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PIXEL ARRANGEMENT STRUCTURE, DISPLAY SUBSTRATE, AND DISPLAY DEVICE

Abstract

A display substrate and a display device. In the display substrate, a connection line between a center of the first sub-pixel and a center of the fourth sub-pixel is a second line segment; a plurality of second sub-pixels and a plurality of third sub-pixels are alternately arranged in the extension direction of the second line segment to form a first sub-pixel column, a plurality of first sub-pixels and a plurality of fourth sub-pixels are alternately arranged in the extension direction of the second line segment to form a second sub-pixel column, in the first sub-pixel column, the plurality of second sub-pixels and the plurality of third sub-pixels are overlapped with the first data line, in the second sub-pixel column, the plurality of first sub-pixels and the plurality of fourth sub-pixels are overlapped with the second data line.

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Background/Summary

[0001] The present application is a continuation of U.S. Ser. No. 19/021,983 filed on Jan. 15, 2025, which is a continuation of U.S. Ser. No. 16/621,904 filed on Dec. 12, 2019, which is a national stage application of PCT international patent application No. PCT/CN2018/124884, filed on Dec. 28, 2018, which claims priority of the Chinese Patent Application No. 201810137016.5, filed on Feb. 9, 2018, the disclosure of which is incorporated herein by reference in its entirety as part of the present application.

TECHNICAL FIELD

[0002] Embodiments of the present disclosure relates to a pixel arrangement structure, a display substrate and a display device.

BACKGROUND

[0003] With the continuous development of display technology, people have higher and higher requirements for the resolution of display devices. Due to the advantages of high display quality, the application range of high-resolution display devices is becoming wider and wider. In general, the resolution of a display device can be improved by reducing the size of pixels and reducing the spacing between pixels. However, the reduction in the size of pixels and the spacing between pixels also requires higher and higher precision of the manufacturing process, which leads to the increase in the difficulty of the manufacturing process and the manufacturing cost of the display device.

[0004] On the other hand, sub-pixel rendering (SPR) technology can make use of the difference of human eyes' resolution to sub-pixels of different colors, change the mode of defining a pixel simply by conventional red, green and blue sub-pixels, share sub-pixels of certain position resolution insensitive colors among different pixels, and use relatively few sub-pixels to simulate and realize the same pixel resolution performance capability, thus reducing the difficulty of the manufacturing process and the manufacturing cost.

SUMMARY

[0005] Embodiments of the present disclosure provide a pixel arrangement structure, a display substrate and a display device. The pixel arrangement structure can improve the distribution uniformity of sensitive color sub-pixels by adjusting the spacing of sensitive color sub-pixels, thereby improving the visual resolution of the pixel arrangement structure and also improving the display quality of the pixel arrangement structure.

[0006] At least one embodiment of the present disclosure provides a pixel arrangement structure, including a plurality of pixel groups; each of the plurality of pixel groups includes a first sub-pixel, a second sub-pixel, a third sub-pixel and a fourth sub-pixel; in each of the plurality of pixel groups, a connection line between a center of the second sub-pixel and a center of the third sub-pixel is a first line segment, the first sub-pixel and the fourth sub-pixel are between the second sub-pixel and the third sub-pixel and are respectively at two sides of the first line segment; a connection line between a center of the first sub-pixel and a center of the fourth sub-pixel is a second line segment;

a length of the second line segment is less than a length of the first line segment.

[0007] For example, a ratio of the length the second line segment to the length the first line segment is less than or equal to $3/4$.

[0008] For example, the second line segment and the first line segment are vertically bisected to each other.

[0009] For example, the ratio of the length of the second line segment to the length of the first line segment is greater than or equal to $3/8$.

[0010] For example, in each of the plurality of pixel groups, the first sub-pixel and the fourth sub-pixel are both strip-shaped, and an extension direction of the first sub-pixel and an extension direction of the fourth sub-pixel do not coincide.

[0011] For example, an included angle between the extension direction of the first sub-pixel and the extension direction of the fourth sub-pixel ranges from 70° to 100° .

[0012] For example, the first sub-pixel and the fourth sub-pixel are symmetrically arranged relative to the first line segment, and/or the second sub-pixel and the third sub-pixel are symmetrically arranged relative to the second line segment.

[0013] For example, the first line segment extends in the first direction and the second line segment extends in a second direction; the plurality of pixel groups are arranged in an array to form a plurality of rows and a plurality of columns, and pixel groups of even rows and pixel groups of odd rows are arranged in a staggered way; a length of a center connection line between the second sub-pixel and the third sub-pixel that are adjacent to each other in two adjacent ones of the plurality of pixel groups in the first direction is less than the length of the first line segment; in two adjacent ones of the odd rows or in two adjacent ones of the even rows, a length of a center connection line between the first sub-pixel and the fourth sub-pixel that are adjacent to each other in two adjacent ones of the plurality of pixel groups in the second direction is greater than the length of the second line segment.

[0014] For example, a ratio of the length of the center connection line between the second sub-pixel and the third sub-pixel that are adjacent to each other in two adjacent ones of the plurality of pixel groups in the first direction to the length of the first line segment is less than or equal to $1/2$; and/or, in two adjacent ones of the odd rows or in two adjacent ones of the even rows, a ratio of the length of the center connection line between the first sub-pixel and the fourth sub-pixel that are adjacent to each other in two adjacent ones of the plurality of pixel groups in the second direction to the length of the second line segment ranges from 1 to 3.

[0015] For example, an extension line of the second line segment of each of the plurality of pixel groups passes through a midpoint of a center connection line between two pixel groups that are adjacent to the pixel group in the second direction and are in a same row with the pixel group.

[0016] For example, in two adjacent ones of the odd rows or in two adjacent ones of the even rows, an intersection point of a center connection line between two third sub-pixels in two adjacent ones of the plurality of pixel groups arranged in the second direction and the first line segment in one pixel group between the two third sub-pixels is between a center of the first line segment and the center of the second sub-pixel of the one pixel group.

[0017] For example, in the same one of the plurality of pixel groups, the closest distance between the second sub-pixel and the first sub-pixel is $L1$, the closest distance between the second sub-pixel and the fourth sub-pixel is $L2$, the closest distance between the third sub-pixel and the first sub-pixel is $L3$, the closest distance between the third sub-pixel and the fourth sub-pixel is $L4$, and $L1=L2=L3=L4$.

