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Hayama

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(54) **LIQUID CRYSTAL DISPLAY PANEL, AND METHOD FOR TESTING SUBSTRATE FOR LIQUID CRYSTAL DISPLAY PANEL**

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(73) Assignee: **Sharp Kabushiki Kaisha**, Osaka (JP)

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(30) **Foreign Application Priority Data**

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G02F 1/13	(2006.01)
G02F 1/1335	(2006.01)
G02F 1/1337	(2006.01)

(52) **U.S. Cl.**
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USPC 349/153, 192, 114, 123, 124
See application file for complete search history.

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(57) **ABSTRACT**

A liquid crystal display panel (**1**) includes a TFT substrate (**10**), a CF substrate (**20**) facing the TFT substrate (**10**), a liquid crystal layer (**25**) provided between the TFT substrate (**10**) and the CF substrate (**20**), an alignment film configured to control alignment of the liquid crystal layer (**25**), and a sealing member (**26**) sandwiched between the TFT substrate (**10**) and the CF substrate (**20**) and formed in the shape of a frame surrounding the liquid crystal layer (**25**). In a region (**35**) where the sealing member (**26**) is to be provided, a metal pattern (**2**) is provided which is configured to reflect infrared light emitted from a Fourier transform infrared spectrometer toward the Fourier transform infrared spectrometer in order to determine the presence or absence of the alignment film in the region (**35**).

20 Claims, 11 Drawing Sheets

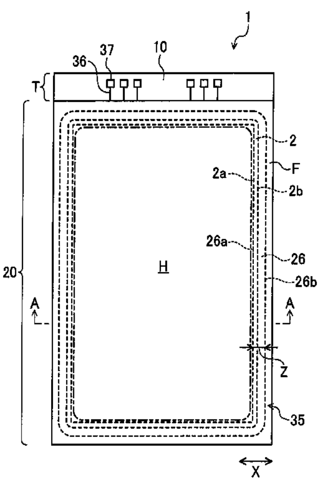


FIG.1

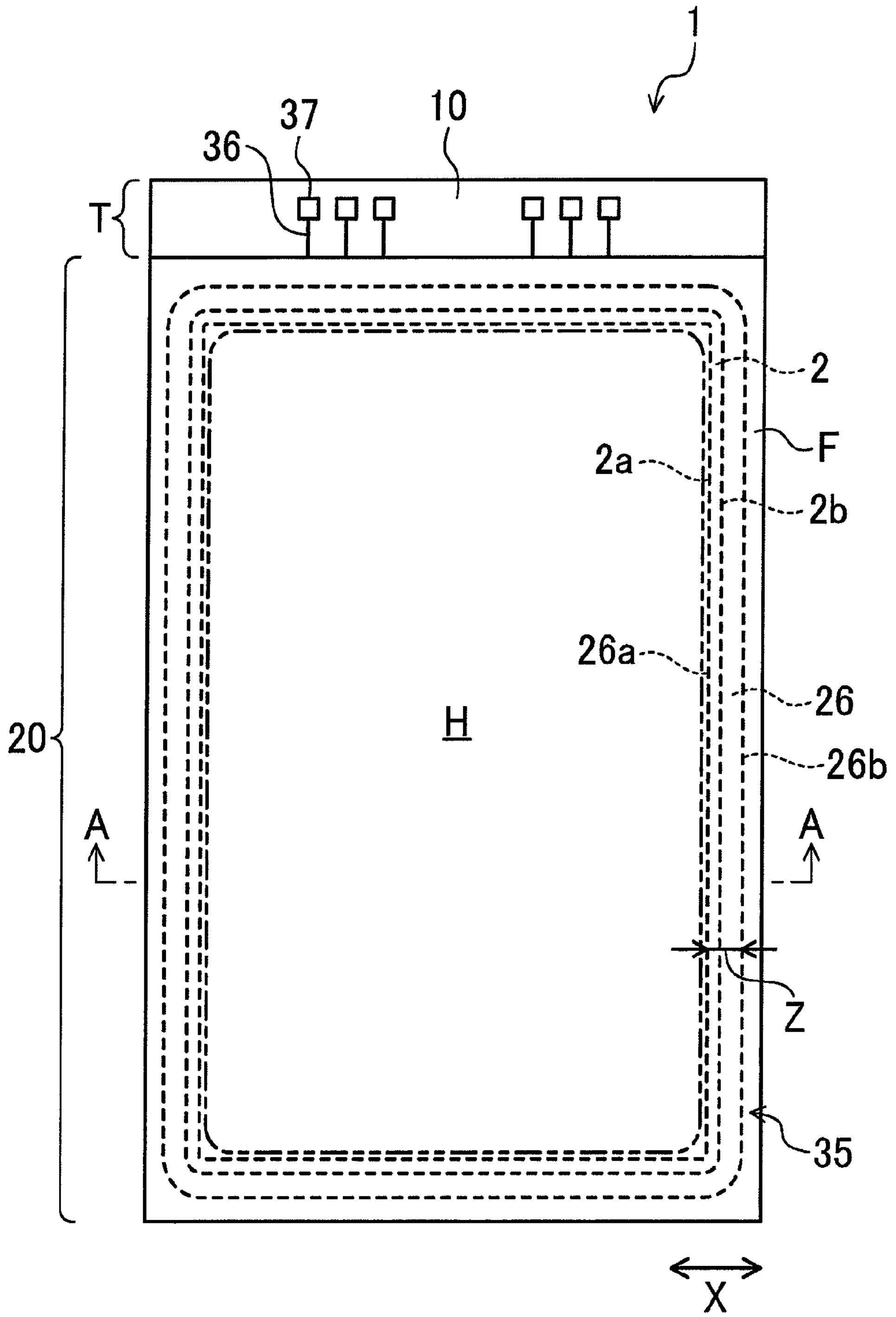
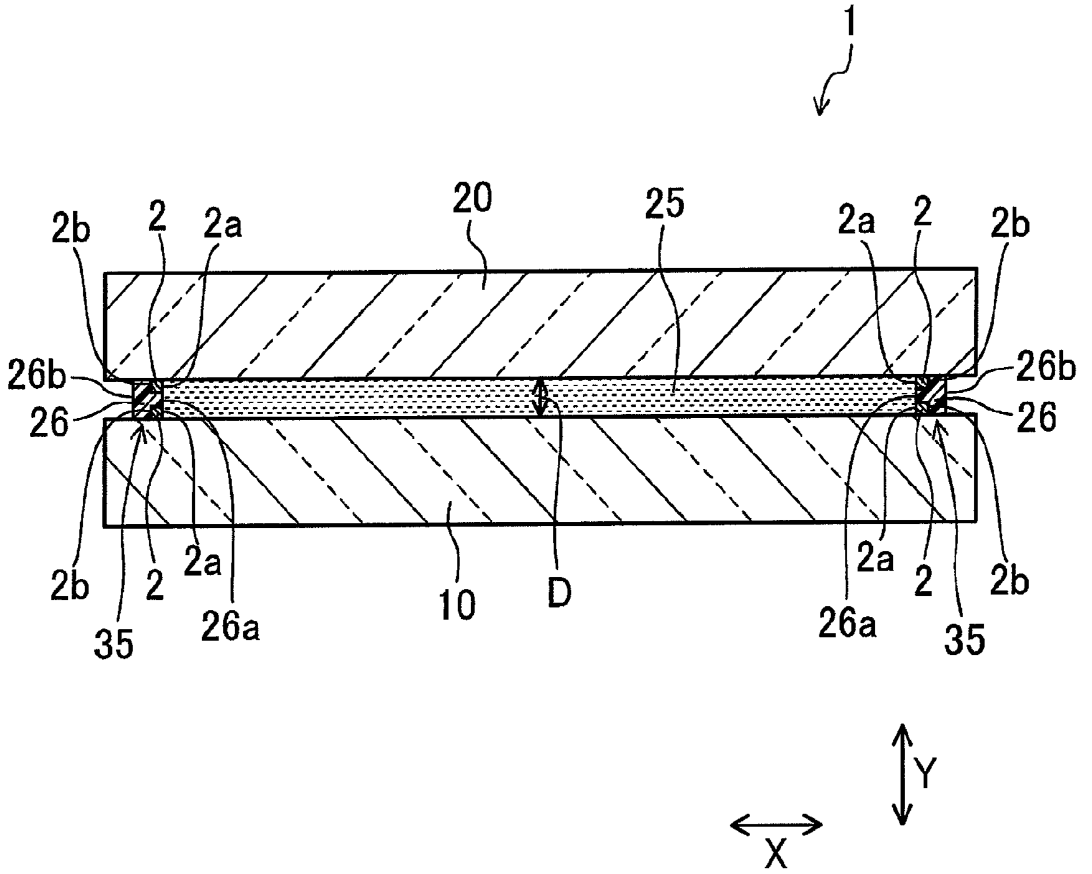


FIG.2


1
20
25
2b
2
2a
2a
2
2b
26b
26
26b
26
2b
2
2a
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26a
10
D
26a
2a
2
2b
35
Y
X

