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### SEMICONDUCTOR DEVICE HAVING A HIGH BREAKDOWN VOLTAGE CAPACITOR AND METHOD FOR FORMING THE SAME

#### Abstract

A semiconductor device includes a substrate, the substrate includes a capacitor region and a metal wiring region. The capacitor region includes a lower electrode formed on the substrate, an interlayer insulating layer formed on the lower electrode, a dielectric layer pattern formed on the interlayer insulating layer, and an upper electrode formed on the dielectric layer pattern. The metal wiring region includes a lower metal wiring formed parallel to the lower electrode, the interlayer insulating layer formed on the lower metal wiring, an upper insulating layer formed on the interlayer insulating layer and having a thickness smaller than a thickness of the interlayer insulating layer, and an upper metal wiring formed on the upper insulating layer, and formed in parallel with the upper electrode. The upper insulating layer and the dielectric layer pattern are formed of different materials.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This is a divisional application of U.S. application Ser. No. 17/508,132 filed on Oct. 22, 2021, which claims the benefit under 35 U.S.C. 119(a) of Korean Patent Application No. 10-2021-0026681 filed on Feb. 26, 2021 with the Korean Intellectual Property Office, the entire disclosure of which is incorporated herein by reference for all purposes.

### BACKGROUND

#### 1. Field

[0002] The present disclosure relates to a semiconductor device, including a high breakdown voltage capacitor having a high breakdown voltage characteristic and a method of manufacturing the same.

#### 2. Description of Related Art

[0003] A thick silicon oxide layer (SiO<sub>2</sub>) is generally used to form a high breakdown voltage capacitor. Such a high breakdown voltage capacitor is widely used in digital isolator devices. However, because the band gap energy of the silicon oxide layer is relatively high, it may be difficult to meet a super high breakdown voltage characteristic of the digital isolator.

[0004] Therefore, the alternative art proposed forming a super high breakdown voltage capacitor structure using a dielectric layer having a band gap energy lower than that of a silicon oxide layer. However, a dielectric layer having a low band gap may be unnecessarily formed not only in the capacitor region but also in peripheral devices. Accordingly, an additional process may occur when manufacturing a peripheral device, which may increase the manufacturing cost of a semiconductor device.

### SUMMARY

[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0006] In one general aspect, a semiconductor device includes a substrate, the substrate includes a capacitor region and a metal wiring region. The capacitor region includes a lower electrode formed on the substrate, an interlayer insulating layer formed on the lower electrode, a dielectric layer pattern formed on the interlayer insulating layer, and an upper electrode formed on the dielectric layer pattern. The metal wiring region includes a lower metal wiring formed parallel to the lower electrode, the interlayer insulating layer formed on the lower metal wiring, an upper insulating layer formed on the interlayer insulating layer and having a thickness smaller than a thickness of the interlayer insulating layer, and an upper metal wiring formed on the upper insulating layer, and formed in parallel with the upper electrode. The upper insulating layer and the dielectric layer pattern are formed of different materials.

[0007] The upper insulating layer and the dielectric layer pattern may be in contact with each other, and a thickness of the dielectric layer pattern may be formed to be thinner than the thickness of the upper insulating layer.

[0008] The dielectric layer pattern may include an upper dielectric layer and a lower dielectric layer, and a thickness of the upper dielectric layer may be formed to be different from a thickness of the lower dielectric layer.

[0009] The dielectric layer pattern may be formed of a dielectric material having a band gap lower than a band gap of the upper insulating layer.

[0010] The dielectric layer pattern may include any one of silicon rich oxide, SiON, or SiN.

[0011] An area of the dielectric layer pattern in a top view may be formed to be larger than an area of the upper electrode.

[0012] The dielectric layer pattern may be formed of first and second dielectric layer patterns that may be formed apart from each other.

[0013] The interlayer insulating layer, formed between the first and second dielectric layer patterns, may be in direct contact with the upper electrode.

[0014] A bottom surface of the upper insulating layer may be formed to be lower than a bottom surface of the dielectric layer pattern.

[0015] In another general aspect, a method for manufacturing a semiconductor device includes forming a lower electrode on a semiconductor substrate, forming an interlayer insulating layer on the lower electrode, forming a dielectric layer pattern on the interlayer insulating layer;

[0016] forming an upper insulating layer on the interlayer insulating layer using a material different from a material of the dielectric layer pattern, and forming an upper metal wiring and an upper electrode on the upper insulating layer and the dielectric layer pattern, respectively.

[0017] The forming of the upper insulating layer may include depositing a thick insulating layer over the dielectric layer pattern and the interlayer insulating layer, removing the thick insulating layer formed on the dielectric layer pattern, and forming the upper insulating layer having a thickness thinner than a thickness of the interlayer insulating layer.

[0018] The removing of the thick insulating layer formed on the dielectric layer pattern may be by a chemical mechanical polishing (CMP) process.

[0019] The dielectric layer pattern may be formed of a plurality of layers.

[0020] A bottom surface of the upper insulating layer may be formed to be deeper than a bottom surface of the dielectric layer pattern.

[0021] A thickness of the dielectric layer pattern overlapping the upper electrode may be formed to be greater than a thickness of the dielectric layer pattern that does not overlap the upper electrode.

[0022] The dielectric layer pattern may include an upper dielectric layer and a lower dielectric layer, and a thickness of the upper dielectric layer may be greater than a thickness of the lower dielectric layer.

[0023] The dielectric layer pattern may be formed of a dielectric material having a band gap lower than the upper insulating layer. The dielectric material may be used with PECVD silicon rich oxide or PECVD SiON or PECVD SiN.

[0024] In another general aspect, a semiconductor device, includes a lower electrode on a semiconductor substrate, an interlayer insulating layer formed on the lower electrode, a dielectric layer pattern formed on the interlayer insulating layer, an upper insulating layer formed, on the interlayer insulating layer, of a material different from a material of the dielectric layer pattern, and an upper metal wiring and an upper electrode formed on the upper insulating layer and the dielectric layer pattern, respectively.