[0018] For example, the closest distance between the second sub-pixel and one of the first sub-pixel and the fourth sub-pixel is $L5$, the closet distance between the third sub-pixel and one of the first sub-pixel and the fourth sub-pixel is $L6$, the second sub-pixel and the third sub-pixel are in a pixel group being adjacent to the first sub-pixel or the fourth sub-pixel in the second direction and are not in the same row with the first sub-pixel or the fourth sub-pixel, and $L5=L6$.

[0019] For example, opposite of two adjacent sub-pixels sides are approximately parallel or have an included angle less than 45 degrees, and the adjacent sub-pixels include any two adjacent ones selected from the group consisting of the first sub-pixel, the second sub-pixel, the third sub-pixel, and the fourth sub-pixel.

[0020] For example, the first sub-pixel and the fourth sub-pixel are sub-pixels of the same color.

[0021] At least one embodiment of the present disclosure provides a display substrate, including the pixel arrangement structure according to at least one embodiment of the present disclosure.

[0022] At least one embodiment of the present disclosure provides a display device, including the display substrate according to at least one embodiment of the present disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In order to clearly illustrate the technical solution of the embodiments of the present disclosure, the drawings of the embodiments will be briefly described in the following; it is obvious that the described drawings are only related to some embodiments of the present disclosure and thus are not limitative of the present disclosure.

[0024] FIG. 1 is a schematic diagram of a pixel arrangement structure;

[0025] FIG. 2 is a schematic diagram of a pixel arrangement structure according to an embodiment of the present disclosure;

[0026] FIG. 3A is a schematic diagram of a pixel arrangement structure according to an embodiment of the present disclosure;

[0027] FIG. 3B is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0028] FIG. 3C is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0029] FIG. 4 is a schematic diagram of a pixel arrangement structure according to an embodiment of the present disclosure;

[0030] FIG. 5A is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0031] FIG. 5B is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0032] FIG. 6 is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0033] FIG. 7A is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0034] FIG. 7B is a schematic diagram of a pixel arrangement structure according to another embodiment of the present disclosure;

[0035] FIG. 8 is a schematic diagram of a pixel arrangement structure, drive lines, and data lines according to another embodiment of the present disclosure; and

[0036] FIG. 9 is a cross-sectional view of a display substrate according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0037] In order to make objects, technical details and advantages of the embodiments of the present disclosure apparent, the technical solutions of the embodiment will be described in a clearly and fully understandable way in connection with the drawings related to the embodiments of the present disclosure. It is obvious that the described embodiments are just a part but not all of the embodiments of the present disclosure. Based on the described embodiments herein, those skilled in the art can obtain other embodiment(s), without any inventive work, which should be within the

scope of the present disclosure.

[0038] Unless otherwise defined, all the technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which the present disclosure belongs. The terms “first,” “second,” etc., which are used in the description and the claims of the present application for disclosure, are not intended to indicate any sequence, amount or importance, but distinguish various components. The terms “comprise,” “comprising,” “include,” “including,” etc., are intended to specify that the elements or the objects stated before these terms encompass the elements or the objects and equivalents thereof listed after these terms, but do not preclude the other elements or objects. The phrases “connect”, “connected”, etc., are not intended to define a physical connection or mechanical connection, but may include an electrical connection, directly or indirectly.

[0039] FIG. 1 illustrates a schematic diagram of a pixel arrangement structure. As illustrated in FIG. 1, the pixel arrangement structure is a typical pentile arrangement. A minimum repeating unit includes two green sub-pixels **0111**, a red sub-pixel **0112** and a blue sub-pixel **0113**. The pixels are uniformly distributed, and high pixel per inch (PPI) display is easy to realize.

[0040] The inventor(s) of the present application found that, in the pixel arrangement structure illustrated in FIG. 1, the distance between the two green sub-pixels **0111** in the minimum repeating unit is relatively large, which is not conducive to improving visual resolution and is easy to appear color edges and graininess. Generally, in the minimum repeating unit in FIG. 1, the center connection line LS02 between the two green sub-pixels **0111** is approximately the same length as the connection line LS01 of the center of the red sub-pixel **0112** and the center of the blue sub-pixel **0113** in the minimum repeating unit.

[0041] Even after SPR technology is adopted, high resolution products still need a higher PPI (pixel per inch) sub-pixel patterning process to be manufactured, thus still being restricted by the manufacturing process precision. Therefore, it is necessary to improve the pixel arrangement structure in order to reduce the manufacturing process difficulty and make high resolution products suitable for mass production.

[0042] In order to manufacture a display device with high resolution, it is needed to reduce the size of pixels and the spacing between pixels. However, the reduction in the size of pixels and the spacing between pixels also requires higher and higher precision of the manufacturing process, which will lead to the increase in the difficulty and cost of the manufacturing process of the display device. For example, when manufacturing an active matrix organic light emitting diode (AMOLED) display device with high resolution, because the limitation of process precision of fine metal mask (FMM) technology, the manufacturing process for manufacturing an AMOLED display device with high resolution (e.g., greater than **300** pixels per inch (PPI)) is difficult and costly. The advantages and disadvantages of pixel arrangement have great influence on the display effect. A good pixel arrangement can improve the display quality of the picture, increase the aperture ratio, reduce the color mixing and reduce the process difficulty.

[0043] As illustrated in FIG. 2, at least one embodiment of the present disclosure provides a pixel arrangement structure, including a plurality of pixel groups **01**. Each of the plurality of pixel groups **01** includes a first sub-pixel **111**, a second sub-pixel **112**, a third sub-pixel **113** and a fourth sub-pixel **114**. In each of the plurality of pixel groups **01**, a connection line between a center C2 of the second sub-pixel **112** and a center C3 of the third sub-pixel **113** is a first line segment LS1; the first sub-pixel **111** and the fourth sub-pixel **114** are between the second sub-pixel **112** and the third sub-pixel **113** and are respectively at two sides of the first line segment LS1. A connection line between a center C1 of the first sub-pixel **111** and a center C4 of the fourth sub-pixel **114** is a second line segment LS2. A length of the second line segment LS2 is less than a length of the first line segment LS1. For example, in order to obtain a good pixel arrangement effect, a ratio of the length the second line segment LS2 to the length the first line segment LS1 is less than or equal to 3/4.

