

The projection unit 300 includes a liquid crystal display (not shown) as an image display device. The liquid crystal display serves to display a reproduced image of the video signal to thereby display an image projected on the screen 203.

FIG. 26 is a schematic diagram illustrating a projection unit 300.

With reference to FIG. 26, the projection unit 300 has three transmission liquid crystal devices 311R, 311G and 311B and full-color images are projected.

Light emitted from a light source 312 passes through a filter 313 to cut off ultraviolet rays and infrared rays, becomes white light including red, green and blue lights and enters a glass rod 314 along an optical axis from the light source 312 to the liquid crystal devices 311R, 311G and 311B. The incident plane of light in the glass rod 314 is located in the vicinity of the focus of a parabolic mirror used in the light source 312 and the light from the light source 312 efficiently enters the glass rod 314.

A relay lens 315 is arranged on a light output surface of the glass rod 314, and the white light going out from the glass rod 314 becomes parallel light by the action of the relay lens 315 and a subsequent collimate lens 316 and enters a mirror 317.

The white light reflected by the mirror 317 is divided into two luminous

fluxes by a dichroic mirror 318R transmitting red light only and the transmitted red light is reflected by a mirror 319 to illuminate a liquid crystal device 311R from behind.

The green and blue lights reflected by the dichroic mirror 318R are further divided into two luminous fluxes by a dichroic mirror 318G reflecting green light only. The green light reflected by the dichroic mirror 318G illuminates a liquid crystal device 311G from behind. The blue light passing through the dichroic mirror 318G is reflected by mirrors 318B and 320 to illuminate a liquid crystal device 311B from behind.

Each of the liquid crystal devices 311R, 311G and 311B are composed of a liquid crystal device of TN mode and the respective liquid crystal devices display density patterns of red, green and blue images respectively to constitute a full-color image. A composite prism 324 is placed so that its center is at the optically equal distance from these liquid crystal devices 311R, 311G and 311B, and a projector lens 325 is placed so as to face the light output surface of the composite prism 324. Two dichroic planes 324a and 324b are placed inside the composite prism 324 and they combine the red light passing through the liquid crystal device 311R, the green light passing through the liquid crystal device 311G and the blue light passing through the liquid crystal device 311B to allow the composite light to enter the projector lens 325.

The projector lens 325 is placed on a projection light axis extending from the centers of light output surfaces of the liquid crystal devices 311R, 311G and 311B to the centers of a screen 303 via the centers of the composite prism 324 and the projector lens 325. The projector lens 325 is placed so that its objective focal plane agrees with the light output surfaces of the liquid crystal devices 311R, 311G and

311B and its imaging focal plane agrees with the screen 303. Thus, the full-color image composed by the composite prism 324 is allowed to form an image on the screen 303.

Polarizing plates 326R, 326G and 326B are placed near the incident planes of illuminated light of the liquid crystal devices 311R, 311G and 311B. Optical compensatory elements 327R, 327G and 327B and polarizing plates 328R, 328G and 328B are respectively placed near the light output surfaces of the liquid crystal devices 311R, 311G and 311B. The polarizing plates 326R, 326G and 326B near the incident planes are arranged in cross nicol disposition with respect to the polarizing plates 328R, 328G and 328B near the light output surfaces. The polarizing plates 326R, 326G and 326B function as polarizers and polarizing plates 328R, 328G and 328B function as analyzers.

The liquid crystal display according to the present invention has the liquid crystal devices 311R, 311G and 311B; the polarizing plates 326R, 326G, 326B, 328R, 328G and 328B; and the optical compensatory elements 327R, 327G and 327B.

The operations of the liquid crystal devices for respective color channels, and the operations of the polarizing plates and the optical compensatory elements sandwiching these liquid crystal devices are basically the same though some differences exist based on each colored light. The operations will be illustrated below by taking a red channel as an example.

The illuminated red light reflected by the mirror 319 is converted into linearly polarized light by the action of the polarizing plate 326R near the incident plane and enters the liquid crystal device 311R. In a normally white mode, a signal voltage is applied to a pixel to thereby allow a liquid crystal of TN mode used in the liquid crystal device 311R to display black in a red image. In the procedure, liquid

crystal molecules in the liquid crystal layer have various postures in their alignment. Thus, an image light outgoing from the light output surface of the liquid crystal device 311R does not become a fully linearly polarized light but an elliptically polarized light because of optical rotation and birefringence of the liquid crystal layer even when the illuminated red light becomes a parallel pencil and enters the liquid crystal device 311R. This causes light leakage from the polarizing plate 328R serving as analyzer and fails to produce full black. In a normally black mode, slight inclination of the liquid crystal molecules causes insufficient black level.

When the light contains a component which passes through the liquid crystal molecules in the liquid crystal device at an angle in black state, the image light modulated by the liquid crystal layer becomes elliptically polarized light having an optical phase slightly different from that of linearly polarized light. This causes light leakage from the polarizing plate 328R serving as analyzer and fails to yield sufficient black level.

The liquid crystal projector of the present invention is equipped with the liquid crystal display of the present invention using the optical compensatory element of the present invention. The optical compensatory element 327R serves to optically compensate the liquid crystal layer in black state more precisely and to prevent light leakage at a wide viewing angle.

The liquid crystal projector of the present invention can thereby exhibit wide viewing angle, high contrast and high image quality.

Examples

The present invention will be described in further detail with reference to several examples below, which are not intended to limit the scope of the present invention.

(Example 1)

Example 1 is an example of the optical compensatory element 10 according to the first configuration as shown in FIG. 1, and it is the optical compensatory element in which alignment layer 4A, second optically anisotropic layer 3A, alignment layer 4B, second optically anisotropic layer 3B and antireflective layer 5B are laminated in this order on one surface of support 1, first optically anisotropic layer 2 and antireflective layer 5A are laminated in this order on the other surface of the support 1, outermost surfaces of antireflective layers 5A and 5B are held by holding members 6 and 6A and periphery side is sealed by seal 7.

< Preparation of Optical Compensatory Element >

The optical compensatory element of above configuration was prepared using a glass substrate as support 1.

- First Optically Anisotropic Layer -

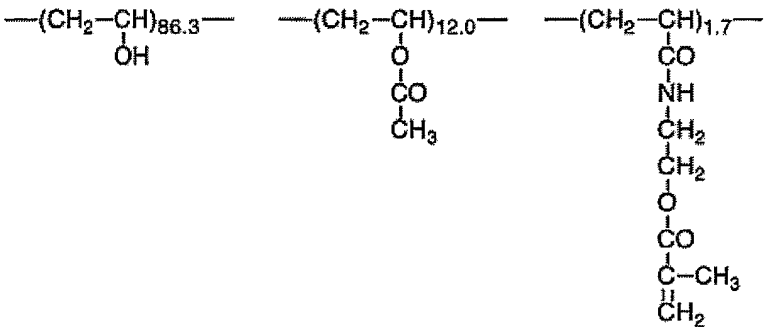
SiO_2 layer and TiO_2 layer were formed alternately on the glass substrate by vapor deposition under reduced pressure using a sputtering apparatus and the first optically anisotropic layer 2 which made up of a periodic multilayered structure of 52 layers having 26 layers each of SiO_2 and TiO_2 layer was prepared. The entire thickness of formed first optically anisotropic layer 2 was 760nm and retardation Rth was 200nm.

- Preparation of Antireflective Layer -

SiO_2 and TiO_2 layers were vapor deposited alternately on the surface of obtained first optically anisotropic layer 2 under reduced pressure using a sputtering apparatus to form an antireflective layer 5A. The thickness of formed reflective layer 5A was 0.24μm.

- Alignment Layer -

A coating solution for alignment layer containing 20g of modified polyvinyl alcohol of Structural Formula (3) below, 360g of water (solvent), 120g of methanol and 1.0g of glutaraldehyde (crosslinking agent) was prepared.



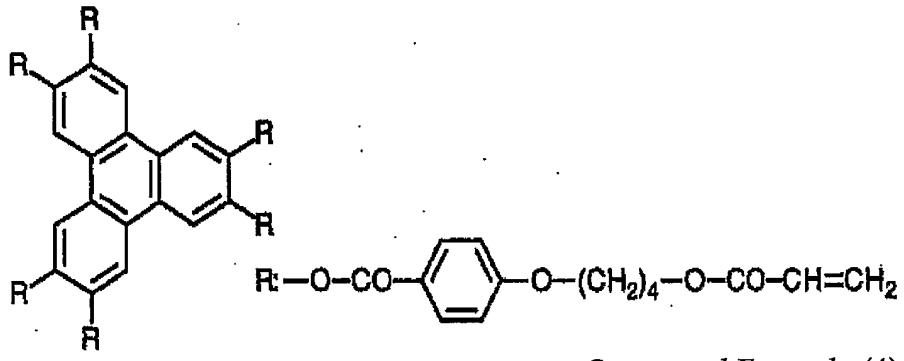
Structural Formula (3)

Next, the coating solution for alignment layer was allowed to drip into the other surface of the first optically anisotropic layer 2 and was spin coated at 1,000rpm. And the coating solution for alignment layer was then dried for 3 minutes with hot air at 100°C to form an alignment layer of 600nm thickness. Next, rubbing was performed on formed alignment layer to form an alignment layer 4A which is oriented in a predetermined alignment direction.

- Preparation of Polymerizable Liquid Crystal Compound -

4.27g of discotic liquid crystal compound of Structural Formula (4) below, 0.42g of ethylene oxide-modified trimethylolpropane triacrylate (V#360, manufactured by Osaka Organic Chemical Industry Ltd.), 0.09g of cellulose acetate butylate (CAB551-0.2, manufactured by Eastman Chemical Company), 0.02g of cellulose acetate butylate (CAB531-1, manufactured by Eastman Chemical Company), 0.14g of photopolymerization initiator (IRGACURE907, manufactured by Ciba-Geigy Chemical Corporation), 0.05g of sensitizing agent (Kayacure DETX-S,

manufactured by Nippon Kayaku Co., Ltd.) were dissolved in 15.0g of methylethylketone as a solvent to prepare a coating solution for polymerzable liquid crystal compound.



Structural Formula (4)

100ml/m^2 of coating solution for polymerizable liquid crystal compound was allowed to drip into the surface of the alignment layer 4A and was spin coated at 1,500rpm. The polymerizable liquid crystal compound was then aligned by heating for 5 minutes in the constant temperature zone of 130°C. The polymerizable liquid crystal compound was polymerized and the alignment condition of liquid crystal structure was fixed by UV irradiation using a high-pressure mercury lamp at irradiation energy of 300mJ/cm^2. And it was then stand to cool to room temperature and the second optically anisotropic layer 3A was formed.

In formed second optically anisotropic layer 3A, the discotic liquid crystal compound was hybrid aligned since the angle (alignment angle) formed between the normal line of the normal axis of disc surface and the normal line of the glass substrate increases from 10° to 62° from the glass substrate toward the air interface side. The alignment angle of the discotic liquid crystal compound was determined by measuring retardations at various observation angles using an ellipsometer

(M-150, manufactured by JASCO Corporation), assuming an optical indicatrix model based on determined retardations and calculating the alignment angle according to a technique described in "Design Concepts of the Discotic Negative Birefringence Compensation Films SID98 DIGEST".

Next, on the surface of the second optically anisotropic layer 3A, an alignment layer 4B was formed so that the alignment direction of the alignment layer 4B was substantially perpendicular to that of the alignment layer 4A. A second optically anisotropic layer 3B was formed on the surface of the alignment layer 4B in the same manner as for the second optically anisotropic layer 3A.

The material and blending quantity of the alignment layer 4B and the second optically anisotropic layer 3B were the same as for the alignment layer 4A and the second optically anisotropic layer 3A.

In the resultant second optically anisotropic layer 3B, the discotic liquid crystal compound was hybrid aligned since the angle (alignment angle) formed between the normal line of the normal axis of the disc surface and the normal line of the glass substrate increases from 7° to 60° from the glass substrate toward the air interface side. In addition, the resultant second optically anisotropic layer 3B was homogenous layer with no defects such as schlieren.

- Formation of Antireflective Layer -

An antireflective layer 5B was formed by depositing layers of SiO_2 and TiO_2 on the surface of the second optically anisotropic layer 3B alternately by vapor deposition under reduced pressure using a sputtering apparatus. The thickness of resultant antireflective layer was 0.24μm.

