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### SEMICONDUCTOR DEVICE HAVING FUNCTIONAL PATTERNS IN REDUNDANT REGIONS OF DOUBLE SEAL RING

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#### Abstract

A semiconductor structure includes a first circuit region; a first inner seal ring at least partially surrounding the first circuit region; and an outer seal ring at least partially surrounding the first inner seal ring. The outer seal ring includes a first corner and a substantially triangular corner seal ring (CSR) structure at the first corner. The first inner seal ring includes a second corner adjacent to and spaced away from the CSR structure. The semiconductor structure further includes a first region between a first side of the first corner and a first side of the second corner that is parallel to the first side of the first corner, and multiple functional patterns in the first region.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This is a continuation application of U.S. application Ser. No. 17/711,847, filed Apr. 1, 2022, which is herein incorporated by reference in its entirety.

### BACKGROUND

[0002] In semiconductor technologies, a semiconductor wafer is processed through various fabrication steps to form integrated circuits (IC). Typically, several circuits or IC dies are formed onto the same semiconductor wafer. The wafer is then diced to cut out the circuits formed thereon. To protect the circuits from moisture degradation, ionic contamination, and dicing processes, a seal ring is formed around each IC die. This seal ring is formed during fabrication of the many layers that comprise the circuits, including both the front-end-of-line (FEOL) processing and back-end-of-line processing (BEOL). The FEOL includes forming transistors, capacitors, diodes, and/or resistors onto the semiconductor substrate. The BEOL includes forming metal layer interconnects and vias that provide routing to the components of the FEOL.

[0003] Although existing seal ring structures and fabrication methods have been generally adequate for their intended purposes, improvements are desired. For example, it is desirable to form certain seal rings to be fully closed or partially closed depending on chip architecture by utilizing a double seal ring with an outer seal ring and multiple inner seal rings. It is also desirable to fully utilize the space between the outer seal ring and the inner seal rings.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale and are used for illustration purposes only. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0005] FIG. 1 is a top plan view of a semiconductor structure with multiple circuit regions and multiple seal rings and with functional patterns in redundant regions according to aspects of the present disclosure.

[0006] FIG. 2 is a top plan view of a semiconductor structure where inner seal rings are selectively opened, and interconnects are selectively formed between circuit regions according to aspects of the present disclosure.

[0007] FIGS. 3, 4, 5, and 6 are closeup top plan views of the semiconductor structure shown in the area C in FIG. 1 according to embodiments of the present disclosure.

[0008] FIG. 7 is a cross-sectional view of a portion of the semiconductor structure shown in FIG. 1 along the “Cut-A” line of FIG. 1, according to various aspects of the present disclosure.

[0009] FIG. 8 is a cross-sectional view of a portion of the semiconductor structure shown in FIG. 1 along the “Cut-B” line of FIG. 1, according to various aspects of the present disclosure.

[0010] FIG. 9 shows a cross-sectional view of various layers of the semiconductor structure shown in FIG. 1, according to an embodiment of the present disclosure.

### DETAILED DESCRIPTION

[0011] The following disclosure provides many different embodiments, or examples, for

implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0012] Further, spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The 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. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly. Still further, when a number or a range of numbers is described with “about,” “approximate,” and the like, the term encompasses numbers that are within certain variations (such as  $\pm 10\%$  or other variations) of the number described, in accordance with the knowledge of the skilled in the art in view of the specific technology disclosed herein, unless otherwise specified. For example, the term “about 5 nm” may encompass the dimension range from 4.5 nm to 5.5 nm, 4.0 nm to 5.0 nm, etc.

[0013] This application generally relates to semiconductor structures and fabrication processes, and more particularly to providing a seal ring structure that includes dual seal rings or double seal rings. The dual seal rings include an outer seal ring enclosing or surrounding two or more inner seal rings. Each inner seal ring surrounds a circuit region (or an IC area, a chip area, or an IC die). Certain regions of the inner seal rings can be selectively formed to be open or closed depending on chip architecture. For example, two circuit regions may be formed to have interconnects (wafer-level interconnects) between them, thereby resulting in connected dies, or they may be formed as separate, individual dies. In the former situation, the inner seal rings surrounding each circuit region are partially open to allow interconnects to go through. In the latter situation, the inner seal rings surrounding each circuit region are fully closed. In either case, the outer seal ring is fully closed. In the former situation, the wafer is diced (or cut) outside of the outer seal ring, and the outer seal ring provides fully enclosed protection to the connected dies. In the latter situation, the wafer is diced between the inner seal rings, the outer seal ring is also cut, and the inner seal rings provide fully enclosed protection to individual dies.

