

Description

Title of Invention: CIRCULAR POLARIZING PLATE AND FLEXIBLE IMAGE
DISPLAY DEVICE USING SAME

Technical Field

[0001] The present invention relates to a circularly polarizing plate and a flexible image display apparatus using the same.

Background Art

[0002] The number of opportunities for the use of a display apparatus for, for example, a smart device typified by a smart phone, digital signage, or a window display under strong ambient light has been increasing in recent years. Along with the increase, there has been occurring a problem such as: the reflection of the ambient light by the display apparatus itself or a reflector to be used in the display apparatus, such as a touch panel portion, a glass substrate, or a metal wiring; or the reflection of a background on the display apparatus or the reflector. In particular, an organic electroluminescence (EL) display apparatus that has started to be put into practical use in recent years is liable to cause a problem, such as the reflection of the ambient light or the reflection of the background because the apparatus has a metal layer having high reflectivity. In view of the foregoing, it has been known that such problem is prevented by arranging, as an antireflection film, a circularly polarizing plate including a retardation film (typically

a $\lambda/4$ plate) on a viewer side.

[0003] Incidentally, with regard to the organic EL display apparatus, practical application of an organic EL display apparatus having a flexible or bendable (foldable) configuration has been promoted by utilizing its features that a liquid crystal display apparatus does not have. However, when the related-art circularly polarizing plate is used, a problem arises in that undesired bending and/or warping occurs in the organic EL display apparatus.

Citation List

Patent Literature

- [0004] [PTL 1] JP 2010-139548 A
- [PTL 2] JP 2003-207640 A
- [PTL 3] JP 2004-226842 A
- [PTL 4] JP 3815790 B2
- [PTL 5] JP 2014-170221 A

Summary of Invention

Technical Problem

[0005] The present invention has been made in order to solve the problem of the related art described above, and a primary object of the present invention is to provide a circularly polarizing plate that has less curling resulting from each of state change and temporal change, and hence, when applied to a flexible image display apparatus,

can suppress undesired bending and warping of the image display apparatus.

Solution to Problem

[0006] According to one aspect of the present invention, a circularly polarizing plate is provided. The circularly polarizing plate includes, in this order: a first protective layer; a polarizer; a second protective layer; and a retardation layer having an in-plane retardation $Re(550)$ of from 80 nm to 200 nm, wherein the second protective layer has a moisture permeability at 40°C and a relative humidity of 92% of less than 160 g/m²/24 H, and wherein the circularly polarizing plate is used for a flexible image display apparatus.

In one embodiment of the invention, the second protective layer is omitted, wherein the retardation layer doubles as a protective layer for the polarizer, and wherein the retardation layer has a moisture permeability at 40°C and a relative humidity of 92% of less than 160 g/m²/24 H.

In one embodiment of the invention, an angle θ formed between an absorption axis of the polarizer and a slow axis of the retardation layer is from 35° to 55°.

In one embodiment of the invention, the circularly polarizing plate further includes a hard coat layer on an outer side of the

first protective layer.

In one embodiment of the invention, the circularly polarizing plate further includes: a pressure-sensitive adhesive layer at an outermost portion of the circularly polarizing plate on a retardation layer side; and a release liner, which is temporarily bonded to a surface of the pressure-sensitive adhesive layer.

In one embodiment of the invention, the circularly polarizing plate further includes a surface protective film, which is temporarily bonded to an outermost portion of the circularly polarizing plate on a first protective layer side.

In one embodiment of the invention, the circularly polarizing plate has a curling amount of within ± 6 mm when placed under an environment having a temperature of $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and a relative humidity of $55\% \pm 10\%$ for 72 hours under each of the following states: a state in which the circularly polarizing plate has temporarily bonded thereto the release liner and the surface protective film; a state in which the release liner has been peeled and removed from the circularly polarizing plate, and the circularly polarizing plate has temporarily bonded thereto the surface protective film; and a state in which the release liner and the surface protective film have been peeled and removed from the circularly polarizing plate.

According to another aspect of the present invention, a flexible image display apparatus is provided. The flexible image display apparatus includes the circularly polarizing plate.

Advantageous Effects of Invention

[0007] According to the present invention, in the circularly polarizing plate, the moisture permeability of the layer adjacent to the display cell side of the polarizer is optimized, and thus the circularly polarizing plate having less curling resulting from each of state change (typically peeling of the surface protective film and/or peeling of the release liner) and temporal change can be realized. As a result, when the circularly polarizing plate is applied to a flexible image display apparatus, undesired bending and warping of the image display apparatus can be satisfactorily suppressed.

Brief Description of Drawings

[0008] FIG. 1 is a schematic sectional view of a circularly polarizing plate according to one embodiment of the present invention.

Description of Embodiments

[0009] Embodiments of the present invention are described below. However, the present invention is not limited to these embodiments.

[0010] (Definitions of Terms and Symbols)

The definitions of terms and symbols used herein are as described below.

(1) Refractive Indices (n_x , n_y , and n_z)

" n_x " represents a refractive index in a direction in which an in-plane refractive index is maximum (that is, slow axis direction), " n_y " represents a refractive index in a direction perpendicular to the slow axis in the plane (that is, fast axis direction), and " n_z " represents a refractive index in a thickness direction.

(2) In-plane Retardation (R_e)

" $R_e(\lambda)$ " refers to an in-plane retardation of a film measured at 23°C with light having a wavelength of λ nm. For example, " $R_e(550)$ " refers to an in-plane retardation of a film measured at 23°C with light having a wavelength of 550 nm. The $R_e(\lambda)$ is determined from the equation " $R_e = (n_x - n_y) \times d$ " when the thickness of a film is represented by d (nm).

(3) Thickness Direction Retardation (R_{th})

" $R_{th}(\lambda)$ " refers to a thickness direction retardation of a film measured at 23°C with light having a wavelength of λ nm. For example, " $R_{th}(550)$ " refers to a thickness direction retardation of a film measured at 23°C with light having a wavelength of 550 nm. The $R_{th}(\lambda)$ is determined from the equation " $R_{th} = (n_x - n_z) \times d$ " when the thickness

of a film is represented by d (nm).

(4) Nz Coefficient

An Nz coefficient is determined from the equation " $Nz=R_{th}/R_e$ ".

[0011] A. Overall Configuration of Circularly Polarizing Plate

A circularly polarizing plate according to an embodiment of the present invention may be typically used for a flexible image display apparatus (typically an organic EL display apparatus). FIG. **1** is a schematic sectional view of a circularly polarizing plate according to one embodiment of the present invention. A circularly polarizing plate **100** according to this embodiment includes a first protective layer **11**, a polarizer **20**, a second protective layer **12**, and a retardation layer **30** in the stated order. In the circularly polarizing plate **100**, the first protective layer **11** and the retardation layer **30** are typically on the viewer side and the display cell side of the image display apparatus, respectively. The in-plane retardation $R_e(550)$ of the retardation layer **30** is from 80 nm to 200 nm. The retardation layer **30** typically functions as a so-called $\lambda/4$ plate. An angle θ formed between the absorption axis of the polarizer **20** and the slow axis of the retardation layer **30** is typically from 35° to 55° , preferably from 38° to 52° , more preferably from 42° to 48° , still more preferably about 45° .

[0012] In one embodiment, the circularly polarizing plate **100**

may further include a hard coat layer **40** on the outer side of the first protective layer **11** as in the illustrated example. In one embodiment, the circularly polarizing plate **100** may further include another retardation layer (not shown). The optical characteristics (e.g., in-plane retardation, thickness direction retardation, Nz coefficient, and refractive index characteristic), number, combination, arrangement positions, and the like of the other retardation layers may be appropriately set depending on purposes. In one embodiment, the circularly polarizing plate **100** may further include a conductive layer or an isotropic substrate with a conductive layer (both not shown). In this case, the circularly polarizing plate may be applied to a so-called inner touch panel-type input display apparatus, which includes a built-in touch sensor between a display cell (e.g., an organic EL cell) and a polarizing plate.

[0013] In practical use, the circularly polarizing plate **100** may further include a pressure-sensitive adhesive layer **50** at the outermost portion thereof on the retardation layer **30** side as in the illustrated example. When the pressure-sensitive adhesive layer is arranged in advance, the circularly polarizing plate **100** can be easily bonded to another optical member (e.g., a display cell of an image display apparatus). In this case, it is preferred that a release liner **60** be temporarily bonded to the surface of the pressure-sensitive adhesive layer **50** to protect the pressure-sensitive adhesive layer **50** until the circularly polarizing

plate is used. Further, in practical use, the circularly polarizing plate **100** may include a surface protective film **70** temporarily bonded to the outermost portion thereof on the first protective layer **11** side as in the illustrated example. The term "surface protective film" as used herein means a film for temporarily protecting the circularly polarizing plate at the time of an operation, and is different from a protective layer for the polarizer (polarizer protective film), such as the first protective layer **11** or the second protective layer **12**.

