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(54) **CAPACITOR STRUCTURE AND METHOD OF MANUFACTURING THE SAME**

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(57) **ABSTRACT**

In a capacitor structure and a method of manufacturing the capacitor structure, first and second conductive patterns are formed on a substrate. The first and second conductive patterns extend in a first direction. The first and second conductive patterns are alternately arranged to be spaced apart from one another in a second direction substantially perpendicular to the first direction. An insulating interlayer is formed on the substrate to cover the first and second conductive patterns. Third and fourth conductive patterns extending in a third direction lying at an angle of between about 0° and about 90° relative to the first direction are formed on the insulating interlayer. The third and fourth conductive patterns are alternately arranged to be spaced apart from one another in a fourth direction substantially perpendicular to the third direction.

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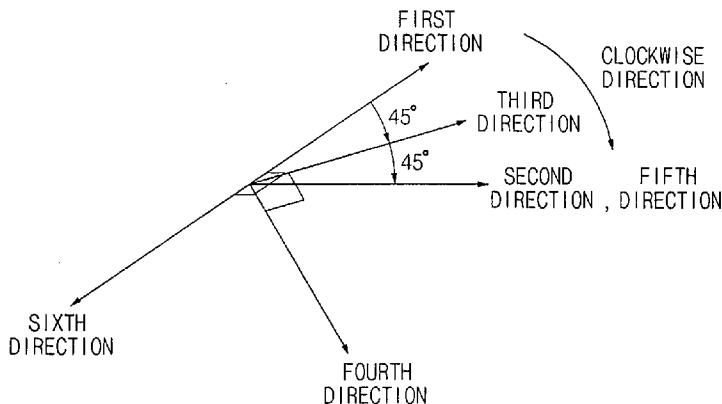
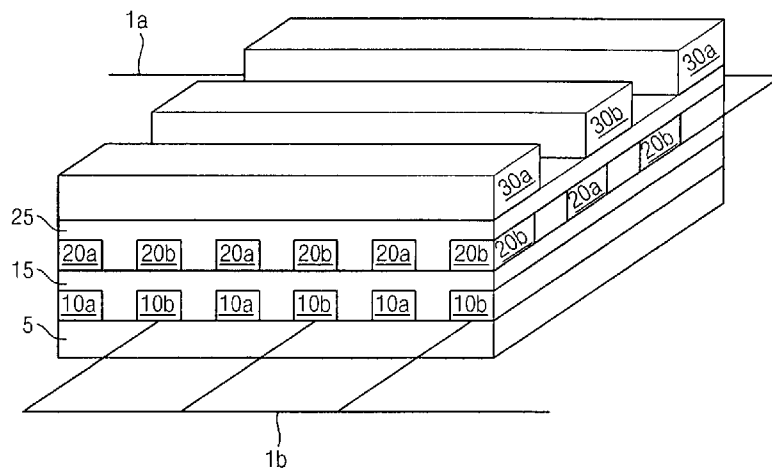


FIG. 1  
(CONVENTIONAL ART)

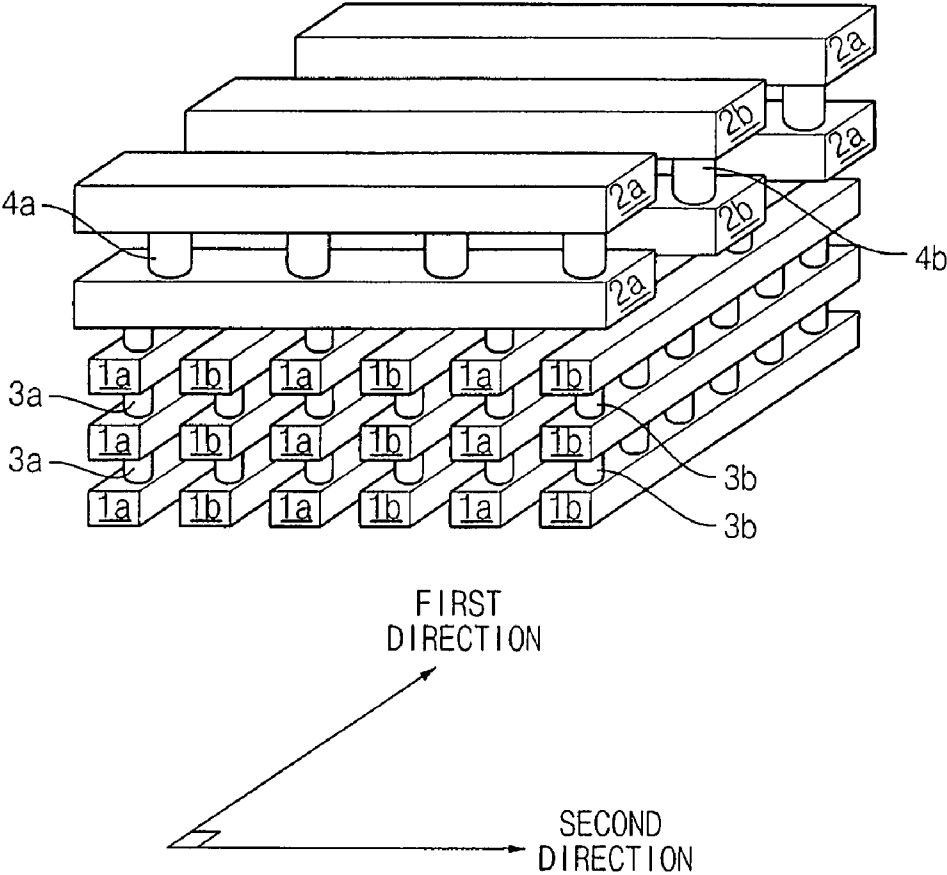


FIG. 2

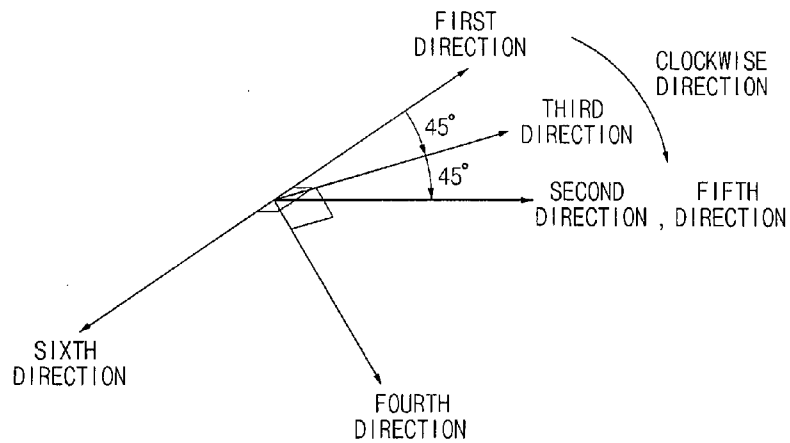
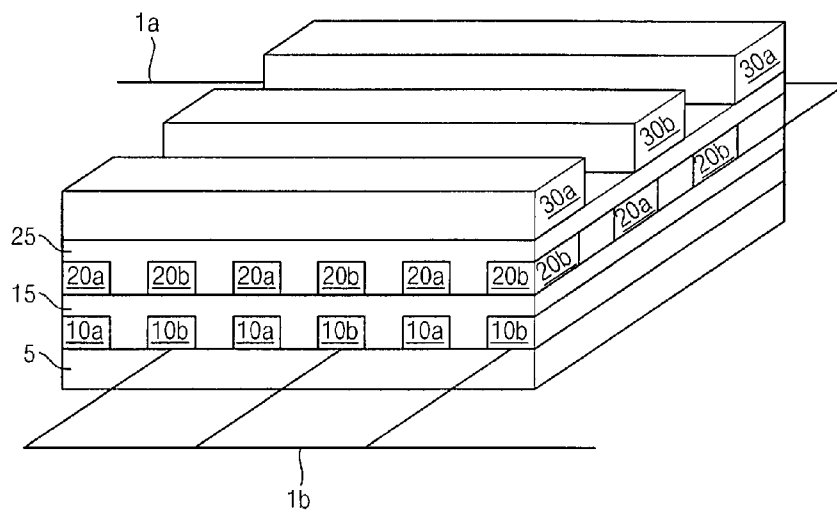