Finally, an optical compensatory element was produced.

- Sealing of Optical Compensatory Element -

The optical compensatory element formed was held by the holding members 6 and 6A which are in the form of glass plates so as to cover entire front and back surfaces of the optical compensatory element, and the optical compensatory element and the glass plates were attached firmly to each other. Next, work area was depressurized and the optical compensatory element was deaerated. By this procedure, impurities inside the laminated body, for example, acidic compounds such as water, oxygen, nitrogen oxide, sulfur oxide, and the like and molecules such as various solvent gases generated in the manufacturing process of the optical compensatory element are removed.

And it was filled with nitrogen gas. Finally, one-component epoxy bond (stract bond XN-21-S-B, manufactured by Mitsui Chemical, Inc.) as seal 7 was coated onto the side of the optical compensatory element followed by heating and curing at 100°C for 10 minutes to seal the optical compensatory element.

[Liquid Crystal Display]

(Example 1A)

A liquid crystal display of Example 1A was obtained by laminating the above-prepared optical compensatory element onto a liquid crystal device of TN mode in a normally white mode at a voltage of 1.5V for white state and 3V for black state.

(Example 2A)

A liquid crystal display of Example 2A was obtained similarly to Example 1A, except for sealing the optical compensatory element by placing it into a glass case and sealing the openings.

(Example 3A)

A liquid crystal display of Example 3A was obtained similarly to Example

2A except for only deaeration of the optical compensatory element under reduced pressure was performed and filling with nitrogen gas was not conducted.

(Example 4A)

A liquid crystal display of Example 4A was obtained similarly to Example 2A except for utilizing triacetylcellulose film having the same retardation value as the first optically anisotropic layer on the support of the optical compensatory element.

(Comparative Example 1A)

A liquid crystal display of Comparative Example 1A was obtained by preparing the optical compensatory element similarly to Example 4A and then a tip of the glass case was destroyed enabling to perform matter exchange with surroundings.

(Comparative Example 2A)

A liquid crystal display of Comparative Example 2A was obtained similarly to Example 1A except for the optical compensatory element was not sealed.

(Examples 1A to 4A and Comparative Examples 1A and 2A)

(Evaluation of Contrast in Liquid Crystal Display)

The contrast of liquid crystal displays of Examples 1A to 4A and Comparative Examples 1A and 2A were determined at a position with elevation angle of 20° and azimuth angle of 45° from the front of the display surface using a conoscope (manufactured by Autronic-Melcher GmbH). The contrast was determined based on the ratio of illumination intensity in white state to illumination intensity in black state (illumination intensity in white state/illumination intensity in black state).

(Examples 1B to 4B and Comparative Examples 1B and 2B)

- Preparation of Liquid Crystal Projector -

Each three liquid crystal displays corresponding to red, green, and blue colors of Examples 1A to 4A and Comparative Examples 1A and 2A were integrated into a liquid crystal projector of TN mode to yield liquid crystal projectors of Examples 1B to 4B and Comparative Examples 1B and 2B.

< Evaluation of Contrast in Liquid Crystal Projector >

With respect to the liquid crystal projectors obtained, the illumination intensities in white and black state, and the contrast ratio thereof (illumination intensity in white state/illumination intensity in black state) on the screen set at a distance of 3m from the projector lens were determined.

- Evaluation Method for Use over Time Mandatory Testing -

The use over time mandatory tests for the liquid crystal displays of Examples 1A to 4A and Comparative Examples 1A and 2A and the liquid crystal projectors of Examples 1B to 4B and Comparative Examples 1B and 2B were conducted at each accelerate condition for 96 hours using a light source equivalent to two billions lux of white light for contrast evaluation. The results are shown in Table 1.

Liquid Crystal Display

Table 1

	Contrast	
	Beginning	After Test
Example 1A	210	195
Example 2A	215	200
Example 3A	210	190
Example 4A	220	180
Comparative Example 1A	232	95
Comparative Example 2A	225	100

From the result shown in Table 1, it was concluded that contrast in the liquid crystal displays of Examples 1A to 4A were not degraded compared to the liquid crystal displays of Comparative Examples 1A and 2A.

Liquid Crystal Projector

Table 2

	Contrast	
	Beginning	After Test
Example 1B	750	740
Example 2B	750	740
Example 3B	750	730
Example 4B	650	620
Comparative Example 1B	680	300
Comparative Example 2B	760	350

From the result shown in Table 2, it was concluded that contrast in the liquid crystal displays of Examples 1B to 4B were not degraded compared to the liquid

crystal displays of Comparative Examples 1B and 2B.

(Example 5)

- Preparation of Wave Plate -

Example 5 is an example of the wave plate 210 according to the first configuration as shown in FIG. 9, and it is the wave plate in which first optically anisotropic layer 2 and antireflective layer 5A are laminated in this order on one surface of support 1 and alignment layer 4A, second optically anisotropic layer 3A, alignment layer 4B, second optically anisotropic layer 3B, protective layer 6P and antireflective layer 5B are laminated in this order on the other surface of support 1.

-- Preparation of First Optically Anisotropic Layer --

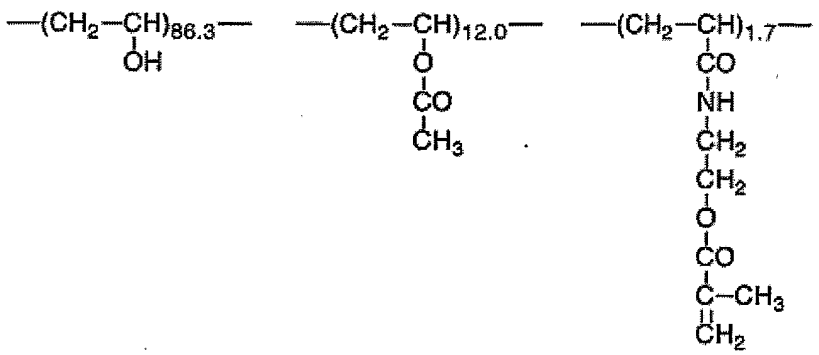
SiO_2 and TiO_2 layers were deposited alternately on the glass substrate by vapor deposition under reduced pressure using a sputtering apparatus, and the first optically anisotropic layer 2 containing periodic multilayered structure of 52 layers having 26 layers each of SiO_2 and TiO_2 layer was prepared. The entire thickness of the first optically anisotropic layer 2 was 760nm and retardation Rth was 200nm.

-- Preparation of Antireflective Layer --

SiO_2 and TiO_2 layers were deposited alternately on the surface of obtained first optically anisotropic layer 2 by vapor deposition under reduced pressure using a sputtering apparatus to form an antireflective layer 5A. The thickness of antireflective layer 5A was 0.24μm.

-- Preparation of Alignment Layer --

A coating solution for alignment layer containing 20g of modified polyvinyl alcohol of Structural Formula (3) below, 360g of water (solvent), 120g of methanol and 1.0g of glutaraldehyde (crosslinking agent) was prepared.

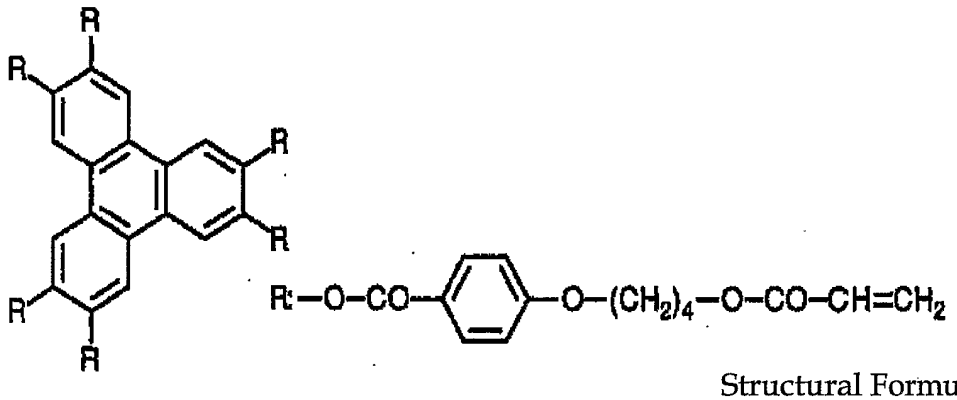


Structural Formula (3)

Next, 100ml/m^2 of the coating solution for alignment layer was allowed to drip into the opposite surface of the first optically anisotropic layer 2 and was spin coated at 1,000rpm. And the coating solution for alignment layer was then dried for 3 minutes with hot air at 100°C to form an alignment layer of 600nm thickness. Next, rubbing was performed on the alignment layer to prepare the alignment layer 4A which is oriented in a predetermined alignment direction.

-- Preparation of Polymerizable Liquid Crystal Compound -

4.27g of discotic liquid crystal compound of Structural Formula (4) below, 0.42g of ethylene oxide-modified trimethylolpropane triacrylate (V#360, manufactured by Osaka Organic Chemical Industry Ltd.), 0.09g of cellulose acetate butylate (CAB551-0.2, manufactured by Eastman Chemical Company), 0.02g of cellulose acetate butylate (CAB531-1, manufactured by Eastman Chemical Company), 0.14g of photopolymerization initiator (IRGACURE907, manufactured by Ciba-Geigy Chemical Corporation), 0.05g of sensitizing agent (Kayacure DETX-S, manufactured by Nippon Kayaku Co., Ltd.) were dissolved in 15.0g of methylethylketone as a solvent to prepare a coating solution for polymerzable liquid crystal compound.



Structural Formula (4)

100ml/m^2 of the coating solution for polymerizable liquid crystal compound was allowed to drip into the surface of the alignment layer 4A and was spin coated at 1,500rpm. The polymerizable liquid crystal compound was then aligned by heating for 5 minutes in constant temperature zone of 130°C. The polymerizable liquid crystal compound was polymerized and the alignment condition of liquid crystal structure was fixed by UV irradiation using a high-pressure mercury lamp at irradiation energy of 300mJ/cm^2. And it was then stand to cool to room temperature and the second optically anisotropic layer 3A was formed.

In resultant second optically anisotropic layer 3A, the discotic liquid crystal compound was hybrid aligned since the angle (alignment angle) formed between the normal line of the normal axis of the disc surface and the normal line of the glass substrate increases from 10° to 62° from the glass substrate toward the air interface side. The alignment angle of the discotic liquid crystal compound was determined by measuring retardations at various observation angles using an ellipsometer (M-150, manufactured by JASCO Corporation), assuming a refractive index ellipsoid model based on measured retardations and calculating the alignment angle according to a technique described in "Design Concepts of the Discotic Negative

Birefringence Compensation Films SID98 DIGEST".

Next, on the surface of the second optically anisotropic layer 3A, an alignment layer 4B was formed so that the alignment direction of the alignment layer 4B was substantially perpendicular to that of the alignment layer 4A. A second optically anisotropic layer 3B was formed on the surface of the alignment layer 4B in the same manner as for the second optically anisotropic layer 3A.

The material and blending quantity of the alignment layer 4B and the second optically anisotropic layer 3B were the same as for the alignment layer 4A and the second optically anisotropic layer 3A.

In resultant second optically anisotropic layer 3B, the discotic liquid crystal compound was hybrid aligned since the angle (alignment angle) formed between the normal line of the normal axis of the disc surface and the normal line of the glass substrate increases from 7° to 60° from the glass substrate toward the air interface side. In addition, the resultant second optically anisotropic layer 3B was homogenous layer with no defects such as schlieren.

-- Preparation of Protective Layer –

A protective layer 6P was prepared by depositing alumina on the surface of obtained second optically anisotropic layer 3B by vapor deposition after the second optically anisotropic layer 3B was washed in a glass washing bath. The thickness of prepared protective layer 6P was 0.2μm.

-- Preparation of Antireflective Layer –

An antireflective layer 5B was prepared by depositing SiO_2 and TiO_2 layers alternately on the surface of obtained protective layer 6P by vapor deposition under reduced pressure using a sputtering apparatus. The thickness of prepared antireflective layer 5B was 0.24μm.

(Example 5A)

- Preparation of Liquid Crystal Display -

A liquid crystal display of Example 5A was prepared by laminating the above-prepared wave plate onto a liquid crystal device of TN mode in a normally white mode at a voltage of 1.5V for white state and 3V for black state.

(Example 6A)

A liquid crystal display of Example 6A was prepared similarly to Example 5A except for the thickness of the protective layer 6P of Example 5A was changed from 0.2μm to 0.4μm.

