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Xiao et al.

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(54) **DISPLAY SUBSTRATE, FINE METAL MASK SET AND DISPLAY DEVICE**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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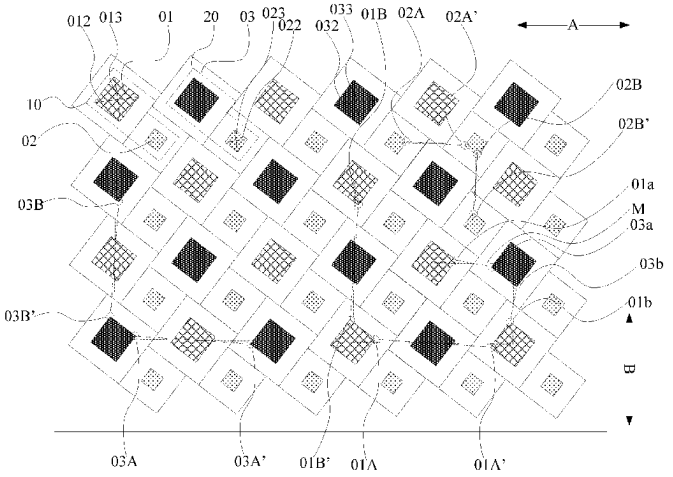
(74) *Attorney, Agent, or Firm* — Kinney & Lange, P.A.

(57) **ABSTRACT**

First sub-pixels and third sub-pixels are alternated in first and second directions to form first type of rows along the first direction and first type of columns along the second direction, and second sub-pixels form second type of rows along the first direction and second type of columns along the second direction. In at least one first type of row, a connection line between centers of first and third sub-pixels adjacent to each other is not parallel to the first direction, a connection line between centers of first sub-pixels adjacent to each other is parallel to the first direction, and a connection line between centers of third sub-pixels adjacent to each other is parallel to the first direction. In at least one of the
(Continued)



second type of rows, a connection line between centers of second sub-pixels adjacent to each other is parallel to the first direction.

14 Claims, 15 Drawing Sheets

Related U.S. Application Data

continuation of application No. 16/462,214, filed as application No. PCT/CN2018/114564 on Nov. 8, 2018, now Pat. No. 11,145,693.

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C23C 14/24	(2006.01)
H10K 71/00	(2023.01)
H10K 71/16	(2023.01)

(52) **U.S. Cl.**

CPC ***C23C 14/24*** (2013.01); ***H10K 59/352*** (2023.02); ***H10K 71/00*** (2023.02); ***H10K 71/166*** (2023.02); *G09G 2300/0452* (2013.01)

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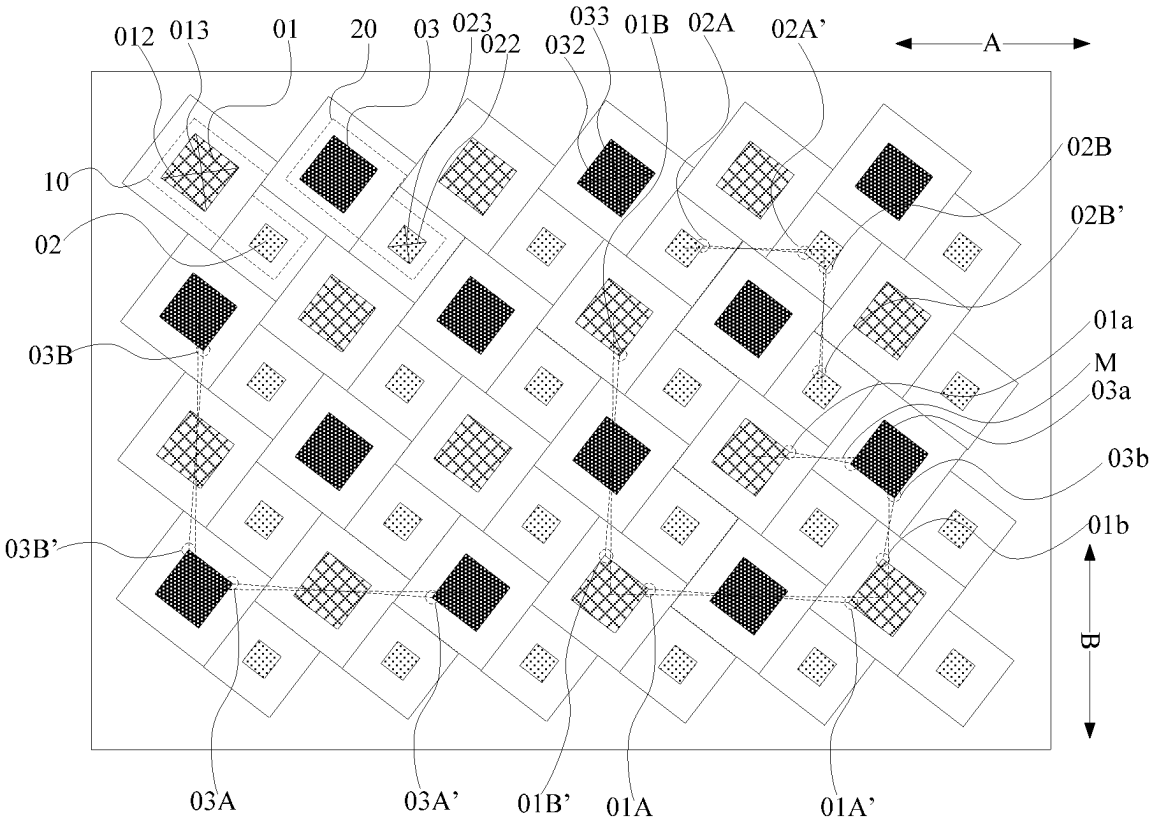
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FIG. 1