[0014] Each constituent layer or optical film of the circularly polarizing plate is laminated through the intermediation of any appropriate adhesion layer (adhesive layer or pressure-sensitive adhesive layer). A typical example of an adhesive for forming the adhesive layer is a polyvinyl alcohol-based adhesive. A typical example of a pressure-sensitive adhesive for forming the pressure-sensitive adhesive layer is an acrylic pressure-sensitive adhesive.

[0015] In the present invention, the moisture permeability of the second protective layer **12** at 40°C and a relative humidity of 92% is less than 160 g/m²/24 H. In one embodiment of the present invention, the second protective layer **12** is omitted, and the retardation layer **30** may double as a protective layer for the polarizer **20**. In this case, it is appropriate that the moisture permeability

of the retardation layer **30** at 40°C and a relative humidity of 92% be less than 160 g/m²/24 H. That is, according to each of the embodiments of the present invention, the moisture permeability of the layer adjacent to the display cell side of the polarizer **20** is optimized, and thus a circularly polarizing plate having less curling resulting from each of state change (typically peeling of the surface protective film and/or peeling of the release liner) and temporal change can be realized. As a result, when the circularly polarizing plate is applied to a flexible image display apparatus, undesired bending and warping of the image display apparatus can be satisfactorily suppressed. That is, each of the embodiments of the present invention solves a problem revealed only when a circularly polarizing plate is applied to a flexible (or foldable) image display apparatus. This is an unexpected excellent effect obtained by repeating trial and error on the optimization of the characteristics of a film-forming material itself and the thickness of a film, while maintaining optical characteristics desired of the layer (film) adjacent to the display cell side of the polarizer, in view of the fact that the moisture permeability of the film is influenced by both the material and the thickness. The moisture permeability may be measured in conformity to JIS Z 0208 (cup method).

[0016] The circularly polarizing plate according to the embodiment of the present invention has a curling amount of preferably within ±6 mm, more preferably within ±5 mm, still more preferably

within ± 4 mm when placed under an environment (typically under a cleanroom environment) having a temperature of $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and a relative humidity of $55\% \pm 10\%$ for 72 hours under each of the following states: (i) a state in which the circularly polarizing plate has temporarily bonded thereto the release liner **60** and the surface protective film **70**; (ii) a state in which the release liner **60** has been peeled and removed from the circularly polarizing plate, and the circularly polarizing plate has temporarily bonded thereto the surface protective film **70**; and (iii) a state in which the release liner **60** and the surface protective film **70** have been peeled and removed from the circularly polarizing plate. In particular, the circularly polarizing plate according to the embodiment of the present invention has a feature in that the curling amount resulting from temporal change under the state (iii) is small. That is, control of curling under each of the states (i) and (ii) has been performed in the related art, and in a related-art rigid image display apparatus, it has been sufficient to perform only the control of curling under each of these states. Meanwhile, it has been found that, when the curling amount resulting from temporal change under the state (iii) is set to the above-mentioned range, bending and warping of a flexible (or foldable) image display apparatus itself can be satisfactorily suppressed. The curling amount resulting from temporal change under the state (iii) can be controlled by optimizing the moisture permeability of the layer adjacent to the display cell side of the polarizer as described above.

[0017] The above-mentioned embodiments may be combined as appropriate, and modifications obvious in the art may be made to the constituent elements in the embodiments. In addition, the constituent elements in the embodiments may each be replaced with an optically equivalent configuration.

[0018] Now, the constituent elements of the circularly polarizing plate are described in more detail.

[0019] B. First Protective Layer

The first protective layer **11** is formed of any appropriate film that may be used as a protective layer for the polarizer. Specific examples of a material serving as a main component of the film include transparent resins, for example, a cellulose-based resin, such as triacetylcellulose (TAC), a polyester-based resin, a polyvinyl alcohol-based resin, a polycarbonate-based resin, a polyamide-based resin, a polyimide-based resin, a polyether sulfone-based resin, a polysulfone-based resin, a polystyrene-based resin, a polynorbornene-based resin, a polyolefin-based resin, a (meth)acrylic resin, and an acetate-based resin. Another example thereof is a thermosetting resin or a UV-curable resin, such as a (meth)acrylic resin, a urethane-based resin, a (meth)acrylic urethane-based resin, an epoxy-based resin, or a silicone-based resin. Still another example thereof is a glassy polymer, such as

a siloxane-based polymer. In addition, a polymer film described in JP 2001-343529 A (WO 01/37007 A1) may also be used. As a material for the film, for example, there may be used a resin composition containing a thermoplastic resin having a substituted or unsubstituted imide group in a side chain and a thermoplastic resin having a substituted or unsubstituted phenyl group and a nitrile group in side chains. An example thereof is a resin composition containing an alternate copolymer formed of isobutene and N-methylmaleimide and an acrylonitrile-styrene copolymer. The polymer film may be, for example, a product obtained by subjecting the resin composition to extrusion molding.

[0020] Any appropriate thickness may be adopted as the thickness of the first protective layer as long as the effect of the present invention is obtained. The thickness of the first protective layer is, for example, from 5 μm to 70 μm , preferably from 15 μm to 50 μm . When surface treatment to be described later is performed, the thickness of the first protective layer is a thickness including the thickness of a surface treatment layer.

[0021] The circularly polarizing plate of the present invention is typically arranged on the viewer side of an image display apparatus, and the first protective layer **11** is typically arranged on the viewer side. Therefore, the first protective layer **11** may be subjected to any appropriate surface treatment depending on purposes. In one

embodiment, hard coat treatment may be performed to form the hard coat layer **40** as described above. As a material for forming the hard coat layer, for example, there is given a UV-curable resin containing an acrylic resin (acrylate or urethane acrylate) or an epoxy-based resin as a main component. The hard coat layer may be formed by: applying a solution containing a monomer or oligomer of such UV-curable resin, and as required, a photopolymerization initiator and a leveling agent to the first protective layer and drying the solution; and curing the dried applied layer through irradiation with light (typically UV light). Other specific examples of the surface treatment include antireflection treatment, anti-sticking treatment, and antiglare treatment. Further/alternatively, the first protective layer **11** may be subjected to treatment for improving viewability in the case of viewing through polarized sunglasses (typically imparting a circular (elliptical) polarization function or imparting an ultra-high retardation) as required. When such treatment is performed, even in the case of viewing a display screen through a polarizing lens, such as polarized sunglasses, excellent viewability can be realized. Therefore, the circularly polarizing plate can be suitably applied even to an image display apparatus that may be used outdoors.

[0022] C. Polarizer

Any appropriate polarizer may be adopted as the polarizer **20**. For example, a resin film for forming the polarizer may be a

single-layer resin film, or may be a laminate of two or more layers.

[0023] Specific examples of the polarizer formed of a single-layer resin film include: a product obtained by subjecting a hydrophilic polymer film, such as a polyvinyl alcohol (PVA)-based film, a partially formalized PVA-based film, or an ethylene-vinyl acetate copolymer-based partially saponified film, to dyeing treatment with a dichroic substance, such as iodine or a dichroic dye, and stretching treatment; and a polyene-based alignment film, such as a dehydration-treated product of PVA or a dehydrochlorination-treated product of polyvinyl chloride. Of those, a polarizer obtained by dyeing a PVA-based film with iodine and uniaxially stretching the resultant is preferably used because of its excellent optical characteristics.

[0024] The dyeing with iodine is performed by, for example, immersing the PVA-based film in an aqueous solution of iodine. The stretching ratio of the uniaxial stretching is preferably from 3 times to 7 times. The stretching may be performed after the dyeing treatment or may be performed simultaneously with the dyeing. In addition, the stretching may be performed before the dyeing. The PVA-based film is subjected to, for example, swelling treatment, cross-linking treatment, washing treatment, or drying treatment as required. For example, when the PVA-based film is washed with water by being immersed in water before the dyeing, the soil or

antiblocking agent on the surface of the PVA-based film can be washed off. In addition, the PVA-based film can be swollen to prevent dyeing unevenness or the like.

