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(54) **WIRE GRID POLARIZER AND LIQUID CRYSTAL DISPLAY DEVICE USING THE POLARIZER**

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(52) **U.S. Cl.** ..... **349/96**

(58) **Field of Classification Search** ..... None  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,545,648 A \* 10/1985 Shulman et al. .... 349/114

6,122,103 A	9/2000	Perkins et al.
6,532,111 B2	3/2003	Kurtz et al.
6,739,723 B1	5/2004	Haven et al.
7,289,173 B2	10/2007	Kawazu et al.
2002/0044351 A1	4/2002	Nilsen
2005/0122588 A1	6/2005	Kunisada et al.
2007/0087549 A1 *	4/2007	Yamaki et al. .... 438/613
2008/0129931 A1 *	6/2008	Takahashi et al. .... 349/96
2008/0303986 A1 *	12/2008	Yamaki et al. .... 349/96

**FOREIGN PATENT DOCUMENTS**

EP	1 241 490 A2	9/2002
EP	1 387 190 A1	2/2004
JP	09-090122	4/1997
JP	2003-502708	1/2003
WO	WO-00/79317 A1	6/2000
WO	WO 00/79317 A1	12/2000

\* cited by examiner

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(57) **ABSTRACT**

A wire grid polarizer has a resin substrate having grid-shaped convex portions, a dielectric layer provided to cover the grid-shaped convex portions of the resin substrate and at least part of side faces of the portions, and metal wires provided on the dielectric layer. The wire grid polarizer has a microstructural concavo-convex grid structure having grid-shaped convex portions, is not limited in structure, and has both the excellent degree of polarization and excellent transmittance over a wide range in the visible region.