[0025] The dielectric layer pattern may include a lower dielectric layer and an upper dielectric layer, and a thickness of the lower dielectric layer may be uniform.

[0026] A bottom surface of the upper insulating layer may be formed to be deeper than a bottom surface of the dielectric layer pattern.

[0027] The dielectric layer pattern may include a region overlapping the upper electrode, a region that does not overlap the upper electrode, and a region in which the pattern thickness of the dielectric layer may be changed. A thickness of the region overlapping the upper electrode may be greater than a thickness of the region not overlapping the upper electrode.

[0028] The dielectric layer pattern may include an upper dielectric layer and a lower dielectric layer, and a thickness of the upper dielectric layer may be formed to be greater than a thickness of the lower dielectric layer.

[0029] The dielectric layer pattern may be formed of a dielectric material having a band gap lower than a band gap of the upper insulating layer. The upper insulating layer may include a silicon oxide layer, and the dielectric layer pattern may include any one of silicon rich oxide, SiON, or SiN.

[0030] A thickness of the dielectric layer pattern and a thickness of the upper insulating layer may be different from each other.

[0031] In another general aspect, a semiconductor device includes a substrate. The substrate includes a first region and a second region. The first region includes a lower electrode formed on the substrate, an interlayer insulating layer formed on the lower electrode, a dielectric layer pattern formed on the interlayer insulating layer, and an upper electrode formed on the dielectric layer pattern. The second region includes an upper insulating layer formed on the interlayer insulating layer and having a thickness smaller than a thickness of the interlayer insulating layer, and an upper metal wiring formed on the upper insulating layer, and formed in a same plane with the upper electrode. A lower surface of the upper insulating layer and a lower surface of the dielectric layer pattern are in different planes.

[0032] The second region may further include a first lower metal wiring and the lower electrode formed on a same plane, wherein the interlayer insulating layer is further formed on the lower metal wiring, a second lower metal wiring formed at an intermediate position between the first lower metal wiring and the upper insulating layer, and a first via connecting the first lower metal wiring to the second lower metal wiring and a second via connecting the second lower metal wiring to the upper metal wiring.

[0033] The first region may be a capacitor region and the second region may be a metal wiring region.

[0034] The upper insulating layer and the dielectric layer pattern may be formed of different materials.

[0035] Each of the upper insulating layer and the dielectric layer pattern has a contour that includes an inclined portion.

[0036] Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0037] FIG. 1 is a cross-sectional view of a semiconductor device, including a high breakdown voltage capacitor, according to one or more examples of the present disclosure.

[0038] FIG. 2 illustrates a cross-section and a plan view of a high breakdown voltage capacitor according to one or more examples of the present disclosure.

[0039] FIGS. 3 and 4 are views illustrating a cross-section and a plan view of a high breakdown voltage capacitor according to another example of the present disclosure.

[0040] FIG. 5 illustrates a cross-section and a plan view of a high breakdown voltage capacitor according to another example of the present disclosure.

[0041] FIGS. 6A-6L are process diagrams illustrating a manufacturing process of a semiconductor

device, including a high breakdown voltage capacitor according to one or more examples of the present disclosure.

[0042] Throughout the drawings and the detailed description, the same reference numerals refer to the same elements. The drawings may not be to scale, and the relative size, proportions, and depiction of elements in the drawings may be exaggerated for clarity, illustration, and convenience.

#### DETAILED DESCRIPTION

[0043] The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein. However, various changes, modifications, and equivalents of the methods, apparatuses, and/or systems described herein will be apparent after an understanding of the disclosure of this application. For example, the sequences of operations described herein are merely examples, and are not limited to those set forth herein, but may be changed as will be apparent after an understanding of the disclosure of this application, with the exception of operations necessarily occurring in a certain order. Also, descriptions of features that are known after understanding of the disclosure of this application may be omitted for increased clarity and conciseness.

[0044] The features described herein may be embodied in different forms, and are not to be construed as being limited to the examples described herein. Rather, the examples described herein have been provided merely to illustrate some of the many possible ways of implementing the methods, apparatuses, and/or systems described herein that will be apparent after an understanding of the disclosure of this application.

[0045] Throughout the specification, when an element, such as a layer, region, or substrate, is described as being “on,” “connected to,” or “coupled to” another element, it may be directly “on,” “connected to,” or “coupled to” the other element, or there may be one or more other elements intervening therebetween. In contrast, when an element is described as being “directly on,” “directly connected to,” or “directly coupled to” another element, there can be no other elements intervening therebetween.

[0046] As used herein, the term “and/or” includes any one and any combination of any two or more of the associated listed items.

[0047] Although terms such as “first,” “second,” and “third” may be used herein to describe various members, components, regions, layers, or sections, these members, components, regions, layers, or sections are not to be limited by these terms. Rather, these terms are only used to distinguish one member, component, region, layer, or section from another member, component, region, layer, or section. Thus, a first member, component, region, layer, or section referred to in examples described herein may also be referred to as a second member, component, region, layer, or section without departing from the teachings of the examples.

[0048] Spatially relative terms such as “above,” “upper,” “below,” and “lower” may be used herein for ease of description to describe one element's relationship to another element as shown in the figures. Such spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, an element described as being “above” or “upper” relative to another element will then be “below” or “lower” relative to the other element. Thus, the term “above” encompasses both the above and below orientations depending on the spatial orientation of the device. The device may also be oriented in other ways (for example, rotated 90 degrees or at other orientations), and the spatially relative terms used herein are to be interpreted accordingly.

[0049] The terminology used herein is for describing various examples only, and is not to be used to limit the disclosure. The articles “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “includes,” and “has” specify the presence of stated features, numbers, operations, members, elements, and/or combinations thereof, but do not preclude the presence or addition of one or more other features, numbers, operations, members, elements, and/or combinations thereof.

[0050] Due to manufacturing techniques and/or tolerances, variations of the shapes shown in the drawings may occur. Thus, the examples described herein are not limited to the specific shapes shown in the drawings, but include changes in shape that occur during manufacturing.