[0025] A specific example of the polarizer obtained by using a laminate is a polarizer obtained by using: a laminate of a resin substrate and a PVA-based resin layer (PVA-based resin film) laminated on the resin substrate; or a laminate of a resin substrate and a PVA-based resin layer formed on the resin substrate through application. The polarizer obtained by using the laminate of the resin substrate and the PVA-based resin layer formed on the resin substrate through application may be produced by, for example, a method involving: applying a PVA-based resin solution to the resin substrate; drying the solution to form the PVA-based resin layer on the resin substrate, thereby providing the laminate of the resin substrate and the PVA-based resin layer; and stretching and dyeing the laminate to turn the PVA-based resin layer into the polarizer. In this embodiment, the stretching typically includes the stretching of the laminate under a state in which the laminate is immersed in an aqueous solution of boric acid. The stretching may further include the aerial stretching of the laminate at high temperature (e.g., 95°C or more) before the stretching in the aqueous solution of boric acid as required. The resultant laminate of the resin substrate and the polarizer may be used as it is (i.e., the resin substrate may be used as a protective layer for the polarizer).

Alternatively, a product obtained as described below may be used: the resin substrate is peeled from the laminate of the resin substrate and the polarizer, and any appropriate protective layer in accordance with purposes is laminated on the peeling surface. Details of such method of producing a polarizer are described in, for example, JP 2012-73580 A, the description of which is incorporated herein by reference in its entirety.

[0026] The thickness of the polarizer is preferably 25 μm or less, more preferably from 1 μm to 22 μm , still more preferably from 1 μm to 12 μm , particularly preferably from 3 μm to 12 μm . When the thickness of the polarizer falls within such range, curling at the time of heating can be satisfactorily suppressed and satisfactory appearance durability at the time of heating is obtained.

[0027] The polarizer preferably shows absorption dichroism at any wavelength in the wavelength range of from 380 nm to 780 nm. As described above, the single layer transmittance of the polarizer is from 43.0% to 46.0%, preferably from 44.5% to 46.0%. The polarization degree of the polarizer is preferably 97.0% or more, more preferably 99.0% or more, still more preferably 99.9% or more.

[0028] D. Second Protective Layer

The moisture permeability of the second protective layer **12**

at 40°C and a relative humidity of 92% is less than 160 g/m²/24 H as described above, and is preferably 155 g/m²/24 H or less, more preferably 150 g/m²/24 H or less. When the moisture permeability is set to such range, as described above, a circularly polarizing plate having less curling resulting from each of state change (typically peeling of the surface protective film and/or peeling of the release liner) and temporal change can be realized. A lower limit for the moisture permeability of the second protective layer is, for example, 10 g/m²/24 H.

[0029] The second protective layer may be formed of any appropriate film that can be used as a protective layer for a polarizer as long as the second protective layer can have the above-mentioned moisture permeability. A typical example of a material for forming the second protective layer is an acrylic resin. In one embodiment, a (meth)acrylic resin having a glutarimide structure is used as the acrylic resin. The (meth)acrylic resin having a glutarimide structure is described in, for example, JP 2006-309033 A, JP 2006-317560 A, JP 2006-328329 A, JP 2006-328334 A, JP 2006-337491 A, JP 2006-337492 A, JP 2006-337493 A, JP 2006-337569 A, JP 2007-009182 A, JP 2009-161744 A, and JP 2010-284840 A, the descriptions of which are incorporated herein by reference.

[0030] In another embodiment, a (meth)acrylic resin having a lactone ring structure is used as the acrylic resin. The

(meth)acrylic resin having a lactone ring structure is described in, for example, JP 2000-230016 A, JP 2001-151814 A, JP 2002-120326 A, JP 2002-254544 A, and JP 2005-146084 A, the descriptions of which are incorporated herein by reference.

[0031] The (meth)acrylic resin has a glass transition temperature (T_g) of preferably 115°C or more, more preferably 120°C or more, still more preferably 125°C or more, particularly preferably 130°C or more. This is because excellent durability can be obtained. An upper limit value for the T_g of the (meth)acrylic resin is not particularly limited, but is preferably 170°C or less from the viewpoint of formability or the like.

[0032] The (meth)acrylic resin has a mass-average molecular weight (sometimes referred to as weight-average molecular weight) of preferably from 1,000 to 2,000,000, more preferably from 5,000 to 1,000,000, still more preferably from 10,000 to 500,000, particularly preferably from 50,000 to 500,000.

[0033] It is preferred that the second protective layer **12** be optically isotropic. The phrase "be optically isotropic" as used herein refers to having an in-plane retardation Re(550) of from 0 nm to 10 nm and a thickness direction retardation Rth(550) of from -10 nm to +10 nm.

[0034] The thickness of the second protective layer is, for example, from 15 μm to 35 μm , preferably from 15 μm to 25 μm . With such thickness, the above-mentioned moisture permeability can be realized while optical characteristics desired as an inner (display cell side) protective layer for the polarizer are maintained.

[0035] E. Retardation Film

The retardation layer **30** may have any appropriate optical characteristics and/or mechanical characteristics depending on purposes. The retardation layer **30** typically has a slow axis. As described above, the angle θ formed between the slow axis of the retardation layer **30** and the absorption axis of the polarizer **11** is typically from 35° to 55° , and is preferably from 38° to 52° , more preferably from 42° to 48° , still more preferably about 45° . When the angle θ falls within such range, a circularly polarizing plate having an extremely excellent circular polarization characteristic (consequently an extremely excellent antireflection characteristic) can be obtained by using the retardation layer **30** as a $\lambda/4$ plate as described later.

[0036] The retardation layer **30** preferably has a refractive index characteristic of showing a relationship of $n_x > n_y \geq n_z$. The retardation layer is typically arranged in order to impart an antireflection characteristic to the polarizing plate, and may function as a $\lambda/4$ plate. The in-plane retardation $R_e(550)$ of the

retardation layer is from 80 nm to 200 nm as described above, and is preferably from 100 nm to 180 nm, more preferably from 110 nm to 170 nm. Herein, " $n_y=n_z$ " encompasses not only a case in which n_y and n_z are exactly equal to each other, but also a case in which n_y and n_z are substantially equal to each other. Therefore, a relationship of $n_y < n_z$ may be satisfied without impairing the effect of the present invention.

[0037] The n_z coefficient of the retardation layer is preferably from 0.9 to 3, more preferably from 0.9 to 2.5, still more preferably from 0.9 to 1.5, particularly preferably from 0.9 to 1.3. When such relationship is satisfied, in the case of using the circularly polarizing plate to be obtained for an image display apparatus, an extremely excellent reflection hue can be achieved.

[0038] The retardation layer may show such a reverse wavelength dispersion characteristic that its retardation value increases with an increase in wavelength of measurement light, may show such a positive wavelength dispersion characteristic that the retardation value reduces with an increase in wavelength of the measurement light, or may show such a flat wavelength dispersion characteristic that the retardation value remains substantially unchanged even when the wavelength of the measurement light is changed. In one embodiment, the retardation layer shows the reverse wavelength dispersion characteristic. In this case, the retardation layer has

a ratio $\text{Re}(450)/\text{Re}(550)$ of preferably 0.8 or more and less than 1, more preferably 0.8 or more and 0.95 or less. With such configuration, an extremely excellent antireflection characteristic can be realized. In another embodiment, the retardation layer shows the flat wavelength dispersion characteristic. In this case, the retardation layer preferably has a ratio $\text{Re}(450)/\text{Re}(550)$ of from 0.99 to 1.03, and preferably has a ratio $\text{Re}(650)/\text{Re}(550)$ of from 0.98 to 1.02.

[0039] The retardation layer contains a resin having an absolute value of a photoelastic coefficient of preferably $2 \times 10^{-11} \text{ m}^2/\text{N}$ or less, more preferably from $2.0 \times 10^{-13} \text{ m}^2/\text{N}$ to $1.5 \times 10^{-11} \text{ m}^2/\text{N}$, still more preferably from $1.0 \times 10^{-12} \text{ m}^2/\text{N}$ to $1.2 \times 10^{-11} \text{ m}^2/\text{N}$. When the absolute value of the photoelastic coefficient falls within such range, a retardation change hardly occurs in the case where a shrinkage stress is generated at the time of heating. As a result, heat unevenness in an image display apparatus to be obtained can be satisfactorily prevented.