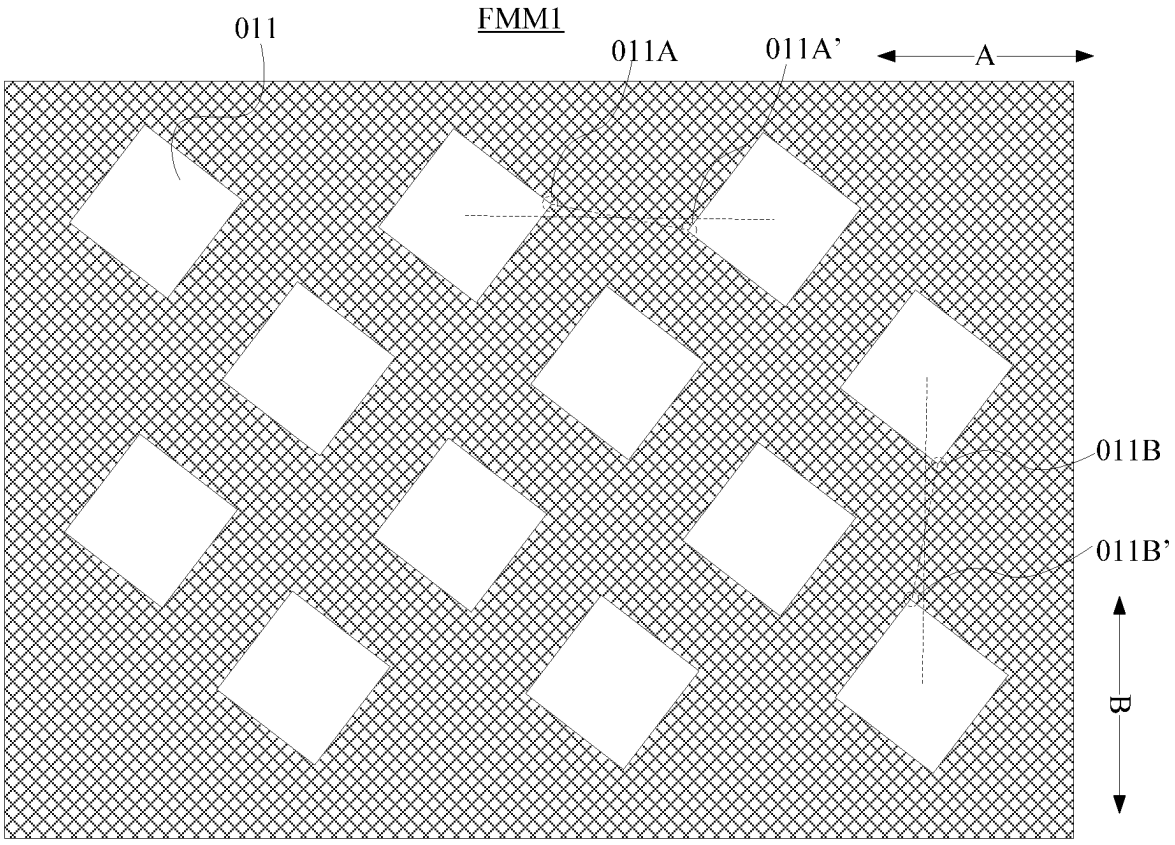

FIG.2

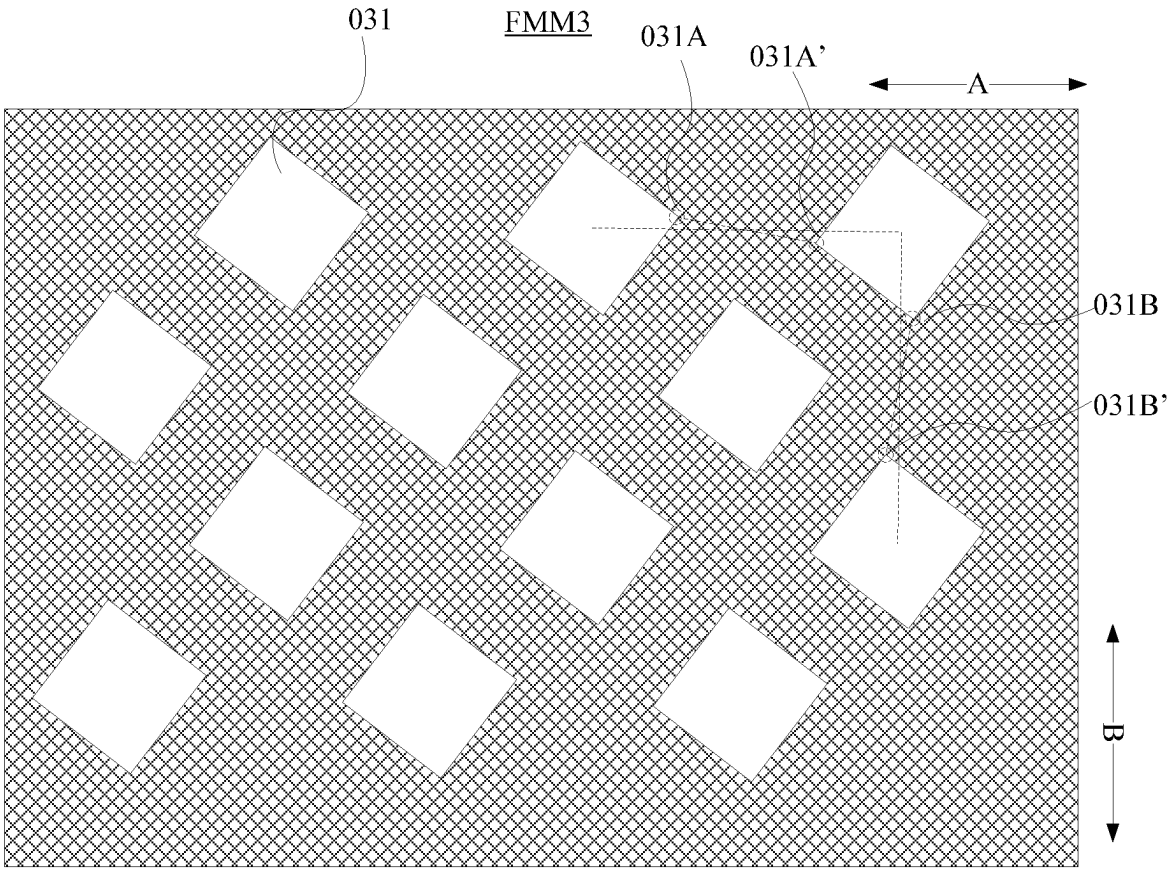

FIG.3

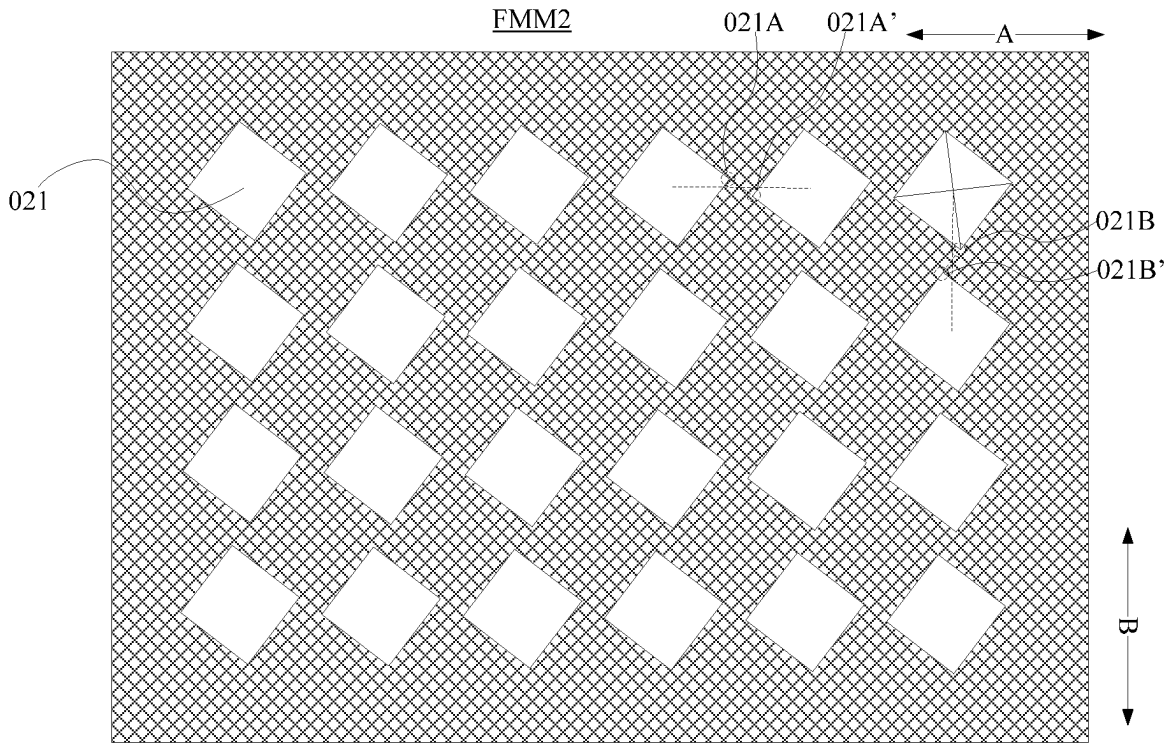

FIG.4

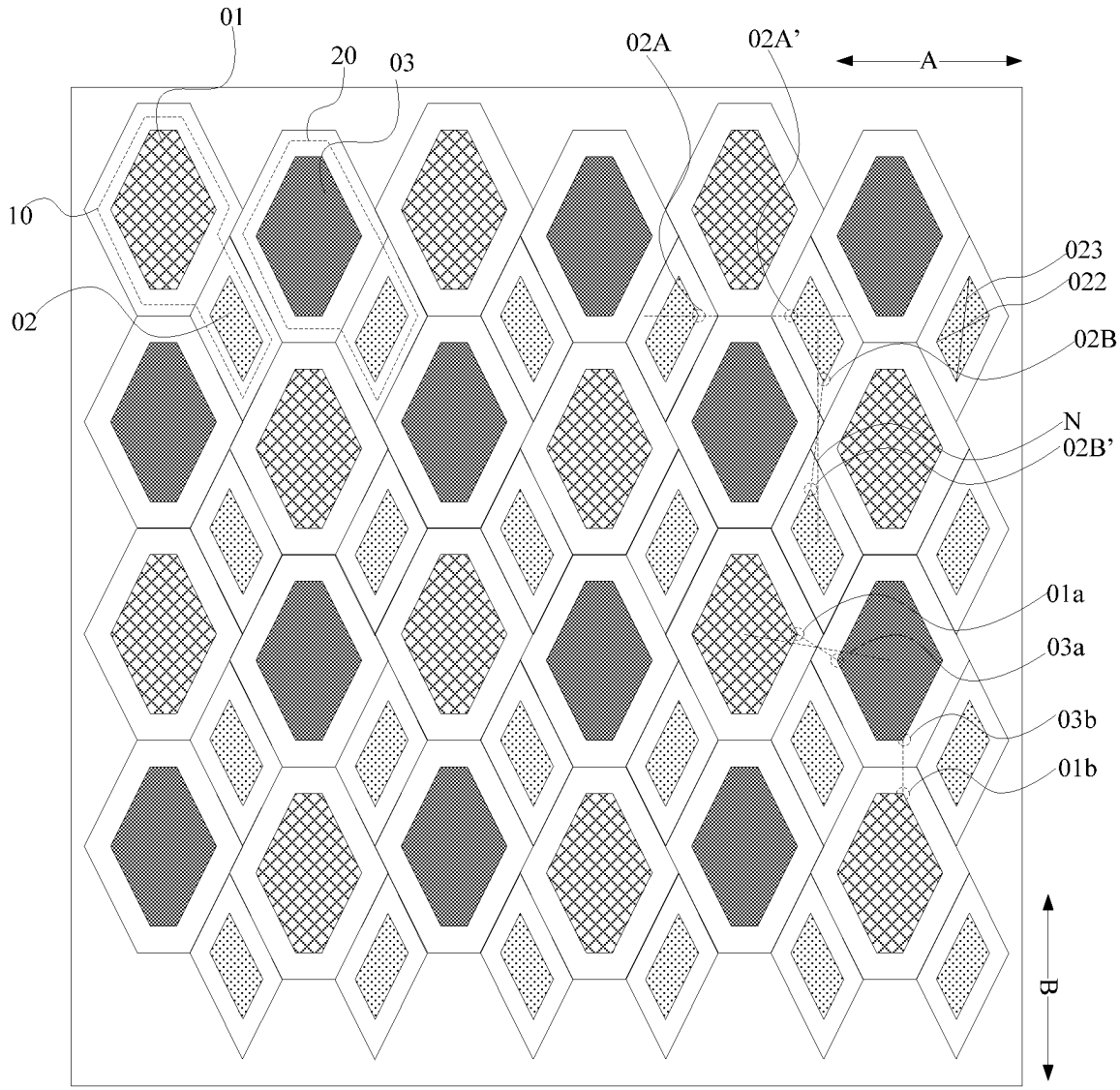

FIG.5