[0051] The features of the examples described herein may be combined in various ways as will be apparent after an understanding of the disclosure of this application. Further, although the examples described herein have a variety of configurations, other configurations are possible as will be apparent after an understanding of the disclosure of this application.

[0052] The present disclosure provides a semiconductor device in which a dielectric layer having a low band gap is formed only in a high breakdown voltage capacitor region and a method of manufacturing the same.

[0053] FIG. 1 is a cross-sectional view of a semiconductor device, including a high breakdown voltage capacitor, according to one or more examples of the present disclosure. As illustrated in FIG. 1, the semiconductor device includes an interconnection area or a metal wiring region **10** and a capacitor region **20**.

[0054] The metal wiring region **10** is a region in which metal wirings connected to respective devices are formed for driving devices such as CMOS, LDMOS, EDMOS, and BJT. Therefore, because devices such as CMOS, LDMOS, EDMOS, and BJT operate at a much lower voltage than a high breakdown voltage capacitor, the metal wiring region **10** may be referred to as a low voltage region. Alternatively, the metal wiring region **10** may be viewed as a region in which a pad is formed. Herein, it is noted that use of the term ‘may’ with respect to an example or embodiment, e.g., as to what an example or embodiment may include or implement, means that at least one example or embodiment exists where such a feature is included or implemented while all examples and embodiments are not limited thereto.

[0055] On the other hand, the high breakdown voltage capacitor region **20** is a region where a voltage of hundreds to tens of thousands of volts (V) is applied. Therefore, the high breakdown voltage capacitor region **20** may be referred to as a high breakdown voltage region or a high breakdown voltage capacitor. The voltage of hundreds to tens of thousands of volts (V) across the capacitor region should not reach the metal wiring region. A digital isolator requires such a high breakdown voltage capacitor region **20**. Hereinafter, the high breakdown voltage capacitor region **20** is simply referred to as a capacitor region **20** for convenience of description.

[0056] The metal wiring region **10** and the capacitor region **20** commonly include a substrate **100** underneath. The substrate **100** may be a p-type semiconductor substrate, an n-type semiconductor substrate, a silicon on insulator (SOI) substrate, or the like.

[0057] The metal wiring region **10** may include a lower insulating layer **105** formed on the substrate **100** and a plurality of inter-metal dielectrics (IMDs) **110**, **120**, and **130**. The lower insulating layer **105** formed between the metal wiring and the substrate may be referred to as a pre-metal dielectric (PMD) layer. The lower insulating layer **105** and the interlayer insulating layers **110**, **120**, and **130** may be formed of different materials or the same material. For example, the lower insulating layer **105** may include a SiN/SiO<sub>2</sub> layer deposited by a plasma-enhanced chemical vapor deposition (PECVD) process. And it may further include phosphorus silicate glass (PSG) or boron phosphorus silicate glass (BPSG). And it may further include a cap layer such as a tetraethyl orthosilicate (TEOS) layer deposited by the PECVD method.

[0058] In addition, the interlayer insulating layers **110**, **120**, and **130** may be formed as a layer based on a silicon oxide layer deposited by a PECVD method by using tetraethyl orthosilicate (TEOS). Then, the oxide layer is planarized through an etchback or CMP process. Thus, the interlayer insulating layers **110**, **120**, and **130** are mainly composed of a silicon oxide material. In the present disclosure, three interlayer insulating layers **110**, **120**, and **130** are exemplified, but there may be more interlayer insulating layers if desired. In addition, to distinguish from the upper insulating layer **200**, the three interlayer insulating layers **110**, **120**, and **130** may be referred to as a plurality of lower interlayer insulating layers. Here, to prevent bowing of the wafer, it may be

desirable to form PE-TEOS (Plasma-enhanced tetraethyl-orthosilicate) having low compressive stress on at least one of the interlayer insulating layers **110**, **120**, and **130**.

[0059] In the example, the first to the third interlayer insulating layers are illustrated and referred to as the first interlayer insulating layer **110** and second and third interlayer insulating layers **120** and **130**. The first to third interlayer insulating layers **110**, **120**, and **130** may have different thicknesses, and the thickness of the first interlayer insulating layer **110** may be formed to be thinner than the other second and third interlayer insulating layers **120** and **130**. In a non-limiting example, the first interlayer insulating layer **110** may be formed to have a thickness of 0.4 to 1.5  $\mu\text{m}$ , and the second interlayer insulating layer **120** and the third interlayer insulating layer **130** may each have a thickness of 3 to 8  $\mu\text{m}$ .

[0060] The metal wiring region **10** may include a plurality of lower metal wirings **112**, **122**, and **132** for each of the interlayer insulating layers **110**, **120**, and **130** formed for electrical connection with the MOS transistor. Here, the plurality of lower metal wirings **112**, **122**, and **132** may be formed of an aluminum (Al) or copper (Cu) material. A first metal wiring **112** is formed on the lower insulating layer **105**. In addition, the second metal wiring **122** is formed on the first interlayer insulating layer **110**, and the third metal wiring **132** is formed on the second interlayer insulating layer **120**. In addition, an upper metal wiring **150** is formed on the third interlayer insulating layer **130** and the upper insulating layer **200**. The upper metal wiring **150** may be connected to a bond pad (not illustrated).

[0061] In addition, to connect the metal wirings **112**, **122**, **132** and the upper metal wiring **150** to each other, a plurality of vias **140a**, **140b**, **140c** may be formed in the interlayer insulating layers **110**, **120**, **130**. Each of the vias **140a**, **140b**, and **140c** may be filled with a metallic material. In such a way, in the metal wiring region **10**, each of the metal wirings **112**, **122**, and **132** are electrically connected to each other through the plurality of the first via **140a**, the second via **140b**, and the third via **140c**.