**11 Claims, 5 Drawing Sheets**

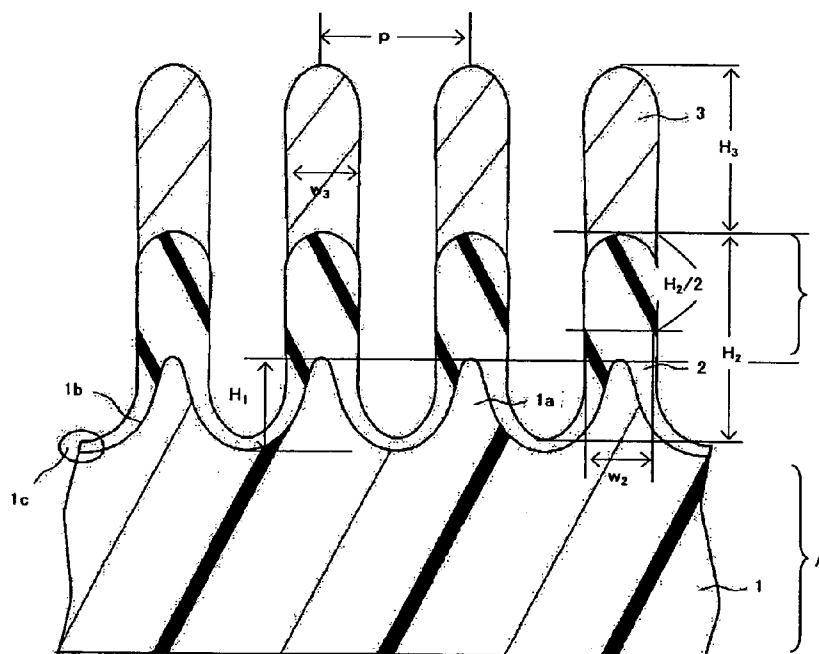


FIG. 1

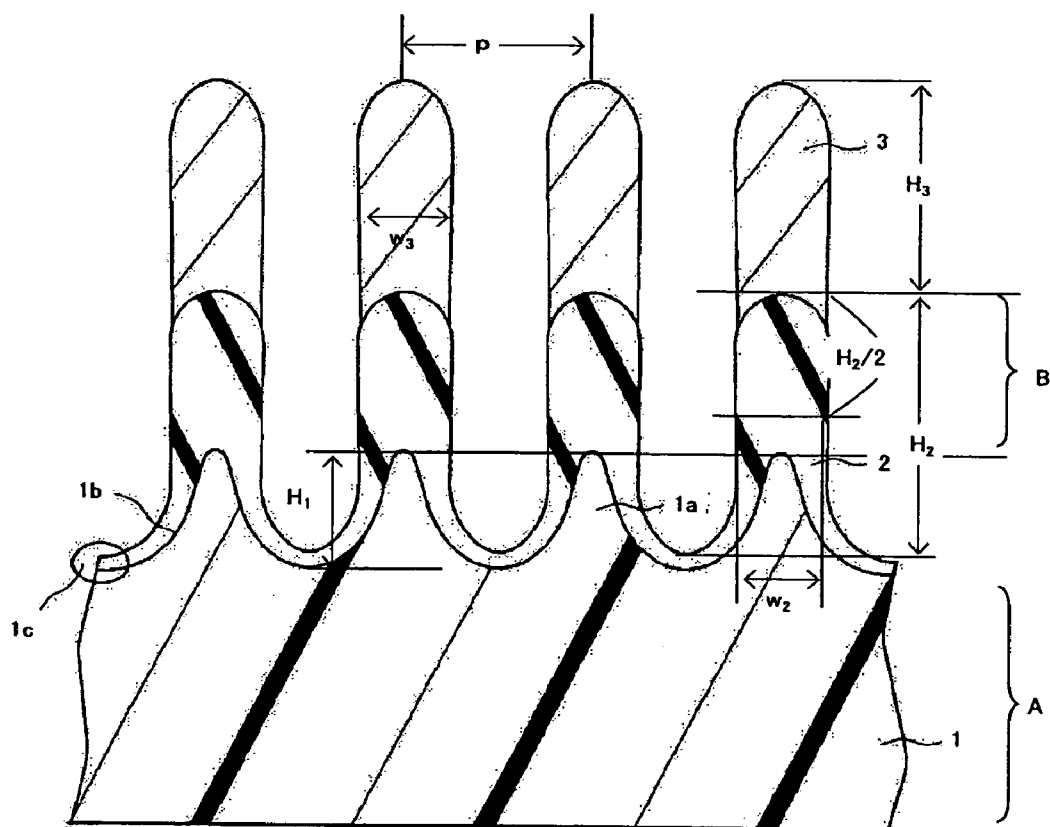


FIG. 2

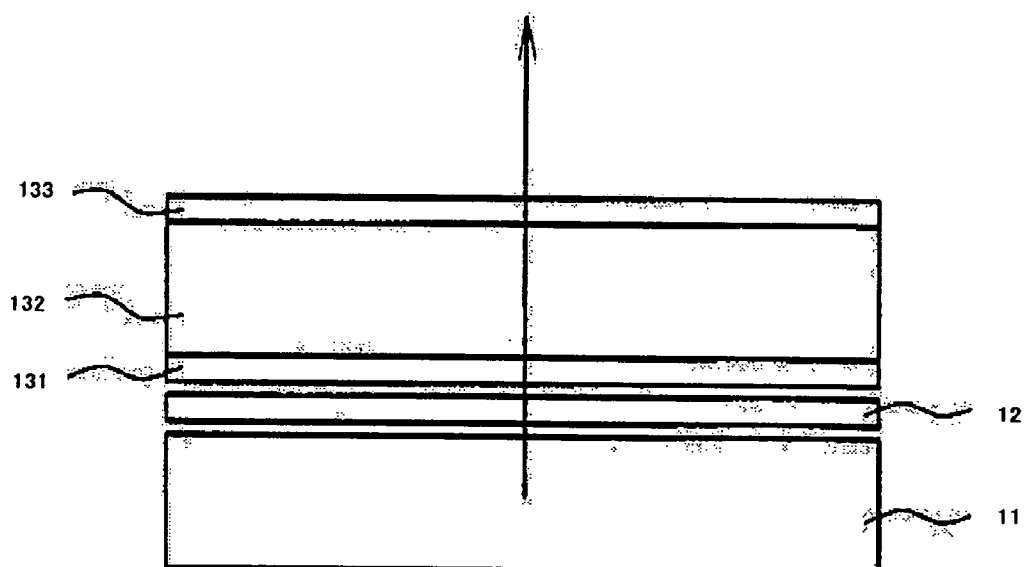
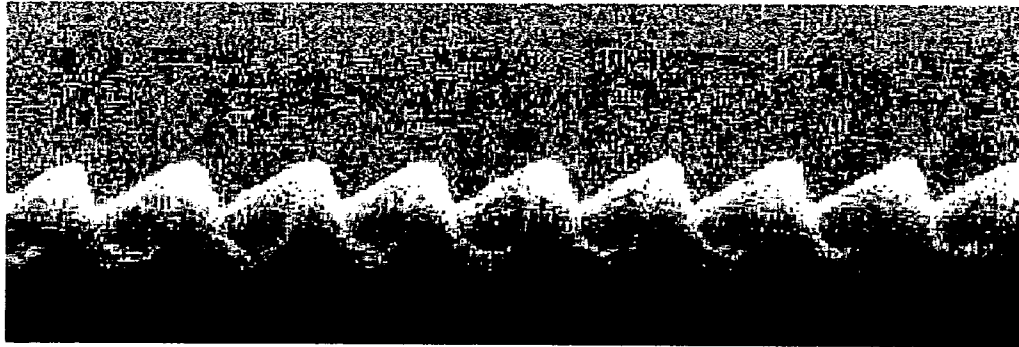
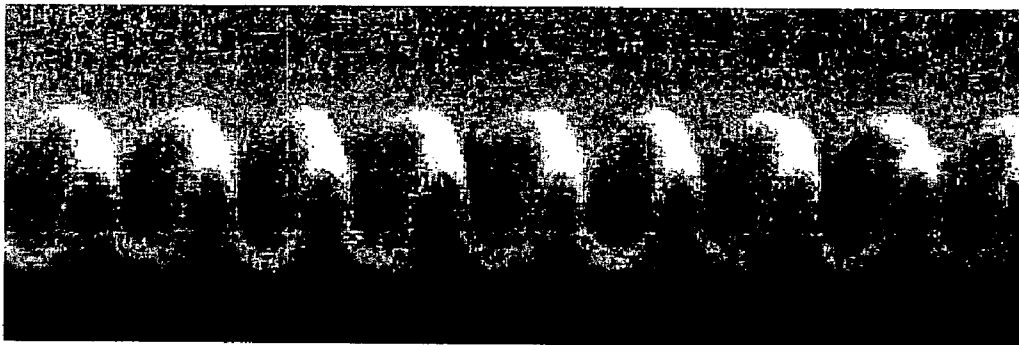


FIG.3

(a)



(b)



(c)