(Example 7A)

A liquid crystal display of Example 7A was prepared similarly to Example 5A except for the thickness of the protective layer 6P of Example 5A was changed from 0.2μm to 0.8μm.

(Comparative Example 3A)

A liquid crystal display of Comparative Example 3A was prepared similarly to Example 5A except for not disposing the protective layer 6P of Example 5A.

(Examples 5A to 7A and Comparative Example 3A)

- Evaluation of Contrast in Liquid Crystal Display -

Each contrast of the above-prepared liquid crystal displays of Examples 5A to 7A and Comparative Example 3A was determined at a position with elevation angle of 20° and azimuth angle of 45° from the front of the display surface using a conoscope (manufactured by Autronic-Melcher GmbH). The contrast was determined based on the ratio of illumination intensity in white state to illumination intensity in black state (illumination intensity in white state/illumination intensity in black state). The surface condition was observed by eyes.

(Examples 5B to 7B and Comparative Example 3B)

- Preparation of Liquid Crystal Projector –

Each three liquid crystal displays corresponding to red, green and blue colors of Examples 5A to 7A and Comparative Example 3A were integrated into a liquid crystal projector of TN mode to yield liquid crystal projectors of Examples 5B to 7B and Comparative Example 3B.

< Evaluation of Contrast in Liquid Crystal Projector >

With respect to the liquid crystal projectors obtained, the illumination intensities in white and black state and the contrast determined from the ratio thereof (illumination intensity in white state/illumination intensity in black state) on the screen set at a distance of 3m from the projector lens were determined.

-- Evaluation Method for Use over Time Mandatory Testing --

The use over time mandatory tests for the liquid crystal displays of Examples 5A to 7A and Comparative Example 3A and the liquid crystal projectors of Examples 5B to 7B and Comparative Example 3B were conducted at each accelerate condition for 96 hours using a light source equivalent to two billions lux of white light for contrast evaluation. The results are shown in Tables 3 and 4.

Table 3

Liquid crystal display

	Thickness of Protective Layer (μm)	Surface Condition	Contrast	
			Beginning	After Test
Example 5A	0.2	no cracks	230	200
Example 6A	0.4	no cracks	230	200
Example 7A	0.8	no cracks	220	190
Comparative Example 3A	none	no cracks	230	110

From the result shown in Table 3, it was concluded that contrast in the liquid crystal displays of Examples 5A to 7A were not degraded compared to the liquid crystal displays of Comparative Example 3A.

Table 4

Liquid crystal projector

	Thickness of Protective Layer (μm)	Contrast	
		Beginning	After Test
Example 5B	0.2	750	700
Example 6B	0.4	750	700
Example 7B	0.8	720	600
Comparative Example 3B	none	730	300

From the result shown in Table 4, it was concluded that contrast in the liquid crystal projectors of Examples 5B to 7B were not degraded compared to the liquid crystal projectors of Comparative Example 3B.

Industrial Applicability

The optical compensatory element, wave plate and liquid crystal display according to the present invention can be suitably used for mobile phones, monitors for personal computers, television set and liquid crystal projectors.

CLAIMS

1. An optical compensatory element comprising:

a sealing unit,

wherein the optical compensatory element is sealed by the sealing unit.

2. The optical compensatory element according to claim 1, wherein the sealing unit comprises a holding member which holds the optical compensatory element and a sealing member which seals the periphery side of the optical compensatory element.

3. The optical compensatory element according to one of claims 1 and 2, wherein the holding member is at least one of inorganic vapor-deposited film and glass.

4. The optical compensatory element according to one of claims 1 to 3, wherein the optical compensatory element utilizes a twisted nematic liquid crystal device.

5. The optical compensatory element according to one of claims 1 to 4, wherein the optical compensatory element is a viewing-angle widening film.

6. The optical compensatory element according to one of claims 1 to 5, wherein the optical compensatory element comprises a first optically anisotropic layer formed of inorganic material and a second optically anisotropic layer formed of polymerizable liquid crystal compound on a support,

wherein the first optically anisotropic layer is a periodic multilayered structure having a repeating unit and the repeating unit comprises plural layers having different refractive indices laminated in a regular order and the periodic multilayered structure as a whole exhibits a negative refractive index anisotropy, and

wherein the second optically anisotropic layer is formed of polymerizable liquid crystal compound having a liquid crystal structure wherein the alignment angle of the liquid crystal structure is a hybrid alignment which varies in the thickness direction of the second optically anisotropic layer.

7. The optical compensatory element according to claim 6, wherein the second optically anisotropic layer comprises two layers having different alignment direction.

8. A method for manufacturing an optical compensatory element comprising:

forming of an optical compensatory element by laminating optically anisotropic layers on a support, and

sealing of an optical compensatory element wherein the optical compensatory element is sealed by a sealing unit under a deoxygenated atmosphere.

9. The method for manufacturing an optical compensatory element according to claim 8, wherein the optical compensatory element is sealed under the atmosphere further filled with an inactive gas.

10. A wave plate comprising:

a protective layer on a wave film,

wherein the protective layer comprises at least an inorganic layer containing an inorganic material.

11. The wave plate according to claim 10, wherein the inorganic material is alumina.

12. The wave plate according to one of claims 10 and 11, wherein the thickness of the protective layer is 0.05μm to 0.8μm.

13. The wave plate according to one of claims 10 to 12, wherein the wave

plate is utilized as an optical compensatory element for a twisted nematic liquid crystal device.

14. The wave plate according to one of claims 10 to 13, wherein the wave film comprises at least an optically anisotropic layer formed of polymerizable liquid crystal compound having a liquid crystal structure.

15. The wave plate according to claim 14, wherein the alignment angle of the liquid crystal structure in the optically anisotropic layer formed of polymerizable liquid crystal compound having the liquid crystal structure is a hybrid alignment which varies in the thickness direction of the optically anisotropic layer.

16. The wave plate according to one of claims 10 to 15, wherein the wave plate is a viewing-angle widening film.

17. The wave plate according to one of claims 10 to 16, wherein the wave plate comprises a first optically anisotropic layer formed of inorganic material and a second optically anisotropic layer formed of polymerizable liquid crystal compound on a support,

wherein the first optically anisotropic layer is a periodic multilayered structure having a repeating unit and the repeating unit comprises plural layers having different refractive indices laminated in a regular order and the periodic multilayered structure as a whole exhibits a negative refractive index anisotropy, and

wherein the second optically anisotropic layer is formed of polymerizable liquid crystal compound having the liquid crystal structure wherein the alignment angle of the liquid crystal structure is the hybrid alignment which varies in the thickness direction of the second optically anisotropic layer.

18. The wave plate according to claim 17, wherein the second optically

anisotropic layer comprises two layers having different alignment direction.

19. A method for manufacturing a wave plate comprising:

forming of a coated layer on a support by coating the polymerizable composition comprising a polymerizable liquid crystal compound having a liquid crystal structure,

forming of an optically anisotropic layer by fixing the alignment angle of the liquid crystal structure by polymerization in a state of hybrid alignment which varies in the thickness direction of the coated layer, and

forming of a protective layer comprising at least an inorganic layer containing an inorganic material on the optically anisotropic layer.

20. A liquid crystal display comprising:

at least a pair of electrodes and a liquid crystal device having a liquid crystal molecule encapsulated in between the pair of electrodes,

an optical compensatory element placed on one side or both sides of the liquid crystal device, and

a polarizing element facing the liquid crystal device and the optical compensatory element,

wherein the optical compensatory element is the optical compensatory element according to one of claims 1 to 7.

21. A liquid crystal display comprising:

at least a pair of electrodes and a liquid crystal device having a liquid crystal structure encapsulated in between the pair of electrodes,

a wave plate placed on one side or both sides of the liquid crystal device, and

a polarizing element facing the liquid crystal device and the wave plate,

wherein the wave plate is the wave plate according to one of claims 10 to 18.

22. A liquid crystal projector comprising:

a light source,

a liquid crystal display wherein an illuminating light is irradiated from the light source, and

a projection optical system for forming an image on a screen from light optically modulated by the liquid crystal display,

wherein the liquid crystal display is the liquid crystal display according to one of claims 20 and 21.