[0014] In an embodiment of the present disclosure, the outer and the inner seal rings have the same shape and the same structure other than that the inner seal rings can be selectively open or closed. Further, each of the inner and the outer seal rings has a rectangular periphery (i.e., their exterior outline is rectangular or substantially rectangular) and four corner seal ring (CSR) structures at the four interior corners of the rectangular periphery. The CSR structures are triangular shaped for various mechanical concerns. The regions between the inner seal rings and the outer seal ring are referred to as redundant regions. Similarly, a redundant region also exists between the inner seal rings.

[0015] In some approaches, the outer seal ring is placed next to and abutting the inner seal rings to save chip area. In such approaches, the redundant regions may have a width about 30  $\mu\text{m}$  to 40  $\mu\text{m}$ . Further, in such approaches, no patterns or only dummy patterns are placed in the redundant regions. Dummy patterns do not perform any circuit functions but may be used for improving pattern density uniformity across a wafer.

[0016] In an embodiment of the present disclosure, the redundant regions are intentionally made

larger by placing the outer seal ring further away from and not abutting the inner seal rings. For example, the width of one or more of the redundant regions may be in a range from smaller than 40  $\mu\text{m}$  to greater than 200  $\mu\text{m}$ , for example, in a range from about 30  $\mu\text{m}$  to about 220  $\mu\text{m}$  such as from about 40  $\mu\text{m}$  to about 200  $\mu\text{m}$  or from about 70  $\mu\text{m}$  to about 200  $\mu\text{m}$ . In some embodiment, the width of one or more of the redundant regions is equal to or greater than the width of a scribe line, which may be in a range from about 60  $\mu\text{m}$  to about 180  $\mu\text{m}$ . Further, functional patterns (for example, test lines and/or other monitoring circuits) are placed in the redundant regions of the present disclosure. The functional patterns are opposite to the dummy patterns as they perform certain functions for manufacturers and/or designers. For example, the functional patterns may be used to monitor passivation cracks, reduce noise for high frequency circuits, extract inductance or capacitance, monitor critical dimensions, monitor overlay margin, measure film thickness, and so on.

[0017] The present disclosure may seem counter-intuitive because it seems to take a larger chip area than needed. However, when considered for the overall utilization of the wafer, the present disclosure provides benefits over other approaches. For example, when the redundant region is relatively narrow, such as less than 40  $\mu\text{m}$ , it is limited as to what type pattern(s) can be placed in the redundant region. For example, to accommodate a test line or other testing and/or monitoring circuit, an area of at least about 60  $\mu\text{m}$  to 70  $\mu\text{m}$  wide is needed. Thus, when the redundant region is relatively narrow, it cannot accommodate a test line or other testing and/or monitoring circuit and these type of circuit patterns (or functional patterns) have to be placed in the scribe line regions or inside the inner seal rings. Essentially, certain wafer areas are still used for these patterns in addition to having the redundant regions being empty or having only dummy patterns.

Comparatively speaking, embodiments of the present disclosure increase the wafer utilization. Further, depending on how individual dies are exposed on a wafer (for example, using a photolithography stepper), certain scribe line regions may not be available for accommodating any patterns. By using the present disclosure where functional patterns are placed in the redundant regions, the individual dies can be more flexibly exposed, such as a single die per exposure or multiple dies per exposure, without concerns about how to place the functional patterns in the scribe line regions. Those of ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein.

[0018] FIG. 1 is a top plan view of a semiconductor structure (or semiconductor device) **100**, such as a manufactured wafer or a part thereof, constructed according to an embodiment of the present disclosure. The semiconductor structure **100** includes an outer seal ring **350** that encloses (or surrounds) multiple inner seal rings **300**. Each inner seal ring **300** encloses a circuit region (or IC die) **150**. The embodiment depicted in FIG. 1 shows two inner seal rings **300** enclosing two circuit regions **150**. In other embodiments (not shown), the outer seal ring **350** may enclose more than two inner seal rings **300** and more than two circuit regions **150**. In some embodiments, each circuit region **150** may perform the same function. For example, each circuit region **150** may be a memory chip or a processor chip. In some embodiments, the circuit regions **150** may perform different functions. For example, one circuit region **150** may be a transmitter chip (such as a wireless transmitter) and another circuit region **150** may be a receiver chip (such as a wireless receiver). In the embodiment depicted in FIG. 1, each circuit region **150** is produced as an individual die or chip. For example, the semiconductor structure **100** is diced (or cut) along scribe lines **180** as illustrated in FIG. 1. As a result, the outer seal ring **350** is also cut. The inner seal rings **300** stay intact during the dicing process and provide sealing and protective functions to each individual circuit region **150** (also referred to as individual dies **150** for this embodiment).