[0040] When, as described above, the second protective layer **12** is omitted and the retardation layer **30** doubles as a protective layer for the polarizer **20**, the moisture permeability of the retardation layer at 40°C and a relative humidity of 92% is less than $160 \text{ g/m}^2/24 \text{ H}$ as described above, and is preferably $120 \text{ g/m}^2/24 \text{ H}$ or less, more preferably $100 \text{ g/m}^2/24 \text{ H}$ or less. When the moisture

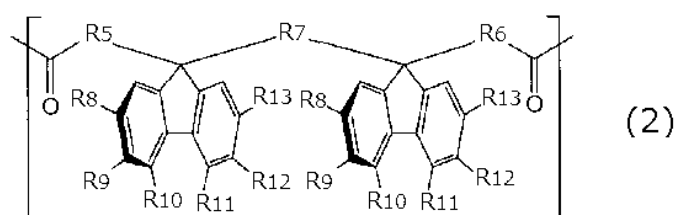
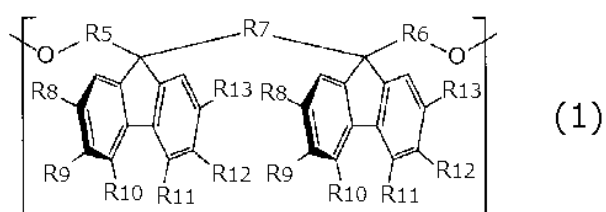
permeability is set to such range, as described above, a circularly polarizing plate having less curling resulting from each of state change (typically peeling of the surface protective film and/or peeling of the release liner) and temporal change can be realized. A lower limit for the moisture permeability of the retardation layer is, for example, 10 g/m²/24 H.

[0041] The thickness of the retardation layer is preferably 60 μm or less, more preferably from 30 μm to 58 μm. With such thickness, the above-mentioned moisture permeability can be realized while optical characteristics desired as a λ/4 plate for imparting a circular polarization function are maintained.

[0042] The retardation layer **30** may be constituted of any appropriate resin film that can satisfy the above-mentioned characteristics. Typical examples of such resin include a cyclic olefin-based resin, a polycarbonate-based resin, a cellulose-based resin, a polyester-based resin, a polyvinyl alcohol-based resin, a polyamide-based resin, a polyimide-based resin, a polyether-based resin, a polystyrene-based resin, and an acrylic resin. When the retardation layer is constituted of a resin film showing the reverse wavelength dispersion characteristic, a polycarbonate-based resin may be suitably used. When the retardation layer is constituted of a resin film showing the flat wavelength dispersion characteristic, a cyclic olefin-based resin may be suitably used.

[0043] Any appropriate polycarbonate resin may be used as the above-mentioned polycarbonate resin as long as the effect of the present invention is obtained. The polycarbonate resin preferably contains: a structural unit derived from a fluorene-based dihydroxy compound; a structural unit derived from an isosorbide-based dihydroxy compound; and a structural unit derived from at least one dihydroxy compound selected from the group consisting of an alicyclic diol, an alicyclic dimethanol, di-, tri-, or polyethylene glycol, and an alkylene glycol or spiroglycol. The polycarbonate resin preferably contains a structural unit derived from a fluorene-based dihydroxy compound, a structural unit derived from an isosorbide-based dihydroxy compound, a structural unit derived from an alicyclic dimethanol, and/or a structural unit derived from di-, tri-, or polyethylene glycol, and more preferably contains a structural unit derived from a fluorene-based dihydroxy compound, a structural unit derived from an isosorbide-based dihydroxy compound, and a structural unit derived from di-, tri-, or polyethylene glycol. The polycarbonate resin may contain a structural unit derived from any other dihydroxy compound as required. Details of the polycarbonate resin that may be suitably used in the present invention are described in, for example, JP 2014-10291 A and JP 2014-26266 A, the descriptions of which are incorporated herein by reference.

[0044] In one embodiment, a polycarbonate-based resin containing an oligofluorene structural unit may be used. An example of the polycarbonate-based resin containing an oligofluorene structural unit is a resin containing a structural unit represented by the following general formula (1) and/or a structural unit represented by the following general formula (2).



In each of the general formula (1) and the general formula (2), R₅ and R₆ each independently represent a direct bond, or a substituted or unsubstituted alkylene group having 1 to 4 carbon atoms (preferably an alkylene group having 2 or 3 carbon atoms on its main chain). R₇ represents a direct bond, or a substituted or unsubstituted alkylene group having 1 to 4 carbon atoms (preferably an alkylene group having 1 or 2 carbon atoms on its main chain). R₈ to R₁₃ each independently represent a hydrogen atom, a substituted or

unsubstituted alkyl group having 1 to 10 (preferably 1 to 4, more preferably 1 or 2) carbon atoms, a substituted or unsubstituted aryl group having 4 to 10 (preferably 4 to 8, more preferably 4 to 7) carbon atoms, a substituted or unsubstituted acyl group having 1 to 10 (preferably 1 to 4, more preferably 1 or 2) carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 10 (preferably 1 to 4, more preferably 1 or 2) carbon atoms, a substituted or unsubstituted aryloxy group having 1 to 10 (preferably 1 to 4, more preferably 1 or 2) carbon atoms, a substituted or unsubstituted acyloxy group having 1 to 10 (preferably 1 to 4, more preferably 1 or 2) carbon atoms, a substituted or unsubstituted amino group, a substituted or unsubstituted vinyl group having 1 to 10 (preferably 1 to 4) carbon atoms, a substituted or unsubstituted ethynyl group having 1 to 10 (preferably 1 to 4) carbon atoms, a sulfur atom having a substituent, a silicon atom having a substituent, a halogen atom, a nitro group, or a cyano group. At least two adjacent groups of R₈ to R₁₃ may be bonded to each other to form a ring.

[0045] In one embodiment, fluorene rings contained in the oligofluorene structural units each have a configuration in which all of R₈ to R₁₃ represent hydrogen atoms, or each have a configuration in which R₈ and/or R₁₃ represent any one selected from the group consisting of a halogen atom, an acyl group, a nitro group, a cyano group, and a sulfo group, and R₉ to R₁₂ each represent a hydrogen atom.

[0046] Details of the polycarbonate-based resin containing an oligofluorene structural unit are described in, for example, JP 2015-212816 A, the description of which is incorporated herein by reference.

[0047] The glass transition temperature of the polycarbonate resin is preferably 110°C or more and 150°C or less, more preferably 120°C or more and 140°C or less. When the glass transition temperature is excessively low, the heat resistance of the resin tends to deteriorate and hence the resin may cause a dimensional change after its forming into a film. In addition, the image quality of an organic EL panel to be obtained may reduce. When the glass transition temperature is excessively high, the forming stability of the resin at the time of its forming into a film may deteriorate. In addition, the transparency of the film may be impaired. The glass transition temperature is determined in conformity to JIS K 7121 (1987).

[0048] The molecular weight of the polycarbonate resin may be expressed as a reduced viscosity. The reduced viscosity is measured with an Ubbelohde viscometer at a temperature of 20.0°C±0.1°C after precise adjustment of a polycarbonate concentration to 0.6 g/dL through the use of methylene chloride as a solvent. A lower limit for the reduced viscosity is generally preferably 0.30 dL/g, more

preferably 0.35 dL/g or more. An upper limit for the reduced viscosity is generally preferably 1.20 dL/g, more preferably 1.00 dL/g, still more preferably 0.80 dL/g. When the reduced viscosity is lower than the lower limit value, a problem may occur in that the mechanical strength of a formed product is reduced. Meanwhile, when the reduced viscosity is higher than the upper limit value, a problem may occur in that fluidity during forming is lowered to lower productivity and formability.

[0049] As the polycarbonate-based resin film, a commercially available film may also be used. Specific examples of the commercially available product include products available under the product names "PURE-ACE WR-S", "PURE-ACE WR-W", and "PURE-ACE WR-M" from Teijin Limited, and a product available under the product name "NRF" from Nitto Denko Corporation.