FIG. 1

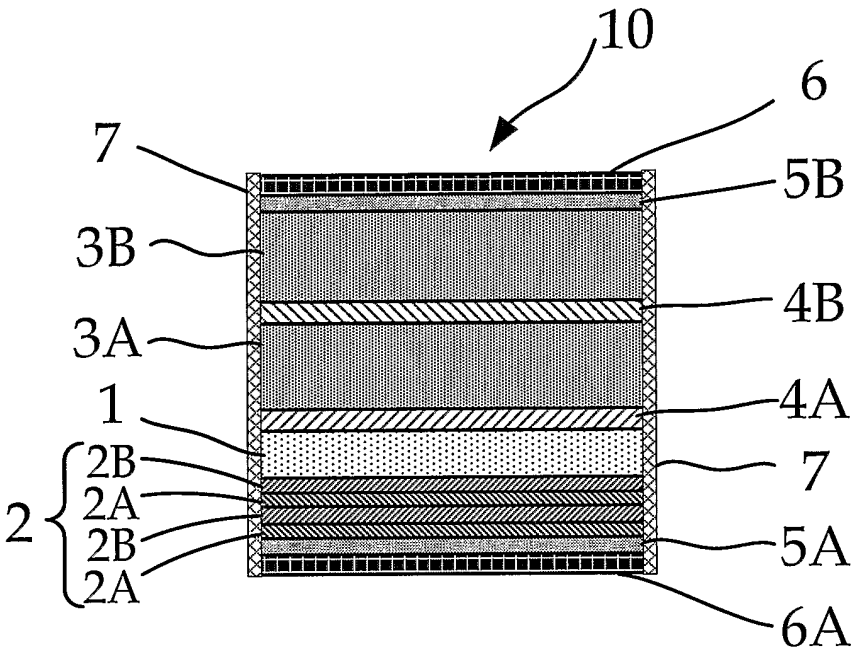

10
6
7
5B
3B
4B
3A
4A
1
7
2B
2A
2
2B
2A
5A
6A

FIG. 2

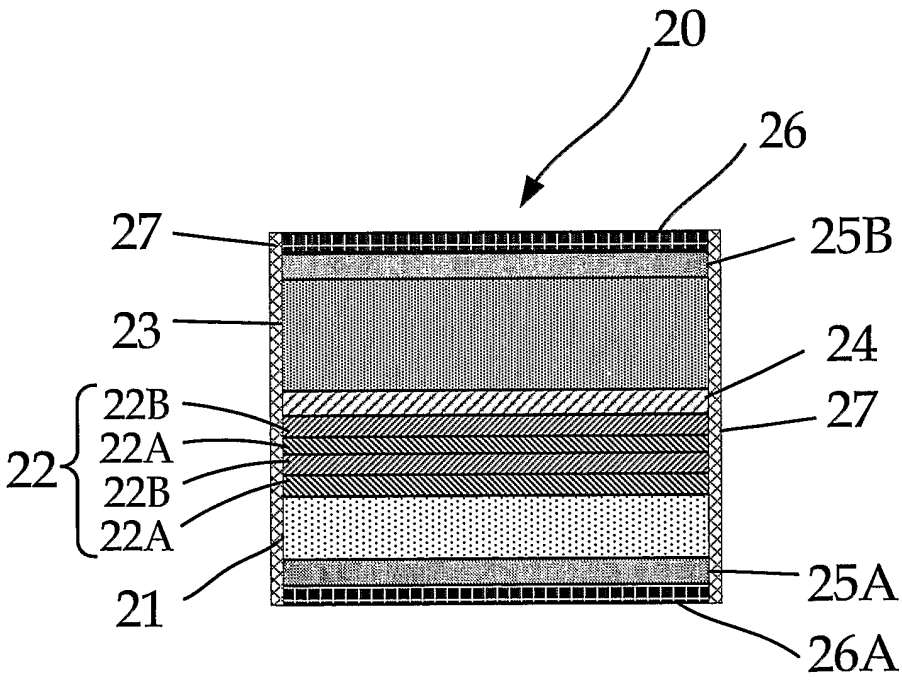

20
26
27
25B
23
24
22B
27
22A
22
22B
22A
21
25A
26A

FIG. 3

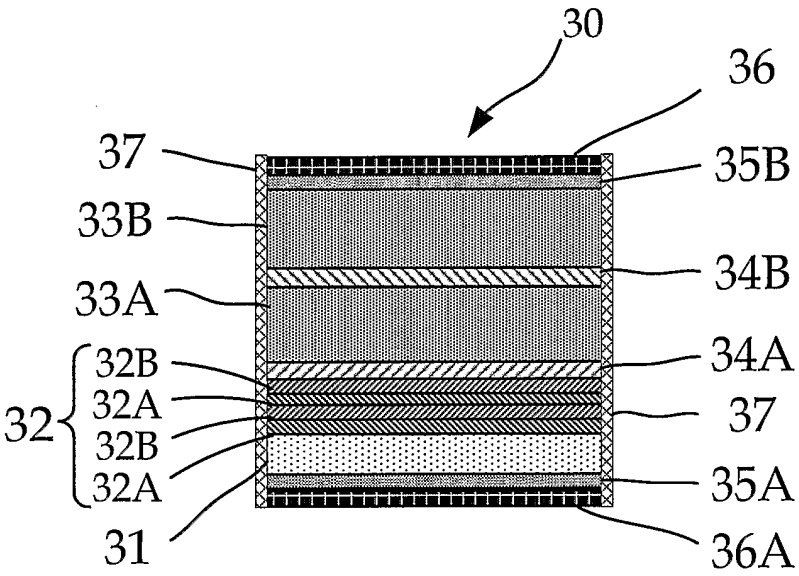

30
36
37
35B
33B
34B
33A
34A
32B
32A
37
32
32B
32A
35A
31
36A

FIG. 4

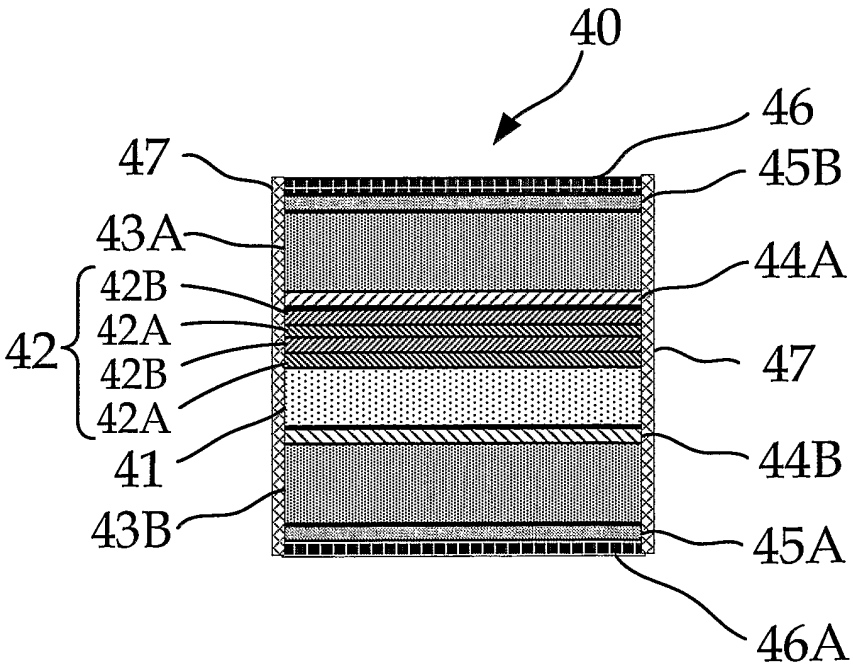

40
46
47
45B
43A
44A
42B
42A
47
42
42B
42A
41
44B
43B
45A
46A

FIG. 5

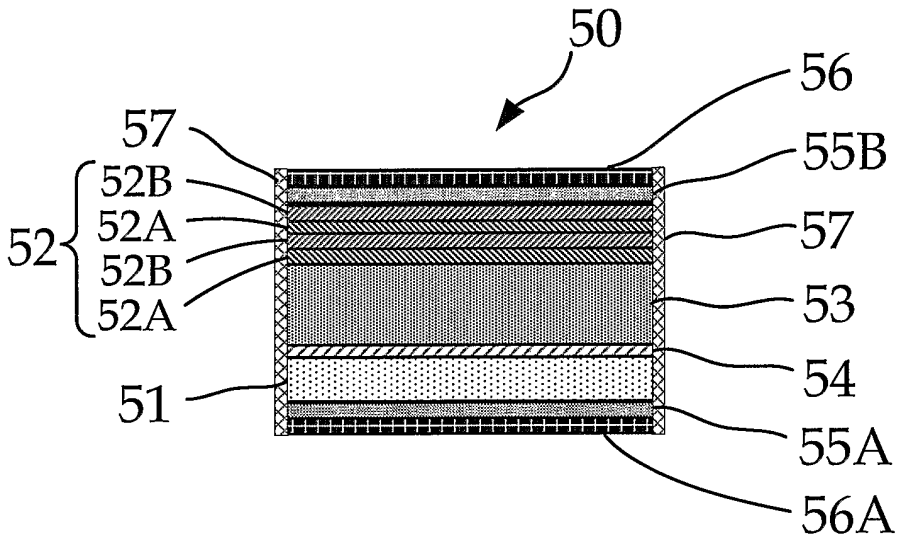

50
56
57
55B
52B
52A
52
57
52B
52A
53
54
51
55A
56A

FIG. 6

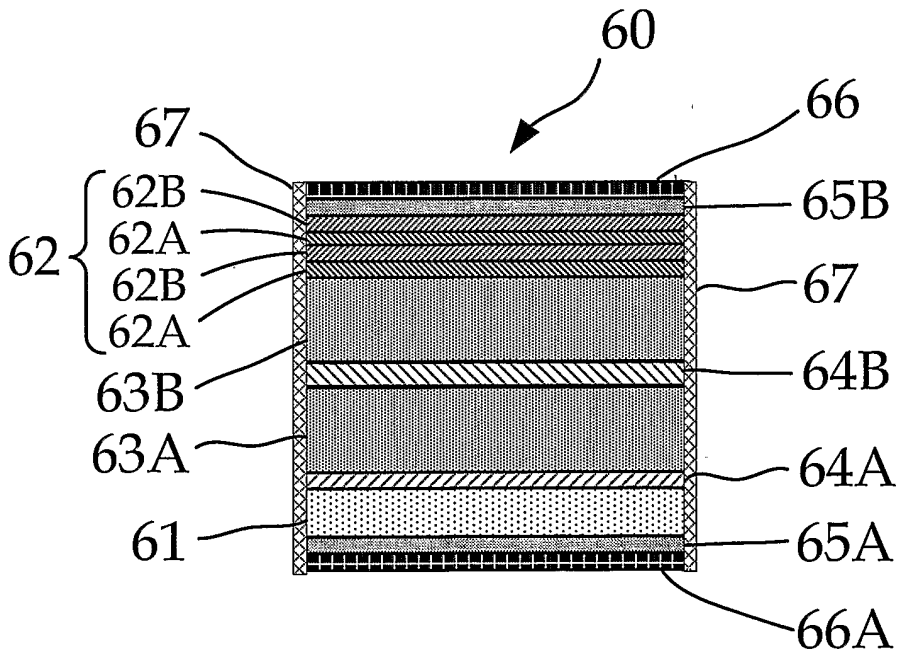

60
66
67
65B
62B
62A
62
67
62B
62A
64B
63B
63A
64A
61
65A
66A

FIG. 7

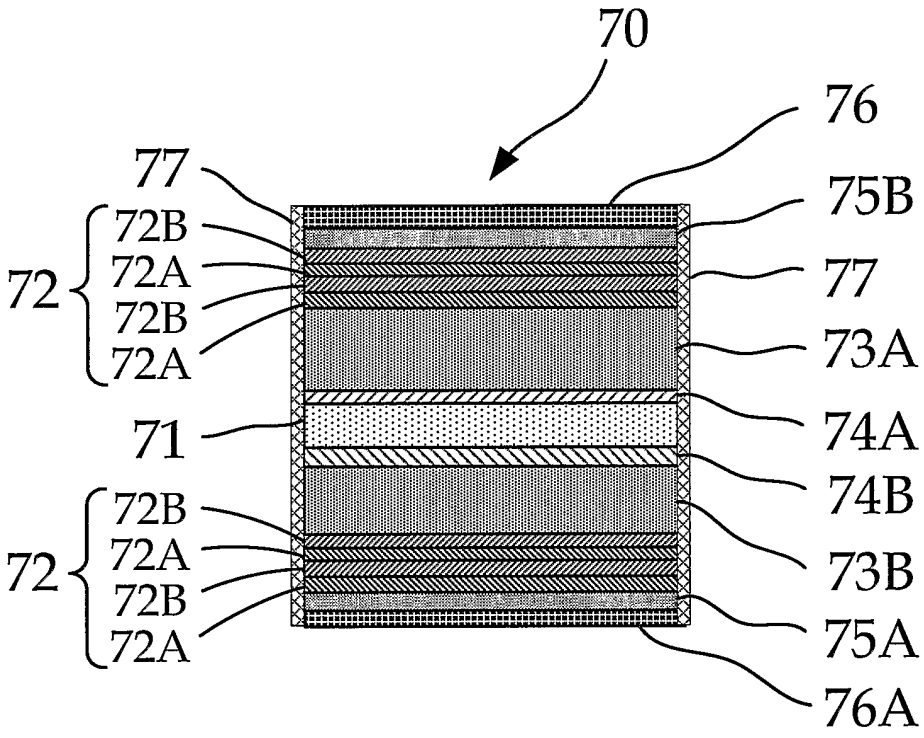

70
76
77
75B
72
72B
72A
72B
72A
77
73A
74A
71
74B
72
72B
72A
72B
72A
73B
75A
76A

FIG. 8

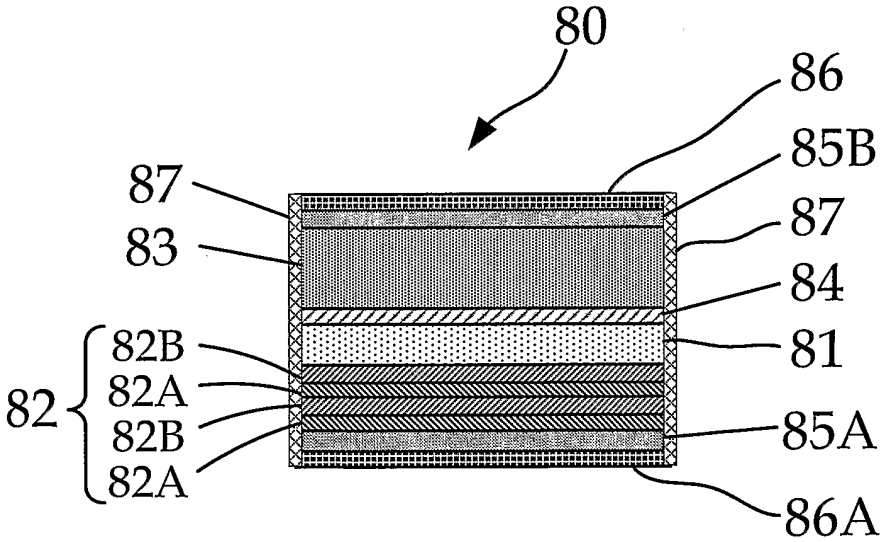

80
86
85B
87
87