[0019] The outer seal ring **350** has a rectangular or substantially rectangular periphery. In other words, the exterior outline (or exterior periphery) **350'** of the outer seal ring **350** is rectangular or

substantially rectangular. The outer seal ring **350** further includes four corner seal ring (CSR) structures **360** at the four interior corners of the rectangular or substantially rectangular periphery. In an embodiment, the CSR structure **360** is triangular or substantially triangular. For example, the periphery of each CSR structure **360** is a right triangle or a right isosceles triangle. The legs of the triangle run parallel to the edges of the periphery of the outer seal ring **350**, and the hypotenuse of the triangle is adjacent to but not abutting the inner seal rings **300**. The CSR structures **360** provide various mechanical benefits to the outer seal ring **350**, such as preventing layer peeling at the corner of the chips during dicing processes. With the CSR structures **360**, the interior outline (or interior boundary) of the outer seal ring **350** is octagonal or substantially octagonal.

[0020] Still referring to FIG. **1**, each inner seal ring **300** has the same structure as the outer seal ring **350** in this embodiment. In other words, each inner seal ring **300** has a rectangular or substantially rectangular periphery and has four CSR structures **310** at the four interior corners of the rectangular or substantially rectangular periphery. The interior outline (or interior boundary) of each inner seal ring **300** is octagonal or substantially octagonal. Using the same structure in both the inner seal rings **300** and the outer seal ring **350** advantageously reduces the manufacturer's time spent on qualifying different seal ring structures. In the present embodiment, the inner seal rings **300** are spaced away from the outer seal ring **350** (see also FIGS. **3-6**) so that the exterior corners of the inner seal rings **300** are spaced away from the hypotenuse of the CSR structures **360**. In some embodiments, the outer seal ring **350** has a horizontal dimension (along the “X” direction) about 26 mm and a vertical dimension (along the “Y” direction) about 33 mm. In an embodiment such as shown in FIG. **1** where two circuit regions **150** are enclosed by the outer seal ring **350**, the horizontal dimension X1 of the inner seal ring **300** is in a range of about 10 mm to 26 mm and the vertical dimension Y1 of the inner seal ring **300** is in a range of about 10 mm to about 16 mm. In an alternative embodiment (for example, where more than two circuit regions **150** are enclosed in the outer seal ring **350**), the dimensions X1 and Y1 may be different from the above ranges.

[0021] The semiconductor structure **100** further includes redundant regions **400s** between the outer seal ring **350** and the inner seal rings **300**. In embodiments, the width (d2x and d2y as shown in FIGS. **3-6**) of the redundant regions **400s** are in a range of about 30  $\mu\text{m}$  to about 200  $\mu\text{m}$  and at least one of the redundant regions **400s** has a width in a range of about 60  $\mu\text{m}$  to about 200  $\mu\text{m}$ , such as from about 80  $\mu\text{m}$  to about 200  $\mu\text{m}$ , for example, to accommodate multiple functional patterns **410** therein.

[0022] The semiconductor structure **100** further includes functional patterns **410** in redundant regions **400s**. For purposes of simplicity, only some functional patterns **410** are shown in the top left area of the semiconductor structure **100**. In various embodiments, the functional patterns **410** may be placed in any one of or all of the redundant regions **400s**. In some embodiments, at least one of the redundant regions **400s** includes multiple (such as three or more) functional patterns **410** arranged across the width of the respective redundant regions **400s**.

[0023] Furthermore, the region between the inner seal rings **300** is a redundant region **400m** in some embodiments (such as the embodiment of FIG. **1**), while part of it becomes a circuit region in an alternative embodiment (such as the embodiment of FIG. **2**). The redundant region **400m** is rectangular or substantially rectangular in an embodiment. In an embodiment, the redundant region **400m** has a width (along “Y” direction) of about 60  $\mu\text{m}$  to about 200  $\mu\text{m}$  (such as about 65  $\mu\text{m}$  to about 180  $\mu\text{m}$ ) and a length (along “X” direction) of about 1 mm to about 26 mm. In the following discussion, both the redundant regions **400s** and the redundant region **400m** are referred to as redundant regions **400**. In some embodiments, functional patterns **410** are placed in both redundant regions **400s** and redundant region **400m**. In some embodiments, functional patterns **410** are placed in the redundant regions **400s** only and not in the redundant region **400m**.

[0024] In an embodiment, the functional patterns **410** include patterns that perform certain monitoring, testing, and/or circuit functions such as a test line, a passivation crack monitor circuit, a low noise seal ring pattern, an inductance monitor, a capacitance monitor, a resistance monitor, an

inline critical dimension (CD) monitor, an overlay monitor, a film thickness monitor, multiple instances of the above, or a combination of the above. These types of functional patterns are at least 40  $\mu\text{m}$  wide in some embodiments of the present disclosure.