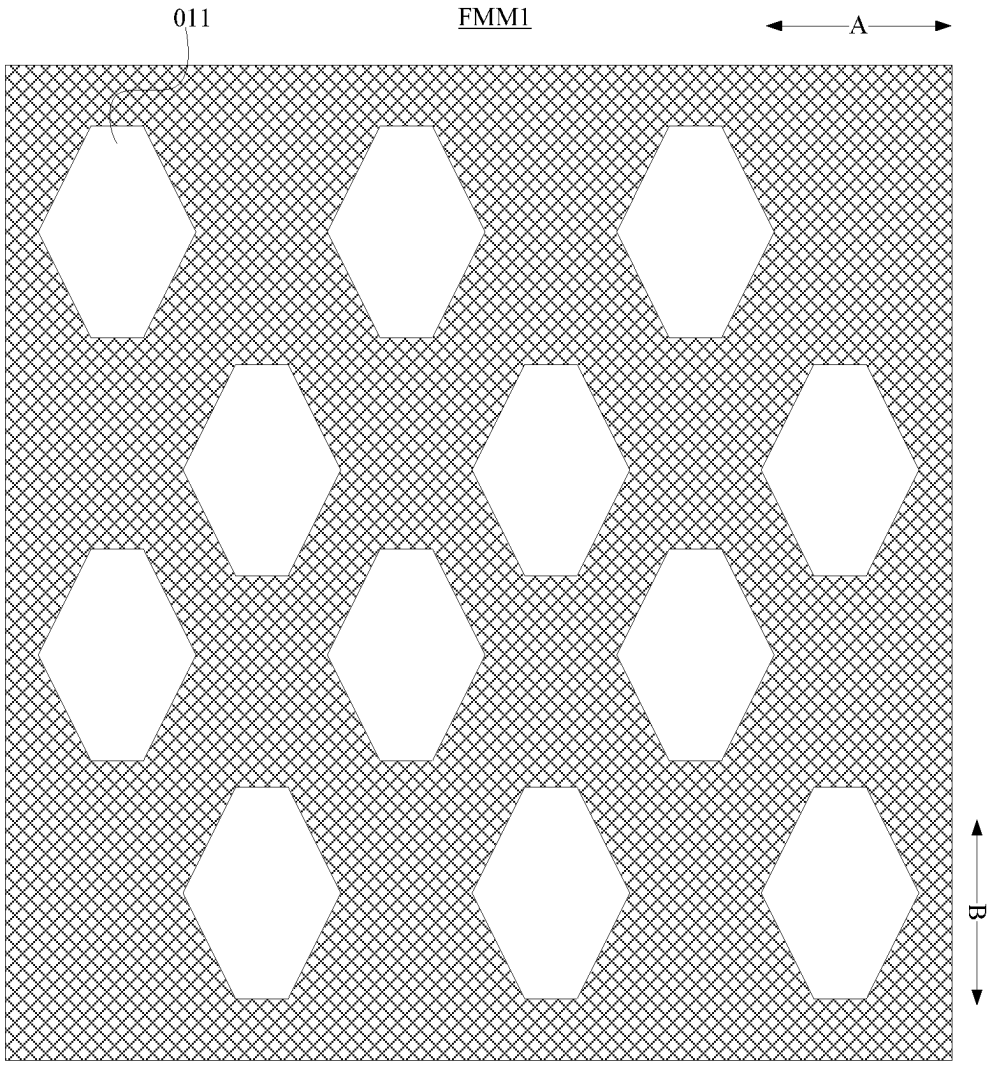

FIG.6

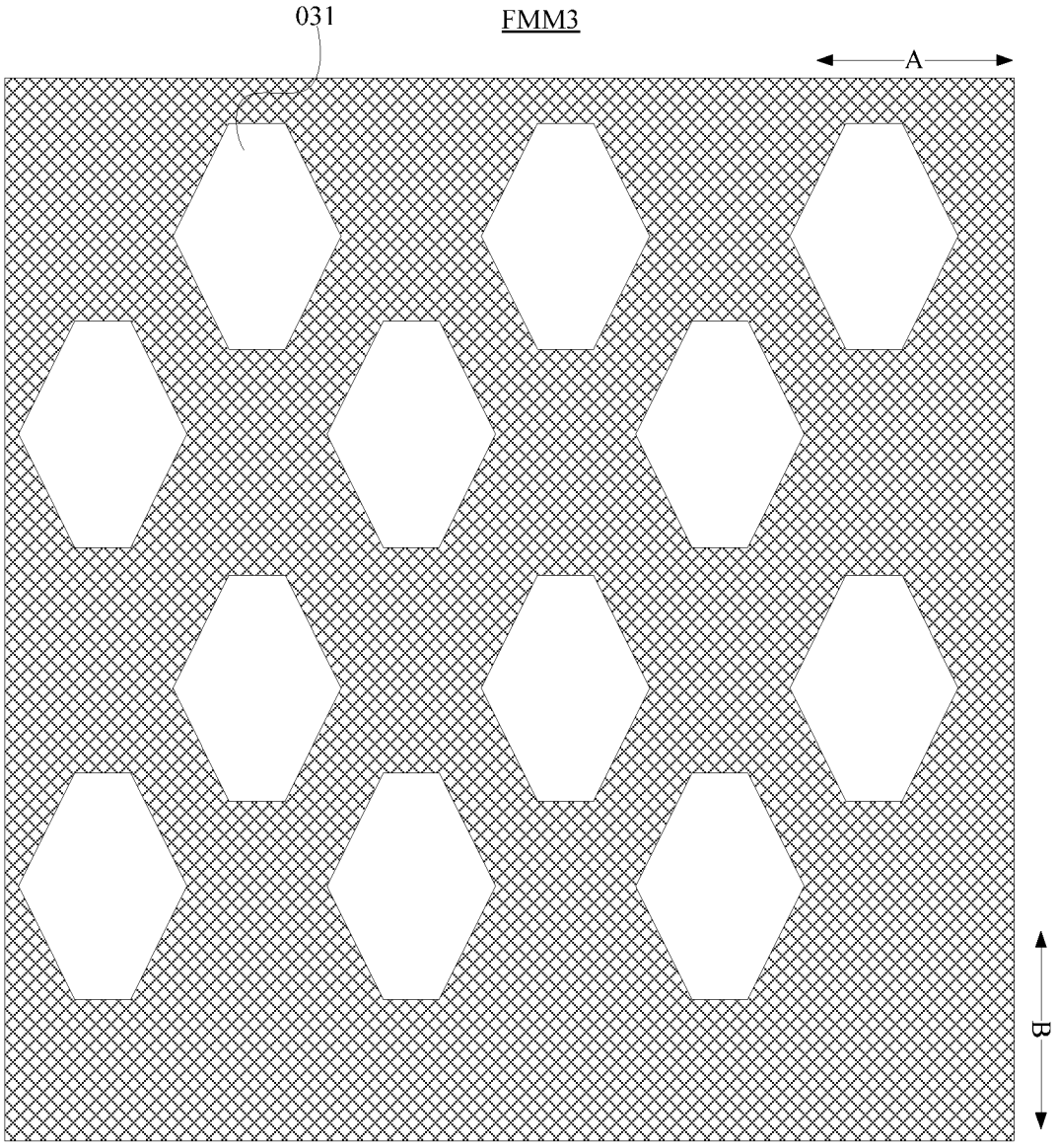

FIG.7

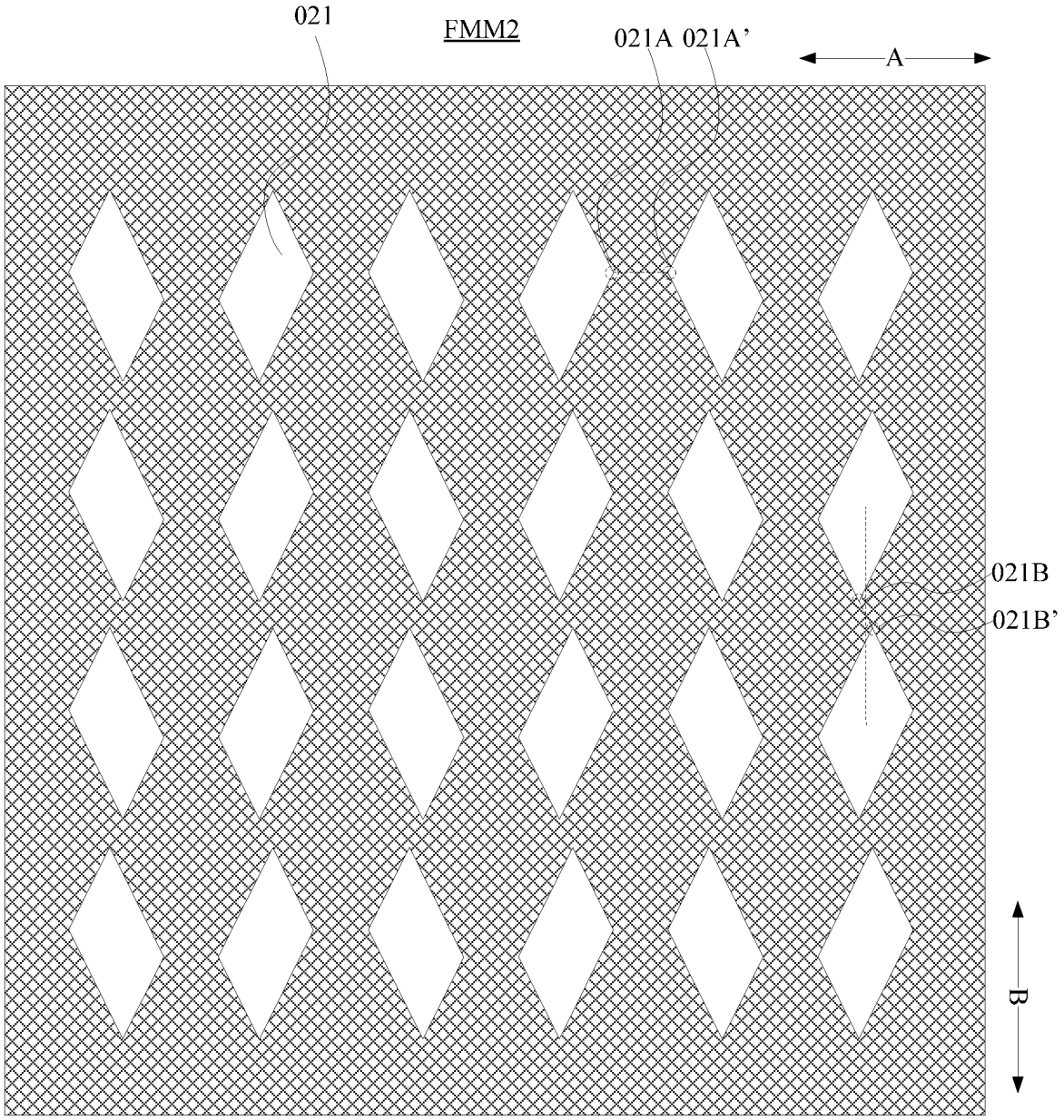

FIG.8

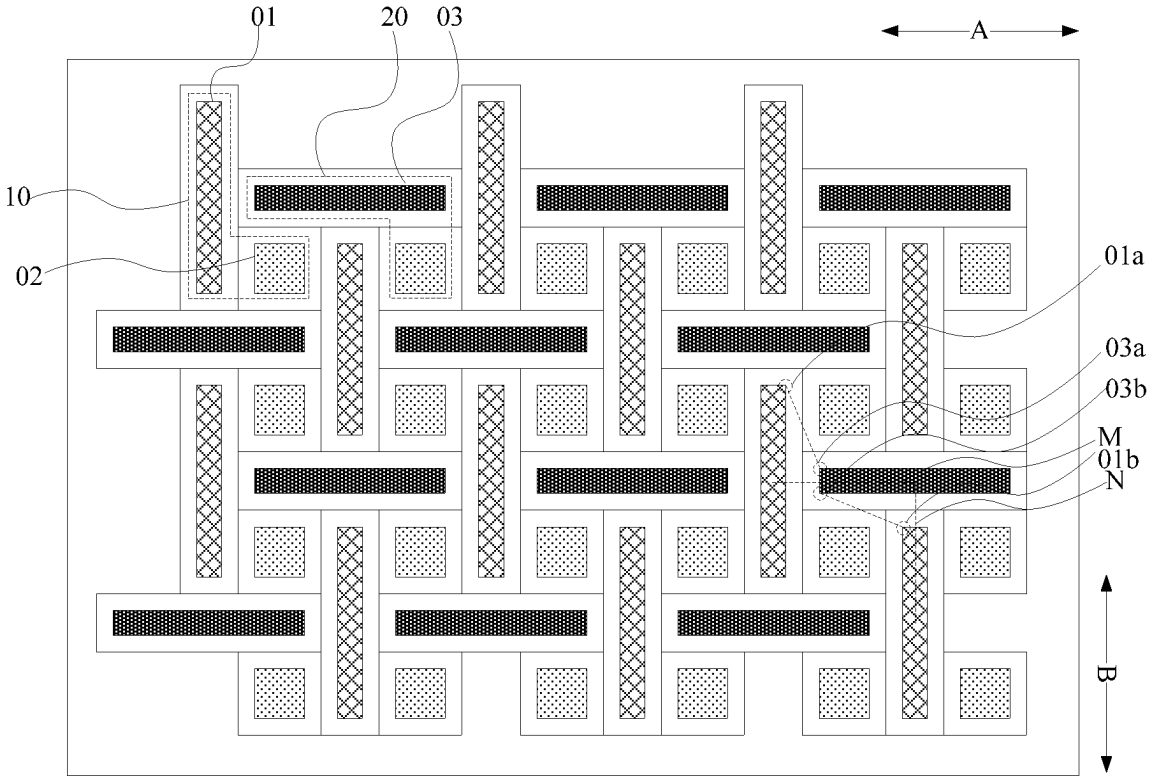

FIG.9

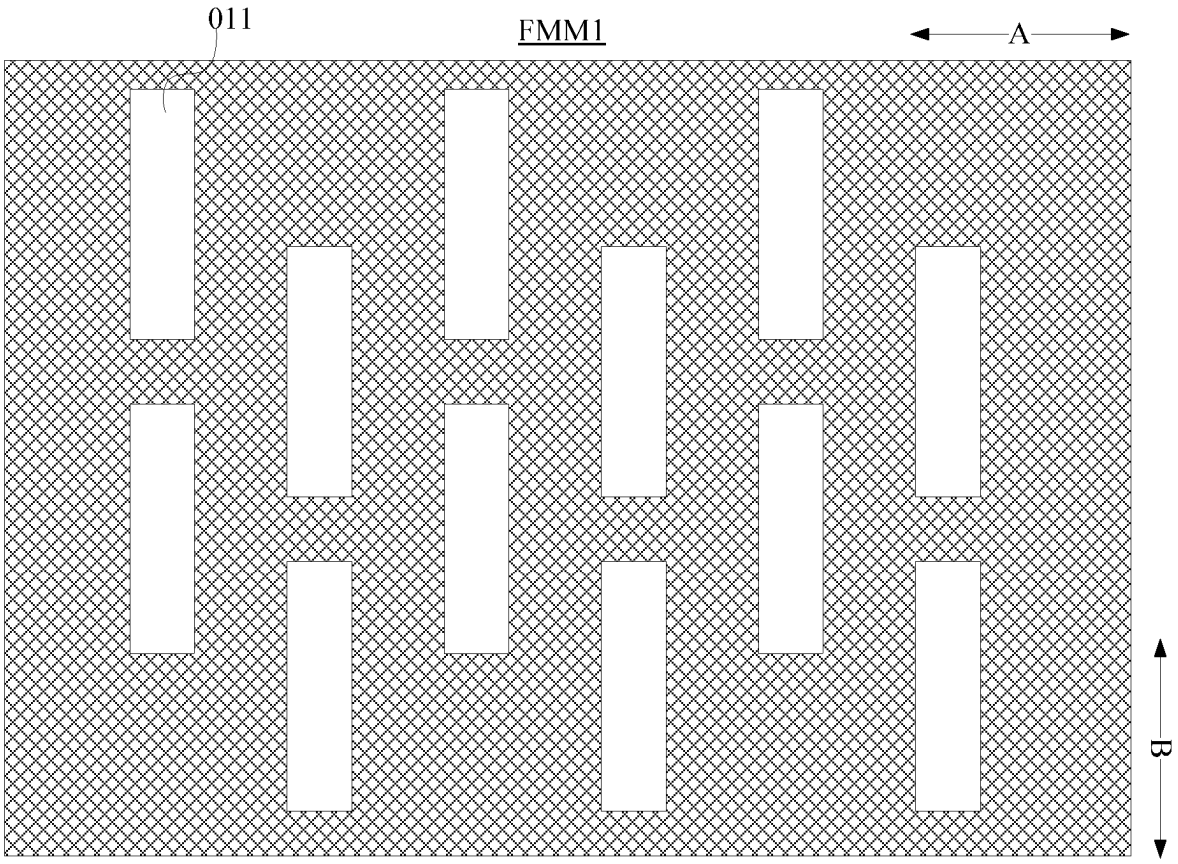

