

SPECIFICATION

TIMEPIECE

5 TECHNICAL FIELD

The invention relates to a timepiece (watch and clock) for displaying at least time information such as hour, minute, and second, or calendar information such as date, days of the week, month, and year by use of a liquid crystal display panel.

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BACKGROUND TECHNOLOGY

A timepiece for indicating digital display of time information such as hour, minute, and second, and calendar information such as date, days of the week, month, and year, by use of a liquid crystal display panel, has
15 been in widespread use for wrist watches and clocks, provided with a crystal oscillation circuit.

There has also been in use a combination timepiece wherein an analog display indicating time information by the hands of the watch is used in combination with digital display indicating time information and
20 calendar information in numbers and letters.

Further, there has been proposed an analog watch for selectively displaying markers in various patterns, or for displaying simulated hands for an hour hand, minute hand, and a second hand, by making up the dial thereof based on a liquid crystal display panel.

25 In a conventional liquid crystal display panel for displaying time information and calendar information, as in a watch or clock, a liquid

crystal cell filled with liquid crystals is sandwiched between two transparent substrates each having an electrode on an inner facing surface thereof, and an upper polarizing film and a lower polarizing film are disposed, respectively, on the external opposite surface of each transparent substrate. If an electric field is applied to the liquid crystals by applying a voltage to the pair of electrodes on the transparent substrates holding the liquid crystal cell therebetween, the optical property of the liquid crystals is changed, thereby locally controlling transmission and absorption of light falling on the liquid crystal display panel such that a predetermined display is effected.

Each of the upper polarizing film and the lower polarizing film is a polarizing film absorbing the light linearly polarized in the direction orthogonal to the transmission axis thereof.

In the case of a watch using the conventional liquid crystal display panel described above, time information and calendar information are displayed in dark against a white background in the normally white mode that is common.

However, by simply displaying time information and calendar information in dark against the white background as described in the foregoing, neither variation in design nor fun of use can be offered, leading to rapid decline in product popularity among consumers. Probably as a result, consumption of digital watches has recently been on the decline, and neither combination timepieces nor analog watches with liquid crystal display panels have received market acceptance.

Therefore, by use of the monochromatic color liquid crystal display panel in which a background portion of a display and a display portion are

colored, attempts have been made to improve digital watches and so forth capable of providing variation in design and colored display.

In reference to the monochromatic color liquid crystal display panel like this, several types have been proposed in the past.

5 A first type is a monochromatic color liquid crystal display panel made up by providing a color polarizing film on the outer side of a liquid crystal cell thereof. This type has generally been in widespread use due to its simple constitution.

10 A second type is a monochromatic color liquid crystal display panel wherein a dichroic pigment is mixed in nematic liquid crystals sealed in a liquid crystal cell thereof, and the dichroic pigment is caused to move together with the nematic liquid crystals by the action of nematic liquid crystal molecules, and this type is called a guest-host LCD.

15 However, with any of these conventional-type monochromatic color liquid crystal display panels, colored characters and colored graphics produced by a dye or the dichroic pigment are displayed against a background in white, or white characters and white graphics are displayed against a background color produced by the dye or the dichroic pigment. Consequently, contrast declines. Furthermore, since the numbers of
20 available dyes and dichroic pigments are limited, there is also a problem that the number of colors in which such liquid crystal display panels as described above can indicate display.

25 Accordingly, there has been proposed a third type of monochromatic color liquid crystal display panel comprising a polarizing film, a 90° twisted nematic (TN) liquid crystal cell, a retardation film for circularly polarizing film (a quarter-wavelength plate, $1/4\lambda$ plate), a

cholestric liquid crystal polymer sheet, and a light absorbing member.

Referring to Fig. 15, the display principle of the monochromatic color liquid crystal display panel of this type is described hereinafter.

Shown in Fig. 15, the monochromatic color liquid crystal display panel is made up of a polarizing film 8, a twist-aligned 90° TN liquid crystal cell which is not shown, a retardation film 9 for circularly polarized light, a cholestric liquid crystal polymer sheet 10, and a light absorbing member 11.

In the left-hand part of the figure, an OFF-state indicating colored display is shown, wherein the polarizing film 8 and the retardation film 9 for circularly polarized light are disposed such that the transmission axis 8b of the polarizing film 8 is inclined 45° clockwise toward the phase delay axis 9a of the retardation film 9 for circularly polarized light. As a result, linearly polarized light transmitted through the polarizing film 8 is turned into right-handed circularly polarized light after passing through the retardation film 9 for circularly polarized light.

In the cholestric liquid crystal polymer sheet 10, a twist direction 10a is right handed, and a twist pitch is close to a natural light wavelength, and accordingly, upon the right-handed circularly polarized light falling on the cholestric liquid crystal polymer sheet 10, light components in a scattering band width $\Delta\lambda$ around a scattering center wavelength λ_c are reflected due to the selective scattering phenomenon. Transmitted light composed of light components in wavelength regions, other than the scattering band width $\Delta\lambda$, is absorbed by the light absorbing member 11 made of a black paper or a black plastic sheet, whereupon a bright reflected color can be obtained.

If one defines n as the refractive index of a cholestric liquid crystal polymer, and P as the twist pitch of the cholestric liquid crystal polymer, the scattering center wavelength λ_c is given by the following formula:

$$\lambda_c = n \times P$$

5 Hence, the cholestric liquid crystal polymer sheet 10 having various reflected colors can be obtained by adjusting the twist pitch P of the cholestric liquid crystal polymer.

Meanwhile, in the right-hand part of Fig. 15, an ON-state indicating black display is shown, wherein the polarizing film 8 and the
10 retardation film 9 for circularly polarized light are disposed such that the transmission axis 8a of the polarizing film 8 is inclined 45° counterclockwise toward the phase delay axis 9a of the retardation film 9 for circularly polarized light by rotating the transmission axis 8a of the polarizing film 8 through 90° , so that linearly polarized light after passing
15 through the retardation film 9 for circularly polarized light is turned into left-handed circularly polarized light.

Accordingly, even if the left-handed circularly polarized light falls on the cholestric liquid crystal polymer sheet 10 having the twist direction 10a which is right handed, the selective scattering phenomenon does not
20 occur. As a result, all components of the left-handed circularly polarized light are transmitted through the cholestric liquid crystal polymer sheet 10, and absorbed by the light absorbing member 11, thus indicating black display.

If a 90° TN liquid crystal cell is installed between the polarizing
25 film 8 and the retardation film 9 for circularly polarized light instead of rotating the transmission axis 8a of the polarizing film 8, this makes it

possible to change by about 90° the polarization direction of linearly polarized light falling on the retardation film 9 for circularly polarized light depending on whether or not a voltage is applied to the TN liquid crystal cell, so that a background part in the OFF-state and display parts in
5 the ON-state can be controlled optionally. Consequently, a monochromatic color liquid crystal display panel having such a constitution is able to display black characters against a colored background in a bright metallic tone.

Such related art as described above has been disclosed in Japanese
10 Patent Laid-Open No. S52 - 5550 and Japanese Patent Laid-Open No. H6-230362. There has also been disclosed in, for example, Japanese Patent Laid-Open No. H6-230371, a similar liquid crystal display panel comprising a first polarizing film, a TN liquid crystal cell, a second polarizing film, a retardation film for circularly polarized light, a cholestric
15 liquid crystal polymer sheet, and a light absorbing member, wherein the second polarizing film is installed between the TN liquid crystal cell and the retardation film for circularly polarized light.

However, with these monochromatic color liquid crystal display panels using the cholestric liquid crystal polymer sheet, illumination by
20 backlighting is not feasible because of use of an opaque light absorbing member made of a black paper, a black plastic sheet, or so forth, thus causing a problem that display can not be shown in a dark environment such as at night, and so forth.

Accordingly, use of the liquid crystal display panel like this for
25 displaying time display and calendar display causes a disadvantage in that time and other information can not been recognized in a dark environment

such as at night, and so forth.

DISCLOSURE OF THE INVENTION

The invention has been developed to solve the problem described
5 above, and it is therefore an object of the invention to provide a timepiece
capable of rendering timepiece information of time, calendar and so forth
visible even in a dark environment such as at night, and so forth, so that
timepiece information by characters and graphics in a bright color can be
displayed against a black background, or conversely, timepiece
10 information by characters and graphics in a black color can be displayed in
a colored background, using a backlight.

To this end, a timepieces according to the invention provided with
a liquid crystal display panel, capable of displaying at least time
information or calendar information, and the liquid crystal display panel
15 comprises a TN liquid crystal cell with about 90° twisted nematic liquid
crystals sealed in-between a pair of transparent substrates having
respective electrodes, a first polarizing film disposed on the visible side of
the TN liquid crystal cell, and a second polarizing film, a retardation film
for circularly polarized light, a cholestric liquid crystal polymer sheet, a
20 translucent light absorbing member, and a backlight disposed successively
on a side of the TN liquid crystal cell, opposite from the visible side
thereof.

In place of the TN liquid crystal cell of said liquid crystal display
panel, an STN liquid crystal cell with 180° to 270° twisted nematic liquid
25 crystals sandwiched between a pair of transparent substrates having
respective electrodes may be installed, a retardation film may be disposed

on the visible side of the STN liquid crystal cell, and a first polarizing film may be disposed on the outer side of the retardation film. Further, in place of the retardation film, a twist retardation film may be disposed.

Furthermore, instead of installing the translucent light absorbing member, a light emitting face of the backlight may be caused to have a function of scattering polarized light, and the backlight may be disposed opposite to the cholestric liquid crystal polymer sheet.

Otherwise, a liquid crystal display panel of respective timepieces according to the invention may comprise the TN liquid crystal cell, a first polarizing film disposed on the visible side of the TN liquid crystal cell, and a first retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a second retardation film for circularly polarized light, a second polarizing film, a translucent light absorbing member, and a backlight disposed successively on a side of the TN liquid crystal cell, opposite from the visible side thereof.

In this case as well, instead of installing the translucent light absorbing member, a light emitting face of the backlight may be caused to have a function of scattering polarized light, and the backlight may be disposed opposite to the cholestric liquid crystal polymer sheet.

With any of the timepieces described above, in place of the TN liquid crystal cell of said liquid crystal display panel, the STN liquid crystal cell may be installed, a retardation film may be disposed on the visible side of the STN liquid crystal cell, and a first polarizing film may be disposed on the outer side of the retardation film. Further, in place of the retardation film, a twisted retardation film may be disposed.