83
84
82
82B
82A
82B
82A
81
85A
86A

FIG. 9

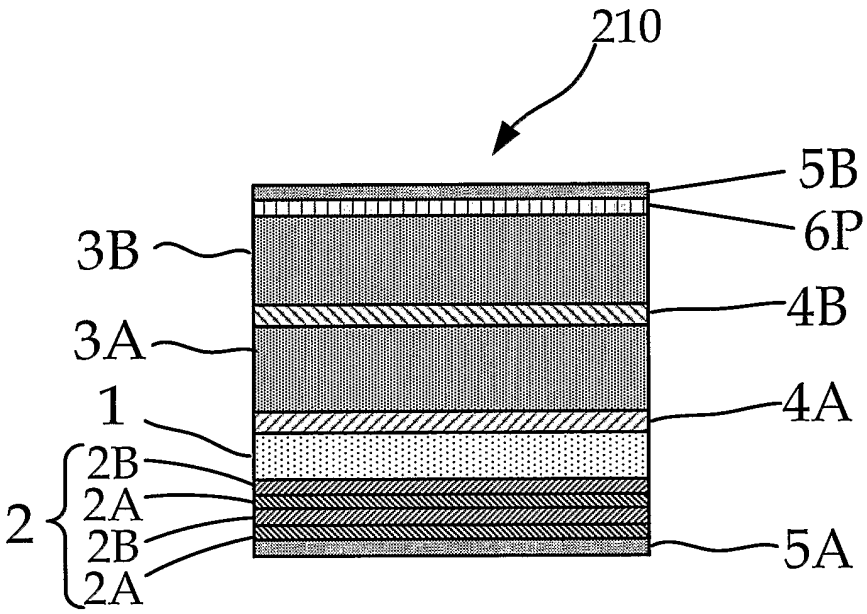

210
5B
6P
3B
4B
3A
4A
1
2B
2A
2
2B
2A
5A

FIG. 10

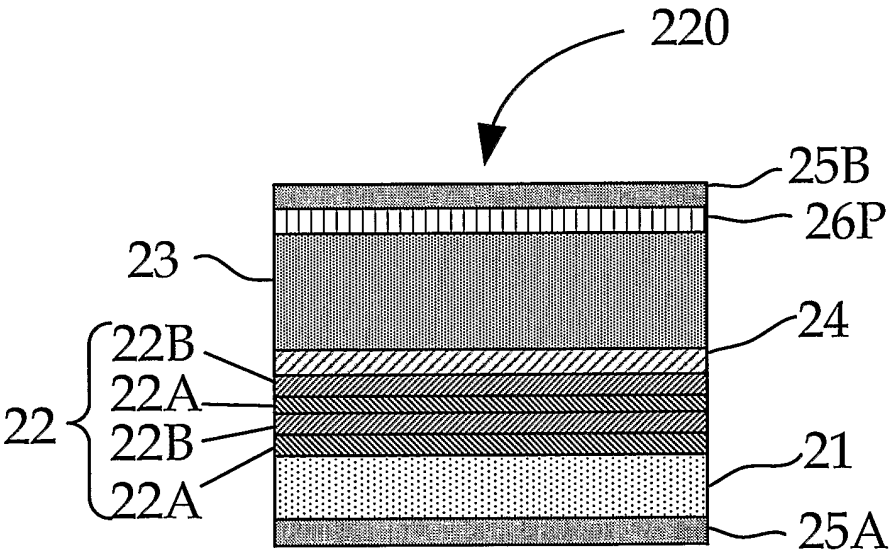

220
25B
26P
23
24
22B
22A
22
22B
22A
21
25A

FIG. 11

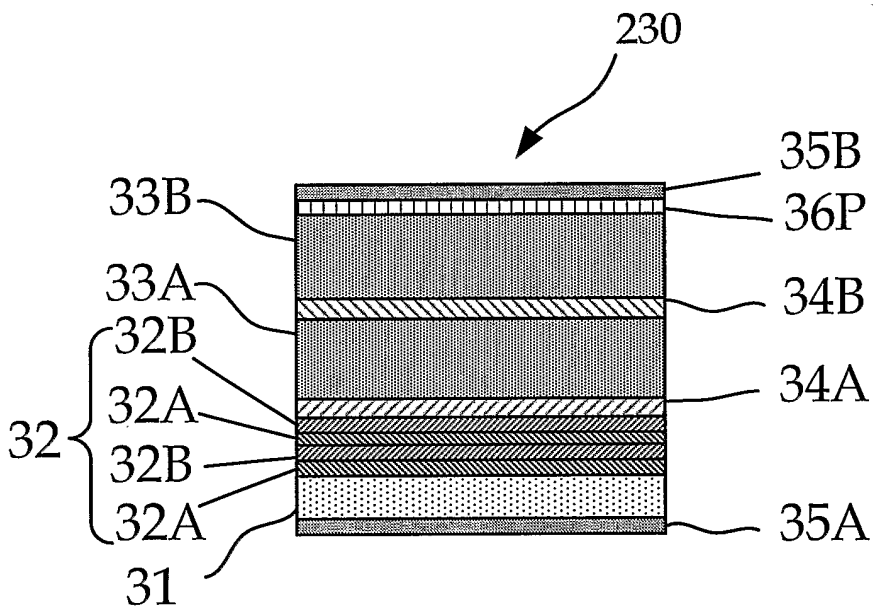

230
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33B
36P
33A
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32B
34A
32
32A
32B
32A
35A
31

FIG. 12

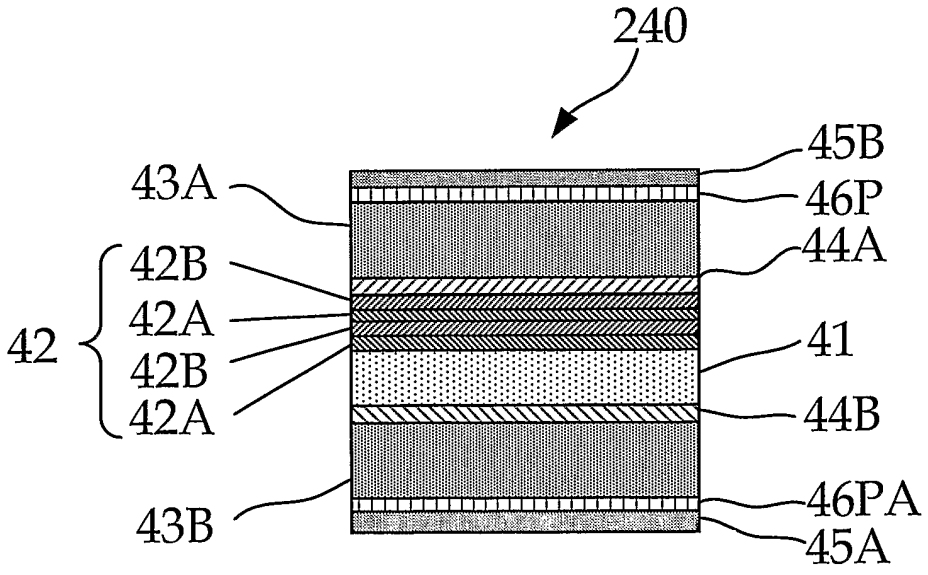

240
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43A
46P
44A
42B
42
42A
41
42B
42A
44B
46PA
43B
45A

FIG. 13

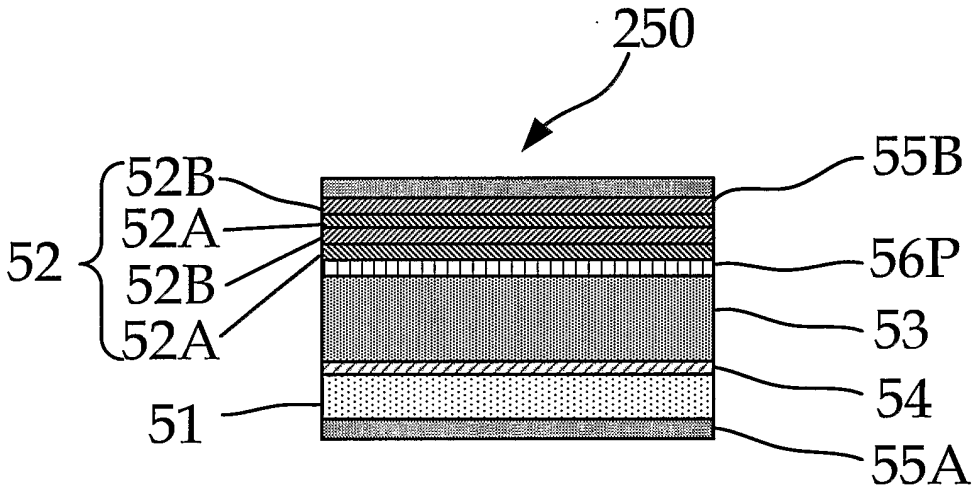

250
52
52B
52A
52B
52A
51
55B
56P
53
54
55A

FIG. 14

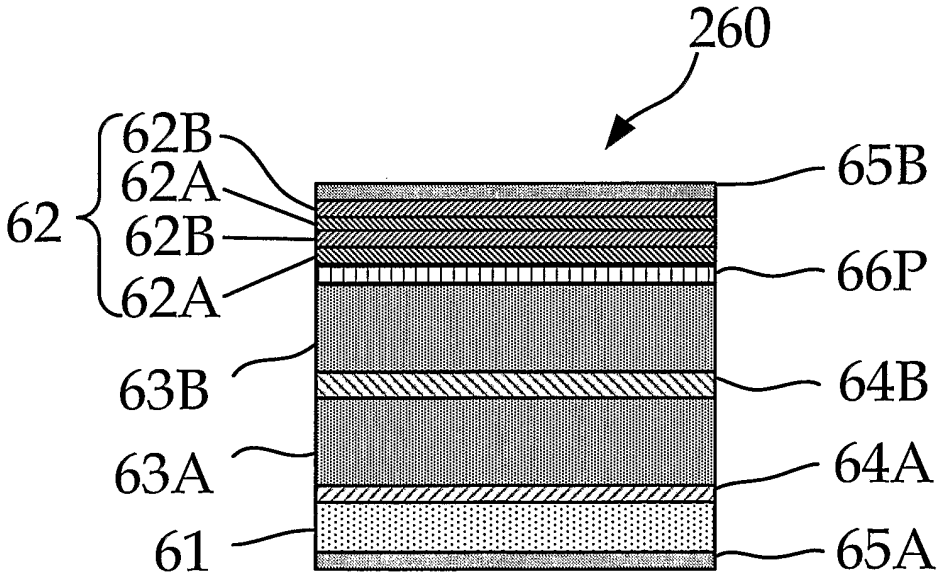

260
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62B
62A
62B
62A
63B
63A
61
65B
66P
64B
64A
65A