FIG.10

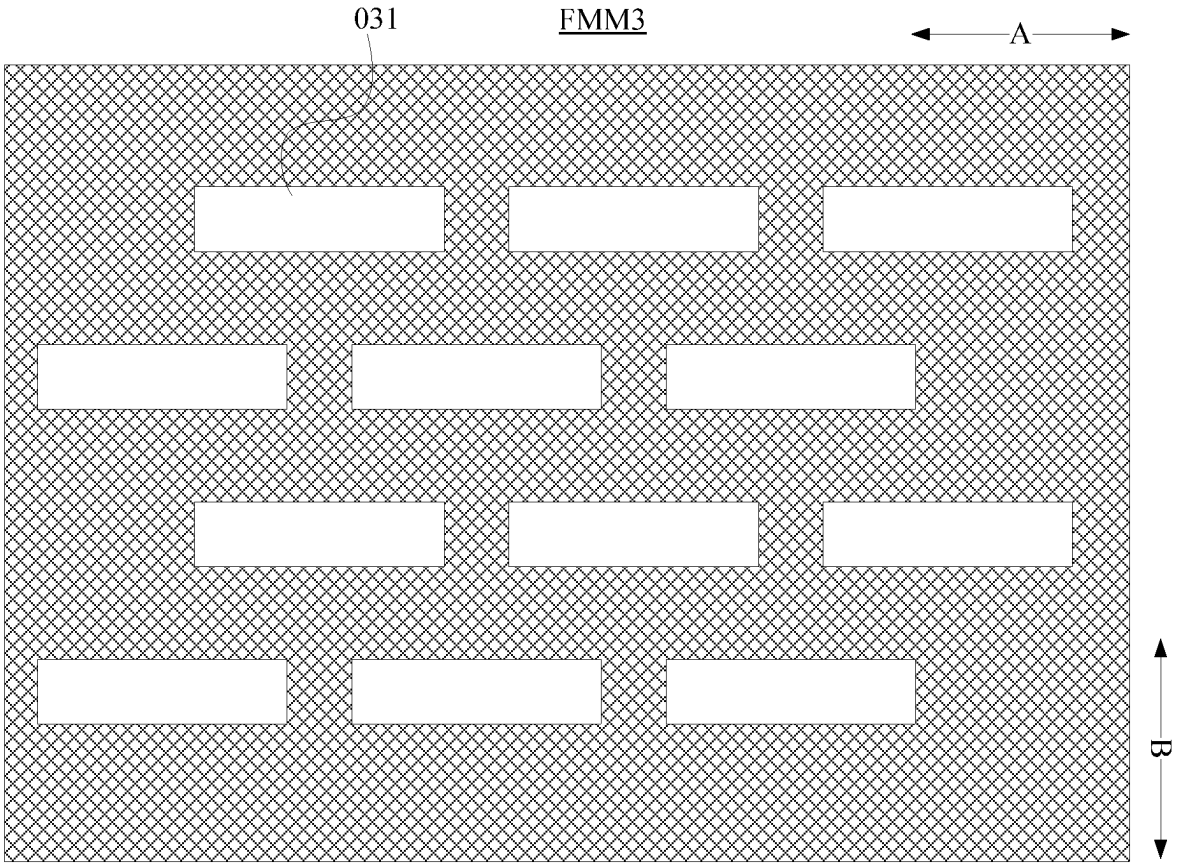

FIG.11

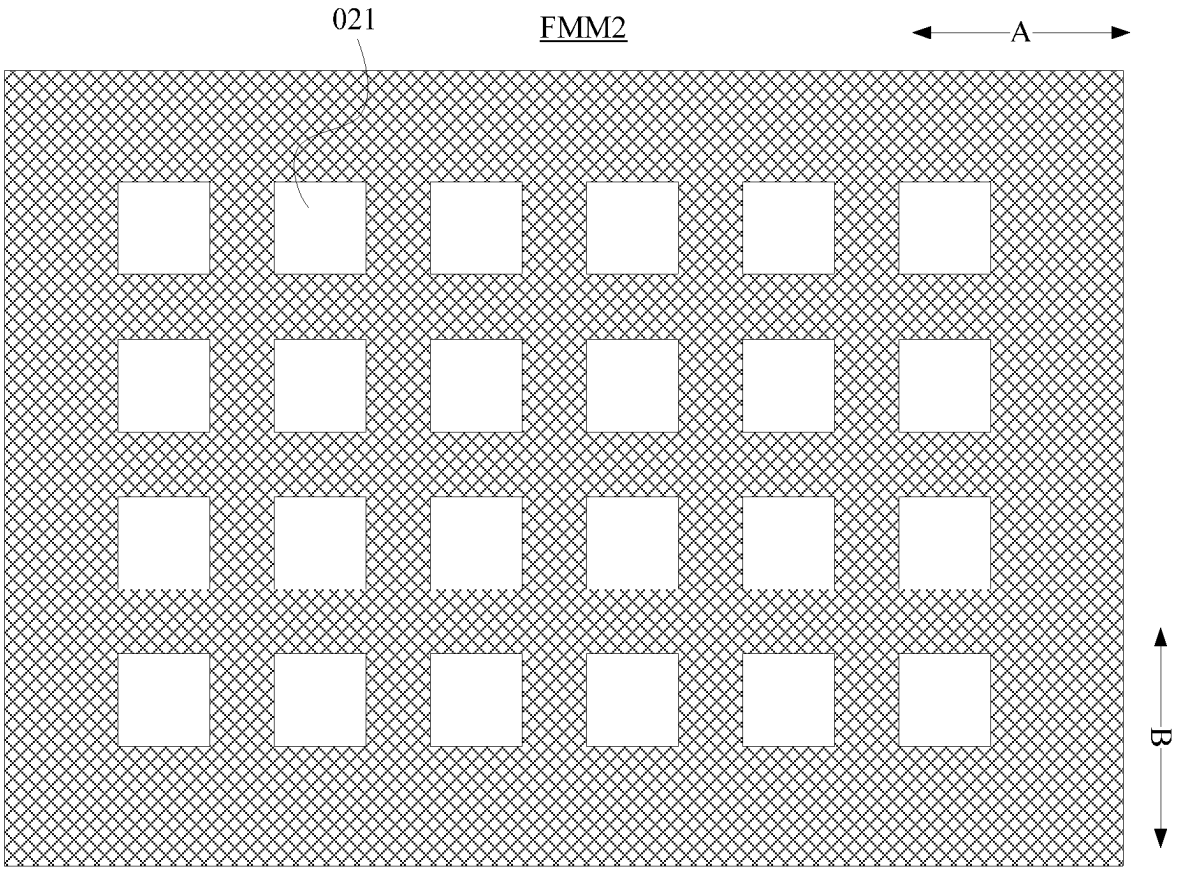

FIG.12

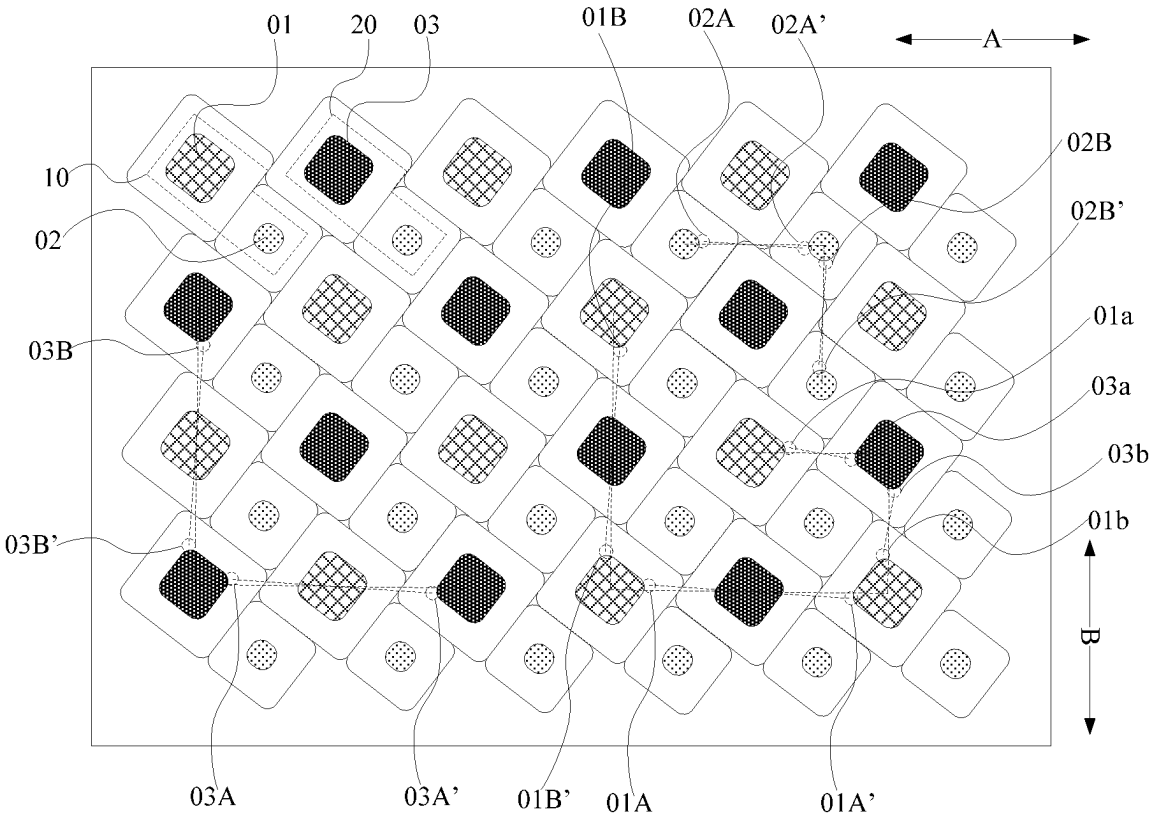
01
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FIG.13