Further, a luminescence center wavelength of the backlight is

preferably deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

More preferably, the backlight has not less than two luminescence center wavelengths, and at least one of the luminescence center
5 wavelengths is deviated by not less than 50 nm from a selective scattering center wavelength of the cholestric liquid crystal polymer sheet.

Furthermore, a reflection-type polarizing film (a polarizing film reflecting the light linearly polarized in the direction orthogonal to the transmission axis thereof) may be disposed as the second polarizing film.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic sectional view showing a constitution of a liquid crystal display panel used in a timepiece according to a first embodiment of the invention;

15 Fig. 2 is a schematic illustration showing relative positions of respective components of the liquid crystal display panel according to the first embodiment of the invention;

Fig. 3 is a schematic sectional view showing a constitution of a liquid crystal display panel used in a timepiece according to a second
20 embodiment of the invention;

Fig. 4 is a schematic illustration showing relative positions of respective components of the liquid crystal display panel according to the second embodiment of the invention;

Fig. 5 is a schematic sectional view showing a constitution of a
25 liquid crystal display panel used in a timepiece according to a third embodiment of the invention;

Fig. 6 is a schematic illustration showing relative positions of respective components of the liquid crystal display panel according to the third embodiment of the invention;

Fig. 7 is a schematic sectional view showing a constitution of a liquid crystal display panel used in a timepiece according to a fourth embodiment of the invention;

Fig. 8 is a schematic sectional view showing a constitution of a liquid crystal display panel used in a timepiece according to a fifth embodiment of the invention;

Fig. 9 is a schematic sectional view showing a constitution of a liquid crystal display panel used in a timepiece according to a sixth embodiment of the invention;

Fig. 10 is a schematic illustration showing relative positions of respective components of the liquid crystal display panel according to the sixth embodiment of the invention;

Fig. 11 is a diagrammatic view showing transmittance and emission spectrum of a backlight, of the liquid crystal display panel used in a timepiece according the first to sixth embodiments of the invention;

Fig. 12 is a diagrammatic view showing transmittance and emission spectrum of a backlight, of a liquid crystal display panel used in a timepiece according to a seventh embodiment of the invention;

Fig. 13 is a perspective view of a digital indicating type watch, showing the external view thereof;

Fig. 14 is a sectional view of the same watch, showing the internal construction thereof; and

Fig. 15 is a schematic perspective view illustrating the display

principle of a conventional monochromatic color liquid crystal display panel using a cholestric liquid crystal polymer sheet.

5 BEST MODE FOR CARRYING OUT THE INVENTION

A construction, operation and effect of a timepiece according to a preferred embodiment of the invention is now described in detail as follows with attached drawings. At first, constructions, operations and effects of the respective embodiments of the liquid crystal display panel for
10 displaying time information and calendar information are described.

First Embodiment of Liquid Crystal Display Panel: Fig. 1, Fig. 2 and Fig.
11

A construction of a liquid crystal display panel used in a timepiece
15 according to a first embodiment of the invention is now described with reference to Figs. 1 and 2.

Fig. 1 is a schematic sectional view of the liquid crystal display panel, and Fig. 2 is a view showing relative positions of respective elements thereof.

20 The liquid crystal display panel according to the first embodiment comprises, shown in Fig. 1, a first transparent substrate 1 made of a glass plate having a thickness of 0.7 mm on which first transparent electrodes 3 made of indium tin oxide (hereinafter referred to as "ITO") are provided, a second transparent substrate 2 made of a glass plate having a thickness of
25 0.7 mm on which a second transparent electrodes 4 made of ITO are provided, and a sealant 5 for laminating the pair of substrates, wherein 90°

twist-aligned nematic liquid crystals 6 are sealed in between the pair of transparent first and second substrates 1 and 2, thereby forming a TN liquid crystal cell 7.

A first polarizing film 17 is disposed on a visible side (a side where an observer sees, the upper side in Fig. 1) on the second substrate 2 of the TN liquid crystal cell 7, and a second polarizing film 18, a retardation film 9 for circularly polarized light, a cholesteric liquid crystal polymer sheet 10, a translucent light absorbing member 15 and a backlight 16 are disposed successively on a side opposite from the visible side, thereby constituting a liquid crystal display panel 40.

The first substrate 1, the second polarizing film 18, the retardation film 9 for circularly polarized light and the cholesteric liquid crystal polymer sheet 10 are bonded to one another by an acrylic adhesive (not shown). Further, the first polarizing film 17 and the second substrate 2 are also bonded to each other by an acrylic adhesive (not shown).

Suppose the difference of birefringence Δn of the nematic liquid crystals 6 used in the TN liquid crystal cell is 0.15, and a cell gap d between the first substrate 1 and the second substrate 2 is 8000 nm. Accordingly, the Δnd value of the TN liquid crystal cell 7 which is a product of the difference of birefringence Δn of the nematic liquid crystals 6 and the cell gap d is 1200 nm. As the Δnd value decreases, the optical rotatory power lowers, and hence it is preferable that the Δnd value is not less than 500 nm.

An alignment layer (not shown) is formed, respectively, on an inner surface of the first transparent electrodes 3, and an inner surface of the second transparent electrodes 4. Accordingly, as shown in Fig. 2, an

alignment direction 7a of lower liquid crystal molecules points 45° downward to the right when rubbing treatment in the direction of -45° on the basis of the horizontal axis H is applied to the first substrate 1, while an alignment direction 7b of upper liquid crystal molecules points 45° upward to the right when rubbing treatment in the direction of $+45^\circ$ on the basis of the horizontal axis H is applied to the second substrate 2, thereby forming the left-handed twist-aligned 90° TN liquid crystal cell 7.

The first polarizing film 17 is disposed such that the transmission axis 17a thereof points 45° upward to the right in the same manner as the alignment direction 7b of upper liquid crystal molecules of the TN liquid crystal cell 7, while second polarizing film 18 is disposed such that the transmission axis 18a thereof points 45° downward to the right in the same manner as the alignment direction 7a of lower liquid crystal molecules of the TN liquid crystal cell 7.

The retardation film 9 for circularly polarized light is prepared by spreading a polycarbonate resin to a thickness of about $60\text{ }\mu\text{m}$, and the phase difference value is 140 nm , and a phase delay axis 9a thereof is oriented horizontally. The cholesteric liquid crystal polymer sheet 10 is disposed underneath the retardation film 9 for circularly polarized light, while a film prepared by dyeing polyethylene terephthalate (PET) having a thickness of $20\text{ }\mu\text{m}$ with a black dye so that the transmittance becomes 50 % is installed as the translucent light absorbing member 15.

The cholesteric liquid crystal polymer sheet 10 is a sheet-like triacetylcellulose (TAC) film formed by applying alignment treatment to a base film (not shown) of $80\text{ }\mu\text{m}$ thickness, applying cholesteric liquid crystal polymer thereon, adjusting at a high temperature showing a liquid

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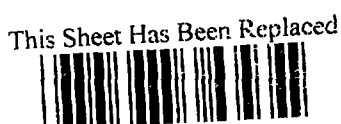
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crystal phase so as to set the twist pitch to 380 nm and rotate clockwise with planer alignment in parallel with the base film before cooling to not higher than the glass-transition temperature for solidification. Accordingly, the twist central axis is perpendicular to the base frame.

5 An electroluminescence plate (hereinafter referred to as "EL plate") having a thickness of 200 μ m, and showing emitted light in a bluish green color used for the backlight 16. Even if the cholestric liquid crystal polymer sheet 10, the translucent light absorbing member 15 and the backlight 16 are disposed at whatever rotational angle within respective
10 planes in parallel with each other, displaying characteristic will not be affected, and therefore, in Fig. 2, illustration of disposition directions is omitted.

Next, operation of displaying color of the liquid crystal display panel according to the first embodiment of the invention is described
15 hereinafter.

In the liquid crystal display panel 40, the linearly polarized light which falls on the liquid crystal display panel from the visible side and passed the first polarizing film 17 and is polarized in the direction of the transmission axis 17a in a state where no voltage is applied to the first
20 transparent electrodes 3 and the second transparent electrodes 4 of the TN liquid crystal cell 7 falls on the TN liquid crystal cell 7 in the alignment direction 7b of upper liquid crystal molecules, and is rotated by 90° by the TN liquid crystal cell 7 and outgoes after it is turned into the linearly polarized light in the alignment direction 7a of lower liquid crystal
25 molecules. Since the second polarizing film 18 is disposed such that the alignment direction 7a of lower liquid crystal molecules and the



transmission axis 18a of the second polarizing film 18 are in parallel with each other, the linearly polarized light falling on the second polarizing film 18 passes the second polarizing film 18 as it is.

Accordingly, the polarized light falls on the retardation film 9 for
 5 circularly polarized light while it is rotated clockwise by 45° from the phase delay axis 9a. Accordingly, it is turned into right-handed circularly polarized light in the same manner as the OFF-state shown in Fig. 13, which is the same as the twist direction 10a of the cholesteric liquid crystal polymer sheet 10. Accordingly, when the right-handed
 10 circularly polarized light falls on the cholesteric liquid crystal polymer sheet 10, light components in a scattering bandwidth $\Delta\lambda$ around a scattering center wavelength λ_c are reflected due to the selective scattering phenomenon, and light components transmitted through wavelength regions, other than the scattering bandwidth $\Delta\lambda$, is absorbed by the
 15 translucent light absorbing film 15, whereupon a reflected color in a bright metallic tone can be obtained.

If one defines n as the refractive index of a cholesteric liquid crystal polymer, and P as the twist pitch of the cholesteric liquid crystal polymer, the scattering center wavelength λ_c is given by the following formula: $\lambda_c =$
 20 $n \times P$

Since right-twisted cholesteric liquid crystal polymer having n as 1.65, P as 370 nm is employed in this embodiment, the scattering center wavelength λ_c becomes 610 nm, thereby obtaining a golden reflected color in a metallic tone.

25 Now, when a voltage is applied between the first transparent electrodes 3 of the TN liquid crystal cell 7 and the second transparent

electrodes 4 of the same, molecules of the nematic liquid crystals 6 are caused to rise up, the light rotation property is extinguished. Then, linearly polarized light polarized in the alignment direction 7b of upper liquid crystal molecules falls on the TN liquid crystal cell 7, it passed as it is.

5 Accordingly, the linearly polarized light falling on the second polarizing film 18 after passing the TN liquid crystal cell 7 is polarized in the direction intersecting the transmission axis 18a thereof at right angles, so that all components of light falling on the second polarizing film 18 are absorbed thereby, indicating black display.

