

TITLE OF THE INVENTION

INSPECTION METHOD, AND MANUFACTURING METHOD FOR
LIQUID CRYSTAL DISPLAY USING INSPECTION METHOD

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an inspection method and a manufacturing method for liquid crystal displays using the inspection method. It especially relates to a method of inspecting joints when a substrate is divided into a plurality of regions for
10 separate exposures to form a predetermined pattern, and also relates to a manufacturing method for liquid crystal displays using the inspection method.

Description of the Background Art

Liquid crystal displays using thin-film transistors (TFTs) generally have TFTs formed by photolithography on one side of a substrate. Photolithography transfers a
15 predetermined pattern onto a substrate using an exposure system. However, as substrates are increasing in size, it becomes difficult to achieve batch exposure using a single mask. Thus, with increasing size of substrates, it becomes necessary to divide each substrate into a plurality of regions for exposures using a plurality of masks, thereby to form a predetermined pattern.

20 However, if a substrate is divided into a plurality of regions for exposures, joints between patterns formed in the respective regions become an issue. More specifically, depending on differences between exposure systems or depending on manufacturing errors of masks themselves, patterns from one shot to another during exposure are misaligned in different directions, and thereby joints between patterns can
25 be mismatched in overlap regions.

Such mismatches at joints can change transistor characteristics in forming TFTs on a substrate. And, a great change in transistor characteristics results in a great difference from normal transistor characteristics and can be recognized by human eyes as uneven display. This uneven display is also called uneven shots and can be the cause of
5 a defective panel.

In order to reduce unevenness in display due to mismatches at joints, measures using human visibility have been disclosed in Japanese Patent Application Laid-open No. 2003-315831 and Japanese republication of PCT international application No. WO95/16276. In those documents, there is an overlap region provided between one and
10 the other regions to be exposed, the overlap region arbitrarily including a part that is exposed during exposure of the one region and another part that is exposed during exposure of the other region. The part exposed during exposure of the one region is a non-exposed part during exposure of the other region. On the contrary, the part exposed during exposure of the other region is a non-exposed part during exposure of the one
15 region.

In the above documents, the parts that are exposed during exposure of the one region and the parts that are exposed during exposure of the other region are arbitrarily mixed within an overlap region in order to prevent the one and the other regions from being linearly joined together and thereby to make it difficult for human beings to
20 visually recognize unevenness in display due to mismatches at joints.

However, even the use of the techniques disclosed in the above documents still has the problem that unevenness in display may be recognized by human eyes, for example in the case where a more rigid accuracy of overlap of layers formed on a substrate is required, or depending on differences between exposure systems or depending
25 on manufacturing errors of masks.

Especially, in a first step of photolithography to pattern a first layer on a substrate, there is no criterion (alignment mark) for aligning regions to be exposed, on the substrate. Thus, regions to be exposed are aligned referring to the relative positions of alignment marks formed on masks to be exposed and alignment marks formed on a stage
5 supporting the substrate. In a second and later steps, alignment marks formed with the pattern in the first step are used for alignment of regions to be exposed.

Accordingly, the accuracy of alignment of regions to be exposed in the second and later steps is influenced by the alignment marks formed in the first step. That is, poor alignment accuracy in the first step degrades the accuracy of joints between patterns,
10 in which case uneven display can be recognized even with the use of the techniques disclosed in the above documents.

Taking a concrete example, a first step of photolithography forms a gate pattern on a substrate, a second step of photolithography forms an etching pattern of silicon, and a third step of photolithography forms source and drain patterns. Through the first to
15 third steps, transistors are formed on a substrate.

In the first step, as above described, there is no alignment mark on a substrate. Thus, joints between patterns may sometimes be inaccurate, for example depending on differences between exposure systems or depending on manufacturing errors of masks. Such inaccurate joints between patterns formed in the first step have an influence on
20 patterns to be formed in the second and third steps. For example, an etching pattern of silicon may overlap the edge of a source or drain pattern, and leakage becomes likely to occur in that overlap region.

On such a liquid crystal display panel as above, leakage can occur at joints between patterns, which may then cause variations in charge characteristics of pixels and
25 thereby result in poor display called flicker.