[0050] The cyclic olefin-based resin is a generic term for resins each polymerized by using a cyclic olefin as a polymerization unit, and examples thereof include resins described in JP 01-240517 A, JP 03-14882 A, and JP 03-122137 A. Specific examples thereof include: a ring-opened (co)polymer of the cyclic olefin, an addition polymer of the cyclic olefin, a copolymer (typically a random copolymer) of the cyclic olefin and an α -olefin, such as ethylene or propylene, and graft-modified products obtained by modifying the polymers with unsaturated carboxylic acids or derivatives

thereof; and hydrogenated products thereof. Specific examples of the cyclic olefin include norbornene-based monomers. Examples of the norbornene-based monomers include: norbornene, alkyl and/or alkylidene substituted products thereof, such as 5-methyl-2-norbornene, 5-dimethyl-2-norbornene, 5-ethyl-2-norbornene, 5-butyl-2-norbornene, and 5-ethylidene-2-norbornene, and polar group (e.g., halogen) substituted products thereof; dicyclopentadiene and 2,3-dihydrodicyclopentadiene; dimethanooctahydronaphthalene, alkyl and/or alkylidene substituted products thereof, and polar group (e.g., halogen) substituted products thereof, such as 6-methyl-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene, 6-ethyl-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene, 6-ethylidene-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene, 6-chloro-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene, 6-cyano-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene, 6-pyridyl-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene, and 6-methoxycarbonyl-1,4:5,8-dimethano-1,4,4a,5,6,7,8,8a-octahydronaphthalene; and trimers or tetramers of cyclopentadiene, such

as

4,9:5,8-dimethano-3a,4,4a,5,8,8a,9,9a-octahydro-1H-benzoindene

and

4,11:5,10:6,9-trimethano-3a,4,4a,5,5a,6,9,9a,10,10a,11,11a-dodecahydro-1H-cyclopentaanthracene.

[0051] In the present invention, any other cycloolefin that may be subjected to ring-opening polymerization may be used in combination with the cycloolefin to the extent that the object of the present invention is not impaired. Specific examples of such cycloolefin include compounds each having one reactive double bond, such as cyclopentene, cyclooctene, and 5,6-dihydrodicyclopentadiene.

[0052] The number-average molecular weight (M_n) of the cyclic olefin-based resin measured by a gel permeation chromatograph (GPC) method based on a toluene solvent is preferably from 25,000 to 200,000, more preferably from 30,000 to 100,000, most preferably from 40,000 to 80,000. When the number-average molecular weight falls within the range, a film that is excellent in mechanical strength and has satisfactory solubility, satisfactory formability, and satisfactory casting operability can be obtained.

[0053] A commercially available film may be used as the cyclic olefin-based resin film. Specific examples thereof include:

products available under the product names "ZEONEX" and "ZEONOR" from Zeon Corporation; a product available under the product name "Arton" from JSR Corporation; a product available under the product name "TOPAS" from TICONA; and a product available under the product name "APEL" from Mitsui Chemicals, Inc.

[0054] The retardation layer **30** is obtained by, for example, stretching a film formed from the resin. Any appropriate forming processing method may be adopted as a method of forming a film from the resin. Specific examples thereof include a compression molding method, a transfer molding method, an injection molding method, an extrusion molding method, a blow molding method, a powder forming method, an FRP molding method, a cast coating method (e.g., a casting method), a calender molding method, and a hot-press method. Of those, an extrusion molding method or a cast coating method is preferred. This is because the extrusion molding method or the cast coating method can increase the smoothness of the film to be obtained and provide satisfactory optical uniformity. Forming conditions may be appropriately set depending on, for example, the composition and kind of the resin to be used and desired characteristics of the retardation layer. Many film products are commercially available as the polycarbonate-based resin or the cyclic olefin-based resin as described above, and hence each of the commercially available films may be subjected as it is to stretching treatment.

[0055] The thickness of the resin film (unstretched film) may be set to any appropriate value depending on, for example, the desired thickness and desired optical characteristics of the retardation layer, and stretching conditions to be described later. The thickness is preferably from 50 μm to 300 μm .

[0056] Any appropriate stretching method and stretching conditions (such as a stretching temperature, a stretching ratio, and a stretching direction) may be adopted for the stretching. Specifically, one kind of various stretching methods, such as free-end stretching, fixed-end stretching, free-end shrinkage, and fixed-end shrinkage, may be employed alone, or two or more kinds thereof may be employed simultaneously or sequentially. With regard to the stretching direction, the stretching may be performed in various directions or dimensions, such as a lengthwise direction, a widthwise direction, a thickness direction, and an oblique direction.

[0057] In one embodiment, the retardation film is produced by subjecting the resin film to uniaxial stretching or fixed-end uniaxial stretching. A specific example of the fixed-end uniaxial stretching is a method involving stretching the resin film in its widthwise direction (lateral direction) while running the film in its lengthwise direction. The stretching ratio is preferably from

1.1 times to 3.5 times.

[0058] In another embodiment, the retardation film may be produced by obliquely stretching a resin film having an elongate shape in a direction at the angle θ with respect to its lengthwise direction in a continuous manner. The adoption of the oblique stretching provides a stretched film having an elongate shape with an alignment angle of the angle θ with respect to the lengthwise direction of the film (slow axis in the direction at the angle θ), enables a roll-to-roll process upon, for example, its lamination with the polarizer, and can simplify a production process. The angle θ may be an angle formed between the absorption axis of the polarizer and the slow axis of the retardation layer in the circularly polarizing plate. As described above, the angle θ is typically from 35° to 55° , preferably from 38° to 52° , more preferably from 42° to 48° , still more preferably about 45° .

[0059] As a stretching machine to be used for the oblique stretching, for example, there is given a tenter stretching machine capable of applying feeding forces, or tensile forces or take-up forces, having different speeds on left and right sides in a lateral direction and/or a longitudinal direction. Examples of the tenter stretching machine include a lateral uniaxial stretching machine and a simultaneous biaxial stretching machine, and any appropriate stretching machine may be used as long as the resin film having

an elongate shape can be continuously subjected to the oblique stretching.

[0060] Through appropriate control of each of the speeds on the left and right sides in the stretching machine, a retardation layer (substantially a retardation film having an elongate shape) having the desired in-plane retardation and having a slow axis in the desired direction can be obtained.

[0061] The stretching temperature of the film may be changed depending on, for example, the desired in-plane retardation value and thickness of the retardation layer, the kind of the resin to be used, the thickness of the film to be used, and the stretching ratio. Specifically, the stretching temperature is preferably from $T_g-30^{\circ}\text{C}$ to $T_g+60^{\circ}\text{C}$, more preferably from $T_g-15^{\circ}\text{C}$ to $T_g+55^{\circ}\text{C}$, most preferably from $T_g-10^{\circ}\text{C}$ to $T_g+50^{\circ}\text{C}$. When the stretching is performed at such temperature, a first retardation layer having characteristics that are appropriate in the present invention can be obtained. T_g refers to the glass transition temperature of the material for forming the film.

[0062] A retardation film having the desired optical characteristics (e.g., refractive index characteristic, in-plane retardation, and N_z coefficient) can be obtained by appropriately selecting the stretching method and stretching conditions.

[0063] F. Conductive Layer or Isotropic Substrate with Conductive Layer

The conductive layer may be formed by forming a metal oxide film on any appropriate substrate by any appropriate film formation method (e.g., a vacuum deposition method, a sputtering method, a CVD method, an ion plating method, or a spraying method). Examples of the metal oxide include indium oxide, tin oxide, zinc oxide, an indium-tin composite oxide, a tin-antimony composite oxide, a zinc-aluminum composite oxide, and an indium-zinc composite oxide. Of those, an indium-tin composite oxide (ITO) is preferred.

[0064] When the conductive layer contains a metal oxide, the thickness of the conductive layer is preferably 50 nm or less, more preferably 35 nm or less. A lower limit for the thickness of the conductive layer is preferably 10 nm.

[0065] The conductive layer may be transferred from the substrate onto the retardation layer to serve alone as a constituent layer of the circularly polarizing plate, or may be laminated, as a laminate with the substrate (substrate with a conductive layer), on the retardation layer. It is preferred that the substrate be optically isotropic, and hence the conductive layer may be used, as an isotropic substrate with a conductive layer, for the circularly polarizing plate.

[0066] Any appropriate isotropic substrate may be adopted as the optically isotropic substrate (isotropic substrate). Examples of a material for forming the isotropic substrate include: a material containing, as a main skeleton, a resin having no conjugated system, such as a norbornene-based resin or an olefin-based resin; and a material having a cyclic structure, such as a lactone ring or a glutarimide ring, in a main chain of an acrylic resin. The use of such material can suppress and reduce the expression of a retardation caused by the alignment of molecular chains when the isotropic substrate is formed. The thickness of the isotropic substrate is preferably 50 μm or less, more preferably 35 μm or less. A lower limit for the thickness of the isotropic substrate is, for example, 20 μm .

[0067] The conductive layer and/or the conductive layer of the isotropic substrate with a conductive layer may be patterned as required. Through the patterning, a conductive part and an insulating part may be formed. As a result, an electrode may be formed. The electrode may function as a touch sensor electrode for detecting contact on a touch panel. Any appropriate method may be adopted as a patterning method. Specific examples of the patterning method include a wet etching method and a screen printing method.