FIG. 15

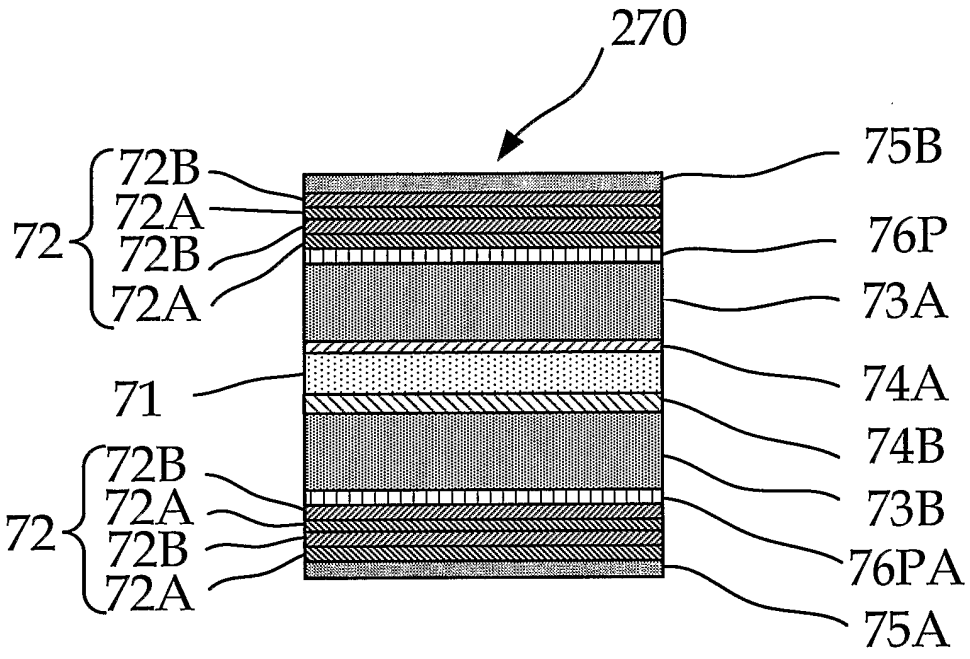

270
72
72B
72A
72B
72A
71
72
72B
72A
72B
72A
75B
76P
73A
74A
74B
73B
76PA
75A

FIG. 16

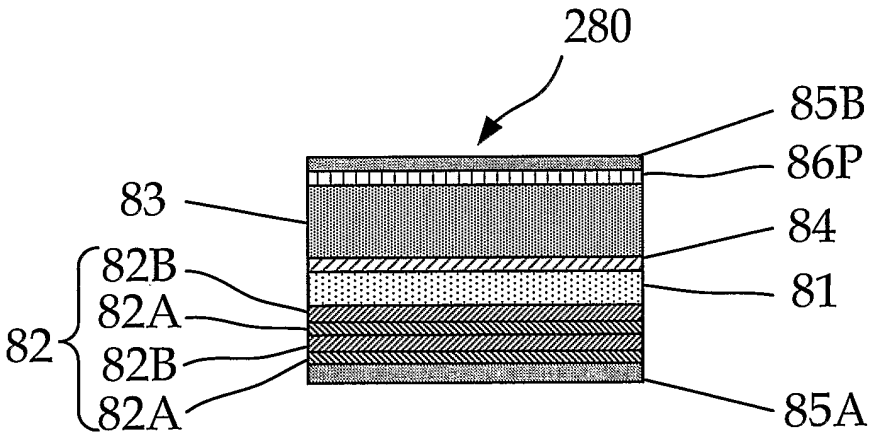

280
83
82
82B
82A
82B
82A
85B
86P
84
81
85A

FIG. 17

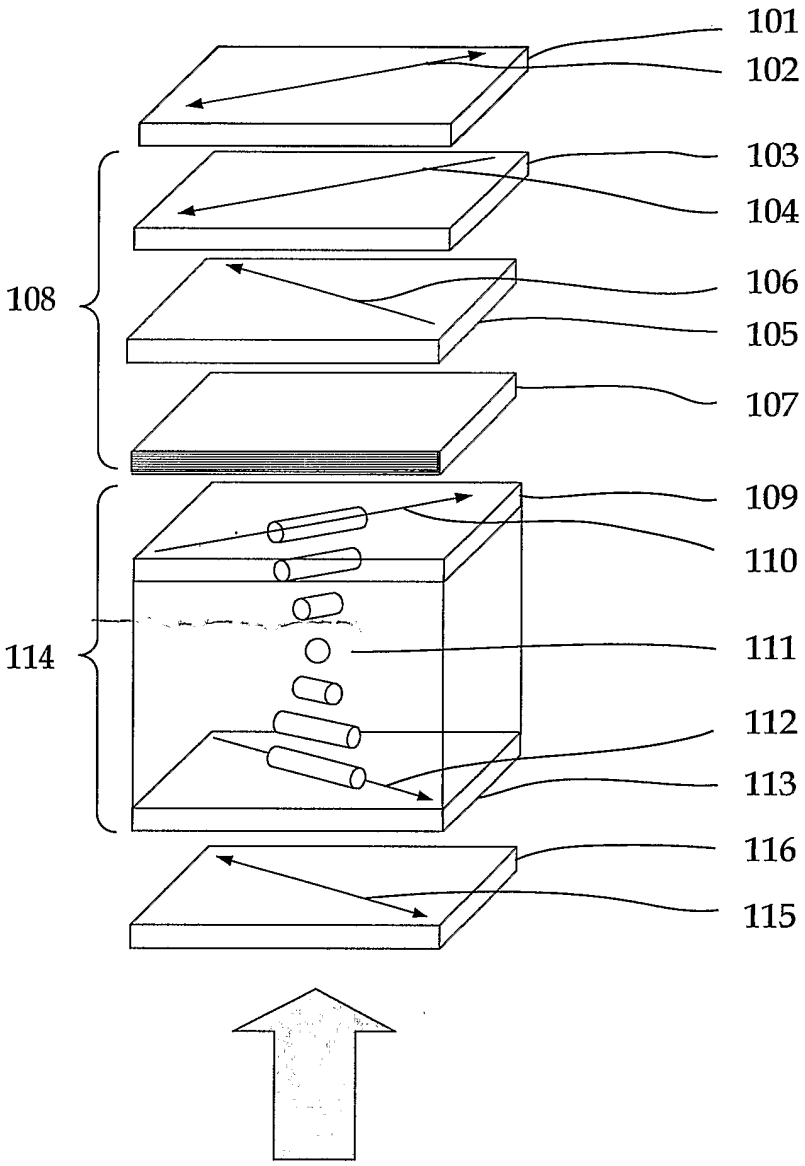


FIG. 18

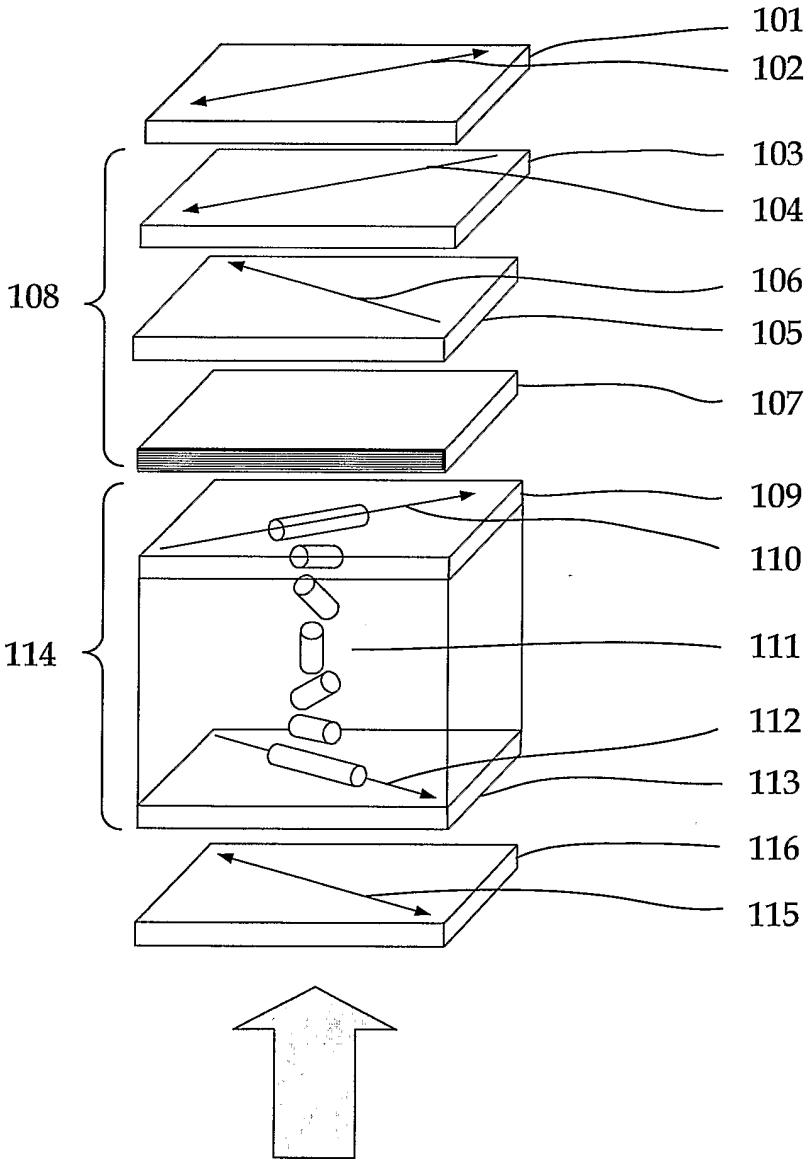


FIG. 19

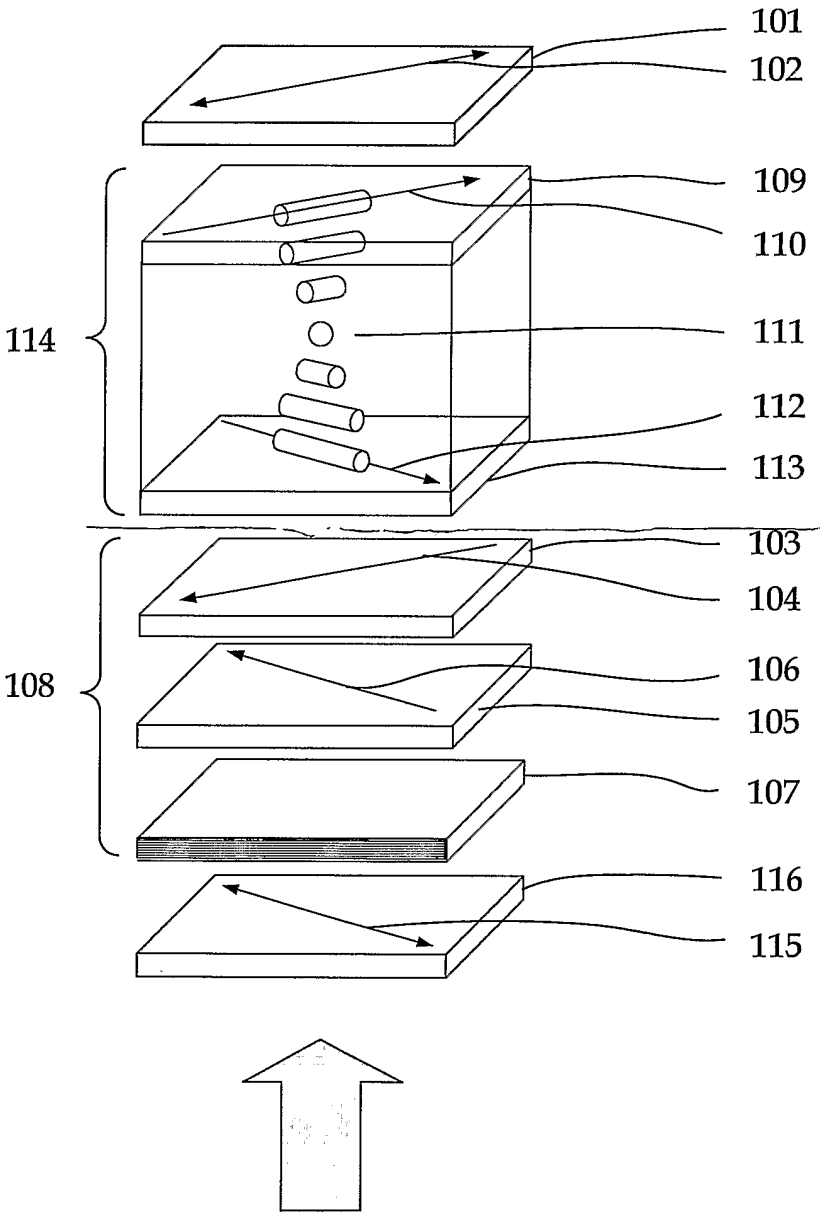


FIG. 20

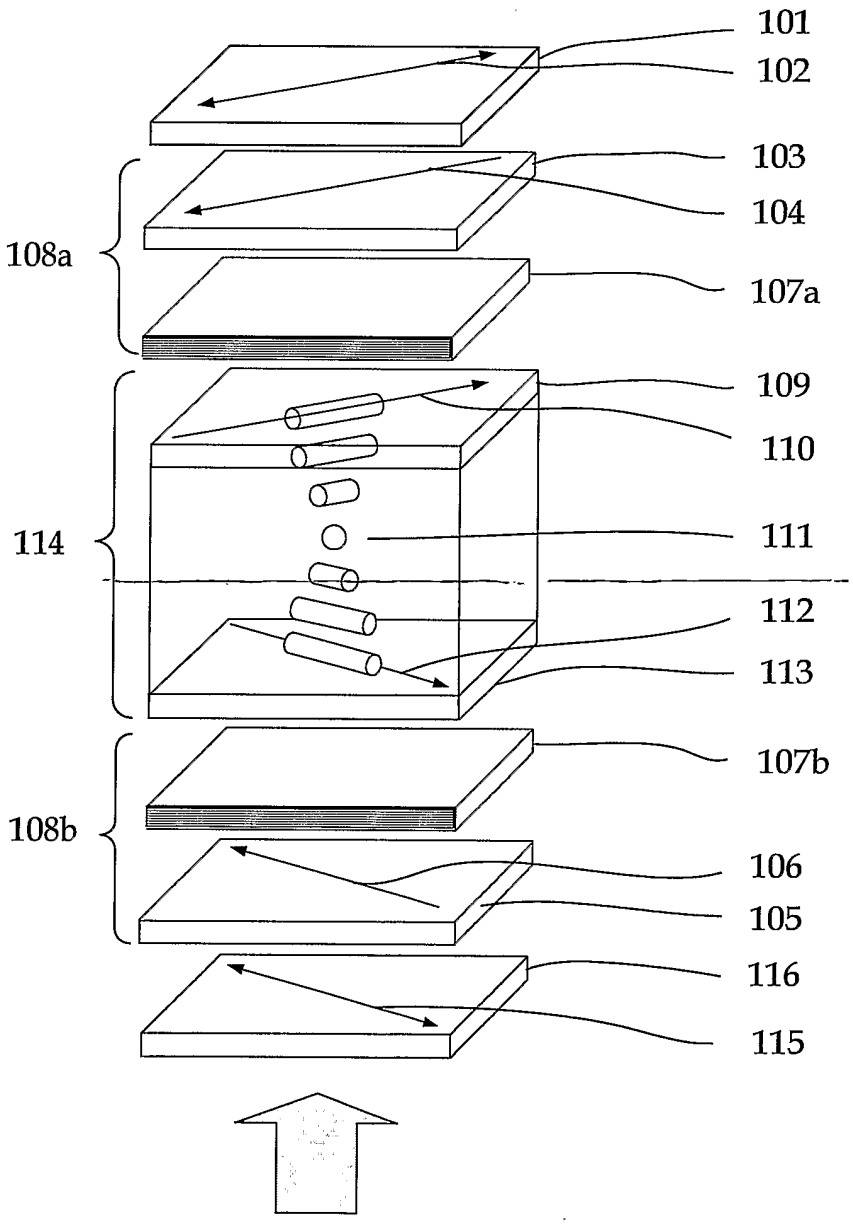

101
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108a
107a
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114
111
112
113
107b
108b
106
105
116
115

