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(71) Applicant: **SMART LIQUID CRYSTAL TECHNOLOGIES CO., LTD.** [CN/CN]; No. 280 Huangpu Jiang Road, Changshu New & Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN).

(72) Inventors: **XUE, Jiuzhi**; 3243 Taylor Court, Broomfield, CO 80023 (US). **ZHAO, Hui**; No. 128 Huangpu Jiang Road, Changshu New&Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN). **ZHANG, Hongwei**; No. 128 Huangpu Jiang Road, Changshu New&Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN). **WANG, Danni**; No. 128 Huangpu Jiang Road, Changshu New&Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN). **DING, Yuming**; No. 128 Huangpu Jiang Road, Changshu New&Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN). **YOU, Shizhi**; No. 128 Huangpu Jiang Road, Changshu New&Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN). **YU, Tianshi**; No. 128 Huangpu Jiang Road, Changshu New&Hi-tech Industrial Development Zone, Suzhou, Jiangsu 215500 (CN).

(74) Agent: **BEIJING ARETE INTELLECTUAL PROPERTY AGENCY**; Suite 1201, Building 3, Zhubang 2000 Business Center, No. 98 Ba Li Zhuang Xi Li, Chaoyang District, Beijing 100025 (CN).

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(54) **Title:** A POLARIZING BACKLIGHT UNIT, METHOD OF MANUFACTURING THE SAME AND LIQUID CRYSTAL DISPLAY DEVICE USING THE SAME

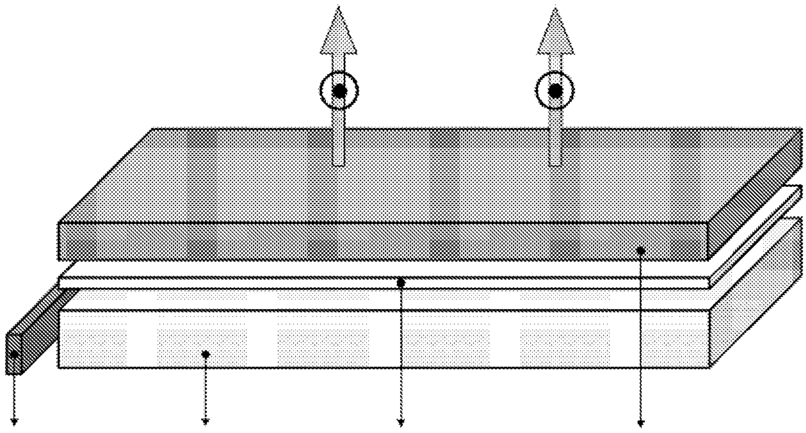

Figure 1

(57) **Abstract:** A polarizing backlight unit, a method of manufacturing the same, and a liquid crystal display device using the same. The backlight unit comprises: a light source (100); a polarizing lightguide (200) configured with a light incident surface (201) and a light exiting surface, wherein unpolarized light from the light source (100) enters the polarizing lightguide (200) through the light incident surface (201), and exits from the light exiting surface in the form of polarized light; a light propagation correction layer (300) placed over the polarizing lightguide (200) and comprised of optically isotropic materials; a low-refractive-index layer (400) that is sandwiched between the polarizing lightguide(200) and the light propagation correction layer (300). Backlight units emit polarized light with controlled illumination cone angles, and liquid crystal display devices employing the backlight units show increased brightness in desired viewing directions.

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A polarizing backlight unit, method of manufacturing the same and liquid crystal display device using the same

Technical Field

The present invention is related to polarizing backlight units and methods for controlling the output characteristics of backlights that use light propagation correction layer and other function constructions.

Background of the Invention

Flat panel displays such as liquid crystal displays (LCDs) are integral parts of many electronic devices today. As a non-emissive display device, one type of LCDs form images by receiving light from an external illumination system such as a backlight unit. However, due to its operating principle, conventional LCDs only use about 5% of the light emitted from a light source. Such low light use efficiency is mainly due to light absorption in polarization plates and color filters of the liquid crystal displays. Among them, the polarization plates disposed on both sides of the liquid crystal display, absorb more than 50% of unpolarized incident light, therefore they are one of the key factors of the low light use efficiency of the liquid crystal display.

One solution is to add a reflective polarizing film (such as DBEF made by 3M company) between a unpolarized backlight unit and a liquid crystal display panel, in order to reflect the unused polarized light back to the backlight unit, and to reuse it. The film transmits light of one polarization and reflects light of the perpendicular polarization. The reflected light re-enters the lightguide of the backlight unit, is depolarized, and is partially converted to the correct polarization states. Such a film can increase the axial brightness by about 60%.

Another solution is to use a backlight unit which is capable of emitting polarized light directly, combining with reflection type or scattering type polarizers, to improve the light utilization rate. Here the polarization separation technology is directly applied in the backlight unit through the technologies of polarization-related total reflection/scattering and optical anisotropy liquid crystal layer coating to emit polarized light. As disclosed in U.S. Pat.No.57293311, a backlight system comprises a specially designed optical waveguide plate, where the unpolarized light is coupled into the waveguide plate via its lateral surface section and propagates forward. The waveguide plate is featured with grooves filled with optical anisotropy materials. The refractive index of the waveguide material is n_p, and the refractive index of the optically anisotropic material is n_o and n_e. In order to meet the requirement of polarization separation, either of n_o or n_e is equal to or substantially equal to n_p. However, during the manufacturing process, filling materials into the grooves is difficult, and the manufacturing of the waveguide plate with the special grooves structure is very costly.

The method disclosed by CN Pat. No. 100564998 made an improvement where a backlight unit with a layered structure is given and the polarization separation layer is separated from the lightguide. However, due to the underlying physical principles, the emitting light rays need to meet a certain angular requirement (such as the direction of the exiting light rays have to be near the normal line), which greatly limits the selection of the size, shape and materials of the microstructures.

In addition, though prior art overcomes the defect of wide distribution of the exiting angles, the distribution of exiting angles is determined along with the structure of the polarization separation, and then further modulation is difficult, which further limits the selection of the structure and the materials.

Therefore, there remains a need for such a backlight unit, which can emit polarized light and improve the light utilization efficiency. Meanwhile, the direction distribution of both incident light and the emiting polarized light can be flexibly tuned, which simplifies the manufacturing process, reduces the cost, and improves the producing efficiency.

Summary of the Invention

The present invention is concerned generally with a polarizing backlight unit for filtering selected light polarizations to enhance light illumination and image output, the polarizing backlight unit comprising: a light source; a polarizing lightguide configured with a light incident surface and a light exiting surface, wherein the light incident surface is connected with the light exiting surface, and the light source faces the light incident surface, wherein unpolarized light from the light source enters the polarizing lightguide through the light incident surface, and exits from the light exiting surface in the form of polarized light; a light propagation correction layer placed over the polarizing lightguide with a size substantially the same as that of the polarizing lightguide, wherein the light propagation correction layer is comprised of optically isotropic materials; and a low-refractive-index layer sandwiched between the polarizing lightguide and the light propagation correction layer. In an alternative embodiment, the backlight unit further comprises a light source adjustment layer disposed between the light incident surface of the polarizing lightguide and the light source. In a preferred embodiment, the refractive index of the light propagation correction layer is 1.40 -1.65. In a preferred embodiment, the low-refractive-index layer is an air gap.

In a preferred embodiment, parallel-array tilting triangular prisms extending in the direction parallel to the light incident surface are disposed at the light propagation correction layer surface which is away from the polarizing lightguide. In an alternative embodiment, groove structures extending in the direction perpendicular to the light incident surface are further disposed on the light propagation correction layer surface close to the polarizing lightguide. In a preferred embodiment, the cross section of the groove structures is sinusoidal or wavy or isosceles triangle.

In another alternative embodiment, the backlight unit further comprising an additional light propagation correction layer placed over the light propagation correction layer with a size substantially the same as that of the polarizing lightguide, or sandwiched between the light propagation correction layer and the low-refractive-index layer, wherein parallel-array isosceles triangle prisms extending in the direction perpendicular to the light incident surface are disposed with equal-intervals on the surface of the additional light propagation correction layer. In a preferred embodiment, the base angle of the isosceles triangle prisms varies between 35 degrees and 50 degrees.

In a further preferred embodiment, the ratio of the distance between adjacent apex angles of the prisms to the length of bottom edge of the prisms varies between 1 and 2.

In yet another preferred embodiment, the polarizing lightguide comprises: a substrate layer, wherein micro-prisms extending in the direction parallel to the light incident surface are disposed on the upper surface of the substrate layer; and a birefringent layer, wherein the lower surface of the birefringent layer is seamlessly and closely combined with the upper surface of the substrate layer, and the upper surface of the birefringent layer is substantially smooth, and the optical axis of the birefringent layer is substantially parallel to the extending direction of the micro-prisms, wherein the refractive index of the substrate layer is substantially consistent with the ordinary refractive index of the birefringent layer. In an alternative embodiment, the polarizing lightguide further comprises a supporting layer disposed beneath the lower surface of the substrate layer, wherein the refractive index of the supporting layer is 1.45-1.65. In a preferred embodiment, the birefringent layer is a liquid crystal layer. In further preferred embodiment, the refractive index difference between the extraordinary light and the ordinary light of the liquid crystal layer is in the range of 0.1- 0.35. In another preferred embodiment, the thickness of the substrate layer is variable.