Further, if there are a plurality of exposure systems that can be used for patterning of the first step, differences between those exposure systems will result in different degrees of accuracy of joints between patterns even if exposure is performed under the same defined conditions. For example, when a substrate patterned in the first step is patterned in the second step, variations among different exposure systems in the accuracy of joints between patterns in the first step make it difficult to control the accuracy of joints between patterns in the second step.

More specifically, during patterning of the second step, it is necessary to determine which exposure systems were used for the patterning of the first step and to set exposure conditions for the second step according to the result of the determination. This can introduce the problem of reducing productivity.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an inspection method that is capable of improving the accuracy of joints between patterns by quantitatively measuring the accuracy of joints between patterns, and to provide a manufacturing method for liquid crystal displays using the inspection method.

According to the present invention, the inspection method is for inspecting the accuracy of a joint between patterns involving different exposures when a substrate is divided into a plurality of regions for separate exposures to form a predetermined pattern. It includes the following steps: the step of, in an overlap region where a first and a second regions out of the plurality of regions overlap each other, measuring a first distance between a first pattern element obtained during exposure of a first region and a second pattern element obtained during exposure of the first region and located approximately parallel to the first pattern element; the step of, in the overlap region, measuring a second

distance between the second pattern element and a third pattern element obtained during exposure of the second region and joined with the first pattern element; and the step of determining a difference between the first and the second distances to quantify the accuracy of a joint by measurement.

5 Since the inspection method of the present invention has the step of determining a difference between the first and the second distances to quantify the accuracy of a joint by measurement, it is possible to quantitatively control the accuracy of joints between patterns. This brings about the effect of improving the accuracy of joints between patterns.

10 These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Figs. 1A and 1B show regions to be exposed according to a first preferred embodiment of the present invention;

Fig. 2 is a plan view showing a liquid crystal display according to the first preferred embodiment of the present invention;

20 Fig. 3 is a plan view showing a substrate with gate and capacitance interconnections patterned thereon according to the first preferred embodiment of the present invention;

Figs. 4A and 4B are plan views showing joints in an overlap region according to the first preferred embodiment of the present invention;

25 Fig. 5 is a diagram for explaining a method of manufacturing a liquid crystal display according to the first preferred embodiment of the present invention;

Figs. 6 and 7 are plan views for explaining the effect of the liquid crystal display according to the first preferred embodiment of the present invention;

Fig. 8 is a plan view showing masks used in a liquid crystal display according to a second preferred embodiment of the present invention;

5 Fig. 9 is a plan view showing measurement patterns in the liquid crystal display according to the second preferred embodiment of the present invention;

Figs. 10A and 10B are plan views for explaining the measurement patterns in the liquid crystal display according to the second preferred embodiment of the present invention;

10 Fig. 11 is a plan view showing measurement patterns in another liquid crystal display according to the second preferred embodiment of the present invention; and

Fig. 12 is a plan view showing masks used in the liquid crystal display according to the second preferred embodiment of the present invention.

15 DESCRIPTION OF THE PREFERRED EMBODIMENTS

(First Preferred Embodiment)

When a substrate is divided into a plurality of regions for separate exposures to form a predetermined pattern, especially according to a first preferred embodiment of the present invention, two regions are provided as shown in Fig. 1A and each are exposed
20 using masks to form a single pattern on the substrate. Fig. 1A shows a region 1 indicated by the thin line on the left and a region 2 indicated by the thick line on the right. During exposures of the regions 1 and 2 on the substrate, the regions 1 and 2 are not simply located side by side but are located to overlap each other to provide an overlap region 3 as shown in Fig. 1B. Exposures may start with either the region 1 or the region
25 2. Although not shown, the overlap region 3 is a region which includes a subregion that

is exposed during exposure of the region 1 but not exposed during exposure of the region 2, and a subregion that is exposed during exposure of the region 2 but not exposed during exposure of the region 1.