[0068] G. Image Display Apparatus

The circularly polarizing plate described in the section A to the section F may be applied to a flexible image display apparatus. Therefore, the present invention encompasses a flexible image display apparatus using such circularly polarizing plate. A typical example of the flexible image display apparatus is an organic EL display apparatus. A flexible image display apparatus according to an embodiment of the present invention includes, on its viewer side, the circularly polarizing plate described in the section A to the section F. The circularly polarizing plate is laminated so that the retardation layer may be on the display cell (e.g., organic EL cell) side (so that the polarizer may be on the viewer side).

[0069] The flexible organic EL display apparatus may be realized by, for example, using a flexible or foldable material to form a substrate of the organic EL cell. Typical examples of such material include thin glass provided with flexibility, a film of a thermoplastic resin or a thermosetting resin, an alloy, and a metal. Examples of the thermoplastic resin or the thermosetting resin include a polyester-based resin, a polyimide-based resin, an epoxy-based resin, a polyurethane-based resin, a polystyrene-based resin, a polyolefin-based resin, a polyamide-based resin, a polycarbonate-based resin, a silicone-based resin, a fluorine-based resin, and an acrylonitrile-butadiene-styrene copolymer resin. Examples of the alloy include stainless steel, alloy 36, and alloy 42. Examples of the metal include copper, nickel, iron, aluminum,

and titanium.

[0070] The configuration of the organic EL display apparatus is well known in the art, and hence detailed description thereof is omitted. Details of the flexible or foldable organic EL display apparatus are described in, for example, JP 4601463 B2 and JP 4707996 B2, the descriptions of which are incorporated herein by reference.

Examples

[0071] Now, the present invention is specifically described by way of Examples. However, the present invention is not limited by Examples below. Measurement methods for characteristics are as described below.

[0072] (1) Thickness

Measurement was performed with a digital micrometer (KC-351C manufactured by Anritsu Corporation).

(2) Retardation Values of Retardation Layer

The refractive indices n_x , n_y , and n_z of a retardation layer used in each of Examples and Comparative Examples were measured with an automatic birefringence measuring apparatus (manufactured by Oji Scientific Instruments Co., Ltd., Automatic Birefringence Analyzer KOBRA-WPR). The measurement wavelength for an in-plane retardation R_e was from 450 nm and 550 nm, the measurement wavelength

for a thickness direction retardation R_{th} was 550 nm, and the measurement temperature was 23°C.

(3) Moisture Permeability

A film constituting a second protective layer or a retardation layer was subjected to measurement in conformity to JIS Z 0208 (cup method).

(4) Curling Amount

A circularly polarizing plate obtained in each of Examples and Comparative Examples was measured for its curling amount when placed under a cleanroom environment having a temperature of 25°C±5°C and a relative humidity of 55%±10% for 72 hours under each of the following states: (i) a state in which the circularly polarizing plate had temporarily bonded thereto a release liner and a surface protective film; (ii) a state in which the release liner had been peeled and removed from the circularly polarizing plate, and the circularly polarizing plate had temporarily bonded thereto the surface protective film; and (iii) a state in which the release liner and the surface protective film had been peeled and removed from the circularly polarizing plate. Specifically, the circularly polarizing plate was left to stand still on a stand free of static electricity so that its central portion was brought into contact with the stand, and warping of the circularly polarizing plate after a lapse of 72 hours was measured with a metal ruler made of steel.

The highest of the warpings in the four corners of the circularly polarizing plate was adopted as the curling amount. Further, a case in which the circularly polarizing plate was warped to its first protective layer side (hard coat layer side) was marked with the "plus" symbol, and a case in which the circularly polarizing plate was warped to its second protective layer side (pressure-sensitive adhesive layer side) was marked with the "minus" symbol. A case in which the curling amount was within ± 6 mm was evaluated as "satisfactory", and a case in which the curling amount was more than 6 mm was evaluated as "unsatisfactory".

[0073] [Reference Example 1: Production of Polarizing Plate]

An elongate roll of a polyvinyl alcohol (PVA)-based resin film having a thickness of 60 μm (manufactured by Kuraray Co., Ltd., product name: "PE6000") was uniaxially stretched in its elongate direction with a roll stretching machine at a ratio of 5.9 times in the elongate direction, and at the same time, was subjected to swelling, dyeing, cross-linking, and washing treatments, followed finally by drying treatment. Thus, a polarizer 1 having a thickness of 22 μm was produced.

Specifically, in the swelling treatment, the film was stretched at a ratio of 2.2 times while being treated with pure water at 20°C. Then, in the dyeing treatment, the film was stretched at a ratio of 1.4 times while being treated in an aqueous solution at 30°C

containing iodine and potassium iodide at a weight ratio of 1:7, whose iodine concentration had been adjusted so that the polarizer to be obtained had a single layer transmittance of 45.0%. Further, two-stage cross-linking treatment was adopted for the cross-linking treatment. In the first-stage cross-linking treatment, the film was stretched at a ratio of 1.2 times while being treated in an aqueous solution at 40°C having dissolved therein boric acid and potassium iodide. The boric acid content and potassium iodide content of the aqueous solution of the first-stage cross-linking treatment were set to 5.0 wt% and 3.0 wt%, respectively. In the second-stage cross-linking treatment, the film was stretched at a ratio of 1.6 times while being treated in an aqueous solution at 65°C having dissolved therein boric acid and potassium iodide. The boric acid content and potassium iodide content of the aqueous solution of the second-stage cross-linking treatment were set to 4.3 wt% and 5.0 wt%, respectively. In addition, in the washing treatment, the film was treated in an aqueous solution of potassium iodide at 20°C. The potassium iodide content of the aqueous solution of the washing treatment was set to 2.6 wt%. Finally, in the drying treatment, the film was dried at 70°C for 5 minutes. Thus, the polarizer 1 was obtained.

On both surfaces of the resultant polarizer 1, through the intermediation of a polyvinyl alcohol-based adhesive, a methacrylic resin film having a glutarimide ring structure (thickness: 20 μ m,

corresponding to the second protective layer) and an HC-TAC film (thickness: 47 μm , corresponding to the first protective layer) having a hard coat (HC) layer formed by hard coat treatment on one surface of a TAC film were respectively bonded. Thus, a polarizing plate 1 having a configuration "first protective layer/polarizer 1/second protective layer" was obtained.

The methacrylic resin film having a glutarimide ring structure was produced as described below. Methacrylic resin pellets each having a glutarimide ring structure was dried at 100.5 kPa and 100°C for 12 hours, and extruded using a single-screw extruder from a T-die at a die temperature of 270°C to be formed into a film shape. The resultant film was stretched in its conveying direction (MD) under an atmosphere having a temperature higher than the glass transition temperature T_g of the resin by 10°C, and was then stretched in a direction (TD) perpendicular to the conveying direction under an atmosphere having a temperature higher than the glass transition temperature T_g of the resin by 7°C. The resultant film substantially showed optical isotropy.

[0074] [Reference Example 2: Production of Polarizing Plate]

An elongate roll of a polyvinyl alcohol (PVA)-based resin film having a thickness of 30 μm (manufactured by Kuraray Co., Ltd., product name: "PE3000") was uniaxially stretched in its elongate direction with a roll stretching machine at a ratio of 5.9 times

in the elongate direction, and at the same time, was subjected to swelling, dyeing, cross-linking, and washing treatments, followed finally by drying treatment. Thus, a polarizer 2 having a thickness of 12 μm was produced. An HC-PC film (thickness: 25 μm , corresponding to the first protective layer) having a hard coat (HC) layer formed by hard coat treatment on one surface of a polycarbonate-based resin film was bonded to one surface of the resultant polarizer 2 through the intermediation of a polyvinyl alcohol-based adhesive. Thus, a polarizing plate 2 having a configuration "first protective layer/polarizer 2" was obtained.

[0075] [Reference Example 3: Production of Polarizing Plate]

On both surfaces of the polarizer 2 obtained in Reference Example 2, through the intermediation of a polyvinyl alcohol-based adhesive, a TAC film manufactured by Konica Minolta, Inc. (product name: KC2UA, thickness: 25 μm , corresponding to the second protective layer) and an HC-TAC film (thickness: 32 μm , corresponding to the first protective layer) having a hard coat (HC) layer formed by hard coat treatment on one surface of the TAC film were respectively bonded. Thus, a polarizing plate 3 having a configuration "first protective layer/polarizer 2/second protective layer" was obtained.