In a preferred embodiment, parallel-array prisms are disposed on the surface of the light source adjustment layer which is close to the light source, wherein the prisms extend in the direction parallel to the light exiting surface. In a preferred embodiment, any base angle of the prisms is in a range of 0-90 degrees (include 90 degrees). In an alternative embodiment, the prisms are equally spaced, and the ratio of the distance between adjacent apex angles of the prisms to the length of the bottom edge of the prisms is between 1 and 2. In an alternative embodiment, the prisms are Fresnel lens.

In an alternative embodiment, parallel-array convex structures extending in the direction perpendicular to the light exiting surface are disposed on the surface of the light source adjustment layer close to the light source, and the cross section of the convex structures is a shape of a light cup.

In a preferred embodiment, a method of manufacturing a polarizing backlight unit of claim 1 or 2 is disclosed, comprising: forming a polarizing lightguide, a light source, a light propagation correction layer and a low-refractive-index layer independently, assembling all layers by stacking, wherein the stacking process comprises firstly disposing the low-refractive-index layer and the light propagation correction layer on the light exiting surface and sandwiching the low-refractive-index layer between the light propagation correction layer and the polarizing lightguide, then disposing the light source on the light incident surface, wherein the method of assembling comprises lamination. In an alternative embodiment, the method further comprises: forming the light source adjustment layer independently, disposing the light source adjustment layer between the light source and the polarizing lightguide.

In a preferred embodiment, a liquid crystal display device is disclosed, comprising a liquid crystal display panel and the backlight unit as mentioned above, wherein the liquid crystal display panel is disposed on the light exiting surface side of the backlight unit, and transmission axis of the polarizer of the liquid crystal panel close to the backlight unit is substantially parallel to the polarization direction of the exiting light from the backlight unit.

The backlight unit disclosed by present invention can emit polarized light to improve the light utilization rate of the backlight unit. Meanwhile, the angular distribution of the polarized light out of the polarization separation layer is adjusted by the light propagation correction layer, to make the direction of the polarized light symmetrically distributed around the surface normal, so that the manufacturing complexity of the polarization separation layer is greatly reduced and the choosing range of the available materials of the polarization separation layer is widened. According to the present invention, the light source adjustment layer is further used for adjustment angular distribution of the incident light, so that the utilization rate of the incident light is further improved. In addition, the components of the backlight unit can be independently manufactured and assembled flexibly, thus further simplifying the manufacturing process of the backlight unit and reducing the cost.

Brief Description of the drawings

The present invention will become more apparent by the description of embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a schematic view illustrating the structure of the backlight unit according to an embodiment of the present invention.

FIG. 2 is a schematic view illustrating the working principle of the backlight unit according to an embodiment of the present invention.

FIG. 3 is a schematic view illustrating the structure of the light propagation correction layer according to an embodiment of the present invention.

FIG. 4 is a schematic view of a cross section and the working principle of the structure according to FIG. 3.

FIG. 5 is a structural and cross-sectional schematic view of the light propagation correction layer according to an embodiment of the present invention.

FIG. 6 is a schematic view illustrating the structure of the additional light propagation correction layer according to an embodiment of the present invention.

FIG. 7 is a schematic view of a cross section and the working principle of the structure according to FIG. 6.

FIG. 8 is a schematic view of a structure and the working principle of the polarizing lightguide according to an embodiment of the present invention.

FIG. 9 is a principle schematic view of adjustment of light exiting intensity by changing the thickness of a substrate layer of the present invention.

FIG. 10 is a schematic view illustrating the structure of a polarizing lightguide comprising a supporting layer according to an embodiment of the present invention.

FIG. 11 is a schematic view illustrating the structure of a backlight unit according to an embodiment of the present invention.

FIG. 12 is a schematic view illustrating the working principle of a light source adjustment layer according to an embodiment of the present invention.

FIG. 13 is a schematic view illustrating a cross-section of a light source adjustment layer according to an embodiment of the present invention.

FIG. 14 is a schematic view illustrating a top view and a structure of a light source adjustment layer according to an embodiment of the present invention.

FIG. 15 is a schematic view illustrating assembling method of each layer according to an embodiment of the present invention.

Detailed Description of the Invention

In the following description, for the purpose of explanation so as to have a comprehensive understanding of the invention, numerous specific details are disclosed, however, it is obvious to those skilled in the art, that the invention can be implemented without these specific details. In other embodiments, well-known structures and devices are shown in block diagrams in the invention. The exemplary embodiments are merely illustrative of the invention, rather than limiting the scope of the present invention being defined by appended claims thereof.

Referring to FIG. 1, a polarizing backlight unit according to an embodiment of the present invention is shown. The backlight unit comprising a light source 100, a polarizing lightguide 200 which guides light and converts unpolarized light generated by the light source 100 into polarized light, a light propagation correction layer 300 correcting the exiting direction of polarized light, and a low-refractive-index layer 400 located between the polarizing lightguide 200 and the light propagation correction layer 300. Among them, the polarizing lightguide 200, the light propagation correction layer 300 and the low-refractive-index layer 400 are disposed in a parallel stack mode and have substantially same sizes. The low-refractive-index layer 400 is used for separating the polarizing lightguide 200 and the light propagation correction layer 300, therefore polarized light converted in the polarizing lightguide 200 can be coupled out from the light exiting surface of the polarizing lightguide 200. The low-refractive-index layer 400 can be an air gap, and the thickness can be adjusted, for instance, by using spacers.

As shown in FIG. 2, the polarizing lightguide 200 is configured with a light incident surface 201, a light exiting surface connecting the light incident surface 201, and a lateral surface 202 opposite to the light incident surface 201. The light source 100 is disposed towards the light incident surface 201. Light generated by the light source 100 enters the polarizing lightguide 200 from the light incident surface 201, and keeps reflecting on its upper surface and lower surface in a waveguide form. During the process, light in a waveguide form keeps interacting with the internal structure of the polarizing lightguide 200 (described in detail below), wherein s-polarization light is separated and has a certain possibility to exit from the light exiting surface (upper surface) of the polarizing lightguide 200, and p-polarization light continues to propagate forward while part of p-polarization light is converted into s-polarization light. In general, depending on the internal structure and materials of the polarizing lightguide 200, the exiting direction of s-polarization light is not necessarily distributed symmetrically along the normal line of the upper surface, such as light rays 211 and 212 in FIG. 2. In most applications, exiting light is required to be symmetrically distributed along the normal line of the light exiting surface of the backlight unit, as such the internal structure and materials of the polarizing lightguide 200 are required to be optimal, which limits the selection of its structure and materials. Here the role of the light propagation correction layer 300 is to adjust the light rays 211 and 212 from obliquely distributed to the normal symmetry distribution, as shown with the light rays 311 and 312. Meanwhile, since light propagation correction layer 300 is made of optically isotropic materials, the polarization of the transmitted light can be well preserved, that is, the polarization of the light rays 311 and 312 is same as that of the light rays 211 and 212, which is s-polarization, so as to ensure the polarization of the emitting light of the backlight unit. The refractive index of the light propagation correction layer is 1.40-1.65, and its transmittance is more than 90%. LEDs or CCFL may be used as light sources according to the present invention. Generally, conventional light sources provide substantially incoherent, uncollimated light; but coherent, collimated light can also be used according to the inventions herein.

In one embodiment, a parallel-array tilting triangular prisms with equal-intervals are formed on the upper surface of the light propagation correction layer 300, wherein the prisms extend in the direction parallel to the light incident surface 201, as shown in FIG. 3. The height of the prisms is 5-50 microns. As shown in FIG. 4, after entering the light propagation correction layer 300, the light rays 321, 322, 323 or 324 occurs refraction or re-refraction after total internal reflection on the surfaces of the prisms, and leave the surfaces to form light rays 331,332,333 or 334 with new propagation directions. The cross section of the prisms has a shape of an oblique triangle. By adjusting the two base angles of the oblique triangle, the obliquely distributed incident light 211 and 212 are converted into symmetrically distributed exit light 311 and 312. The degrees of the base angles depend on the inclination of the incident polarized light entering the light propagation correction layer 300, that is, the inclination of the polarized light exited from the polarizing lightguide 200, further, the structure and the materials of the polarizing lightguide 200. In preferred embodiments, the ratio of the distance L_1 between adjacent apex angles of the prisms to the length L_2 of bottom edge of the prisms is between 1 and 2.