[0025] Test lines (also referred to as testlines or test keys) are often included in scribe line regions. In the present embodiment, test lines are included in the redundant regions **400** as functional patterns **410** in addition to or alternative to test lines included in the scribe line regions. Each test line may include a plurality of testing devices that are formed in the same way as how the circuit regions **150** are formed. By studying parametric test results in the testing devices, it is possible to detect IC manufacturing errors and monitor the performance of various stages of the IC manufacturing process. For example, a testing device may include one or more circuit elements, either passive or active, or a combination thereof, such as a transistor (e.g., field-effect transistor FET or bipolar junction transistor BJT), a resistor, a capacitor, an inductor, a contact, a via, an electrical fuse (e-fuse), a memory cell, etc. The test line may further include testing pads and other circuitry for conducting the tests through the testing devices.

[0026] A passivation crack monitor circuit is a very thin pattern that is used to monitor whether the dicing process (or die sawing process) causes cracks in the inner seal ring **300** and the circuit region **150**. For example, when dicing along the scribe lines **180**, the passivation layer (a layer above the upper metal layer) may crack due to mechanical stress. The passivation crack monitor circuit can be used to monitor such crack(s). Based on the monitored results, manufacturer may decide whether the circuit region is good for next fabrication stage such as further testing and/or packaging. In some approaches, a passivation crack monitor circuit is placed in the scribe line regions. However, placing it in the redundant region **400s** makes it closer to the circuit region **150**, thereby making the monitored results more accurate.

[0027] A low noise seal ring pattern can be used to channel noise out of the circuit regions **150**. For example, in some designs, the circuit region **150** may include high frequency or ultra-high frequency circuits. This type of circuits may produce noise that affects the operation of other circuits. For another example, the circuit region **150** may include both digital circuits and analog circuits and it is desirable to shield the analog circuits from the switching noise of the digital circuits. In these examples, a low noise seal ring pattern (or simply, a low noise pattern) may be placed in the redundant regions **400s** as a functional pattern **410** and is connected to the inner seal ring **300**, the circuit region **150**, or both. For example, as shown in FIG. 6, a functional pattern **410** is connected to the inner seal ring **300** by a connection **412**, and another functional pattern **410** is connected to the circuit region **150** by a connection **414**. Either or both functional patterns **410** may be a low noise pattern. The low noise pattern may be further connected to a ground plane to channel high frequency noise from the circuit region **150** to the ground plane, thereby improving the performance of the circuit region **150**.

[0028] An inductance monitor may be used to monitor the inductance of the circuit region **150**. For example, the circuit region **150** may be designed to have inductors. Similar inductors or a portion thereof are also formed in the redundant regions **400** as one or more functional patterns **410**. By monitoring the inductance of these functional patterns **410**, manufacturer may decide whether the inductor(s) in the circuit region **150** meet the design target.

[0029] A capacitance monitor may be used to monitor the capacitance of the circuit region **150**. For example, the circuit region **150** may be designed to have capacitors. Similar capacitors or a portion thereof are also formed in the redundant regions **400** as one or more functional patterns **410**. By monitoring the capacitance of these functional patterns **410**, manufacturer may decide whether the capacitors in the circuit region **150** meet the design target.

[0030] A resistance monitor may be used to monitor the resistance of the circuit region **150**. For example, the circuit region **150** may be designed to have resistors. Similar resistors or a portion thereof are also formed in the redundant regions **400** as one or more functional patterns **410**. By monitoring the resistance of these functional patterns **410**, manufacturer may decide whether the

resistors in the circuit region **150** meet the design target.

[0031] An inline critical dimension (CD) monitor may be used to monitor the CD of circuit patterns in the circuit region **150**. For example, a CD monitor may be formed as a functional pattern **410**, at least one dimension of which is designed to match a critical dimension of the circuit patterns in the circuit region **150**. By measuring the dimension of the CD monitor during manufacturing processes (an inline measurement), manufacturer may learn whether the circuit patterns in the circuit region **150** have been fabricated within specification.

[0032] An overlay monitor may be used to monitor the overlay errors or overlay margin between two vertically stacked layers in the circuit region **150**. For example, an overlay monitor may be formed as multiple functional patterns **410** vertically stacked (along the Z direction, see FIG. 7) in the redundant regions **400**. By measuring the amount of overlay between these functional patterns **410**, manufacturer may learn whether the overlay between vertically stacked layers in the circuit region **150** have been fabricated within specification.