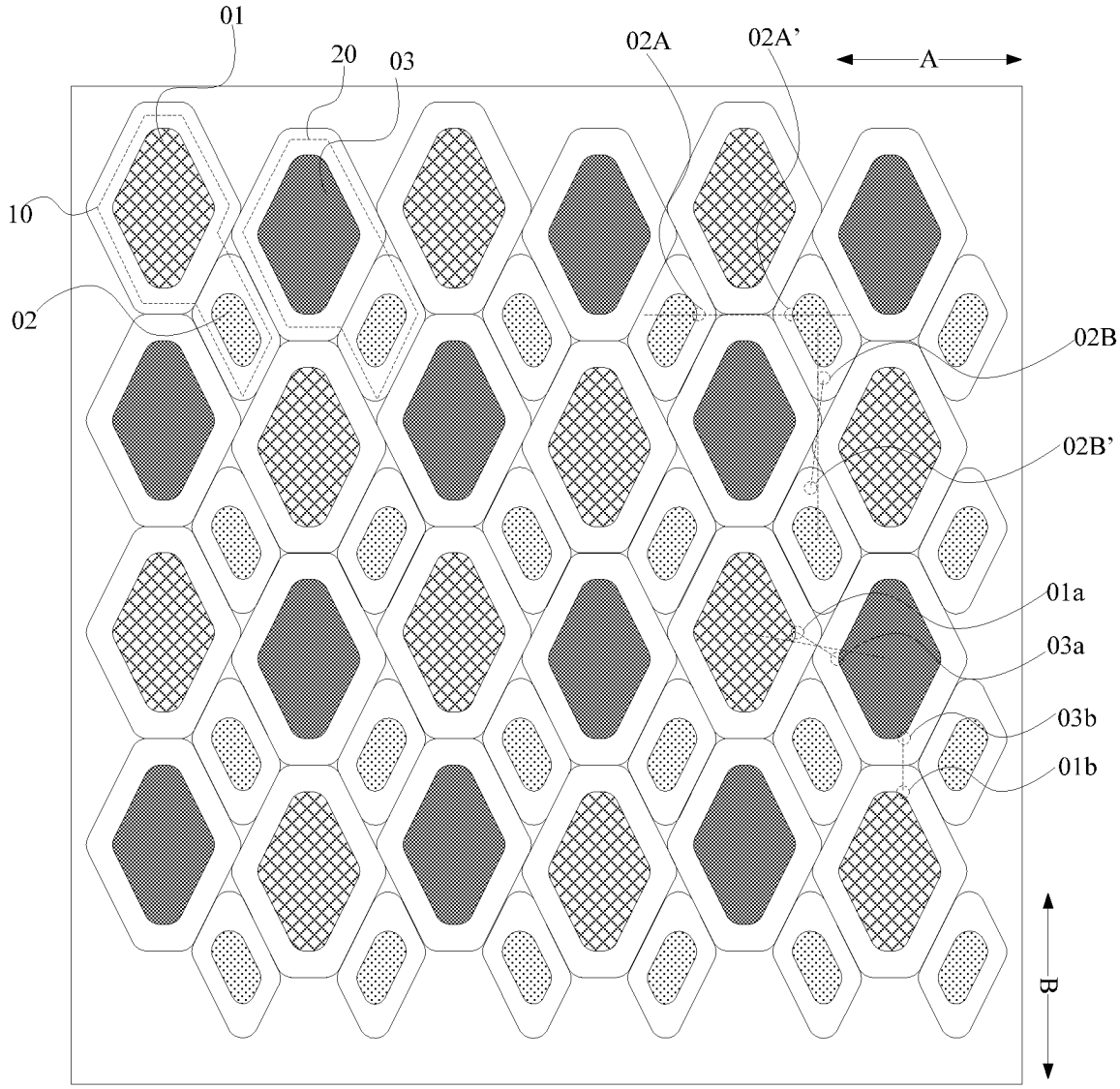

FIG.14

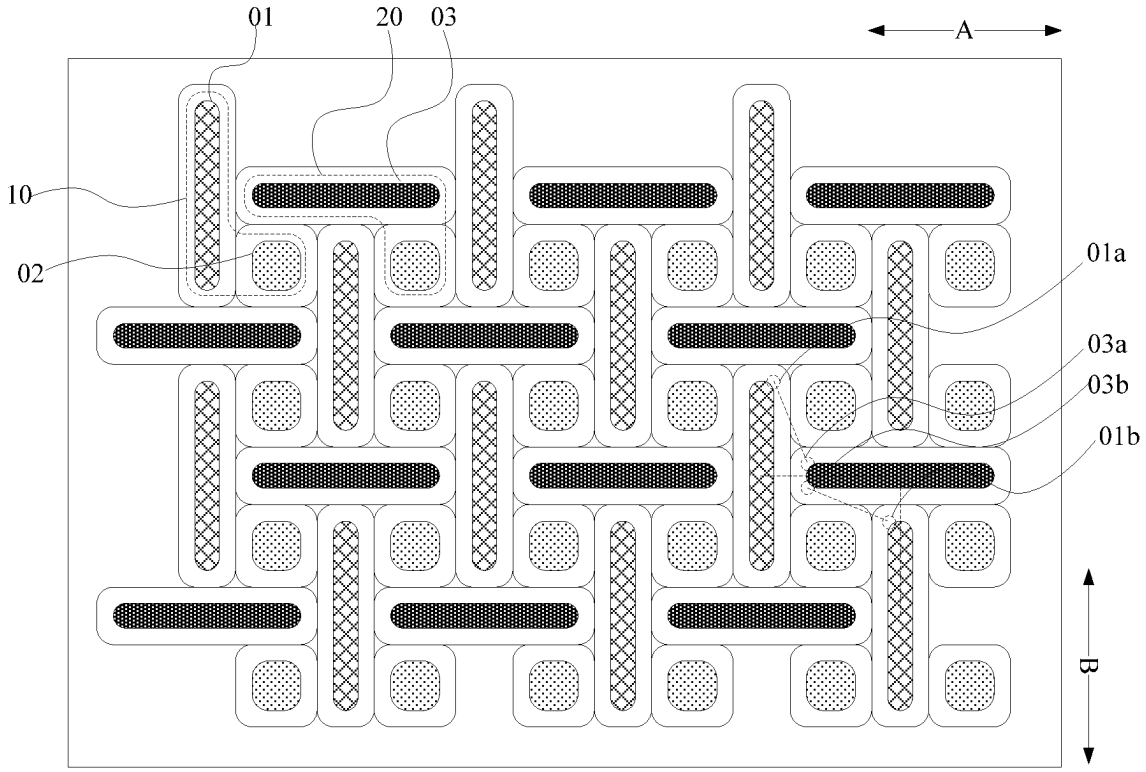

FIG.15

DISPLAY SUBSTRATE, FINE METAL MASK SET AND DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation application of U.S. patent application Ser. No. 17/448,200, filed on Sep. 20, 2021, which is a continuation application of U.S. patent application Ser. No. 16/462,214, filed on May 17, 2019, which is a Section 371 National Stage Application of International Application No. PCT/CN2018/114564, filed on Nov. 8, 2018, which in turn claims the benefit of Chinese Patent Application No. 20180002775.0, filed on Jan. 2, 2018, the whole disclosures of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to the field of display technology, and in particular, to a display substrate, a fine metal mask set and a display device.

BACKGROUND

Organic light emitting diode (OLED) displays are one of the hotspots in the field of flat panel displays. Compared with liquid crystal displays, OLED display has the advantages of low energy consumption, low production cost, self-illumination, wide viewing angle, fast response and so on. At present, in the field of flat panel displays such as mobile phones, PDAs, and digital cameras, OLED displays have begun to replace the traditional liquid crystal displays (LCDs).

SUMMARY

Some embodiments of the present disclosure provide a display substrate comprising: a plurality of first pixels and a plurality of second pixels alternately arranged in both a first direction and a second direction, wherein each of the first pixels comprises a first sub-pixel and a second sub-pixel, and each of the second pixels comprises a third sub-pixel and a second sub-pixel, wherein the second sub-pixels are evenly arranged in a matrix, wherein the first sub-pixel and the third sub-pixel are both in a polygonal shape, and are alternately arranged in both the first direction and the second direction; in a group consisting of one first sub-pixel and one third sub-pixel adjacent to each other in the first direction, a line connecting a vertex of the one first sub-pixel closest to the one third sub-pixel with a vertex of the one third sub-pixel closest to the one first sub-pixel intersects an extension line in the first direction and an extension line in the second direction.

In some embodiments, in a group consisting of one first sub-pixel and one third sub-pixel adjacent to each other in the second direction, a line connecting a vertex of the one first sub-pixel closest to the one third sub-pixel with a vertex of the one third sub-pixel closest to the one first sub-pixel intersects the extension line in the first direction and the extension line in the second direction; or in a group consisting of one first sub-pixel and one third sub-pixel adjacent to each other in the second direction, a line connecting a vertex of the one first sub-pixel closest to the one third sub-pixel with a vertex of the one third sub-pixel closest to the one first sub-pixel is parallel to the extension line in the second direction.

In some embodiments, each of the second sub-pixels is in a shape of polygon, and in a group consisting of two adjacent second sub-pixels in the second direction, a line connecting a vertex of one of the two adjacent second sub-pixels closest to the other of the two adjacent second sub-pixels with a vertex of the other of the two adjacent second sub-pixels closest to the one of the two adjacent second sub-pixels intersects the extension line in the first direction and the extension line in the second direction.

In some embodiments, in a group consisting of two adjacent second sub-pixels in the first direction, a line connecting a vertex of one of the two adjacent second sub-pixels closest to the other of the two adjacent second sub-pixels with a vertex of the other of the two adjacent second sub-pixels closest to the one of the two adjacent second sub-pixels intersects the extension line in the first direction and the extension line in the second direction; or in a group consisting of two adjacent second sub-pixels in the first direction, a line connecting a vertex of one of the two adjacent second sub-pixels closest to the other of the two adjacent second sub-pixels with a vertex of the other of the two adjacent second sub-pixels closest to the one of the two adjacent second sub-pixels is parallel to the extension line in the first direction.

In some embodiments, in a group consisting of two adjacent first sub-pixels in the first direction, a line connecting a vertex of one of the two adjacent first sub-pixels closest to the other of the two adjacent first sub-pixels with a vertex of the other of the two adjacent first sub-pixels closest to the one of the two adjacent first sub-pixels intersects the extension line in the first direction and the extension line in the second direction; in a group consisting of two adjacent first sub-pixels in the second direction, a line connecting a vertex of one of the two adjacent first sub-pixels closest to the other of the two adjacent first sub-pixels with a vertex of the other of the two adjacent first sub-pixels closest to the one of the two adjacent first sub-pixels intersects the extension line in the first direction and the extension line in the second direction; in a group consisting of two adjacent third sub-pixels in the first direction, a line connecting a vertex of one of the two adjacent third sub-pixels closest to the other of the two adjacent third sub-pixels with a vertex of the other of the two adjacent third sub-pixels closest to the one of the two adjacent third sub-pixels intersects the extension line in the first direction and the extension line in the second direction; and in a group consisting of two adjacent third sub-pixels in the second direction, a line connecting a vertex of one of the two adjacent third sub-pixels closest to the other of the two adjacent third sub-pixels with a vertex of the other of the two adjacent third sub-pixels closest to the one of the two adjacent third sub-pixels intersects the extension line in the first direction and the extension line in the second direction.

In some embodiments, in the group consisting of the one first sub-pixel and the one third sub-pixel adjacent to each other in the first direction, the vertex of the one first sub-pixel closest to the one third sub-pixel and the vertex of the one third sub-pixel closest to the one first sub-pixel are respectively located on either side of a line connecting a center of the one first sub-pixel with a center of the one third sub-pixel.

In some embodiments, in the group consisting of the one first sub-pixel and the one third sub-pixel adjacent to each other in the first direction, the vertex of the one first sub-pixel closest to the one third sub-pixel and the vertex of the one third sub-pixel closest to the one first sub-pixel are

distanced from a line connecting the center of the one first sub-pixel with the center of the one third sub-pixel by different distances.

In some embodiments, the vertex of the one first sub-pixel closest to the one third sub-pixel and the vertex of the one third sub-pixel closest to the one first sub-pixel substantially have an equal distance to a line connecting a center of the one first sub-pixel with a center of the one third sub-pixel.

In some embodiments, the first sub-pixel, the second sub-pixel, and the third sub-pixel are in a shape selected from at least one of square or rhombus, first diagonal lines of the first sub-pixels, the second sub-pixel, and the third pixel are parallel to each other, and the second diagonal lines of the first sub-pixel, the second sub-pixel, and the third sub-pixel are parallel to each other.

In some embodiments, an included angle between each of the first diagonal lines and the first direction is substantially greater than 0° and less than 45°, and an included angle between each of the second diagonal lines and the second direction is substantially greater than 0° and less than 45°.

In some embodiments, the second sub-pixel is in a shape of a quadrangle, and an included angle between one diagonal line of the quadrangle and the first direction is substantially greater than 0° and less than 45°, an included angle between the other diagonal line of the quadrangle and the second direction is substantially greater than 0° and less than 45°, both the first sub-pixel and the third sub-pixel are in a shape of a hexagon, and the hexagon is axisymmetric and has two axes of symmetry, and one of the two axes of symmetry is parallel to the first direction, and the other of the two axes of symmetry is parallel to the second direction.

In some embodiments, the second sub-pixel is in a shape of quadrangle, and both the first sub-pixel and the third sub-pixel are in a shape of rectangle, an extending direction of a long side of the first sub-pixel is perpendicular to an extending direction of a long side of the third sub-pixel.

In some embodiments, a line connecting a center of one first sub-pixel with a center of one third sub-pixel is parallel to the first direction, the one first sub-pixel and the one third sub-pixel being adjacent to each other in the first direction, and a line connecting a center of one first sub-pixel with a center of one third sub-pixel is parallel to the second direction, the one first sub-pixel and the one third sub-pixel being adjacent to each other in the second direction.

In some embodiments, at least a part of the first sub-pixels, the second sub-pixels, and the third sub-pixels have rounded corners.

In some embodiments, the first sub-pixel, the second sub-pixel, and the third sub-pixel are a red sub-pixel, a green sub-pixel, and a blue sub-pixel, respectively.

In some embodiments, at least one second sub-pixel is surrounded by two first sub-pixels and two third sub-pixels adjacent thereto.

In some embodiments, the first sub-pixel and the third sub-pixel are in the same shape and have the same area.

In some embodiments, an area of a single second sub-pixel is smaller than an area of a single first sub-pixel or an area of a single third sub-pixel.

Some embodiments of the present disclosure provide a fine metal mask set for manufacturing the display substrate of the above embodiments, wherein the fine metal mask set comprises: a first fine metal mask having a plurality of first opening regions, one of the first opening regions having a shape and a position corresponding to the first sub-pixel; a second fine metal mask having a plurality of second opening regions, one of the second opening regions having a shape and a position corresponding to the second sub-pixel; and a third fine metal mask having a plurality of third opening regions, one of the third opening regions having a shape and a position corresponding to the third sub-pixel.

Some embodiments of the present disclosure provide a display device comprising the display substrate of the above embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic structural view of a display substrate according to some embodiments of the present disclosure;

FIG. **2** is a schematic structural view of a first fine metal mask corresponding to a first sub-pixel shown in FIG. **1** according to some embodiments of the present disclosure;

FIG. **3** is a schematic structural view of a third fine metal mask corresponding to a third sub-pixel shown in FIG. **1** according to some embodiments of the present disclosure;

FIG. **4** is a schematic structural view of a second fine metal mask corresponding to a second sub-pixel shown in FIG. **1** according to some embodiments of the present disclosure;

FIG. **5** is a schematic structural view of a display substrate according to some embodiments of the present disclosure;

FIG. **6** is a schematic structural view of a first fine metal mask corresponding to a first sub-pixel shown in FIG. **5** according to some embodiments of the present disclosure;

FIG. **7** is a schematic structural view of a third fine metal mask corresponding to a third sub-pixel shown in FIG. **5** according to some embodiments of the present disclosure;

FIG. **8** is a schematic structural view of a second fine metal mask corresponding to a second sub-pixel shown in FIG. **5** according to some embodiments of the present disclosure;

FIG. **9** is a schematic structural view of a display substrate according to some embodiments of the present disclosure;

FIG. **10** is a schematic structural view of a first fine metal mask corresponding to a first sub-pixel shown in FIG. **9** according to some embodiments of the present disclosure;

FIG. **11** is a schematic structural view of a third fine metal mask corresponding to a third sub-pixel shown in FIG. **9** according to some embodiments of the present disclosure;

FIG. **12** is a schematic structural view of a second fine metal mask corresponding to a second sub-pixel shown in FIG. **9** according to some embodiments of the present disclosure;

FIG. **13** is a schematic structural view of a pixel arrangement structure according to some embodiments of the present disclosure;

FIG. **14** is a schematic structural view of a pixel arrangement structure according to some embodiments of the present disclosure;

FIG. **15** is a schematic structural view of a pixel arrangement structure according to some embodiments of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In order to make the objects, technical solutions and advantages of the present disclosure more clear, the present disclosure will be further described in detail below with reference to the accompanying drawings. It is apparent that the described embodiments are only a part of the embodiments of the present disclosure, and not all of them. All other embodiments obtained by those skilled in the art based on the embodiments of the present disclosure without creative efforts are within the scope of the present disclosure.