[0062] The upper insulating layer **200** of the metal wiring region may be formed of a material such as a silicon oxide layer ( $\text{SiO}_2$ ), a silicon nitride layer ( $\text{SiN}$ ), or a silicon oxynitride layer ( $\text{SiON}$ ). In an example of the present disclosure, a silicon oxide layer is taken as an example. The upper insulating layer **200** is formed to include at least two regions having different thicknesses. That is, it may be divided into a region A overlapping under the upper metal wiring **150** and regions B and C outside the upper metal wiring **150**. Here, the thickness (A) of the upper insulating layer **200** in the region overlapping the upper metal wiring **150** and the thickness (B) of the upper insulating layer **200** in the region not overlapping the upper metal wiring **150** may be formed differently from each other. For example, the thickness of B is formed to be thinner than that of A. In addition, the region C that does not overlap with the upper metal wiring **150** is an inclined region that changes from A's thickness to B's thickness.

[0063] In FIG. 1, the capacitor region **20** includes a lower insulating layer **105**, a first metal wiring **114**, a first interlayer insulating layer **110**, a first via **140a**, a bottom electrode **124**, a second interlayer insulating layer **120**, a third interlayer insulating layer **130**, a dielectric layer pattern **300**, and a top electrode **160**. The first metal wiring **114** may be formed simultaneously when forming the first metal wiring **112** in the metal wiring region. The lower electrode **124** is formed together when forming the second metal wiring **122** of the metal wiring region **10**, and formed under the capacitor region **20** to which a high breakdown voltage is applied. The lower electrode **124** and the first metal wiring **114** may be electrically connected to each other through the first via **140a**.

Alternatively, the lower electrode **124** may be directly connected to the second metal wiring **122**. In addition, it may be connected in various ways.

[0064] A metal layer corresponding to the third metal wiring **132** of the metal wiring region **10** is not formed in the capacitor region **20**. Instead, very thick interlayer insulating layers **120** and **130** are required to secure super high breakdown voltage characteristics. Therefore, the total thickness of the thick interlayer insulating layers **120** and **130** may have a range of 10-50  $\mu\text{m}$ . The capacitor

region **20** does not require a via structure connecting the upper electrode **160** and the lower electrode **124** to each other.

[0065] In the capacitor region **20**, the dielectric layer pattern **300** is formed of a dielectric material having a low band gap energy characteristic and may be formed of one or more layers. In addition, the dielectric layer pattern **300** is formed before forming the upper metal wiring **150** and the upper electrode **160**. Therefore, it may be formed in a shape having a specific pattern in a desired region only under the upper electrode **160**. In addition, it may be formed in the capacitor region **20** only without being formed in the metal wiring region **10** by the patterning process.

[0066] In the capacitor region **20**, the dielectric layer pattern **300** improves the isolator's characteristics, and it is deposited with a material having band gap energy lower than that of the upper insulating layer **200** or the second interlayer insulating layer **120** or the third interlayer insulating layer **130**. The dielectric material having such a low band gap characteristic may include PECVD silicon rich oxide (PE-SRO) or PECVD SiON (PE-SiON), PECVD SiN (PE-SiN). Here, the dielectric layer pattern **300** may be formed in a shape of a single layer in which only one of PE-SRO, PE-SiON, and PE-SiN is deposited. Alternatively, it may be formed of two bi-layers, PE-SRO/PE-SiN composed of a lower dielectric layer PE-SRO and an upper dielectric layer PE-SiN. Alternatively, it may be formed of two bi-layers, PE-SRO/PE-SiON composed of a lower dielectric layer PE-SRO and an upper dielectric layer PE-SiON. Alternatively, it may be formed of two bi-layers, PE-SiON/PE-SiN composed of a lower dielectric layer PE-SiON and an upper dielectric layer PE-SiN. Here, it is known that a thermally grown amorphous SiO<sub>2</sub> layer has a 9.3 eV (electron volt) band gap. The band gap of PE-SiON is ~7.5 eV which is lower than that of the SiO<sub>2</sub> layer, and the PE-SiN layer also has a value in the range of 4.7-6. PE-SRO is known to have a lower band gap value than SiO<sub>2</sub>. The band gap of the PE-SRO layer is made of a material having a band gap higher than that of PE-SiN (4.7-6).

[0067] Referring to FIG. **1**, the dielectric layer pattern **300** has two regions having different thicknesses. It may be divided into a region D overlapping under the upper electrode **160** and regions E and F that do not overlap with the upper electrode **160**. The E region is formed to be thinner than the D region. The region F, an intermediate region, is a region having an inclination angle and is a region changing from the thickness of D to the thickness of E. As illustrated in the figure, the thickness D of the dielectric layer pattern **300** overlapping the upper electrode **160** is formed to be greater than the thickness E of the dielectric layer pattern **300** in a region outside the upper electrode **160**. Therefore, it is formed to be inclined (region F) so that the thickness decreases from the side to the outside of the top electrode **160**. The dielectric layer pattern **300** formed in such a way provides a function of effectively mitigating an electric field applied to the lower portion of the upper electrode **160**.

[0068] As illustrated in FIG. **1**, the lower surface **130t** of the upper insulating layer **200** is formed to be lower than the lower surface **300i** of the dielectric layer pattern **300**. Therefore, there is a step (G) between the two lower surfaces due to the etching process forming the dielectric layer pattern. The etching process with reference to the manufacturing process is to be described later.

[0069] FIG. **2** illustrates a cross-section and a plan view of a high breakdown voltage capacitor according to one or more examples of the present disclosure. The shape of the dielectric layer pattern proposed by the present disclosure is specifically illustrated.

[0070] In FIG. **2**, the semiconductor device includes a lower dielectric layer **310** and an upper dielectric layer **320** having a lower band gap characteristic than a silicon oxide layer at a lower portion of the upper electrode **160** when viewed together in a-a' cross-section. The lower/upper dielectric layers **310** and **320** are positioned between the third interlayer insulating layer **130** and the upper electrode **160**.

[0071] Compared with FIG. **1**, there is a difference only in that the dielectric layer pattern is composed of a plurality of layers of the lower dielectric layer **310** and the upper dielectric layer **320**, but other configurations are the same. The lower dielectric layer **310** may be formed of



PECVD silicon rich oxide (PE-SRO) or SiON (band gap: ~7.5), and the upper dielectric layer **320** may be formed of PE-SiN (band gap: 4.7-6). Here, a material having a band gap higher than that of PE-SiN (band gap: 4.7-6) is used as the band gap of the PE-SRO layer. Of course, it may be formed with one layer, or with three or more layers. Even in such a case, the thickness of the entire layer is formed to be thinner than that of the upper insulating layer **200** of FIG. **1**.