FIG. 3

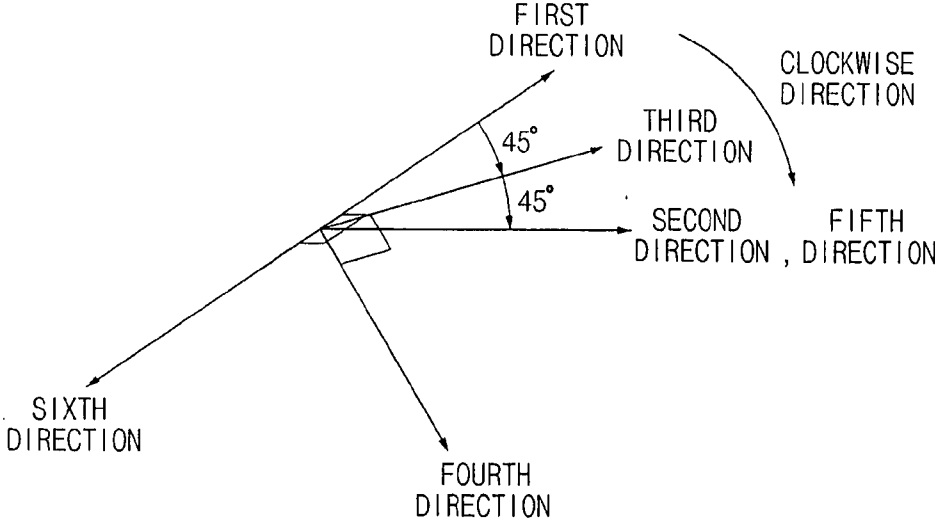
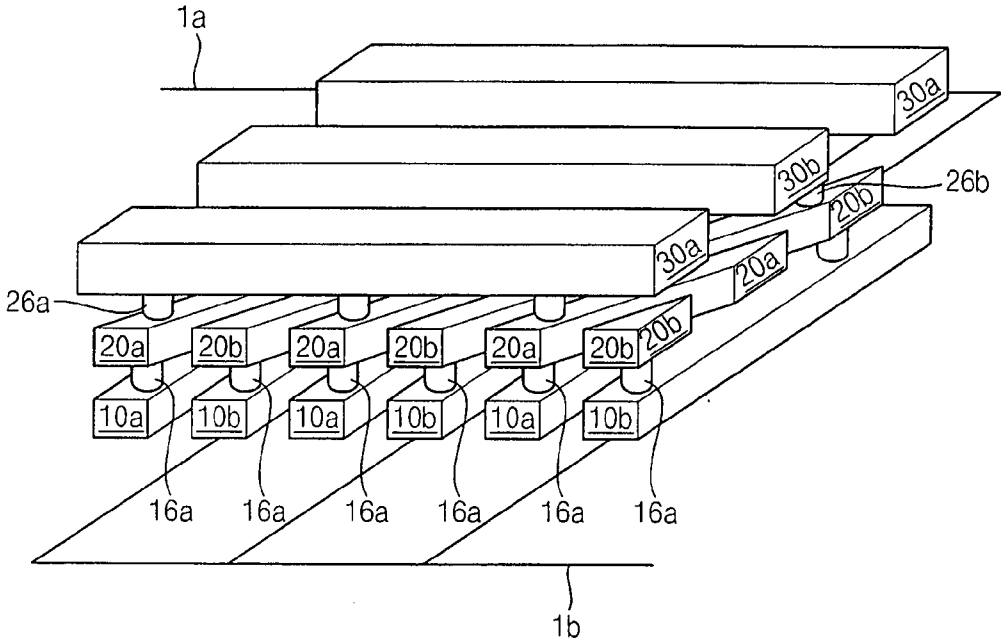


FIG. 4

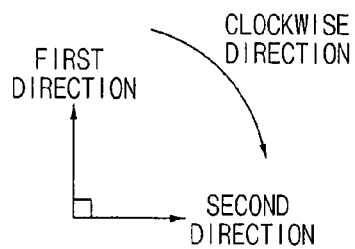
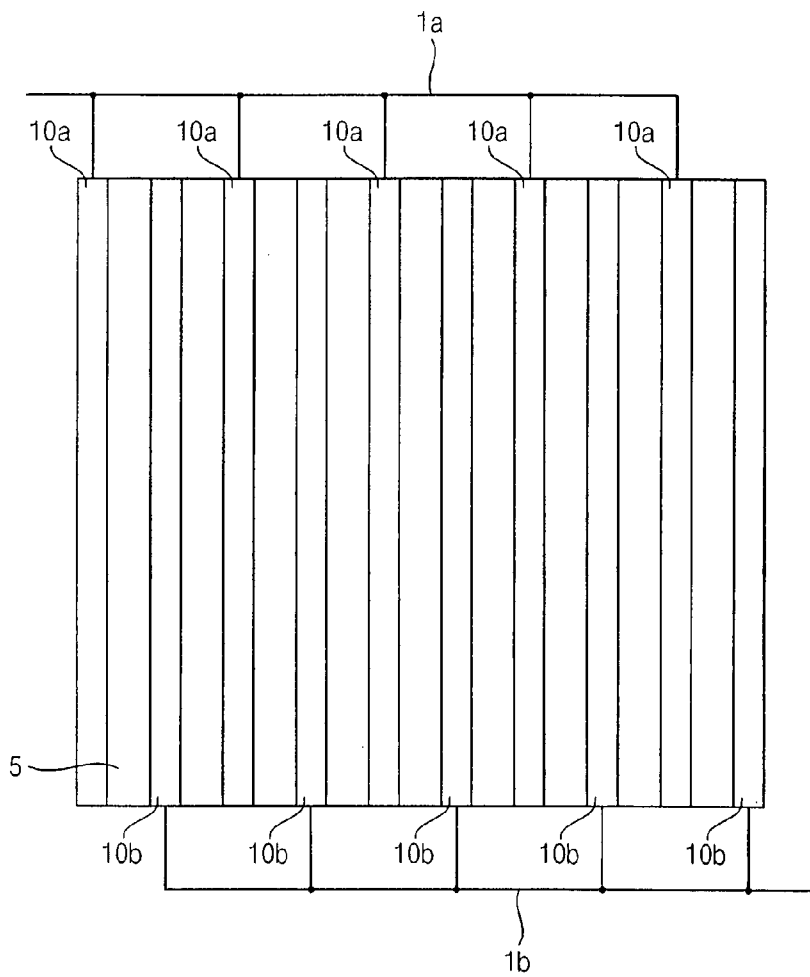


FIG. 5

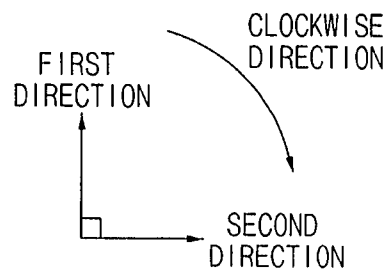
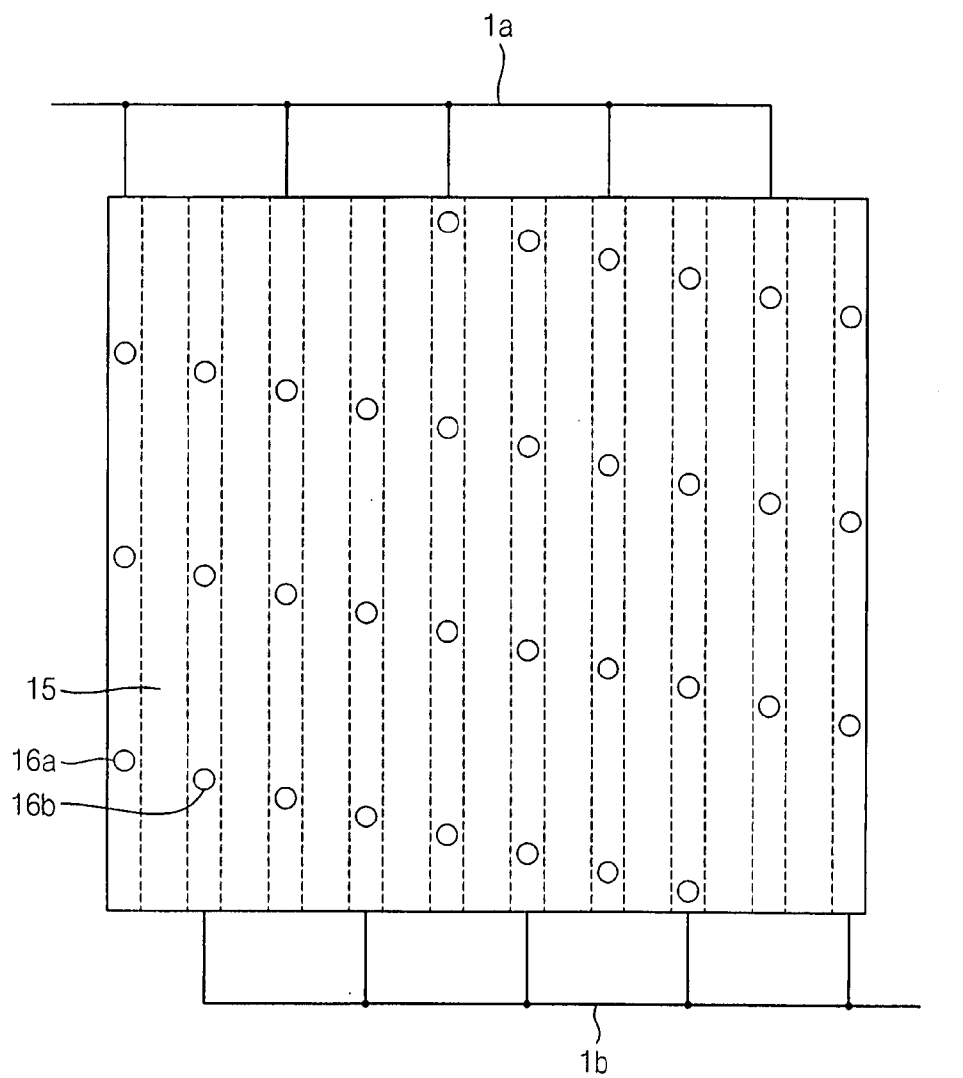