[0076] [Reference Example 4: Production of Polarizing Plate]

A polarizing plate 4 having a configuration "first protective layer/polarizer 1/second protective layer" was obtained in the same

manner as in Reference Example 1 except that a TAC film manufactured by Konica Minolta, Inc. (product name: KC2CT1, thickness: 20 μm) was used as the second protective layer.

[0077] [Reference Example 5: Production of Polarizing Plate]

An elongate roll of a polyvinyl alcohol (PVA)-based resin film having a thickness of 60 μm (manufactured by Kuraray Co., Ltd., product name: "PE6000") was uniaxially stretched in its elongate direction with a roll stretching machine at a ratio of 5.9 times in the elongate direction, and at the same time, was subjected to swelling, dyeing, cross-linking, and washing treatments, followed finally by drying treatment. Thus, a polarizer 3 having a thickness of 23 μm was produced. A low-reflection TAC film (thickness: 71 μm , corresponding to the first protective layer; manufactured by Dai Nippon Printing Co., Ltd., product name: "DSG-03HL") having a hard coat (HC) layer formed by low-reflection hard coat treatment on one surface of a TAC film was bonded to one surface of the resultant polarizer 3 through the intermediation of a polyvinyl alcohol-based adhesive. Thus, a polarizing plate 5 having a configuration "first protective layer/polarizer 3" was obtained.

[0078] [Reference Example 6: Production of Retardation Film constituting Retardation Layer]

1. Production of Polycarbonate Resin Film

26.2 Parts by mass of isosorbide (ISB), 100.5 parts by mass

of 9,9-[4-(2-hydroxyethoxy)phenyl]fluorene (BHEPF), 10.7 parts by mass of 1,4-cyclohexanedimethanol (1,4-CHDM), 105.1 parts by mass of diphenyl carbonate (DPC), and 0.591 part by mass of cesium carbonate serving as a catalyst (0.2 mass% aqueous solution) were each loaded into a reaction vessel. Under a nitrogen atmosphere, as a first step of a reaction, the heating medium temperature of the reaction vessel was set to 150°C and the raw materials were dissolved while being stirred as required (about 15 minutes).

Then, the pressure in the reaction vessel was changed from normal pressure to 13.3 kPa, and while the heating medium temperature of the reaction vessel was increased to 190°C in 1 hour, generated phenol was taken out of the reaction vessel.

The temperature in the reaction vessel was kept at 190°C for 15 minutes. After that, as a second step, the pressure in the reaction vessel was set to 6.67 kPa, the heating medium temperature of the reaction vessel was increased to 230°C in 15 minutes, and generated phenol was taken out of the reaction vessel. As the stirring torque of the stirrer increased, the temperature was increased to 250°C in 8 minutes, and in order to remove generated phenol, the pressure in the reaction vessel was reduced to 0.200 kPa or less. After predetermined stirring torque had been reached, the reaction was stopped, and the produced reaction product was extruded into water and then pelletized to provide a polycarbonate resin having the

following composition: BHEPF/ISB/1,4-CHDM=47.4 mol%/37.1 mol%/15.5 mol%.

The resultant polycarbonate resin had a glass transition temperature of 136.6°C and a reduced viscosity of 0.395 dL/g.

The resultant polycarbonate resin was vacuum-dried at 80°C for 5 hours, and then a polycarbonate resin film having a thickness of 120 µm was produced using a film-forming apparatus including a single-screw extruder (manufactured by Isuzu Kakoki, screw diameter: 25mm, cylinder preset temperature: 220°C), a T-die (width: 200mm, preset temperature: 220°C), a chill roll (preset temperature: 120°C to 130°C), and a take-up unit.

[0079] 2. Production of Retardation Film

The resultant polycarbonate resin film was laterally stretched using a tenter stretching machine to provide a retardation film having a thickness of 50 µm. In this case, the stretching ratio was 250%, and the stretching temperature was set to from 137°C to 139°C.

The resultant retardation film had an Re(550) of from 137 nm to 147 nm, a ratio Re(450)/Re(550) of 0.89, an Nz coefficient of 1.21, and an alignment angle (direction of its slow axis) of 90° with respect to its elongate direction. The retardation film was

used as a retardation layer 1.

[0080] [Reference Example 7: Production of Retardation Film constituting Retardation Layer]

A retardation film having a thickness of 55 μm was obtained in the same manner as in Reference Example 6 except that a polycarbonate resin film having a thickness of 140 μm was produced. The resultant retardation film had an $\text{Re}(550)$ of 147 nm, a ratio $\text{Re}(450)/\text{Re}(550)$ of 0.89, an Nz coefficient of 1.21, and an alignment angle (direction of its slow axis) of 90° with respect to its elongate direction. The retardation film was used as a retardation layer 2.

[0081] [Reference Example 8: Production of Retardation Film constituting Retardation Layer]

1. Production of Polycarbonate Resin Film

38.06 Parts by weight (0.059 mol) of bis[9-(2-phenoxy-carbonyl-ethyl)fluoren-9-yl]methane, 53.73 parts by weight (0.368 mol) of isosorbide (manufactured by Roquette Frères, product name: "POLYSORB"), 9.64 parts by weight (0.067 mol) of 1,4-cyclohexanedimethanol (cis-trans mixture, manufactured by SK Chemicals), 81.28 parts by weight (0.379 mol) of diphenyl carbonate (manufactured by Mitsubishi Chemical Corporation), and 3.83×10^{-4} part by weight (2.17×10^{-6} mol) of calcium acetate monohydrate serving as a catalyst were loaded into a reaction vessel, and the reaction

apparatus was purged with nitrogen while the pressure therein was reduced. Under a nitrogen atmosphere, the raw materials were dissolved while being stirred at 150°C for about 10 minutes. As a first step of a reaction, the temperature was increased to 220°C over 30 minutes, and the solution was subjected to a reaction for 60 minutes at normal pressure. Then, the pressure was reduced from normal pressure to 13.3 kPa over 90 minutes, and kept at 13.3 kPa for 30 minutes to take generated phenol out of the reaction system. Then, as a second step of the reaction, while the heating medium temperature was increased to 240°C over 15 minutes, the pressure was reduced to 0.10 kPa or less over 15 minutes to take generated phenol out of the reaction system. After predetermined stirring torque had been reached, the reaction was stopped by returning the pressure to normal pressure with nitrogen. Produced polyester carbonate was extruded into water and the strand was cut to provide polycarbonate resin pellets.

2. Production of Retardation Film

A film formed from the polycarbonate resin pellets was obliquely stretched to provide a retardation film having a thickness of 58 μm . In this case, the stretching direction was set to 45° with respect to the lengthwise direction of the film. In addition, the stretching ratio was adjusted to from 2 times to 3 times so that the retardation film expressed a retardation of $\lambda/4$. In addition, the stretching temperature was set to 148°C (i.e., the T_g of the

unstretched modified polycarbonate film+5°C). The resultant retardation film had an $\text{Re}(550)$ of 141 nm, a ratio $\text{Re}(450)/\text{Re}(550)$ of 0.83, an N_z coefficient of 1.1, a photoelastic coefficient of 16×10^{-12} Pa, and an alignment angle (direction of its slow axis) of 45° with respect to its elongate direction. The retardation film was used as a retardation layer 3.

[0082] [Example 1]

The second protective layer surface of the polarizing plate 1 and the retardation layer 1 were bonded to each other through the intermediation of an acrylic pressure-sensitive adhesive so that an angle formed between the absorption axis of the polarizer and the slow axis of the retardation layer was 45° , to thereby provide a circularly polarizing plate 1. An acrylic pressure-sensitive adhesive layer (thickness: 15 μm) was arranged on the retardation layer surface of the resultant circularly polarizing plate 1, and a release liner was temporarily bonded to the surface of the pressure-sensitive adhesive layer. Further, a surface protective film was temporarily bonded to the first protective layer surface. The protective film used was obtained by applying a pressure-sensitive adhesive having a thickness of 10 μm to a PET film having a thickness of 38 μm . The moisture permeability of the second protective layer at 40°C and a relative humidity of 92% was 150 $\text{g}/\text{m}^2/24 \text{ H}$. The resultant circularly polarizing plate 1 was subjected to the evaluation (4) for curling amounts. The results

are shown in Table 1. Further, an organic EL cell was removed from a flexible organic EL display apparatus (manufactured by Samsung, product name: "Galaxy S6 Edge"). Meanwhile, the release liner was peeled from the circularly polarizing plate 1, and the circularly polarizing plate 1 was bonded to the organic EL cell through the intermediation of the pressure-sensitive adhesive layer. Further, the surface protective film was peeled from the circularly polarizing plate bonded to the organic EL cell. The organic EL cell having bonded thereto the circularly polarizing plate 1 was left to stand under the conditions of 23°C and 55%RH for 72 hours, and then the presence or absence of warping was visually observed. As a result, neither warping nor bending was found.