3  
2  
1



FIG.4

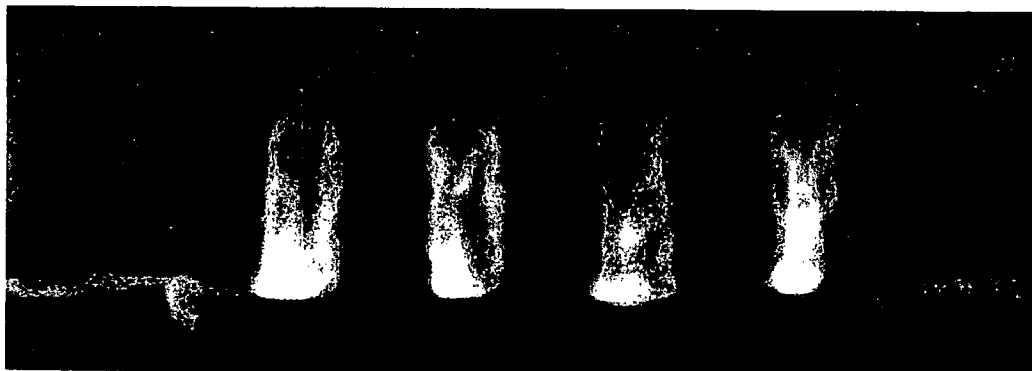


FIG. 5

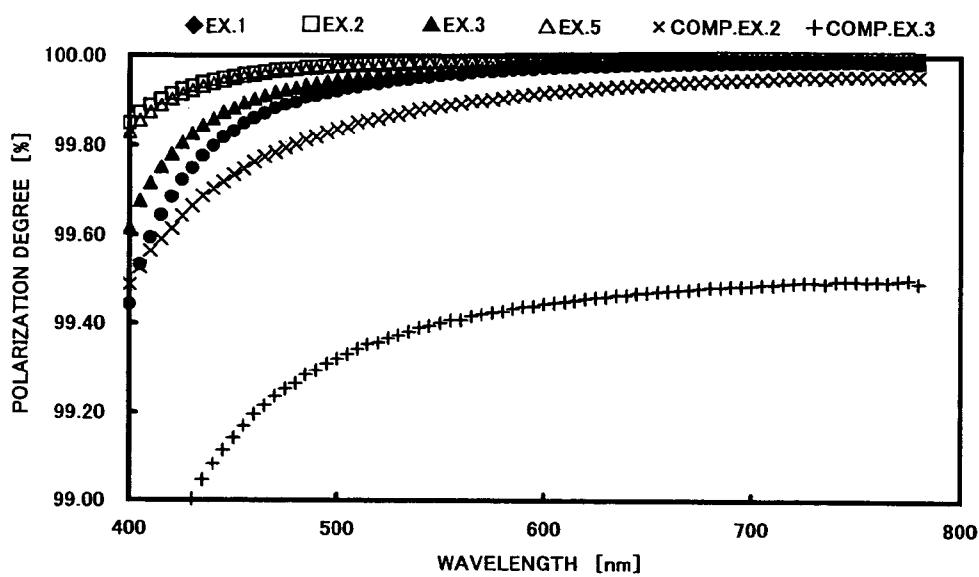


FIG. 6

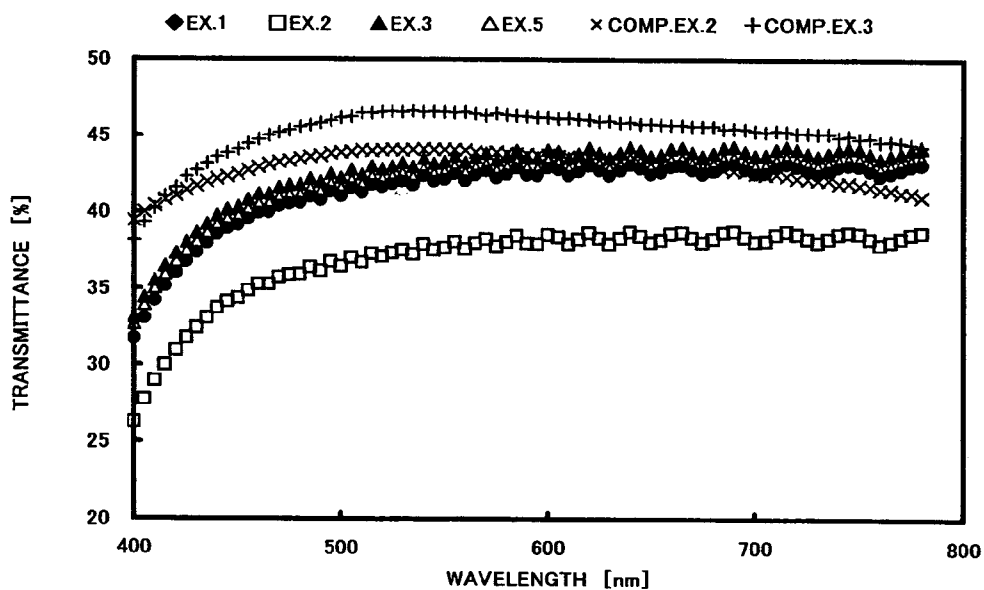
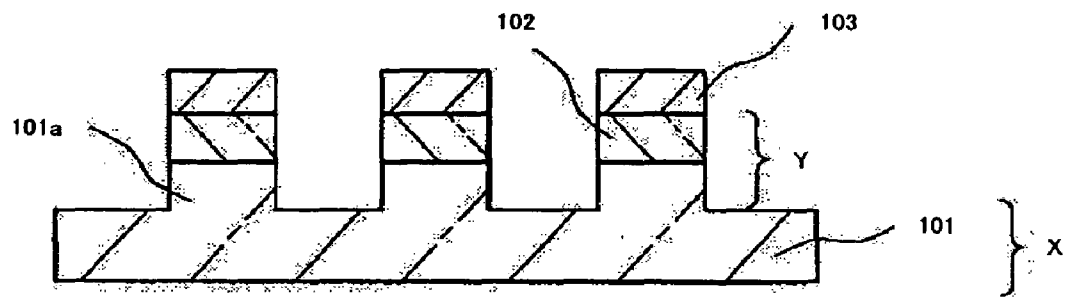


FIG. 7



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# WIRE GRID POLARIZER AND LIQUID CRYSTAL DISPLAY DEVICE USING THE POLARIZER

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a wire grid polarizer and liquid crystal display device using the wire grid polarizer.

### 2. Related Background Art

The recent development of photolithography technique has enabled formation of a microstructural pattern with pitches of the level of the wavelength of light. Members and products with such extremely small pitches are of wide application and useful not only in the semiconductor field but also in the optical field.

For example, in a wire grid where conductor lines comprised of metal and the like are arranged in the shape of a grid with specific pitches on a substrate, when the pitches are remarkably smaller than (for example, less than half) the incident light (for example, visible light with wavelengths of 400 nm to 800 nm), the wire grid reflects almost all the electric field vector component of the light vibrating in parallel with the conductor lines, while allowing almost all the electric field vector component of the light perpendicular to the conductor lines to pass through the grid, and is capable of being used as a polarizer to generate a polarized light beam. The wire grid polarizer reflects the light which is not passed through to be reused, and is desirable from the viewpoint of effective use of the light. However, in the existing photolithography technique, it has been difficult to implement a microstructural concavo-convex grid with pitches of the level of 120 nm or less in a large area of 100 cm<sup>2</sup> or more.

In recent years, a wire grid polarizer has been developed which has a microstructural concavo-convex grid with small pitches (Japanese Patent Laid-Open No.2003-502708). As shown in FIG. 7, the wire grid polarizer has a configuration where conductive elements **103** are formed via dielectric films **102** on grid-shaped convex portions **101a** of a glass substrate **101**. In the wire grid polarizer, the refractive index of a base portion X of the glass substrate **101** is set lower than the refractive index of a region Y with a thickness of the grid convex portion **101a** and dielectric film **102**. By preparing such a configuration, it is possible to shift to a short-wavelength region a resonance point of causing a resonance phenomenon such that transmission and reflection characteristics of the light rapidly change, and to improve the efficiency of transmission and reflection.

However, the above-mentioned wire grid polarizer needs to consider resonance in the visible light spectrum when the polarizer is used as a diffraction grating, and has a problem that a sufficient degree of polarization is not obtained in a short-wavelength region of the visible light.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a wire grid polarizer and liquid crystal display device using the wire grid polarizer providing both an excellent degree of polarization and excellent transmittance over a wide range in the visible region.

A wire grid polarizer of the invention has a resin substrate having grid-shaped convex portions, a dielectric layer provided to cover the grid-shaped convex portions of the resin substrate and at least part of side faces of the portions, and metal wires provided on the dielectric layer.

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In the wire grid polarizer of the invention, it is preferable that a refractive index of a region including the dielectric layer positioned higher than top portions of the grid-shaped convex portions is higher than a refractive index of the resin substrate.

In the wire grid polarizer of the invention, it is preferable that a refractive index of the dielectric layer is higher than the refractive index of the resin substrate.

In the wire grid polarizer of the invention, it is preferable that pitches of the grid-shaped convex portions of the resin substrate are 120 nm or less.

In the wire grid polarizer of the invention, it is preferable that the dielectric layer is comprised of titanium oxide, cerium oxide, zirconium oxide, aluminium oxide, yttrium oxide, silicon oxide, silicon nitride, aluminium nitride, or a compound thereof.

In the wire grid polarizer of the invention, it is preferable that the metal wires are comprised of aluminium or an alloy thereof.

In the wire grid polarizer of the invention, it is preferable that the metal wires are provided leaning to one side faces of the dielectric layer.

In the wire grid polarizer of the invention, it is preferable that unit dimensions are 100 cm<sup>2</sup> or more.

A liquid crystal display device of the invention has a liquid crystal panel, a lighting member that applies light to the liquid crystal panel, and the above-mentioned wire grid polarizer disposed between the liquid crystal panel and the lighting member. In the liquid crystal display device of the invention, the liquid crystal panel is preferably a transmission liquid crystal panel.