FIG. 6

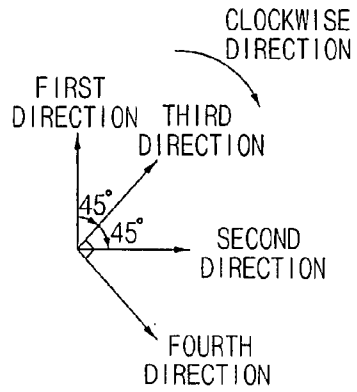
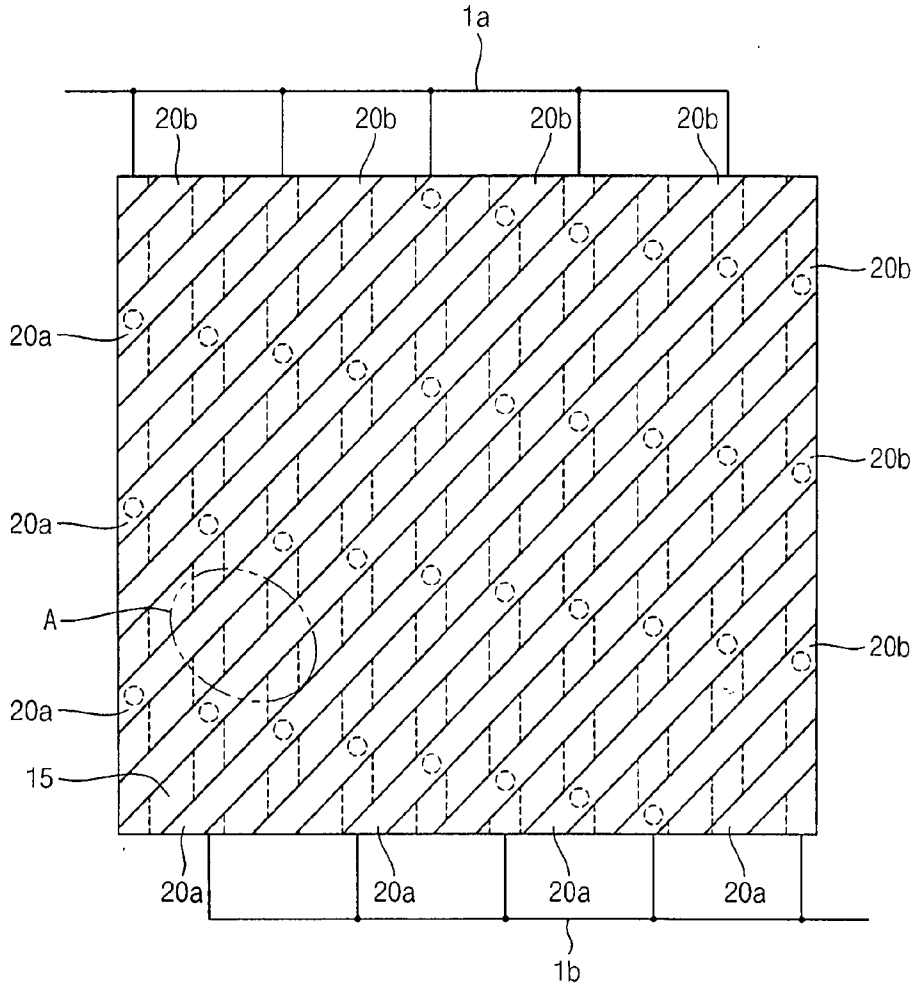


FIG. 7

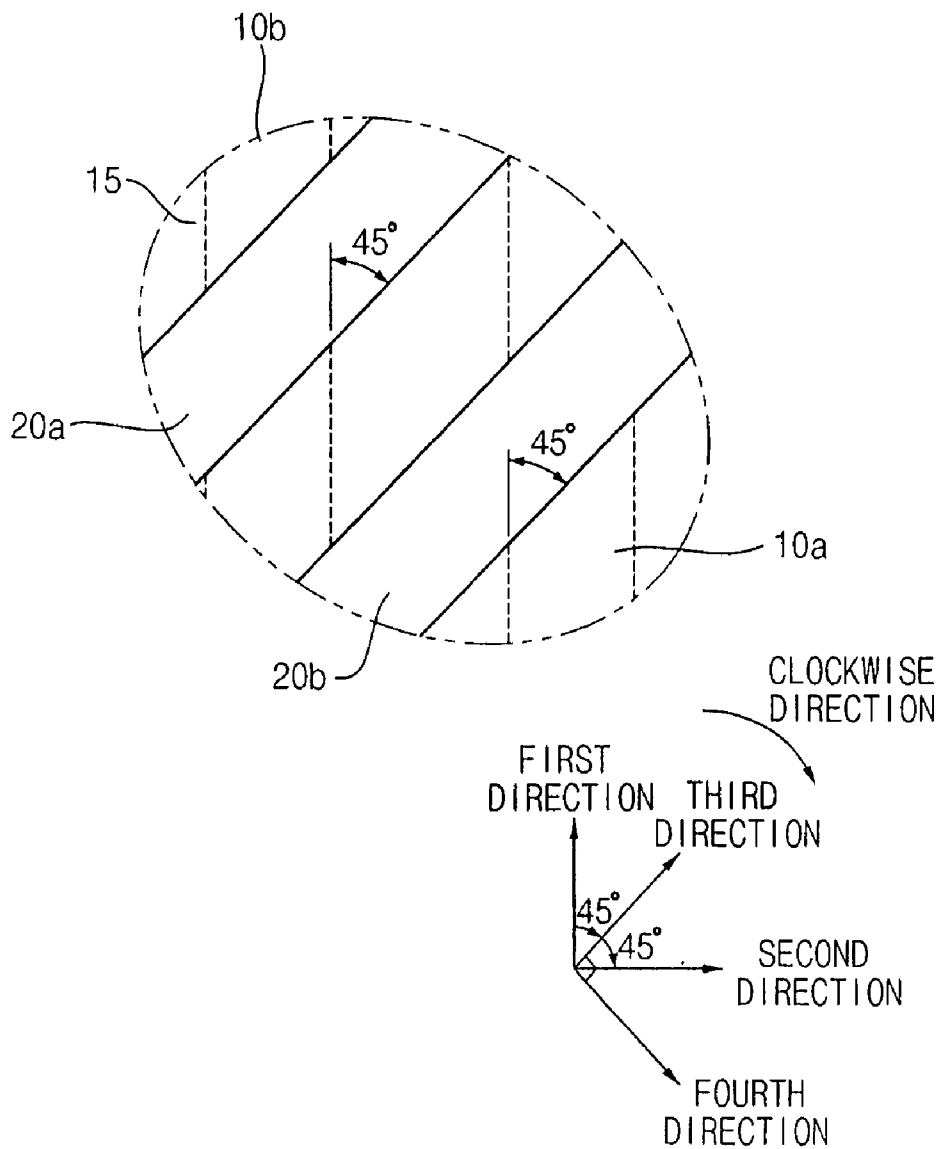




FIG. 8

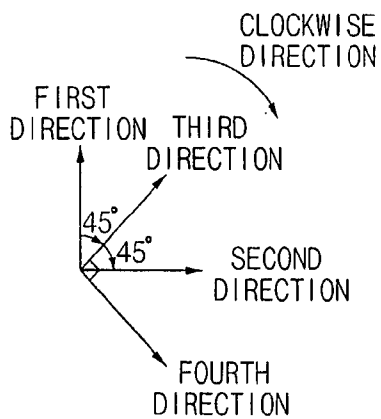
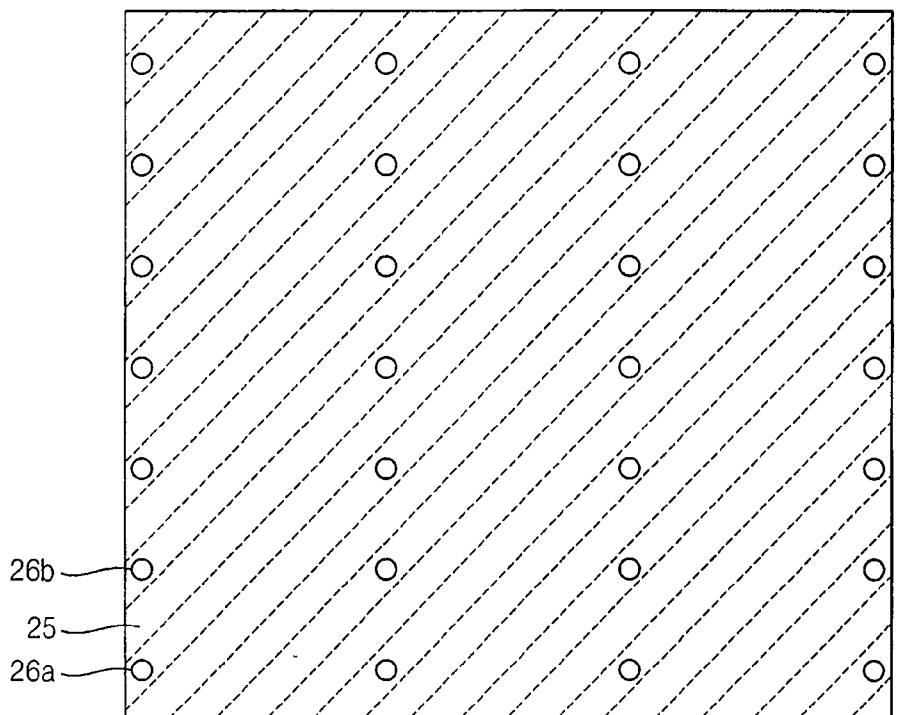