In an alternative embodiment, the lower surfaces of the light propagation correction layer 300 has parallel-array and equal-interval groove structures at the same time, which extend in the direction perpendicular to the light incident surface 201, as shown in FIG. 5. The cross section of the groove structures has a sinusoidal or wavy shape, as shown in FIG. 5, or an isosceles triangle shape. Their function is to make the total light intensity of the polarized light exited from the polarizing lightguide 200 uniform in lateral direction (perpendicular to the extending direction of the groove structures). With regard to the sinusoidal or wavy groove structures, the perpendicular distance between wave peaks and valleys L_3, and the horizontal distance between adjacent wave peaks or valleys L_4 are not more than 100 microns.

In another embodiment, besides the light propagation correction layer 300, another additional light propagation correction layer 300a is included. The upper surface of the additional light propagation correction layer 300a is configured with parallel-array and equal-interval prisms extending in the direction perpendicular to the light incident surface 201, as shown in FIG. 6. The cross section of the prisms has an isosceles triangle shape whose base angle can be changed from 35 degrees to 50 degrees. The height of the isosceles triangle is 5-50 microns, and the ratio of the distance between adjacent apex angles of the prisms L_5 to the length of bottom edge of the prisms L_6 is between 1 and 2. The additional light propagation correction layer 300a can be placed either over the upper layer of the light propagation correction layer 300, or between the light propagation correction layer 300 and the low-refractive-index layer 400. As shown in FIG. 7, the additional light propagation correction layer 300a can collapse large-angle incident rays scattering in the lateral direction into small-angle rays, so improving the light intensity distribution of the backlight unit.

In another embodiment, as shown in FIG. 8, the polarizing lightguide 200 may comprise a substrate layer 203 and a birefringent layer 204, and micro-prisms extending in a direction parallel to the light incident surface 201 are disposed on the upper surface of the substrate layer 203, which is seamlessly and closely combined with the birefringent layer 204. The other surface of the birefringent layer 204 away from the substrate layer is a substantially smooth surface. The birefringent layer 204 is comprised of birefringent materials, and has an ordinary refractive index n_o and an extraordinary refractive index n_e, where n_e is greater than n_o. The optical axis of birefringent layer 204 is substantially parallel to the extending direction of the micro-prisms on the substrate layer 203, therefore the birefringence Δn of the birefringent layer 204 is the largest in the direction orthogonal to the extending direction, which improves the polarization separation efficiency. In a preferred embodiment, the birefringent layer 204 is a liquid crystal layer, whose birefringence $\Delta n = n_e - n_o$ is between 0.1 and 0.35. The substrate layer 203 is comprised of optical isotropic medium, and the refractive index of the substrate layer 203 is substantially consistent with n_o of the birefringent layer 204. Inside the birefringent layer 204, the s-polarization light and the p-polarization light have different propagation paths. For example, for s-polarization ray 221, total internal reflection occurs at the interface between the micro-prisms and the birefringent layer 204, therefore the ray propagation direction meets the escaping requirements, resulting in exiting of the ray from the upper surface of the polarizing lightguide 200. For p-polarization ray 222, due to the fact that the refractive indexes in the substrate layer 203 and the birefringent layer 204 are substantially equal, n_o total internal reflection occurs at interface, and the ray can propagate along the original direction in waveguide, and cannot escape from the upper surface of the polarizing lightguide 200, achieving polarization separation and selectively exiting of s-polarization light. After scattering or polarization rotation, part of p-polarization light propagating in waveguide is converted into s-polarization light to exit out from the upper surface. In a preferred embodiment, the thickness L_7 of the substrate layer 203 can be adjusted so as to adjust the intensity of the polarized light exiting from the light exiting surface. As shown in FIG. 9, light incident in the direction 113 is continuously reflected in the substrate layer 203 in waveguide, during that s-polarization light exit out of the light exiting surface. When the thickness of the substrate layer 203 is reduced, the number of reflection within the same propagation distance will increase, as well as the probability of the interaction with the micro-prism structure, resulting in the enhancement of the light emitting intensity. In a preferred embodiment, the thickness of the substrate layer 203 should not be less than the height of the light source 100, so the incident light generated from the light source 100 can all enter the substrate layer 203. In a preferred embodiment, the height of the micro-prisms of the substrate layer 203 is not larger than 100 microns, and the thickness of the birefringent layer 204 is not smaller than the height of the micro-prisms, so that the micro-prism structure is immersed in the birefringent layer 204.

In an alternative embodiment, the polarizing lightguide 200 may further include a supporting layer 205. As shown in FIG. 10, the upper surface of the supporting layer 205 is seamlessly and closely combined with the lower surface of the substrate layer 203, and their contact surfaces are substantially matched. The supporting layer 205 can be comprised of optically isotropic materials, and the refractive index is 1.45-1.65; it may also be comprised of materials partially birefringent, such as PET materials, where the polarization of light is continuously rotated in the propagation process, converting p-polarization to s-polarization.

The angular distribution of the light exiting from the polarizing lightguide 200 depends on birefringence Δn of the birefringent layer 204 and the shape of the micro structures on the inner surface of the substrate layer 203. Regard to the pre-disposed micro structures and optimized birefringent materials, the light exiting from the polarizing lightguide 200 can be symmetrically distributed along the normal direction of the light exiting surface. Otherwise, the angular distribution of the exiting light will be slanted, which limits the selection of the birefringent materials. By adding the light propagation correction layer 300, the angular distribution of exiting light can be corrected, so that the exiting light are symmetrically distributed along the normal direction, which relaxes the requirement on the materials and reducing the cost.

In another embodiment, the backlight unit may further include a light source adjustment layer 500. As shown in FIG. 11, the light source adjustment layer 500 is disposed between the light source 100 and the polarizing lightguide 200, and its surface areas substantially match that of the light source 100 and the light incident surface of polarizing lightguide 200. Light emitted from a light source, such as LED, has a specific angular distribution. The light emitted by the light source 100 are classified into small-angle rays 111 and large-angle rays 112 according to the angle between the rays and the coordinate axes, where the direction distribution of the small-angle light 111 is close to the normal direction of the light emitting surface of the light source 100, while the direction distribution of the large-angle rays 112 is deviated from the normal direction, as shown in FIG. 12. During propagation in the polarizing lightguide 200 and interacting with the birefringent layer 204, the large-angle rays 112 meet the exiting conditions of the polarizing lightguide 200 and exit from the light exiting surface; while the small-angle light 111 cannot meet the exiting conditions of the polarizing lightguide 200 and continue to propagate in waveguide mode, and eventually escapes the waveguide from the lateral surface 202. In general, the large-angle light such as rays 112 only accounts for 30% or less of the total light. The light source adjustment layer 500 can adjust angular distribution of the light emitted by the light source 100, convert part of the small-angle rays 111 into large-angle rays 512, and increase the percentage of the large-angle light rays 512, thus the amount of light exiting from the light exiting surface of the polarizing lightguide 200 is increased, as well as the light intensity of the backlight unit. In a preferred embodiment, after passing through light source adjustment layer 500, the ratio of the large-angle rays to the total light intensity can be increased to 60% or more.

As shown in FIG. 13 (a), the light source adjustment layer 500 has parallel-array prisms disposed on the light incident surface, and the prisms extend in a direction parallel to the light exiting surface of the polarizing lightguide 200. The height of the prisms is 5-50 microns. Small-angle rays entering the light source adjustment layer 500 are refracted twice through the surface of the prisms and the right side of the light source adjustment layer 500, which causes an outward deflection effect, and therefore changes into large-angle rays. The prisms can be an isosceles triangle or an oblique triangle, and the two base angles can be 0 to 90 degrees (including 90 degrees). In an alternative embodiment, the prisms are disposed at equal intervals, as shown in FIG. 13 (b), and the ratio of the distance L_8 between adjacent apex angles of the prisms to the length L_9 of bottom edge of the prisms is between 1 and 2. In another alternative embodiment, as shown in FIG. 13 (c), the prisms are Fresnel lens. In other alternative embodiment, the prisms may include other useful facet shapes, for example, parabolic, elliptical, hyperbolic, circular, exponential, polynomial, polygonal, and combinations thereof. In another alternative embodiment, the light source adjustment layer 500 has parallel-array convex structures disposed on the light incident surface, but with an extending direction perpendicular to the light exiting surface of the polarizing lightguide 200, as shown in the top view on the left side of FIG. 14. The cross section of the convex structures is a light cup shape. The size of the base plate of the light cup is matched with the size of the LED chip in the light source 100. The large-angle light rays in the transverse direction can be reflected by the side surface of the light cup and change into small-angle light rays, which narrow the angular distribution of the light laterally. The wall shape of the light cup can be a conic curve, a straight line or a broken line connected end to end.