[0044] The pixel arrangement structure provided by at least one embodiment of the present

disclosure reduces the distance between the first sub-pixel and the fourth sub-pixel in the same pixel group. On the one hand, the pixel arrangement can be made tighter, the color mixing risk can be reduced, the color edge can be improved, and the visual graininess can be improved. On the other hand, the spacing between sub-pixels can be widened to facilitate fabrication. Alternatively, a balance can be found between the tightness of pixel arrangement and the spacing between sub-pixels, so that the pixel arrangement is relatively tight and the spacing between sub-pixels (pixel defining layer spacing) is widened to a certain extent, which is beneficial to reducing the risk of color mixing, improving color edges, improving the visual graininess and widening the spacing between sub-pixels.

[0045] For example, the shape of each sub-pixel given in the embodiments of the present disclosure can be defined by a pixel defining layer, but is not limited thereto. For example, each sub-pixel in the figure is an actual light emitting area. The specific shape of each sub-pixel can be set according to the preparation process. For example, the actual light emitting area can be determined by the shape of at least one of the electrode, the light emitting layer, and the pixel defining layer. For example, when the pixel arrangement structure is applied to an OLED display substrate and the first sub-pixel and the fourth sub-pixel are of the same color, the light emitting layer patterns of the first sub-pixel and the fourth sub-pixel in the same pixel group can also be formed by vapor deposition using the same opening of the mask plate.

[0046] For example, the first sub-pixel **111** and the fourth sub-pixel **114** can be sub-pixels of human eye sensitive color, for example, may be green sub-pixels, yellow sub-pixels, white sub-pixels, etc. For example, the areas of the first sub-pixel **111** and the fourth sub-pixel **114** are relatively small compared to the second sub-pixel **112** and the third sub-pixel **113**. For example, the area of the first sub-pixel **111** is smaller than the area of the second sub-pixel **112**, and/or the area of the first sub-pixel **111** is smaller than the area of the third sub-pixel **113**. Similarly, the fourth sub-pixel **114** may refer to the above description of the area of the first sub-pixel **111**. That is, the area of the fourth sub-pixel **114** is smaller than the area of the second sub-pixel **112**, and/or the area of the fourth sub-pixel **114** is smaller than the area of the third sub-pixel **113**.

[0047] The pixel arrangement structure provided by at least one embodiment of the present disclosure can improve the distribution uniformity of the sensitive color sub-pixels by adjusting the spacing of the sensitive color sub-pixels in the visual position, thereby improving the visual resolution of the pixel arrangement structure and improving the display quality.

[0048] The second sub-pixel **112** and the third sub-pixel **113** may be sub-pixels of color insensitive to human eyes. For example, one of the second sub-pixel **112** and the third sub-pixel **113** is a red sub-pixel and the other is a blue sub-pixel, but is not limited thereto. In this embodiment of the present disclosure, the second sub-pixel **112** is a red sub-pixel and the third sub-pixel **113** is a blue sub-pixel. It should be noted that when the pixel arrangement structure adopts the red green blue (RGB) mode, the above-mentioned human eye sensitive color can be green.

[0049] As illustrated in FIG. 2, the first line segment LS1 can extend in the first direction X and the second line segment LS2 can extend in the second direction Y. For example, the first direction X is perpendicular to the second direction Y. For example, in each pixel group **01**, the first sub-pixel **111** and the fourth sub-pixel **114** are arranged with the first direction X as an axis of symmetry, so that the pixel structure is arranged more uniformly. For example, the first sub-pixel **111** is uniformly arranged relative to the second sub-pixel **112** and the third sub-pixel **113**, and is kept consistent, so that the pixel structure is arranged more uniformly.

[0050] As illustrated in FIG. 2, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, the second line segment LS2 is perpendicular to the first line segment LS1. Thus, the pixel arrangement can be made more uniform. For example, the second line segment LS2 is located on the perpendicular bisector of the first line segment LS1. At this time, the widths of sub-pixels of each color in the first direction X can be the same, but are not limited thereto. Therefore, the pixel structure distribution can be made more uniform, the picture

display quality is higher, and the problem of display graininess at lower PPI is improved.

[0051] As illustrated in FIG. 2, for convenience of description, a plurality of square dashed frames are provided, each dashed frame has a length of $1/2L$, and four dashed frames can form a square with a side length of L . In FIG. 2, there is a pixel group **01** in the dark rectangle dashed frame. The pixel group **01** can be the minimum repeating unit of the pixel arrangement structure. For example, the pixel arrangement structure can be obtained by translating and copying the minimum repeating unit. For example, sub-units that can be translated and repeated to be arranged to form a pixel structure are not included in the minimum repeating unit.

[0052] As illustrated in FIG. 2, the first line segment **SL1** is perpendicular to the second line segment **SL2** and is vertically bisected with each other. The first line segment **SL1** vertically bisects the second line segment **SL2**. The second line segment **SL2** also vertically bisects the first line segment **SL1**. For example, in the pixel group **01**, the maximum area enclosed by the connection lines between the centers of the first sub-pixel **111**, the second sub-pixel **112**, the fourth sub-pixel **114** and the third sub-pixel **113** is rhombus, and the first line segment **SL1** and the second line segment **SL2** are respectively diagonal lines of the rhombus.

[0053] As illustrated in FIG. 2, in the pixel group **01**, the distance between the center **C1** of the first sub-pixel **111** and the center **C4** of the fourth sub-pixel **114** can be greater than or equal to $1/2L$, for example, the distance can range from $1/2L$ to L . For example, the first sub-pixel **111** and the fourth sub-pixel may adopt sub-pixels of the same color. When the first sub-pixel **111** and the fourth sub-pixel adopt sub-pixels of the same color, such as the first sub-pixel **111**, the setting of the distance can also avoid the situation that two adjacent first sub-pixels are difficult to distinguish due to the close distance between the adjacent first sub-pixels and are combined into one by human vision, thus avoiding the graininess caused thereby. Therefore, the pixel arrangement structure can improve the distribution uniformity of the first sub-pixels, thereby improving the visual resolution and also improving the display quality.