Fig. 2 shows patterns formed by separate exposures of the two regions 1 and 2 as shown in Fig. 1B. Fig. 2 schematically shows predetermined patterns of gate interconnection 4, capacitance interconnection 5, a silicon layer 6, source interconnection 7, and a drain electrode 8, all of which are formed in the region 1 except the overlap region 3, in the region 2 except the overlap region 3, and in the overlap region 3. Those patterns are formed through steps of photolithography. More specifically, the gate interconnection 4 and the capacitance interconnection 5 are patterned in a first step of photolithography, the silicon layer 6 is patterned in a second step of photolithography, and the source interconnection 7 and the drain electrode 8 are patterned in a third step of photolithography.

As described in the background of the present invention, the patterns formed in the first step of photolithography are important to the accuracy of joints between patterns formed in the overlap region 3. Thus, this preferred embodiment has described an inspection method for quantitatively inspecting the accuracy of joints between patterns in the first step. Fig. 3 shows a substrate after the gate interconnection 4 and the capacitance interconnection 5 are patterned in the first step.

The overlap region 3 shown in Fig. 3 includes a subregion 3A inside the broken line and a subregion 3B outside the broken line. The subregion 3A is a region that is exposed during exposure of the region 1, and the subregion 3B is a region that is exposed during exposure of the region 2. The subregion 3A exposed during exposure of the region 1 is a non-exposed part during exposure of the region 2, and the subregion 3B exposed during exposure of the region 2 is a non-exposed part during

exposure of the region 1.

Thus, the overlap region 3 shown in Fig. 3 includes a part where the gate interconnection 4 and the capacitance interconnection 5 patterned during exposure of the region 1 and those patterned during exposure of the region 2 are joined together. This joining part (joint 9) is, as shown in Fig. 3, inwardly depressed in the shape of triangles. Thus, the joint 9 is visually recognizable with microscopes or the like. Depending on the conditions of the joint 9, the joint 9 may be in the shape of a step, instead of being inwardly depressed in the shape of triangles.

Fig. 4A is an enlarged view inside the overlap region 3, showing the gate interconnection 4 and the capacitance interconnection 5 patterned in the first step of photolithography. A region shown under the broken line corresponds to the subregion 3A which is exposed during exposure of the region 1 and is to be a non-exposed part during exposure of the region 2. On the other hand, a region shown above the broken line corresponds to the subregion 3B which is exposed during exposure of the region 2 and is to be a non-exposed part during exposure of the region 1.

That is, the gate interconnection 4 shown on the left of the broken line and the capacitance interconnection 5 are patterned during exposure of the region 1, and the gate interconnection 4 shown on the right of the broken line is patterned during exposure of the region 2. It is noted herein that the present invention is not only limited to this example; for example, the gate interconnection 4 shown on the right of the broken line may be patterned during exposure of the region 1, and the gate interconnection 4 on the left of the broken line and the capacitance interconnection 5 may be patterned during exposure of the region 2.

Then in this preferred embodiment, a distance between the gate interconnection 4 and the capacitance interconnection 5 is measured on each side of the

joint 9 in the gate interconnection 4 (i.e., the boundary between the subregions 3A and 3B). Specifically, as shown in Fig. 4A, a distance 10 from the capacitance interconnection 5 to the gate interconnection 4 in the subregion 3A, and a distance 11 from the capacitance interconnection 5 to the gate interconnection 4 in the subregion 3B are measured. Here, the distance between the gate interconnection 4 and the capacitance interconnection 5 means the shortest distance from the gate interconnection 4 to the capacitance interconnection 5 which is provided approximately parallel to the gate interconnection 4.

Then, by computing a difference between the measured distances 10 and 11, the accuracy of the joint 9 between patterns (in the gate interconnection 4) can be quantified. That is, since the distance 10 is measured based on the gate interconnection 4 and the capacitance interconnection 5 which are both patterned within the subregion 3A, and the distance 11 is measured based on the gate interconnection 4 which is patterned within the subregion 3B and the capacitance interconnection 5 which is patterned within the subregion 3A, determining a difference therebetween allows quantification of the accuracy of the joint 9.