FIG.3

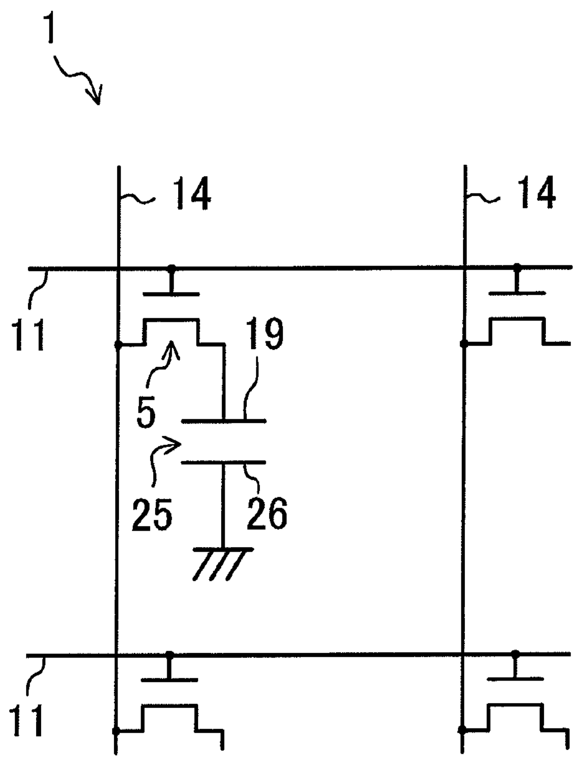


FIG.4

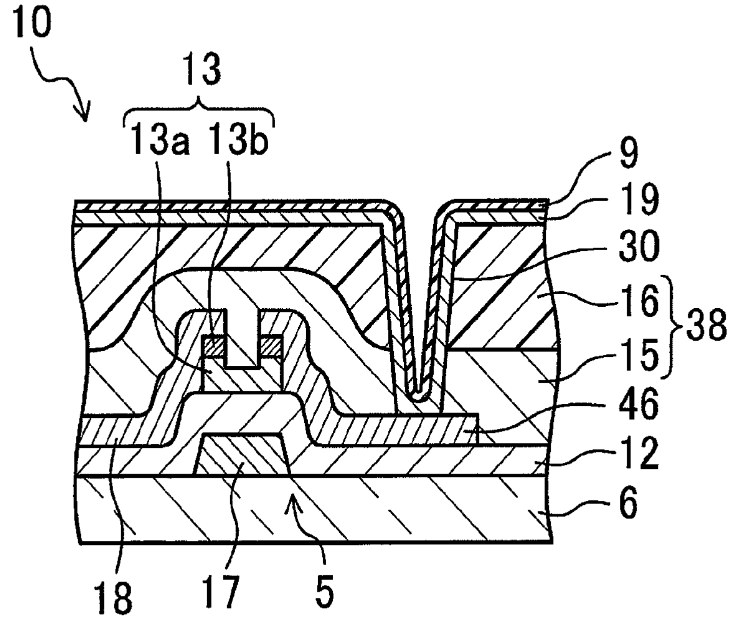


FIG.5

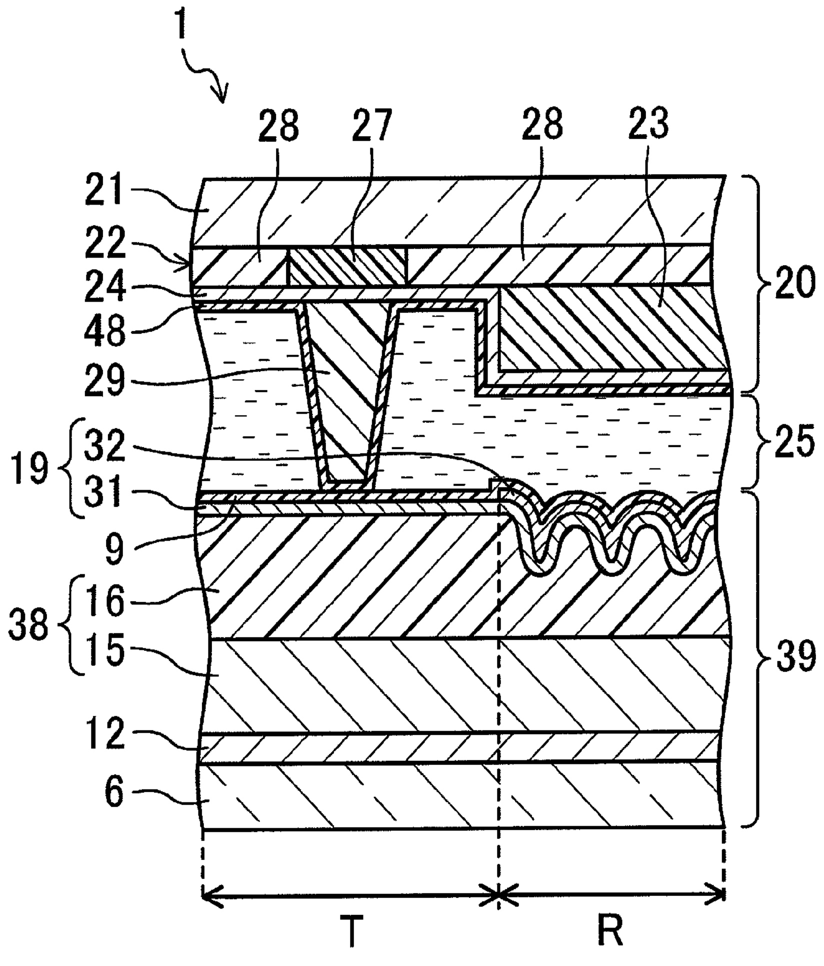


FIG.6

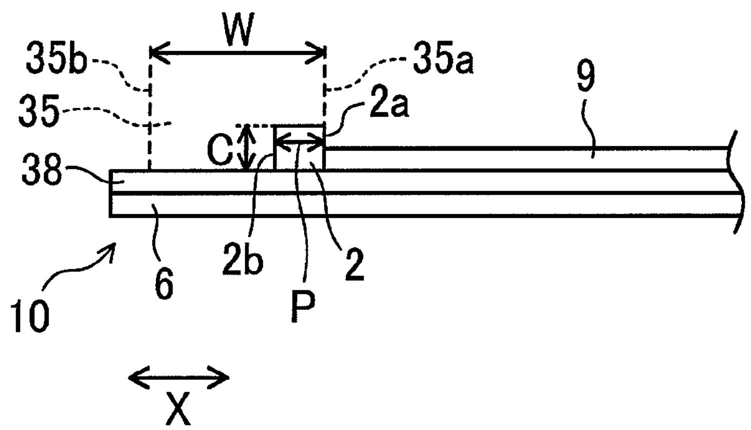


FIG.7

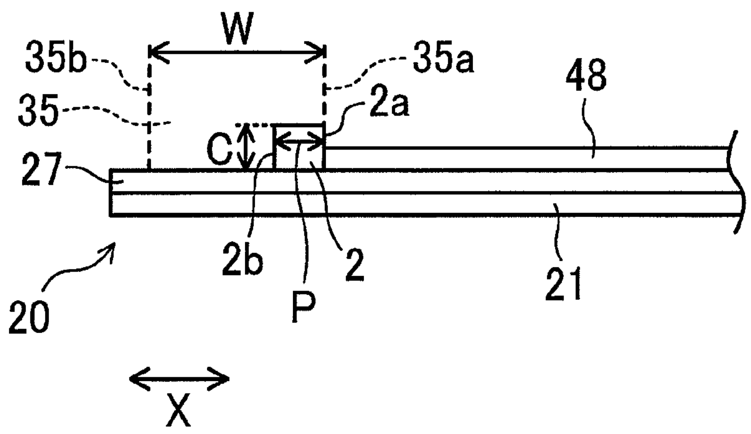


FIG.8

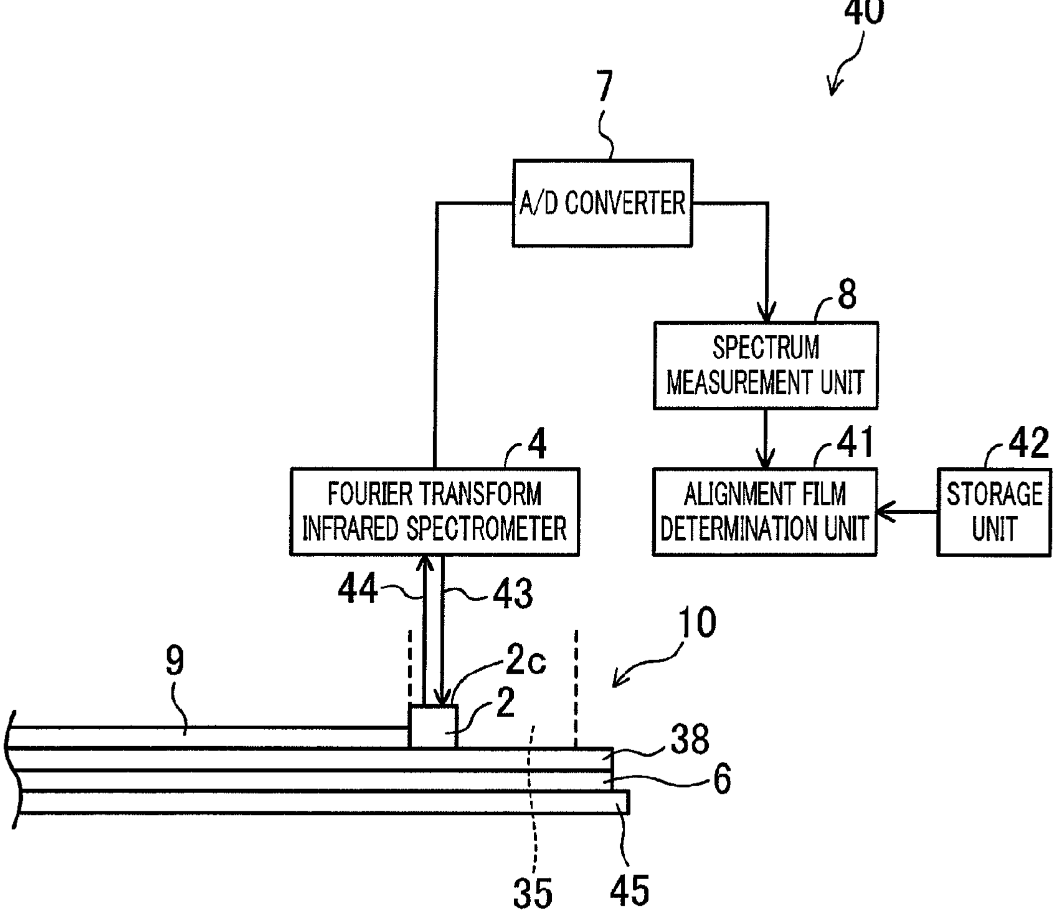

40
7
A/D CONVERTER
8
SPECTRUM MEASUREMENT UNIT
4
FOURIER TRANSFORM INFRARED SPECTROMETER
41
ALIGNMENT FILM DETERMINATION UNIT
42
STORAGE UNIT
44
43
10
9
2c
2
38
6
35
45

FIG.9

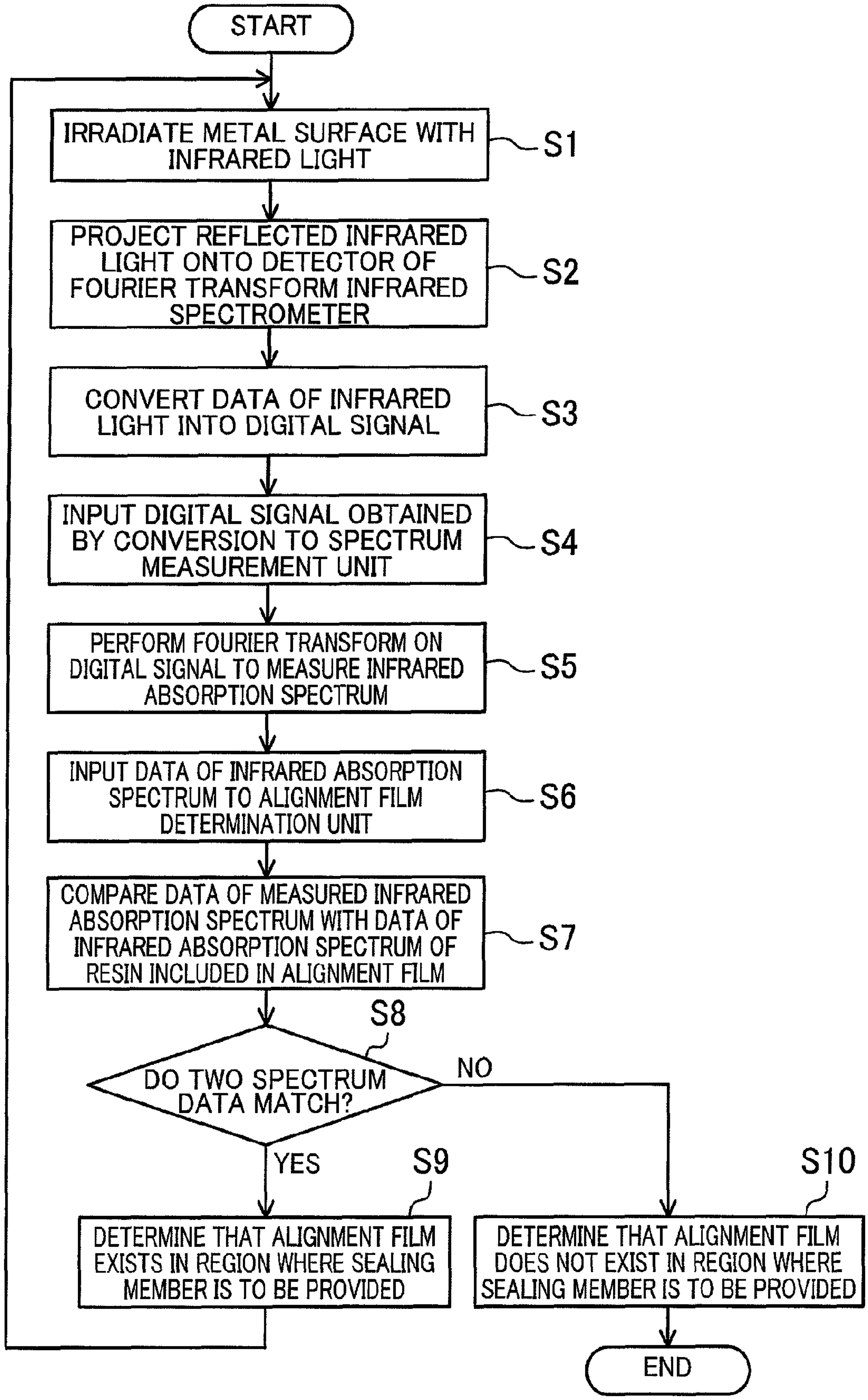

START
IRRADIATE METAL SURFACE WITH INFRARED LIGHT
S1
PROJECT REFLECTED INFRARED LIGHT ONTO DETECTOR OF FOURIER TRANSFORM INFRARED SPECTROMETER
S2
CONVERT DATA OF INFRARED LIGHT INTO DIGITAL SIGNAL
S3
INPUT DIGITAL SIGNAL OBTAINED BY CONVERSION TO SPECTRUM MEASUREMENT UNIT
S4
PERFORM FOURIER TRANSFORM ON DIGITAL SIGNAL TO MEASURE INFRARED ABSORPTION SPECTRUM
S5
INPUT DATA OF INFRARED ABSORPTION SPECTRUM TO ALIGNMENT FILM DETERMINATION UNIT
S6
COMPARE DATA OF MEASURED INFRARED ABSORPTION SPECTRUM WITH DATA OF INFRARED ABSORPTION SPECTRUM OF RESIN INCLUDED IN ALIGNMENT FILM
S7
S8
DO TWO SPECTRUM DATA MATCH?
NO
YES
S9
S10
DETERMINE THAT ALIGNMENT FILM EXISTS IN REGION WHERE SEALING MEMBER IS TO BE PROVIDED
DETERMINE THAT ALIGNMENT FILM DOES NOT EXIST IN REGION WHERE SEALING MEMBER IS TO BE PROVIDED
END