[0054] As illustrated in FIG. 2, the distance between the center **C3** of the third sub-pixel **113** and the center **C2** of the second sub-pixel **112** can be $4/3L$. In order to make the ratio of the length of the second line segment **LS2** to the length of the first line segment **LS1** less than or equal to $3/4$, the distance between the third sub-pixel **113** and the second sub-pixel **112** in the same pixel group can be increased and/or the distance between the first sub-pixel **111** and the fourth sub-pixel **114** can be decreased under the condition permitted by the process.

[0055] As illustrated in FIG. 2, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, in order to obtain a closely arranged pixel structure, the ratio of the lengths of the second line segment **LS2** and the first line segment **LS1** can be greater than or equal to $3/8$.

[0056] For example, as illustrated in FIG. 2A, in a pixel group, the first sub-pixel **111** and the second sub-pixel **112** are sub-pixels of different colors, the first sub-pixel **111** and the second sub-pixel **112** form a pixel **P**, the third sub-pixel **113** and the fourth sub-pixel **114** are sub-pixels of different colors, the third sub-pixel **113** and the fourth sub-pixel **114** form a pixel **P**, and sub-pixels of other surrounding pixels need to be borrowed for color display when displaying an image. For example, the first sub-pixel **111** and the fourth sub-pixel **114** are green sub-pixels, the second sub-pixel **112** is red sub-pixel, and the third sub-pixel **113** is blue sub-pixel. For example, a red sub-pixel and a green sub-pixel form a pixel, and a blue sub-pixel and a green sub-pixel form a pixel. The pixel **P** here only includes sub-pixels of two colors. When displaying an image, it is necessary to use sub-pixels of other surrounding pixels for color display. Therefore, the pixel **P** here can also be referred to as a virtual pixel.

[0057] FIG. 3A illustrates the pixel arrangement structure with the dashed lines in FIG. 2 removed. The dashed lines, centers, etc. given in the embodiments of the present disclosure are for convenience of describing the given virtual lines, virtual centers. For example, the center can be the center of gravity, the intersection point of perpendicular bisector of opposite sides, etc., but is not

limited thereto.

[0058] FIG. 3B illustrates a pixel arrangement structure provided by one or more embodiments of the present disclosure. In the same pixel group **01**, the first sub-pixel **111** and the fourth sub-pixel **114** adopt the same color. For example, both are the first sub-pixel **111**. Because the sub-pixels of the same color do not have the problem of color mixing, the light emitting layer patterns of the first sub-pixel **111** and the fourth sub-pixel **114** in the same pixel group **01** can be vapor deposited using the same opening of the mask plate, thereby being beneficial to the screening of the mask plate, having small screening pressure and improving the quality of the screening.

[0059] As illustrated in FIG. 3B, because the slope of the first sub-pixels **111** of the same row is low, when the first sub-pixels **111** belonging to the same row display straight lines together, the fluctuation amplitude of the first sub-pixels of adjacent pixel groups is small due to the low slope (dashed line with dense dots in FIG. 3B), thus avoiding the situation that two straight lines generated by interlocking with straight lines displayed in adjacent rows due to large fluctuation amplitude are difficult to distinguish and are combined into one visually by human eyes. Therefore, the pixel arrangement structure can improve the visual resolution.

[0060] FIG. 3C illustrates a pixel arrangement structure provided by one or more embodiments of the present disclosure. As illustrated in FIG. 3C, in each pixel group **01**, the first sub-pixel **111** and the fourth sub-pixel **114** are sub-pixels of the same color, and can include, for example, two types of pixel groups, in which pairs of sub-pixels of the same color in one type of pixel group are first sub-pixels (e.g., green sub-pixels), and pairs of sub-pixels of the same color in another type of pixel group are fourth sub-pixels (e.g., white sub-pixels or yellow sub-pixels). The colors of the two sub-pixels arranged in pairs between the second sub-pixel and the third sub-pixel in the pixel group adjacent in the diagonal direction of each pixel group are different from the colors of the sub-pixels arranged in pairs between the second sub-pixel and the third sub-pixel in the pixel group.

[0061] FIG. 4 illustrates a pixel arrangement structure provided by one or more embodiments of the present disclosure. As illustrated in FIG. 4, the first line segment LS1 can extend in the first direction X, and a length D1 of a center connection line LS3 between the second sub-pixels **112** and the third sub-pixels **113** that are adjacent to each other in two adjacent ones of the plurality of pixel groups **01** in the first direction X is less than a length of the first line segment LS1, so that pixels can be closely arranged. In FIG. 4, the length of the first line segment LS1 is $4/3L$, but is not limited thereto. For example, the length of the first line segment LS1 can range from $11/9L$ to $13/9L$.

[0062] For example, in order to allow the tight arrangement of pixels and process conditions to be combined, the ratio of the length D1 of the center connection line LS3 between the center of the second sub-pixel **112** and the center of the third sub-pixel **113** that are adjacent to each other in the two adjacent ones of the plurality of pixel groups **01** in the first direction to the length of the first line segment LS1 is less than or equal to $1/2$. In FIG. 4, the length D1 is $2/3L$, but it is not limited thereto. For example, the length D1 can range from $5/9L$ to $7/9L$.

[0063] As illustrated in FIG. 4, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, a plurality of pixel groups **01** are arranged in an array, including a plurality of rows and a plurality of columns, for example, the pixel arrangement structure includes a plurality of first pixel groups **011** located in odd rows and a plurality of second pixel groups **012** located in even rows. For example, pixel groups of even rows and pixel groups of odd rows are arranged in a staggered way. The second line segment LS2 can extend in the second direction Y. For example, in order to realize pixel arrangement density in the column direction, in the adjacent odd rows or in the adjacent even rows, the length D2 of the center connection line L14 between the first sub-pixel **111** and the fourth sub-pixel **114** that are adjacent to each other in two adjacent ones of the plurality of pixel groups **01** in the second direction Y is greater than the length of the second line segment LS2. For example, in adjacent odd rows or in adjacent even rows, the ratio of the length D2 of the center connection line L14 between the first sub-pixel **111** and the

fourth sub-pixel **114** that are adjacent to each other in the two adjacent ones of the plurality of pixel groups **01** in the second direction Y to the length of the second line segment LS2 ranges from 1 to 3.