In the example shown in Fig. 4A, there is almost no difference between the distances 10 and 11. However, if the joint 9 in the gate interconnection 4 is in the shape of a step as shown in Fig. 4B, the difference between the distances 10 and 11 is great. While Fig. 4B shows the example where the distance 10 is greater than the distance 11, the relationship between the distances 10 and 11 may be inverse depending on the conditions of the joint 9.

If the difference between the distances 10 and 11 is great as shown in Fig. 4B and it is not less than a predetermined value, correction is made on exposure systems. Here, the predetermined value is a target value that is determined

based on design, past production data, or the like. If the difference is greater than the target value, there is a high possibility of occurrence of defects such as uneven display.

Fig. 5 is a flowchart showing a manufacturing method for liquid crystal displays, used in the first step of photolithography for patterning a first layer on a substrate. First, in step S1, patterning is performed under defined exposure conditions. In step S2, the accuracy of joints between patterns formed in step S1 (in the examples of Figs. 4A and 4B, the gate interconnection 4 and the capacitance interconnection 5) is quantified by measurement, using the aforementioned inspection method. More specifically, in the examples of Figs. 4A and 4B, within the overlap region 3, the distance 10 between the gate interconnection 4 formed during exposure of the region 1 and the capacitance interconnection 5 formed during exposure of the region 1 and located approximately parallel to the gate interconnection 4 is measured, and the distance 11 between the capacitance interconnection 5 and the gate interconnection 4 which is formed in the subregion 3B during exposure of the region 2 and is joined with the gate interconnection 4 formed in the subregion 3A is measured. Then, the difference between the distances 10 and 11 is measured to quantify the accuracy of the joint 9. The accuracy of joints is higher as the measured difference is smaller, while the accuracy of joints is lower as the measured distance is greater.

In step S3, it is determined whether the difference measured in step S2 (specifically, the difference between the distances 10 and 11) is not less than a predetermined value or not. If the measured difference (the value of the accuracy of the joint) is not less than the predetermined value, the process goes to step S4. If the measured difference is smaller than the predetermined value, the process goes to step S5.

In step S4, correction is made on the exposure conditions of exposure systems in order to make the measured difference smaller than the

predetermined value. Correction of the exposure conditions includes, for example, control of the positions of the regions 1 and 2 to be exposed. On the other hand, if the measured difference is smaller than the predetermined value, production, i.e., the first step of photolithography, is started in step S5.

5 In this way, the inspection method according to this preferred embodiment allows quantification of the accuracy of joints by measuring the distances 10 and 11 between patterns on both sides of the joint 9 and computing a difference therebetween. Quantification of the accuracy of joints allows control of the accuracy of joints, thereby improving the accuracy of joints.

10 Further, in the manufacturing method for liquid crystal displays according to this preferred embodiment, correction is made on exposure systems at a preparatory stage of production, using the inspection method for quantifying the accuracy of joints. Thus, it is possible to improve the accuracy of joints and thereby to reduce display defects (e.g., uneven shots) due to poor accuracy of joints. More specifically, if
15 the accuracy of joints in the first step of photolithography is low as shown in Fig. 4B, the accuracy of joints in the second and third steps will be influenced by that in the first step as shown in Fig. 7. In such a case, the edge of the silicon layer 6 may overlap the edge of the gate interconnection 4 as shown in Fig. 7, which may then result in display defects. However in this preferred embodiment, the aforementioned correction made on the
20 exposure systems improves the accuracy of joints in the first step of photolithography as shown in Fig. 4A and accordingly improves the accuracy of joints in the second and third steps as shown in Fig. 6, thereby resulting in reduction in display defects.

(Second Preferred Embodiment)

 This preferred embodiment describes another inspection method different from
25 the one described in the first preferred embodiment. Also in this preferred embodiment,

a substrate is divided into a plurality of regions for separate exposures to form a predetermined pattern. Thus, as shown in Fig. 1A, a substrate is divided into the regions 1 and 2 to form a predetermined pattern on the substrate. However, patterns are formed in not the whole but only parts (hereinafter also referred to as pixel parts) of the regions 1 and 2. The other parts of the regions 1 and 2 are non-patterned parts where no patterns are formed. The pixel parts constitute part of a predetermined pattern formed on the substrate.