In another embodiment, the invention discloses a method of manufacturing the backlight unit mentioned above, comprising: forming a polarizing lightguide 200, a light propagation correction layer 300 and a low-refractive-index layer 400 independently, and then assembling them by stacking to form a backlight unit. As shown in FIG. 15 (a), the light propagation correction layer 300 and the low-refractive-index layer 400 are spliced on the light exiting surface of the polarizing lightguide 200, and the low-refractive-index layer 400 is sandwiched between the light propagation correction layer 300 and the polarizing lightguide 200; and the light source 100 is placed on the light incident surface of the polarizing lightguide 200. In a preferred embodiment, the low-refractive-index layer 400 is an air gap, and the light propagation correction layer 300 and the polarizing lightguide 200 have an air gap between them, and the thickness of the air gap can be controlled by spacers. Similarly, an air gap is reserved between the light source 100 and the polarizing lightguide 200. In an alternative embodiment, the manufacturing method of the backlight unit further comprising forming the light source adjustment layer 500 independently, and placing the light source adjustment layer 500 between the light source 100 and the polarizing lightguide 200, as shown in FIG. 15 (b). The light source adjustment layer 500 can be attached to the light incident surface of the polarizing lightguide 200 through glue 600, and then the light source 100 is placed next to the light source adjustment layer 500 through method mentioned above.

In another embodiment of the invention, a liquid crystal display device is disclosed, comprising one of backlight unit described in above embodiments and a liquid crystal display panel, where the liquid crystal display panel is disposed on the light exiting side of the backlight unit, and optical axis of the lower polarizer in the liquid crystal display panel close to the backlight unit is substantially parallel to the polarization of the light from the backlight unit. When the light passes through the lower polarizer, since its polarization is substantially parallel to the transmission axis of the lower polarizer, high transmittance of the light, almost 100% transmittance under ideal conditions can be achieved. Therefore the light utilization ratio of the backlight unit can be improved, and the energy consumption can be reduced. Meanwhile, due to the fact that the intensity and the angular distribution of the exiting light of the backlight unit are specially engineered, the overall display brightness is more uniform and the display viewing angle has more freedom of adjustability, resulting in an excellent display effect.

While the present invention has been described in connection with certain example embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims, and equivalents thereof.

Claims

1. A polarizing backlight unit comprising:

a light source;

a polarizing lightguide configured with a light incident surface and a light exiting surface, wherein the light incident surface is connected with the light exiting surface, and the light source faces the light incident surface, wherein unpolarized light from the light source enters the polarizing lightguide through the light incident surface, and exits from the light exiting surface in the form of polarized light;

a light propagation correction layer placed over the polarizing lightguide with a size substantially the same as that of the polarizing lightguide, wherein the light propagation correction layer is comprised of optically isotropic materials; and

a low-refractive-index layer sandwiched between the polarizing lightguide and the light propagation correction layer.

2. The backlight unit of claim 1, wherein the backlight unit further comprises a light source adjustment layer disposed between the light incident surface of the polarizing lightguide and the light source.

3. The backlight unit of claim 1 or 2, wherein parallel-array tilting triangular prisms extending in the direction parallel to the light incident surface are disposed at the light propagation correction layer surface which is away from the polarizing lightguide.

4. The backlight unit of claim 3, wherein groove structures extending in the direction perpendicular to the light incident surface are further disposed on the light propagation correction layer surface close to the polarizing lightguide.

5. The backlight unit of claim 4, wherein the cross section of the groove structures is sinusoidal or wavy.

6. The backlight unit of claim 4, wherein the cross section of the groove structures is isosceles triangle.

7. The backlight unit of claim 3, wherein the backlight unit further comprising an additional light propagation correction layer placed over the light propagation correction layer with a size substantially the same as that of the polarizing lightguide, or sandwiched between the light propagation correction layer and the low-refractive-index layer, wherein parallel- array isosceles triangle prisms extending in the direction perpendicular to the light incident surface are disposed with equal intervals on the surface of the additional light propagation correction layer.

8. The backlight unit of claim 7, wherein the base angle of the isosceles triangle prisms varies between 35 degrees and 50 degrees.

9. The backlight unit of claim 3, 6 or 7, wherein the ratio of the distance between adjacent apex angles of the prisms to the length of bottom edge of the prisms varies between 1 and 2.

10. The backlight unit of claim 1 or 2, wherein the refractive index of the light propagation correction layer is 1.40 -1.65.

11. The backlight unit of claim 1 or 2, wherein the polarizing lightguide comprises:

a substrate layer, wherein micro-prisms extending in the direction parallel to the light incident surface are disposed on the upper surface of the substrate layer; and

a birefringent layer, wherein the lower surface of the birefringent layer is seamlessly and closely combined with the upper surface of the substrate layer, and the upper surface of the birefringent layer is substantially smooth, and the optical axis of the birefringent layer is substantially parallel to the extending direction of the micro-prisms,

wherein the refractive index of the substrate layer is substantially consistent with the ordinary refractive index of the birefringent layer.

12. The backlight unit of claim 11, wherein the birefringent layer is a liquid crystal layer.

13. The backlight unit of claim 12, wherein the refractive index difference between the extraordinary light and the ordinary light of the liquid crystal layer is in the range of 0.1- 0.35.

14. The backlight unit of claim 11, wherein the thickness of the substrate layer is variable.

15. The backlight unit of claim 11, wherein the polarizing lightguide further comprises a supporting layer disposed beneath the lower surface of the substrate layer, wherein the refractive index of the supporting layer is 1.45-1.65.

16. The backlight unit of claim 2, wherein parallel-array prisms are disposed on the surface of the light source adjustment layer which is close to the light source, wherein the prisms extend in the direction parallel to the light exiting surface.

17. The backlight unit of claim 16, wherein any base angle of the prisms is in a range of 0-90 degrees.

18. The backlight unit of claim 17, wherein the prisms are equally spaced, and the ratio of

the distance between adjacent apex angles of the prisms to the length of the bottom edge of the prisms is between 1 and 2.

19. The backlight unit of claim 16, wherein the prisms are Fresnel lens.

20. The backlight unit of claim 2, wherein parallel-array convex structures extending in the direction perpendicular to the light exiting surface are disposed on the surface of the light source adjustment layer close to the light source.

21. The backlight unit of claim 20, wherein the cross section of the convex structures is a light cup shape.

22. The backlight unit of claim 1 or 2, wherein the low-refractive-index layer is an air gap.

23. A method of manufacturing a polarizing backlight unit of claim 1 or 2, comprising:

forming a polarizing lightguide, a light source, a light propagation correction layer and a low-refractive-index layer independently,

assembling all layers by stacking, wherein the stacking process comprises: firstly disposing the low-refractive-index layer and the light propagation correction layer on the light exiting surface, and sandwiching the low-refractive-index layer between the light propagation correction layer and the polarizing lightguide, then disposing the light source on the light incident surface,

wherein the method of assembling comprises lamination.

24. The method of claim 23, wherein the method further comprises:

forming a light source adjustment layer independently,

disposing the light source adjustment layer between a light source and a polarizing lightguide.

25. A liquid crystal display device, comprising a liquid crystal display panel and the backlight unit of claim 1 or 2, wherein the liquid crystal display panel is disposed on the light exiting side of the backlight unit, and transmission axis of the polarizer of the liquid crystal panel close to the backlight unit is substantially parallel to the polarization direction of the exiting light from the backlight unit.