[0072] The dielectric layer pattern **300** includes a lower dielectric layer **310** and an upper dielectric layer **320**. The thickness of the upper dielectric layer **320** is different from that of the lower dielectric layer **310**. When the dielectric layer pattern is formed of two or more layers, the upper dielectric layer **320** positioned immediately below the upper electrode **160** is formed to include regions having different thicknesses as a whole. The different thicknesses is because the region adjacent to the sidewall of the upper electrode **160** is formed to be inclined according to the etching process. On the other hand, all of the lower dielectric layers **310** have a uniform thickness because it is protected by the upper dielectric layer **320** in the etching process.

[0073] When the semiconductor device of FIG. **2** is viewed from a plan view, the semiconductor device has an upper electrode **160** in the center and an upper dielectric layer **320** completely surrounding the upper electrode **160**. Thus, in a plan view, the region of the dielectric layer pattern **300** is formed to be larger than the region of the upper electrode **160**.

[0074] FIGS. **3** and **4** are views illustrating a cross-section and a plan view of a high breakdown voltage capacitor according to another example of the present disclosure.

[0075] As illustrated in FIG. **3**, the dielectric layer pattern **300** includes a first dielectric layer pattern **300a** and a second dielectric layer pattern **300b** formed apart from each other. A third interlayer insulating layer **130** is formed between the first dielectric layer pattern **300a** and the second dielectric layer pattern **300b**.

[0076] In addition, the first and second dielectric layer patterns **300a** and **300b** include an upper dielectric layer and a lower dielectric layer, respectively. The first dielectric layer pattern **300a** includes a first lower dielectric layer **330** and a first upper dielectric layer **340**. The second dielectric layer pattern **300b** includes a second lower dielectric layer **350** and a second upper dielectric layer **360**. The first and second lower dielectric layers **330** and **350** and the first and second upper dielectric layers **340** and **360** are both formed to overlap the upper electrode **160**.

[0077] Thus, a third interlayer insulating layer **130** is formed between the first lower dielectric layer **330** and the second lower dielectric layer **350**. Likewise, a third interlayer insulating layer **130** is formed between the first upper dielectric layer **340** and the second upper dielectric layer **360**. Therefore, the upper electrode **160** is formed while directly in contact with the first upper dielectric layer **340**, the second upper dielectric layer **360**, and the third interlayer insulating layer **130**.

[0078] From the perspective view of the third interlayer insulating layer **130**, the third interlayer insulating layer **130** is in contact with the side surfaces and bottom surfaces of the lower dielectric layers **330** and **350**. In addition, the side surfaces of the upper dielectric layers **340** and **360** and the bottom surfaces of the upper electrode **160** are in contact with each other.

[0079] In the semiconductor device of FIG. **3** of a plan view, the first dielectric layer pattern **300a** and the second dielectric layer pattern **300b** are connected to each other. In addition, the first dielectric layer pattern **300a** and the second dielectric layer pattern **300b** surround the upper electrode **160**. In a plan view, the area of the dielectric layer pattern **300** is formed to be larger than the area of the upper electrode **160**.

[0080] The cross-section illustrated in FIG. **4** is very similar to the cross-section of FIG. **3**.

[0081] The dielectric layer pattern **300** includes a first dielectric layer pattern **300a** and a second dielectric layer pattern **300b** formed apart from each other. A third interlayer insulating layer **130** is formed between the first dielectric layer pattern **300a** and the second dielectric layer pattern **300b**.

[0082] In addition, the first and second dielectric layer patterns **300a** and **300b** include an upper dielectric layer and a lower dielectric layer, respectively. The first dielectric layer pattern **300a** includes a first lower dielectric layer **330** and a first upper dielectric layer **340**. The second

dielectric layer pattern **300b** includes a second lower dielectric layer **350** and a second upper dielectric layer **360**. The first and second lower dielectric layers **330** and **350** and the first and second upper dielectric layers **340** and **360** are both formed to overlap the upper electrode **160**. [0083] However, there is a difference between FIG. 3 and the plan view of FIG. 4. From a plan view, the first dielectric layer pattern **300a** and the second dielectric layer pattern **300b** are formed physically apart from each other. Therefore, the first dielectric layer pattern **300a** and the second dielectric layer pattern **300b** partially surround the upper electrode **160**.

[0084] The first upper dielectric layer **340** and the second upper dielectric layer **360** are formed to be apart from each other. The first upper dielectric layer **340** and the second upper dielectric layer **360** are formed to be symmetrically spaced apart from each other with respect to the upper electrode **160**. The dielectric layer pattern is removed from the center of the upper electrode **160**. The third interlayer insulating layer **130** is in contact with side surfaces and bottom surfaces of the first and second lower dielectric layers **330** and **350**. Likewise, the third interlayer insulating layer **130** is in contact with the side surfaces of the first and second upper dielectric layers **340** and **360** and the bottom surface of the upper electrode **160**.

[0085] Even if a dielectric layer pattern is formed on the left/right side of the upper electrode **160** as illustrated in FIGS. 3 and 4 described above, an electric field may be effectively removed.

[0086] FIG. 5 illustrates a cross-section and a plan view of a high breakdown voltage capacitor according to another example of the present disclosure.

[0087] As illustrated in FIG. 5, the semiconductor device of the present disclosure may include a dielectric layer pattern **300**, including a lower dielectric layer **370** and an upper dielectric layer **380** formed only in one direction of the upper electrode **160**. Referring to the drawings, the lower/upper dielectric layers **370** and **380** are formed under the upper electrode **160** in a direction adjacent to the metal wiring region **10**. In addition, the lower/upper dielectric layers **370** and **380** are formed to overlap with the part of the left side of the upper electrode **160**, and all of the remaining regions are formed of the interlayer insulating layer **130**. As illustrated in FIG. 5, even if a dielectric layer pattern is formed only in a region adjacent to the metal wiring region **10** among the lower regions of the upper electrode **160**, sufficient breakdown voltage characteristics may be provided. That is, the local electric field concentrated in the corner of the upper electrode **160** may be alleviated.