10 In Fig. 11, the transmittance of the cholesteric liquid crystal polymer sheet 10 adopted in the first embodiment at the selective scattering state (no voltage is applied between the first transparent electrodes 3 and the second transparent electrodes 4) is shown by a solid curve 53, whereas the transmittance of the same when indicating black display (a voltage is applied between the first transparent electrodes 3 and
15 the second transparent electrodes 4) is shown by a solid curve 52. At the selective scattering state, it is found from the curve 53 that right-handed circularly polarized light in the range from 560 nm to 670 nm around the scattering center wavelength of $\lambda_c = 610$ nm is reflected, but light out of
20 the scattering bandwidth transmits as it is. Accordingly, if the transmitted light is restrained from returning to the visible side by absorbing that by the translucent light absorbing film 15, thereby a bright golden color can be performed by the reflected light due to the selective scattering phenomenon. When indicating a black display, as shown by the curve 52,
25 light transmitted through the first polarizing film 17 are almost absorbed by the second polarizing film 18, thereby indicating a black display.

Next, operation of the backlight 16 in Fig. 1 is described hereinafter. A dotted line curve 54 in Fig. 11 is a spectrum showing relative light emitting density of the EL plate showing emitted light in a bluish green color used for the backlight 16 of the liquid crystal display panel 40, which indicates emitted light in a bluish green color in a luminescence center wavelength $\lambda_L = 510$ nm.

With the liquid crystal display panel 40, light does not transmit in an ON-state indicating a black display when a voltage is applied as shown in the curve 52, so that it remains dark even if the backlight 16 is lit up. However, golden reflected color is indicated in a state where no voltage is applied, and light having not more than 560 nm can transmit as shown in the curve 53.

Light emitted by the backlight 16 having luminescence center wavelength $\lambda_L = 510$ nm that is smaller than the selective scattering center wavelength $\lambda_c = 610$ nm of the cholesteric liquid crystal polymer sheet 10 by 100 nm substantially completely transmits through the cholesteric liquid crystal polymer sheet 10, thereby illuminating brightly, so that an excellent visibility can be obtained even at night.

If the translucent light absorbing member 15 and the backlight 16 are provided without installing the second polarizing film 18 in Fig. 1, the liquid crystal display panel capable of indicating monochromatic color in a metallic tone can be obtained. In this case, the operation of displaying color is the same as that in the first embodiment in the case of OFF-state indicating a golden display, but in the case of ON-state indicating a black display light outgoing from the retardation film 9 for circularly polarized light is turned into left-handed state of circularly polarized light, and it

transmits through the right-twisted cholesteric liquid crystal polymer sheet 10 so that it is absorbed by the translucent light absorbing member 15 to indicate a black color.

If the backlight 16 is lit up in this state, light transmitted through
5 the translucent light absorbing member 15 illuminates bright because the transmittance in the black display part in the ON-state is high, while light illuminates dark because the transmittance in golden part in the OFF-state is low, thereby indicating an inversion display in monochrome relation contrary to the reflected state using an external light. In this case, the
10 difference in an amount of transmittance of a backlight between ON-state and OFF-state is small, thereby lowering a contrast.

Further, if the backlight 16 of the liquid crystal display panel 40 is lit up in a dim environment, the golden portion in the OFF display reflects the external light and illuminates, while the black portion in the ON state
15 transmits the backlight therethrough and illuminates, so that the contrast between the characters and a background scarcely presents, thereby markedly lowering the visibility.

However, with the liquid crystal display panel 40, it is the same display in a monochrome relation viewing in a reflected state using an
20 external light and viewing in a transmittance state using a backlight, thereby improving the visibility when lighting up the backlight in a dim environment.

With the construction comprising the first polarizing film 17, the TN liquid crystal cell 7, the second polarizing film 18, the retardation film
25 9 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the translucent light absorbing member 15 and the backlight 16, a

display of bright reflected color with high contrast is obtained, and also it becomes a correct conversion even by illumination by backlighting, thereby obtaining the liquid crystal display panel capable of indicating a monochromatic color display in a metallic tone and of enhancing visibility
5 even at night.

Modification of First Embodiment of Liquid Crystal Display Panel

In the foregoing first embodiment, the selective scattering center wavelength λ_c of the cholesteric liquid crystal polymer sheet 10 and the
10 luminescence center wavelength λ_L of the backlight are deviated by 100 nm, but if they are deviated by 50 nm, the brightness of illumination of the backlight is somewhat lowered, which however does not cause any problem.

Although the cholesteric liquid crystal polymer having a pitch $P =$
15 370 nm is used as the cholesteric liquid crystal polymer sheet 10 to form the liquid crystal display panel indicating golden and black displays in the first embodiment, it is possible to change a color tone in a reflecting state by optionally changing a pitch P of the cholesteric liquid crystal polymer. For example, it is possible to obtain a liquid crystal display panel
20 indicating blue and black displays supposing that $P = 300$ nm ($\lambda_c = 490$ nm). In this case, an EL plate having a luminescence center wavelength λ_L of 560 nm, and showing emitted light in an orange color is employed.

Although the an EL plate showing emitted light in a bluish green color is employed as the backlight 16 in the first embodiment, even if a
25 side light consisting of a light emitting diode (LED) showing emitted light in a green color which is attached to a plastic light guide plate is employed,

the bright illumination which is the same as the foregoing can be obtained.

Further, although the first embodiment indicates a colored display in a state where no voltage is applied and a black display in a state where a voltage is applied, if the transmission axis 17a of the first polarizing film 17 is rotated by 90° to be oriented in the same direction as the alignment direction 7a of lower liquid crystal molecule, it is possible to indicate a black display in a state where no voltage is applied and indicate a colored display in a state where a voltage is applied.

Alternatively, even if the transmission axis 18a of the second polarizing film 18 is rotated by 90° , it is possible to indicate a black display in a state where no voltage is applied and a colored display in a state where a voltage is applied.

Although the retardation film 9 for circularly polarized light is disposed between the second polarizing film 18 and the cholesteric liquid crystal polymer sheet 10 in the first embodiment, the retardation film 9 for circularly polarized light can be removed although the reflecting efficiency of the cholesteric liquid crystal polymer sheet 10 is somewhat lowered, and a metallic color becomes somewhat dark.

20 Second Embodiment of Liquid Crystal Display Panel: Fig. 3 and Fig.4

A liquid crystal display panel used in a timepiece according to a second embodiment of the invention is now described with reference to Figs. 3 and 4.

The liquid crystal display panel of this embodiment is the same as the first embodiment in construction except that 225° twist-aligned STN liquid crystal cell as the liquid crystal cell, and that a retardation film are

used.

Figs. 3 and 4 are views for explaining the construction of the liquid crystal display panel of the second embodiment which are the same as Figs. 1 and 2, wherein the components which correspond to those in Figs. 1 and 2 are denoted by the same reference numerals and the explanation thereof is omitted.

The liquid crystal display panel 40 according to the second embodiment comprises a first transparent substrate 1 made of a glass plate having a thickness of 0.7 mm on which a first transparent electrodes 3 made of ITO are provided, a second transparent substrate 2 made of a glass plate having a thickness of 0.7 mm on which second transparent electrodes 4 made of ITO are provided, and a sealant 5 for laminating the pair of substrates 1 and 2 wherein 225° twist-aligned nematic liquid crystals 6 are sealed in between the pair of transparent first and second substrates 1 and 2, thereby forming a STN liquid crystal cell 12.

A retardation film 13 and a first polarizing film 17 are disposed successively outside the second substrate 2 at a visible side of the STN liquid crystal cell 12, and a second polarizing film 18, a retardation film 9 for circularly polarized light, a cholesteric liquid crystal polymer sheet 10, a translucent light absorbing member 15 and a backlight 16 are disposed successively on a side opposite from the visible side, thereby constituting a liquid crystal display panel 40.

The first polarizing film 17, the second polarizing film 18, the cholesteric liquid crystal polymer sheet 10, the retardation film 9 for circularly polarized light, the translucent light absorbing member 15 and the backlight 16 are the same as those employed in the first embodiment.

A first substrate 1, the second polarizing film 18, the retardation film 9 for circularly polarized light and the cholesteric liquid crystal polymer sheet 10 are respectively bonded using an acrylic adhesive (not shown). Further, the first polarizing film 17, the retardation film 13 and a
 5 second substrate 2 are also bonded using an acrylic adhesive (not shown).

Suppose the difference of birefringence Δn of the nematic liquid crystals 6 to be used is 0.15 and a cell gap d between the first substrate 1 and the second substrate 2 is 5400 nm. Accordingly, the Δnd value of the liquid crystal cell which is a product of the difference of the birefringence
 10 Δn of the nematic liquid crystals 6 and the cell gap d is 810 nm. Further, a twist pitch of the nematic liquid crystals 6 is adjusted to 1100 nm.

An alignment layer (not shown) is formed, respectively, on an inner surface of the first transparent electrodes 3, and an inner surface of the second transparent electrodes 4, and shown in Fig. 4, an alignment
 15 direction 12a of lower liquid crystal molecules points 22.5° upward to the right when rubbing treatment in the direction of $+22.5^\circ$ on the basis of the horizontal axis H is applied to the first substrate 1, while an alignment direction 12b of upper liquid crystal molecules points 22.5° downward to the right when rubbing treatment in the direction of -22.5° on the basis of
 20 the horizontal axis H is applied to the second substrate 2, thereby forming the left-handed 225° twist-aligned STN liquid crystal cell 12.

The first polarizing film 17 is disposed such that the transmission axis 17a thereof is oriented in the direction of -70° on the basis of the horizontal axis H, and the retardation film 13 made of polycarbonate resin
 25 and having the thickness of $50 \mu\text{m}$ and phase difference value of 550 nm is disposed between the STN liquid crystal cell 12 and the first polarizing

film 17 such that a phase delay axis 13a thereof is oriented in the direction of 60° on the basis of the horizontal axis H.

The second polarizing film 18 is disposed underneath the STN liquid crystal cell 12 such that the transmission axis 18a thereof is oriented
5 in the direction of -15° on the basis of the horizontal axis H, and the retardation film 9 for circularity polarized light is disposed such that the phase delay axis 9a thereof is oriented in the direction of 30° on the basis of the horizontal axis H so that the phase delay axis 9a forms an angle of 45° with the transmission axis 18a of the second polarizing film 18.

10 To improve viewing angles characteristic, the retardation film 13 uses a biaxial retardation film satisfying the relation of $n_x > n_z > n_y$ supposing that n_x is the refractive index in the phase delay direction, n_y is refractive index in the direction of Y axis and n_z is the refractive index in the thickness direction. It is needless to say that the use of an uniaxial
15 retardation film causes no problem.