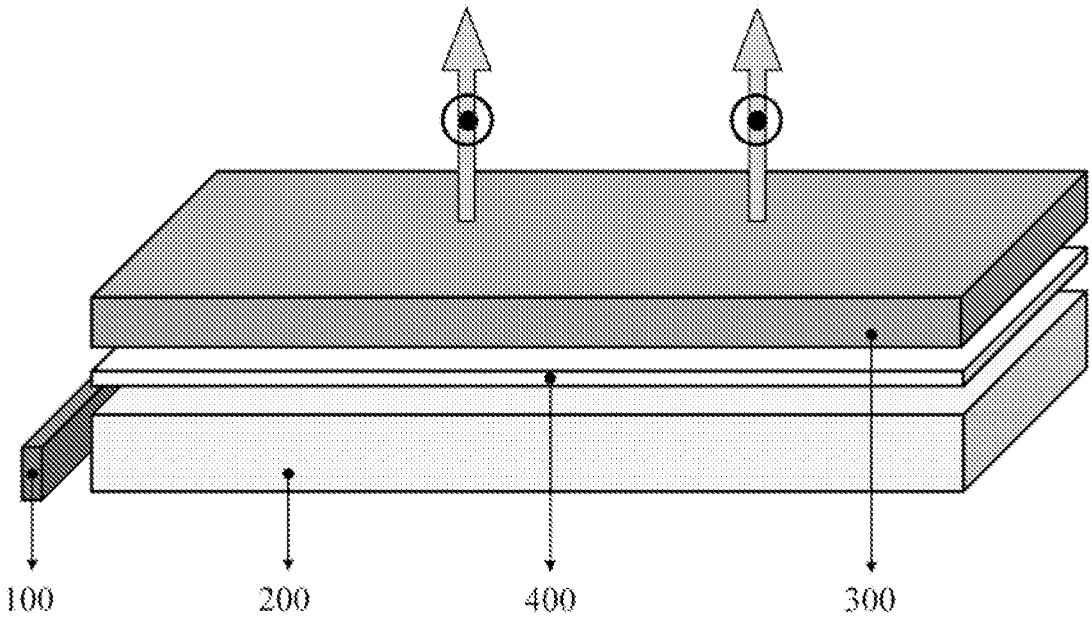


Figure 1

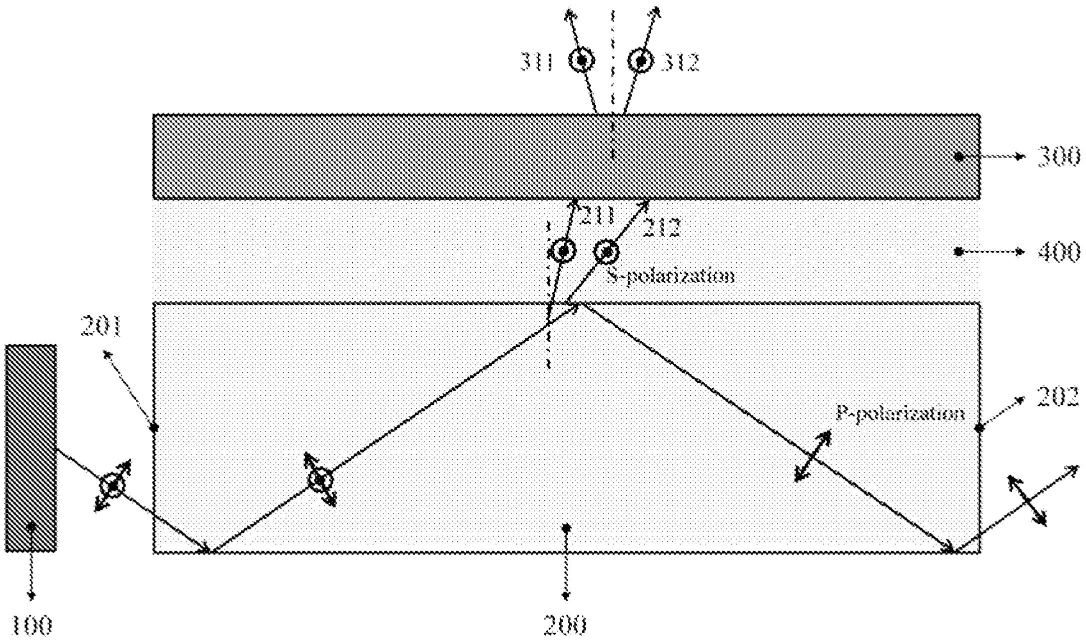


Figure 2

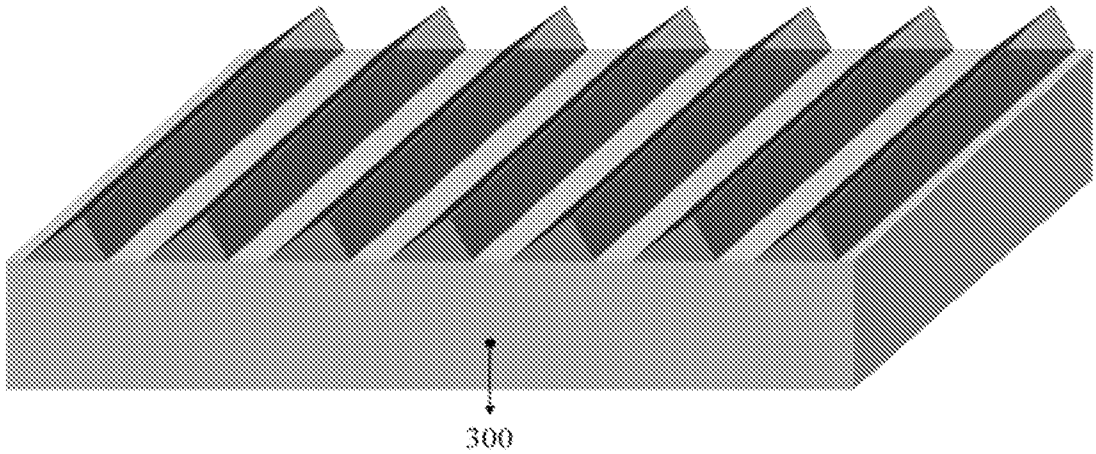
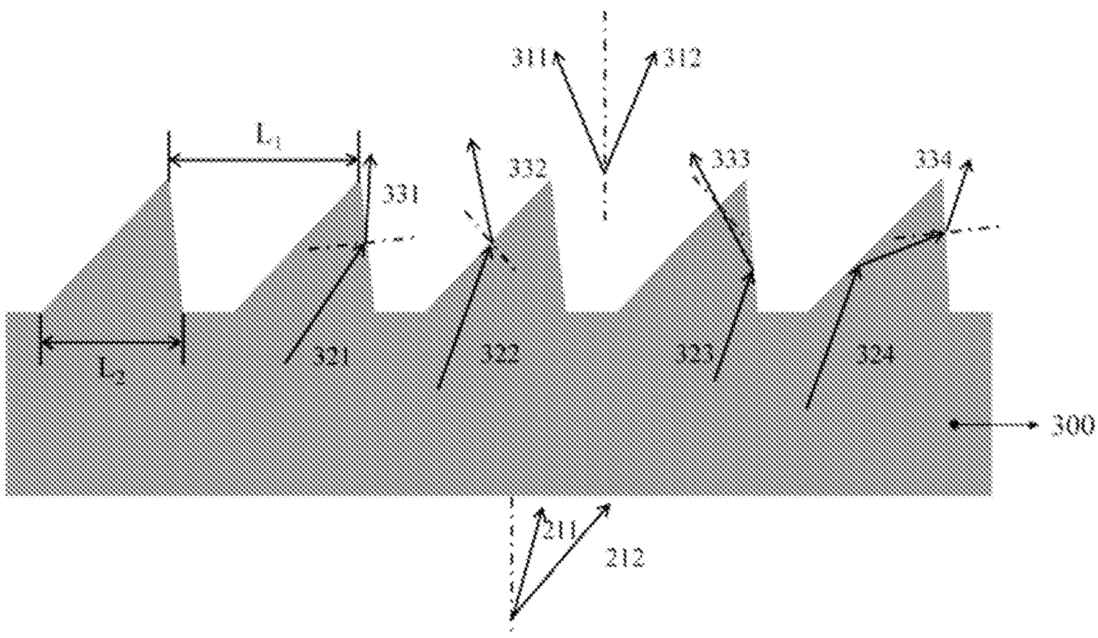


Figure 3



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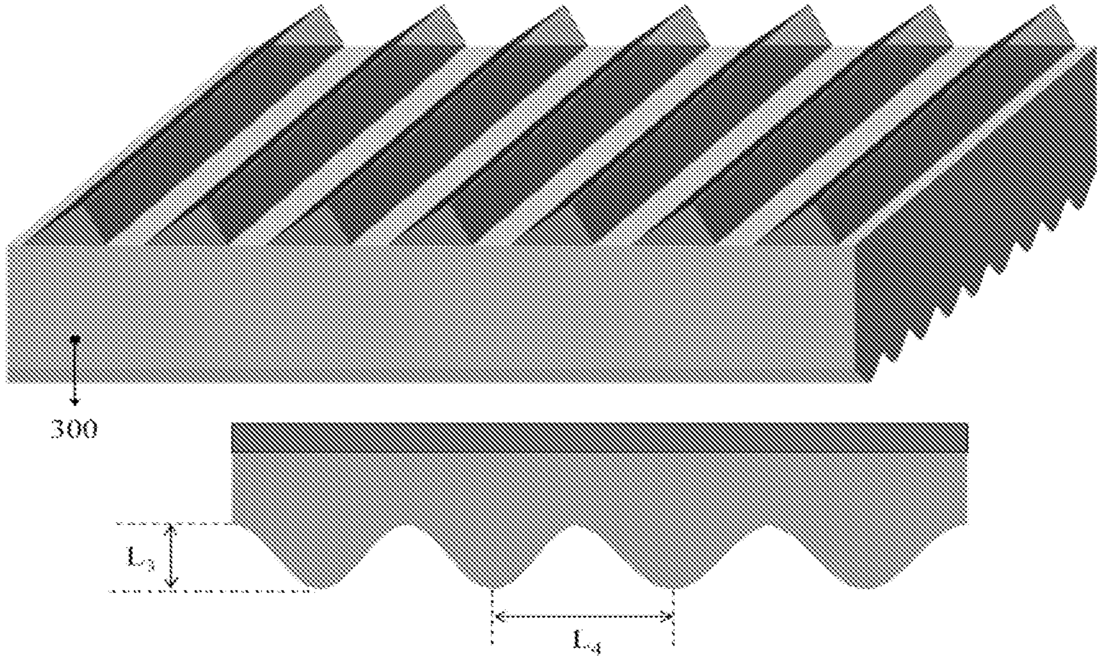
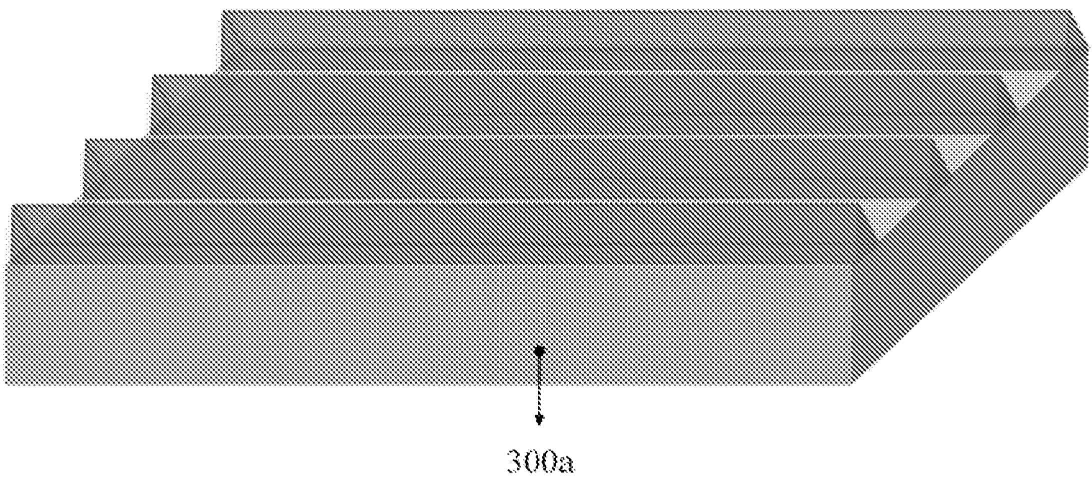