FIG. 9

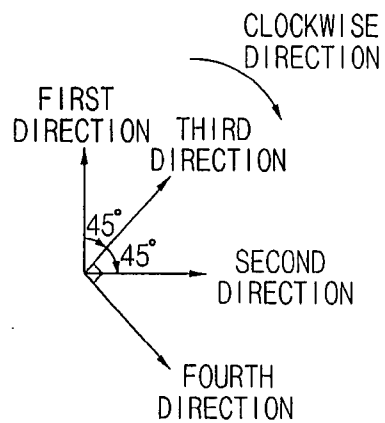
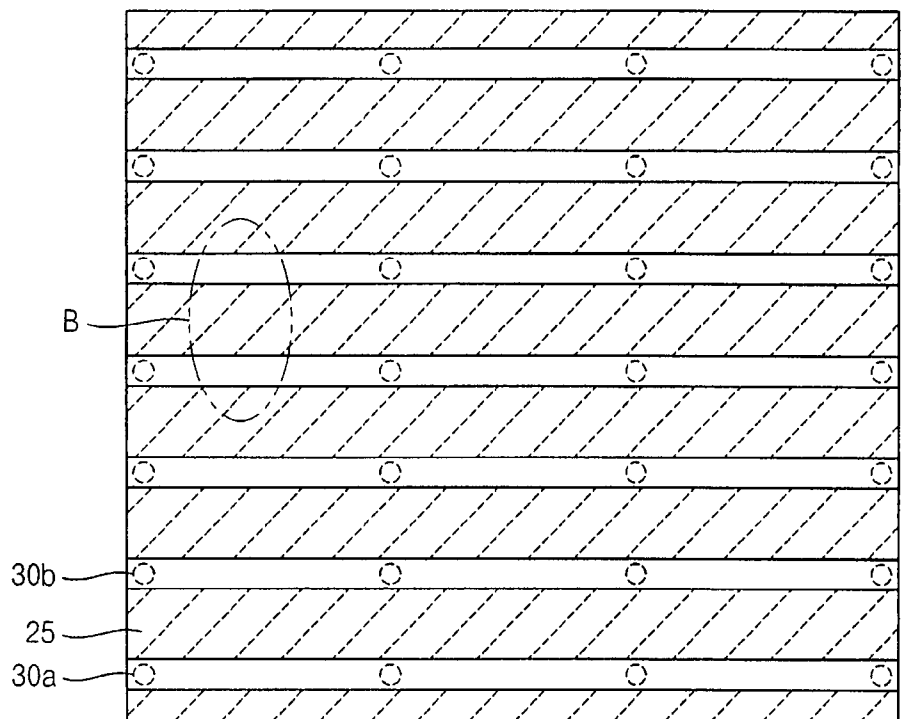
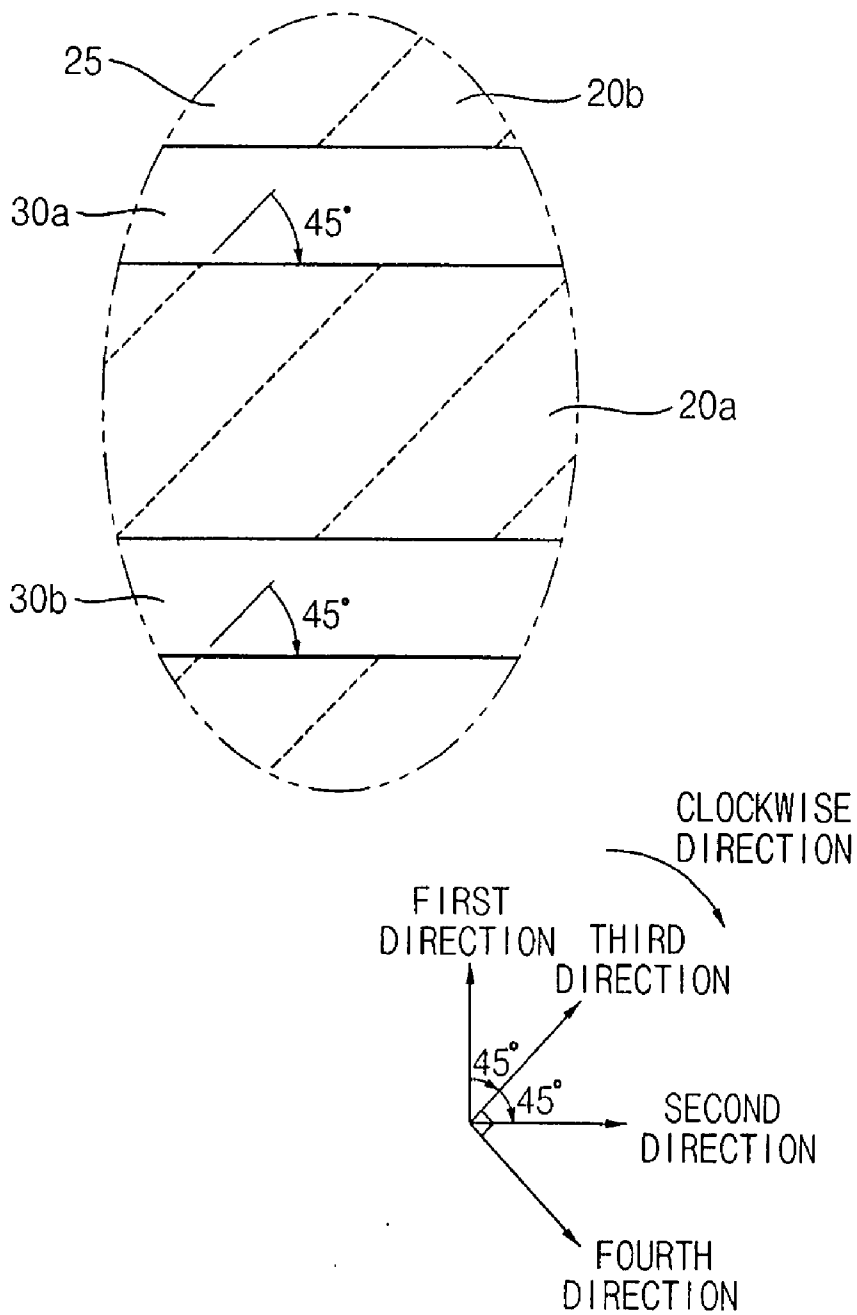


FIG. 10



## CAPACITOR STRUCTURE AND METHOD OF MANUFACTURING THE SAME

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119 to Korean Patent Application No. 10-2006-0116352, filed on Nov. 23, 2006 in the Korean Intellectual Property Office (KIPO), the disclosure of which is incorporated herein by reference in its entirety.

### BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a capacitor structure. More particularly, the present invention relates to a capacitor structure capable of storing charge.

[0004] 2. Description of the Related Art

[0005] FIG. 1 is a perspective view illustrating a conventional capacitor structure. Insulating portions of the capacitor structure are not depicted in FIG. 1 for convenience of explanation. That is, only conductive portions of the capacitor structure are depicted in FIG. 1.

[0006] Referring to FIG. 1, the conventional capacitor structure includes first conductive patterns *1a*, second conductive patterns *1b*, first contacts *3a*, second contacts *3b*, third conductive patterns *2a*, fourth conductive patterns *2b*, third contacts *4a* and fourth contacts *4b*.

[0007] The first conductive patterns *1a* and the second conductive patterns *1b* extend in a first direction. The first and second conductive patterns *1a* and *1b* are alternately arranged in a second direction substantially perpendicular to the first direction such that the first and second conductive patterns *1a* and *1b* are spaced apart from one another in the second direction.

[0008] The first conductive patterns *1a* are vertically and repeatedly stacked. The first conductive patterns *1a* are vertically connected by the first contacts *3a*. The second conductive patterns *1b* are vertically and repeatedly stacked. The second conductive patterns *1b* are vertically connected by the second contacts *3b*.

[0009] The third conductive patterns *2a* and the fourth conductive patterns *2b* are located over the first conductive patterns *1a* and the second conductive patterns *1b*. The third conductive patterns *2a* and the fourth conductive patterns *2b* extend in a second direction substantially perpendicular to the first direction. In addition, the third conductive patterns *2a* and the fourth conductive patterns *2b* are arranged to be spaced apart from one another in the first direction.

[0010] The third conductive patterns *2a* are vertically connected to one another by the third contacts *4a*. In addition, the fourth conductive patterns *2b* are vertically connected to one another by the fourth contacts *4b*. Thus, the first conductive patterns *1a*, the first contacts *3a*, the third conductive patterns *2a* and the third contacts *4a* form a first electric group. In addition, the second conductive patterns *1b*, the second contacts *3b*, the fourth conductive patterns *2b* and the fourth contacts *4b* form a second electric group that is electrically insulated from the first electric group.

[0011] The conventional capacitor structure includes a first capacitor, a second capacitor, a third capacitor and a fourth capacitor because the first electric group is electrically insulated from the second electric group. The first capacitor is horizontally formed between the first conductive patterns *1a*

and the second conductive patterns *1b*. The second capacitor is horizontally formed between the third conductive patterns *2a* and the fourth conductive patterns *2b*. The third capacitor is vertically formed between the first conductive patterns *1a* and the fourth conductive patterns *2b*. The fourth capacitor is vertically formed between the second conductive patterns *1b* and third conductive patterns *2a*.

[0012] As described above, the first direction in which the first conductive patterns *1a* and the second conductive patterns *1b* extend is substantially perpendicular to the second direction in which the third conductive patterns *2a* and the fourth, conductive patterns *2b* extend.

[0013] Thus, portions of the first conductive patterns *1a* and the fourth conductive patterns *2b* that are overlapped and portions of the second conductive patterns *1b* and the fourth conductive patterns *2a* that are overlapped may be shaped substantially like rectangles or squares in the overlapping regions.

[0014] Capacitances of the third and fourth capacitors are substantially proportional to the areas of the overlapped portions, and as described above, the overlapped portions are shaped substantially like rectangles or squares. Thus, the capacitances of the third and fourth capacitors are limited by the rectangular areas of intersection.

[0015] In addition, when the first, second, third and fourth conductive patterns are vertically and repeatedly stacked, the first, second, third and fourth conductive patterns cannot be rotated. Thus, the resulting number of third and fourth capacitors is not large.

### SUMMARY OF THE INVENTION

[0016] An embodiment of the present invention provides a capacitor structure including a large number of capacitors having relatively large capacitance values.

[0017] An embodiment of the present invention provides a method of manufacturing the capacitor structure.

[0018] In accordance with an embodiment of the present invention, a capacitor structure includes a substrate, first conductive patterns, second conductive patterns, an insulating interlayer, third conductive patterns and fourth conductive patterns. The first and second conductive patterns extend in a first direction on the substrate. The first and second conductive patterns are alternately arranged to be spaced apart from one another in a second direction substantially perpendicular to the first direction. The insulating interlayer is formed on the substrate to cover the first and second conductive patterns. The third and fourth conductive patterns extend on the insulating interlayer in a third direction that lies at an angle of between about 0° and about 90° relative to the first direction. The third and fourth conductive patterns are alternately arranged to be spaced apart from one another in a fourth direction substantially perpendicular to the third direction.