FIG.10

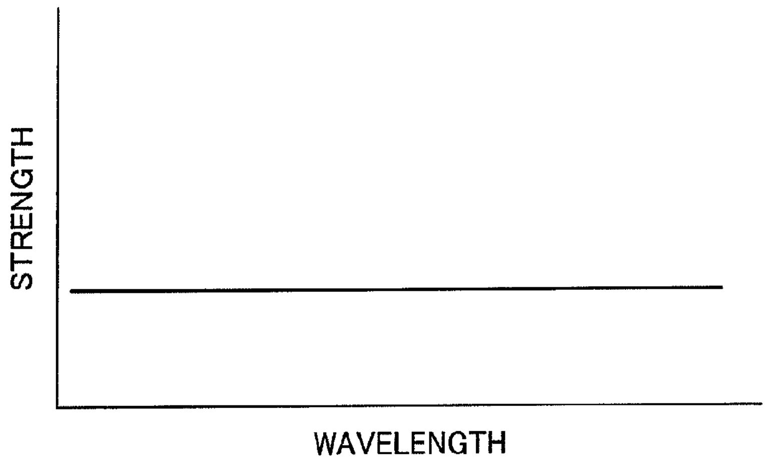

STRENGTH
WAVELENGTH

FIG.11

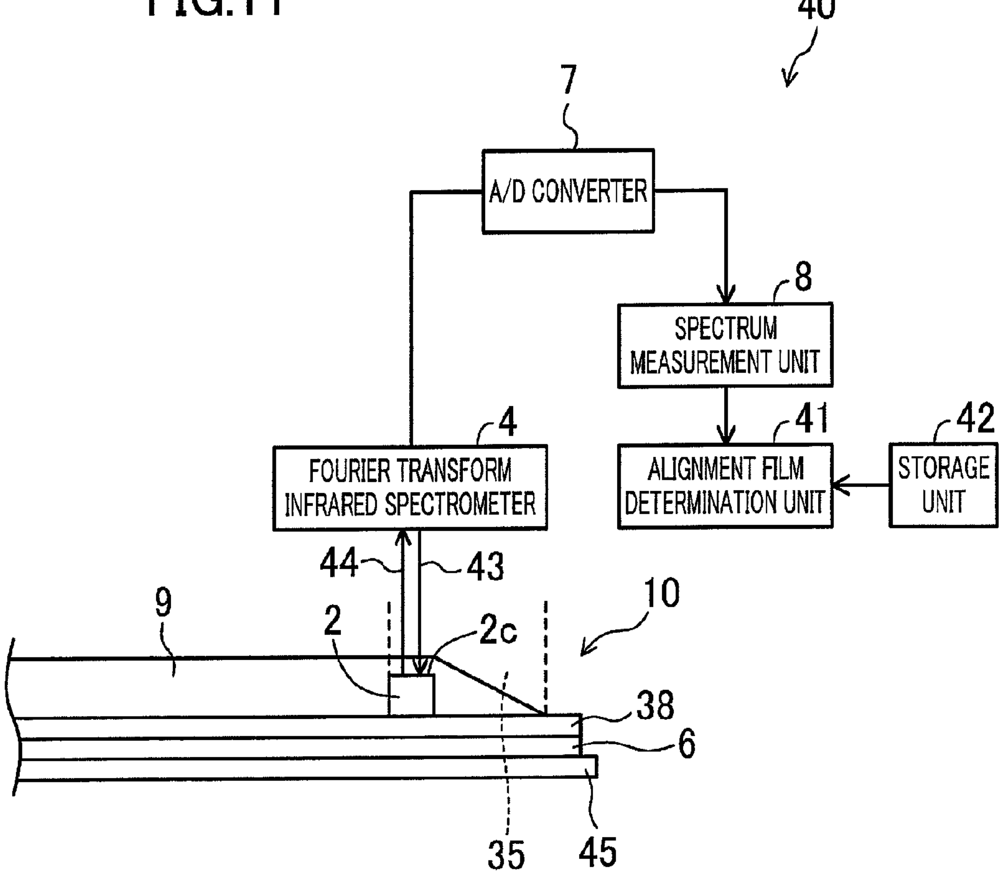

40
7
A/D CONVERTER
8
SPECTRUM MEASUREMENT UNIT
4
FOURIER TRANSFORM INFRARED SPECTROMETER
41
ALIGNMENT FILM DETERMINATION UNIT
42
STORAGE UNIT
44
43
9
2
2c
10
38
6
35
45

FIG.12

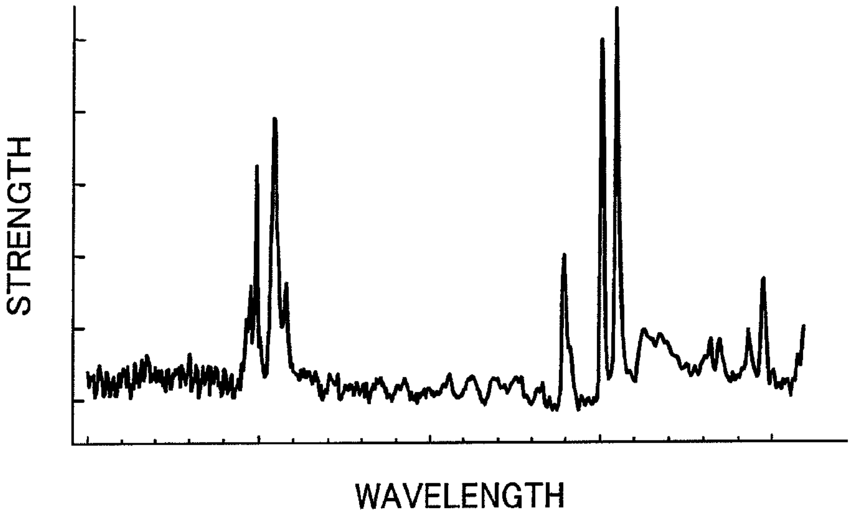


FIG.13

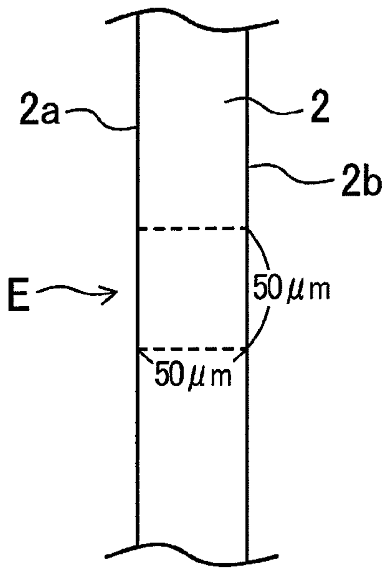


FIG.14

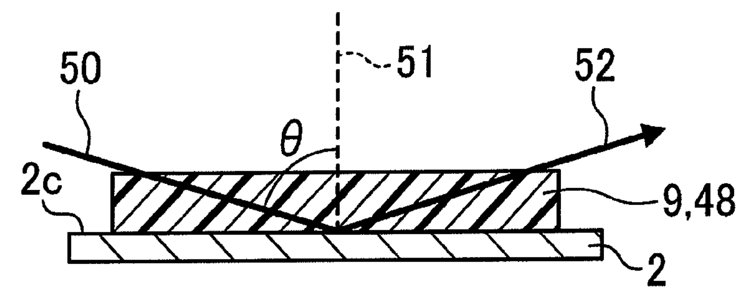


FIG.15

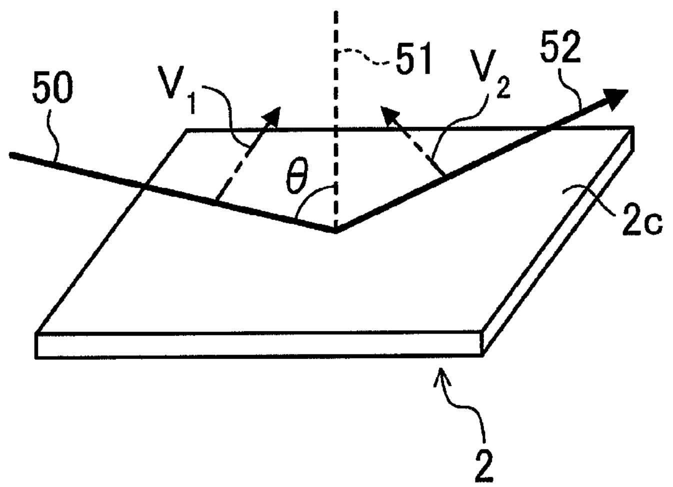
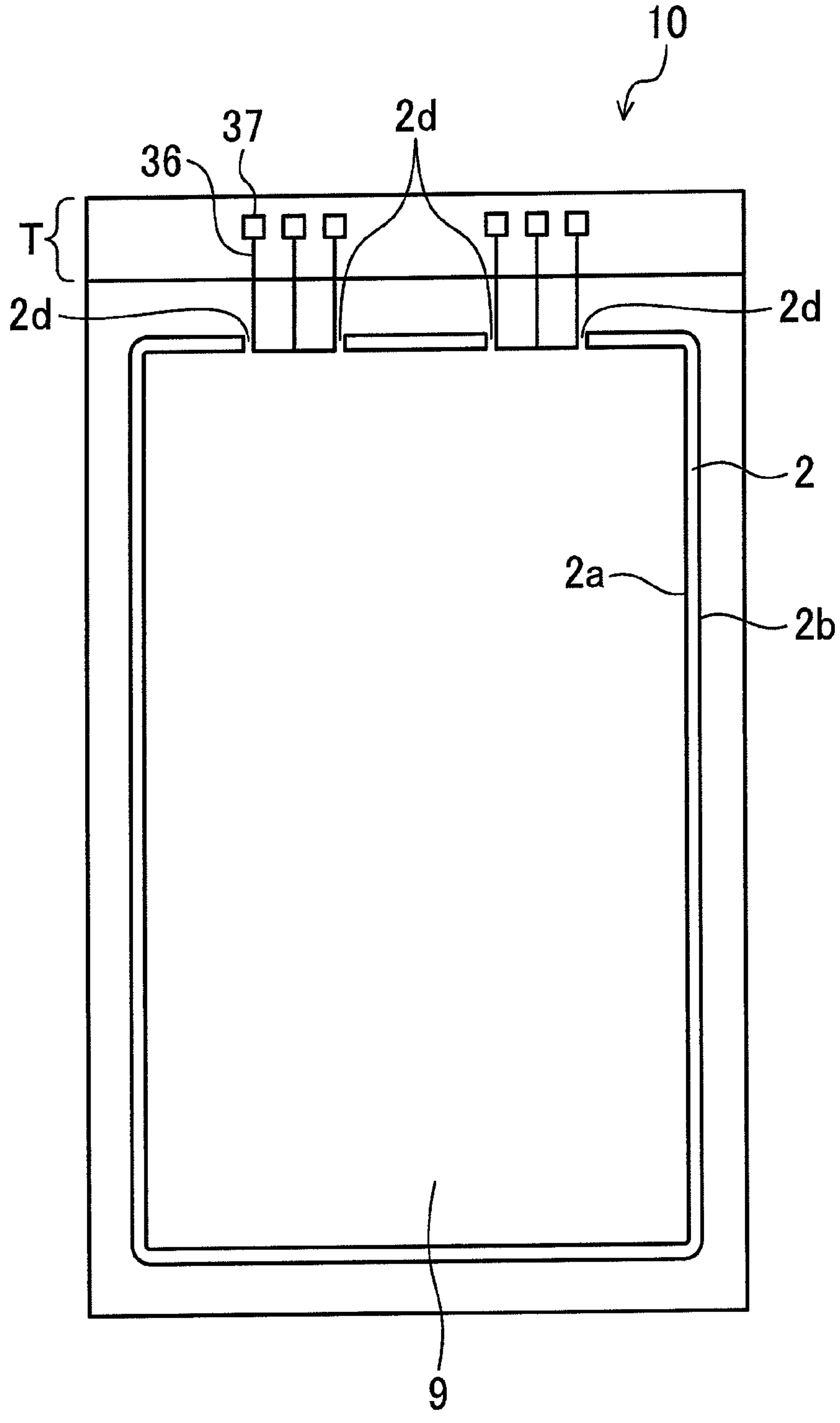


FIG.16



LIQUID CRYSTAL DISPLAY PANEL, AND METHOD FOR TESTING SUBSTRATE FOR LIQUID CRYSTAL DISPLAY PANEL

TECHNICAL FIELD

The present invention relates to liquid crystal display panels, in which a pair of substrates are joined together with a predetermined gap being interposed therebetween and a liquid crystal layer (display medium layer) is enclosed in the gap between the substrates, and methods for testing substrates for liquid crystal display panels.

BACKGROUND ART

In recent years, liquid crystal display panels, which have advantages such as thin thickness, light weight, low-voltage drive, and low power consumption, have been widely used as display panels for various electronic apparatuses such as mobile terminals (e.g., mobile telephones etc.), notebook personal computers, etc.

In general, a liquid crystal display panel includes a pair of substrates (i.e., a thin film transistor (TFT) substrate and a color filter (CF) substrate) facing each other, a liquid crystal layer provided between the pair of substrates, an alignment film which is used to control the alignment of the liquid crystal layer, and a frame-shaped sealing member which is used to bond the pair of substrates together and enclose liquid crystal between the pair of substrates.

Here, in general, the alignment film is formed by applying polyimide resin using a printing technique etc. and thereafter baking. The alignment film is formed on the substrate in a display region and in the vicinity of the sealing member provided around the display region. In this case, if the alignment film is formed in a region where the sealing member is to be provided, then when the sealing member is applied and formed, the alignment film existing between the sealing member and the substrate disadvantageously decreases the bonding strength of the sealing member.