[0064] For example, in two adjacent ones of the odd rows or in two adjacent ones of the even rows, the length D2 of the center connection line L14 between the first sub-pixel **111** and the fourth sub-pixel **114** that are adjacent to each other in the two adjacent ones of the plurality of pixel groups **01** in the second direction Y is greater than the length of the second line segment LS2. Thus, a pixel structure in which six pixel groups are closely arranged around one pixel group can be formed. The odd row pixel groups and the even row pixel groups are staggered. For example, the odd row pixel groups and the even row pixel groups are offset in the first direction X by the length of half a pixel group in the first direction X, for example, the offset length is L, but is not limited thereto. For example, in two adjacent ones of the odd rows or in adjacent ones of the even rows, the ratio of the length D2 of the center connection line between the first sub-pixel **111** and the fourth sub-pixel **114** that are adjacent to each other in the two adjacent ones of the plurality of pixel groups **01** in the second direction Y to the length of the second line segment LS2 ranges from 1 to 3.

[0065] As illustrated in FIG. 4, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, an extension line of the second line segment LS2 of each pixel group **01** passes through a midpoint C0 of a center connection line LSC between two pixel groups **01** that are adjacent to the pixel group **01** in the second direction Y and are located in the same row. The center of each pixel group **01** is C1, and the connection line between the centers C1 of two adjacent pixel groups **01** is the center connection line LSC. For example, the center C1 of the pixel group **01** may be the intersection point of the first line segment LS1 and the second line segment LS2.

[0066] For example, the extension line of the second line segment LS2 of each first pixel group **011** passes through the center C5 of the center connection line LS3 between the adjacent third sub-pixel **113** and the second sub-pixel **112** of the two second pixel groups **012** adjacent to the first pixel group **011** and located in the same row. For example, the center C5 and the center C0 can be the same point.

[0067] As illustrated in FIG. 4, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, in two adjacent ones of the odd rows or in two adjacent ones of the even rows, an intersection point IP1 of a center connection line LS4 between two third sub-pixels **113** in two adjacent ones of the plurality of pixel groups **01** (two adjacent first pixel groups **011** or two adjacent second pixel groups **012**) arranged in the second direction Y and the first line segment LS1 in a pixel group **01** located between the two third sub-pixels **113** is located between a center IPO of the first line segment LS1 and a center C2 of the second sub-pixel **112**. For example, the center IPO of the first line segment LS1 can be the center C1 of the pixel group **01**. For example, the intersection point IP1 is located at the midpoint of the connection line between the center IPO of the first line segment LS1 and the center C2 of the second sub-pixel **112**.

[0068] For example, in adjacent odd rows, the intersection point IP1 of the center connection line LS4 between the two third sub-pixels **113** of the adjacent first pixel groups **011** located in the same column and the first line segment LS1 of the second pixel group **012** adjacent to the third sub-pixel **113** is located at a position between the intersection point IPO of the first line segment LS1 and the second line segment LS2 of the second pixel group **012** and the center C2 of the second sub-pixel **112**. The third sub-pixel **113** above-mentioned can also be replaced by the second sub-pixel **112**.

[0069] For example, in two adjacent ones of the odd rows or two adjacent ones of the even rows, the intersection point of the center connection line between two second sub-pixels **112** in two adjacent pixel groups **01** (two adjacent first pixel groups **011** or two adjacent second pixel groups **012**) arranged in the second direction Y and the first line segment LS1 in the pixel group **01** located between the two second sub-pixels **112** is located between the center IPO of the first line segment LS1 and the center C3 of the third sub-pixel **113**. For example, the intersection point is located at

the midpoint of the connection line between the center IPO of the first line segment LS1 and the center C3 of the third sub-pixel **113**.

[0070] As illustrated in FIG. 4, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, in the same pixel group, the closest distance between the second sub-pixel **112** and the first sub-pixel **111** is L1, the closest distance between the second sub-pixel **112** and the fourth sub-pixel **114** is L2, the closest distance between the third sub-pixel **113** and the first sub-pixel **111** is L3, the closest distance between the third sub-pixel **113** and the fourth sub-pixel **114** is L4, and L1=L2=L3=L4.

[0071] As illustrated in FIG. 4, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, the closest distance between the second sub-pixel **112** and one of the first sub-pixel **111** and the fourth sub-pixel **114** is L5, the closet distance between the third sub-pixel **113** and one of the first sub-pixel **111** and the fourth sub-pixel **114** is L6, the second sub-pixel **112** and the third sub-pixel **113** are in a pixel group being adjacent to the first sub-pixel **111** or the fourth sub-pixel **114** in the second direction and are not in the same row with the first sub-pixel **111** or the fourth sub-pixel **114**, and L5=L6.

[0072] For example, in an embodiment, L1=L2=L3=L4=L5=L6.

[0073] For example, with respect to L1, L2, L3, L4, L5, and L6, the marks about the minimum process spacing d in FIGS. 7A and 7B can also be referred to. Each of the closest distances is the minimum distance between two sub-pixels. For example, L1, L2, L3, L4, L5, and L6 can be made as close as possible to the minimum process spacing d during actual fabrication. For example, the closest distance is the distance between the closest two points on the outer edge of the two sub-pixels.

[0074] As illustrated in FIG. 4, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, the opposite sides of two adjacent sub-pixels are approximately parallel or have an included angle less than 45 degrees, and the adjacent sub-pixels include any two adjacent ones selected from the group consisting of the first sub-pixel **111**, the second sub-pixel **112**, the third sub-pixel **113**, and the fourth sub-pixel **114**.