[0033] A film thickness monitor may be used to monitor the thickness of certain layer(s) (such as a metal layer, an etch stop layer, etc.) in the circuit region **150**. For example, a film thickness monitor may be formed as one or more functional patterns **410** in the redundant regions **400**. By measuring the thickness of the functional pattern **410** (either inline or offline), manufacturer may learn whether the circuit patterns in the circuit region **150** have been fabricated with satisfactory thickness.

[0034] The functional patterns **410** may be of rectangular shapes (including long and/or short rectangles), square shapes, or other shapes and may be formed in any one or more layers that make up the redundant region **400** and the circuit regions **150**. For example, the functional patterns **410** may be formed in semiconductor layer(s), diffusion layer(s), fin layer(s), gate layer(s), contact layer(s), insulating layer(s), via layer(s), and metal layer(s). As discussed earlier, by having the functional patterns **410** in the redundant regions **400**, the wafer is more fully utilized. Furthermore, having the functional patterns **410** in the redundant regions **400** also increases the pattern density uniformity for the benefits of various processes such as photolithography and chemical mechanical planarization (CMP).

[0035] FIG. 2 is a variant of the embodiment shown in FIG. 1 where inner seal rings **300** are formed with openings **500** at selective locations and interconnects **510** (which are conductors) are formed to connect multiple circuit regions **150** through the openings **500**. The interconnects **510** are wafer-level (or die-level) interconnects, which advantageously reduce resistance and improve noise immunity over some off-chip interconnects. The interconnected circuit regions **150** (also referred to as connected dies **150** for this embodiment) form a larger system (or a system-on-wafer). In such embodiments, the semiconductor structure **100** is diced (or cut) along scribe lines **180** that are outside of the outer seal ring **350** as shown in FIG. 2. Thus, the outer seal ring **350** provides sealing and protective functions to the connected dies **150**. In the embodiment depicted in FIG. 2, functional patterns **410** may be formed in the redundant regions **400s** and/or **400m**, similar to the embodiment in FIG. 1. For simplicity, only one functional pattern **410** is shown in FIG. 2.

[0036] In an embodiment, the set of masks (referred to as mask set A) that are used to form the semiconductor structure **100** shown in FIG. 1 and the set of masks (referred to as mask set B) that are used to form the semiconductor structure **100** shown in FIG. 2 share some common masks. A mask is also referred to as a photo mask or photomask and is used to perform photolithography on semiconductor wafers to form features of the semiconductor structure **100**. For example, mask set A and mask set B may share common masks for some of the diffusion layer, fin layer (for FinFETs or gate-all-around transistors), gate layer, contact layer, via layers, and metal layers. The fin layer refers to a semiconductor layer where semiconductor fins for FinFETs or gate-all-around transistors are formed protruding over a semiconductor substrate (such as a silicon substrate). The mask set A and the mask set B differ in those layers where the interconnects **510** are formed, such as some metal layers, particularly high-level metal layers, such as the fifth metal (M5) layer, the sixth metal

(M6) layer, and/or other metal layers. By sharing masks between the mask set A and the mask set B, a manufacturer can selectively produce individual dies **150**, connected dies **150**, or both, with reduced total costs. For example, if each of the mask set A and the mask set B has N masks, the manufacturer may just need to produce M common masks, N.sub.1 masks specifically for the mask set A, and N.sub.2 masks specifically for the mask set B, where  $M+N_{\text{sub.1}}+N_{\text{sub.2}}$  is less than  $2N$ . The less number of masks produced, the less costs to the manufacturer. The individual dies **150** and the connected dies **150** may satisfy different market demands.