[0088] As described in the semiconductor device of the present disclosure, a dielectric layer pattern **300** having one or more layers is formed under the upper electrode **160**, and the dielectric layer pattern may be formed while having various patterns in a specific region of the upper electrode **160**.

[0089] FIGS. 6A-6L are process diagrams illustrating a manufacturing process of a semiconductor device, including a high breakdown voltage capacitor, according to one or more examples of the present disclosure. The semiconductor devices described above are manufactured by the following method.

[0090] According to the present disclosure, a device (not illustrated) is formed on the semiconductor substrate **100**. The device may be applied as a passive device or an active device. In addition, an insulating layer may be deposited to insulate the device. According to an example of the present disclosure, a device and an insulating layer on it are deposited on the semiconductor substrate **100** as described above. In addition, the semiconductor device of the present disclosure is divided into a metal wiring region **10** and a capacitor region **20**. Further, in the semiconductor device, the first to third interlayer insulating layers **110**, **120**, and **130** are formed, as an example, but the number of such interlayer insulating layers may vary.

[0091] As illustrated in FIG. 6A, a lower insulating layer **105** is formed on the semiconductor substrate **100**, and a plurality of first metal wirings **112** and **114** are formed together on the lower insulating layer **105**. When the first metal wirings **112** and **114** are formed, a first interlayer insulating layer **110** is deposited to cover the first metal wirings **112** and **114**. The first interlayer insulating layer **110** may include an oxide layer deposited by a PECVD method using a TEOS

material. A layer such as SiN, SiC, SiOCN, or SiCN may be further included below or above the oxide layer. Also, instead of an oxide layer, it may be formed of a low-k SiOC material. In addition, the first interlayer insulating layer **110** is planarized through a chemical mechanical polishing (CMP) process or an etch back process to have a predetermined thickness, for example, a thickness of 0.4 to 1.5  $\mu\text{m}$  (D1). After the first interlayer insulating layer **110** is formed, a plurality of first vias **140a** is formed in the first interlayer insulating layer **110**. The plurality of first vias **140a** may be formed through a series of mask processes and etching processes. The first via **140a** is filled with a metallic material. The plurality of first vias **140a** is formed simultaneously for the metal wiring region **10** and the capacitor region **20**.

[0092] Then, after depositing a metal material as illustrated in FIG. 6A, a second metal wiring **122** is formed in the metal wiring region **10**, and a lower electrode **124** is formed in the capacitor region **20**, respectively, through a metal patterning process. In this drawing, the first metal wiring **112** and the second metal wiring **122** in the metal wiring region **10** are almost aligned in the vertical direction, but they may be formed while not being aligned with each other. In addition, the capacitor region **20** may also be in a form in which the lower electrode **124** is connected to the second metal wiring **122**.

[0093] FIG. 6B illustrates that the second interlayer insulating layer **120** is formed on the first interlayer insulating layer **110** to a predetermined thickness D2. The second interlayer insulating layer **120** is thicker than the first interlayer insulating layer **110**. The thickness is about 3 to 8  $\mu\text{m}$ . The second interlayer insulating layer **120** may also include an oxide layer deposited by a PECVD method using a TEOS material. A layer such as SiN, SiC, SiOCN, or SiCN may be further included below or above the oxide layer. Also, instead of an oxide layer, it may be formed of a low-k SiOC material. A CMP process or an etch back process etc., is performed to planarize so that it may become the said thickness.

[0094] Referring to FIG. 6C, a second via **140b** is formed in the second interlayer insulating layer **120**. As described above, the second via **140b** may be formed through a mask process and an etching process, and a metal wiring is formed in the second via **140b**. At this time, it is not necessary to form the via in the capacitor region **20**. This is because there is no metal wiring in the capacitor region **20** between the upper electrode **160** and the lower electrode **124**.

[0095] As illustrated in FIG. 6D, the third metal wiring **132** is formed in the metal wiring region **10**. Metal wiring is not formed in the capacitor region **20** because an electrical connection with a semiconductor device is not required. In FIG. 6D, the third metal wiring **132** is electrically connected to the lower second metal wiring **122** and the first metal wiring **112** through vias **140b** and **140a**.

[0096] As illustrated in FIG. 6E, a third interlayer insulating layer **130** is formed to cover the third metal wiring **132**. The thickness D3 of the third interlayer insulating layer **130** is formed to be the same as or similar to the thickness (3 to 8  $\mu\text{m}$ ) of the second interlayer insulating layer **120**. The third interlayer insulating layer **130** may include an oxide layer deposited by a PECVD method using a TEOS material. A layer such as SiN, SiC, SiOCN, or SiCN may be further included below or above the oxide layer. In addition, instead of the oxide layer, it may be formed of a SiOC material having a low dielectric constant (low-k). Like the second interlayer insulating layer **120**, a planarization process may be performed.

[0097] With regards to the interlayer insulating layers **110**, **120**, and **130** in the semiconductor device of the present disclosure, the second interlayer insulating layer **120** and the third interlayer insulating layer **130** are thicker than the first interlayer insulating layer **110**. However, the thicknesses of the second interlayer insulating layer **120** and the third interlayer insulating layer **130** are the same or similar.

[0098] FIG. 6F is a diagram illustrating an example of forming a dielectric layer proposed by the present disclosure. As illustrated in FIG. 6F, a dielectric layer **300'** is deposited to a thickness of 0.10 to 2.5  $\mu\text{m}$  with respect to the entire region of the third interlayer insulating layer **130**. The

dielectric layer **300'** later becomes a dielectric layer pattern **300** formed only in a specific lower region of the upper electrode. The dielectric layer **300'** improves the isolator characteristics of the capacitor region **20**, and a dielectric material having a band gap lower than the oxide layer (SiO.sub.2) constituting the interlayer insulating layers **110**, **120**, and **130** is used. The dielectric material may be PECVD SRO, PECVD SiON, PECVD SiN, or the like, and may be deposited in a form of single layer or bi-layer.