FIG. 21

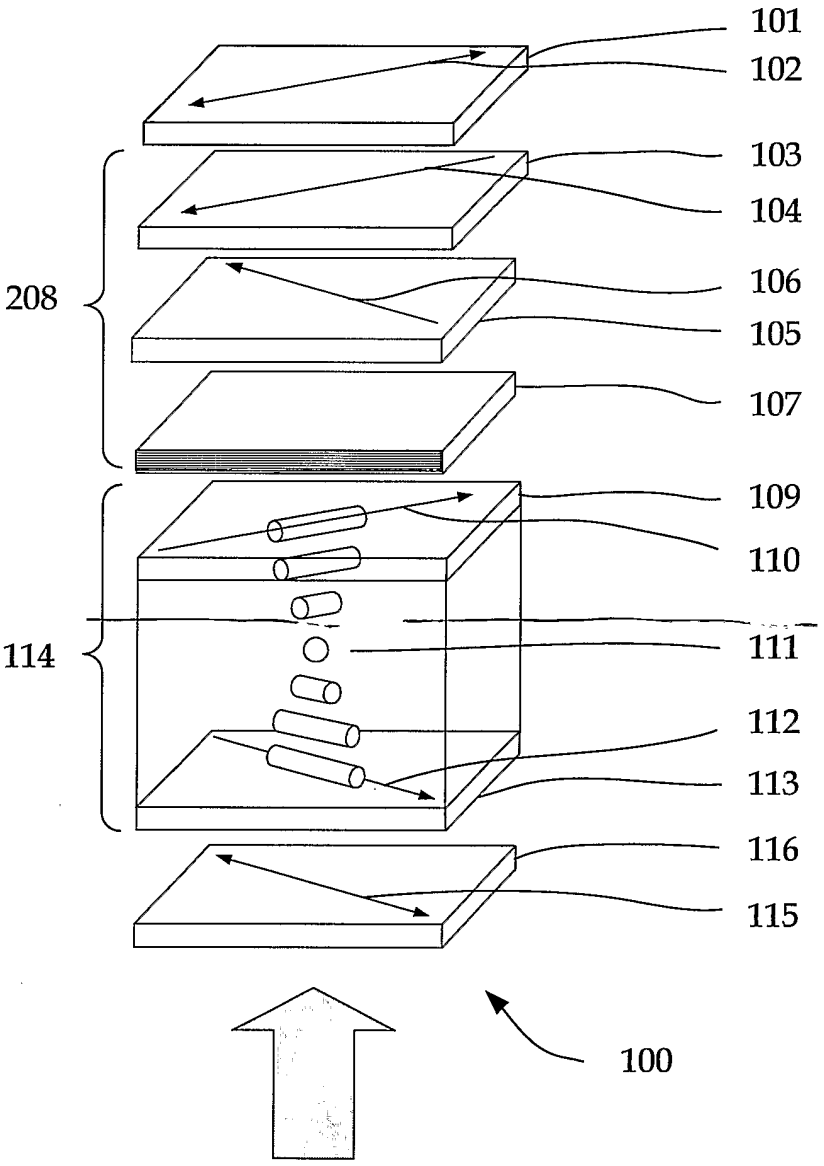

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208
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100

FIG. 22

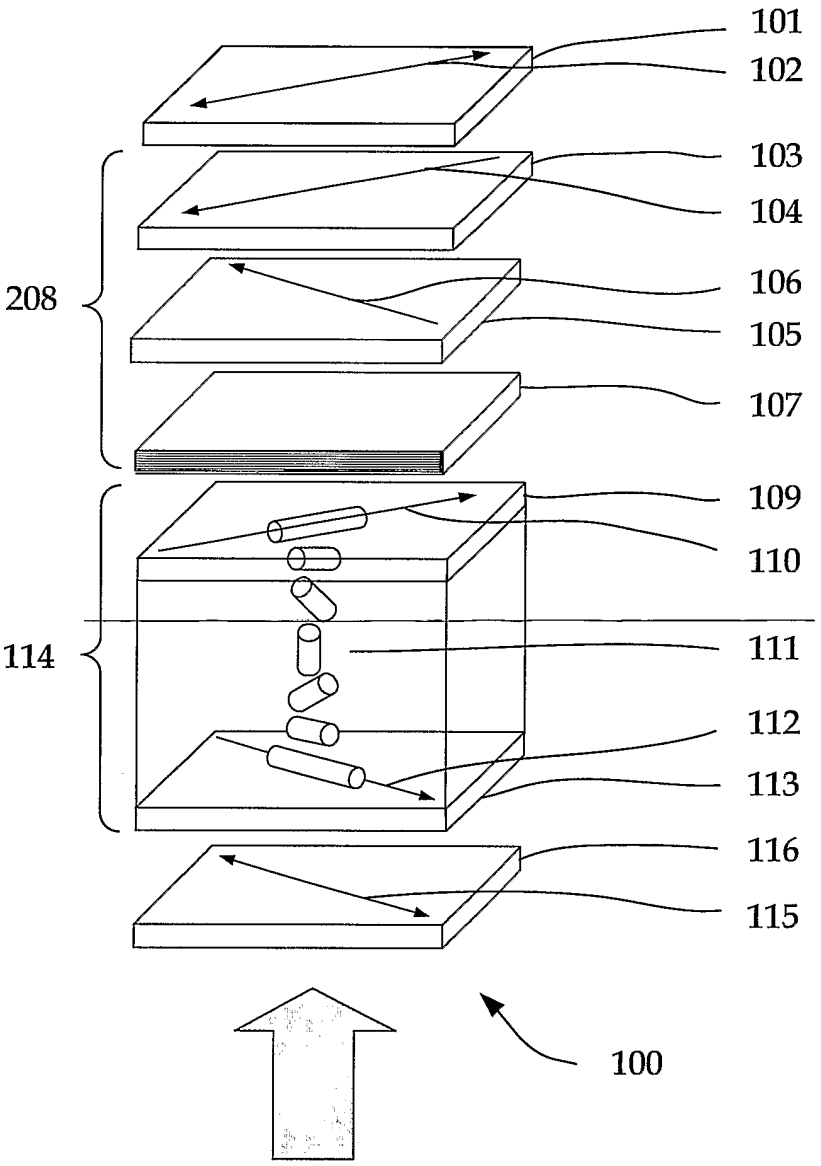

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115
100

FIG. 23

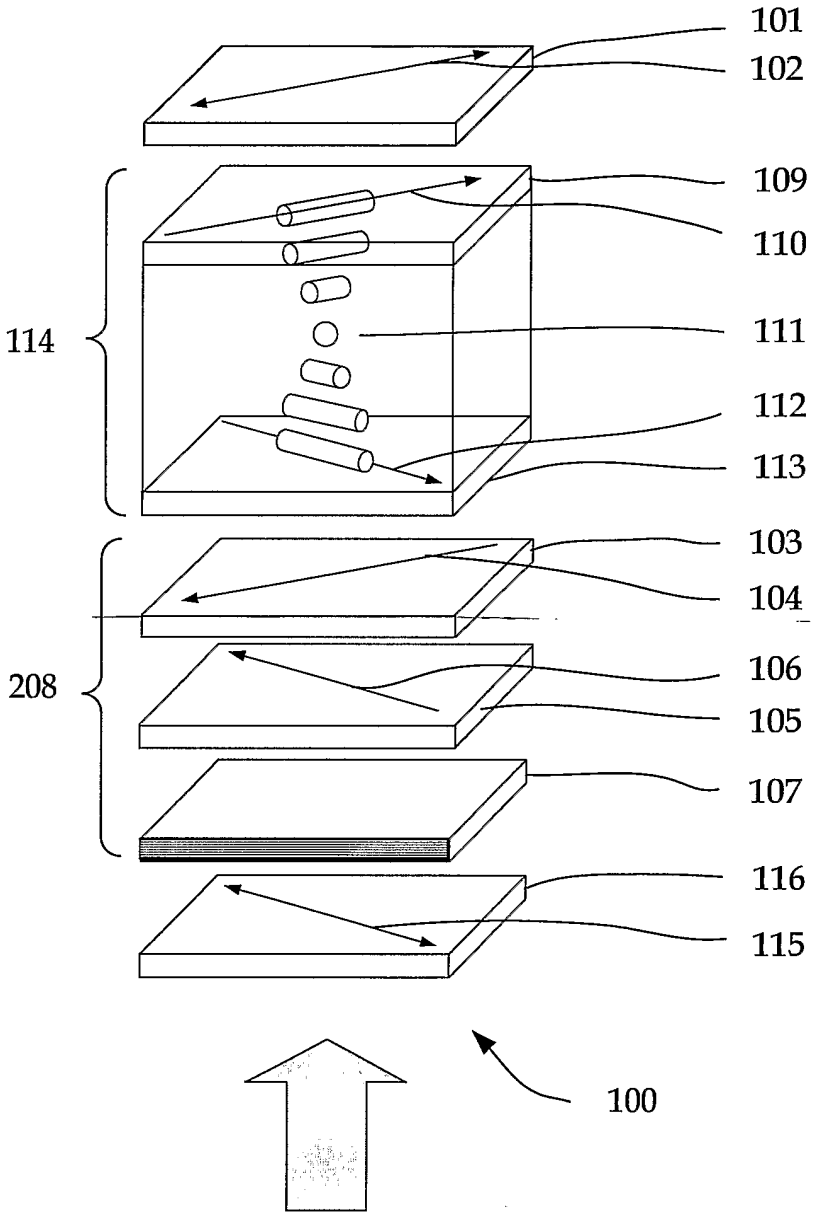

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115
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FIG. 24