A liquid crystal display device of the invention has a light source, the above-mentioned wire grid polarizer that polarizes and divides light from the light source, a liquid crystal display element that transmits or reflects the light polarized by the polarizer, and a projection optical series that projects the light passed through or reflected by the liquid crystal display element onto a screen.

## BRIEF DESCRIPTION OF THE DRAWINGS

The various features of novelty which characterize the invention are pointed out with particularity in the claims attached to and forming a part of this specification. For a better understanding of the invention, its operating advantages, and specific objects attained by its use, reference should be had to the accompanying drawing and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

FIG. 1 is a schematic cross-sectional view showing part of a wire grid polarizer according to an embodiment of the invention;

FIG. 2 is a diagram illustrating a liquid crystal display device using the wire grid polarizer according to the embodiment of the invention;

FIG. 3(a) is a typical SEM image of a cross section of a grid-shaped convex-portion transferred film;

FIG. 3(b) is a typical SEM image of a cross section of a dielectric coated on grid-shaped convex-portion transferred film;

FIG. 3(c) is a typical SEM image of a cross section of the wire grid polarizer according to the embodiment of the invention;

FIG. 4 is a typical SEM image of a cross section of a wire grid polarizer of Comparative Example 2;

FIG. 5 is a graphical plot showing polarization characteristics of wire grid polarizer according to the embodiment of the invention and of wire grid polarizer of Comparative Examples;

FIG. 6 is a graphical plot showing light transmittances characteristics of the wire grid polarizer according to the embodiment of the invention and of the wire grid polarizer of Comparative Examples; and

FIG. 7 is a schematic cross-sectional view showing a wire grid polarizer.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a schematic cross-sectional view showing part of a wire grid polarizer according to an embodiment of the invention. The wire grid polarizer as shown in FIG. 1 is mainly comprised of a resin substrate 1 having grid-shaped convex portions, a dielectric layer 2 provided to cover the grid-shaped convex portions 1a (hereinafter, simply referred to as convex portions 1a as appropriate) of the resin substrate and part of side faces 1b of the convex portions 1a, and metal wires 3 provided on the dielectric layer.

A resin for use in the resin substrate 1 is required to be a resin substantially transparent in the visible region. Examples of such a resin include amorphous thermoplastic resins such as a poly methyl methacrylate resin, poly carbonate resin, polystyrene resin, cycloolefin resin (COP), cross-linked polyethylene resin, polyvinyl chloride resin, polyallylate resin, polyphenylene ether resin, modified polyphenylene ether, polyether imide resin, polyether sulfone resin, polysulfone resin, polyether ketone resin and the like, crystalline thermoplastic resins such as polyethylene terephthalate (PET) resin, polyethylene naphthalate resin, polyethylene resin, polypropylene resin, polybutylene terephthalate resin, aromatic polyester resin, polyacetal resin, polyamide resin and the like, and acryl based, epoxy based or urethane based ultraviolet (UV) curable resins or thermosetting resins and the like. Further, as a substrate, a configuration may be used which is obtained by combining a UV curable resin and/or thermosetting resin that is the resin substrate 1, an inorganic substrate such as glass and the like, the above-mentioned thermoplastic resin, and triacetate resin.

Pitches of the grid-shaped convex portions 1a on the resin substrate of the invention are 120 nm or less, and preferably range from 80 nm to 120 nm, with consideration given to polarization characteristics over a wide range in the visible region. The polarization characteristics improve as the pitch decreases, and in the visible region, sufficient polarization characteristics are obtained using the pitch ranging from 80 nm to 120 nm. Further, when importance is not placed on polarization characteristics of the light with short wavelengths around 400 nm, the pitch can be increased to near 150 nm. In addition, in the invention, the pitch of the grid-shaped convex portions 1a of the resin substrate, the pitch of the dielectric layer, and the pitch of the metal wires are almost the same as the pitch of the wire grid of the invention, and shown by "p" in FIG. 1.

Cross-sectional shapes are not limited particularly in the grid-shaped convex portions 1a, and concave portions 1c of a microstructural concavo-convex grid formed by a plurality of grid-shaped convex portions. For example, cross sections of the portions may be trapezoidal, rectangular, square, and sinusoidal shape such as a prism-shape, semi-circular shape and the like. Herein, the sinusoidal shape means having curvature portions formed by repetition of the concave portion and convex portion. In addition, the curvature portions only

need to have a curved line, and for example, a shape of the concave portion with a constriction is included in the sinusoidal shape. From the viewpoint of easiness of the dielectric layer to cover the grid-shaped convex portions of the resin substrate and at least part of side faces of the portions, an edge or top and a valley of the shape are preferably curved with a moderate curvature. Further, from the viewpoint of improving the adhesion strength between the resin substrate and dielectric layer, the cross section is preferably formed in the sinusoidal shape.

A height difference  $H_1$  (hereinafter, referred to as a height of the convex portion 1a) between the peak of the convex portion 1a and the valley of the concave portion 1c of the resin substrate 1 is 0.5 time to 2.0 times the pitch p of the grid-shaped convex portions 1a, and preferably is 1.0 time to 2.0 times the pitch P, to obtain excellent optical characteristics, further obtain high adhesion strength between the substrate and dielectric layer 2, and coat the dielectric layer selectively and highly on the convex portions 1a.

A width of the convex portion 1a at the half height of the convex portion 1a is preferably 0.3 time to 0.6 time the pitch of the wire grid, in consideration of the coating of the dielectric layer on the side face of the grid-shaped convex portion 1a and deposition of the metal wire via the dielectric layer.

The present invention is not limited particularly to a method of obtaining the resin substrate having the grid-shaped convex portions for use in the invention. For example, such a method includes a method as described in Japanese Patent Application No. 2006-2100 by the Applicant. According to the Application No. 2006-2100, using a metal stamper having a concavo-convex grid formed of grid-shaped convex portions with pitches of 230 nm to 250 nm produced using an interference exposure method, the concavo-convex grid is thermal-transferred to a thermoplastic resin, and the thermoplastic resin provided with the concavo-convex grid is subjected to free-end uniaxial drawing with a draw ration of four to six times in the direction parallel to the longitudinal direction of the grid. As a result, the pitches of the concavo-convex grid transferred to the thermoplastic resin are reduced, and the resin substrate (that is already drawn) is obtained which has a microstructural concavo-convex grid with pitches less than or equal to 120 nm. Then, a metal stamper having the microstructural concavo-convex grid is prepared from the obtained (already-drawn) resin substrate having the microstructural concavo-convex grid using an electrolytic plating method and the like. By using the metal stamper and transferring the microstructural concavo-convex grid to the surface of the resin substrate to form, it is made possible to obtain the resin substrate having grid-shaped convex portions with pitches of 120 nm or less.