Specifically, Fig. 8 shows masks used for the regions 1 and 2. The masks shown in Fig. 8 have mask patterns provided to expose pixel parts 12 at central portions. And, the masks shown in Fig. 8 have measurement patterns 14 and 15 provided in the vicinity of the pixel parts 12 and in non-patterned parts 13.

In Fig. 8, the measurement patterns 14 provided in the lower portion of the region 1 each include an outer measurement pattern 14a having the shape of a large rectangle, and an inner measurement pattern 14b having the shape of a small rectangle. The measurement patterns 15 provided in the upper portion of the region 2 each include an outer measurement pattern 15a having the shape of a small rectangle, and an inner measurement pattern 15b having the shape of a large rectangle. Exposures using the measurement patterns 14a and 15b form patterns in the shape of rectangles on the substrate. On the other hand, exposures using the measurement patterns 14b and 15a form punched patterns in the shape of rectangles on the substrate.

In Fig. 8, there are also the measurement patterns 14 and 15 provided in the upper portion of the region 1 and in the lower portion of the region 2, respectively. Those measurement patterns 14 and 15 are for use to further overlay other regions above the region 1 and under the region 2, respectively.

In this way exposing patterns on the substrate using the two masks shown in

Fig. 8 form the measurement patterns 14 and 15 on the substrate. Fig. 9 is a schematic view of the substrate with the measurement patterns 14 and 15 formed thereon. In Fig. 9, the regions 1 and 2 form the overlap region 3, in which the measurement patterns 14 and 15 overlap each other. More specifically, the punched measurement pattern 15a is
5 formed in the rectangular measurement pattern 14a, and the punched measurement pattern 14b is formed in the rectangular measurement pattern 15b.

In this preferred embodiment, the measurement patterns 14 and 15 are formed to overlap each other in this fashion, and the positions of the measurement patterns 15 relative to the measurement patterns 14 are measured to quantify the accuracy of joints.
10 More specifically, Fig. 10A is an enlarged view showing the measurement patterns 14b and 15b provided on both sides of the pixel part 12. In Fig. 10A, lateral distances 16 from the sides of the measurement patterns 14b to the sides of the measurement pattern 15b are shown by thin arrows, and vertical distances 17 from the sides of the measurement patterns 14b to the sides of the measurement patterns 15b are shown by
15 thick arrows.

In Fig. 10A, the distances 16 on both sides of the pixel part 12 are equal to each other, and the distances 17 on both sides of the pixel part 12 are equal to each other. Thus, it is found quantitatively that the accuracy of joints is high. However, if the distances 16 on both sides of the pixel part 12 are different from each other and the
20 distances 17 on both sides of the pixel part 12 are different from each other as shown in Fig. 10B, it is found quantitatively that the accuracy of joints is low. As a specific example of quantification methods, for example, there is considered a technique for computing a difference between a distance 17 from the top side of the measurement pattern 14b to the top side of the measurement pattern 15b on the left of the pixel part 12
25 and a distance 17 from the top side of the measurement pattern 14b to the top side of the

measurement pattern 15b on the right of the pixel part 12. This inspection method for quantifying the accuracy of joints is also applicable to the flowchart shown in Fig. 5. Specifically, the inspection method according to this preferred embodiment can be used as the inspection method of step S2 shown in Fig. 5.

5 Next, Fig. 11 is a schematic view showing the case where a substrate is divided into four regions to form a predetermined pattern using different masks for the respective regions. In Fig. 11, regions 21, 22, 23, and 24 overlap one another to form an overlap region 25. Each region in Fig. 11 has measurement patterns 26 and 27 formed in the vicinity of its pixel part 12.

10 Fig. 12 shows masks used to expose patterns as shown in Fig. 11 on the substrate. The mask used for the region 21 in Fig. 12 has a mask pattern for forming measurement patterns 26 near above and near on the left of the pixel part 12. Exposure with this mask pattern forms large rectangular measurement patterns 26 on the substrate. The mask used for the region 22 in Fig. 12 has a mask pattern for forming measurement
15 patterns 27 above and on the right of the pixel part 12. Exposure with this mask pattern forms small rectangular punched patterns (measurement patterns) 27 on the substrate.