[0037] FIG. **3** is a closeup top plan view of the semiconductor structure **100** shown in the area C in FIG. **1** according to an embodiment of the present disclosure. In FIG. **3**, the line A-A' denotes the bisector of an interior angle  $\alpha$  of a corner of the outer seal ring **350**, and the line B-B' denotes the bisector of an interior angle  $\beta$  of a corner of the inner seal ring **300**. The two corners are adjacent to each other, thus are referred to as adjacent corners. Since both the outer seal ring **350** and the inner seal rings **300** are substantially rectangular in this embodiment, there are four sets of such adjacent corners and each of the angles  $\alpha$  and  $\beta$  is  $90^\circ$  or substantially  $90^\circ$ . In this embodiment, the line A-A' is the same as the line B-B'. In other words, a common line bisects the interior angle  $\alpha$  and the interior angle  $\beta$ . The inner seal ring **300** is spaced away from the outer seal ring **350**. Particularly, the exterior corner of the inner seal ring **300** is spaced away from the hypotenuse of the CSR structure **360** of the outer seal ring **350** by a distance d1 along the line B-B'. In an embodiment, the distance d1 is greater than  $0\ \mu\text{m}$ , such as in a range from about  $1\ \mu\text{m}$  to about  $240\ \mu\text{m}$ . In an alternative embodiment, the distance d1 is greater than  $240\ \mu\text{m}$ . Still further, the exterior sides **300'** of the inner seal ring **300** are spaced away from the interior sides **350''** of the outer seal ring **350** by a distance d2x along the "X" direction and by a distance d2y along the "Y" direction. In the embodiment of FIG. **3**, the distance d2x equals to the distance d2y and each of them is designed to be large enough to accommodate multiple (such as three or more) functional patterns **410** placed along the respective direction X or Y. For example, each of d2x and d2y may be in a range of  $30\ \mu\text{m}$  to  $200\ \mu\text{m}$ , such as from  $40\ \mu\text{m}$  to  $200\ \mu\text{m}$  or from  $80\ \mu\text{m}$  to  $200\ \mu\text{m}$ .

[0038] FIG. **4** is a closeup top plan view of the semiconductor structure **100** shown in the area C in FIG. **1** according to another embodiment of the present disclosure. In FIG. **4**, the line A-A' still denotes the bisector of the interior angle  $\alpha$ , and the line B-B' still denotes the bisector of the interior angle  $\beta$ . The line B-B' is parallel to and spaced away from the line A-A'. Compared with the embodiment in FIG. **3**, the inner seal ring **300** in the embodiment in FIG. **4** is shifted lower and to the left. This creates more space in the redundant region **400s** above the inner seal ring **300** (labeled as **400s-T**) but reduces space in the redundant region **400s** to the left (along the "X" direction) of the inner seal ring **300** (labeled as **400s-L**). One benefit of this embodiment is that the redundant region **400s-T** can accommodate large functional patterns **410** that would otherwise be difficult or impossible to fit into the redundant region **400s**. In this embodiment, the distance d2y is greater than the distance d2x, for example, by  $10\ \mu\text{m}$  or more. The distance d2y may be designed based on layout usage. The inner seal ring **300** is spaced away from the outer seal ring **350**. Particularly, the exterior corner of the inner seal ring **300** is spaced away from the hypotenuse of the CSR structure **360** of the outer seal ring **350** by a distance d1 along the line B-B'. In an embodiment, the distance d1 is in a range from  $0\ \mu\text{m}$  to about  $240\ \mu\text{m}$ . In some embodiment, the distance d1 is  $0\ \mu\text{m}$ , i.e., the inner seal ring **300** abuts or touches the CSR structure **360**.

[0039] FIG. **5** is a closeup top plan view of the semiconductor structure **100** shown in the area C in FIG. **1** according to yet another embodiment of the present disclosure. In FIG. **5**, the line A-A' still denotes the bisector of the interior angle  $\alpha$ , and the line B-B' still denotes the bisector of the interior angle  $\beta$ . The line B-B' is parallel to and spaced away from the line A-A'. Compared with the embodiment in FIG. **3**, the inner seal ring **300** in the embodiment in FIG. **5** is shifted higher and to the right. This creates more space in the redundant region **400s-L** but reduces space in the redundant region **400s-T**. One benefit of this embodiment is that the redundant region **400s-L** can accommodate large functional patterns **410** that would otherwise be difficult or impossible to fit



into the redundant region **400s**. In this embodiment, the distance  $d2x$  is greater than the distance  $d2y$ , for example, by 10  $\mu\text{m}$  or more. The distance  $d2x$  may be designed based on layout usage. The inner seal ring **300** is spaced away from the outer seal ring **350**. Particularly, the exterior corner of the inner seal ring **300** is spaced away from the hypotenuse of the CSR structure **360** of the outer seal ring **350** by a distance  $d1$  along the line B-B'. In an embodiment, the distance  $d1$  is in a range from 0  $\mu\text{m}$  to about 240  $\mu\text{m}$ . In some embodiment, the distance  $d1$  is 0  $\mu\text{m}$ , i.e., the inner seal ring **300** abuts or touches the CSR structure **360**.

[0040] FIG. 6 illustrates an embodiment whether some functional patterns **410** are electrically connected to the inner seal ring **300** or the circuit region **150**. For example, a functional pattern **410** is electrically connected to the inner seal ring **300** by a connection **412**, and another functional pattern **410** is electrically connected to the circuit region **150** by a connection **414** that goes through an opening **314** in the inner seal ring **300**. Such functional patterns **410** and connections **412**, **414** may be implemented in any of the embodiments discussed above, including the embodiments shown in FIGS. 1-5. The connections **412** and **414** may be implemented in any suitable layer(s) of the semiconductor structure **100**, such as diffusion layers, gate layers, contact layers, or metal layers.