The dielectric constituting the dielectric layer 2 in the invention is required to be transparent substantially in the visible region. Dielectric materials may be suitably used which have high adhesion with the material constituting the resin substrate 1 and the metal constituting the metal wires 3. For example, used are oxides, nitrides, halogen compounds and carbides of silicon (Si) which can be used alone or as a compound thereof (dielectric combined with another element, another dielectric, or compound), and oxides, nitrides, halogen compounds, and carbides of metal, which can be used alone or as a compound thereof, such as aluminium (Al), chromium (Cr), yttrium (Y), zirconium (Zr), tantalum (Ta), titanium (Ti), barium (Ba), indium (In), tin (Sn), zinc (Zn), magnesium (Mg), calcium (Ca), cerium (Ce), copper (Cu) and the like.

In the invention, it is preferable that the refractive index of a region including the dielectric layer positioned higher than



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top portions of the grid-shaped convex portions is higher than the refractive index of the resin substrate. Herein, the region including the dielectric layer positioned higher than top portions of the grid-shaped convex portions indicates a B region in FIG. 1, and means a region having a specific thickness substantially in parallel with the plane of the resin substrate. In other words, the B region is a region including the dielectric layer on the grid-shaped convex portions 1a of the resin substrate 1. The refractive index of the resin substrate is the refractive index of an A region in FIG. 1 i.e. a region of the resin substrate 1 without the grid-shaped convex portions 1a. Further, in the invention, the refractive index of the dielectric layer is preferably higher than the refractive index of the resin substrate.

As dielectrics selected to have the refractive index higher than that of the resin substrate, for example, preferable are oxides and nitrides of silicon or the above-mentioned metal alone or as a compound. More preferable among these are silicon oxide, titanium oxide, cerium oxide, aluminium oxide, yttrium oxide, zirconium oxide, silicon nitride, and aluminium nitride alone or as a compound thereof.

In the invention, in order to obtain sufficient adhesion strength between the resin substrate 1 and metal wires 3, the dielectric layer 2 is provided to cover the grid-shaped convex portions 1a of the resin substrate and at least part of side face portions 1b of the portions 1a. Further, the side faces 1b of the grid-shaped convex portions 1a of the resin substrate 1 are preferably coated with the dielectric layer 2. From the viewpoints of improvement in adhesion between the grid-shaped convex portions 1a and dielectric layer 2 and suppression of low-molecule volatiles generated from the resin substrate, it is more preferable that the entire microstructural concavo-convex grid is covered with the dielectric layer 2. The sufficient adhesion strength is obtained between the resin substrate and dielectric layer by improving the adhesion between the grid-shaped convex portions 1a and dielectric layer 2.

The thickness of the dielectric layer 2 (hereinafter, referred to as a height of the dielectric layer) coated on the grid-shaped convex portions 1a of the resin substrate preferably ranges from 2 nm to 200 nm, from the viewpoints of optical characteristics, adhesion strength between the resin substrate and metal wires, structural strength of the wire grid, time required for coating, selective deposition such that the metal wires are selectively deposited on the convex portions of the dielectric layer or on one side faces of the convex portions of the dielectric layer, and the like. Particularly, the height of the dielectric layer at the peak of the grid-shaped convex portion 1a of the resin substrate is preferably in the range of 5 nm to 150 nm. Further, with respect to a height difference  $H_2$  between the peak of the convex portion and the valley of the concave portion of the concavo-convex grid formed by coating the grid-shaped convex portions 1a of the resin substrate with the dielectric layer 2, the height difference  $H_2$  is preferably in the range of 100 nm to 300 nm, and more preferably in the range of 150 nm to 250 nm, in consideration of the structural strength as a base of the metal wires, optical characteristics and the like.

Assuming a width at the half height of the height difference  $H_2$  as a width  $w_2$  of the dielectric layer (hereinafter, referred to as a width of the dielectric layer), from the viewpoints of optical characteristics and structural strength of the wire grid, it is preferable that the width  $w_2$  of the dielectric layer is 0.3 time to 0.6 time the pitch of the grid-shaped convex portions of the resin substrate. When an oblique deposition method, described later, is used in depositing the metal, the width  $w_2$  of the dielectric layer is preferably 0.1 time to 0.5 time the pitch of the grid-shaped convex portions of the resin sub-

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strate. By this means, the contact area is increased between the dielectric layer and metal wires subsequently formed, resulting in increases in the adhesion strength between the dielectric layer and metal wires and in the structural strength of the wire grid.

As a method of coating the dielectric on the grid-shaped convex portions of the resin substrate and at least part of side faces of the portions, the method is selected as appropriate corresponding to the material constituting the dielectric layer 2. For example, physical deposition methods may be used suitably such as a sputtering method, vacuum deposition method and the like. The sputtering method is preferable from the viewpoint of the adhesion strength.

In the invention, the metal constituting the metal wires 3 is preferably high in light reflectance in the visible region and further high in adhesion with the material constituting the dielectric layer 2. For example, the metal wires 3 are preferably formed of aluminium, silver or an alloy thereof. In terms of cost, the metal wires 3 are more preferably formed of aluminium or an alloy of aluminium.

A width  $w_3$  of the metal wire 3 preferably ranges from 0.3 time to 0.6 time the pitch of the grid-shaped convex portions of the resin substrate, from the viewpoints of optical characteristics such as the degree of polarization, transmittance and the like, and structural strength of the wire grid.

A thickness  $H_3$  of the metal wire 3 (hereinafter, referred to as a height of the metal wire) deposited on convex portions of the dielectric layer 2 coated on the grid-shaped convex portions 1a of the resin substrate preferably ranges from 120 nm to 220 nm, and more preferably, ranges from 140 nm to 200 nm, from the viewpoints of optical characteristics, adhesion strength between the metal wires 3 and convex portions of the dielectric layer 2, structural strength of the wire grid polarizer, and a processing time required for deposition. Further, a ratio  $H_3/w_3$  (aspect ratio) of the height of the metal wire to the width of the metal layer preferably ranges from 2 to 5, and more preferably, ranges from 2 to 4.

A method of depositing the metal on the dielectric layer 2 to form the metal wires 3 is not limited particularly, as long as the method provides sufficient adhesion between the material constituting the dielectric layer 2 and the metal constituting the metal wires 3. For example, physical deposition methods may be used suitably such as the vacuum deposition method, sputtering method, ion plating method and the like. Preferable among the methods is a method enabling the metal to be deposited selectively on convex portions of the dielectric layer 2 or to be deposited selectively leaning to one side faces of the convex portions of the dielectric layer 2. Such a method includes the vacuum deposition method, for example.

In addition, from the viewpoint of optical characteristics, an amount as small as possible is preferable for the metal deposited on the bottom and its vicinity of the concave portion of the microstructural concavo-convex grid. Accordingly, to avoid deposition of the metal at these portions, and further, to facilitate etching (polishing by the etching) described later when the metal is deposited, it is preferable that an oblique deposition method is used to deposit the metal. The oblique deposition method referred to as in the invention is a method for depositing the metal in the direction of an angle (incident angle)  $\theta$  of 30° or less, preferably 10° to 20°, where the angle  $\theta$  is formed between the normal of the plane of the resin substrate and a source of deposition within a plane intersecting perpendicularly the grid longitudinal direction of the microstructural concavo-convex grid.