The shapes and sizes of the various components in the drawings do not reflect true proportions, and are merely intended to illustrate the present disclosure.

A structure of an OLED display mainly includes: a base substrate, and sub-pixels arranged in a matrix on the base substrate. For each of the sub-pixels, an OLED structure is generally formed at a corresponding sub-pixel position of the display substrate by using an evaporation film forming technique in which an organic material passes through a fine metal mask.

However, in an OLED display of the related art, a distance between sub-pixels in the pixel arrangement structure is large, resulting in a small sub-pixel aperture area under the condition of the same resolution, thus it is necessary to increase an driving current to meet the brightness requirement of display. However, the OLED display working under a large driving current easily leads to an increase in the aging speed of the device, thereby shortening a lifetime of the OLED display.

The present disclosure provides a display substrate, the display substrate includes a plurality of first pixels and a plurality of second pixels alternately arranged in both a first direction and a second direction, the first direction and the second direction intersecting each other, for example, perpendicular to each other. Each of the first pixels includes a first sub-pixel and a second sub-pixel, and each of the second pixels includes a third sub-pixel and a second sub-pixel. The second sub-pixels are uniformly distributed in a matrix. The first sub-pixel and the third sub-pixel are both in a polygonal shape, and are arranged alternately in the first direction and the second direction. for one first sub-pixel and one third sub-pixel adjacent to each other in the first direction, a line connecting a vertex of the one first sub-pixel closest to the one third sub-pixel with a vertex of the one third sub-pixel closest to the one first sub-pixel intersects an extension line in the first direction and an extension line in the second direction, for example, a corner of the one first sub-pixel pixel closest to the one third sub-pixel and a corner of the one third sub-pixel closest to the one first sub-pixel are staggered in the second direction. This kind of sub-pixel arrangement is advantageous for improving the compactness of the sub-pixel arrangement. Compared with a pixel arrangement of the related art, the first sub-pixels, the second sub-pixels and the third sub-pixels may be more closely arranged under the same process condition, a distance between adjacent sub-pixels may be reduced as much as possible, so that the sub-pixel aperture area is increased under the condition of the same resolution, and the driving current of the display device is reduced, thereby increasing the lifetime of the display device.

In the present disclosure, for convenience of presentation, for two adjacent polygons, a vertex of one polygon closest to the other polygon and a vertex of the other polygon closest to the one polygon are referred to as adjacent vertexes of the two adjacent polygons, a corner of one polygon closest to the other polygon and a corner of the other polygon closest to the one polygon are referred to as adjacent corners of the two adjacent polygons.

Some embodiments of the present disclosure provides a display substrate, as shown in FIG. **1**, FIG. **5** and FIG. **9**, the display substrate includes: a plurality of first pixels **10** and a plurality of second pixels **20** alternately arranged in a first direction A, for example, a row direction and a second direction B, for example, a column direction.

Each of the first pixels **10** includes a first sub-pixel **01** and a second sub-pixel **02**, each of the second pixels **20** includes a third sub-pixel **03** and a second sub-pixel **02**.

The second sub-pixels **02** are evenly distributed in a matrix, and each of the second sub-pixels **02** is surrounded by two first sub-pixels **01** and two third sub-pixels **03** adjacent thereto.

The first sub-pixel **01** and the third sub-pixel **03** are both in a polygonal shape, and are alternately arranged in the first direction A and the second direction B. For one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A, a corner **01***a* of the one first sub-pixel **01** closest to the one third sub-pixel **03** and a corner **03***a* of the one third sub-pixel **03** closest to the one first sub-pixel **01** (such a group of two corners (**01***a* and **03***a*) are referred to as adjacent corners of the one first sub-pixel **01** and the one third sub-pixel **03** adjacent to each other in the first direction A) are staggered in the second direction B, and vertexes of the corners **01***a* and **03***a* are referred to as adjacent vertexes of the one first sub-pixel **01** and the one third sub-pixel **03**. A line connecting such two adjacent vertexes intersects an extension line in the first direction A and an extension line in the second direction B.

Specifically, in the above display substrates provided by the embodiments of the present disclosure, each second sub-pixel **02** and two first sub-pixels **01** and two third sub-pixels **03** arranged therearound constitute a windmill-like structure, so that the first sub-pixel **01** and the third sub-pixel **03** are alternately arranged in the first direction A and/or the second direction B. Thus, in a first fine metal mask FMM**1** for manufacturing the first sub-pixels **01** or a third fine metal mask FMM**3** for manufacturing the third sub-pixels **03**, the aperture ratio of fine metal mask may be increased in a case where there is a set process pitch between the opening regions adjacent to each other in the first direction A and/or the second direction B, thereby improving the display resolution of the display substrate.

Specifically, in order to facilitate the understanding of the present disclosure, corresponding relationships between the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** and the opening regions of the fine metal mask FMM to which the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** correspond respectively are also shown in FIG. **1**, FIG. **5**, and FIG. **9**. A shape of the opening region is consistent with that of the sub-pixel to which the opening region corresponds, and a size of the opening region is usually larger than that of the sub-pixel to which the opening region corresponds.

Specifically, FIG. **2** shows a structure of a first fine metal mask FMM**1** for manufacturing the first sub-pixel **01** in FIG. **1**, and FIG. **3** shows a structure of a third fine metal mask FMM**3** for manufacturing the third sub-pixel **03** in FIG. **1**, and FIG. **4** shows a structure of a second fine metal mask FMM**2** for manufacturing the second sub-pixel **02** in FIG. **1**. As shown in FIG. **2**, in the first fine metal mask FMM**1**, two adjacent rows of first opening regions **011** are staggered in the first direction A, and two adjacent columns of first opening regions **011** are staggered in the second direction B. As shown in FIG. **3**, in the third fine metal mask FMM**3**, two adjacent rows of third opening regions **031** are staggered in the first direction A, and two adjacent columns of third opening regions **031** are staggered in the second direction B. As shown in FIG. **4**, in the second fine metal mask FMM**2**, second opening regions **021** are arranged in a matrix.

Specifically, FIG. **6** shows a structure of a first fine metal mask FMM**1** for manufacturing the first sub-pixel **01** in FIG. **5**, FIG. **7** shows a structure of a third fine metal mask FMM**3** for manufacturing the third sub-pixel **03** in FIG. **5**, and FIG. **8** shows a structure of a second fine metal mask FMM**2** for manufacturing the second sub-pixel **02** in FIG. **5**. As shown

in FIG. **6**, in the first fine metal mask FMM**1**, two adjacent rows of first opening regions **011** are staggered in the first direction A, and two adjacent columns of first opening regions **011** are staggered in the second direction B. As shown in FIG. **7**, in the third fine metal mask FMM**3**, two adjacent rows of third opening regions **031** are staggered in the first direction A, and two adjacent columns of third opening regions **031** are staggered in the second direction B. As shown in FIG. **8**, in the second fine metal mask FMM**2**, second opening regions **021** are arranged in a matrix, and any two adjacent second opening regions **021** in the first direction A are arranged in mirror symmetry.

Specifically, FIG. **10** shows a structure of a first fine metal mask FMM**1** for manufacturing the first sub-pixel **01** in FIG. **9**, FIG. **11** shows a structure of a third fine metal mask FMM**3** for manufacturing the third sub-pixel **03** in FIG. **9**, and FIG. **12** shows a structure of a second fine metal mask FMM**2** for manufacturing the second sub-pixel **02** in FIG. **9**. As shown in FIG. **10**, in the first fine metal mask FMM**1**, two adjacent rows of first opening regions **011** are staggered in the first direction A, and two adjacent columns of first opening regions **011** are staggered in the second direction B. As shown in FIG. **11**, in the third fine metal mask FMM**3**, two adjacent rows of third opening regions **031** are staggered in the first direction A, and two adjacent columns of third opening regions **031** are staggered in the second direction B. As shown in FIG. **12**, second opening regions **021** are arranged in a matrix, and any two adjacent second opening regions **021** in the first direction A are arranged in mirror symmetry.

In addition, in the above display substrates provided by the embodiments of the present disclosure, compared with the pixel arrangement of the related art, the pixel arrangement of the windmill-like structure may make the first sub-pixel **01**, the second sub-pixel **02** and the third sub-pixel **03** closely arranged under the same process conditions, and reduce the distance between adjacent sub-pixels as much as possible. Moreover, for one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A, a corner **01***a* of the one first sub-pixel **01** closest to the one third sub-pixel **03** and a corner **03***a* of the one third sub-pixel **03** closest to the one first sub-pixel **01** are staggered in the second direction B. Vertexes of the corner **01***a* and the corner **03***a* are adjacent corners of the one first sub-pixel **01** and the one third sub-pixel **03**. A line connecting the adjacent vertexes intersects an extension line in the first direction A and an extension line in the second direction B. In this way, the compactness of the sub-pixel arrangement is improved, the sub-pixel aperture area is increased under the condition of the same resolution, and the driving current of the display device is reduced, thereby increasing the lifetime of the display device.

It should be noted that it refers to an arrangement of pixels in a middle area of the display substrate that each of the second sub-pixels **02** mentioned in the above display substrates provided by the embodiments of the present disclosure is surrounded by two first sub-pixels **01** and two third sub-pixels **03** adjacent thereto. There may be some special cases at the edge of the display substrate, for example, the second sub-pixels **02** are disposed at the edge of the display substrate. In this case, the each of the second sub-pixels **02** may be adjacent to only one first sub-pixel **01** and one third sub-pixel **03**, and is not completely surrounded by the first sub-pixel **01** and the third sub-pixel **03** adjacent thereto.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **1** and FIG. **9**, for one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B, a corner **01***b* of the one first sub-pixel **01** closest to the one third sub-pixel **03** and a corner **03***b* of the one third sub-pixel **03** closest to the one first sub-pixel **01** (such a group of two corners (**01***b* and **03***b*) are referred to as adjacent corners of the one first sub-pixel **01** and the one third sub-pixel **03** adjacent to each other in the second direction B) are staggered in the first direction A. Vertexes of the corner **01***b* and the corner **03***b* are referred to as adjacent vertexes of the one first sub-pixel **01** and the one third sub-pixel **03**. A line connecting such two adjacent vertexes intersects an extension line in the first direction A and an extension line in the second direction B. By using this kind of pixel arrangement, the compactness of the sub-pixel arrangement is improved, the sub-pixel aperture area is increased under the condition of the same resolution, and the driving current of the display device is reduced, thereby increasing the lifetime of the display device.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **5**, for one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B, a corner **01***b* of the one first sub-pixel **01** closest to the one third sub-pixel **03** and a corner **03***b* of the one third sub-pixel **03** closest to the one first sub-pixel **01** are aligned in the first direction A. Vertexes of the corner **01***b* and the corner **03***b* are referred to as adjacent vertexes of the one first sub-pixel **01** and the one third sub-pixel **03**. Aline connecting such two adjacent vertexes is parallel to the extension line in the second direction B.

At present, each sub-pixel in the OLED display device is obtained by evaporation of an organic material through a corresponding opening region of the fine metal mask FMM, and the size of the opening region of the fine metal mask directly determines the size of the sub-pixel. The size of the sub-pixel will be smaller than the corresponding opening region on the fine metal mask FMM. Based on the limitations of preparation process of the fine metal mask of the related art, it is difficult to obtain a higher-resolution display device by the pixel arrangement of the related art.

Based on this, optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **1** and FIG. **5**, each of the second sub-pixels **02** arranged in a matrix generally is in a shape of polygon. For two adjacent second sub-pixels in the second direction B, a corner **02**B of one second sub-pixel **02** closest to the other second sub-pixel **02** and a corner **02**B' of the other second sub-pixel **02** closest to the one second sub-pixel **02** (such a group of two corners (**02**B and **02**B') are referred to as adjacent corners of the two adjacent second sub-pixels **02** in the second direction B) are staggered in the first direction A. Vertexes of the corner **02**B and the corner **02**B' are referred to as adjacent vertexes of the two adjacent second sub-pixels **02**. A line connecting such two adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Thus, for corresponding opening regions **021** of the second fine metal mask FMM**2** for manufacturing the second sub-pixels **02**, as shown in FIGS. **4** and **8**, adjacent corners **021**B and **021**B' of two adjacent second opening regions **021** in the second direction B need to be staggered in the first direction A, and vertexes of the corners **021**B and **021**B' are adjacent vertexes of the two adjacent second opening regions **021**. A line connecting such two adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. In this way, the aperture ratio of the second fine metal mask FMM**2** may be increased in a case

where there is a set process pitch between the second opening regions **021** adjacent to each other in the second direction B, thereby improving the display resolution of the display substrate.