Figure 5



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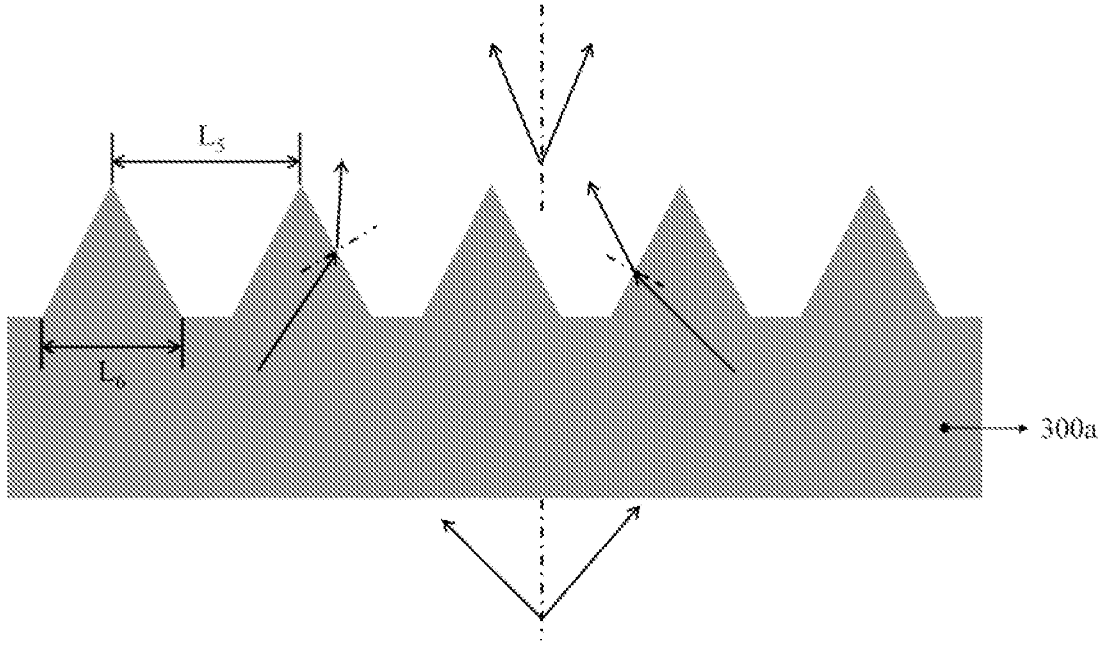