Also, for example, if the alignment film is made of polyimide resin, the moisture permeability of polyimide resin allows the alignment film extending outside the sealing member to absorb ambient moisture, so that the liquid crystal layer inside the sealing member is disadvantageously contaminated.

In order to overcome the drawback, techniques of removing the alignment film formed in the region where the sealing member is to be provided have been proposed. More specifically, for example, a technique of removing the alignment film formed in the region where the sealing member is to be provided, by irradiating with laser light after formation of the alignment film, has been described (see, for example, PATENT DOCUMENT 1). Also, a technique of removing the alignment film formed in the region where the sealing member is to be provided, by using a liftoff technique of removing a water-soluble resist by washing with pure water in a washing step after formation of the alignment film, has been described (see, for example, PATENT DOCUMENT 2).

CITATION LIST

Patent Documents

PATENT DOCUMENT 1: Japanese Patent Publication No. 2007-114361

PATENT DOCUMENT 2: Japanese Patent Publication No. 2009-8868

SUMMARY OF THE INVENTION

Technical Problem

Although, in the techniques described in PATENT DOCUMENTS 1 and 2, the alignment film formed in the region where the sealing member is to be provided can be removed, the presence or absence of the alignment film in the region where the sealing member is to be provided cannot be determined, and therefore, it is disadvantageously difficult to determine whether or not the alignment film has been successfully removed.

It is contemplated that the presence or absence of the alignment film may be determined by visual observation using an optical microscope. In this technique, however, the result of the determination varies from person to person, and considerable effort and time are required, and in addition, it is disadvantageously necessary to destroy the liquid crystal display panel.

Therefore, the present invention has been made in view of the above problems. It is an object of the present invention to provide a liquid crystal display panel in which the presence or absence of an alignment film in a region where a sealing member is to be provided can be determined and it can be reliably determined whether or not the alignment film has been successfully removed from the region where a sealing member is to be provided, and a method for testing a substrate for the liquid crystal display panel.

Solution to the Problem

To achieve the object, a liquid crystal display panel according to the present invention includes a first substrate, a second substrate facing the first substrate, a liquid crystal layer provided between the first substrate and the second substrate, an alignment film provided on a side closer to the liquid crystal layer of each of the first and second substrates, and configured to control alignment of the liquid crystal layer, and a sealing member sandwiched between the first substrate and the second substrate, configured to bond the first substrate and the second substrate together, and formed in the shape of a frame surrounding the liquid crystal layer. In a region where the sealing member is to be provided, a metal pattern is provided which is configured to reflect infrared light emitted from a Fourier transform infrared spectrometer toward the Fourier transform infrared spectrometer in order to determine the presence or absence of the alignment film in the region.

With this configuration, as a mark for determining the presence or absence of the alignment film in the region where the sealing member is to be provided, the metal pattern which reflects infrared light emitted from a Fourier transform infrared spectrometer toward the Fourier transform infrared spectrometer is provided in the region where the sealing member is to be provided. Therefore, the Fourier transform infrared spectrometer can be used to perform a microscopic reflection technique, and therefore, based on an infrared absorption spectrum measured by the Fourier transform infrared spectrometer, the presence or absence of the alignment film in the region where the sealing member is to be provided can be determined. Thus, the presence or absence of the alignment film can be determined by non-contact measurement. In particular, after removal of the alignment film existing in the region where the sealing member is to be provided, the presence or absence of the alignment film in the region where the sealing member is to be provided can be determined. Therefore, it can be reliably confirmed whether or not the alignment film has been successfully removed from the region where the sealing member is to be provided.

As is different from confirmation performed by visual observation using an optical microscope, the result of determination of the presence or absence of the alignment film does not vary from person to person, and in addition, the presence or absence of the alignment film can be determined without destroying the liquid crystal display panel.

Because the presence or absence of the alignment film can be easily determined by non-contact measurement, even if the alignment film exists in the region where the sealing member is to be provided, the alignment film can be removed quickly and easily.

Therefore, the productivity and the yield can be improved.

The metal pattern is provided to perform a microscopic reflection technique using the Fourier transform infrared spectrometer, and therefore, the presence or absence of the alignment film can be determined at low cost.

The metal pattern is provided in the region where the sealing member is to be provided. Therefore, the presence or absence of the alignment film can be determined without impairing the external appearance.

In the liquid crystal display panel of the present invention, the metal pattern may be positioned so that an inner circumferential surface of the metal pattern and an inner circumferential surface of the region are on the same plane.

With this configuration, the alignment film can be blocked at the position of the inner circumferential surface of the metal pattern, whereby the formation of the alignment film in the region where the sealing member is to be provided can be effectively reduced or prevented.

In the liquid crystal display panel of the present invention, the metal pattern may be formed in the shape of a frame along an inner circumferential surface of the region.

With this configuration, the presence or absence of the alignment film can be determined by non-contact measurement over the entire region where the sealing member is to be provided.

In the liquid crystal display panel of the present invention, the metal pattern may have a width of 50 μm or more.

With this configuration, in the Fourier transform infrared spectrometer, the accuracy of detection of infrared light reflected by a surface of the metal pattern can be improved.

In the liquid crystal display panel of the present invention, a thickness C of the metal pattern and a distance D between the first substrate and the second substrate in a thickness direction of the liquid crystal display panel may satisfy a relationship $C<D$.

With this configuration, when the first substrate and the second substrate are bonded together via the sealing member, it is possible to avoid the problem that, due to its thickness, the metal pattern interferes with the bonding of the first substrate and the second substrate. Therefore, the liquid crystal display panel can be manufactured without changing the manufacture conditions.

In the liquid crystal display panel of the present invention, the metal pattern may be made of one selected from the group consisting of tantalum, chromium, molybdenum, nickel, titanium, copper, and aluminum.

With this configuration, the metal pattern can be made of a low-cost and versatile metal material.

In the liquid crystal display panel of the present invention, the metal pattern may be provided on at least one of the first and second substrates.

In the liquid crystal display panel of the present invention, the liquid crystal display panel may be driven in a passive matrix scheme or in an active matrix scheme.

A method according to the present invention is provided for testing a liquid crystal display panel substrate including a substrate, an alignment film provided on the substrate and configured to control alignment of a liquid crystal layer, and a metal pattern provided on the substrate in a region where a sealing member is to be provided. The method includes, at least, an irradiation step of irradiating the metal pattern with infrared light using a Fourier transform infrared spectrometer, a measurement step of receiving the infrared light reflected by the metal pattern using the Fourier transform infrared spectrometer to measure an infrared absorption spectrum, and a determination step of determining, based on the infrared absorption spectrum, the presence or absence of the alignment film in the region.

With this configuration, the infrared light reflected by the metal pattern is received by the Fourier transform infrared spectrometer to measure an infrared absorption spectrum, whereby the presence or absence of the alignment film in the region is determined. Therefore, by performing a microscopic reflection technique using the Fourier transform infrared spectrometer, the presence or absence of the alignment film in the region where the sealing member is to be provided can be determined. Thus, the presence or absence of the alignment film can be determined by non-contact measurement.

Because the presence or absence of the alignment film can be easily determined by non-contact measurement, even if the alignment film exists in the region where the sealing member is to be provided, the alignment film can be removed quickly and easily. Therefore, the productivity and the yield can be improved.

The metal pattern is provided to perform a microscopic reflection technique using the Fourier transform infrared spectrometer, and therefore, the presence or absence of the alignment film can be determined at low cost.

The metal pattern is provided in the region where the sealing member is to be provided. Therefore, the presence or absence of the alignment film can be determined without impairing the external appearance.

When various alignment film removal techniques are examined, the effectiveness of these alignment film removal techniques can be easily determined. Therefore, the alignment film removal techniques can be examined easily and quickly.

In the liquid crystal display panel substrate testing method of the present invention, in the determination step, the infrared absorption spectrum measured using the Fourier transform infrared spectrometer may be compared with another infrared absorption spectrum previously stored, to determine the presence or absence of the alignment film in the region.

With this configuration, the infrared absorption spectrum measured using the Fourier transform infrared spectrometer is compared with another infrared absorption spectrum previously stored, to determine the presence or absence of the alignment film in the region. Therefore, the presence or absence of the alignment film can be tested quickly and accurately using a simple technique.

In the liquid crystal display panel substrate testing method of the present invention, in the irradiation step, the infrared light polarized in parallel to an incidence plane may be incident at an incident angle between 75° and 85° inclusive.

With this configuration, when an infrared absorption spectrum is measured using the Fourier transform infrared spectrometer, the infrared absorption spectrum can be measured using a high-sensitivity reflection technique (or reflection absorption spectroscopy). Therefore, a thin film (alignment film) existing on a surface of the metal pattern can be detected with considerably high sensitivity. Therefore, even if the alignment film is considerably thin, the presence or absence of the alignment film in the region where the sealing member is to be provided can be tested.

Advantages of the Invention

According to the present invention, the presence or absence of the alignment film in the region where the sealing member is to be provided can be determined by non-contact measurement. It can be reliably confirmed whether or not the alignment film has been successfully removed from the region where the sealing member is to be provided. the presence or absence of the alignment film in the region where the sealing member is to be provided can be determined quickly and easily without destroying the liquid crystal display panel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view showing a general configuration of a liquid crystal display panel according to an embodiment of the present invention.

FIG. **2** is a cross-sectional view taken along line A-A of FIG. **1**.

FIG. **3** is a diagram showing an equivalent circuit of the liquid crystal display panel of the embodiment of the present invention.

FIG. **4** is a cross-sectional view showing a general configuration of a TFT substrate included in the liquid crystal display panel of the embodiment of the present invention.

FIG. **5** is a cross-sectional view showing a general configuration of a display portion of the liquid crystal display panel of the embodiment of the present invention.

FIG. **6** is a cross-sectional view showing the general configuration of the TFT substrate included in the liquid crystal display panel of the embodiment of the present invention.

FIG. **7** is a cross-sectional view showing a general configuration of a CF substrate included in the liquid crystal display panel of the embodiment of the present invention.

FIG. **8** is a diagram for describing a method for determining the presence or absence of an alignment film according to an embodiment of the present invention.

FIG. **9** is a flowchart for describing the method for determining the presence or absence of an alignment film according to the embodiment of the present invention.

FIG. **10** is a diagram showing an example infrared absorption spectrum measured by a method for testing a substrate for a liquid crystal display panel according to an embodiment of the present invention.

FIG. **11** is a diagram for determining the presence or absence of an alignment film according to an embodiment of the present invention.

FIG. **12** is a diagram showing an example infrared absorption spectrum measured by the method for testing a substrate for a liquid crystal display panel according to the embodiment of the present invention.

FIG. **13** is a plan view showing a metal pattern in the liquid crystal display panel of the embodiment of the present invention.

FIG. **14** is a diagram for describing a variation of a method for measuring an infrared absorption spectrum in a Fourier transform infrared spectrometer used in the method for testing a substrate for a liquid crystal display panel according to the embodiment of the present invention.

FIG. **15** is a diagram for describing a variation of the method for measuring an infrared absorption spectrum in a Fourier transform infrared spectrometer used in the method for testing a substrate for a liquid crystal display panel according to the embodiment of the present invention.

FIG. **16** is a plan view showing a variation of the metal pattern in the liquid crystal display panel of the embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

Embodiments of the present invention will be described hereinafter with reference to the accompanying drawings. Note that the present invention is not intended to be limited to the embodiments described below.

FIG. **1** is a plan view showing a general configuration of a liquid crystal display panel according to an embodiment of the present invention. FIG. **2** is a cross-sectional view taken along line A-A of FIG. **1**. FIG. **3** is a diagram showing an equivalent circuit of the liquid crystal display panel of the embodiment of the present invention. FIG. **4** is a cross-sectional view showing a general configuration of a TFT substrate included in the liquid crystal display panel of the embodiment of the present invention. FIG. **5** is a cross-sectional view showing a general configuration of a display portion of the liquid crystal display panel of the embodiment of the present invention. FIG. **6** is another cross-sectional view showing the general configuration of the TFT substrate included in the liquid crystal display panel of the embodiment of the present invention. FIG. **7** is a cross-sectional view showing a general configuration of a CF substrate included in the liquid crystal display panel of the embodiment of the present invention.

As shown in FIGS. **1** and **2**, the liquid crystal display panel **1** includes the TFT substrate **10** (a first substrate (a substrate for a liquid crystal display panel)), the CF substrate **20** (a second substrate (a substrate for a liquid crystal display panel)) facing the TFT substrate **10**, and a liquid crystal layer **25** (display medium layer) provided between the TFT substrate **10** and the CF substrate **20**. The liquid crystal display panel **1** also includes a frame-shaped sealing member **26** which is sandwiched between the TFT substrate **10** and the CF substrate **20** to bond the TFT substrate **10** and the CF substrate **20** together and enclose the liquid crystal layer **25**. The sealing member **26** is formed to surround the liquid crystal layer **25**. The TFT substrate **10** and the CF substrate **20** are bonded together via the sealing member **26**.