It is to be noted that, in the above display substrates provided by the embodiments of the present disclosure, the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** all are in a shape of polygon, and the polygon refers to a shape including at least three sides. The polygon may be a concave polygon or a convex polygon, which is not limited herein. In addition, the corner of each sub-pixel described in the present disclosure refers to the corner of the polygon.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **1**, adjacent corners **02**A and **02**A' of two adjacent second sub-pixels **02** in the first direction A may be staggered in the second direction B. Vertexes of the corners **02**A and **02**A are the adjacent vertexes of the two adjacent second sub-pixels **02**. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Thus, for corresponding opening regions **021** of the second fine metal mask FMM**2** for manufacturing the second sub-pixels **02**, as shown in FIG. **4**, adjacent corners **021**A and **021**A' of two adjacent second opening regions **021** in the first direction A need to be staggered in the second direction B, and vertexes of the corners **021**A and **021**A' are adjacent vertexes of the two adjacent second opening regions **021**. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. In this way, the aperture ratio of the second fine metal mask FMM**2** may be increased in a case where there is a set process pitch between the second opening regions **021** adjacent to each other in the first direction A, thereby improving the display resolution of the display substrate.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **5**, adjacent corners **02**A and **02**A' of two adjacent second sub-pixels **02** in the first direction A may be aligned in the second direction B. Vertexes of the corners **02**A and **02**A are the adjacent vertexes of the two adjacent second sub-pixels **02**. A line connecting such two adjacent vertexes is parallel to the extension line in the second direction B. Thus, for corresponding opening regions **021** of the second fine metal mask FMM**2** for manufacturing the second sub-pixels **02**, as shown in FIG. **8**, adjacent corners **021**A and **021**A' of two adjacent second opening regions **021** in the first direction A need to be aligned in the second direction B.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **1**, adjacent corners **03**B and **03**B' of two adjacent third sub-pixels **03** in the second direction B may be staggered in the first direction A. Vertexes of the corners **03**B and **03**B' are the adjacent vertexes of the two adjacent third sub-pixels **03** in the second direction B. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Further, adjacent corners **03**A and **03**A' of two adjacent third sub-pixels **03** in the first direction A may be staggered in the second direction B. Vertexes of the corners **03**A and **03**A' are the adjacent vertexes of the two adjacent third sub-pixels **03** in the first direction A. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Thus, for corresponding third opening regions **031** of the third fine metal mask FMM**3** for manufacturing the third sub-pixels **03**, as shown in FIG. **3**, adjacent corners **031**B and **031**B' of two adjacent third opening regions **031** in the second direction B need to be staggered in the first direction A, and vertexes of the corners **031**B and **031**B' are adjacent vertexes of the two adjacent third opening regions **031**. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Further, adjacent corners **031**A and **031**A' of two adjacent third opening regions **031** in the first direction A need to be staggered in the second direction B, and vertexes of the corners **031**A and **031**A' are adjacent vertexes of the two adjacent third opening regions **031**. Aline connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. In this way, the aperture ratio of the third fine metal mask FMM**3** may be increased in a case where there is a set process pitch between two adjacent third opening regions **031**, thereby improving the display resolution of the display substrate.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **1**, adjacent corners **01**A and **01**A' of two adjacent first sub-pixels **01** in the first direction A may be staggered in the second direction B. Vertexes of the corners **01**A and **01**A' are the adjacent vertexes of the two adjacent first sub-pixels **01** in the first direction A. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Further, adjacent corners **01**B and **01**B' of two adjacent first sub-pixels **03** in the second direction B may be staggered in the first direction A. Vertexes of the corners **01**B and **01**B' are the adjacent vertexes of the two adjacent first sub-pixels **01** in the second direction B. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. In this case, for corresponding first opening regions **011** of the first fine metal mask FMM**1** for manufacturing the first sub-pixels **01**, as shown in FIG. **2**, adjacent corners **011**A and **011**A' of two adjacent first opening regions **031** in the first direction A need to be staggered in the second direction B, and vertexes of the corners **011**A and **011**A' are adjacent vertexes of the two adjacent first opening regions **011**. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. Further, adjacent corners **011**B and **011**B' of two adjacent first opening regions **011** in the second direction B need to be staggered in the first direction A, and vertexes of the corners **011**B and **011**B' are adjacent vertexes of the two adjacent first opening regions **011**. A line connecting the adjacent vertexes intersects the extension line in the first direction A and the extension line in the second direction B. In this way, the aperture ratio of the first fine metal mask FMM**1** may be increased in a case where there is a set process pitch between the first opening regions **011** adjacent to each other, thereby improving the display resolution of the display substrate.

It should be noted that, in the above display substrates provided by the embodiments of the present disclosure, adjacent corners of two adjacent sub-pixels (such as one first sub-pixel and one third sub-pixel adjacent to each other, two adjacent first sub-pixels, two adjacent second sub-pixels or two adjacent third sub-pixels) in one direction, for example the first direction or the second direction, being staggered in another direction, such as the second direction or the first direction refers to that a line connecting vertexes of the adjacent corners of two adjacent sub-pixels is inclined with respect to the one direction. That is, there is a certain

included angle between an extension line of the line and an extension line in the one direction. The included angle is substantially greater than zero and less than 90 degrees. Moreover, in general, the vertexes of the adjacent corners of the two adjacent sub-pixels are the closest points of the two adjacent sub-pixels, thus it is also refers to that the extension line of the line connecting two vertexes intersects the extension line in the one direction.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the staggered arrangement in the second direction B may refers to that the vertexes of the adjacent corners of the two adjacent sub-pixels in the first direction A are respectively located on upper and lower sides of a first imaginary line parallel to the first direction A, or the staggered arrangement in the second direction B may refers to that the vertexes of the adjacent corners of the two adjacent sub-pixels in the first direction A are distanced from the first imaginary line parallel to the first direction A by different distances.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the first imaginary line is generally a line connecting centers of two adjacent sub-pixels in the first direction A.

In the present disclosure, the center may be any one of an intersection point of perpendicular bisectors, a center of gravity, or a symmetry center of the sub-pixel

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the staggered arrangement in the second direction B may be that the vertexes of the adjacent corners of the two adjacent sub-pixels in the first direction A are respectively located on upper and lower sides of the first imaginary line, for example, a line connecting centers of the adjacent two sub-pixels, parallel to the first direction A, and the vertexes of the adjacent corners are distanced from the first imaginary line by the same distance.

Specifically, for example, as shown in FIG. **1**, vertexes of adjacent corners **01***a* and **03***a* of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A are respectively located on the upper and lower sides of a line M connecting centers of the one first sub-pixel **01** and the one third sub-pixel **03**. The vertexes of the adjacent corners **01***a* and **03***a* of the one first sub-pixel **01** and the one third sub-pixel **03** have the same distance to the line M connecting the centers of the one first sub-pixel **01** and the one third sub-pixel **03**. For another example, as shown in FIG. **9**, vertexes of adjacent corners **01***a* and **03***a* of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other are distanced from a line M connecting centers of the one first sub-pixel **01** and the one third sub-pixel **03** (i.e. the first imaginary line) by different distances.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the staggered arrangement in the first direction A may refers to that the vertexes of the adjacent corners of the two adjacent sub-pixels in the second direction B are respectively located on left and right sides of a second imaginary line parallel to the second direction B, or the staggered arrangement in the first direction A may refers to that the vertexes of the adjacent corners of the two adjacent sub-pixels in the second direction B are distanced from the second imaginary line parallel to the second direction B by different distances.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the second imaginary line is a line connecting centers of two adjacent sub-pixels in the second direction.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the staggered arrangement in the first direction A may be may be that the vertexes of the adjacent corners of the two adjacent sub-pixels in the second direction B are respectively located on left and right sides of the second imaginary line, for example, a line connecting centers of the adjacent two sub-pixels, parallel to the second direction B, and the vertexes of the adjacent corners have the same distance to the second imaginary line.

Specifically, for example, as shown in FIG. **5**, vertexes of adjacent corners **02**B and **02**B' of two adjacent second sub-pixels **02** in the second direction B are respectively located on the left and right sides of a line N connecting centers of the two adjacent second sub-pixels **02**. The vertexes of the adjacent corners **02**B and **02**B' of the two adjacent second sub-pixels **02** in the second direction B have the same distance to the line N connecting the centers of the two adjacent second sub-pixels **02**. For another example, as shown in FIG. **9**, vertexes of the adjacent corners **01***b* and **03***b* of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B are distanced from a line N connecting centers of the one first sub-pixel **01** and the one third sub-pixel **03** by different distances.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **9**, the first sub-pixel **01** and the third sub-pixel **03** are all elongated, and extension lines of long sides of the first sub-pixel **01** and the third sub-pixel **03** may intersect. In this case, vertexes of adjacent corners **01***a* and **03***a* of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A are located on the same side of a line connecting centers of the one first sub-pixel **01** and the one third sub-pixel **03**, and are distanced from the line connecting the centers by different distances. Similarly, vertexes of adjacent corners **01***b* and **03***b* of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B are located on the same side of a line connecting centers of the one first sub-pixel **01** and the one third sub-pixel **03**, and are distanced from the line connecting the centers by different distances.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, the first sub-pixel and the third sub-pixel may be in the same shape and have the same area, and the second sub-pixel has an area smaller than that of the first sub-pixel or the third sub-pixel. As shown in FIG. **1**, the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** all are in a shape of square, and the first sub-pixel **01** and the third sub-pixel **03** have the same area, and the area of the second sub-pixel **02** is smaller than that of the first sub-pixel **01** or the third sub-pixel **03**. As shown in FIG. **5**, the first sub-pixel **01** and the third sub-pixel **03** are both hexagonal, and are in the same shape and have the same area. The second sub-pixel **02** is in a shape of quadrangle, such as parallelogram, and the area of the second sub-pixel **02** is smaller than that of the first sub-pixel **01** or the third sub-pixel **03**. As shown in FIG. **9**, the first sub-pixel **01** and the third sub-pixel **03** are both rectangular, and are in the same shape and have the same area. The second sub-pixel **02** is in a shape of quadrangle, such as square, and the area of the second sub-pixel **02** is smaller than that of the first sub-pixel **01** or the third sub-pixel **03**.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, a ratio of a total

area of all the first sub-pixels, a total area of all the second sub-pixels, and a total area of all the third sub-pixels is 1:1.15 to 1.4:1.3 to 1.6.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, a ratio of a total area of all the first sub-pixels, a total area of all the second sub-pixels, and a total area of all the third sub-pixels is 1:1.2 to 1.3:1.4 to 1.5.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, a ratio of a total area of all the first sub-pixels, a total area of all the second sub-pixels, and a total area of all the third sub-pixels is 1:1.27:1.46.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **1**, the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** all are in a shape of square, and first diagonal lines **012**, **022**, and **032** of the first sub-pixel **01**, the second sub-pixel **02** and the third sub-pixel **03** may be parallel to each other, and the second diagonal lines **013**, **023** and **033** of the first sub-pixel **01**, the second sub-pixel **02** and the third sub-pixel **03** may be parallel to each other. An included angle between the first direction A and the first diagonal lines **012**, **022**, **032** of the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** is substantially greater than 0° and less than 45°, and an included angle between the second direction B and the second diagonal lines **012**, **022**, **032** of the first sub-pixel **01**, the second sub-pixel **02** and the third sub-pixel **03** is substantially greater than 0° and less than 45°. It should be noted that corners of the square may be rounded corners, and an approximate square with a certain error on side length or angle belongs to the protection scope of the present disclosure. In addition, as shown in FIG. **1**, the line connecting centers of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A is parallel to the first direction A, and the line connecting centers of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B is parallel to the second direction B.

In other embodiments, the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** may be in a shape of rhombus instead of square in the foregoing embodiments.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **5**, the second sub-pixel **02** may also be in a shape of quadrangle, such as parallelogram. An included angle between a first diagonal line **022** of the quadrangle and the first direction A is substantially greater than 0° and less than 45°, and an included angle between a second diagonal line **023** of the quadrangle and the second direction B is substantially greater than 0° and less than 45°.

The first sub-pixel **01** and the third sub-pixel **03** both are in a shape od hexagon, and the hexagon is an axisymmetric pattern including two axes of symmetry, and one of the two axes of symmetry is parallel to the first direction A, and the other one is parallel to the second direction B. In addition, as shown in FIG. **5**, a line connecting centers of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A is inclined with respect to the first direction A and a line connecting centers of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B is parallel to the second direction B.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **9**, the second sub-pixel **02** may be in a shape of quadrangle, such as square. The first sub-pixel **01** and the third sub-pixel **03** are in a shape of rectangle, and an extending direction of a long side of the first sub-pixel **01** is perpendicular to an extending direction of a long side of the third sub-pixel **03**. A line connecting centers of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the first direction A is parallel to the first direction A and a line connecting centers of one first sub-pixel **01** and one third sub-pixel **03** adjacent to each other in the second direction B is parallel to the second direction B.