In the wire grid polarizer of the invention, unit dimensions are preferably 100  $\mu\text{m}^2$  or more. According to the wire grid polarizer of the invention, grid-shaped convex portions are

transferred and formed onto the resin substrate **1**, the dielectric layer **2** and metal wires **3** are further formed on the portions, and the plate is thereby capable of being prepared, whereby it is possible to obtain such a relatively large plate-shaped member with unit dimensions of 100 cm<sup>2</sup> or more. Therefore, it is possible to decrease the number of junction portions even when the plate is used in a display with a large screen. In this case, it is preferable that junction portions have junction lines with a line width of 100 nm to 100 μm and are configured not to transmit the light.

As described above, the wire grid polarizer of the invention is provided with the dielectric layer **2**, having high adhesion with the resin substrate **1** and metal wires **3**, provided between the resin substrate **1** and metal wires **3**. Therefore, the resin substrate **1** is capable of reliably supporting the dielectric layer **2**, and the dielectric layer **2** can be disposed vertically. As a result, the height of the metal wire can be made relatively high. By the metal wire grid with extremely fine pitches formed on the resin substrate, it is possible to exhibit a degree of polarization of 99.9% or more in almost the entire visible region that is a region of light subject to polarization. In this case, it is preferable that the metal wires substantially have a length of about 10 cm, and are arranged in optically almost parallel with one another with equal pitches in  $6 \times 10^4$  pieces/cm or more in the width direction of the metal wires.

A case will be described below that the wire grid polarizer according to the invention is used in a liquid crystal display device. FIG. 2 shows a mode of a liquid crystal display device using the wire grid polarizer according to this embodiment of the invention.

The liquid crystal display device as shown in FIG. 2 is mainly comprised of a lighting device **11** such as a backlight which emits the light, a wire grid polarizer **12** disposed above the lighting device **11**, and a liquid crystal panel **132** and polarizer **133** disposed above the wire grid polarizer **12**. In other words, the wire grid polarizer **12** according to the invention is arranged between the liquid crystal panel **132** and lighting device **11**.

The liquid crystal panel **132** is a transmission liquid crystal panel, and is configured such that a liquid crystal material and the like are sandwiched between glass substrates or transparent resin substrates. In addition, descriptions are omitted on various optical elements, such as a polarizer protective film, retardation film, diffusion plate, alignment film, transparent electrode, color filter and the like, generally used in the liquid crystal display device.

In the liquid crystal display device with such a structure, the light output from the lighting device **11** is incident on the base side of the resin substrate **1** of the wire grid polarizer **12**, output from the wire side, passed through the liquid crystal panel **132** and output to the outside (the direction of the arrow shown in the figure). In this case, the wire grid polarizer **12** exhibits an excellent degree of polarization in the visible region, and it is thereby possible to obtain high-contrast display. Further, when higher contrast is required, in order to prevent the (external) light incident from the outside of the polarizer **133** i.e. in the direction opposite to the lighting device **11** from being passed through the liquid crystal panel **132**, reflected by the wire grid polarizer **12**, and output again to the outside of the liquid crystal panel **132**, it is preferable to insert an absorption type polarizer **131** using a dichromatic dye such as iodide and the like between the wire grid polarizer **12** and liquid crystal panel **132** with its polarization axis matched with the polarization axis of the wire grid polarizer **12**. In this case, the absorption type polarizer is preferably high in transmittance, and allowed to have a low degree of polarization.

The wire grid polarizer of the invention can be used as a polarizer of a projection liquid crystal display device. The projection liquid crystal display device is mainly comprised of a light source, the wire grid polarizer that polarizes and divides the light from the light source, a liquid crystal display element that transmits or reflects the light polarized by the wire grid polarizer, and a projection optical series that projects the light passed through or reflected by the liquid crystal display element onto a screen. In other words, the wire grid polarizer according to the invention is arranged between the light source and liquid crystal display element.

Described next are Examples performed to clarify the effects of the invention.

#### (Preparation of a Resin Substrate having the Grid-shaped Convex Portions)

Preparation of a COP plate with a concavo-convex grid shape transferred thereto.

Prepared was a nickel stamper having on the surface a concavo-convex grid with the height of the concavo-convex grid of 230 nm. The concavo-convex grid was made by patterning using the laser interference exposure method, sinusoidal shape in cross section and streak grid shape in upper face. The dimensions of the plane were 500 mm both in length and width. Using the nickel stamper, the concavo-convex grid shape was transferred to the surface of a cycloolefin resin (hereinafter, abbreviated as COP) plate with a thickness of 0.5 mm and length and width of 520 mm by hot press method, and a COP plate with the concavo-convex grid shape transferred thereto was thus prepared. The glass transition temperature (T<sub>g</sub>) of the COP was 105° C.

More specifically, hot press was performed as described below. First, a pressing machine was evacuated, and the nickel stamper and COP plate were heated to 190° C. After the nickel stamper and COP plate reached 190° C., the concavo-convex grid of the nickel stamper was transferred to the COP plate at a pressing pressure of 2 Mpa for four minutes of pressing time. Further, with the pressing pressure kept at 2 Mpa, the nickel stamper and COP plate were cooled to 40° C., the vacuum was released, and then, the pressing pressure was released. When the pressing pressure was released, the nickel stamper and COP plate were easily removed. The surface shape of the COP plate with the concavo-convex grid shape transferred thereto was observed using a field-emission scanning electron microscope (hereinafter, abbreviated as FE-SEM) and it was confirmed that the concavo-convex grid shape of the nickel stamper was transferred faithfully.

#### Reduction in Pitch by Drawing

Next, the COP plate with the concavo-convex grid shape transferred thereto was cut into 520 mm×460 mm rectangles to be COP plates for drawing as drawing target members. At this point, the plates were cut so that the longitudinal direction (520 mm) of the 520 mm×460 mm rectangle was substantially parallel with the longitudinal direction of the concavo-convex grid.

Silicon oil was coated on surfaces of the COP plates for drawing by spray, and placed in a circular air oven at about 80° C. for 30 minutes. Next, the COP plate for drawing was fixed by chucks of a drawing machine at its opposite ends of 10 mm in the longitudinal direction, and placed in this state in a circular air oven with the temperature adjusted to 113±1° C. for 10 minutes. Then, drawing was performed at speed of 250 mm/min, and finished when the distance between the chucks was drawn by five times, and twenty seconds later, the drawn COP plate was placed in an atmosphere of room temperature, and cooled with the distance between the chucks kept. The drawn COP plate was almost uniformly constricted at about

40% of the center portion, and the width of the most shrank portion was 200 nm. Similarly, the COP plates were drawn while changing only the distance between the chucks to 3.5 times and 2.5 times, and the minimum widths of the center portions of the drawn COP plates were 240 nm and 280 nm, respectively.

The surface and cross section of each of these three types of drawn COP plates were observed by FE-SEM, and it was understood that the pitch and height of the microstructural concavo-convex grid of each of the plates were 100 nm/95 nm (pitch/height), 120 nm/113 nm, or 140 nm/133 nm, the cross section was in the sinusoidal shape, the shape from the upper face was a streak-shaped grid shape, and that the plates were shrank substantially in similar figures to the concavo-convex grid shape prior to the drawing.