As shown in FIG. **1**, in the liquid crystal display panel **1**, the TFT substrate **10** protrudes from the CF substrate **20** at an upper side thereof. The protruding portion forms a terminal region T into which a plurality of interconnects **36** described below, such as gate lines, source lines, etc., are extended and in which a plurality of terminals **37** for driving the liquid crystal display panel **1** are provided and connected to the interconnects **36**.

In the liquid crystal display panel **1**, a display region (or a middle region) H for displaying an image is provided in a region where the TFT substrate **10** and the CF substrate **20** overlap. Here, the display region H includes a plurality of pixels arranged in a matrix (each pixel is the smallest unit of an image).

The TFT substrate **10** also has a picture-frame region F which is formed around the display region H and does not contribute to displaying. As shown in FIG. **1**, the picture-frame region F is formed in the shape of a frame around the display region H.

Note that, as shown in FIG. **1**, the sealing member **26** is formed in the shape of a rectangular frame surrounding the entire perimeter of the display region H. The sealing member **26** has a frame width Z which is, but not particularly limited to, between 0.5 mm and 2.0 mm inclusive, for example.

The liquid crystal layer **25** is made of, for example, a nematic liquid crystal material, which has electro-optic properties.

As shown in FIGS. **3** and **4**, the TFT substrate **10** includes an insulating substrate **6** (a glass substrate or a plastic substrate, etc.), a plurality of gate lines **11** provided on the insulating substrate **6** and extending in parallel to each other, and a gate insulating film **12** covering the gate lines **11**. The TFT substrate **10** also includes a plurality of source lines **14** provided on the gate insulating film **12** and extending in a direction perpendicular to the gate lines **11** and in parallel to each other, a plurality of TFTs **5** provided at respective corresponding intersection portions of the gate lines **11** and the source line **14**, and an interlayer insulating film **38** including a first interlayer insulating film **15** and a second interlayer insulating film **16** which are successively formed to cover the source lines **14** and the TFTs **5**. The TFT substrate **10** also includes a plurality of pixel electrodes **19** arranged in a matrix on the second interlayer insulating film **16** and connected to the respective corresponding TFTs **5**, and an alignment film **9** covering the pixel electrodes **19**.

As shown in FIG. **4**, the TFT **5** includes a gate electrode **17** which is a laterally protruding portion of the corresponding gate line **11**, the gate insulating film **12** covering the gate electrode **17**, an island-like semiconductor layer **13** on the gate insulating film **12** directly above the gate electrode **17**, and a source electrode **18** and a drain electrode **46** provided on the semiconductor layer **13** and facing each other. Here, the source electrode **18** is a laterally protruding portion of the corresponding source line **14**. As shown in FIG. **4**, the drain electrode **46** is connected to the pixel electrode **19** via a contact hole **30** formed in the first interlayer insulating film **15** and the second interlayer insulating film **16**. As shown in FIG. **5**, the pixel electrode **19** includes a transparent electrode **31** provided on the second interlayer insulating film **16**, and a reflective electrode **32** provided on a surface of the transparent electrode **31**. As shown in FIG. **4**, the semiconductor layer **13** includes an intrinsic amorphous silicon layer **13*a*** as the lower layer and an n^+ amorphous silicon layer **13*b*** doped with phosphorus as the upper layer. The intrinsic amorphous silicon layer **13*a*** exposed through the source electrode **18** and the drain electrode **46** forms a channel region.

Note that the configuration of the TFT substrate **10** is not limited to this. Alternatively, for example, an underlying insulating film may be provided below the gate insulating film **12**, or a protective film or an organic insulating film may be provided above the first interlayer insulating film **15** and the second interlayer insulating film **16**.

As shown in FIG. **5**, in the display portions of the TFT substrate **10** and the liquid crystal display panel **1** including the TFT substrate **10**, the reflective electrode **32** forms a reflective region R, and the transparent electrode **31** exposed through the reflective electrode **32** forms a transmissive region T.

As shown in FIG. **5**, the second interlayer insulating film **16** as the lower layer of the pixel electrode **19** has an uneven surface, and the reflective electrode **32** provided on the surface of the second interlayer insulating film **16** with the transparent electrode **31** being interposed therebetween, also has an uneven surface.

Note that the reflective region R may not be necessarily required, and only the transmissive region T may be provided.

Examples of a material for the first interlayer insulating film **15** include, but are not particularly limited to, silicon oxide (SiO_2), silicon nitride (SiN_x (x is a positive integer)), etc. The first interlayer insulating film **15** preferably has a thickness between 600 nm and 1000 nm inclusive. This is because if the thickness of the first interlayer insulating film **15** is smaller than 600 nm, it may be disadvantageously difficult to flatten the first interlayer insulating film **15**, and if the thickness of the first interlayer insulating film **15** is greater than 1000 nm, it may be disadvantageously difficult to form the contact hole **30** by etching.

As shown in FIG. **5**, the CF substrate **20** includes an insulating substrate **21** (a glass substrate or a plastic substrate, etc.), a color filter layer **22** provided on the insulating substrate **21**, and a transparent layer **23** provided in the reflective region R of the color filter layer **22** and for compensating for a difference in light path between the reflective region R and the transmissive region T. The CF substrate **20** also includes a common electrode **24** covering the transmissive region T of the color filter layer **22** and the transparent layer **23** (i.e., the reflective region R), a pillar-like photospacer **29** provided on the common electrode **24**, and an alignment film **48** covering the common electrode **24** and the photospacer **29**. Note that the color filter layer **22** includes color layers **28** (a red color layer R, a green color layer G, or blue color layer B for each pixel), and a black matrix **27** (light blocking film). The black matrix **27** is provided between adjacent color layers **28** and plays a role in separating the color layers **28** from each other. Also, as shown in FIG. **5**, the black matrix **27** faces an interlayer insulating film **39** included in the TFT substrate **10** with the photospacer **29** being interposed between the black matrix **27** and the interlayer insulating film **39**.

Note that the photospacer **29** is, for example, made of an acrylic photosensitive resin and formed by photolithography.

The black matrix **27** is made of a metal material (tantalum (Ta), chromium (Cr), molybdenum (Mo), nickel (Ni), titanium (Ti), copper (Cu), aluminum (Al), etc.), a resin material in which a black pigment (carbon particles etc.) is dispersed, or a resin material including a multilayer structure of a plurality of light-transmissive color layers having different colors, etc.

Note that the configuration of the CF substrate **20** is not limited to this. Alternatively, for example, a protective film may be provided above the black matrix **27**.

As shown in FIG. **5**, the alignment films **9** and **48** are provided on sides closer to the liquid crystal layer **25** of the TFT substrate **10** and the CF substrate **20**, respectively, and are used to control the alignment of the liquid crystal layer **25**. The alignment films **9** and **48** are, for example, made of polyimide resin and formed by a printing technique (e.g, flexographic printing (transfer printing) as flexography, spin coating, etc.) or a droplet discharge technique of discharging droplets of a liquid material.

The alignment films **9** and **48** have a thickness of about 200 nm in the display region H and a thickness of several nanometers to several tens of nanometers in the vicinity of a region **35** where the sealing member **26** is to be provided other than the display region H.

The semi-transmissive liquid crystal display panel **1** is thus configured so that light entering through the CF substrate **20** in the reflective region R is reflected by the reflective electrode **32** while light from a backlight unit (not shown) entering through the TFT substrate **10** in the transmissive region T is allowed to travel therethrough.

The liquid crystal display panel **1** has one pixel for each pixel electrode. In each pixel, by applying a voltage having a predetermined magnitude to the liquid crystal layer **25** to change the alignment of the liquid crystal layer **25** and thereby adjust the rate of transmission of incident light from, for example, the backlight unit, an image is displayed.

In this embodiment, as shown in FIGS. **2**, **6**, and **7**, a metal pattern **2** which is a reflective member is provided in the region **35** where the sealing member **26** is to be provided.

The metal pattern **2** is a mark for determining the presence or absence of the alignment films **9** and **48** in the region **35** where the sealing member **26** is to be provided. As described below, infrared light emitted from a Fourier transform infrared spectrometer (FT-IR device) is reflected back to the Fourier transform infrared spectrometer by the metal pattern **2** in order to determine the presence or absence of the alignment films **9** and **48** in the region **35** where the sealing member **26**.

A material for the metal pattern **2** is not particularly limited if the material reflects infrared light. In terms of low cost and ease of formation, the metal pattern **2** may be made of the same material of the gate line **11** and the source line **14**, i.e., tantalum (Ta), chromium (Cr), molybdenum (Mo), nickel (Ni), titanium (Ti), copper (Cu), aluminum (Al), etc.

As shown in FIGS. **1** and **2**, the metal pattern **2** is formed around the liquid crystal layer **25**, as with the sealing member **26**. In a width direction X of the sealing member **26**, a position of an inner circumferential surface (i.e., a surface closer to the liquid crystal layer **25** in the width direction X) **2***a* of the metal pattern **2** coincides with a position of an inner circumferential surface (i.e., a surface closer to the liquid crystal layer **25** in the width direction X) **26***a* of the sealing member **26**.

Also, as shown in FIGS. **1** and **2**, in the width direction X of the sealing member **26**, an outer circumferential surface (i.e., a surface opposite to the liquid crystal layer **25** in the width direction X) **2***b* of the metal pattern **2** is located further inside (closer to the liquid crystal layer **25**) than an outer circumferential surface (i.e., a surface opposite to the liquid crystal layer **25** in the width direction X) **26***b* of the sealing member **26**.

Thus, the metal pattern **2** is extended in the width direction X of the sealing member **26** from the position of the inner circumferential surface **26***a* of the sealing member **26** toward the outer circumferential surface **26***b* of the sealing member **26**.

In other words, as shown in FIGS. **6** and **7**, in the TFT substrate **10** and the CF substrate **20** before being bonded together via the sealing member **26** (i.e., before the sealing member **26** is formed), in a width direction (i.e., the width direction of the sealing member **26**) X of the region **35** where the sealing member **26** is to be provided, the position of the inner circumferential surface **2***a* of the metal pattern **2** coincides with a position of an inner circumferential surface (i.e., a surface closer to the liquid crystal layer **25** in the width direction X) **35***a* of the region **35**. Thus, the metal pattern **2** is provided in the region **35** so that the inner circumferential surface **2***a* of the metal pattern **2** and the inner circumferential surface **35***a* of the region **35** are on the same plane.

As shown in FIGS. **1**, **2**, **6**, and **7**, the metal pattern **2** is also formed in the shape of a frame extending along the inner circumferential surface **35***a* of the region **35**.

As shown in FIGS. **6** and **7**, in the width direction X of the region **35**, the outer circumferential surface **2***b* of the metal pattern **2** is also located further inside (closer to the liquid crystal layer **25**) than an outer circumferential surface (i.e., a surface opposite to the liquid crystal layer **25** in the width direction X) **35***b* of the region **35**.

Thus, the metal pattern **2** is extended in the width direction X of the region **35** from the position of the inner circumferential surface **35***a* of the region **35** toward the outer circumferential surface **35***b* of the region **35**.

A thickness C of the metal pattern **2** is preferably thicker (e.g., about 500 nm) than the thickness (e.g., 200 nm) of the alignment films **9** and **48** in order to reliably block the alignment films **9** and **48** at the position of the inner circumferential surface **2***a* of the metal pattern **2**. In general, the thickness of the alignment film in the vicinity of the sealing member region other than the display region is thinner (several nanometers to several tens of nanometers) than 200 nm. Therefore, if the thickness C is about 500 nm, a sufficient effect is expected.

In order to avoid the problem that, due to its thickness, the metal pattern **2** interferes with the bonding of the TFT substrate **10** and the CF substrate **20** via the sealing member **26**, the thickness C of the metal pattern **2** is preferably smaller than a distance D (typically, about 3 μm) between the TFT substrate **10** and the CF substrate **20** in a thickness direction Y of the liquid crystal display panel **1**. In other words, the relationship C<D is preferably satisfied.

In order to improve the detection accuracy of the Fourier transform infrared spectrometer (FT-IR device) for infrared light reflected by a surface of the metal pattern **2**, the metal pattern **2** preferably has a width P of 50 μm or more (i.e., 50 μm or more from the inner circumferential surface **35***a* toward the outer circumferential surface **35***b* of the region **35**).

In this embodiment, the region **35** where the sealing member **26** is to be provided has a width W which can be set between, for example, 0.5 mm and 2.0 mm inclusive, as with the frame width Z of the sealing member **26**.

In order to reliably reflect infrared light emitted from the Fourier transform infrared spectrometer, the metal pattern **2** needs to be provided at an uppermost layer in each of the TFT substrate **10** and the CF substrate **20**. Therefore, in the TFT substrate **10** of FIG. **6**, the metal pattern **2** is provided on the interlayer insulating film **38** on which the alignment film **9** is provided. Similarly, in the CF substrate **20** of FIG. **7**, the metal pattern **2** is provided on the black matrix **27** on which the alignment film **48** is provided.