[0099] As described above, in the present example, the dielectric layer **300'** having a low band gap is formed before the upper electrode **160** is formed. Although described below, the dielectric layer **300'** may be formed only in a portion necessary for the capacitor region **20** while not being formed in the metal wiring region **10** through a patterning process later.

[0100] FIG. **6G** is a diagram illustrating an example in which a dielectric layer pattern is formed by performing a patterning process on a capacitor region. After depositing the entire dielectric layer **300'** having a predetermined thickness of FIG. **6F**, the dielectric layer pattern **300** is formed only in a desired region, including the capacitor region **20** with high breakdown voltage, by using a patterning mask (not illustrated). In FIG. **6G**, '**300**' denotes a dielectric layer pattern formed by the patterning process. The length and shape of the dielectric layer pattern **300** are determined according to the patterning mask. That is, if the shape of the patterning mask is different in FIG. **6G**, the shape of the dielectric layer pattern **300** may be different as in FIGS. **3** to **5** described above. Therefore, according to the examples of the present disclosure, the semiconductor device may provide a dielectric layer pattern having various shapes. In addition, there are only some differences in the patterning process performed in FIG. **6G** in the entire process of the semiconductor device, and all processes before and after are the same. That is, if only the patterning mask is applied differently during the process, it is possible to simply form a dielectric layer pattern suitable for the characteristics of the semiconductor device.

[0101] FIG. **6G** illustrates that the top surface **130t** of the third interlayer insulating layer **130** of the metal wiring region **10** is etched to be deeper than the bottom surface **300i** of the dielectric layer pattern **300**. A pattern mask is provided in the capacitor region **20**, and it is etched to be deeper because the dielectric layer pattern in the metal wiring region **10** is to be completely removed. Therefore, when the patterning process is completed, a predetermined gap occurs between the metal wiring region **10** and the capacitor region **20**, as illustrated in FIG. **1** 'G'.

[0102] FIG. **6H** illustrates that a thick insulating layer **200'** is deposited over the entire region of the metal wiring region **10** and the capacitor region **20**, in a state that the dielectric layer pattern **300** is formed in the capacitor region **20**. Because the dielectric layer pattern **300** is already formed in the capacitor region **20**, the thick insulating layer **200'** is formed to be convex upward in the capacitor region **20**. The thick insulating layer **200'** is deposited to have a thickness of 0.5 to 3.0  $\mu\text{m}$ . The thick insulating layer **200'** may be formed of a silicon oxide layer material. The thick insulating layer **200'** may be formed of a material different from the dielectric layer pattern **300**. While the thick insulating layer **200'** is formed of a silicon oxide layer material, the dielectric layer pattern **300** is formed of a material such as SRO, SiON, or SiN having a band gap smaller than the silicon oxide layer. The thick insulating layer **200'** may be formed of an oxide layer-based material such as the interlayer insulating layer **130** to simplify the process. Therefore, the boundary of the finally formed upper insulating layer **200** and the interlayer insulating layer **130** may not be visible.

[0103] FIG. **6I** illustrates that an etch-back or chemical mechanical polishing (CMP) process is performed to remove the thick insulating layer **200'** on the capacitor region **20**. During the etch back process or the chemical mechanical polishing process, the dielectric layer pattern **300** of the capacitor region **20** functions as an etch stop layer. Because the dielectric layer pattern **300** is formed of a material different from the thick insulating layer **200'**, it may be used as an etch stop layer. Thus, an upper insulating layer **200** having a thin thickness is formed on the interlayer insulating layer **130**. The upper surface of the thin upper insulating layer **200** formed by the chemical mechanical polishing process and the upper surface of the dielectric layer pattern **300** are

planar to each other. When the chemical mechanical polishing process is completed, the thin upper insulating layer **200** remains in the metal wiring region **10**, as illustrated in FIG. **6I**, and the dielectric layer pattern **300** remains in the capacitor region **20**.

[0104] FIG. **6J** is a process of forming a third via **140c** in the third interlayer insulating layer **130** and the upper insulating layer **200**. It may be formed through a mask process and an etching process. Since forming of the third via **140c** of FIG. **6J** only corresponds to the metal wiring region **10**, and there is no dielectric layer pattern **300**; therefore, an additional process for removing the dielectric layer pattern **300** is not required. The third via **140c** is formed by etching the upper insulating layer **200** and the third interlayer insulating layer **130** to form a hole, filling a metal material, and performing an etch back or CMP process.

[0105] Referring to FIG. **6K**, a metal layer **500** is deposited on the upper insulating layer **200** and the dielectric layer pattern **300** to have a predetermined thickness. The metal layer **500** later becomes a pattern for forming the upper metal wiring **150** of the metal wiring region **10** and the upper electrode **160** of the capacitor region **20**.

[0106] Next, it is a process of etching the metal layer **500**. This process may be referred to as a process for forming the upper metal wiring **150** in the metal wiring region **10** and forming the upper electrode **160** in the capacitor region **20**. The etching process of the metal layer **500** is performed after forming a patterning mask for forming the upper metal wiring **150** and the upper electrode **160**. FIG. **6L** illustrates a state in which the etching process of the metal layer **500** is completed.

[0107] Referring to FIG. **6L**, an upper insulating layer **200** and a dielectric layer pattern **300** having different thicknesses are formed. As described above, the upper insulating layer **200** may be divided into regions A, B, and C. Also, the dielectric layer pattern **300** may be divided into regions D, E, and F. The regions B, C, E, and F are formed because the upper insulating layer **200** and the dielectric layer **200'** are partially etched by a dry etching process for forming the upper metal wiring **150** and the upper electrode **160**. Therefore, the upper insulating layer **200** of the region A and the dielectric layer pattern **300** of the region D under the upper metal wiring **150** and the upper electrode **160** are protected from the dry etching process to maintain their thickness. However, the thickness of the upper insulating layer and the dielectric layer in the remaining regions (B, C, E, F) are reduced.