[0075] As illustrated in FIG. 5A, in the pixel arrangement structure provided by one or more embodiments of the present disclosure, the first sub-pixel **111** and the fourth sub-pixel **114** are both strip-shaped, and the extension direction A1 of the first sub-pixel **111** does not coincide with the extension direction A2 of the fourth sub-pixel **114**. For example, the extension direction A1 of the first sub-pixel **111** intersects or has an included angle with the extension direction A2 of the fourth sub-pixel **114**. For example, in each pixel group, the first sub-pixel **111** and the fourth sub-pixel **114** are arranged with the first direction X as an axis of symmetry and inclined at a certain angle. For example, the included angle between the inclination angle and the first direction X ranges from 30 to 50 degrees, and further for example, the included angle is 45 degrees, but is not limited thereto. For example, the extension direction A1 of the first sub-pixel **111** can be the long axis direction of the first sub-pixel **111**, but is not limited thereto. For example, the extension direction A2 of the fourth sub-pixel **114** can be the long axis direction of the fourth sub-pixel **114**, but is not limited thereto.

[0076] As illustrated in FIG. 5A, in each pixel group **01** of the pixel arrangement structure provided by one or more embodiments of the present disclosure, the first sub-pixel **111** and the fourth sub-pixel **114** are symmetrically arranged with respect to the first line segment LS1. For example, in each pixel group **01**, the first sub-pixel **111** and the fourth sub-pixel **114** are asymmetrically arranged with respect to the second line segment LS2.

[0077] For example, the second sub-pixel **112** and the third sub-pixel **113** are symmetrically arranged with respect to the second line segment LS2, but is not limited thereto.

[0078] For example, in this embodiment of the present disclosure, the strip shape means that a length in one direction is greater than a length in another direction, or a dimension in one direction is greater than a dimension in other directions. The strip shape is not limited to a rectangle, and can

be other shapes, for example, may be a long hexagonal shape, an oblong shape, a trapezoid shape, or other shapes. In the embodiments of the present disclosure, the shape of each sub-pixel is not limited to a regular shape, and can be an irregular shape.

[0079] For example, the included angle between the extension direction **A1** of the first sub-pixel **111** and the extension direction **A2** of the fourth sub-pixel **114** ranges from 70 degrees to 100 degrees, further, the included angle can be from 80 degrees to 95 degrees, further, the included angle can be 90 degrees (a right angle), so that the first sub-pixel **111** and the fourth sub-pixel **114** forming a larger area can be utilized to improve the light emitting area and is beneficial to the screening of the mask plate during fabricating the mask plate of the light emitting layer pattern. For example, in a case where the included angle is a right angle, deviations of up and down several degrees can be allowed. For example, it can deviate from 90 degrees by 5 degrees.

[0080] FIG. 5B illustrates a pixel arrangement structure provided by one or more embodiments of the present disclosure, in the pixel arrangement structure, an included angle between an extension direction **A1** of the first sub-pixel **111** and an extension direction **A2** of the fourth sub-pixel **114** is a right angle, and in the same pixel group **01**, the first sub-pixel **111** and the fourth sub-pixel **114** are sub-pixels of the same color.

[0081] FIG. 6 illustrates a pixel arrangement structure provided by one or more embodiments of the present disclosure. As illustrated in FIG. 6, the second sub-pixel **112** and the third sub-pixel **113** can be rhombus or approximately rhombus. Approximate rhombus includes, for example, rounded rhombus, chamfered rhombus, etc., but is not limited thereto. The sub-pixel shape of rhombus or approximately rhombus shape is more favorable for pixel dense arrangement. For example, the first sub-pixel **111** can be relatively symmetrical around the third sub-pixel **113** and the second sub-pixel **112**, with the long sides of the first sub-pixel **111** all facing the second sub-pixel **112** and the short sides all facing the third sub-pixel **113** to ensure the uniformity of pixel arrangement to the greatest extent. The arrangement of the first sub-pixels **111** is more uniform, which can improve the color edge to a certain extent, is conducive to the realization of high PPI, and can improve the pixel aperture ratio as high as possible.

[0082] The shape of each sub-pixel is not limited to the above, and the shapes of the sub-pixels can be adjusted as required. Maximizing the area is the main principle for determining the shape of sub-pixels.

[0083] In order to avoid color mixing, the spacing between different color sub-pixels should be greater than the minimum process spacing d of the patterning process, and some special process symmetry requirements should be considered. For example, the FMM screening requires symmetrical opening patterns and distribution, and the shapes of the first sub-pixel and the fourth sub-pixel can be symmetrical pentagons with right-angle bottom corners respectively (as illustrated in FIG. 2E). It can be seen that the spacing between the second and third sub-pixel of adjacent pixel groups using symmetrically shaped sub-pixels are significantly larger than other spacing between different color sub-pixels (the minimum process spacing d), i.e., there is still usable area in design. Under the condition that FMM screening technology allows or adopts other symmetry insensitive (e.g. CF) processes, asymmetrical sub-pixel shapes can be adopted to realize maximum sub-pixel area.

[0084] FIGS. 7A and 7B illustrate pixel arrangement structures provided by one or more embodiments of the present disclosure. As illustrated in FIGS. 7A and 7B, under the condition that asymmetric sub-pixel shapes are allowed to be adopted, according to the minimum process spacing d of different patterning processes, the shapes of the second sub-pixel **112** and the third sub-pixel **113** can be right-angle trapezoids or right-angle trapezoids with acute angles cut off, so as to maximize the area.

[0085] As illustrated in FIG. 7A, because the shapes of the second sub-pixel **112** and the third sub-pixel **113** are both right-angle trapezoids, compared to the case where the shapes of the second sub-pixel **112** and the third sub-pixel **113** are both hexagonal (a hexagonal shape formed by combining

two pentagons with symmetrical right-angle bottom angles), the acute angle portions **190** of the second sub-pixel **112** and the third sub-pixel **113** can further improve the areas of the second sub-pixel **112** and the third sub-pixel **113**, and thus further improve the space utilization rate in the pixel group. The pixel arrangement structure can improve the space utilization rate in the pixel group. [0086] As illustrated in FIG. 7B, the shapes of the second sub-pixel **112** and the third sub-pixel **113** are both isosceles trapezoids with acute angles cut off. Therefore, when the process accuracy is constant, that is, when the distances between the first sub-pixel **111** and the second sub-pixel **112** and between the first sub-pixel **111** and the third sub-pixel **113** are constant, the areas of the second sub-pixel **112** and the third sub-pixel **113** are increased, thereby improving the utilization rate of the space within the pixel group.