[0019] The first conductive patterns may be electrically connected to one another, the second conductive patterns electrically connected to one another. The first conductive patterns may be electrically connected to one another by a first conductive line connected to end portions of the first conductive patterns. The second conductive patterns may be electrically connected to one another by a second conductive line connected to end portions of the second conductive patterns.

[0020] The first conductive patterns may be electrically connected to the third conductive patterns. The second conductive patterns may be electrically connected to the fourth

conductive patterns. The first and third conductive patterns may be electrically connected to one another by first contacts formed between the first and third conductive patterns through the insulating interlayer. The second and fourth conductive patterns may be electrically connected to one another by second contacts formed between the second and fourth conductive patterns through the insulating interlayer.

**[0021]** The third conductive patterns may be electrically connected to one another by a third conductive line connected to end portions of the third conductive patterns. The third conductive line may be electrically connected to the first conductive line. The fourth conductive patterns may be electrically connected to one another by a fourth conductive line connected to end portions of the fourth conductive patterns. The fourth conductive line may be electrically connected to the second conductive line.

**[0022]** The angle may be about 45°. The first, second, third and fourth conductive patterns may have substantially bar shapes. The insulating interlayer and the third and fourth conductive patterns may be subsequently and repeatedly stacked. Here, each time the third and fourth conductive patterns are stacked, the stacked conductive patterns are rotated by between about 0° and about 90° relative to conductive patterns on a neighboring lower level.

**[0023]** In accordance with an embodiment of the present invention, there is provided a method of manufacturing a capacitor structure. In the method, first and second conductive patterns are formed on the substrate. The first and second conductive patterns extend in a first direction. The first and second conductive patterns are alternately arranged to be spaced apart from one another in a second direction substantially perpendicular to the first direction. An insulating interlayer is formed on the substrate to cover the first and second conductive patterns. Third and fourth conductive patterns extending in a third direction that lies at an angle of between about 0° and about 90° relative to the first direction are formed. The third and fourth conductive patterns are alternately arranged to be spaced apart from one another in a fourth direction substantially perpendicular to the third direction.

**[0024]** A first conductive line may be further formed as one body with the first conductive patterns such that the first conductive line is connected to end portions of the first conductive patterns. A second conductive line may be further formed as one body with the second conductive patterns such that the second conductive line is connected to end portions of the second conductive patterns.

**[0025]** First contacts may be further formed through the insulating interlayer such that the first contacts are connected between the first and third conductive patterns. Second contacts may be further formed through the insulating interlayer such that the second contacts are connected between the second and fourth conductive patterns.

**[0026]** A third conductive line may be further formed as one body with the third conductive patterns such that the third conductive line is connected to end portions of the third conductive patterns. Here, the third conductive line may be electrically connected to the first conductive line.

**[0027]** A fourth conductive line may be further formed as one body with the fourth conductive patterns such that the fourth conductive line is electrically connected to end portions of the fourth conductive patterns. Here, the fourth conductive line may be electrically connected to the second conductive line.

**[0028]** The angle may be about 45°. The first, second, third and fourth conductive patterns may have substantially bar shapes. The insulating interlayer and the third and fourth conductive patterns may be subsequently and repeatedly stacked. Here, each time the third and fourth conductive patterns are stacked, the stacked third and fourth conductive patterns may be rotated by between about 0° and about 90° relative to conductive patterns on a neighboring lower level.

**[0029]** According to embodiments of the present invention, areas of portions where two conductive patterns forming a capacitor are overlapped may be increased. The capacitance of the capacitor may be substantially proportional to the areas of the overlapped portions, and the resulting capacitance of the capacitor can therefore be increased.

**[0030]** In addition, each time the conductive patterns are vertically and repeatedly stacked, the stacked conductive patterns are rotated by a predetermined angle with respect to the lower conductive patterns. Thus, the number of capacitors may be increased.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0031]** The above and other advantages of the embodiments of the present invention will become readily apparent by reference to the following detailed description when considered in conjunction with the accompanying drawings in which:

**[0032]** FIG. 1 is a perspective view illustrating a conventional capacitor structure;

**[0033]** FIG. 2 is a perspective view illustrating a capacitor structure in accordance with an embodiment of the present invention;

**[0034]** FIG. 3 is a perspective view illustrating conductive portions of the capacitor structure in FIG. 2; and

**[0035]** FIGS. 4 to 10 are plan views illustrating a method of manufacturing a capacitor of the type shown in FIGS. 2 and 3.

#### DETAILED DESCRIPTION OF EMBODIMENTS

**[0036]** Embodiments of the present invention will be described with reference to the accompanying drawings. The present invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, the embodiments are provided so that disclosure of the present invention will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. The principles and features of this invention may be employed in varied and numerous embodiments without departing from the scope of the present invention. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity. The drawings are not necessarily to scale. Like reference numerals designate like elements throughout the drawings.

**[0037]** It will also be understood that when an element or layer is referred to as being “on,” “connected to” and/or “coupled to” another element or layer, the element or layer may be directly on, connected and/or coupled to the other element or layer or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly connected to” and/or “directly coupled to” another element or layer, no intervening elements or layers are present. As used herein, the term “and/or” may include any and all combinations of one or more of the associated listed items.

**[0038]** It will also be understood that, although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections. These elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be used to distinguish one element, component, region, layer and/or section from another element, component, region, layer and/or section. For example, a first element, component, region, layer and/or section discussed below could be termed a second element, component, region, layer and/or section without departing from the teachings of the present invention.

**[0039]** Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like may be used to describe an element and/or feature’s relationship to another element(s) and/or feature(s) as, for example, illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use and/or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” and/or “beneath” other elements or features would then be oriented “above” the other elements or features. The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

**[0040]** The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular terms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “includes” and/or “including,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence and/or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

**[0041]** Unless otherwise defined, all terms (including technical and scientific terms) used herein may have the same meaning as what is commonly understood by one of ordinary skill in the art. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized and/or overly formal sense unless expressly so defined herein.

**[0042]** Embodiments of the present invention are described with reference to cross-section illustrations that are schematic illustrations of idealized embodiments of the present invention. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments of the present invention should not be construed as limited to the particular shapes of regions illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated as a rectangle will, typically, have rounded or curved features. Thus, the regions illustrated in the figures are schematic in nature of a device and are not intended to limit the scope of the present invention.

**[0043]** FIG. 2 is a perspective view illustrating a capacitor structure in accordance with an embodiment of the present invention. FIG. 3 is a perspective view illustrating conductive portions of the capacitor structure in FIG. 2. That is, insulat-

ing portions of the capacitor structure in FIG. 2 are not depicted in FIG. 3 for convenience of explanation.

**[0044]** Referring to FIGS. 2 and 3, first and second conductive patterns **10a** and **10b** are provided on a substrate **5**, for example an insulating layer **5**. For example, the first and second conductive patterns **10a** and **10b** can include a metal such as copper (Cu), aluminum (Al) or platinum (Pt). These metals can be used alone or in combination in a metal alloy.

**[0045]** The first and second conductive patterns **10a** and **10b** extend in a first direction on the insulating layer **5**. The first and second conductive patterns **10a** and **10b** are alternately arranged on the insulating layer **5** such that the first and second conductive patterns **10a** and **10b** are spaced apart from one another in a second direction, the second direction being a direction that is rotated clockwise relative to the first direction by about 90°.

**[0046]** The first and second conductive patterns **10a** and **10b** may have various shapes. For example, as illustrated in FIGS. 2 and 3, the first and second conductive patterns **10a** and **10b** can have substantially bar shapes.

**[0047]** The first conductive patterns **10a** may be electrically connected to one another by a first conductive line **1a** connected to end portions of the first conductive patterns **10a**. Here, the first conductive line **1a** can be integrally formed with the first conductive patterns **10a**. Alternatively, the first conductive line **1a** and the first conductive patterns **10a** can be formed by different processes.

**[0048]** The second conductive patterns **10b** may be electrically connected to one another by a second conductive line **1b** connected to end portions of the second conductive patterns **10b**. Here, the second conductive line **1b** may be integrally formed with the second conductive patterns **10b**. Alternatively, the second conductive line **1b** and the second conductive patterns **10b** may be formed by different processes.

**[0049]** That is, the first conductive patterns **10a** are electrically connected to one another by the first conductive line **1a**. In addition, the second conductive patterns **10b** are electrically connected to one another by the second conductive line **1b**. The first conductive patterns **10a** are electrically insulated from the second conductive patterns **10b**.

**[0050]** A first insulating interlayer **15** is provided on the insulating layer **5** such that the first insulating interlayer **15** covers the first and second conductive patterns **10a** and **10b**. The first insulating interlayer **15** can comprise an insulating material such as silicon nitride or silicon oxide.

**[0051]** As described above, the first conductive patterns **10a** are electrically insulated from the second conductive patterns **10b**. In addition, a space between the first conductive patterns **10a** and the second conductive patterns **10b** is filled with the first insulating interlayer **15**. Thus, the first conductive patterns **10a**, the first insulating interlayer **15** and the second conductive patterns **10b** may form a capacitor that is configured in a horizontal direction.

**[0052]** Third conductive patterns **20a** and fourth conductive patterns **20b** are provided on the first insulating interlayer **15**. For example, the third and fourth conductive patterns **20a** and **20b** can be formed using a metal such as copper (Cu), aluminum (Al) or platinum (Pt). These metals may be used alone or in combination in a metal alloy.

**[0053]** The third and fourth conductive patterns **20a** and **20b** may extend in a third direction forming a first angle  $\theta 1$  to the first direction. The third and fourth conductive patterns **20a** and **20b** are alternately arranged such that the third and fourth conductive patterns **20a** and **20b** are spaced apart from

one another in a fourth direction that is rotated clockwise relative to the third direction by about  $90^\circ$ .

[0054] Here, the first angle  $\theta_1$  can be between about  $0^\circ$  and about  $90^\circ$ , so that it is an acute angle. In addition, the third direction may lie at the first angle  $\theta_1$  relative to the first direction in a clockwise direction. Alternatively, the third direction may lie at the first angle  $\theta_1$  relative to the first direction in a counterclockwise direction.