Even if the cholestric liquid crystal polymer sheet 10, the translucent light absorbing member 15 and the backlight 16 are disposed at whatever rotational angle within respective planes in parallel with each other, displaying characteristic will not be affected, and therefore, in Fig. 4,
20 illustration of disposition directions is omitted.

Next, operation of displaying color of the liquid crystal display panel 40 according to the second embodiment of the invention is described hereinafter. With the liquid crystal display panel 40, in a state where no voltage is applied to the STN liquid crystal cell 12, linearly polarized light
25 falling thereon from the visible side thereof (upper side in Fig. 3) through the first polarizing film 17 and polarized in the direction of the

transmission axis 17a of the first polarizing film 17, is turned into a state of elliptic polarized light after transmitted through the STN liquid crystal cell 12 in the case where the retardation film 13 is not installed, so that circularly polarized light can not be produced even after passing through the retardation film 9 for circularly polarized light, thereby indicating insufficient display.

However, since the retardation film 13 is installed between the first polarizing film 17 and the STN liquid crystal cell 12, the linearly polarized light falling on the retardation film 13 through the first polarizing film 17 is turned into a state of elliptic polarized light. The elliptic polarized light is corrected during passage through the STN liquid crystal cell 12, is turned into the substantially linearly polarized light, then it is turned into the linearly polarized light which is at about a 55° counterclockwise angle with respect to the transmission axis 17a of the first polarizing film 17, and outgoes.

Since the second polarizing film 18 is disposed such that the transmission axis 18a of the second polarizing film 18 is oriented in the direction at -15° on the basis of the horizontal axis H, the linearly polarized light falling thereon from the first polarizing film 17 is transmitted through the second polarizing film 18 as it is. Since the retardation film 9 for circularly polarized light is disposed such that the phase delay axis 9a thereof is oriented in the direction of $+45^\circ$ with respect to the transmission axis 18a of the second polarizing film, and linearly polarized light at a 45° clockwise angle with respect to the phase delay axis 9a of the retardation film 9 for circularly polarized light falls thereon, it is turned into right-handed circularly polarized light.

As with the case of the first embodiment, the cholestric liquid crystal polymer sheet 10 which is right-handed is employed, consequently, light component in a scattering bandwidth $\Delta\lambda$ around a scattering center wavelength birefringence λ_c are reflected due to the selective scattering phenomenon, and light components transmitted through wavelength regions, other than the scattering bandwidth $\Delta\lambda$, is absorbed by the translucent light absorbing member 15, whereupon a golden reflected color in a bright metallic tone can be obtained.

Now, when a voltage is applied between the first transparent electrodes 3 of the STN liquid crystal cell 12 and the second transparent electrodes 4 of the same, molecules of the nematic liquid crystals 6 are caused to rise up, and birefringency of the STN liquid crystal cell 12 undergoes a change, so that polarization of linearly polarized light outgoing is rotated by about 90° to be in the direction at $+75^\circ$ on the basis of the horizontal axis H shown in Fig. 4. Accordingly, polarizing direction of the linearly polarized light transmitted through the STN liquid crystal cell 12 is deviated by 90° from the transmission axis 18a of the second polarizing film 18, so that all components of light falling on the second polarizing film 18 are absorbed thereby, indicating black display. Accordingly, it is possible to indicate a black display with high contrast by the use of the second polarizing film 18.

As with the case of the first embodiment, an EL plate having a luminescent center wavelength $\lambda_L = 510$ nm, and showing emitted light in a bluish green color is used for the backlight 16. In a black display state where a voltage is applied, light is not transmitted through the liquid crystal display panel, however, in a state where no voltage is applied and

display in a golden reflected color is indicated, light components having wavelengths not more than 560 nm can be transmitted therethrough.

Accordingly, light emitted by the backlight 16 having luminescence center wavelength λ_L that is smaller than the selected
 5 scattering center wavelength $\lambda_c = 610$ nm of the cholesteric liquid crystal polymer sheet 10 by 100 nm substantially completely transmits, thereby illuminating brightly. Further, so it indicates the same display in brightness relation as the display by an external light without backlighting, enhance visibility can be performed even at night.

10 With the construction comprising the first polarizing film 17, the retardation film 13, the STN liquid crystal cell 12, the second polarizing film 18, the retardation film 9 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the translucent light absorbing member 15, and the backlight 16, a display of bright reflected color with high contrast
 15 is obtained, and it also becomes a correct conversion even by illumination by backlighting, thereby obtaining the liquid crystal display panel capable of indicating a monochromatic color display in a metallic tone and of enhancing visibility even at night.

20 Modification of Second Embodiment of Liquid Crystal Display Panel

Although the 225° twist-aligned STN liquid crystal cell was employed as the STN liquid crystal cell 12 in the second embodiment, the liquid crystal display panel which is the same as that in the second
 25 embodiment can be obtained even if a 180° to 270° twist-aligned STN liquid crystal cell is employed.

Although one piece of retardation film 13 is employed for returning

the state of elliptical polarized light of the STN liquid crystal cell 12 to the linearly polarized light in the second embodiment, if plural pieces of retardation films are employed, the state of elliptical polarized light can be returned to a more complete linearly polarized light, thereby indicating a more excellent black display and a colored display. The plural pieces of retardation films may be installed on one side of the STN liquid crystal cell 12, or they may be divided and installed on both sides of the STN liquid crystal cell 12.

Further, although the retardation film 9 for circularly polarized light is installed between the second polarizing film 18 and the cholesteric liquid crystal polymer sheet 10 in the second embodiment, even if the retardation film 9 for circularly polarized light is omitted, the liquid crystal display panel can be practicably used, though the reflecting efficiency of the cholesteric liquid crystal polymer sheet 10 is somewhat lowered and metallic color becomes somewhat dark.

Third Embodiment of Liquid Crystal Display Panel: Fig. 5 and Fig. 6

A liquid crystal display panel used in a timepiece according to a third embodiment of the invention is now described with reference to Figs. 5 and 6.

Since the liquid crystal display panel of this embodiment is the same as the first embodiment in construction except that 240° twist-aligned STN liquid crystal cell as the liquid crystal cell is used, and that a twisted retardation film is installed.

Figs. 5 and 6 are views for explaining the construction of the liquid crystal display panel of the third embodiment which are the same as Figs. 1

and 2, wherein the components which correspond to those in Figs. 1 and 2 are denoted by the same reference numerals and the explanation thereof is omitted.

5 The liquid crystal display panel 40 according to the third embodiment comprises a first transparent substrate 1 made of a glass plate having a thickness of 0.7 mm on which first transparent electrodes 3 made of ITO are provided, a second transparent substrate 2 made of a glass plate having a thickness of 0.7 mm on which second transparent electrodes 4 made of ITO are provided, and a sealant 5 for laminating the pair of
10 substrates 1 and 2 wherein 240° twist-aligned nematic liquid crystals 6 are sealed in between the pair of transparent first and second substrates 1 and 2, thereby forming a STN liquid crystal cell 14.

A twisted retardation film 19 and a first polarizing film 17 are installed successively outside the second substrate 2 at a visible side of the
15 STN liquid crystal cell 14, and a second polarizing film 18, a retardation film 9 for circularly polarized light, a cholesteric liquid crystal polymer sheet 10, a translucent light absorbing member 15 and a backlight 16 are disposed successively on a side opposite from the visible side, thereby constituting a liquid crystal display panel 40.

20 The first polarizing film 17, the second polarizing film 18, the cholesteric liquid crystal polymer sheet 10, and the retardation film 9 for circularly polarized light, the translucent light absorbing member 15 and the backlight 16 are the same as those employed in the first embodiment.

A first substrate 1, the second polarizing film 18, the retardation
25 film 9 for circularly polarized light and the cholesteric liquid crystal polymer sheet 10 are respectively bonded using an acrylic adhesive (not

shown). Further, the first polarizing film 17, the twisted retardation film 19 and a second substrate 2 are also bonded using an acrylic adhesive (not shown).

Suppose the difference Δn of birefringence of the nematic liquid crystals 6 used in the STN liquid crystal cell 14 is 0.15, and a cell gap d between the first substrate 1 and the second substrate 2 is 5600 nm. Accordingly, the Δnd value of the liquid crystal cell which is a product of the difference of birefringence Δn of the nematic liquid crystals 6 and the cell gap d is 840 nm. Further, the twist pitch of the nematic liquid crystals 6 is adjusted to 1100 nm.

An alignment layer (not shown) is formed, respectively, on an inner surface of the first transparent electrodes 3, and an inner surface of the second transparent electrodes 4, facing each other, and shown in Fig. 6, an alignment direction 14a of lower liquid crystal molecules points 30° upward to the right when rubbing treatment in the direction of +30° on the basis of the horizontal axis H is applied to the first substrate 1, while an alignment direction 14b of upper liquid crystal molecules points 30° downward to the right when rubbing treatment in the direction of -30° on the basis of the horizontal axis H is applied to the second substrate 2, thereby forming the left-handed 240° STN liquid crystal cell 14.

The first polarizing film 17 is disposed such that the transmission axis 17a thereof is oriented in the direction of -45° on the basis of the horizontal axis H and the twisted retardation film 19 having Δnd value of 610 nm and 220° twisted clockwise is disposed between the STN liquid crystal cell 14 and the first polarizing film 17 so as to be oriented in the direction of + 55° on the basis of the horizontal axis H such that a lower

molecule axis 19a thereof intersects the alignment direction 14b of the upper liquid crystal molecules substantially at right angles. Accordingly, an upper molecule axis 19b of the twisted retardation film 19 comes to be oriented in the direction of -85° .

5 The second polarizing film 18 is disposed underneath the first substrate 1 such that the transmission axis 18a thereof is oriented in the direction of $+85^\circ$ on the basis of the horizontal axis H, and the retardation film 9 for circularity polarized light is disposed such that the phase delay axis 9a thereof is oriented in the direction of -50° on the basis of the
10 horizontal axis H so that the phase delay axis 9a forms an angle of 45° with the transmission axis 18a of the second polarizing film 18.

 The twisted retardation film 19 is a triacetylcellulose (TAC) film formed by applying alignment treatment to a base film (not shown) of $80\ \mu\text{m}$ thickness, applying liquid crystal polymer thereon, adjusting thickness
15 and twist pitch thereof at a high temperature showing a liquid crystal phase so as to have a twist angle of 220° before cooling to not higher than the glass-transition temperature for solidification.