[0087] In the pixel arrangement structure provided by one or more embodiments of the present disclosure, the shapes of the second sub-pixel **112** and the third sub-pixel **113** include at least one of isosceles trapezoid, hexagon and rhombus, and the shape of the second sub-pixel **112** includes at least one of pentagon, rectangle and approximate rectangle. The approximate rectangle includes, for example, but is not limited to, a rounded rectangle.

[0088] At least one embodiment of the present disclosure provides a display substrate including any one of the above pixel arrangement structures.

[0089] FIG. 8 illustrates a display substrate provided by one or more embodiments of the present disclosure. As illustrated in FIG. 8, in the same row of pixel groups, the third sub-pixel **113** and the first sub-pixel **111** can be driven by the first drive line DL1, and the second sub-pixel **112** and the fourth sub-pixel **114** can be driven by the second drive line DL2. The first drive line DL1 extends in the direction E1 and the second drive line DL2 extends in the direction E1. For example, the direction E1 is parallel to the first direction X.

[0090] As illustrated in FIG. 8, the first sub-pixel **111** and the fourth sub-pixel **114** in the odd column pixel group can use the first data line DT1 to input data signals, and the second sub-pixel **112** and the third sub-pixel **113** located between the adjacent two first data lines DT1 can use the second data line DT2 to input data signals. For example, the data signal includes a voltage and/or a current. The first data line DT1 extends in the direction E2, and the second data line DT2 also extends in the direction E2, which is parallel to the second direction Y.

[0091] For example, one pixel group includes two pixel units, for example, the first sub-pixel **111** and the second sub-pixel **112** form a pixel unit, the third sub-pixel **113** and the fourth sub-pixel **114** form the other pixel unit. Each pixel unit can share the third sub-pixel **113** or the fourth sub-pixel **114** adjacent thereto for full color display. The display is realized by sub-pixel sharing.

[0092] FIG. 9 is a cross-sectional view of a display substrate provided by an embodiment of the present disclosure. As illustrated in FIG. 9, the structure includes a base substrate **001**, and a buffer layer **002**, a first gate insulation layer **003**, a second gate insulation layer **004**, an interlayer dielectric layer **005**, a planarization layer **006**, and a pixel defining layer **007** sequentially located on the base substrate **001**. As can be seen from FIG. 9, below the sub-pixel, there is a thin film transistor structure including a gate electrode **302**, an active layer **301**, and a drain electrode **303**. The thin film transistor can be one of the thin film transistors in a pixel drive circuit, and the connection relationship with other components can be set according to the specific pixel circuit arrangement, which is not illustrated in detail herein. In addition, a signal line **304** can also be included at a position on the same layer as the drain electrode **303**, and the signal line **304** can also be used as a signal line of a specific function according to different pixel circuit arrangements, for example, a data line or a gate line, etc. As can be seen from FIG. 9, the pixel defining layer **007** can include openings defining sub-pixels. The anode **403** of the sub-pixel and the light emitting layer **503** of the third sub-pixel are located in the openings of the pixel defining layer **007**. It should be noted that the structure of the display substrate is not limited to that illustrated in FIG. 9.

[0093] For example, the anode **403** and the light emitting layer **503** are in contact with each other, so that the light emitting layer can be driven to emit light at a portion in contact with each other,

and therefore, the portion in contact with each other between the anode **403** and the light emitting layer **503** is an effective portion in which the sub-pixel can emit light. Here, the anode **403** serves as a pixel electrode so that different data voltages can be applied to different sub-pixels. However, in the embodiments according to the present disclosure, the electrode used as the pixel electrode of the sub-pixel is not limited to the anode, and the cathode of the light emitting diode may also be used as the pixel electrode. Therefore, in the embodiments of the present disclosure, the shape of the sub-pixel can refer to the shape of a portion where the pixel electrode and the light emitting layer contact each other. For example, for each sub-pixel, the area of the pixel electrode can be slightly larger than the area of the light emitting layer, or the area of the light emitting layer can be slightly larger than the area of the pixel electrode, and the embodiments of the present disclosure is not particularly limited to this. For example, the light emitting layer here can include the electroluminescent layer itself and other function layers located on both sides of the electroluminescent layer, for example, a hole injection layer, a hole transport layer, an electron injection layer, an electron transport layer, and the like. In some embodiments, the shape of a pixel can also be defined by a pixel defining layer. For example, a lower electrode (e.g., an anode) for a light emitting diode can be disposed below a pixel defining layer including an opening for defining a pixel that exposes a portion of the lower electrode. When the light emitting layer is formed in the opening in the pixel defining layer described above, the light emitting layer contacts the lower electrode so that the light emitting layer can be driven to emit light at this portion. Therefore, in this case, the opening of the pixel defining layer defines the shape of the sub-pixel.

[0094] For example, the pixel circuit includes at least one transistor including a gate electrode, an active layer, a source electrode, and a drain electrode. In one example, the signal line is electrically connected to the source electrode or drain electrode of the corresponding transistor through a via hole penetrating through the insulation layer below it. In one example, the active layer of the transistor is formed of a polysilicon layer. On both sides of the channel region of the active layer, the polysilicon layer is conductive to form the source electrode and the drain electrode. For example, the signal line is electrically connected to the polysilicon source or drain electrodes formed by conducting through a via hole. For example, the transistor is a top gate transistor, and a via hole for electrically connecting the signal line to the source or drain electrodes of the corresponding transistor passes through the gate metal layer and the data metal layer, and a portion of the metal pattern of the gate metal layer and the data metal layer can be used as a relay connector for electrically connecting the via hole, but embodiments of the present disclosure are not limited thereto.

[0095] For example, the shapes of the various sub-pixels described in the embodiments of the present disclosure are all approximate shapes. When forming the light emitting layer or various electrode layers, it is not guaranteed that the edges of the sub-pixels are strictly straight lines and the corners are strictly angular. For example, the light emitting layer can be formed by a mask vapor deposition process, and therefore, its corners can be rounded. In some cases, metal etching can have a draft angle, so when forming a light emitting layer of a sub-pixel by vapor deposition, one angle of the light emitting layer can be removed.

[0096] For example, the shapes of the sub-pixels are the shapes of the orthographic projections of the sub-pixels on the base substrate.