 Similarly, the mask used for the region 23 in Fig. 12 has a mask pattern for forming measurement patterns 27 near below and near on the left of the pixel part 12. The mask used for the region 24 in Fig. 12 has a mask pattern for forming measurement
20 patterns 26 near below and near on the right of the pixel part 12.

 Then, patterns are exposed on the substrate using the four masks shown in Fig. 12. As a result of patterning, the patterns shown in Fig. 11 are obtained, and the positions of the measurement patterns 27 relative to the measurement pattern 26 are measured as shown in Figs. 10A and 10B. This allows quantification of the accuracy of
25 joints. Application of this technique to the flowchart shown in Fig. 5 improves the

accuracy of joints.

Now, in the case where a substrate is divided into four regions for separate exposures as shown in Fig. 11, the measurement patterns 26 and 27 can be provided only on a single diagonal line of the pixel part 12 since two sides of each region overlap the other regions. If the measurement patterns 26 and 27 are provided outside the four corners of the pixel part 12, the measurement patterns 26 and 27 will be patterned within adjacent regions.

However, when the measurement patterns 26 and 27 are provided only on a single diagonal line of the pixel part 12, as compared with the case where they are provided outside the four corners of the pixel part 12, there is less information about the accuracy of joints, and thus sufficient correction might not be made. In such a case, patterns within the pixel part 12 should be analyzed to previously remove rotational components of each region before the application of the above technique.

As so far described, in the inspection method according to this preferred embodiment, the measurement patterns 14 and 15 or 26 and 27 are provided near part (pixel part 12) of a predetermined pattern, and the positions of the measurement patterns 15 and 27 relative to the measurement patterns 14 and 26, respectively, are measured to quantify the accuracy of joints. This allows control of the accuracy of joints, thereby improving the accuracy of joints.

While the invention has been shown and described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is therefore understood that numerous modifications and variations can be devised without departing from the scope of the invention.

WHAT IS CLAIMED IS:

1. An inspection method for inspecting the accuracy of a joint between patterns involving different exposures when a substrate is divided into a plurality of regions for separate exposures to form a predetermined pattern,

5 said inspection method comprising the steps of:

 in an overlap region where a first and a second regions out of said plurality of regions overlap each other, measuring a first distance between a first pattern element obtained during exposure of said first region, and a second pattern element obtained during exposure of said first region and located approximately parallel to said first pattern
10 element;

 in said overlap region, measuring a second distance between said second pattern element, and a third pattern element obtained during exposure of said second region and joined with said first pattern element; and

 determining a difference between said first and said second distances to
15 quantify the accuracy of a joint by measurement.

2. An inspection method for inspecting the accuracy of a joint between patterns involving different exposures when a substrate is divided into a plurality of regions for separate exposures to form a predetermined pattern,

20 said inspection method comprising the steps of:

 in an overlap region where a first and a second regions out of said plurality of regions overlap each other, providing a first measurement pattern during exposure of said first region, outside said predetermined pattern;

 in said overlap region, providing a second measurement pattern during
25 exposure of said second region, outside said predetermined pattern; and

measuring a position of said second measurement pattern relative to said first measurement pattern to quantify the accuracy of a joint by measurement.

3. A method of manufacturing a liquid crystal display, including a process of
5 dividing a substrate into a plurality of regions for separate exposures to form a predetermined pattern,

said method comprising the steps of:

(a) forming said predetermined pattern of a first layer on a substrate;

(b) quantifying the accuracy of a joint by measurement, using the inspection
10 method according to either of claims 1 and 2;

(c) determining whether or not a measured value of the accuracy of said joint is not less than a predetermine value;

(d) when the value of the accuracy of said joint is determined not less than a predetermined value in said step (c), correcting exposure positions in said first and said
15 second regions and performing said steps (a) and (b) on a new substrate; and

(e) when the value of the accuracy of said joint is determined smaller than a predetermined value in said step (c), starting production under defined conditions.