 Even if the cholestric liquid crystal polymer sheet 10, the translucent light absorbing member 15, and the backlight 16 are disposed
20 at whatever rotational angle within respective planes in parallel with each other, displaying characteristic will not be affected, and therefore, in Fig. 6, illustration of disposition directions is omitted.

 Next, operation of displaying color with the third embodiment of the liquid crystal display panel according to the invention is described
25 hereinafter.

 With the liquid crystal display panel 40, in a state where no voltage



is applied to the STN liquid crystal cell 14, linearly polarized light falling thereon from the visible side thereof through the first polarizing film 17 is polarized in the direction of the transmission axis 17a of the first polarizing film 17, and is turned into a state of elliptic polarized light after
5 transmitted through the STN liquid crystal cell 14 in the case where the twisted retardation film 19 is not installed, so that circularly polarized light can not produced even after passing through the retardation film 9 for circularly polarized light, thereby indicating insufficient display.

However, since the twisted retardation film 19 is installed between
10 the first polarizing film 17 and the STN liquid crystal cell 14, the linearly polarized light falling on the twist retardation film 19 from the first polarizing film 17 is turned into a state of elliptic polarized light. The elliptic polarized light is corrected during passage through the STN liquid crystal cell 14, is turned into substantially linearly polarized light, and is
15 rotated clockwise by about 50° with respect to the transmission axis 17a of the first polarizing film 17, and outgoes in the direction of polarization at 85° on the basis of the horizontal axis H shown in Fig. 6.

Since the second polarizing film 18 is disposed such that the transmission axis 18a thereof is oriented in the direction at 85° on the basis
20 of the horizontal axis H, the linearly polarized light falling thereon from the first polarizing film 17 is transmitted through the second polarizing film 18 as it is. Since the retardation film 9 for circularly polarized light is disposed such that the phase delay axis 9a thereof is oriented in the direction of $+45^\circ$ with respect to the second polarizing film 18, linearly
25 polarized light at a 45° clockwise angle with respect to phase delay axis of the retardation film 9 for circularly polarized light falls thereon, and is

turned into right-handed circularly polarized light.

As with the case of the first embodiment, the cholestric liquid crystal polymer sheet 10 which is right handed is absorbed, consequently, light components in a scattering bandwidth $\Delta\lambda$ around a scattering center wavelength λ_c are reflected due to the selective scattering phenomenon, and light components transmitted through wavelength regions other than the scattering bandwidth $\Delta\lambda$, is absorbed by the translucent light absorbing member 15, whereupon a golden reflected color in a bright metallic tone can be obtained.

Now, when a voltage is applied between the first transparent electrodes 3 of the STN liquid crystal cell 14 and the second transparent electrodes 4 of the same, molecules of the nematic liquid crystals 6 are caused to rise up, and birefringency of the STN liquid crystal cell 14 undergoes a change, so that polarization direction of linearly polarized light outgoing is rotated by about 90° so as to be in the direction at -5° on the basis of the horizontal axis H. Accordingly, the linearly polarized light transmitted through the STN liquid crystal cell 14 is deviated by 90° from the transmission axis 18a of the second polarizing film 18, so that all components of light falling on the second polarizing film 18 are absorbed thereby, indicating black display.

Further, as a result of using the twisted retardation film 19 in place of the retardation film 13 used in the second embodiment, elliptic polarized light can be fully corrected, and linear polarization characteristics of light transmitted through the STN liquid crystal cell 14 is enhanced, so that display that is brighter and higher contrast than that in the case of the liquid crystal display panel using the retardation film 13 can be obtained.

As with the case of the first embodiment, an EL plate having a luminescent center wavelength $\lambda_L=510$ nm, and showing emitted light in a bluish green color used for the backlight. In a black display state where a voltage is applied, light is not transmitted through the liquid crystal display panel 40, however, in a state where no voltage is applied and display in a golden reflected color is indicated, light components having wavelengths not more than 560 nm can be transmitted therethrough.

Accordingly, light emitted by the backlight 16 having luminescence center wavelength λ_L that is smaller than the selected scattering center wavelength $\lambda_c = 610$ nm of the cholesteric liquid crystal polymer sheet 10 by 100 nm completely transmits, thereby illuminating brightly. Further, it becomes a correct conversion which is the same as the display by an external light when the backlight 16 is not lit up, so that an excellent visibility can be obtained even at night.

With the construction comprising the first polarizing film 17, the twisted retardation film 19, the second polarizing film 18, the retardation film 9 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the translucent light absorbing member 15, and the backlight 16, it is possible to obtain a liquid crystal display panel capable of indicating a bright reflected colored display with high contrast, and the display by illumination of backlight is not inverted, thereby indicating a monochromatic color display in a metallic tone with high visibility even at night.

25 Modification of Third Embodiment of Liquid Crystal Display Panel

Although the 240° twist-aligned STN liquid crystal cell was

employed as the STN liquid crystal cell 14 in the third embodiment, the liquid crystal display panel which is the same as that in the third embodiment can be obtained even if a 180° to 270° twist-aligned STN liquid crystal cell is employed.

5 Further, although the retardation film 9 for circularly polarized light is installed between the second polarizing film 18 and the cholesteric liquid crystal polymer sheet 10 in the third embodiment, even if the retardation film 9 for circularly polarized light is omitted, the liquid crystal display panel is feasible while the reflecting efficiency of the cholesteric
10 liquid crystal polymer sheet 10 is somewhat lowered and metallic color becomes somewhat dark.

Fourth Embodiment of Liquid Crystal Display Panel: Fig. 7

A liquid crystal display panel used in a timepiece according to a
15 fourth embodiment of the invention is now described with reference to Fig. 7.

Since the liquid crystal display panel of this embodiment is the same as the second embodiment in construction except that the translucent light absorbing member 15 is removed, the different point alone is
20 described hereinafter.

A liquid crystal display panel 40 in the fourth embodiment comprises an STN liquid crystal cell 12 with about 225° twisted nematic liquid crystals 6 sealed therein, a retardation film 13 and a first polarizing film 17 disposed successively on a visible side (upper side in Fig. 7), and a
25 second polarizing film 18, a retardation film 9 for circularly polarized light, a cholesteric liquid crystal polymer sheet 10 and a backlight 16 disposed

successively on a side opposite from the visible side (lower side in Fig. 7).

The backlight 16 has a function of scattering polarized light at its light emitting surface, namely, a surface opposite to the cholesteric liquid crystal polymer sheet 10.

5 The operation for displaying colors by the liquid crystal display panel 40 in the fourth embodiment is described next. In a state where no voltage is applied to the STN liquid crystal cell 12 in the liquid crystal display panel 40, a linearly polarized light which falls on the retardation film 13 from the visible side through the first polarizing film 17 is turned
10 in a state of an elliptic polarized light when it passes through the retardation film 13. The elliptic polarized light is corrected during passage through the STN liquid crystal cell 12, is turned into substantially linearly polarized light, and outgoes having a polarizing direction rotated counterclockwise by about 55° with respect to the transmission axis 17a of
15 the first polarizing film 17 shown in Fig. 4.

Since the second polarizing film 18 is disposed so that a transmission axis 18a of the second polarizing film 18 is oriented in the direction of -15° on the basis of a horizontal axis H, the linearly polarized light falling thereon from the first polarizing film 17 passes the second
20 polarizing film 18 as it is.

Since the retardation film 9 for circularly polarized light is disposed at the angle of $+45^\circ$ with respect to the second polarizing film 18, the linearly polarized light passed through the second polarizing film 18 falls so that polarization thereof is at a 45° clockwise angle with respect to
25 a phase delay axis 9a of the retardation film 9 for circularly polarized light, and it is turned into a right-handed circularly polarized light.

Since the fourth embodiment employed the cholesteric liquid crystal polymer sheet 10 which is twisted right in the same manner as the first embodiment, light components in a scattering band width $\Delta\lambda$ is reflected around a scattering center wavelength λ_c are reflected due to the selective scattering phenomenon.

Transmitted light other than light components in the scattering band width $\Delta\lambda$ reaches the backlight 16 because the translucent light absorbing member 15 provided in the second embodiment is not provided in the fourth embodiment. An EL plate showing emitted light in a bluish green is employed as the backlight 16 in the same manner as the second embodiment. The EL plate is prepared by printing granular light emitting bodies on a base film, then covering the base film with a film forming a transparent electrode thereon. Accordingly, the light emitting surface of the EL plate has a function of scattering polarized light so that transmitted light other than the light components in the scattering band width $\Delta\lambda$ and reached the backlight 16 is disturbed its polarized state by the granular light emitting bodies, and hence it is reflected.

In Fig. 7, the reflected light from the backlight 16 transmits through the cholesteric liquid crystal polymer sheet 10, then transmits through the retardation film 9 for circularly polarized light again and reaches the second polarizing film 18. However, a state of polarization is disturbed by the backlight 16, the light can not be returned to a complete linearly polarized light by the retardation film 9 for circularly polarized light, and hence the reflected light from the backlight 16 is almost absorbed by the second polarizing film 18. Accordingly, it is possible to obtain a reflected gold color in a bright metallic tone even if the translucent light

absorbing member 15 is omitted.

When a voltage is applied between first transparent electrodes 3 of the STN liquid crystal cell 12 and second transparent electrodes 4 thereof, the molecules in the nematic liquid crystals 6 are caused to rise up, and
5 birefringency of the STN liquid crystal cell 12 undergoes a change, so that polarization direction of the linearly polarized outgoing light is rotated by about 90° so as to be in the direction at $+75^\circ$ with respect to the horizontal axis H. Accordingly, since the polarization direction of the linearly polarized light transmitted through the STN liquid crystal cell 12 is
10 deviated by 90° from the transmission axis 18a of the second polarizing film 18, so that all components of light falling on the second polarizing film 18 are absorbed thereby, indicating black display.

Since the liquid crystal display panel employs the EL plate having a luminescence center wavelength of $\lambda_L = 510$ nm, and showing emitted
15 light in a bluish green color as the backlight 16 in the same manner as the first embodiment, the light can not be transmitted in a black display state where no voltage is applied, while light in wavelength of not more than 560 nm can be transmitted in a state where golden reflected color is displayed when no voltage is applied, so that a brightness relation is
20 indicated in the same way as the display by external light, and hence an excellent visibility can be obtained.

Since the translucent light absorbing member is not provided in the liquid crystal display panel of the fourth embodiment compared with the second embodiment, the amount of transmitted light increases when the
25 backlight is lit up to increase display brightness, so that bright illumination can be obtained.