[0083] [Example 2]

The polarizer surface of the polarizing plate 2 and the retardation layer 2 were bonded to each other through the intermediation of a PVA-based adhesive so that an angle formed between the absorption axis of the polarizer and the slow axis of the retardation layer was 45°, to thereby provide a circularly polarizing plate 2. An acrylic pressure-sensitive adhesive layer (thickness: 15 μm) was arranged on the retardation layer surface of the resultant circularly polarizing plate 2, and a release liner was temporarily bonded to the surface of the pressure-sensitive adhesive layer. Further, a surface protective film was temporarily bonded to the first protective layer surface. The moisture permeability of the

retardation layer at 40°C and a relative humidity of 92% was 70 g/m²/24 H. The resultant circularly polarizing plate 2 was subjected to the evaluation (4) for curling amounts. The results are shown in Table 1. Further, the resultant circularly polarizing plate 2 was bonded to an organic EL cell in the same manner as in Example 1, and subjected to the same evaluation as in Example 1. As a result, neither warping nor bending was found.

[0084] [Example 3]

The polarizer surface of the polarizing plate 5 and the retardation layer 3 were bonded to each other through the intermediation of a PVA-based adhesive so that an angle formed between the absorption axis of the polarizer and the slow axis of the retardation layer was 45°, to thereby provide a circularly polarizing plate 5. An acrylic pressure-sensitive adhesive layer (thickness: 20 μm) was arranged on the retardation layer surface of the resultant circularly polarizing plate 5, and a release liner was temporarily bonded to the surface of the pressure-sensitive adhesive layer. Further, a surface protective film was temporarily bonded to the first protective layer surface. The moisture permeability of the retardation layer at 40°C and a relative humidity of 92% was 80 g/m²/24 H. The resultant circularly polarizing plate 5 was subjected to the evaluation (4) for curling amounts. The results are shown in Table 1. Further, the resultant circularly polarizing plate 5 was bonded to an organic EL cell in the same manner as in Example

1, and subjected to the same evaluation as in Example 1. As a result, neither warping nor bending was found.

[0085] [Comparative Example 1]

The polarizer surface of the polarizing plate 3 and the retardation layer 1 were bonded to each other through the intermediation of an acrylic pressure-sensitive adhesive so that an angle formed between the absorption axis of the polarizer and the slow axis of the retardation layer was 45°, to thereby provide a circularly polarizing plate 3. An acrylic pressure-sensitive adhesive layer (thickness: 15 μm) was arranged on the retardation layer surface of the resultant circularly polarizing plate 3, and a release liner was temporarily bonded to the surface of the pressure-sensitive adhesive layer. Further, a surface protective film was temporarily bonded to the first protective layer surface. The moisture permeability of the second protective layer at 40°C and a relative humidity of 92% was 1,000 g/m²/24 H. The resultant circularly polarizing plate 3 was subjected to the evaluation (4) for curling amounts. The results are shown in Table 1. Further, the resultant circularly polarizing plate 3 was bonded to an organic EL cell in the same manner as in Example 1, and subjected to the same evaluation as in Example 1. As a result, warping was found.

[0086] [Comparative Example 2]

The polarizer surface of the polarizing plate 4 and the

retardation layer 1 were bonded to each other through the intermediation of an acrylic pressure-sensitive adhesive so that an angle formed between the absorption axis of the polarizer and the slow axis of the retardation layer was 45°, to thereby provide a circularly polarizing plate 4. An acrylic pressure-sensitive adhesive layer (thickness: 15 µm) was arranged on the retardation layer surface of the resultant circularly polarizing plate 4, and a release liner was temporarily bonded to the surface of the pressure-sensitive adhesive layer. Further, a surface protective film was temporarily bonded to the first protective layer surface. The moisture permeability of the second protective layer at 40°C and a relative humidity of 92% was 1,500 g/m²/24 H. The resultant circularly polarizing plate 4 was subjected to the evaluation (4) for curling amounts. The results are shown in Table 1. Further, the resultant circularly polarizing plate 4 was bonded to an organic EL cell in the same manner as in Example 1, and subjected to the same evaluation as in Example 1. As a result, warping was found.

[0087]

Table 1

	Moisture permeability (g/m ² /24 H)	Curling (after lapse of 72 hours from bonding)		
		State (i)	State (ii)	State (iii)
Example 1	150	Satisfactory (2 mm to 4 mm)	Satisfactory (1 mm to 2 mm)	Satisfactory (1 mm to 4 mm)
Example 2	70	Satisfactory (-2 mm to 0 mm)	Satisfactory (0 mm to 2 mm)	Satisfactory (0 mm to 3 mm)
Example 3	80	Satisfactory (-2 mm to 3 mm)	Satisfactory (-3 mm to 5 mm)	Satisfactory (-4 mm to 0 mm)
Comparative Example 1	1,000	Satisfactory (-2 mm to 1 mm)	Satisfactory (-1 mm to 0 mm)	Unsatisfactory (-18 mm to -12 mm)

Comparative Example 2	1,500	Satisfactory (1 mm to 2 mm)	Satisfactory (1 mm to 3 mm)	Unsatisfactory (-13 mm to -10 mm)
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[0088] <Evaluation>

As apparent from Table 1, it is found that the circularly polarizing plates of Examples of the present invention each have a small curling amount resulting from temporal change under a state in which the release liner and the surface protective film have been peeled therefrom. As a result, it has been confirmed that, when each of the circularly polarizing plates is applied to a flexible image display apparatus, bending and warping of the image display apparatus itself can be satisfactorily suppressed.

Industrial Applicability

[0089] The circularly polarizing plate of the present invention is suitably used for a flexible image display apparatus (e.g., an organic EL display apparatus).

Reference Signs List

[0090] **11** first protective layer

12 second protective layer

20 polarizer

30 retardation layer

40 hard coat layer

50 pressure-sensitive adhesive layer

70 surface protective film

100 circularly polarizing plate

Claims

[Claim 1] A circularly polarizing plate, comprising, in this order:

a first protective layer;

a polarizer;

a second protective layer; and

a retardation layer having an in-plane retardation $R_e(550)$ of from 80 nm to 200 nm,

wherein the second protective layer has a moisture permeability at 40°C and a relative humidity of 92% of less than 160 g/m²/24 H, and

wherein the circularly polarizing plate is used for a flexible image display apparatus.

[Claim 2] The circularly polarizing plate according to claim 1,

wherein the second protective layer is omitted,

wherein the retardation layer doubles as a protective layer for the polarizer, and

wherein the retardation layer has a moisture permeability at 40°C and a relative humidity of 92% of less than 160 g/m²/24 H.

[Claim 3] The circularly polarizing plate according to claim 1 or 2, wherein an angle θ formed between an absorption axis of the polarizer and a slow axis of the retardation layer is from 35° to 55°.

[Claim 4] The circularly polarizing plate according to any one of claims 1 to 3, further comprising a hard coat layer on an outer side of the first protective layer.

[Claim 5] The circularly polarizing plate according to any one of claims 1 to 4, further comprising:

a pressure-sensitive adhesive layer at an outermost portion of the circularly polarizing plate on a retardation layer side; and

a release liner, which is temporarily bonded to a surface of the pressure-sensitive adhesive layer.

[Claim 6] The circularly polarizing plate according to any one of claims 1 to 5, further comprising a surface protective film, which is temporarily bonded to an outermost portion of the circularly polarizing plate on a first protective layer side.

[Claim 7] The circularly polarizing plate according to claim 5 or 6, wherein the circularly polarizing plate has a curling amount of within ± 6 mm when placed under an environment having a temperature of $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and a relative humidity of $55\% \pm 10\%$ for 72 hours under each of the following states:

a state in which the circularly polarizing plate has temporarily bonded thereto the release liner and the surface protective film;

a state in which the release liner has been peeled and removed from the circularly polarizing plate, and the circularly polarizing plate has temporarily bonded thereto the surface protective film; and

a state in which the release liner and the surface protective film have been peeled and removed from the circularly polarizing plate.

[Claim 8] A flexible image display apparatus, comprising the circularly polarizing plate of any one of claims 1 to 7.