Next, a method for testing the TFT substrate **10** and the CF substrate **20** for a liquid crystal display panel (i.e., a method for determining the presence or absence of an alignment film in a region where a sealing member is to be provided) will be described. FIG. **8** is a diagram for describing the method for determining the presence or absence of an alignment film according to an embodiment of the present invention. FIG. **9** is a flowchart for describing the method for determining the presence or absence of an alignment film according to the embodiment of the present invention. Note that, here, a method for determining the presence or absence of an alignment film in a region where a sealing member is to be provided in the TFT substrate **10** will be described by way of example.

As shown in FIG. **8**, a determination device **40** for the liquid crystal display panel **1** of this embodiment includes a Fourier transform infrared spectrometer **4**, an A/D converter **7** connected to the Fourier transform infrared spectrometer **4**, and a spectrum measurement unit **8** which is connected to the A/D converter **7** and is used to measure an infrared absorption spectrum of a resin (e.g., polyimide resin) of which the alignment film **9** is made. The determination device **40** also includes an alignment film determination unit **41** which is connected to the spectrum measurement unit **8** and is used to determine the presence or absence of the alignment film **9** in the region **35** where the sealing member **26** is to be provided, and a storage unit **42** which is connected to the alignment film determination unit **41** and is used to store predetermined data for determining the presence or absence of the alignment film **9**.

The presence or absence of the alignment film **9** in the region **35** where the sealing member **26** is to be provided is determined as follows. Initially the Fourier transform infrared spectrometer **4** emits infrared light **43** toward the metal pattern **2**, so that a surface **2***c* of the metal pattern **2** is irradiated with the infrared light **43** (step S**1**).

Note that a movable stage **45** may be provided on which the TFT substrate **10** is placed and supported. The stage **45** may be freely moved so that the surface **2***c* of the metal pattern **2** is reliably irradiated with the infrared light **43** emitted from the Fourier transform infrared spectrometer **4**.

The infrared light **43** is almost totally reflected by the surface **2***c* of the metal pattern **2**, and the reflected infrared light **44** is projected back onto a light receiving surface of a detector provided in the Fourier transform infrared spectrometer **4**, and the infrared light **44** reflected by the metal pattern **2** is received by the Fourier transform infrared spectrometer **4** (step S**2**).

More specifically, the infrared light **43** emitted from a light source of the Fourier transform infrared spectrometer **4** passes through an aperture which is provided in the Fourier transform infrared spectrometer **4** and is narrowed so that only a target region (i.e., a region where the metal pattern **2** is provided) is irradiated, and thereafter, is reflected by the surface **2***c* of the metal pattern **2** to pass through the aperture again, whereby diffracted light is removed. In other words, infrared light which has passed through the aperture, the metal pattern **2**, and the aperture sequentially is projected onto the light receiving surface of the detector.

Next, data of the infrared light **44** projected onto the light receiving surface of the detector is converted from an analog signal into a digital signal by the A/D converter **7** (step S**3**). Next, the resulting digital signal is input to the spectrum measurement unit **8** (step S**4**), which performs a Fourier transform on the input digital signal, whereby an infrared absorption spectrum is measured (step S**5**).

Here, as shown in FIG. **8**, if the alignment film **9** does not exist in the region **35** where the sealing member **26** is to be provided (i.e., the alignment film **9** is not extended beyond the inner circumferential surface **2***a* of the metal pattern **2** into the region **35** where the sealing member **26** is to be provided), the alignment film **9** does not exist on the surface **2***c* of the metal pattern **2** which is irradiated with the infrared light **43**. Therefore, as shown in FIG. **10**, a component corresponding to the alignment film **9** (i.e., a component corresponding to polyimide resin) does not appear in an infrared absorption spectrum measured by the spectrum measurement unit **8**, i.e., there is not a peak in the measured infrared absorption spectrum.

On the other hand, as shown in FIG. **11**, if the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided (i.e., the alignment film **9** is extended beyond the inner circumferential surface **2***a* of the metal pattern **2** into the region **35** where the sealing member **26** is to be provided), the alignment film **9** exists on the surface **2***c* of the metal pattern **2** which is irradiated with the infrared light **43**. Therefore, the infrared light **43** incident to the surface **2***c* of the metal pattern **2** is absorbed by a component (i.e., polyimide resin) of the alignment film **9**. Therefore, as shown in FIG. **12**, a component corresponding to the alignment film **9** (i.e., a component corresponding to polyimide resin) appears in an infrared absorption spectrum measured by the spectrum measurement unit **8**, i.e., there is a peak in the measured infrared absorption spectrum.

Note that if the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided, the infrared light **43** emitted from the Fourier transform infrared spectrometer **4** passes through the alignment film **9** to reach the surface **2***c* of the metal pattern **2**. Thereafter, the infrared light **43** is almost totally reflected by the surface **2***c* of the metal pattern **2**, and the reflected infrared light **44** passes through the alignment film **9** again and is then projected onto the light receiving surface of the detector of the Fourier transform infrared spectrometer **4**.

More specifically, the infrared light **43** emitted from the light source of the Fourier transform infrared spectrometer **4** passes through the aforementioned aperture and then the alignment film **9**, is reflected by the surface **2***c* of the metal pattern **2**, and then passes through the aperture again, whereby diffracted light is removed. In other words, infrared light which has passed through the aperture, the alignment film **9**, the metal pattern **2**, the alignment film **9**, and the aperture sequentially is projected onto the light receiving surface of the detector.

Next, data of the measured infrared absorption spectrum is input to the alignment film determination unit **41** (step S**6**). The alignment film determination unit **41** is connected to the storage unit **42** which stores data of an infrared absorption spectrum of the resin (e.g., polyimide resin) of which the alignment film **9** is made.

The alignment film determination unit **41** determines, based on the infrared absorption spectrum measured by the Fourier transform infrared spectrometer **4**, whether or not the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided.

More specifically, the alignment film determination unit **41** reads, from the storage unit **42**, the infrared absorption spectrum data of the resin (e.g., polyimide resin) of the alignment film **9**, and compares the data of the measured infrared absorption spectrum with the previously stored infrared absorption spectrum data of the resin of the alignment film **9** (step S**7**). The alignment film determination unit **41** determines whether or not the data of the measured infrared absorption spectrum matches the infrared absorption spectrum data of the resin of the alignment film **9** read from the storage unit **42** (step S**8**).

In other words, the alignment film determination unit **41** compares an infrared absorption spectrum measured by the Fourier transform infrared spectrometer **4** with an infrared absorption spectrum previously stored in the storage unit **42**, to determine the presence or absence of the alignment film **9** in the region **35** where the sealing member **26** is to be provided.

For example, if, as shown in FIG. **11**, the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided, as shown in FIG. **12** an infrared absorption spectrum measured by the Fourier transform infrared spectrometer **4** is the infrared absorption spectrum of polyimide resin, and matches the infrared absorption spectrum data of the resin (i.e., polyimide resin) of the alignment film **9** read from the storage unit **42**. Therefore, the alignment film determination unit **41** determines that the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided (step S**9**).

On the other hand, if, as shown in FIG. **8**, the alignment film **9** does not exist in the region **35** where the sealing member **26** is to be provided, as shown in FIG. **10** an infrared absorption spectrum measured by the Fourier transform infrared spectrometer 4 does not have a peak and does not match the infrared absorption spectrum data of the resin (i.e., polyimide resin) of the alignment film **9** read from the storage unit **42**. Therefore, the alignment film determination unit **41** determines that the alignment film **9** does not exist in the region **35** where the sealing member **26** is to be provided (step S**10**).

Note that if it is determined that the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided, the alignment film **9** existing in the region **35** where the sealing member **26** is to be provided is removed, and thereafter, steps S**1**-S**10** are performed again to determine the presence or absence of the alignment film **9** in the region **35** where the sealing member **26** is to be provided (i.e., it is determined whether or not the alignment film **9** has been successfully removed from the region **35** where the sealing member **26** is to be provided), thereby confirming that the alignment film **9** does not exist in the region **35** where the sealing member **26** is to be provided.

In the Fourier transform infrared spectrometer of this embodiment, the measurement is preferably performed using a wavelength in a mid-infrared wavelength region (wavelength: 2.5-25 μm) which is easily absorbed by a functional group of an organic compound molecule.

The wave number (the reciprocal of the wavelength) is preferably 4000-650 cm^{-1}. In this wave number range, not only polyimide resin but also most organic materials can be identified. Therefore, it can be said that a low wave number region (650-400 cm^{-1}) is not required.

Moreover, among FT-IR detectors, a mercury-cadmium-tellurium (MCT) detector, which has a relatively high sensitivity, is preferably used. Note that, the measurable wave number region of the MCT detector is 4000-650 cm^{-1}. Because the MCT detector does not have detection capability in the aforementioned low wave number region (650-400 cm^{-1}), it can be said that the low wave number region (650-400 cm^{-1}) is not required even when the MCT detector is used.

Assuming that the resolution during measurement is, for example, 4 cm^{-1} and the number of integrations is 32, as shown in FIG. **13** an area E for a single measurement operation can be set to 50 μm (width)×50 μm (length). In the case of these settings, the measurement time is about two minutes, i.e., the measurement can be done considerably quickly.

Thus, in this embodiment, similar to the sealing member **26**, the frame-shaped metal pattern **2** is provided along the inner circumferential surface **35***a* of the region **35**, i.e., the metal pattern **2** is formed around the liquid crystal layer **25**. As a result, the presence or absence of the alignment film **9** can be determined at any position in the entire region **35** where the sealing member **26** is to be provided.

Next, a method for manufacturing the liquid crystal display panel of this embodiment will be described by way of example. Note that the manufacturing method of this embodiment includes a TFT substrate fabrication process, a CF substrate fabrication process, and a substrate bonding process.

<TFT Substrate Fabrication Process>

Initially, for example, a titanium film, an aluminum film, and a titanium film, etc. are successively formed on the entire insulating substrate **6** by sputtering, and thereafter, patterning is performed by photolithography, thereby forming the gate line **11** and the gate electrode **17** each having a thickness of about 4000 Å.

Next, on the entire substrate on which the gate line **11** and the gate electrode **17** have been formed, for example, a silicon nitride film etc. is formed by plasma-enhanced chemical vapor deposition (CVD), thereby forming the gate insulating film **12** having a thickness of about 4000 Å.

Moreover, on the entire substrate on which the gate insulating film **12** has been formed, for example, an intrinsic amorphous silicon film (thickness: about 2000 Å) and an n^+ amorphous silicon film doped with phosphorus (thickness: about 500 Å) are successively formed by plasma-enhanced CVD, and thereafter, patterning is performed by photolithography, thereby forming, on the gate electrode **17**, an island-like semiconductor formation layer having a multilayer structure of the intrinsic amorphous silicon layer and the n^+ amorphous silicon layer.

Thereafter, on the entire substrate on which the semiconductor formation layer has been formed, for example, an aluminum film and a titanium film, etc. are successively formed by sputtering, and thereafter, patterning is performed by photolithography, thereby forming the source line **14**, the source electrode **18**, and the drain electrode **46** each having a thickness of about 2000 Å.

Next, the n^+ amorphous silicon layer in the semiconductor formation layer is etched using the source electrode **18** and the drain electrode **46** as a mask to perform patterning, thereby forming a channel region. Thus, the semiconductor layer **13** and the TFT **5** including the semiconductor layer **13** are formed.

Moreover, on the entire substrate on which the TFT **5** has been formed, for example, a silicon nitride film etc. is formed by plasma-enhanced CVD, thereby forming the first interlayer insulating film **15** having a thickness of about 4000 Å.

Thereafter, on the entire substrate on which the first interlayer insulating film **15** has been formed, for example, a positive photosensitive resin having a thickness of about 3 μm is applied by spin coating, and the applied photosensitive resin is uniformly exposed to light with relatively low illuminance using a first photomask having a plurality of circular light blocking portions which are separated from each other and randomly distributed. Next, the applied photosensitive resin is uniformly exposed to light with relatively high illuminance using a second photomask having an opening at a position corresponding to the contact hole **30** on the drain electrode **46**, and thereafter, is developed. As a result, the portion of the photosensitive resin exposed to light with high illuminance is completely removed, and the portion of the photosensitive resin exposed to light with low illuminance is partially removed, leaving about 40% of the thickness, and the unexposed portion of the photosensitive resin is partially removed, leaving about 80% of the thickness. Moreover, the substrate in which the photosensitive resin has been developed is heated to about 200° C., so that the photosensitive resin is melted, thereby forming the second interlayer insulating film **16** having the reflective region R which has a smooth uneven surface (including smooth protruding and recessed portions). Thereafter, the first interlayer insulating film **15** exposed through the second interlayer insulating film **16** is etched to form the contact hole **30**.

Next, on the entire substrate (i.e., on the second interlayer insulating film **16**), a transparent conductive film (e.g., an ITO film etc.) is formed by sputtering, and thereafter, patterning is performed by photolithography, thereby forming, on the insulating substrate **6**, the transparent electrode **31** having a thickness of about 1000 Å.