#### Preparation of Nickel Stampers

Surfaces of obtained drawn COP plates with respective pitches of 100 nm, 120 nm and 140 nm were coated with gold in 30 nm by sputtering as processing of providing conductivity, and given electro-nickel-plating, and nickel stampers were prepared each with a thickness of 0.3 mm, distance in the longitudinal direction (hereinafter, referred to as a length) of the grid of 300 mm, and distance in the direction (hereinafter, referred to as a width) perpendicular to the longitudinal direction of the grid of 180 mm.

#### Preparation of Grid-shaped Convex-portion Transferred Films using UV Curable Resin.

A UV curable resin (TB3078D, Three Bond Co., Ltd. Refractive index: 1.41) with a thickness of about 0.03 mm was coated on a polyethylene terephthalate resin film (hereinafter, referred to as a PET film) with a thickness of 0.1 mm. With the coated surface downward, the PET film was mounted on each of the above-mentioned nickel stampers respectively having microstructural concavo-convex grids with pitches of 100 nm, 120 nm and 140 nm starting with the end portions for the air not to enter between the nickel stamper and film, and radiated with UV rays of 1000 mJ/cm<sup>2</sup> from the PET film side using a UV lamp with the center wavelength of 365 nm to transfer the microstructural concavo-convex grid of the nickel stamper. Then, the PET film was removed from the nickel stamper, and further radiated with UV rays of 500 mJ/cm<sup>2</sup> under an atmosphere of nitrogen to cure an uncured component of the UV curable resin on the PET film, and prepared was a film (hereinafter, referred to as a grid-shaped convex-portion transferred film) with the microstructural grid with a length of 300 mm and width of 180 mm transferred thereto. The cross section of the grid-shaped convex-portion transferred film was observed using FE-SEM to obtain the height H<sub>1</sub> of the convex portion of the grid-shaped convex-portion transferred film. The results are shown in Table 1. FIG. 3(a) is a typical SEM image of the cross section of the grid-shaped convex-portion transferred film. The grid-shaped convex-portion transferred film obtained by the above-mentioned method was used as a resin substrate having the grid-shaped convex portions.

#### (Preparation of a Wire Grid Polarizer: Examples 1 to 6)

##### Formation of a Dielectric Layer using a Sputtering Method

A dielectric layer was formed on each of the grid-shaped convex-portion transferred films respectively having three kinds of pitches prepared by the above-mentioned method, using the sputtering method. This embodiment describes the case of using silicon nitride or silicon oxide as the dielectric. The dielectric was coated at an Ar gas pressure of 0.67 Pa, sputtering power of 4 w/cm<sup>2</sup> and coating rate of 0.22 nm/sec. A glass substrate with a smooth substrate was set in a sputtering machine as a thickness comparative sample concur-

rently with the grid-shaped convex-portion transferred film, and film formation was performed so that a deposition thickness of the dielectric layer on the smooth glass substrate was 20 nm. The cross section of the grid-shaped convex-portion transferred film coated with the dielectric was observed using FE-SEM to obtain the height difference H<sub>2</sub>. Further, using a spectroscopic ellipsometer, refractive indexes of the dielectric and B region were obtained. The results are also shown in Table 1. FIG. 3(b) is a typical SEM image of the cross section of the grid-shaped convex-portion transferred film (hereinafter, referred to as a dielectric deposited grid-shaped convex-portion transferred film) with the dielectric layer formed thereon.

##### Deposition of Metal using a Vacuum Deposition Method

After the dielectric layers were formed on the grid-shaped convex-portion transferred films respectively having three types of pitches, metal wires were formed using an electron beam vacuum deposition method (EB deposition method). This embodiment describes the case of using aluminium (Al) as metal. Deposition of Al was performed at room temperature, a degree of vacuum of  $2.5 \times 10^{-3}$  Pa and deposition rate of 4 nm/sec. A glass substrate with a smooth substrate was set in an EB deposition machine as a thickness comparative sample concurrently with the dielectric coated grid-shaped convex-portion transferred film, and deposition was performed so that a thickness of Al deposition on the smooth substrate was 200 nm. In Examples 1 to 5, an angle  $\theta$  formed between the normal of the substrate plane and the deposition source was 10° within the plane perpendicularly intersecting the longitudinal direction of the grid, and only in Example 6, such an angle was 20°.

##### Removal of Unnecessary Metal by Etching

After the dielectric layers and Al was deposited on the grid-shaped convex-portion transferred films respectively having three types of pitches, the films were cleaned (etching) in an aqueous 0.1 wt % sodium hydroxide solution at room temperature for 30 to 90 seconds of the processing time while being changed at ten-second intervals, and rinsed immediately to halt etching. After the films were dried, the degree of polarization and transmittance were measured on the light with a wavelength of 550 nm, and films with the degree of polarization of 99.95% or more and the maximum transmittance were selected (except Example 2 where the film with the degree of polarization of 99.99% or more and maximum transmittance was selected) to be wire grid polarizers of the invention. The wire grid polarizers were 300 mm long and 180 mm wide. The cross section of each of three types of wire grid polarizers was observed using FE-SEM to measure the pitch of the grid-shaped convex portions, and height and width of deposited aluminium. The results are also shown in Table 1. FIG. 3(c) is a typically SEM image of the cross section of the obtained wire grid polarizer. As can be seen from FIG. 3(c), the dielectric layer 2 is formed on the resin substrate (UV curable resin) 1, and the metal wires (Al layer) 3 are formed on the dielectric layer 2. Polarization performance was evaluated on the prepared wire grid polarizers. The results are shown in Table 1, and FIGS. 5 and 6.

As Comparative Example 1, aluminium was deposited on the grid-shaped convex-portion transferred film in the same way as in the above-mentioned Examples except the dielectric not coated, and cleaned in the aqueous 0.1 wt % sodium hydroxide solution for 60 seconds. In this case, wires of Al required to exhibit the polarization performance were present, but removed partially from the grid-shaped convex portions of the substrate, and it was not possible to prepare any wire grid polarizers to be evaluated.

As Comparative example 2, a commercially available wire grid polarizer (ProFlux Polarizer PPL03C (General Purpose), MOXTEK Inc.) with a glass substrate as a base was used.

Herein,  $I_{\max}$  represents the intensity of transmitted light in parallel Nicol state, while  $I_{\min}$  represents the intensity of transmitted light in orthogonal Nicol state.