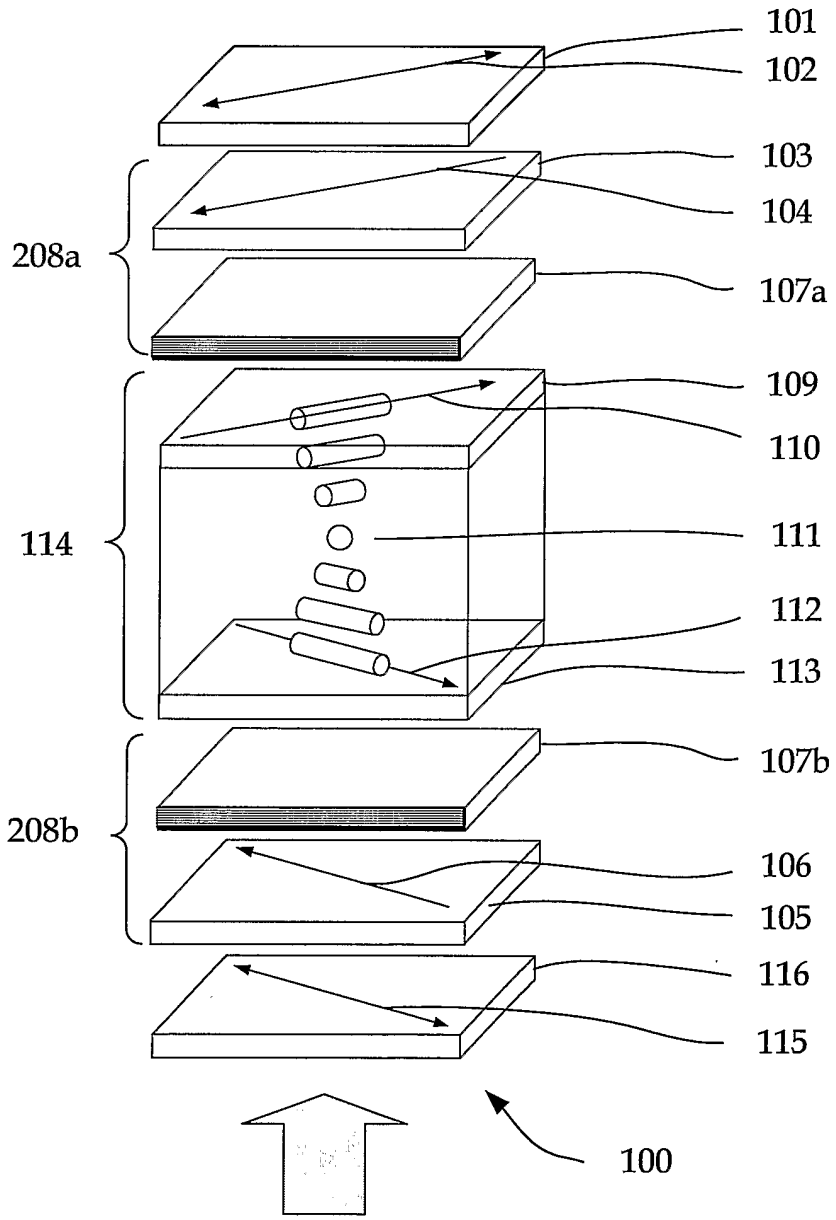

101
102
103
104
208a
107a
109
110
114
111
112
113
107b
208b
106
105
116
115
100

FIG. 25

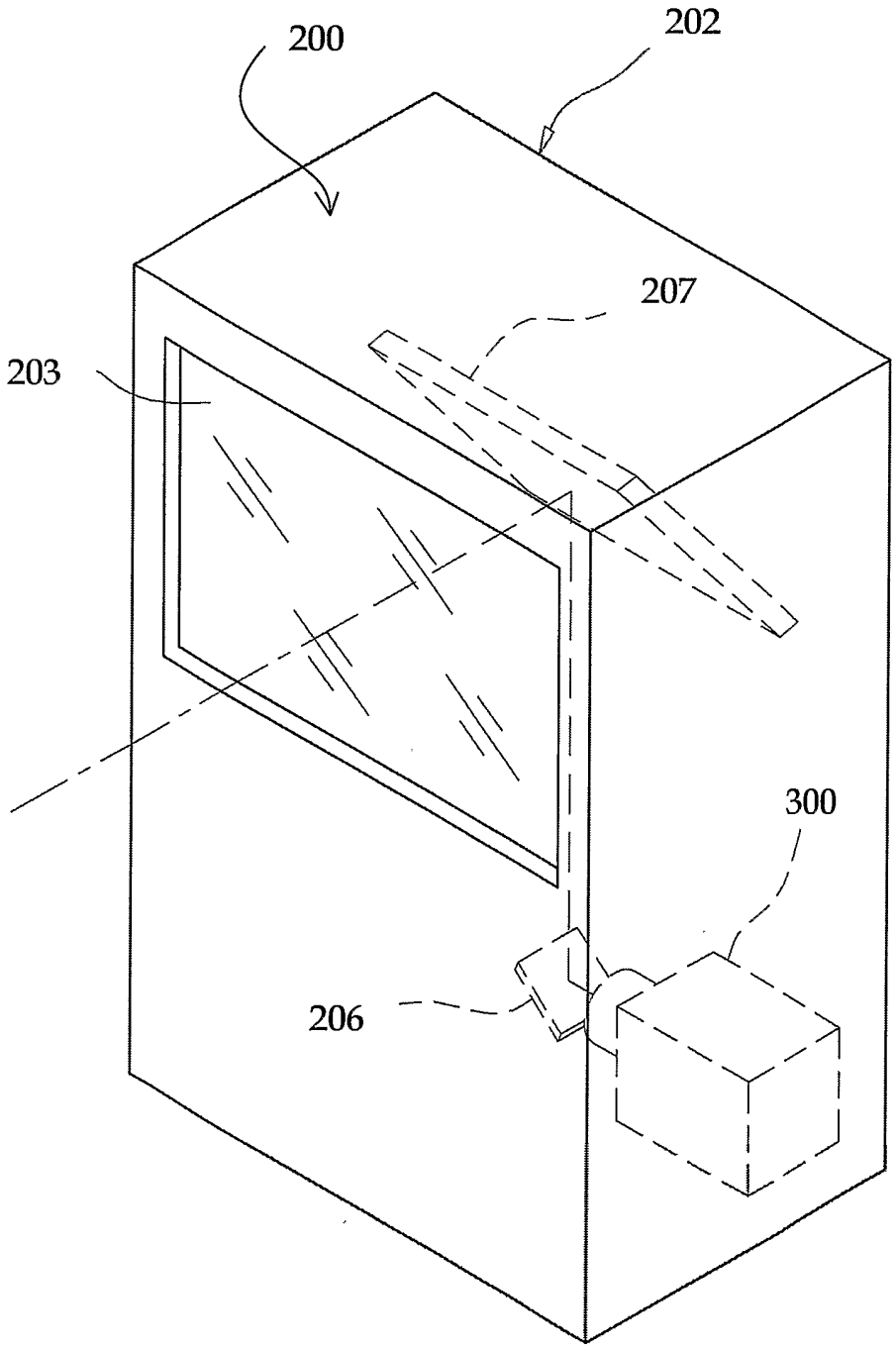
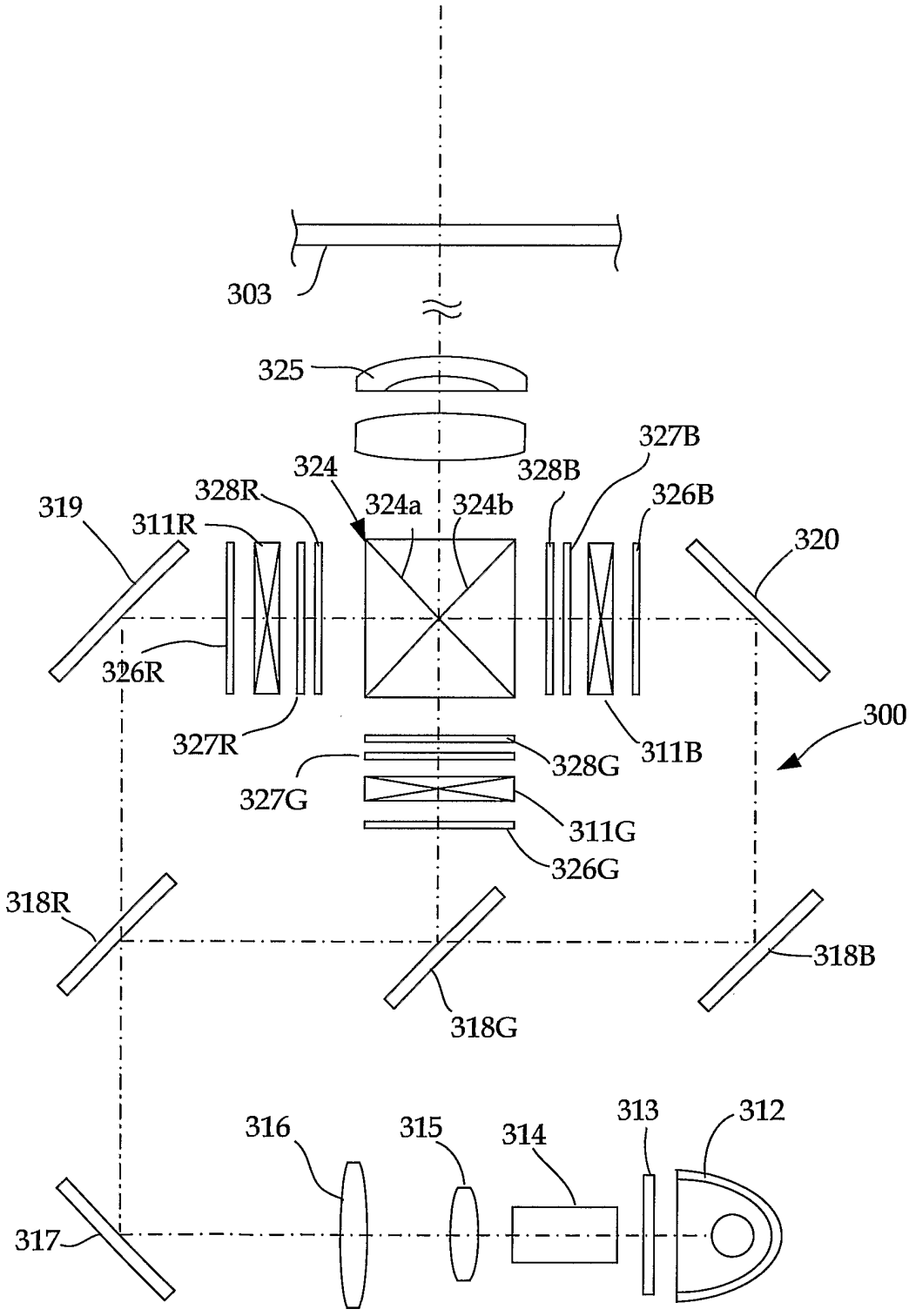


FIG. 26


303
325
327B
324
328B
328R
324a
324b
326B
319
311R
320
326R
327R
311B
300
328G
327G
311G
326G
318R
318B
318G
316
315
314
313
312
317

INTERNATIONALSEARCHREPORT

International application No.
PCT/JP2005/022403

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. *G02B5/30*(2006.01), *G02F1/13363*(2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. G02B5/30, G02F1/13363

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2006
Registered utility model specifications of Japan 1996-2006
Published registered utility model applications of Japan 1994-2006

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-509726 A (MERCK PATENT GESELLSCHAFT MIT BESCHRAENKTER HAFTUNG) 2003.03.11, Full text, all drawings, particularly, [Claim 1], [Claim 11]-[Claim 12], [0009], [0032]-[0039] & WO 01/020395 A1 & EP 1212653 A1 & AU 200074192 A & KR 2002064284 A	1-22
Y	JP 8-50206 A (FUJI PHOTO FILM CO., LTD.) 1996.02.20, Full text, all drawings, particularly, [Claim 1]-[Claim 8], [0015], [0017], [0071]-[0072] & US 5583679 A & KR 267894 B1 & DE 19519928 A1	1-22

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
10.03.2006	20.03.2006

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Masaaki Moriuchi Telephone No. +81-3-3581-1101 Ext. 3271

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/022403

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2004-301891 A (NIKON CORP.) 2004.10.28, Full text, all drawings, particularly, [Claim 1], [Claim 5] (Family none)	1-3 4-9,20,22
Y	JP 2004-170712 A (FUJI PHOTO FILM CO., LTD.) 2004.06.17, Full text, all drawings, [Claim 1]-[Claim 4] & US 2004/0095535 A1	6,17
Y	JP 2001-235760 A (SHARP CORP.) 2001.08.31, Full text, all drawings, particularly, [Claim 1] & US 6639647 B1 & US 2004/0051838 A1	8-9
X Y	JP 2002-156624 A (FUJI PHOTO FILM CO., LTD.) 2002.05.31, Full text, all drawings, particularly, [Claim 1]-[Claim 4], [0044] & US 2002/0060762 A1 & KR 2002038550 A	10-12 13-19,21-22

INTERNATIONALSEARCHREPORT

International application No.
PCT/JP2005/022403

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The special technical features of claims 1 and dependent claims on 1 relate to "an optical compensatory element comprising: sealing unit, wherein the optical compensatory element is sealed by the sealing unit" while the special technical features of claims 10 and dependent claims on 10 relate to "a wave plate comprising: a protective layer on wave film, wherein the protective layer comprises at least an inorganic layer containing an inorganic material".

There is no technical relationship among those inventions involving one or more of the same or corresponding technical features.

Therefore, these groups of inventions are not so linked as to form a single general inventive concept.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☑ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.