[0041] FIG. 7 shows a cross-sectional view of a portion of the semiconductor structure **100** along the "Cut-A" line of FIG. 1, according to various aspects of the present disclosure. Referring to FIG. 7, the outer seal ring **350** includes multiple sub seal rings such as sub seal rings **212a**, **212b**, **212c**, and **212d**, which will be further discussed below. Further, the functional patterns **410** are present in the redundant region **400s**. The functional patterns **410** at different layers of the semiconductor structure **100** may or may not be connected depending on their designed functionality.

[0042] Referring to FIG. 7, the semiconductor structure **100** includes a substrate **202**. The substrate **202** is a silicon substrate in the present embodiment. The substrate **202** may alternatively include other semiconductor materials in various embodiment, such as germanium, silicon carbide, gallium arsenide, gallium phosphide, indium phosphide, indium arsenide, indium antimonide, SiGe, GaAsP, AlInAs, AlGaAs, GaInAs, GaInP, GaInAsP, or combinations thereof. The substrate **202** may include doped active regions such as a P-well and/or an N-well **204** (see FIG. 9). The substrate **202** may also further include other features such as a buried layer, and/or an epitaxy layer. Furthermore, the substrate **202** may be a semiconductor on insulator such as silicon on insulator (SOI). In other embodiments, the substrate **202** may include a doped epitaxy layer, a gradient semiconductor layer, and/or may further include a semiconductor layer overlying another semiconductor layer of a different type such as a silicon layer on a silicon germanium layer. The substrate **202** includes active regions (such as N.sup.+ or P.sup.+ doped regions) that are configured as an NMOS device (e.g., nFET) or a PMOS device (e.g., pFET). The substrate **202** may include underlying layers, devices, junctions, and other features (not shown). The outer seal ring **350**, the inner seal rings **300**, the functional patterns **410**, and the circuit regions **150** are built in or on the substrate **202**. The substrate **202** further includes an assembly isolation **170** (FIG. 8) between the inner seal rings **300** and the circuit regions **150** and scribe line regions (for scribe lines **180**) surrounding the outer seal ring **350** and optionally going through the outer seal ring **350**.

[0043] The outer seal ring **350** includes the sub seal rings **212a**, **212b**, **212c**, and **212d**. The sub seal ring **212a** is wider than the other sub seal rings, thus may be referred to as the main sub seal ring. Having multiple nested sub seal rings ensures that at least the inner sub seal ring(s) is/are protected from cracks during dicing (e.g., die sawing). For example, the sub seal rings **212c** and **212d** can protect the sub seal rings **212a** and **212b** from damages that may occur during dicing.

[0044] Each of the sub seal rings **212a**, **212b**, **212c**, and **212d** includes one or more conductive features **218** disposed on the substrate **202**, such as disposed on active regions of the substrate **202**. The conductive features **218** may include multiple conductors vertically stacked, and may include doped semiconductors, metals, conductive nitride, conductive oxide, or other types of conductive materials. Over the conductive features **218**, each of the sub seal rings **212a**, **212b**, **212c**, and **212d**

further includes multiple metal layers **251** stacked one over another and vertically connected by metal vias **252**. Metal layers **251** and metal vias **252** may comprise copper, copper alloys, or other conductive materials and may be formed using single damascene or dual damascene processes. Each of the metal layers **251** and the metal vias **252** may include a conductive barrier layer (such as TiN or TaN) surrounding a metal core (such as copper). In an embodiment, each of the metal layers **251** is formed into a ring or a ring-like structure (such as a substantially square ring) that surrounds the inner seal rings **300** and the circuit regions **150**. In other words, each of the metal layers **251** is formed into a closed structure and extends along the edges of the area occupied by the inner seal rings **300** and the circuit regions **150**. In the present embodiment, a ring or a ring-like structure refers to a closed structure, which may be rectangular, square, substantially rectangular, substantially square, or in other polygonal shapes. In an embodiment, the outer vias **252** (the vias **252** that are the closest and the furthest, respectively, from the inner seal rings **300** and the circuit regions **150**) are formed into the shape of a ring. Thus, they are also referred to as via bars. The inner vias **252** are formed into discrete vias along a line parallel to the outer vias **252**. In the present embodiment, each of the sub seal rings **212a** and **212c** further includes an aluminum pad **264**. [0045] The conductive features **218**, the metal layers **251**, and the metal vias **252** are embedded in dielectric layers **210**. The dielectric layers **210** may include silicon oxide, silicon nitride, silicon oxynitride, low-k dielectric materials, extreme low-k (ELK) dielectric materials, or other suitable dielectric materials (for example, including silicon, oxygen, nitrogen, carbon, or other suitable isolation constituent), or combinations thereof. The semiconductor structure **100** further includes a passivation layer **260** over the dielectric layers **210** and another passivation layer **262** over the passivation layer **260**. Each of the aluminum pads **264** includes a top portion that is disposed over the passivation layer **260** and a bottom portion that penetrates the passivation layer **260** and electrically connects to the sub seal rings **212a** and **212c**. In an embodiment, each of the aluminum pads **264** is formed into a shape of a ring that surrounds the inner seal rings **300** and the circuit regions **150**. Thus, the aluminum pads **264** may also be referred to as aluminum rings **264**. Aluminum pads **264** may be formed simultaneously with the formation of bond pads (not shown) that are exposed on the top surface of circuit regions **150**. The passivation layer **262** is disposed over the passivation layer **260** and the aluminum pads **264**. Passivation layers **260** and **262** may be formed of oxides, nitrides, and combinations thereof, and may be formed of the same or different materials.