As mentioned above, with the construction comprising the liquid crystal display panel comprising the first polarizing film 17, the retardation film 13, the STN liquid crystal cell 12, the second polarizing film 18, the retardation film 9 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10 and the backlight 16, it is possible to obtain a liquid crystal display panel capable of indicating bright reflected color with high contrast, and indicating the same display in brightness relation between illumination by backlighting and the display by an external light, and indicating a monochromatic color display in high metallic tone to enhance high visibility even at night.

Modification of Fourth Embodiment of Liquid Crystal Display Panel

Although the STN liquid crystal cell 12 and the retardation film 13 are employed in the fourth embodiment, the function of scattering polarized light on the light emitting surface of the backlight 16 may be utilized while removing the translucent light absorbing member 15 in the same manner as the liquid crystal display panel of the fourth embodiment even in the liquid crystal display panel employing the TN liquid crystal cell 7 used in the first embodiment, or in the liquid crystal display panel employing the STN liquid crystal cell 14 and the twisted phase difference plate 19 used in the third embodiment. Even in such cases, a bright display can be obtained when the backlight is lit up, compared with the liquid crystal display panels in the first and third embodiment.

Further, although the EL plate showing emitted light in a bluish green color is used as the backlight 16 in the fourth embodiment, it is possible to use a side light provided with a light emitting diode showing

emitted light in a green color which is attached to a plastic light guide plate. In this case, an effective function of scattering polarized light can be obtained by providing irregularities on the surface of the plastic light guide plate, a reflector having a rough surface at the lower portion of the plastic
5 light guide, or the like.

Fifth Embodiment of Liquid Crystal Display Panel: Fig. 8

A liquid crystal display panel used in a timepiece according to a fifth embodiment of the invention is now described with reference to Fig.
10 8.

Since the liquid crystal display panel of this embodiment is the same as the second embodiment in construction as explained with reference to Figs. 3 and 4 except that the second polarizing film is a reflection-type polarizing film, the different point alone is described
15 hereinafter with reference to Fig. 8.

A liquid crystal display panel 40 in the fourth embodiment comprises an STN liquid crystal cell 12 with about 225° twisted nematic liquid crystal sealed therein, a retardation film 13, and a first polarizing film 17 disposed successively on a visible side (upper side in Fig. 8), and a
20 reflective polarizing film 26, a retardation film 9 for circularly polarized light, a cholesteric liquid crystal polymer sheet 10, translucent light absorbing member 15 and a backlight 16 disposed successively on a side opposite from the visible side (lower side in Fig. 8).

The reflection-type polarizing film 26 is first described. The first
25 polarizing film 17 and the second polarizing film 18 which have been employed in the first to fourth embodiments are formed of normal

polarizing films, namely, absorption-type polarizing films which absorb linearly polarized light having polarizing direction which intersects a transmission axis at right angle, and indicates a black display. On the other hand, the reflection-type polarizing film reflects linearly polarized light having polarizing direction which intersects a transmission axis at right angle, and indicates a silver display. In the fifth embodiment, a product called as D-BEF manufactured by Sumitomo 3M corporation is used as a reflection-type polarizing film.

The operation for displaying colors by the liquid crystal display panel 40 in the fifth embodiment is described next. In a state where no voltage is applied to the STN liquid crystal cell 12 in the liquid crystal display panel 40, a linearly polarized light which falls on the retardation film 13 from the visible side through the first polarizing film 17 is turned in a state of an elliptic polarized light when it passes through the retardation film 13. The elliptic polarized light is corrected during passage through the STN liquid crystal cell 12, is turned into substantially linearly polarized light, and outgoes having a polarization direction rotated counterclockwise by about 55° with respect to the transmission axis 17a of the first polarizing film 17 shown in Fig. 4.

Since the transmission axis of the reflection-type polarizing film 26 is the same of the transmission axis 18a of the second polarizing film 18 in the second embodiment and is disposed so that it is oriented in the direction of 15° on the basis of a horizontal axis H. Accordingly, the linearly polarized light which falls on from the first polarizing film 17 passes through the reflection-type polarizing film 26 as it is.

Since a phase delay axis 9a of the retardation film 9 for circularly

polarized light is disposed at an angle of $+45^\circ$ relative to a transmission axis of the reflection-type polarizing film 26, the linearly polarized light which passed through the reflection-type polarizing film 26 falls at a 45° clockwise angle with respect to a phase delay axis 9a of the retardation film 9 for circularly polarized light and it is turned into right-handed circularly polarized light.

Since the fifth embodiment employed the cholesteric liquid crystal polymer sheet 10 which is twisted right in the same manner as the first embodiment, light components in a scattering band width $\Delta\lambda$ is reflected around a scattering center wavelength λ_c are reflected due to the selective scattering phenomenon, and light transmitted through wavelength regions other than the scattering bandwidth $\Delta\lambda$, is absorbed by the translucent light absorbing member 15, whereupon a golden reflected color in a bright metallic tone can be obtained.

When a voltage is applied between first transparent electrodes 3 of the STN liquid crystal cell 12 and second transparent electrodes 4 thereof, the molecules in the nematic liquid crystals 6 are caused to rise up, and birefringency of the STN liquid crystal cell 12 undergoes a change, so that polarization of the linearly polarized light outgoing is rotated by about 90° so as to be in the direction at $+75^\circ$ with respect to the horizontal axis H. Accordingly, since polarization direction of the linearly polarized light transmitted through the STN liquid crystal cell 12 is deviated by 90° from the transmission axis of the second polarizing film 26, so that almost all components of light falling on the second polarizing film 26 are reflected thereby, indicating silver display.

Since the liquid crystal display panel employs the EL plate having

a luminescence center wavelength of $\lambda_L = 510$ nm, and showing emitted light in a bluish green color as the backlight 16 in the same manner as the first embodiment, the light can not be transmitted in a silver display state where a voltage is applied, while light in a wavelength of not more than
5 560 nm can be transmitted in a state where a golden reflected color is displayed when no voltage is applied, and further the same display in brightness relation between the display therein and the display by an external light without lighting up the backlight can be obtained, to enhance high visibility even at night.

10 As mentioned above, with the construction comprising the liquid crystal display panel comprising the first polarizing film 17, the retardation film 13, the STN liquid crystal cell 12, the reflection-type polarizing film 26, the retardation film 9 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the translucent light absorbing member 15
15 and the backlight 16, it is possible to obtain a liquid crystal display panel capable of indicating silver characters against background in gold with bright reflected color, which becomes a correct conversion display in the same manner as the display by an external light even illumination by backlighting, and of indicating a monochromatic color display in a metallic
20 tone with high visibility even at night.

Modification of Fifth Embodiment of Liquid Crystal Display Panel

Although the STN liquid crystal cell 12 and the retardation film 13 are employed in the fifth embodiment, if a reflection-type polarizing film
25 26 is employed in place of a second polarizing film 18 even in the liquid crystal display panel employing the TN liquid crystal cell 7 in the first

embodiment, and the liquid crystal display panel employing the STN liquid crystal cell 14 and twisted retardation film 19 in the third embodiment, the same liquid crystal display panel as the fifth embodiment can be obtained.

Further, although the liquid crystal display panel displays a silver character against a background in gold in this embodiment, it is possible to display a golden character against a background in silver by twisting a transmission axis 17a of a first polarizing film 17 by 90°. Further, it is also possible to obtain a liquid crystal display panel capable of displaying a variety of colors such as blue characters in a metallic tone against a background in silver, green character in a metallic tone against a background in silver by changing twist pitch of a cholesteric liquid crystal polymer sheet 10.

Still further, although a translucent light absorbing member 15 was provided between the backlight 16 and the cholesteric liquid crystal polymer sheet 10 in this embodiment, even if function of scattering polarized light of the light emitting surface of the backlight 16 is utilized while removing the translucent light absorbing member 15 as mentioned in the fourth embodiment, the same liquid crystal display panel as the fourth embodiment can be obtained.

20

Sixth Embodiment of Liquid Crystal Display Panel: Fig. 9 and Fig. 10

A liquid crystal display panel used in a timepiece according to a sixth embodiment of the invention is now described with reference to Fig. 9 and Fig. 10.

Since the liquid crystal display panel of this embodiment is the same as the first embodiment in construction except that two pieces

retardation films for circularly polarized light are employed and the position of a second polarizing film 18 is different, the different points alone are described hereinafter.

The liquid crystal display panel 40 comprises, as shown in Fig. 9, a first polarizing film 17, a TN liquid crystal cell 7, a cholesteric liquid crystal polymer sheet 10, a second polarizing film 18, a translucent light absorbing member 15 and a backlight 16 disposed successively on the visible side (upper side in Fig. 9), which are the same as the first embodiment.

A first retardation film 27 for circularly polarized light disposed between the TN liquid crystal cell 7 and the cholesteric liquid crystal polymer sheet 10, and a second retardation film 28 for circularly polarized light 28 disposed between the cholesteric liquid crystal polymer sheet 10 and the second polarizing film 18 are respectively called as a quarter-wavelength plate which is the same as the retardation film 9 for circularly polarized light (Fig. 1) as employed in the first embodiment, and which is prepared by spreading a polycarbonate resin to a thickness of about 60 μ m, and the phase difference value is 140 nm.

A first substrate 1, the first retardation film 27 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the second retardation film 28 for circularly polarized light and the second polarizing film 18 are respectively bonded using an acrylic adhesive (not shown). Further, the first polarizing film 17 and a second substrate 2 are also bonded to each other using an acrylic adhesive (not shown).

Shown in Fig. 10, the transmission axis 17a of the first polarizing film 17 points 45° upward to the right in the same manner as alignment

direction 7b of the upper liquid crystal molecules of the TN liquid crystal cell 7, and a transmission axis 18a of the second polarizing film 18 points 45° upward to the right in the same manner as an alignment direction 7b of the upper liquid crystal molecules of the TN liquid crystal cell 7, while a
 5 phase delay axis 27a of the first retardation film 27 for circularly polarized light and a phase delay axis 28a of the second retardation film 28 for circularly polarized light are respectively disposed horizontally.

The operation for displaying colors by the liquid crystal display panel 40 of the sixth embodiment is described next.

10 In a state where no voltage is applied to the TN liquid crystal cell 7 in the liquid crystal display panel 40, a linearly polarized light which is changed to the direction of the transmission axis 17a and which falls thereon from a visible side through the first polarizing film 17 is polarized in the direction same as alignment direction 7b of the upper liquid crystal
 15 molecules of the TN liquid crystal cell 7 and falls thereon, and is rotated by 90° by the TN liquid crystal cell 7 and it outgoes after it is turned into a linearly polarized light in the alignment direction 7a of the lower liquid crystal molecules.