Figure 7

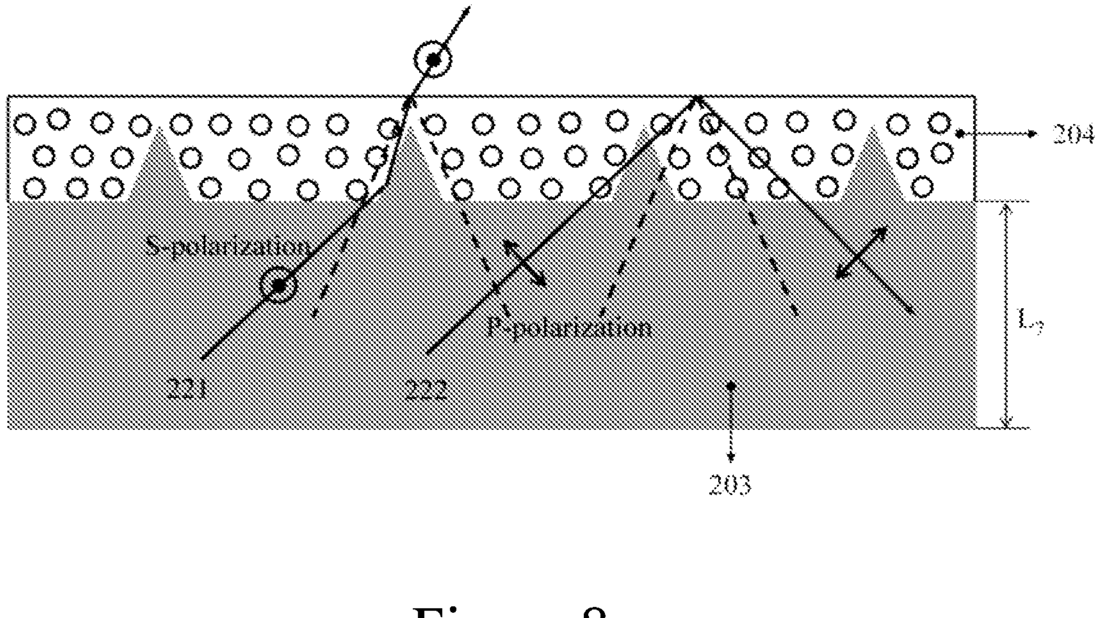


Figure 8

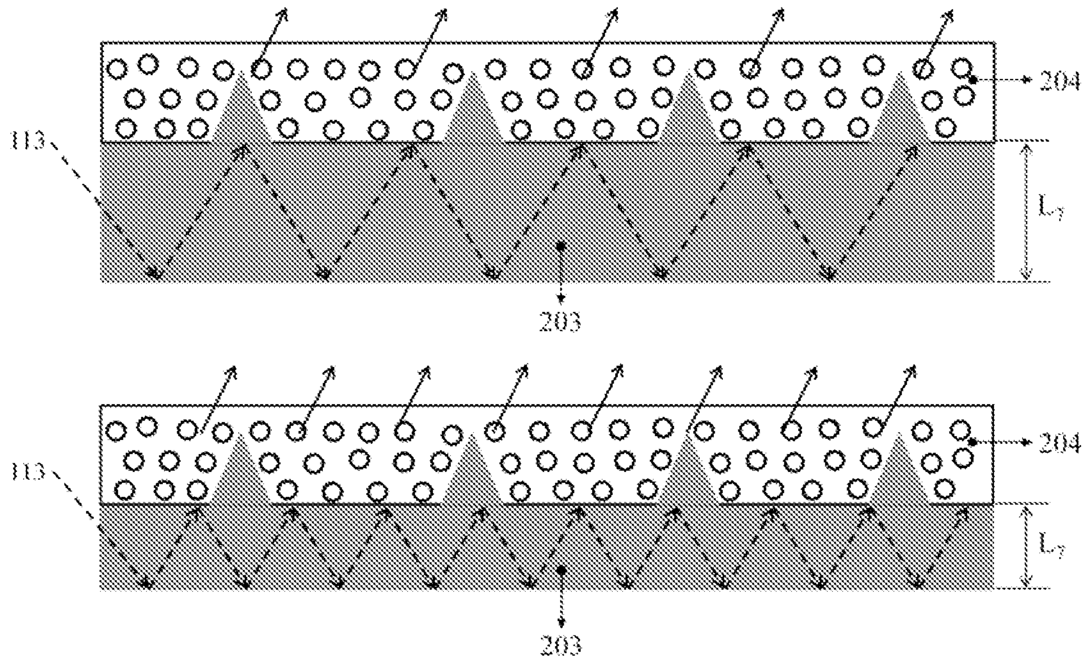


Figure 9

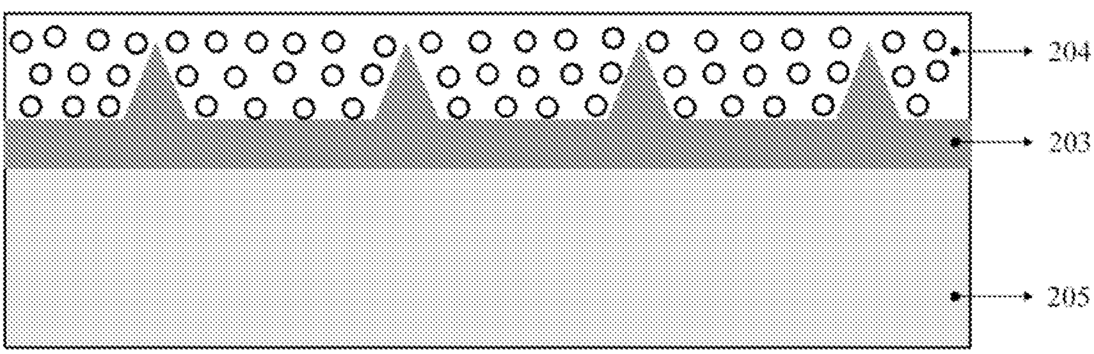


Figure 10

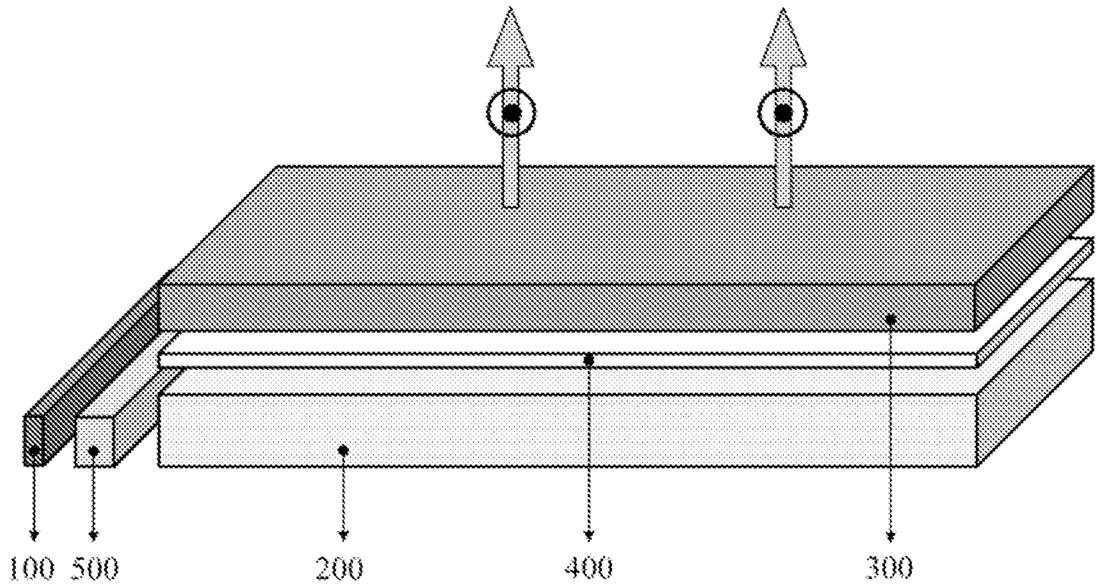


Figure 11

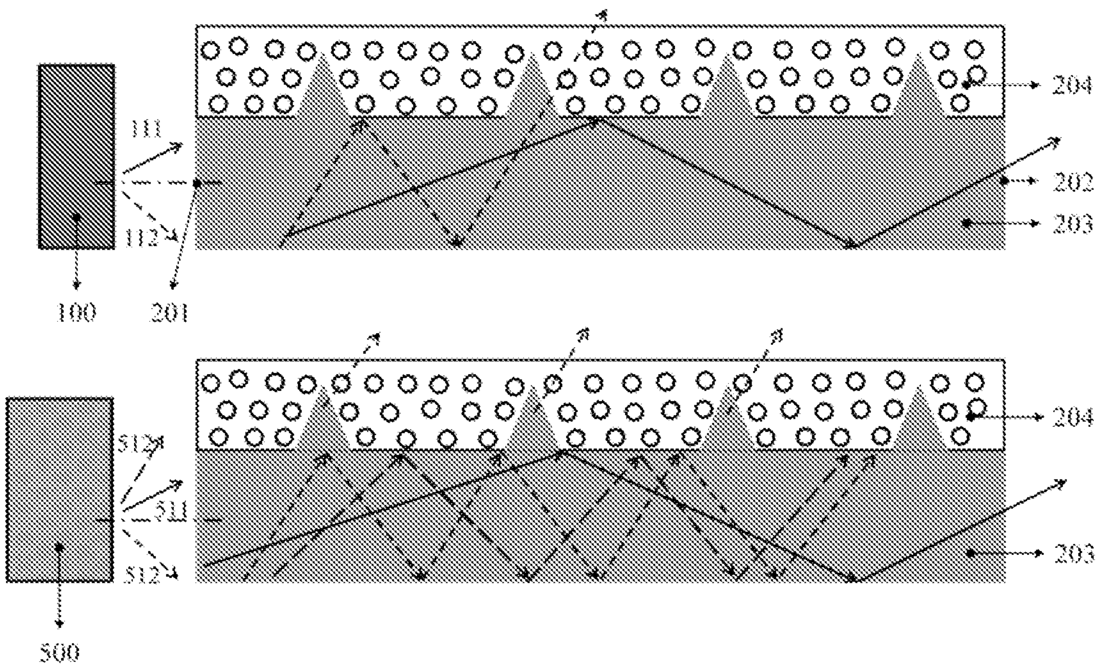


Figure 12

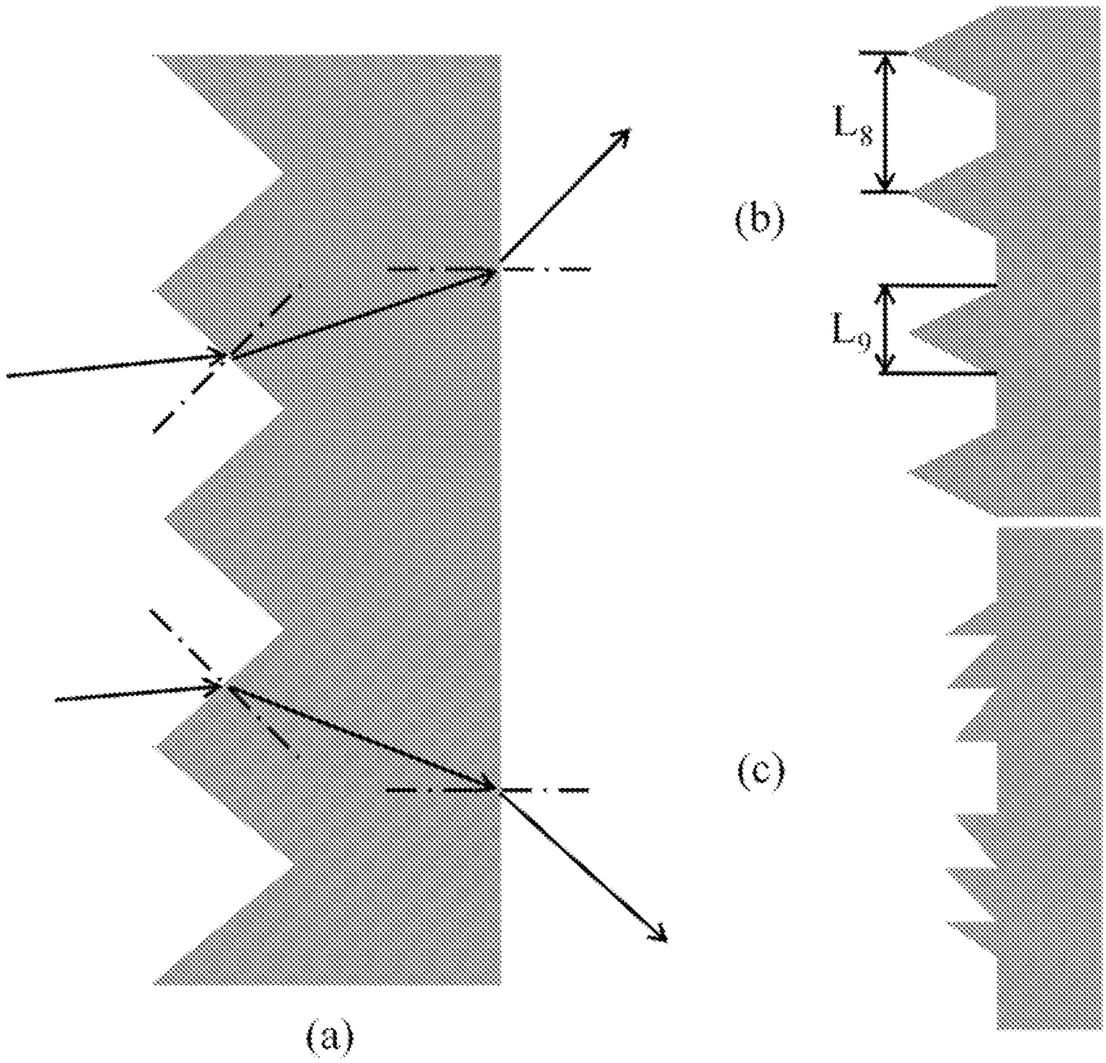


Figure 13

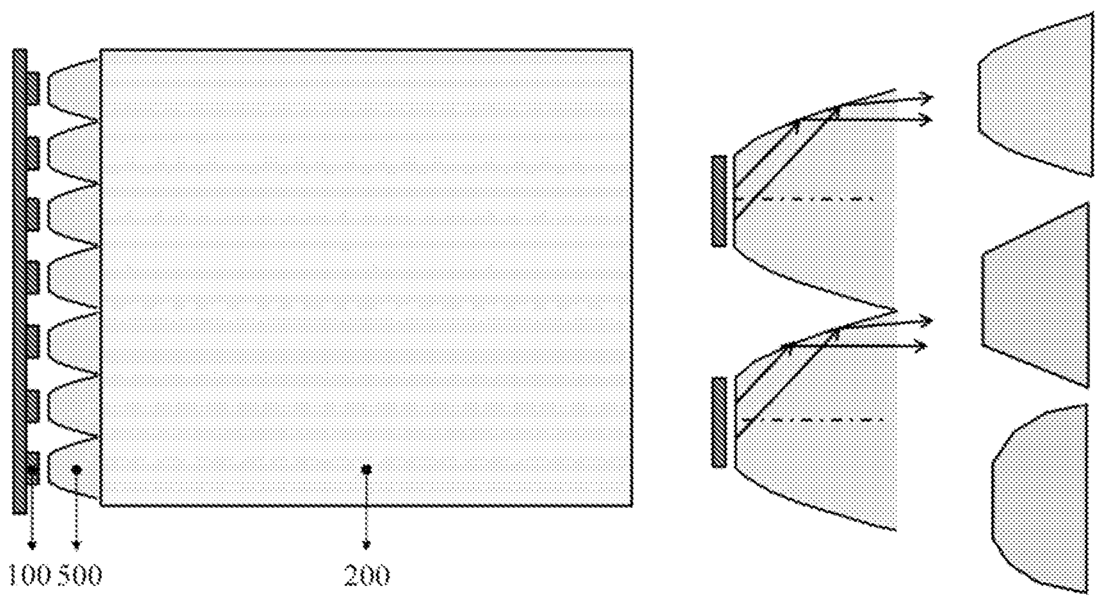
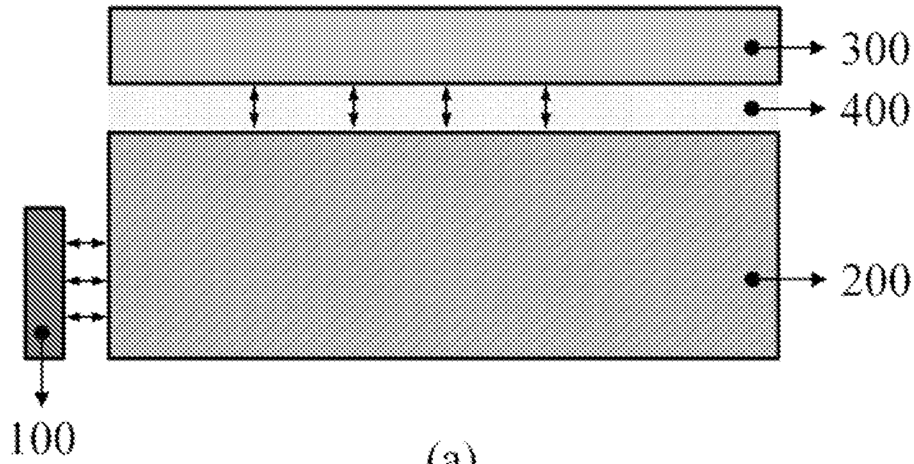
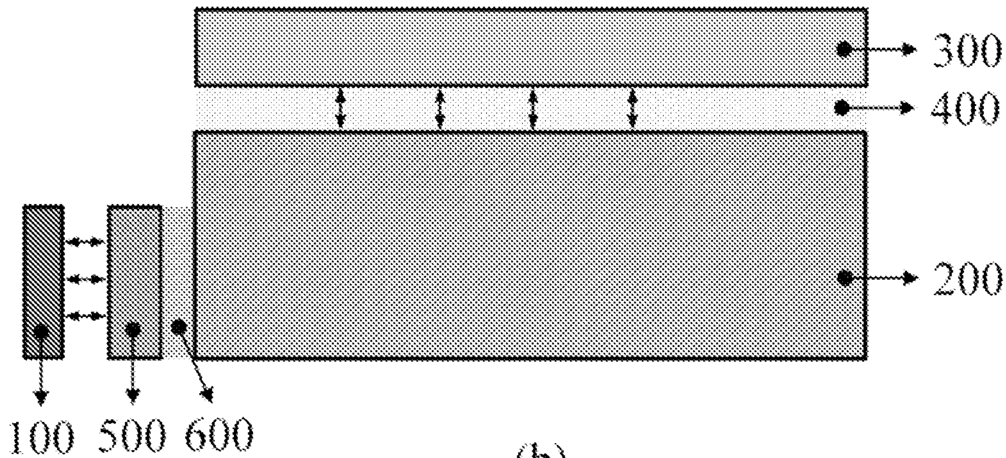


Figure 14



(a)



(b)

Figure 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/094520

A. CLASSIFICATION OF SUBJECT MATTER

G02F 1/13357(2006.01)i； G02B 6/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02F1/-,G02B6/-

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

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

CNPAT,CNKI,WPI,EPODOC: backlight, back w light, light w guide, lightguide, polari+, focus, prism?, angle, angular, liquid, crystal, birefringen+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 20070028827 A (SAMSUNG ELECTRONICS CO., LTD.) 13 March 2007 (2007-03-13) description, paragraphs [23]-[81], figures 1-6	1-10、16-25
Y	KR 20070028827 A (SAMSUNG ELECTRONICS CO., LTD.) 13 March 2007 (2007-03-13) description, paragraphs [23]-[81], figures 1-6	11-15
Y	CN 104316990 A (BOE TECHNOLOGY GROUP CO., LTD.) 28 January 2015 (2015-01-28) description, paragraphs [0033]-[0065], figures 2-9	11-15
A	CN 1166209 A (PHILIPS ELECTRONICS N.V.) 26 November 1997 (1997-11-26) The whole document	1-25
A	CN 1558999 A (KONINKL PHILIPS ELECTRONICS N.V.) 29 December 2004 (2004-12-29) The whole document	1-25
A	CN 1735768 A (SHARP K.K.) 15 February 2006 (2006-02-15) The whole document	1-25