[0055] In the present embodiment, a case where the third direction is at an angle of about  $45^\circ$  relative to the first direction in the clockwise direction is described for convenience of explanation. However, as described above, the present invention is not construed as being limited to the present embodiment.

[0056] The third and fourth conductive patterns  $20a$  and  $20b$  may have various shapes. For example, as illustrated in FIGS. 2, 3, and 6, the third and fourth conductive patterns  $20a$  and  $20b$  can have substantially bar shapes.

[0057] First and second contacts  $16a$  and  $16b$  are formed through the first insulating interlayer  $15$ . The first and second contacts  $16a$  and  $16b$  may be formed using a conductive metal such as tungsten (W) or copper (Cu). These metals may be used alone or in combination in an alloy.

[0058] Particularly, the first contacts  $16a$  may be formed through portions of the first insulating interlayer  $15$  where the first conductive patterns  $10a$  and the third conductive patterns  $20a$  are overlapped such that the first contacts  $16a$  electrically connect the first conductive patterns  $10a$  to the third conductive patterns  $20a$ . The second contacts  $16b$  may be formed through portions of the first insulating interlayer  $15$  where the second conductive patterns  $10b$  and the fourth conductive patterns  $20b$  are overlapped such that the second contacts  $16b$  electrically connect the second conductive patterns  $10b$  to the fourth conductive patterns  $20b$ .

[0059] Alternatively, the first contacts  $16a$  are not formed. In this case, a third conductive line electrically connected to end portions of the third conductive patterns  $20a$  is formed, and third conductive line is electrically connected to the first conductive line  $1a$ .

[0060] In addition, in an alternative embodiment, the second contacts  $16b$  are not formed. In this case, a fourth conductive line electrically connected to end portions of the fourth conductive patterns  $20b$  is formed. The fourth conductive line is electrically connected to the second conductive line  $1b$ .

[0061] The first conductive patterns  $10a$  are not electrically connected to the fourth conductive patterns  $20b$ . The second conductive patterns  $10b$  are not electrically connected to the third conductive patterns  $20a$ .

[0062] That is, the first and third conductive patterns  $10a$  and  $20a$  electrically connected to one another may form an electric group. In addition, the second and fourth conductive patterns  $10b$  and  $20b$  electrically connected to one another may form another electric group.

[0063] The first insulating interlayer  $15$  and the second conductive patterns  $10b$  are located under the third conductive patterns  $20a$ ; also the first insulating interlayer  $15$  and the first conductive patterns  $10a$  are located under the fourth conductive patterns  $20b$ .

[0064] As described above, the third conductive patterns  $20a$ , the first insulating interlayer  $15$  and the second conductive patterns  $10b$  can form a capacitor structure in the vertical direction because the third conductive patterns  $20a$  are electrically insulated from the second conductive patterns  $10b$ .

Also, the fourth conductive patterns  $20b$ , the first insulating interlayer  $15$  and the first conductive patterns  $10a$  can form a capacitor structure in the vertical direction because the fourth conductive patterns  $20b$  are electrically insulated from the first conductive patterns  $10a$ .

[0065] Here, portions where the third conductive patterns  $20a$  and the second conductive patterns  $10b$  are overlapped and portions where the fourth conductive patterns  $20b$  and the first conductive patterns  $10a$  are overlapped may be shaped substantially like parallelograms other than a square and a rectangle because the first direction lies at the first acute angle  $\theta_1$  relative to the third direction.

[0066] That is, the portion where the third conductive patterns  $20a$  and the second conductive patterns  $10b$  are overlapped and the portion where the fourth conductive patterns  $20b$  and the first conductive patterns  $10a$  are overlapped may be shaped substantially like parallelograms having an acute interior angle. Here, the acute interior angle is the first angle  $\theta_1$ .

[0067] In the present embodiment, the acute interior angle of the parallelogram is about  $45^\circ$  because the third direction lies at an angle of about  $45^\circ$  relative to the first direction in the clockwise direction.

[0068] The capacitance of a capacitor is substantially proportional to the areas of the overlapped portions. As described above, the overlapped portions are shaped substantially like the parallelogram having the acute interior angle. Thus, the capacitance may be increased as compared to a case where the overlapped portions are shaped substantially like the square and the rectangle, since the area of the overlapped portions shaped like a parallelogram is greater than the area of the overlapped portions shaped like the rectangle or square, assuming the same width of conductive patterns in each case.

[0069] A second insulating interlayer  $25$  is provided on the first insulating interlayer  $15$  to cover the third and fourth conductive patterns  $20a$  and  $20b$ . The second insulating interlayer  $25$  can include substantially the same insulating material as the first insulating interlayer  $15$ .

[0070] As described above, the third conductive patterns  $20a$  and fourth conductive patterns  $20b$  are electrically insulated from one another. In addition, the space between the third conductive patterns  $20a$  and the fourth conductive patterns  $20b$  is filled with the second insulating interlayer  $25$ . Thus, the third conductive patterns  $20a$ , the second insulating interlayer  $25$  and the fourth conductive patterns  $20b$  form a capacitor in a horizontal direction.

[0071] Fifth and sixth conductive patterns  $30a$  and  $30b$  are located on the second insulating interlayer  $25$ . For example, the fifth and sixth conductive patterns  $30a$  and  $30b$  can be formed of the same conductive metal or metal alloy as that of the third and fifth conductive patterns  $20a$  and  $20b$ .

[0072] The fifth and sixth conductive patterns  $30a$  and  $30b$  extend in a fifth direction that lies at a second angle  $\theta_2$  relative to the third direction. The fifth and sixth conductive patterns  $30a$  and  $30b$  are alternately arranged to be spaced apart from one another in a sixth direction that is rotated clockwise relative to the fifth direction by about  $90^\circ$ .

[0073] Here, the second angle  $\theta_2$  may be an acute angle between about  $0^\circ$  and about  $90^\circ$ . In addition, the fifth direction may lie at the second angle  $\theta_2$  relative to the third direction in a clockwise direction. Alternatively, the fifth direction may lie at the second angle  $\theta_2$  relative to the third direction in a counterclockwise direction.

[0074] In the present embodiment, a case where the fifth direction lies at an angle of about 45° relative to the third direction in a clockwise direction is described for the convenience of explanation. In this example, the fifth direction can be substantially the same as the second direction because the fifth direction lies at an angle of about 45° relative to the third direction in the clockwise direction.

[0075] The fifth and sixth conductive patterns 30a and 30b can be formed to have various shapes. For example, as illustrated in FIGS. 2, 3, and 9, the fifth and sixth conductive patterns 30a and 30b may have substantially bar shapes.

[0076] Third and fourth contacts 26a and 26b are provided through the second insulating interlayer 25. The third and fourth contacts 26a and 26b may include the same metal as that of the first and second contacts 16a and 16b.

[0077] Particularly, the third contacts 26a may be formed through portions of the second insulating interlayer 25 where the third conductive patterns 20a and the fifth conductive patterns 30a are overlapped such that the third contacts 26a electrically connect the third conductive patterns 20a to the fifth conductive patterns 30a. The fourth contacts 26b may be formed through portions of the second insulating interlayer 25 where the fourth conductive patterns 20b and the sixth conductive patterns 30b are overlapped such that the fourth contacts 26b electrically connect the fourth conductive patterns 20b to the sixth conductive patterns 30b.

[0078] In an alternative embodiment, the third contacts 26a are not formed. In this case, a fifth conductive line electrically connected to end portions of the fifth conductive patterns 30a is formed. The fifth conductive line can be electrically connected to the first conductive line 1a. In addition, in the alternative embodiment, the fourth contacts 26b are not formed. In this case, a sixth conductive line electrically connected to end portions of the sixth conductive patterns 30b is formed. The sixth conductive line can be electrically connected to the second conductive line 1b.

[0079] The third conductive patterns 20a are insulated from, and are not electrically connected to, the sixth conductive patterns 30b. The fourth conductive patterns 20b are insulated from, and are not electrically connected to, the fifth conductive patterns 30a. That is, the first, third and fifth conductive patterns 10a, 20a and 30a electrically connected to one another may form an electric group. The second, fourth and sixth conductive patterns 10b, 20b and 30b electrically connected to one another may form another electric group.

[0080] The second insulating interlayer 25 and the fourth conductive patterns 20b are located under the fifth conductive patterns 30a. The second insulating interlayer 25 and the second conductive patterns 20a are located under the sixth conductive patterns 30b. The fifth conductive patterns 30a, the second insulating interlayer 25 and the fourth conductive patterns 20b form a capacitor in the vertical direction because the fifth conductive patterns 30a are electrically insulated from the fourth conductive patterns 20b. The sixth conductive patterns 30b, the second insulating interlayer 25 and the third conductive patterns 20a form a capacitor structure in the vertical direction because the sixth conductive patterns 30b are electrically insulated from the third conductive patterns 20a.

[0081] Here, portions where the fifth conductive patterns 30a and the fourth conductive patterns 20b are overlapped and portions where the sixth conductive patterns 30b and the third conductive patterns 20a are overlapped may be shaped substantially like parallelograms other than a square and a

rectangle because the third direction lies at the second angle  $\theta 2$  relative to the fifth direction.

[0082] That is, portions where the fifth conductive patterns 30a and the fourth conductive patterns 20b are overlapped and portions where the sixth conductive patterns 30b and the third conductive patterns 20a are overlapped may be shaped substantially like parallelograms having an acute interior angle. In this case, the acute angle interior angle is the second angle  $\theta 2$ .

[0083] In the present embodiment, the parallelogram has an acute interior angle of about 45° because the fifth direction lies at an angle of about 45° relative to the third direction in a clockwise direction. As described above, the overlapped portions are shaped substantially like the parallelogram having the acute interior angle. Thus, the capacitance may be increased relative to a case where the overlapped portions are shaped substantially like a square or rectangle, assuming conductive patterns of the same width.