The linearly polarized light outgoing from the TN liquid crystal cell
 20 7 falls on the phase delay axis 27a of the first retardation film 27 for circularly polarized light as a 45° right-handed linearly polarized light. Accordingly, as shown in the OFF-state in Fig. 13, the light falls thereon is turned into a right -handed circularly polarized light, and it is rotated clockwise same as the twisting direction 10a of the cholesteric liquid
 25 crystal polymer sheet 10, so that light components in a scattering band width $\Delta\lambda$ is reflected around a scattering center wavelength λ_c are

reflected due to the selective scattering phenomenon. Further, transmitted light in wavelength regions other than the scattering bandwidth $\Delta\lambda$ transmits through the second retardation film 28 for circularly polarized light, but it is absorbed by the translucent light absorbing member 15, whereupon a golden reflected color in a bright metallic tone is obtained.

If the voltage is applied between first transparent electrodes 3 and second transparent electrodes 4, molecules of a nematic liquid crystals nematic liquid crystals 6 are caused to rise up to extinguish the light rotation property so that linearly polarized light falling thereon from the alignment direction 7b of the upper liquid crystal molecules transmits through the TN liquid crystal cell 7 in the same direction as it is. Accordingly, the linearly polarized light transmitted through the TN liquid crystal cell 7 falls on the first retardation film 27 for circularly polarized light at a 45° counterclockwise angle, so that it is turned into a left-handed circularly polarized light shown in the ON-state in Fig. 13. Further, the linearly polarized light is opposite to the twisting direction 10a of the cholesteric liquid crystal polymer sheet 10, so that light having all the wavelengths transmits through the cholesteric liquid crystal polymer sheet 10.

Light which transmitted through the cholesteric liquid crystal polymer sheet 10 is returned to linearly polarized light at the second retardation film 28 for circularly polarized light but the oscillation direction thereof is rotated by 90° from the direction in which light falls on the first retardation film 27 for circularly polarized light, and becomes the same direction as an alignment direction 7a of the lower liquid crystal molecules. Since the transmission axis 18a of the second polarizing film

18 is disposed at $+45^\circ$ which is the same as the alignment direction 7b of the upper liquid crystal molecules, light transmitted through the second retardation film 28 for circularly polarized light is absorbed by the second polarizing film 18 to indicate a black display.

5 An EL plate having a luminescence center wavelength λ_L of 510 nm, and showing emitted light in a bluish green color is employed as a backlight 16 in the same manner as the first embodiment. When the backlight 16 is lit up in a black display state where a voltage is applied, light transmitted through the second polarizing film 18 is rotated by 90° by
10 the second retardation film 28 for circularly polarized light and the first retardation film 27 for circularly polarized light, and it is absorbed by the first polarizing film 17, and hence it does not transmit through light of the backlight 16.

15 In an OFF-state displaying golden reflected color when no voltage is applied, light in a wavelength of not more than 560 nm can transmit so that it is well illuminated, and the same display in brightness relation between the display therein and the display by an external light without lighting up by the backlight 16 (correct conversion display) to enhance a good visibility even at night.

20 Accordingly, with the construction comprising the first polarizing film 17, the TN liquid crystal cell 7, the first retardation film 27 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the second retardation film 28 for circularly polarized light, the second polarizing film 18, the translucent light absorbing member 15 and the
25 backlight 16, it is possible to obtain a liquid crystal display panel capable of indicating bright reflected color display with high contrast, and

indicating the same display in brightness relation between illumination by backlighting and the display by an external light, and indicating a monochromatic color display in a metallic tone with high visibility even at night.

5

Modification of the Sixth Embodiment of Liquid Crystal Display Panel

Although the TN liquid crystal cell 7 is employed in the sixth embodiment, even if the first retardation film 27 for circularly polarized light, the cholesteric liquid crystal polymer sheet 10, the second retardation
10 film 28 for circularly polarized light and the second polarizing film 18 are employed in the liquid crystal display panel employing the STN liquid crystal cell 12 and the retardation film 13 used in the second embodiment, or in the liquid crystal display panel employing an STN liquid crystal cell 20, the twisted retardation film 19 used in the third embodiment, the liquid
15 crystal display panel which is the same as the sixth embodiment can be obtained.

Further, in this modification, although the translucent light absorbing member 15 is disposed between the backlight 16 and the second polarizing film 18, the liquid crystal display panel similar to the sixth
20 embodiment obtained even if the translucent light absorbing member 15 is removed as explained in the fourth embodiment.

Still further, although a normal absorption-type polarizing film is employed as the second polarizing film 18, a reflection-type polarizing film can be employed as explained in the polarizing film 18, a reflection-
25 type polarizing film can be employed as explained in the fifth embodiment.

Seventh Embodiment of Liquid Crystal Display Panel: Fig. 12

A liquid crystal display panel used in a timepiece according to a seventh embodiment of the invention is now described with reference to Fig. 12.

5 Since the liquid crystal display panel of the seventh embodiment is the same as the second embodiment in construction as explained in Fig. 3 except that an EL plate showing emitted light in a white color is employed as a backlight, the explanation of the construction thereof using the sectional view is omitted.

10 The EL plate showing emitted light in a white color is prepared by coating fluorescent dye having light emitting wavelength of 580 nm on the surface of the EL plate showing emitted light in a bluish green color employed in the second embodiment. A light emitting spectrum of the EL plate showing emitted light in a white color and transmittance curve of
15 the liquid crystal display panel are shown in Fig. 12.

The light emitting operation and the operation when the backlight is lit up in the seventh embodiment of the invention are now described with reference to Fig. 12.

In Fig. 12, the transmittance of the liquid crystal display panel in a
20 state where no voltage is applied to the liquid crystal display panel in the seventh embodiment at the selective scattering state is shown by a solid curve 53, whereas the transmittance of the same in a state where no voltage is applied to the liquid crystal display panel at the black display state is shown by a solid curve 52. In a state where no voltage is applied, it is
25 found from the curve 53 that right-handed circularly polarized light in the range from 560 nm to 670 nm around the scattering center wavelength of

$\lambda_c = 610$ nm is reflected, but light components in wavelength regions other than the scattering bandwidth transmit as they are.

Accordingly, if the transmitted light is absorbed by the translucent light absorbing member 15 or the returning of light to the visible side is restrained by the function of scattering polarized light on the light emitting surface of the backlight 16, it is possible to indicate a bright golden display by the reflected light due to the selective scattering phenomenon.

On the other hand, in a state where a voltage is applied, it is found from the curve 52 that light transmitted through the first polarizing film 17 is almost absorbed by the second polarizing film 18 to indicate a black display.

The operation of the backlight 16 is described next. Since the EL plate showing emitted light in a white color is prepared by printing fluorescent dye having luminescence center wavelength of 580 nm on the surface of the EL plate showing emitted light in a bluish green color, it has two luminescence center wavelengths. A curve 55 denoted by broken line in Fig. 12 shows a relative light emitting spectrum of the EL plate showing emitted light in a white color used in the seventh embodiment. The EL plate showing emitted light in a white color has two light luminescence peaks, i.e., a first luminescence center wavelength $\lambda_{L1} = 490$ nm and a second luminescence center wavelength $\lambda_{L2} = 580$ nm, and it shows whitish light emitting color.

Although the liquid crystal display panel indicates a golden reflected color display in a state where no voltage is applied, light having a wavelength of not more than 560 nm can transmit through the cholesteric liquid crystal polymer sheet 10. Accordingly, light having the first light

luminescence peak, and light having the wavelength which is shorter than the second luminescence center wavelength λ_{L2} of the second light luminescence peak respectively transmit through the cholesteric liquid crystal polymer sheet 10 and can brightly illuminate so that a high
5 visibility can be obtained even at night.

By the employment of not less than two luminescence center wavelengths as the backlight 16 as described above, it is possible to indicate a bright reflected color display with high contrast and to indicate the same display in brightness relation between the display therein and the
10 display by an external light without illumination by backlighting, thus indicating a monochromatic color display in a metallic tone with a high visibility even at night.

Modification of Seventh Embodiment of Liquid Crystal Display Panel

15 Although the STN liquid crystal cell 12 and the retardation film 13 are employed in the seventh embodiment, if the EL plate showing emitted light in a white color having a plurality of luminescence center wavelengths as the back light 16 is employed even in the liquid crystal display panel employing the TN liquid crystal cell 7 used in the first
20 embodiment, or in the liquid crystal display panel employing the STN liquid crystal cell 20 and the twisted retardation film 19 used in the third embodiment, the liquid crystal display panel which is the same as the seventh embodiment can be obtained.

Although the EL plate showing emitted light in a white color is
25 prepared by coating florescent dye having light emitting wavelength 580 nm on the surface of an EL plate showing emitted light in a bluish green

color in the seventh embodiment, it is possible to employ the EL plate showing emitted light in a white color prepared by printing fluorescent dye on the lower side of a transparent electrode on the surface of the EL plate showing emitted light in a bluish green color or by mixing fluorescent dye
5 into bluish green light emitting body.

Further, although an EL plate having two luminescence center wavelengths, namely, the luminescence center wavelengths $\lambda_{L1} = 490$ nm and $\lambda_{L2} = 580$ nm has been used as the backlight 16 in the seventh embodiment, if at least one light emitting wavelength is deviated from the
10 selective scattering center wavelength λ_c of the cholesteric liquid crystal polymer sheet 10 by not less than 50 nm, bright display can be obtained when the EL plate is lit up.

Still further, although an EL film showing emitted light in a white color is used as the backlight 16 in the seventh embodiment, even if a side
15 light provided with two kinds of, i.e., green and red light emitting diodes in light emitting color which are attached to a plastic light guide plate, or a side light provided with white fluorescent light in light emitting color which is attached to a plastic light guide plate is used in this embodiment, the same bright illumination can be obtained.

20 Still further, although the translucent light absorbing member 15 is provided between the backlight 16 and the cholesteric liquid crystal polymer sheet 10 in the seventh embodiment, it is needless to say that the same liquid crystal display panel as the seventh embodiment can be obtained even if the translucent light absorbing member 15 is removed as
25 explained in the fourth embodiment.

Watch Embodying the Invention

Fig. 13 is a perspective view of a digital indicating type watch, showing the external view thereof, and Fig. 14 a sectional view of the same watch, showing the internal construction thereof.

A case 20 of the quartz watch is made up of a glass plate 22 and a case back cover 23, integrally joined with a case body 21 made of metal.