[0108] According to this process, the present disclosure may form the dielectric layer pattern **300** having a low band gap energy only in the high breakdown voltage capacitor region **20**. In addition, the dielectric layer pattern **300** may be formed of one or more layers, and the length and shape of the dielectric layer pattern may be variously designed according to the etching process. In such a way, because the dielectric layer pattern **300** having a band gap characteristic lower than the silicon oxide layer may be formed only in a specific region under the upper electrode **160**, it is possible to freely make layout of the semiconductor device and minimize unnecessary processes.

[0109] According to the present disclosure as described above, the manufacturing process of the peripheral device is facilitated because the dielectric layer pattern for high breakdown voltage characteristics is formed only in the high breakdown voltage capacitor region and is removed from the peripheral device.

[0110] While this disclosure includes specific examples, it will be apparent after an understanding of the disclosure of this application that various changes in form and details may be made in these examples without departing from the spirit and scope of the claims and their equivalents. The examples described herein are to be considered in a descriptive sense only, and not for purposes of limitation. Descriptions of features or aspects in each example are to be considered as being applicable to similar features or aspects in other examples. Suitable results may be achieved if the described techniques are performed in a different order, and/or if components in a described system, architecture, device, or circuit are combined in a different manner, and/or replaced or supplemented by other components or their equivalents. Therefore, the scope of the disclosure is

defined not by the detailed description, but by the claims and their equivalents, and all variations within the scope of the claims and their equivalents are to be construed as being included in the disclosure.

## Claims

1. A method for manufacturing a semiconductor device, the method comprising: forming a first lower metal wiring and a lower electrode on a same plane of a substrate; forming a first inter-metal insulating layer over the first lower metal wiring and the lower electrode; forming a first via in the first inter-metal insulating layer to electrically connect to the first lower metal wiring; forming a second lower metal wiring on the first inter-metal insulating layer; forming a second inter-metal insulating layer over the second lower metal wiring; depositing a first dielectric layer over the second inter-metal insulating layer; patterning the first dielectric layer to remove a portion overlapping the second lower metal wiring, thereby forming a first dielectric layer pattern on the second inter-metal insulating layer; depositing a second dielectric layer over the second inter-metal insulating layer; patterning the second dielectric layer to remove a portion overlapping the first dielectric layer pattern, thereby forming a second dielectric layer pattern on the second inter-metal insulating layer; forming a second via in the second inter-metal insulating layer to electrically connect the second lower metal wiring to an upper metal wiring; and forming the upper metal wiring on the second dielectric layer pattern and forming an upper electrode on the first dielectric layer pattern, wherein the upper electrode overlaps the lower electrode, and wherein the first dielectric layer pattern includes an inclined portion along a contour thereof.
2. The method of claim 1, wherein patterning the first dielectric layer to remove the portion overlapping the second lower metal wiring comprises performing a patterning process.
3. The method of claim 1, wherein removing the portion of the second dielectric layer overlapping the first dielectric layer pattern comprises performing a chemical mechanical polishing (CMP) process.
4. The method of claim 1, wherein the first dielectric layer pattern has a first band gap energy that is less than a band gap energy of the second inter-metal insulating layer.
5. The method of claim 4, wherein the second dielectric layer pattern has a second band gap energy that is greater than the first band gap energy of the first dielectric layer pattern.
6. The method of claim 1, wherein the first dielectric layer pattern comprises: an upper dielectric layer formed of silicon nitride (SiN); and a lower dielectric layer formed of silicon-rich oxide (SRO) or silicon oxynitride (SiON), wherein the lower dielectric layer has a uniform thickness across the substrate.
7. The method of claim 1, wherein a bottom surface of the first dielectric layer pattern is disposed at a higher level than a bottom surface of the second dielectric layer pattern.
8. A method for manufacturing a semiconductor device, the method comprising: forming a first lower metal wiring and a lower electrode on a semiconductor substrate; forming a first inter-metal insulating layer over the first lower metal wiring and the lower electrode; forming a second inter-metal insulating layer over the first inter-metal insulating layer; forming a first dielectric layer pattern on the second inter-metal insulating layer, wherein first dielectric layer pattern has a first band gap energy that is less than a band gap energy of the second inter-metal insulating layer; forming a second dielectric layer pattern adjacent to the first dielectric layer pattern on the second inter-metal insulating layer, wherein the second dielectric layer pattern has a second band gap energy that is greater than the first band gap energy of the first dielectric layer pattern; and forming an upper metal wiring over the second dielectric layer pattern and forming an upper electrode over the first dielectric layer pattern, wherein the first dielectric layer pattern includes a contour having an inclined portion.
9. The method of claim 8, wherein forming the first dielectric layer pattern on the second inter-

metal insulating layer comprises: depositing a first dielectric layer on the second inter-metal insulating layer; and removing a portion of the first dielectric layer overlapping the first lower metal wiring, such that the first dielectric layer pattern remains on the second inter-metal insulating layer.

**10.** The method of claim 8, wherein forming the second dielectric layer pattern on the second inter-metal insulating layer comprises: depositing a second dielectric layer on the first dielectric layer pattern and the second inter-metal insulating layer; and removing a portion of the second dielectric layer overlapping the first dielectric layer pattern, such that the second dielectric layer pattern remains on the second inter-metal insulating layer.

**11.** The method of claim 8, wherein the first dielectric layer pattern comprises: an upper dielectric layer comprising silicon nitride (SiN); and a lower dielectric layer comprising silicon-rich oxide (SRO) or silicon oxynitride (SiON), wherein the lower dielectric layer has a uniform thickness across the substrate.

**12.** The method of claim 8, wherein a bottom surface of the first dielectric layer pattern is positioned higher than a bottom surface of the second dielectric layer pattern.

**13.** The method of claim 8, further comprising: forming a first via connected to the first lower metal wiring; forming a second lower metal wiring connected to the first via; and forming a second via penetrating the second dielectric layer pattern and the second inter-metal insulating layer and connected to the second lower metal wiring, and wherein the upper metal wiring is connected to the second via.

**14.** The method of claim 8, wherein the upper electrode overlaps the lower electrode and the first dielectric layer pattern.

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