Specifically, in the above-described pixel arrangements provided by the embodiments of the present disclosure, the shapes and directions of the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** are not limited to the above three cases, and the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** may also be in a shape of circle, ellipse or convex polygon, etc., and it is not limited herein.

The first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** may have the same or similar shapes, or may have different shapes, which is not limited herein.

It should be noted that, in the embodiments of the present disclosure, patterns of sub-pixels being consistent with each other refers to that the sub-pixels have the same or similar shapes. For example, two sub-pixels both are in a shape of triangle, the two sub-pixels are considered to have a consistent shape regardless of whether the areas thereof are equal. Conversely, the pattern of the sub-pixels being inconsistent refers to that the sub-pixels have different shapes, for example, one is in a shape of circle and another one is in a shape of rectangle.

Optionally, in the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **13** to FIG. **15**, the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** may be in a shape of polygon having rounded corners. That is, on the basis of FIG. **1**, FIG. **5** and FIG. **9**, the shapes of the second sub-pixel **02**, the first sub-pixel **01**, and the third sub-pixel **03** may be rounded. The corresponding opening regions of the fine metal mask FMM for manufacturing the sub-pixels may have corresponding rounded corners to reduce the difficulty in manufacturing the fine metal mask FMM. The radius of the rounded corners is generally controlled to about 10 μm.

Optionally, the specific shapes, positional relationships, parallel and angular relationships of the first sub-pixel **01**, the second sub-pixel **02**, and the third sub-pixel **03** may be designed according to requirements. and in actual processes, there may be some deviations due to limitations of process conditions or other factors. Therefore, the sub-pixels may be arranged in the pixel arrangement manner provided by the embodiments of the present disclosure, as long as the shapes, the positions, and the relative positional relationships of the sub-pixels substantially satisfy the above conditions.

Optionally, in the display substrates provided by the embodiments of the present disclosure, the first sub-pixel **01** may be a red sub-pixel, and the third sub-pixel **03** may be a blue sub-pixel; or the first sub-pixel **01** may be a blue sub-pixel, and the third sub-pixel **03** may be a red sub-pixel, the second sub-pixel **02** is a green sub-pixel. In this way, adjacent green sub-pixel, red sub-pixel, and blue sub-pixel may constitute an illuminating pixel point. Specifically, it may be understood that one illuminating pixel point includes one green sub-pixel, and one quarter of each of two red sub-pixels and two blue sub-pixels adjacent the one green sub-pixel. That is, each red sub-pixel is shared by four illuminating pixel points, and each blue sub-pixel is elec-

trically shared by four illuminating pixels, so that high-resolution display effect is achieved by using a low physical resolution display device through borrowing color principle.

Based on the same inventive concept, some embodiments of the present disclosure further provides a fine metal mask set for manufacturing the above display substrates provided by the embodiments of the present disclosure, as shown in FIG. **2** to FIG. **4**, FIG. **6** to FIG. **8**, FIG. **10** to FIG. **12**, the fine metal mask set includes a first fine metal mask FMM**1**, a second fine metal mask FMM**2**, and a third fine metal mask FMM**3**. The first fine metal mask FMM**1** has a plurality of first opening regions **011** having corresponding shapes and positions with the first sub-pixels **01**, the second fine metal mask FMM**2** has a plurality of second opening regions **021** having corresponding shapes and positions with the second sub-pixels **02**, and the third fine metal mask FMM**3** has a plurality of third opening regions **031** having corresponding shapes and positions with the third sub-pixels **03**.

Optionally, in the above-mentioned fine metal masks provided by the embodiments of the present disclosure, as shown in FIG. **2** to FIG. **4** and FIG. **8**, the opening regions may generally be in a shape of a polygon, and adjacent corners of two opening regions adjacent to each other in the first direction are staggered in the second direction, and/or adjacent corners of two opening regions adjacent to each other in the second direction are staggered in the first direction. Specifically, as shown in FIG. **2**, in the first fine metal mask FMM**1** for manufacturing the first sub-pixels **01**, adjacent corners **011**A and **011**A of two first opening regions **011** adjacent to each other in the first direction A are ' staggered in the second direction B, and the adjacent corners **011**B and **011**B' of two first opening regions **011** adjacent to each other in the second direction B are also staggered in the first direction A. As shown in FIG. **3**, in the third fine metal mask FMM**3** for manufacturing the third sub-pixels **03**, adjacent corners **031**A and **031**A' of two third opening regions **031** adjacent to each other in the first direction A are staggered in the second direction B, and adjacent corners **031**B and **031**B' of two third opening regions **031** adjacent to each other in the second direction B are also staggered in the first direction A. As shown in FIG. **4**, in the second fine metal mask FMM**2** for manufacturing the second sub-pixels **02**, adjacent corners **021**A and **021**A' of two second opening regions **021** adjacent to each other in the first direction A are staggered in the second direction B, and adjacent corners **021**B and **021**B' of two second opening regions **021** adjacent to each other in the second direction B are also staggered in the first direction A. As shown in FIG. **8**, in the second fine metal mask FMM**2** for fabricating the second sub-pixels **02**, adjacent corners **021**B and **021**B' of two second opening regions **021** adjacent to each other in the second direction B are staggered in the first direction A, and adjacent corners **021**A and **021**A' of two second opening region **021** adjacent to each other in the first direction A are aligned in the second direction B.

By adopting the fine metal masks as described above, it is possible to increase the aperture ratio of the fine metal masks FMM in a case where there is a set process pitch between the opening regions adjacent to each other, thereby improving the display resolution of the produced display substrate.

Based on the same inventive concept, some embodiments of the present disclosure further provide a display device including any of the above display substrates provided by the embodiments of the present disclosure. The display device may be any product or component having a display function, such as a mobile phone, a tablet computer, a television, a display, a notebook computer, a digital photo frame, a navigator, and the like. For the implementation of the display device, reference may be made to the embodiments of the above display substrates, and the repeated description is omitted.

The display substrate, the fine metal mask set and the display device are provided by the embodiments of the present disclosure, the display substrate includes a plurality of first pixels and a plurality of second pixels alternately arranged in a first direction and a second direction. The first pixel includes a first sub-pixel and a second sub-pixel, and the second pixel includes a third sub-pixel and a second sub-pixel. The second sub-pixels are evenly arranged in a matrix, and each second sub-pixel and two first sub-pixels and two third sub-pixels arranged therearound constitute a windmill-like structure. The first sub-pixel and the third sub-pixel are both in a polygonal shape, and alternately arranged in the first direction and the second direction. A line connecting adjacent vertexes of one first sub-pixel and one third sub-pixel adjacent to each other in the first direction intersects an extension line in the first direction and an extension line in the second direction, for example, adjacent corners of the one first sub-pixel and the one third sub-pixel adjacent to each other in the first direction are staggered in the second direction. This kind of sub-pixel arrangement is advantageous for improving the compactness of the sub-pixel arrangement. In the pixel arrangement of the windmill-like structure, compared with a pixel arrangement of the related art, the first sub-pixel, the second sub-pixel and the third sub-pixel may be closely arranged under the same process condition, a distance between adjacent sub-pixels may be reduced as much as possible, so that the sub-pixel aperture area is increased under the condition of the same resolution, and the driving current of the display device is reduced, thereby increasing the lifetime of the display device.

It will be apparent to those skilled in the art that various changes and modifications may be made in the present disclosure without departing from the spirit and scope of the disclosure. Thus, if such modifications and variations of the present disclosure are within the scope of the appended claims and their equivalents, the present invention is also intended to cover such modifications and variations.

What is claimed is:

1. A display substrate, comprising:

a plurality of first sub-pixels;

a plurality of second sub-pixels; and

a plurality of third sub-pixels;

wherein:

the plurality of first sub-pixels and the plurality of third sub-pixels are alternated in a first direction and a second direction so as to form a first type of rows along the first direction and a first type of columns along the second direction;

the plurality of second sub-pixels form a second type of rows along the first direction and a second type of columns along the second direction, the first type of rows and the second type of rows are alternated in the second direction, and the first type of columns and the second type of columns are alternated in the first direction;

in at least one of the first type of rows, a connection line between a center of a first sub-pixel and a center of a third sub-pixel adjacent to the first sub-pixel is not parallel to the first direction, a connection line between centers of first sub-pixels adjacent to each other is parallel to the first direction, and a connec-

tion line between centers of third sub-pixels adjacent to each other is parallel to the first direction; and

in at least one of the second type of rows, a connection line between centers of second sub-pixels adjacent to each other is parallel to the first direction;

in the at least one of the first type of rows, for a first sub-pixel and a third sub-pixel adjacent to each other, the first sub-pixel has a first vertex closest to the third sub-pixel, the third sub-pixel has a second vertex closest to the first sub-pixel, and a connection line between the first vertex and the second vertex is inclined with respect to the first direction; and

in the at least one of the first type of rows, the connection line between the center of the first sub-pixel and the center of the third sub-pixel adjacent to the first sub-pixel is inclined with respect to the connection line between the first vertex and the second vertex.

2. The display substrate according to claim **1**, wherein in at least one of the first type of rows, center points of the first sub-pixels are arranged along a first straight line, and center points of the third sub-pixels are arranged along a second straight line, wherein the first straight line is parallel to the second straight line.

3. The display substrate according to claim **1**, wherein in at least one of the first type of columns, a connection line between centers of first sub-pixels adjacent to each other is parallel to the second direction, and a connection line between centers of third sub-pixels adjacent to each other is parallel to the second direction.

4. The display substrate according to claim **3**, wherein the connection line between the centers of the first sub-pixels adjacent to each other and the connection line between the centers of the third sub-pixels adjacent to each other are on a same straight line.

5. The display substrate according to claim **1**, wherein in at least one of the second type of columns, a connection line between centers of second sub-pixels adjacent to each other is parallel to the second direction.

6. The display substrate according to claim **1**, wherein in at least one of the second type of rows, a connection line between vertices of two adjacent second sub-pixels which are closest to each other is parallel to the first direction.

7. The display substrate according to claim **1**, wherein in at least one of the second type of rows, for three adjacent second sub-pixels,

a connection line between vertices of a middle second sub-pixel and a second sub-pixel on a first side of the middle second sub-pixel which are closest to each other is located on a third straight line, a connection line between vertices of the middle second sub-pixel and a second sub-pixel on a second side of the middle second sub-pixel which are closest to each other is located on a fourth straight line, and the third straight line is parallel to the fourth straight line.

8. The display substrate according to claim **7**, wherein:

in the at least one of the second type of rows, center points of second sub-pixels are arranged along a fifth straight line; and

the third straight line and the fourth straight line are located on two sides of the fifth straight line in the second direction.

9. The display substrate according to claim **1**, wherein in at least one of the second type of columns, a connection line between vertices of adjacent second sub-pixels which are closest to each other is inclined with respect to the second direction.

10. The display substrate according to claim **1**, wherein each of the first sub-pixels and the third sub-pixels has a symmetric shape, and each of the first sub-pixels and the third sub-pixels has a first axis of symmetry along the first direction and a second axis of symmetry along the second direction.

11. The display substrate according to claim **10**, wherein the first sub-pixels and the third sub-pixels have a same shape.

12. The display substrate according to claim **10**, wherein each of the first sub-pixels and the third sub-pixels has a shape of a hexagon, and the hexagon has a first pair of opposite edges, a second pair of opposite edges, and a third pair of opposite edges, wherein the first pair of opposite edges are parallel to the first direction, and lengths of the first pair of opposite edges are less than lengths of the second pair of opposite edges and lengths of the third pair of opposite edges.

13. The display substrate according to claim **1**, wherein the second sub-pixels have a shape of a parallelogram, the parallelogram has a first pair of opposite edges and a second pair of opposite edges, and lengths of the first pair of opposite edges are different from lengths of the second pair of opposite edges.

14. The display substrate according to claim **13**, wherein:

each of the first sub-pixels and the third sub-pixels has a shape of a hexagon, and the hexagon has a first pair of opposite edges, a second pair of opposite edges, and a third pair of opposite edges, wherein the first pair of opposite edges of the hexagon is parallel to the first direction, and lengths of the first pair of opposite edges of the hexagon are less than lengths of the second pair of opposite edges of the hexagon and lengths of the third pair of opposite edges of the hexagon; and

the first pair of opposite edges of the parallelogram are parallel to one of the second and third pairs of opposite edges of the hexagon, and the second pair of opposite edges of the parallelogram are parallel to the other of the second and third pairs of opposite edges of the hexagon.

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