The glass plate 22 is made of a transparent material such as sapphire glass, tempered glass, or plastics, and integrally joined with the front face of the case body 21 by means of direct bonding, or fitting therein via a packing. The case back cover 23 is integrally joined with the back face of the case body 21 by means of screwing therein or fitting therein via a packing.

Thus, the case 20 has an airtight inner structure so as not to allow ingress of dust or moisture therein.

Any one liquid crystal display panel 40 of said respective embodiments to serve as a display for indicating time and so forth is installed on the side of the glass plate 22 inside the case 20.

The liquid crystal display panel 40 comprises a time display section 40a for displaying hour, minute, and second, a calendar display section 40b for displaying month, date, days of the week, and a colon mark display section 40c for blinking every second.

Further, the liquid crystal display panel 40 is capable of displaying a function of time display for 12 consecutive hours or 24 consecutive hours, of displaying a function of calendar display for month, date and days of the week, an alarm function, a stopwatch function, a timer function,

and so forth.

Changeover among such various functions, and correction of time are executed by manipulating a plurality of switching buttons 24 installed in the side of the case body 21 of the case 20. A packing is provided
5 between each of the switching buttons 24 and the case body 21 so as not to allow ingress of dust and moisture into the case 20.

As shown in Fig. 14, the quartz watch has an inner structure such that the liquid crystal display panel 40 and a printed circuit board 30 are disposed substantially in parallel with each other inside the case 20, and a
10 battery 31 for serving as a driving power source of the printed circuit board 30 is installed on the case back cover 23 side of the printed circuit board 30.

A semiconductor integrated circuit 33 comprising a crystal oscillator 32 having an oscillation frequency of 32,768 Hz, a crystal
15 oscillation circuit for generating a predetermined signal by oscillating the crystal oscillator 32, a counting down circuit, a driving circuit for driving the liquid crystal display panel 40, a central processing unit (CPU) for overall control of the quartz watch, and so forth is mounted on the printed circuit board 30.

20 The liquid crystal display panel 40 is electrically connected with the printed circuit board 30 via a zebra rubber connector 34 disposed therebetween. The zebra rubber connector 34 is disposed so as to be compressed thicknesswise in order to ensure electrical connection between the liquid crystal display panel 40 and the printed circuit board 30.

25 The zebra rubber connector 34 is made up of electrically conductive layers, composed of insulating silicone rubber with carbon and

metal particles contained therein, and formed at a predetermined pitch, and electrically conductive in the direction of thickness thereof via the respective electrically conductive layers, but in a transversely insulated condition between adjacent electrically conductive layers.

5 A connection terminal pattern is formed on the faces of the liquid crystal display panel 40 and the printed circuit board 30, opposite to each other, respectively, in such a fashion as to correspond to vertically conductive parts of the zebra rubber connector 34, formed of the electrically conductive layer, respectively, and insulation parts of the zebra
10 rubber connector 34, alternately disposed, and in dimensions at the same pitch as that for the vertically conductive parts.

 In this quartz watch, the liquid crystal display panel 40 for displaying time information and calendar information, is capable of indicating a single reflected color display in a bright metallic tone, and is
15 capable of displaying a monochromatic color which can be visible even at dark environment such as night by lighting up the backlight, through the use of the time display section 40a and the calendar display section 40b, time display and calendar display can be indicated distinctly in color display at night .

20

INDUSTRIAL APPLICABILITY

 As is evident from the above explanation, it is possible to obtain the timepiece, having the liquid crystal display panel for displaying time information and calendar information capable of indicating a single
25 reflected color display in a bright metallic tone, and capable of displaying a monochromatic color which can be visible even at dark environment

such as night by lighting up the backlight, therefore, time display and calendar display can be indicated distinctly in color display at night.

Further, if the liquid crystal display panel does not employ a translucent light absorbing member, it is possible to indicate a
5 monochromatic color display in a bright metallic tone to obtain more bright reflected color, and also time display and calendar display can be indicated more luminous when the backlight is lit up.

What is claimed is:

1. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information, said liquid crystal display panel comprising:

5 a TN liquid crystal cell with about 90° twisted nematic liquid crystals sealed in-between a pair of transparent substrates having respective transparent electrodes;

 a first polarizing film disposed on the visible side of the TN liquid crystal cell; and

10 a second polarizing film, a retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a translucent light absorbing member and a backlight disposed successively on a side of the TN liquid crystal cell, opposite from the visible side thereof.

2. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information, said liquid crystal display panel comprising:

 an STN liquid crystal cell with 180° to 270° twisted nematic liquid crystals sandwiched between a pair of transparent substrates having respective transparent electrodes;

20 a retardation film disposed on the visible side of the STN liquid crystal cell;

 a first polarizing film disposed on the outer side of the retardation film; and

25 a second polarizing film, a retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a translucent light absorbing member and a backlight disposed successively on a side of the



STN liquid crystal cell, opposite from the visible side thereof.

3. The timepiece according to claim 2, wherein the retardation film of said liquid crystal display panel is a twisted retardation film.

4. A timepiece comprising a liquid crystal display panel capable
5 of displaying at least either of time information and calendar information, said liquid crystal display panel comprising:

a TN liquid crystal cell with about 90° twisted nematic liquid crystals sealed in-between a pair of transparent substrates having respective transparent electrodes;

10 a first polarizing film disposed on the visible side of the TN liquid crystal cell; and

a second polarizing film, a retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet and disposed successively on a side of the TN liquid crystal cell, opposite from the visible side
15 thereof,

wherein a face of said backlight, opposite to said cholestric liquid crystal polymer sheet, has a function of scattering polarized light.

5. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information,
20 said liquid crystal display panel comprising:

an STN liquid crystal cell with 180° to 270° twisted nematic liquid crystals sandwiched between a pair of transparent substrates having respective transparent electrodes;

a retardation film disposed on the visible side of the STN liquid
25 crystal cell;

a first polarizing film disposed on the outer side of the retardation



film; and

a second polarizing film, a retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet and a backlight disposed successively on a side of the STN liquid crystal cell, opposite from the visible side thereof,

wherein a face of said backlight, opposite to said cholestric liquid crystal polymer sheet, has a function of scattering polarized light.

6. A timepiece according to claim 5, wherein the retardation film of said liquid crystal display panel is a twisted retardation film.

10 7. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information, said liquid crystal display panel comprising:

15 a TN liquid crystal cell with about 90° twisted nematic liquid crystals sealed in-between a pair of transparent substrates having respective transparent electrodes;

a first polarizing film disposed on the visible side of the TN liquid crystal cell; and

20 a first retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a second retardation film for circularly polarized light, a second polarizing film, a translucent light absorbing member and a backlight disposed successively on a side of the TN liquid crystal cell, opposite from the visible side thereof.

25 8. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information, said liquid crystal display panel comprising:

an STN liquid crystal cell with 180° to 270° twisted nematic liquid



crystals sandwiched between a pair of transparent substrates having respective transparent electrodes;

a retardation film disposed on the visible side of the STN liquid crystal cell;

5 a first polarizing film disposed on the outer side of the retardation film; and

a first retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a second retardation film for circularly polarized light, a second polarizing film, a translucent light absorbing member and a backlight disposed successively on a side of the STN liquid crystal cell, opposite from the visible side thereof.

9. A timepiece according to claim 8, wherein the retardation film of said liquid crystal display panel is a twisted retardation film.

10. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information, said liquid crystal display panel comprising:

a TN liquid crystal cell with about 90° twisted nematic liquid crystals sealed in-between a pair of transparent substrates having respective transparent electrodes;

20 a first polarizing film disposed on the visible side of the TN liquid crystal cell; and

a first retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a second retardation film for circularly polarized light, a second polarizing film and a backlight disposed successively on a side of the TN liquid crystal cell, opposite from the visible side thereof,



wherein a face of said backlight, opposite to said second polarizing film, has a function of scattering polarized light.

11. A timepiece comprising a liquid crystal display panel capable of displaying at least either of time information and calendar information,
5 said liquid crystal display panel comprising:

an STN liquid crystal cell with 180° to 270° twisted nematic liquid crystals sandwiched between a pair of transparent substrates having respective transparent electrodes;

a retardation film disposed on the visible side of the STN liquid
10 crystal cell;

a first polarizing film disposed on the outer side of the retardation film; and

a first retardation film for circularly polarized light, a cholestric liquid crystal polymer sheet, a second retardation film for circularly
15 polarized light, a second polarizing film and a backlight disposed successively on a side of the STN liquid crystal cell, opposite from the visible side thereof,

wherein a face of said backlight, opposite to said second polarizing film, has a function of scattering polarized light.

20 12. A timepiece according to claim 11, wherein the retardation film of said liquid crystal display panel is a twisted retardation film.

13. A timepiece according to claim 1, wherein a luminescence center wavelength of the backlight of said liquid crystal display panel is deviated by not less than 50 nm from a selected scattering center
25 wavelength of the cholestric liquid crystal polymer sheet.

14. A timepiece according to claim 4, wherein a luminescence



center wavelength of the backlight of said liquid crystal display panel is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

15 15. A timepiece according to claim 7, wherein a luminescence center wavelength of the backlight of said liquid crystal display panel is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

10 16. A timepiece according to claim 10, wherein a luminescence center wavelength of the backlight of said liquid crystal display panel is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

15 17. A timepiece according to claim 1, wherein the backlight of said liquid crystal display panel has not less than two luminescence center wavelengths, and at least one of the luminescence center wavelengths is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

20 18. A timepiece according to claim 4, wherein the backlight of said liquid crystal display panel has not less than two luminescence center wavelengths, and at least one of the luminescence center wavelengths is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

25 19. A timepiece according to claim 7, wherein the backlight of said liquid crystal display panel has not less than two luminescence center wavelengths, and at least one of the luminescence center wavelengths is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.



20. A timepiece according to claim 10, wherein the backlight of said liquid crystal display panel has not less than two luminescence center wavelengths, and at least one of the luminescence center wavelengths is deviated by not less than 50 nm from a selected scattering center wavelength of the cholestric liquid crystal polymer sheet.

21. A timepiece according to claim 1, wherein the second polarizing film of said liquid crystal display panel is a reflection-type polarizing film.

22. A timepiece according to claim 4, wherein the second polarizing film of said liquid crystal display panel is a reflection-type polarizing film.

23. A timepiece according to claim 7, wherein the second polarizing film of said liquid crystal display panel is a reflection-type polarizing film.

24. A timepiece according to claim 10, wherein the second polarizing film of said liquid crystal display panel is a reflection-type polarizing film.