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 September 2018	**26 September 2018**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**GUAN,Jian**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53962635**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2001049008 A (TEIJIN LTD.) 20 February 2001 (2001-02-20) The whole document	1-25

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
KR	20070028827	A	13 March 2007	None			
CN	104316990	A	28 January 2015	CN	104316990	B	29 August 2017
CN	1166209	A	26 November 1997	DE	69632521	D1	24 June 2004
				US	5729311	A	17 March 1998
				CN	1183407	C	05 January 2005
				JP	H10508151	A	04 August 1998
				EP	0787316	A1	06 August 1997
				WO	9708582	A1	06 March 1997
				DE	69632521	T2	12 May 2005
				KR	100388372	B1	28 November 2003
				EP	0787316	B1	19 May 2004
				KR	97707459	A	01 December 1997
CN	1558999	A	29 December 2004	KR	100905100	B1	30 June 2009
				AT	448442	T	15 November 2009
				DE	60234365	D1	24 December 2009
				JP	4437920	B2	24 March 2010
				CN	100564998	C	02 December 2009
				EP	1432948	A1	30 June 2004
				US	7265800	B2	04 September 2007
				JP	2005504412	A	10 February 2005
				KR	20040047848	A	05 June 2004
				EP	1432948	B1	11 November 2009
				WO	03027568	A1	03 April 2003
				US	2003058383	A1	27 March 2003
CN	1735768	A	15 February 2006	CN	100591989	C	24 February 2010
				US	7425089	B2	16 September 2008
				WO	2004042273	A1	21 May 2004
				US	2006056196	A1	16 March 2006
				JP	4208878	B2	14 January 2009
				KR	20050072788	A	12 July 2005
				AU	2003275721	A1	07 June 2004
				KR	100846947	B1	17 July 2008
JP	2001049008	A	20 February 2001	None			