[0084] In the present embodiment, the conductive patterns are vertically stacked three times. In addition, the stacked conductive patterns are rotated by a predetermined angle, such as an acute angle, with respect to the lower conductive patterns so that the shape of the overlapped portions becomes the parallelogram having a relatively increased area, and therefore capable of increasing the capacitance of the resulting device. In various embodiments, the conductive patterns may be vertically stacked, for example, at least six times. In this case also, each time the conductive patterns are stacked, the subsequently stacked conductive patterns are rotated by the predetermined angle with respect to the preceding lower conductive patterns.

[0085] FIGS. 4 to 10 are plan views illustrating a method of manufacturing a capacitor, for example, the capacitor shown in FIGS. 2 and 3.

[0086] Referring to FIG. 4, first and second conductive patterns 10a and 10b are formed on an insulating layer 5. For example, the first and second conductive patterns 10a and 10b may be formed using a metal such as copper (Cu), aluminum (Al) or platinum (Pt). These metals may be used alone or in combination in an alloy.

[0087] The first and second conductive patterns 10a and 10b extend in a first direction on the insulating layer 5. The first and second conductive patterns 10a and 10b are alternately arranged on the insulating layer 5 to be spaced apart from one another in a second direction rotated clockwise from the first direction by about 90°.

[0088] The first and second conductive patterns 10a and 10b may have various shapes. For example, as illustrated in FIG. 4, the first and second conductive patterns 10a and 10b can have substantially bar shapes.

[0089] The first conductive patterns 10a may be electrically connected to one another by a first conductive line 1a connected to end portions of the first conductive patterns 10a. Here, the first conductive line 1a may be integrally formed with the first conductive patterns 10a. Alternately, the first conductive line 1a and the first conductive patterns 10a may be formed by different processes.

[0090] The second conductive patterns 10b are electrically connected to one another by a second conductive line 1b connected to end portions of the second conductive patterns 10b. Here, the second conductive line 1b may be integrally formed with the second conductive patterns 10b. Alternatively, the second conductive line 1b and the second conductive patterns 10b may be formed by different processes.



[0091] That is, the first conductive patterns **10a** are electrically connected to one another by the first conductive line **1a**. In addition, the second conductive patterns **10b** are electrically connected to one another by a second conductive line **1b**. However, the first conductive patterns **10a** are electrically insulated from the second conductive patterns **10b**.

[0092] Referring to FIG. 5, a first insulating interlayer **15** is formed on the insulating layer **5** to cover the first and second conductive patterns **10a** and **10b**. The first insulating interlayer **15** may be formed using an insulating material such as silicon nitride and silicon oxide.

[0093] As described above, the first conductive patterns **10a** are electrically insulated from the second conductive patterns **10b**. In addition, a space between the first conductive patterns **10a** and the second conductive patterns **10b** is filled with the first insulating interlayer **15**. Thus, the first conductive patterns **10a**, the first insulating interlayer **15** and the second conductive patterns **10b** form a capacitor structure in a horizontal direction.

[0094] After, the first insulating interlayer **15** is formed, first and second contacts **16a** and **16b** are formed through the first insulating interlayer **15** to be electrically connected to the first and second conductive patterns **10a** and **10b**, respectively. The first and second contacts **16a** and **16b** may include a metal such as tungsten (W) or copper (Cu). These metals may be used alone or in combination in an alloy.

[0095] Particularly, the first contacts **16a** may be formed on portions of the first conductive patterns **10a** to be overlapped by third conductive patterns **20a** (see FIG. 6) that are subsequently formed. In addition, the second contacts **16b** are formed on portions of the second conductive patterns **10b** to be overlapped by fourth conductive patterns **20a** (see FIG. 6) that are subsequently formed.

[0096] Referring to FIG. 6, the third conductive patterns **20a** and the fourth conductive patterns **20b** are formed on the first insulating interlayer **15**. For example, the third and fourth conductive patterns **20a** and **20b** may be formed using a metal such as copper (Cu), aluminum (Al) or platinum (Pt). These metals may be used alone or in combination in an alloy.

[0097] The third and fourth conductive patterns **20a** and **20b** extend in a third direction that is at a first angle  $\theta_1$  relative to the first direction. The third and fourth conductive patterns **20a** and **20b** are alternately arranged to be spaced apart from one another in a fourth direction that is rotated clockwise relative to the third direction by about  $90^\circ$ .

[0098] Here, the first angle  $\theta_1$  may be an acute angle between about  $0^\circ$  and about  $90^\circ$ . In addition, the third direction may form the first angle  $\theta_1$  from the first direction in a clockwise direction. Alternatively, the third direction may form the first angle  $\theta_1$  from the first direction in a counter-clockwise direction.

[0099] In the present embodiment, a case where the third direction forms about  $45^\circ$  to the first direction in the clockwise direction is described for convenience of explanation. However, as described above, the present invention is not to be construed as being limited to the present embodiment.

[0100] The third and fourth conductive patterns **20a** and **20b** may have various shapes. For example, as illustrated in FIG. 6, the third and fourth conductive patterns **20a** and **20b** have substantially bar shapes.

[0101] Here, the first conductive patterns **10a** (see FIG. 8) and the third conductive patterns **20a** are electrically connected to each other by the first contacts **16a** (see FIG. 5). The

second conductive patterns **10b** and the fourth conductive patterns **20b** are electrically connected to each other by the second contacts **16b**.

[0102] In an alternative embodiment, the first contacts **16a** are not formed. In this case, a third conductive line connected to end portions of the third conductive patterns **20a** is formed. The third conductive line is then connected to the first conductive line **1a**. In addition, in the alternative embodiment, the second contacts **16b** are not formed. In this case, a fourth conductive line connected to end portions of the fourth conductive patterns **20b** is formed. The fourth conductive line is then connected to the second conductive line **1b**.

[0103] The first conductive patterns **10a** are not electrically connected to the fourth conductive patterns **20a**. In addition, the second conductive patterns **10b** are not electrically connected to the third conductive patterns **20a**.

[0104] That is, the first and third conductive patterns **10a** and **20a** that are electrically connected to one another may form an electric group. In addition, the second and fourth conductive patterns **10b** and **20b** that are electrically connected to one another may form another electric group.

[0105] FIG. 7 is an enlarged view of portion "A" of FIG. 6.

[0106] Referring to FIG. 7, the first insulating interlayer **15** and the second conductive patterns **10b** are subsequently located under the third conductive patterns **20a**. The first insulating interlayer **15** and the first conductive patterns **10a** are subsequently located under the fourth conductive patterns **20b**.

[0107] As described above, the third conductive patterns **20a**, the first insulating interlayer **15** and the second conductive patterns **10b** can form a capacitor structure in a vertical direction because the third conductive patterns **20a** are electrically insulated from the second conductive patterns **10b**. The fourth conductive patterns **20b**, the first insulating interlayer **15** and the first conductive patterns **10a** can also vertically form a capacitor structure, because the fourth conductive patterns **20b** are electrically insulated from the first conductive patterns **10a**.

[0108] Here, portions where the third conductive patterns **20a** and the second conductive patterns **10b** are overlapped and portions where the fourth conductive patterns **20b** and the first conductive patterns **10a** are overlapped may be shaped substantially like parallelograms other than a square and a rectangle because the first direction lies at the first angle  $\theta_1$  relative to the third direction. That is, the portion where the third conductive patterns **20a** and the second conductive patterns **10b** are overlapped and the portion where the fourth conductive patterns **20b** and the first conductive patterns **10a** are overlapped may be shaped substantially like parallelograms having an acute interior angle. Here, the acute interior angle may be the first angle  $\theta_1$ .

[0109] In the present embodiment, the acute interior angle of the parallelogram is about  $45^\circ$  because the third direction lies at an angle of about  $45^\circ$  relative to the first direction in a clockwise direction.

[0110] The capacitance of a capacitor is substantially proportional to areas of the overlapped portions. As described above, the overlapped portions are shaped substantially like the parallelogram having the acute interior angle. Thus, the capacitance may be relatively increased as compared to a case where the overlapped portions are shaped substantially like the square and the rectangle, owing to the increased area of overlap.

[0111] Referring to FIG. 8, a second insulating interlayer 25 can be formed on the first insulating interlayer 15 to cover the third and fourth conductive patterns 20a and 20b. The second insulating interlayer 25 may be formed using the same insulating material as that of the first insulating interlayer 15.

[0112] As described above, the third conductive patterns 20a are electrically insulated from the fourth conductive patterns 20b. In addition, a space between the third conductive patterns 20a and the fourth conductive patterns 20b is filled with the second insulating interlayer 25. Thus, the third conductive patterns 20a, the second insulating interlayer 25 and the fourth conductive patterns 20b can form a capacitor structure in a horizontal direction.

[0113] After the second insulating interlayer 25 is formed, third and fourth contacts 26a and 26b are formed through the second insulating interlayer 25 to be electrically connected to the third and fourth conductive patterns 20a and 20b, respectively. The third and fourth contacts 26a and 26b can be formed using the same conductive metal as that of the first and second contacts 16a and 16b.

[0114] Particularly, the third contacts 26a are formed on portions of the third conductive patterns 20a that are to be overlapped by fifth conductive patterns 30a (see FIG. 9) that are subsequently formed. In addition, the fourth contacts 26b are formed on portions of the fourth conductive patterns 20b that are to be overlapped by sixth conductive patterns 30b (see FIG. 9).

[0115] Referring to FIG. 9, fifth and sixth conductive patterns 30a and 30b are formed on the second insulating interlayer 25. For example, the fifth and sixth conductive patterns 30a and 30b may be formed using the same metal as that of the third and fourth conductive patterns 20a and 20b.