Next, on the entire substrate on which the transparent electrode **31** has been formed, a molybdenum film (thickness: about 750 Å) and an aluminum film (thickness: about 1000 Å) are successively formed by sputtering. Thereafter, the reflective electrode **32** is formed on a surface of the transparent electrode **31** in the reflective region R by patterning by photolithography, thereby forming the pixel electrode **19** including the transparent electrode **31** and the reflective electrode **32**.

Next, on the entire interlayer insulating film **38**, for example, a titanium film and an aluminum film are formed by sputtering, and thereafter, patterning is performed by photolithography, thereby forming the metal pattern **2** having a predetermined thickness (e.g., about 500 nm) in the shape of a frame in the region **35** where the sealing member **26** is to be provided.

Next, the entire substrate is washed, and thereafter, polyimide resin is applied by a printing technique etc. on the entire substrate on which the pixel electrode **19** has been formed, and thereafter, a rubbing treatment is performed, thereby forming the alignment film **9** having a thickness of about 200 nm.

Next, by using the aforementioned determination method of steps S**1**-S**10**, the presence or absence of the alignment film **9** in the region **35** where the sealing member **26** is to be provided is performed.

In this case, as described above in step S**10**, if the alignment film determination unit **41** determines that the alignment film **9** does not exist in the region **35** where the sealing member **26** is to be provided, the fabrication process of the TFT substrate **10** is ended.

On the other hand, as described above in step S**9**, if the alignment film determination unit **41** determines that the alignment film **9** exists in the region **35** where the sealing member **26** is to be provided, the alignment film **9** existing in the region **35** where the sealing member **26** is to be provided (i.e., the alignment film **9** existing on the surface **2***c* of the metal pattern **2**) is removed.

Note that the alignment film **9** may be removed by any techniques including, for example, a laser removal technique, a plasma removal technique, and a liftoff technique using a water-soluble resist. After removal of the alignment film **9** existing in the region **35** where the sealing member **26** is to be provided, steps S**1**-S**10** are performed again to determine the presence or absence of the alignment film **9** in the region **35** where the sealing member **26** is to be provided (i.e., it is determined whether or not the alignment film **9** has been successfully removed from the region **35** where the sealing member **26** is to be provided). After confirming that the alignment film **9** does not exist in the region **35** where the sealing member **26** is to be provided, the fabrication process of the TFT substrate **10** is ended.

Also, as described above, in the width direction X of the region **35** where the sealing member **26** is to be provided, the metal pattern **2** is provided so that the position of the inner circumferential surface **2***a* of the metal pattern **2** coincides with the position of the inner circumferential surface **35***a* of the region **35** (i.e., in the region **35**, the inner circumferential surface **2***a* of the metal pattern **2** and the inner circumferential surface **35***a* of the region **35** are on the same plane). As a result, as shown in FIGS. **6** and **8**, the alignment film **9** is blocked at the position of the inner circumferential surface **2***a* of the metal pattern **2** (i.e., the inner circumferential surface **35***a* of the region **35** where the sealing member **26** is to be provided), whereby the formation of the alignment film **9** in the region **35** where the sealing member **26** is to be provided can be effectively reduced or prevented.

Thus, the TFT substrate **10** can be fabricated.

<CF Substrate Fabrication Process>

Initially, on the entire insulating substrate **21** (e.g., a glass substrate etc.), for example, a positive photosensitive resin in which a black pigment (e.g., carbon particles etc.) is dispersed is applied by spin coating, and the applied photosensitive resin is exposed to light through a photomask and then developed and heated, thereby forming the black matrix **27** having a thickness of about 2.0 μm.

Next, on the substrate on which the black matrix **27** has been formed, for example, a red-, green-, or blue-colored acrylic photosensitive resin is applied, and the applied photosensitive resin is exposed to light through a photomask and then developed to perform patterning, thereby forming a color layer with a selected color (e.g., a red color layer R) **28** having a thickness of about 2.0 μm. Moreover, for the two other colors, a similar process is repeated to for the two other color layers (e.g., a green color layer G and a blue color layer B) **28** each having a thickness of about 2.0 μm. Thus, the color filter layer **22** having the red color layer R, the green color layer G, and the blue color layer B is formed.

Next, on the substrate on which the color filter layer **22** has been formed, an acrylic photosensitive resin is applied by spin coating, and the applied photosensitive resin is exposed to light through a photomask and then developed, thereby forming the transparent layer **23** having a thickness of about 2 μm. Next, on the entire substrate on which the transparent layer **23** has been formed, for example, an ITO film is formed by sputtering, and thereafter, patterning is performed by photolithography, thereby forming the common electrode **24** having a thickness of about 1500 Å.

Next, on the entire substrate on which the common electrode **24** has been formed, an acrylic photosensitive resin is applied by spin coating, and the applied photosensitive resin is exposed to light through a photomask and then developed, thereby forming the photospacer **29** having a thickness of about 4 μm.

Next, on the entire black matrix **27**, for example, a titanium film and an aluminum film are formed by sputtering, and thereafter, patterning is performed by photolithography, thereby forming the metal pattern **2** having a predetermined thickness (e.g., about 500 nm) in the shape of a frame in the region **35** where the sealing member **26** is to be provided.

Next, the entire substrate is washed, and thereafter, on the entire substrate on which the common electrode **24** has been formed, polyimide resin is applied by a printing technique etc., thereby forming the alignment film **48** having a thickness of about 200 nm.

Next, by using the determination method described above in steps S**1**-S**10**, the presence or absence of the alignment film **48** in the region **35** where the sealing member **26** is to be provided is determined.

In this case, as described above in step S**10**, if the alignment film determination unit **41** determines that the alignment film **48** does not exist in the region **35** where the sealing member **26** is to be provided, the fabrication process of the CF substrate **20** is ended.

On the other hand, as described above in step S**9**, if the alignment film determination unit **41** determines that the alignment film **48** exists in the region **35** where the sealing member **26** is to be provided, the alignment film **48** existing in the region **35** where the sealing member **26** is to be provided (i.e., the alignment film **48** existing on the surface **2***c* of the metal pattern **2**) is removed by the aforementioned laser removal technique, plasma removal technique, or liftoff technique using a water-soluble resist, etc. After removal of the alignment film **48**, steps S**1**-S**10** are performed again to determine the presence or absence of the alignment film **48** in the region **35** where the sealing member **26** is to be provided. After confirming that the alignment film **48** does not exist in the region **35** where the sealing member **26** is to be provided, the fabrication process of the CF substrate **20** is ended.

Note that, also in this case, as described above, in the width direction X of the region **35** where the sealing member **26** is to be provided, the metal pattern **2** is provided so that the position of the inner circumferential surface **2***a* of the metal pattern **2** coincides with the position of the inner circumferential surface **35***a* of the region **35**. As a result, as shown in FIG. **7**, the alignment film **48** is blocked at the position of the inner circumferential surface **2***a* of the metal pattern **2** (i.e., the inner circumferential surface **35***a* of the region **35** where the sealing member **26** is to be provided), whereby the formation of the alignment film **48** in the region **35** where the sealing member **26** is to be provided can be effectively reduced or prevented.

Thus, the CF substrate **20** can be fabricated.

<Bonding Process>

Initially, for example, the sealing member **26** made of an ultraviolet curable resin is formed, using a dispenser, in the shape of a frame on the CF substrate **20** fabricated by the CF substrate fabrication process in the region **35** where the sealing member **26** is to be provided.

In this case, as shown in FIGS. **1** and **2**, the sealing member **26** is formed around the liquid crystal layer **25** so that the position of the inner circumferential surface **2***a* of the metal pattern **2** formed on the CF substrate **20** coincides with the position of the inner circumferential surface **26***a* of the sealing member **26** in the width direction X of the sealing member **26**, and the sealing member **26** covers the metal pattern **2**.

Next, a liquid crystal material is dropped in a region inside the sealing member **26** of the CF substrate **20** on which the sealing member **26** has been formed.

Moreover, the CF substrate **20** on which the liquid crystal material has been dropped and the TFT substrate **10** which has been fabricated in the TFT substrate fabrication process are bonded together under reduced pressure, and thereafter, the two-substrate structure is exposed to the atmospheric pressure, so that pressure is applied to the front and rear surfaces of the two-substrate structure.

In this case, as shown in FIGS. **1** and **2**, the sealing member **26** is positioned so that the position of the inner circumferential surface **2***a* of the metal pattern **2** formed on the TFT substrate **10** coincides with the position of the inner circumferential surface **26***a* of the sealing member **26** in the width direction X of the sealing member **26**, and the sealing member **26** covers the metal pattern **2**.

Next, the sealing member **26** sandwiched between the two substrates is irradiated with UV light, and thereafter, the two-substrate structure is heated, thereby curing the sealing member **26**.

Thus, the liquid crystal display panel **1** of FIG. **1** can be fabricated.

Note that, in the bonding process, the liquid crystal material may be injected by a vacuum injection technique. In this case, initially, the sealing member **26** made of a thermosetting resin (e.g., epoxy resin) is formed in the shape of a frame on the CF substrate **20** in the region **35** where the sealing member **26** is to be provided. Thereafter, the TFT substrate **10** is put on the CF substrate **20** on which the sealing member **26** has been formed so that the TFT substrate **10** and the CF substrate **20** overlap in the display region H, whereby the TFT substrate **10** and the CF substrate **20** are joined together via the sealing member **26**.

Next, the sealing member **26** is cured by a thermal treatment (e.g., a thermal treatment at 200° C. when epoxy resin is used). Thereafter, a liquid crystal material inlet (not shown) formed in the sealing member **26** is made contact with a liquid crystal material in vacuum atmosphere, and thereafter, the two-substrate structure is placed back in the atmosphere, whereby the liquid crystal material is injected through the liquid crystal material inlet into the inside of the sealing member **26**. As a result, the liquid crystal layer **25** is formed inside the sealing member **26**, and the TFT substrate **10** and the CF substrate **20** are bonded together. Note that after injection of the liquid crystal material, the liquid crystal material inlet is sealed by a sealing material, such as an ultraviolet curable resin etc.

According to this embodiment described above, the following advantages can be obtained.

(1) In this embodiment, in the region **35** where the sealing member **26** is to be provided, the metal pattern **2** is provided which reflects the infrared light **43** emitted from the Fourier transform infrared spectrometer **4** toward the Fourier transform infrared spectrometer **4** in order to determine the presence or absence of the alignment films **9** and **48** in the region **35**. Therefore, the Fourier transform infrared spectrometer **4** can be used to perform a microscopic reflection technique, and therefore, based on an infrared absorption spectrum measured by the Fourier transform infrared spectrometer **4**, the presence or absence of the alignment films **9** and **48** in the region **35** where the sealing member **26** is to be provided can be determined. Thus, the presence or absence of the alignment films **9** and **48** can be determined by non-contact measurement.

(2) In particular, after removal of the alignment films **9** and **48** existing in the region **35** where the sealing member **26** is to be provided, the presence or absence of the alignment films **9** and **48** in the region **35** where the sealing member **26** is to be provided can be determined. Therefore, it can be reliably confirmed whether or not the alignment films **9** and **48** has been successfully removed from the region **35** where the sealing member **26** is to be provided.

(3) As is different from confirmation performed by visual observation using an optical microscope, the result of determination of the presence or absence of the alignment films **9** and **48** does not vary from person to person, and in addition, the presence or absence of the alignment films **9** and **48** can be determined without destroying the liquid crystal display panel **1**.

(4) The presence or absence of the alignment films **9** and **48** can be easily determined by non-contact measurement. Therefore, even if the alignment films **9** and **48** exist in the region **35** where the sealing member **26** is to be provided, the alignment films **9** and **48** can be removed quickly and easily. Therefore, the productivity and the yield can be improved.

(5) The metal pattern **2** is provided to perform a microscopic reflection technique using the Fourier transform infrared spectrometer **4**, and therefore, the presence or absence of the alignment films **9** and **48** can be determined at low cost.

(6) The metal pattern **2** is provided in the region **35** where the sealing member **26** is to be provided. Therefore, the presence or absence of the alignment films **9** and **48** can be determined without impairing the external appearance.

(7) In this embodiment, the metal pattern **2** is positioned so that the inner circumferential surface **2***a* of the metal pattern **2** and the inner circumferential surface **35***a* of the region **35** are on the same plane. Therefore, the alignment films **9** and **48** can be blocked at the position of the inner circumferential surface **2***a* of the metal pattern **2**, whereby the formation of the alignment films **9** and **48** in the region **35** where the sealing member **26** is to be provided can be effectively reduced or prevented.

(8) In this embodiment, the frame-shaped metal pattern **2** is provided along the inner circumferential surface **35***a* of the region **35**. Therefore, the presence or absence of the align-

ment films **9** and **48** can be determined by non-contact measurement over the entire region **35** where the sealing member **26** is to be provided.

(9) In this embodiment, the width P of the metal pattern **2** is set to 50 μm or more. Therefore, in the Fourier transform infrared spectrometer **4**, the accuracy of detection of infrared light reflected by the surface **2***c* of the metal pattern **2** can be improved.