TABLE 1

	MATERIAL OF DIELECTRIC *1	AVERAGE REFRACTIVE INDEX OF REGION B	p [nm]	H1 [nm]	H2 [nm]	H3 [nm]	w3 [nm]	POLARIZATION DEGREE [%] *2	TRANSMITTANCE [%] *2
EX. 1	SILICON NITRIDE	1.59	140	128	165	153	67	99.96	42
EX. 2	SILICON NITRIDE	1.59	140	128	165	180	69	99.99	38
EX. 3	SILICON NITRIDE	1.56	120	110	141	151	54	99.97	43
EX. 4	SILICON OXIDE	1.24	120	110	155	153	54	99.97	41
EX. 5	SILICON NITRIDE	1.56	100	92	128	145	45	99.99	43
EX. 6	SILICON NITRIDE	1.56 *3	120	110	144	152	54	99.97	41
COMP. EX. 1	NON		120	110	—	NOT FORMED	NOT FORMED	—	—
COMP. EX. 2	—		144	—	—	180	70	99.89	44
COMP. EX. 3			144	—	—	150	68	99.40	47

\*1 REFRACTIVE INDEX OF SILICON OXIDE: 1.49  
REFRACTIVE INDEX OF SILICON NITRIDE: 2.05

\*2 VALUES OF THE DEGREE OF POLARIZATION AND LIGHT TRANSMITTANCE FOR LIGHT WITH A WAVELENGTH OF 550 NM

\*3 THE REFRACTIVE INDEX OF THE B REGION PRIOR TO DEPOSITION OF ALUMINIUM BECAUSE OF ALUMINIUM DEPOSITED ON THE CONVEX PORTION

As Comparative Example 3, the same commercially available wire grid polarizer with a glass substrate as a base as in Comparative Example 2 was etched in the aqueous 0.1 wt % sodium hydroxide solution for 20 seconds, rinsed immediately to halt etching, and dried.

The cross section of each of the wire grid polarizers was observed using FE-SEM to measure the pitch of the grid-shaped convex portions and the height and width of the metal wire. The results are also shown in Table 1. Further, FIG. 4 shows a SEM image of the cross section of the wire grid polarizer of Comparative Example 2. As can be seen from FIG. 4, the metal wires (Al) are formed on the glass substrate. These wire grid polarizers were evaluated on polarization performance as in the Examples. The results are also shown in Table 1, and FIGS. 5 and 6.

(Evaluation of Polarization Performance using a Spectrophotometer)

The degree of polarization and light transmittance were measured on each of obtained wire grid polarizers of the Examples and Comparative Examples using a spectrophotometer. Herein, the intensity of transmitted light was measured in parallel Nicol state and orthogonal Nicol state for linearly polarized light, and the degree of polarization and light transmittance were calculated from following equations. A range of measured wavelengths was from 400 nm to 800 nm as the visible light. FIG. 5 shows changes in degree of polarization in the range of 400 nm to 800 nm, and FIG. 6 shows changes in light transmittance in the range of 400 nm to 800 nm.

$$\text{Degree of polarization} = [(I_{\max} - I_{\min}) / (I_{\max} + I_{\min})] \times 100\%$$

$$\text{Light transmittance} = [(I_{\max} + I_{\min}) / 2] \times 100\%$$

As can be seen from FIG. 5, wire grid polarizers (Examples 1, 2, 3 and 5) according to the present invention exhibited excellent degrees of polarization over almost the entire visible region. Further, as can be seen from FIG. 6, the wire grid polarizers according to the invention exhibited excellent light transmittances over almost the entire visible region. Meanwhile, as shown in FIG. 5, wire grid polarizers of the Comparative Examples were low in the degree of polarization at short wavelengths in the visible region. Thus, it was found that the wire grid polarizer according to the invention has the microstructural concavo-convex grid, is not limited in structure, and has both the excellent degree of polarization and excellent transmittance over a wide range in the visible region.

According to the invention, since a wire grid polarizer has a resin substrate having grid-shaped convex portions, a dielectric layer provided to cover the grid-shaped convex portions of the resin substrate and at least part of side faces of the portions, and metal wires provided on the dielectric layer, it is possible to obtain the wire grid polarizer which is provided with adequate adhesion among the resin substrate, dielectric layer and metal wires, and has both the excellent degree of polarization and excellent transmittance over a wide range in the visible region. Further, it is possible to obtain the wire grid polarizer with the pitch of 120 nm or less, and to achieve the excellent degree of polarization and excellent transmittance. Furthermore, it is possible to manufacture the wire grid polarizer with the large area of 100 cm<sup>2</sup> or more with ease.

The present invention is not limited to the above-mentioned embodiment and examples, and is capable of being carried into practice with various modifications thereof. For example, the dimensions and materials in the above-men-

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tioned embodiment and examples are illustrative, and are capable of being modified as appropriate. Further, the polarizer in the above-mentioned embodiment is not necessarily a plate-shaped member, and may be in the form of a sheet or in the form of a film when necessary. The above-mentioned embodiment describes the case of applying the wire grid polarizer to a liquid crystal display device, but the invention is applicable similarly to devices requiring polarization other than the liquid crystal display device. Further, the invention is capable of being carried into practice in various modifications as appropriate without departing from the scope of the invention.

This application is based on the Japanese Patent Applications No. 2005-301883 filed on Oct. 17, 2005 and No. 2006-232967 filed on Aug. 30, 2006, the entire contents of which are expressly incorporated by reference herein.

What is claimed is:

1. A wire grid polarizer comprising:

a resin substrate having grid-shaped convex portions;  
a dielectric layer provided to cover the grid-shaped convex portions of the resin substrate and at least part of side faces of the portions; and

metal wires provided on convex portions of the dielectric layer such that the top of metal wires exist at a greater distance from the resin substrate than the convex portions of the dielectric layer.

2. The wire grid polarizer according to claim 1, wherein a refractive index of a region including the dielectric layer positioned higher than top portions of the grid-shaped convex portions is higher than a refractive index of the resin substrate.

3. The wire grid polarizer according to claim 1, wherein a refractive index of the dielectric layer is higher than the refractive index of the resin substrate.

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4. The wire grid polarizer according to claim 1, wherein pitches of the grid-shaped convex portions of the resin substrate are 120 nm or less.

5. The wire grid polarizer according to claim 1, wherein the dielectric layer is comprised of titanium oxide, cerium oxide, zirconium oxide, aluminium oxide, yttrium oxide, silicon oxide, silicon nitride, aluminium nitride, or a compound thereof.

6. The wire grid polarizer according to claim 1, wherein the metal wires are comprised of aluminium or an alloy thereof.

7. The wire grid polarizer according to claim 1, wherein the metal wires are provided leaning to one side faces of the dielectric layer.

8. The wire grid polarizer according to claim 1, wherein unit dimensions are 100 cm<sup>2</sup> or more.

9. A liquid crystal display device comprising:

a liquid crystal panel;

a lighting member that applies light to the liquid crystal panel; and

the wire grid polarizer according to claim 1 disposed between the liquid crystal panel and the lighting member.

10. The liquid crystal display device according to claim 9, wherein the liquid crystal panel is a transmission liquid crystal panel.

11. A liquid crystal display device comprising:

a light source;

the wire grid polarizer according to claim 1 that polarizes and divides light from the light source;

a liquid crystal display element that transmits or reflects the light polarized by the polarizer; and

a projection optical series that projects the light passed through or reflected by the liquid crystal display element onto a screen.

\* \* \* \* \*