[0116] The fifth and sixth conductive patterns 30a and 30b extend in a fifth direction that lies at a second angle  $\theta 2$  relative to the third direction. The fifth and sixth conductive patterns 30a and 30b are alternately arranged to be spaced apart from one another in a sixth direction rotated clockwise from the fifth direction by about  $90^\circ$  (see FIG. 3).

[0117] Here, the second angle  $\theta 2$  may be between about  $0^\circ$  and about  $90^\circ$ . In addition, the fifth direction may lie at the second angle  $\theta 2$  relative to the third direction in a clockwise direction. Alternatively, the fifth direction may lie at the second angle  $\theta 2$  relative to the third direction in a counterclockwise direction.

[0118] In the present embodiment, a case where the fifth direction forms the second angle  $\theta 2$  with the third direction in the clockwise direction is described for convenience of explanation. The fifth direction may be substantially the same as the second direction because, in the example given, the fifth direction is rotated clockwise from the third direction by about  $45^\circ$ .

[0119] The fifth and sixth conductive patterns 30a and 30b may have various shapes. For example, as illustrated in FIG. 9, the fifth and sixth conductive patterns 30a and 30b may have substantially bar shapes.

[0120] Here, the third conductive patterns 20a are electrically connected to the fifth conductive patterns 30a by the third contacts 26a (see FIG. 8). The fourth conductive patterns 20b are electrically connected to the sixth conductive patterns 30b by the fourth contacts 26b.

[0121] In an alternative embodiment, the third contacts 26a need not be formed. In this case, a fifth conductive line con-

nected to end portions of the fifth conductive patterns 30a is formed. The fifth conductive line is then connected to the first conductive line 1a.

[0122] In addition, the fourth contacts 26b need not be formed. In this case, a sixth conductive line connected to end portions of the sixth conductive patterns 30b is formed. The sixth conductive line is then connected to the second conductive line 1b.

[0123] The third conductive patterns 20a are not electrically connected to the sixth conductive patterns 30a. The fourth conductive patterns 20b are not electrically connected to the fifth conductive patterns 30a. That is, the first, third and fifth conductive patterns 10a, 20a and 30a that are electrically connected to one another may form an electric group. In addition, the second, fourth and sixth conductive patterns 10b, 20b and 30b that are electrically connected to one another may form another electric group.

[0124] FIG. 10 is an enlarged view of "B" portion in FIG. 9.

[0125] Referring to FIG. 10, the second insulating interlayer 25 and the fourth conductive patterns 20b are subsequently located under the fifth conductive patterns 30a. The second insulating interlayer 25 and the second conductive patterns 20a are subsequently located under the sixth conductive patterns 30b.

[0126] As described above, the fifth conductive patterns 30a are electrically insulated from the fourth conductive patterns 20b. Thus, the fifth conductive patterns 30a, the second insulating interlayer 25 and the fourth conductive patterns 20b form a capacitor structure in a vertical direction. Also, the sixth conductive patterns 30b, the second insulating interlayer 25 and the third conductive patterns 20a form a capacitor structure in the vertical direction because the sixth conductive patterns 30b are electrically insulated from the third conductive patterns 20a.

[0127] Here, portions where the fifth conductive patterns 30a and the fourth conductive patterns 20b are overlapped and portions where the sixth conductive patterns 30b and the third conductive patterns 20a are overlapped may be shaped substantially like parallelograms other than a square and a rectangle because the third direction lies at the second angle  $\theta 2$  relative to the fifth direction.

[0128] That is, the portion where the fifth conductive patterns 30a and the fourth conductive patterns 20b are overlapped and the portion where the sixth conductive patterns 30b and the third conductive patterns 20a are overlapped may be shaped like parallelograms having an acute interior angle. Here, the acute interior angle is the second angle  $\theta 2$ .

[0129] In the present embodiment, the acute interior angle of the parallelogram is about  $45^\circ$  because the fifth direction lies at about  $45^\circ$  relative to the third direction in a clockwise direction. The capacitance may be increased relative to a case where the overlapped portions are shaped substantially like the square and the rectangle because the overlapped portions are shaped substantially like the parallelogram having the acute interior angle, and therefore have a relatively greater area.

[0130] In the present embodiment as described, the conductive patterns are vertically stacked three times. In addition, the stacked conductive patterns are rotated by a predetermined angle with respect to the lower conductive patterns so that the shape of the overlapped portions becomes the parallelogram capable of increasing the capacitance. In other embodiments, the conductive patterns may be vertically stacked a number of times, for example, at least six times. In

this case also, each time the conductive patterns are stacked, the stacked conductive patterns are rotated by the predetermined angle with respect to the lower conductive patterns.

**[0131]** According to embodiments of the present invention, the areas of portions where two conductive patterns forming a capacitor are overlapped may be increased. The capacitance of the capacitor may be substantially proportional to the areas of the overlapped portions, and thus the capacitance of the resulting capacitor can be increased.

**[0132]** In addition, each time the conductive patterns are vertically and repeatedly stacked, the stacked conductive patterns are rotated by a predetermined angle with respect to the lower conductive patterns. Thus, the number of capacitors may be increased, and/or the capacitance of the resulting capacitor is increased.

**[0133]** The foregoing embodiments are illustrative of the present invention, which should not be construed as being limiting thereof. Although a few embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

What is claimed is:

1. A capacitor structure comprising:

a substrate;

first and second conductive patterns extending in a first direction on the substrate, the first and second conductive patterns being alternately arranged to be spaced apart from one another in a second direction substantially perpendicular to the first direction;

an insulating interlayer on the substrate to cover the first and second conductive patterns; and

third and fourth conductive patterns extending on the insulating interlayer in a third direction that lies at an angle of between about 0° and about 90° relative to the first direction, the third and fourth conductive patterns being alternately arranged to be spaced apart from one another in a fourth direction substantially perpendicular to the third direction.

2. The capacitor structure of claim 1, wherein the first conductive patterns are electrically connected to one another, and the second conductive patterns are electrically connected to one another.

3. The capacitor structure of claim 2, wherein the first conductive patterns are electrically connected to one another by a first conductive line connected to end portions of the first conductive patterns.

4. The capacitor structure of claim 2, wherein the second conductive patterns are electrically connected to one another by a second conductive line connected to end portions of the second conductive patterns.

5. The capacitor structure of claim 2, wherein the first conductive patterns are electrically connected to the third

conductive patterns, and the second conductive patterns are electrically connected to the fourth conductive patterns.

6. The capacitor structure of claim 5, wherein the first and third conductive patterns are electrically connected to one another by first contacts formed between the first and third conductive patterns through the insulating interlayer.

7. The capacitor structure of claim 5, wherein the second and fourth conductive patterns are electrically connected to one another by second contacts formed between the second and fourth conductive patterns through the insulating interlayer.

8. The capacitor structure of claim 5, wherein the third conductive patterns are electrically connected to one another by a third conductive line connected to end portions of the third conductive patterns, the third conductive line being electrically connected to the first conductive line.

9. The capacitor structure of claim 5, wherein the fourth conductive patterns are electrically connected to one another by a fourth conductive line connected to end portions of the fourth conductive patterns, and the fourth conductive line electrically connected to the second conductive line.

10. The capacitor structure of claim 1, wherein the angle is about 45°, the first, second, third and fourth conductive patterns having substantially bar shapes.

11. The capacitor structure of claim 1, wherein the insulating interlayer and the third and fourth conductive patterns are subsequently and repeatedly stacked; and

wherein each time the third and fourth conductive patterns are stacked, the stacked conductive patterns are rotated by between about 0° and about 90° relative to conductive patterns on a neighboring lower level.

12. A method of manufacturing a capacitor structure, the method comprising:

forming first and second conductive patterns on a substrate, the first and second conductive patterns extending in a first direction, the first and second conductive patterns being alternately arranged to be spaced apart from one another in a second direction substantially perpendicular to the first direction;

forming an insulating interlayer on the substrate to cover the first and second conductive patterns; and

forming third and fourth conductive patterns on the insulating interlayer, the third and fourth conductive patterns extending in a third direction that lies at an angle of between about 0° and about 90° relative to the first direction, the third and fourth conductive patterns being alternately arranged to be spaced apart from one another in a fourth direction substantially perpendicular to the third direction.

13. The method of claim 12, further comprising:

integrally forming a first conductive line with the first conductive patterns such that the first conductive line is connected to end portions of the first conductive patterns.

14. The method of claim 12, further comprising:

integrally forming a second conductive line with the second conductive patterns such that the second conductive line is connected to end portions of the second conductive patterns.

15. The method of claim 12, further comprising:

forming first contacts through the insulating interlayer such that the first contacts are connected between the first and third conductive patterns.

**16.** The method of claim **12**, further comprising:  
forming second contacts through the insulating interlayer  
such that the second contacts are connected between the  
second and fourth conductive patterns.

**17.** The method of claim **13**, further comprising:  
integrally forming a third conductive line with the third  
conductive patterns such that the third conductive line is  
connected to end portions of the third conductive pat-  
terns; and

wherein the third conductive line is electrically connected  
to the first conductive line.

**18.** The method of claim **14**, further comprising:  
integrally forming a fourth conductive line with the fourth  
conductive patterns such that the fourth conductive line  
is electrically connected to end portions of the fourth  
conductive patterns; and

wherein the fourth conductive line is electrically connected  
to the second conductive line.

**19.** The method of claim **12**, wherein the angle is about  $45^\circ$ ,  
the first, second, third and fourth conductive patterns having  
substantially bar shapes.

**20.** The method of claim **13**, further comprising subse-  
quently and repeatedly stacking the insulating interlayer and  
the third and fourth conductive patterns; and

wherein each time the third and fourth conductive patterns  
are stacked, the stacked third and fourth conductive pat-  
terns are rotated by between about  $0^\circ$  and about  $90^\circ$   
relative to conductive patterns on a neighboring lower  
level.

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