(10) In this embodiment, the thickness C of the metal pattern **2** and the distance D between the TFT substrate **10** and the CF substrate **20** in the thickness direction Y of the liquid crystal display panel **1** are assumed to satisfy the relationship $C<D$. Therefore, when the TFT substrate **10** and the CF substrate **20** are bonded together via the sealing member **26**, it is possible to avoid the problem that, due to its thickness, the metal pattern **2** interferes with the bonding of the TFT substrate **10** and the CF substrate **20**. Therefore, the liquid crystal display panel **1** can be manufactured without changing the manufacture conditions.

(11) In this embodiment, the metal pattern **2** is made of one selected from the group consisting of tantalum, chromium, molybdenum, nickel, titanium, copper, and aluminum. Therefore, the metal pattern **2** can be made of a low-cost and versatile metal material.

(12) In this embodiment, the infrared light **44** reflected by the metal pattern **2** is received by the Fourier transform infrared spectrometer **4** to measure an infrared absorption spectrum, and based on the measured infrared absorption spectrum, the presence or absence of the alignment films **9** and **48** in the region **35** is determined. Therefore, when various alignment film removal techniques are examined, the effectiveness of these alignment film removal techniques can be easily determined. Therefore, the alignment film removal techniques can be examined easily and quickly.

(13) In this embodiment, an infrared absorption spectrum measured by the Fourier transform infrared spectrometer **4** is compared with another infrared absorption spectrum previously stored to determine the presence or absence of the alignment films **9** and **48** in the region **35**. Therefore, the presence or absence of the alignment films **9** and **48** can be tested quickly and accurately using a simple technique.

Note that the above embodiment may be changed or modified as follows.

When a Fourier transform infrared spectrometer is used to measure an infrared absorption spectrum, an infrared absorption spectrum of the surface **2***c* of the metal pattern **2** to be analyzed may be measured using a high-sensitivity reflection technique (or reflection absorption spectroscopy).

In the high-sensitivity reflection technique, as shown in FIGS. **14** and **15**, infrared light (incident light) **50** is caused to enter the surface **2***c* of the metal pattern **2** at a predetermined incident angle (an angle between a normal line **51** of the metal pattern **2** and the infrared light **50**) θ ($75° \leq \theta \leq 85°$), where the infrared light (P-polarized light) **50** is polarized in parallel to the incidence plane (a plane formed by the normal line **51** and the incident light **50**). The infrared light **50** reflected by the surface **2***c* of the metal pattern **2** is projected again onto the light receiving surface of the detector provided in the Fourier transform infrared spectrometer **4**. The presence or absence of the alignment films **9** and **48** in the region **35** where the sealing member **26** is to be provided is determined in a manner similar to steps **S1**-**S10**.

In the high-sensitivity measurement technique, the vibration direction (polarization direction) of the electric field vector of the infrared light is parallel to the incidence plane. Therefore, as shown in FIG. **15**, the electric field vector V_1 of the incident light (i.e., the infrared light **50**) and the electric field vector V_2 of the reflective light (infrared light **52**) intensify each other at the surface **2***c* of the metal pattern **2**, so that stationary vibrating electric field perpendicular to the surface **2***c* of the metal pattern **2** is formed.

Because the incident angle θ of the infrared light **50** is set to $75° \leq \theta \leq 85°$, a distance over which the infrared light **50** transmits through the alignment films **9** and **48** formed on the surface **2***c* of the metal pattern **2** can be elongated.

Therefore, it is possible to detect a thin film (i.e., the alignment films **9** and **48**) existing on the surface **2***c* of the metal pattern **2** with high sensitivity. Therefore, even when the alignment films **9** and **48** are considerably thin (e.g., several nanometers to several tens of nanometers), the presence or absence of the alignment films **9** and **48** in the region **35** where the sealing member **26** is to be provided can be determined.

Also, as shown in FIG. **16**, an interconnect extraction portion **2***d* for extracting a plurality of interconnects **36** (e.g., gate lines, source lines, etc.) into the terminal region T may be formed in the metal pattern **2**. With this configuration, it is possible to reliably avoid contact between the metal pattern **2** and the interconnects **36**, whereby electrical leakage between the metal pattern **2** and the interconnects **36** can be avoided.

Although, in the above embodiment, the metal pattern **2** is provided on both of the TFT substrate **10** and the CF substrate **20**, the metal pattern **2** may be provided on at least one of the TFT substrate **10** and the CF substrate **20**.

In the above embodiment, a voltage is applied to the pixel in an active matrix drive scheme. Alternatively, a voltage may be applied to the pixel in a passive matrix drive scheme. In this case, first electrodes may be provided on the TFT substrate **10**, second electrodes may be provided on the CF substrate **20**, and the first and second electrodes may be arranged to be orthogonal to each other, and pixels may be provided at respective corresponding intersection portions of the first electrodes and the second electrodes.

Although, in the above embodiment, the liquid crystal display panel **1** has been described as a display panel by way of example, the present invention is also applicable to other display panels, such as an organic EL display panel etc.

INDUSTRIAL APPLICABILITY

The present invention is useful for, for example, a liquid crystal display panel, in which a pair of substrates are bonded together with a predetermined gap being interposed therebetween and a liquid crystal layer (display medium layer) is enclosed in the gap between the pair of substrates, and a method for testing the substrates for the liquid crystal display panel.

DESCRIPTION OF REFERENCE CHARACTERS

1 LIQUID CRYSTAL DISPLAY PANEL
2 METAL PATTERN
2*a* INNER CIRCUMFERENTIAL SURFACE OF METAL PATTERN
4 FOURIER TRANSFORM INFRARED SPECTROMETER
8 SPECTRUM MEASUREMENT UNIT
9 ALIGNMENT FILM
10 TFT SUBSTRATE (FIRST SUBSTRATE)
20 CF SUBSTRATE (SECOND SUBSTRATE)
25 LIQUID CRYSTAL LAYER
26 SEALING MEMBER
35 REGION WHERE SEALING MEMBER IS TO BE PROVIDED

35*a* INNER CIRCUMFERENTIAL SURFACE OF REGION WHERE SEALING MEMBER IS TO BE PROVIDED
41 ALIGNMENT FILM DETERMINATION UNIT
42 STORAGE UNIT
43 INFRARED LIGHT
44 INFRARED LIGHT
48 ALIGNMENT FILM
C THICKNESS OF METAL PATTERN
D DISTANCE BETWEEN TFT SUBSTRATE AND CF SUBSTRATE
P WIDTH OF METAL PATTERN

The invention claimed is:

1. A liquid crystal display panel comprising:
a first substrate;
a second substrate facing the first substrate;
a liquid crystal layer provided between the first substrate and the second substrate;
an alignment film provided on a side closer to the liquid crystal layer of each of the first and second substrates, and configured to control alignment of the liquid crystal layer; and
a sealing member sandwiched between the first substrate and the second substrate, configured to bond the first substrate and the second substrate together, and formed in the shape of a frame surrounding the liquid crystal layer,
wherein
in a region where the sealing member is to be provided, a metal pattern is provided which is configured to reflect infrared light emitted from a Fourier transform infrared spectrometer toward the Fourier transform infrared spectrometer in order to determine the presence or absence of the alignment film in the region.

2. The liquid crystal display panel of claim **1**, wherein
the metal pattern is formed in the shape of a frame along an inner circumferential surface of the region.

3. The liquid crystal display panel of claim **2**, wherein
the metal pattern has a width of 50 μm or more.

4. The liquid crystal display panel of claim **2**, wherein
a thickness of the metal pattern and a distance between the first substrate and the second substrate in a thickness direction of the liquid crystal display panel satisfy a relationship represented by:

$$C<D$$

where C is the thickness of the metal pattern and D is the distance between the first substrate and the second substrate in the thickness direction of the liquid crystal display panel.

5. The liquid crystal display panel of claim **2**, wherein
the metal pattern is made of one selected from the group consisting of tantalum, chromium, molybdenum, nickel, titanium, copper, and aluminum.

6. The liquid crystal display panel of claim **1**, wherein
the metal pattern has a width of 50 μm or more.

7. The liquid crystal display panel of claim **6**, wherein
a thickness of the metal pattern and a distance between the first substrate and the second substrate in a thickness direction of the liquid crystal display panel satisfy a relationship represented by:

$$C<D$$

where C is the thickness of the metal pattern and D is the distance between the first substrate and the second substrate in the thickness direction of the liquid crystal display panel.

8. The liquid crystal display panel of claim **6**, wherein
the metal pattern is made of one selected from the group consisting of tantalum, chromium, molybdenum, nickel, titanium, copper, and aluminum.

9. The liquid crystal display panel of claim **1**, wherein
a thickness of the metal pattern and a distance between the first substrate and the second substrate in a thickness direction of the liquid crystal display panel satisfy a relationship represented by:

$$C<D$$

where C is the thickness of the metal pattern and D is the distance between the first substrate and the second substrate in the thickness direction of the liquid crystal display panel.

10. The liquid crystal display panel of claim **1**, wherein
the metal pattern is made of one selected from the group consisting of tantalum, chromium, molybdenum, nickel, titanium, copper, and aluminum.

11. The liquid crystal display panel of claim **1**, wherein
the metal pattern is provided on at least one of the first and second substrates.

12. The liquid crystal display panel of claim **1**, wherein
the liquid crystal display panel is driven in a passive matrix scheme or in an active matrix scheme.

13. A liquid crystal display panel comprising:
a first substrate;
a second substrate facing the first substrate;
a liquid crystal layer provided between the first substrate and the second substrate;
an alignment film provided on a side closer to the liquid crystal layer of each of the first and second substrates, and configured to control alignment of the liquid crystal layer; and
a sealing member sandwiched between the first substrate and the second substrate, configured to bond the first substrate and the second substrate together, and formed in the shape of a frame surrounding the liquid crystal layer, wherein
in a region where the sealing member is to be provided, a metal pattern is provided which is configured to reflect infrared light emitted from a Fourier transform infrared spectrometer toward the Fourier transform infrared spectrometer in order to determine the presence or absence of the alignment film in the region, and
the metal pattern is positioned so that an inner circumferential surface of the metal pattern and an inner circumferential surface of the region are on the same plane.

14. The liquid crystal display panel of claim **13**, wherein
the metal pattern is formed in the shape of a frame along an inner circumferential surface of the region.

15. The liquid crystal display panel of claim **13**, wherein
the metal pattern has a width of 50 μm or more.

16. The liquid crystal display panel of claim **13**, wherein
a thickness of the metal pattern and a distance between the first substrate and the second substrate in a thickness direction of the liquid crystal display panel satisfy a relationship represented by:

$$C<D$$

where C is the thickness of the metal pattern and D is the distance between the first substrate and the second substrate in the thickness direction of the liquid crystal display panel.

17. The liquid crystal display panel of claim **13**, wherein
the metal pattern is made of one selected from the group consisting of tantalum, chromium, molybdenum, nickel, titanium, copper, and aluminum.

18. A method for testing a liquid crystal display panel substrate, wherein

the liquid crystal display panel substrate includes

a substrate,

an alignment film provided on the substrate and configured to control alignment of a liquid crystal layer, and

a metal pattern provided on the substrate in a region where a sealing member is to be provided, and

the method includes at least:

an irradiation step of irradiating the metal pattern with infrared light using a Fourier transform infrared spectrometer;

a measurement step of receiving the infrared light reflected by the metal pattern using the Fourier transform infrared spectrometer to measure an infrared absorption spectrum; and

a determination step of determining, based on the infrared absorption spectrum, the presence or absence of the alignment film in the region.

19. The method of claim 18, wherein

in the determination step, the infrared absorption spectrum measured using the Fourier transform infrared spectrometer is compared with another infrared absorption spectrum previously stored, to determine the presence or absence of the alignment film in the region.

20. The method of claim 18, wherein

in the irradiation step, the infrared light polarized in parallel to an incidence plane is incident at an incident angle between 75° and 85° inclusive.

* * * * *

专利名称(译)	液晶显示面板，以及测试液晶显示面板用基板的方法		
公开(公告)号	US8730446	公开(公告)日	2014-05-20
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[标]申请(专利权)人(译)	羽山孝文		
申请(专利权)人(译)	羽山孝文		
当前申请(专利权)人(译)	夏普株式会社		
[标]发明人	HAYAMA TAKAFUMI		
发明人	HAYAMA, TAKAFUMI		
IPC分类号	G02F1/1335 G02F1/13 G02F1/1339 G02F1/1337		
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代理机构(译)	桦木，STEWART，KOLASCH与桦木，LLP		
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摘要(译)

液晶显示面板（1）包括TFT基板（10），面向TFT基板（10）的CF基板（20），设置在TFT基板（10）和CF基板之间的液晶层（25）（20），构造成控制液晶层（25）的对准的取向膜，以及夹在TFT基板（10）和CF基板（20）之间并形成框架周围的形状的密封构件（26）液晶层（25）。在要设置密封构件（26）的区域（35）中，设置金属图案（2），其配置成将从傅立叶变换红外光谱仪发射的红外光朝向傅里叶变换红外光谱仪反射，以便确定区域（35）中是否存在取向膜。