[0097] At least one embodiment of the present disclosure provides a display device including any one of the above display substrates. Thus, the resolution of the display device can be improved, and further a display device with real high resolution can be provided. In addition, because the symmetry of the pixel arrangement structure is better, the display effect of the display device is better.

[0098] For example, in some examples, the display device can be any product or component with display function such as a smart phone, a tablet computer, a television, a display, a notebook computer, a digital photo frame, a navigator, etc.

[0099] The following statements should be noted:

[0100] (1) The accompanying drawings involve only the structure(s) in connection with the embodiment(s) of the present disclosure, and other structure(s) can be referred to common design(s).

[0101] (2) In case of no conflict, features in one embodiment or in different embodiments can be combined.

[0102] What have been described above are only specific implementations of the present disclosure, the protection scope of the present disclosure is not limited thereto. Any changes or substitutions easily occur to those skilled in the art within the technical scope of the present disclosure should be covered in the protection scope of the present disclosure. Therefore, the protection scope of the present disclosure should be based on the protection scope of the claims.

Claims

1. A display substrate, comprising a plurality of pixel groups; each of the plurality of pixel groups comprises a first sub-pixel, a second sub-pixel, a third sub-pixel and a fourth sub-pixel; in each of the plurality of pixel groups, a connection line between a center of the second sub-pixel and a center of the third sub-pixel is a first line segment, the first sub-pixel and the fourth sub-pixel are between the second sub-pixel and the third sub-pixel and are respectively at two sides of the first line segment, a connection line between a center of the first sub-pixel and a center of the fourth sub-pixel is a second line segment; a first data line, extending in an extension direction of the second line segment; a second data line, extending in the extension direction of the second line segment, wherein a plurality of second sub-pixels and a plurality of third sub-pixels are alternately arranged in the extension direction of the second line segment to form a first sub-pixel column, a plurality of first sub-pixels and a plurality of fourth sub-pixels are alternately arranged in the extension direction of the second line segment to form a second sub-pixel column, in the first sub-pixel column, the plurality of second sub-pixels and the plurality of third sub-pixels are overlapped with the first data line, in the second sub-pixel column, the plurality of first sub-pixels and the plurality of fourth sub-pixels are overlapped with the second data line.
2. The display substrate according to claim 1, wherein the first data line comprises a plurality of first sub-parts and a plurality of second sub-parts which are alternately arranged in the extension direction of the second line segment, a shortest distance between each of the plurality of first sub-parts and the second data line is a first distance, and a shortest distance between each of the plurality of second sub-parts and the second data line is a second distance, the first distance is smaller than the second distance.
3. The display substrate according to claim 1, wherein a part of the second data line overlapping with the first sub-pixel or the fourth sub-pixel extends in the extension direction of the second line segment.
4. The display substrate according to claim 1, wherein, in each of the plurality of pixel groups, the first sub-pixel and the fourth sub-pixel are both strip-shaped, a connection line between a first point on an edge of the first sub-pixel and a second point on an edge of the fourth sub-pixel which are closest points between the edge of the first sub-pixel and the edge of the fourth sub-pixel is not overlapped with a connection line between a center of the first sub-pixel and a center of the fourth sub-pixel.
5. The display substrate according to claim 4, wherein an included angle between an extension direction of the first sub-pixel and an extension direction of the fourth sub-pixel ranges from 70° to 100°.
6. The display substrate according to claim 4, wherein a shape of the first sub-pixel and a shape of the fourth sub-pixel are both rounded rectangles.
7. The display substrate according to claim 1, wherein third distances between the first data line

- and centers of the plurality of second sub-pixels and the plurality of third sub-pixels which are overlapped with the first data line are substantially equal, fourth distances between the second data line and centers of the plurality of first sub-pixels and the plurality of fourth sub-pixels which are overlapped with the first data line are substantially equal.
- 8.** The display substrate according to claim 7, wherein the third distances and the fourth distances are smaller than a closest distance between the first data line and the second data line.
- 9.** The pixel arrangement structure according to claim 1, wherein a ratio of the length the second line segment to the length the first line segment is less than or equal to $3/4$.
- 10.** The display substrate according to claim 1, wherein the first sub-pixel and the fourth sub-pixel are symmetrically arranged relative to the first line segment, and/or the second sub-pixel and the third sub-pixel are symmetrically arranged relative to the second line segment.
- 11.** The display substrate according to claim 1, wherein a shape of the second sub-pixel and a shape of the third sub-pixel are rounded rhombuses or chamfered rhombuses.
- 12.** The display substrate according to claim 1, wherein the first sub-pixel and the fourth sub-pixel are sub-pixels of the same color, the second sub-pixel and the third sub-pixel are configured to emit light of different colors.
- 13.** The display substrate according to claim 11, wherein the first sub-pixel and the fourth sub-pixel are configured to emit green light, the second sub-pixel is configured to emit red light, and the third sub-pixel is configured to emit blue light.
- 14.** The display substrate according to claim 1, wherein, in each of the plurality of pixel groups, the third sub-pixel and the first sub-pixel are driven by a first driving line.
- 15.** The display substrate according to claim 13, wherein, in each of the plurality of pixel groups, the first sub-pixel, the second sub-pixel and the third sub-pixel are overlapped with the first driving line.
- 16.** The display substrate according to claim 1, wherein, in each of the plurality of pixel groups, the second sub-pixel and the fourth sub-pixel are driven by a second driving line.
- 17.** The display substrate according to claim 16, wherein, in each of the plurality of pixel groups, the fourth sub-pixel, the second sub-pixel and the third sub-pixel are overlapped with the second driving line.
- 18.** The display substrate according to claim 1, wherein the first line segment extends in a first direction, the second line segment extends in a second direction, and the first direction is perpendicular to the second direction.
- 19.** The display substrate according to claim 1, further comprising: a base substrate, wherein each of the first sub-pixel, the second sub-pixel, the third sub-pixel and the fourth sub-pixel comprises a pixel circuit, an anode, and a pixel opening, the pixel circuit comprises a transistor, an orthographic projection of the anode on the base substrate is overlapped with an orthographic projection of the transistor on the base substrate, and an orthographic projection of the pixel opening on the base substrate is overlapped with a drain electrode of the transistor on the base substrate.
- 20.** A display device, comprising the display substrate according to claim 1.
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