[0046] A trench **261** is provided in the passivation layer **262** above the sub seal ring **212b**. Another trench **263** is provided in the passivation layer **262** above the sub seal ring **212d**. In an embodiment, each of the trenches **261** and **263** is formed into a shape of a ring surrounding the inner seal rings **300** and the circuit regions **150**. An advantageous feature of the dual trenches **261**, **263** is that if a crack occurs in the scribe line during dicing, the crack will be stopped by the trench **263**. Even if the crack propagates across the trench **263**, if at all, the stress of the crack is substantially reduced by the trench **261**. As discussed above, one of the functionalities of the functional patterns **410** is to monitor such crack. The semiconductor structure **100** may include other features and layers not shown in FIG. 7.

[0047] As shown in FIG. 7, the functional patterns **410** may include features in various layers such as diffusion layers, gate layers, contact layers, metal layers, via layers, and insulating layers depending on the functionality of the functional patterns **410**. For example, some functional patterns **410** may include transistors, conductors, and/or insulators.

[0048] FIG. 8 shows a cross-sectional view of a portion of the semiconductor structure **100** along the “Cut-B” line of FIG. 1 according to various aspects of the present disclosure. Referring to FIG. 8, similar to the outer seal ring **350**, the inner seal ring **300** also includes multiple sub seal rings such as sub seal rings **212a**, **212b**, **212c**, and **212d**. The features of the inner seal ring **300** are the same as those of the outer seal ring **350**, except that, for example, the dimensions of the sub seal rings may be different between them.

[0049] The semiconductor structure **100** further includes an assembly isolation **170** between the inner seal ring **300** and the circuit region **150**. The assembly isolation **170** includes an isolation structure (such as shallow trench isolation) **230**. The isolation structure **230** may include silicon oxide, silicon nitride, silicon oxynitride, other suitable isolation material (for example, including silicon, oxygen, nitrogen, carbon, or other suitable isolation constituent), or combinations thereof. Isolation structure **230** can include different structures, such as shallow trench isolation (STI) structures and/or deep trench isolation (DTI) structures. In some embodiments, the semiconductor structure **100** may include various dummy lines and dummy vias in the assembly isolation **170**.

[0050] FIG. **9** shows a cross-sectional view of the semiconductor structure **100**, illustrating various layers therein including wells (or diffusion layer) **204**, isolation structure **230**, fin layer **215**, gate layer **240**, gate via layer **242**, contact layer (not shown, but at the same level as the gate layer **240**), via layer (not shown, but at the same level as the gate via layer **242**), the first through sixth metal (M1, M2, M3, M4, M5, and M6) layers **251**, and the first through fifth via (via1, via2, via3, via4, and via5) layers **252**. The semiconductor structure **100** may include other layers or features not shown in FIG. **9**.

[0051] The wells **204** are formed in or on the substrate **202** in the circuit regions **150**, and in some embodiment also in the redundant regions **400s** for certain functional patterns **410**. The wells **204** include p-type doped regions configured for n-type transistors, and n-type doped regions configured for p-type transistors. The fin layer **215** includes fin-shaped semiconductor material(s) (or fins) protruding from the substrate **202**. In an embodiment, the fins for NMOSFET include single crystalline silicon or intrinsic silicon or another suitable semiconductor material; and the fins for PMOSFET may comprise silicon, germanium, silicon germanium, or another suitable semiconductor material. In an embodiment, functional patterns **410** are also formed in the fin layer, in the form of semiconductor fins. The isolation structure **230** has been discussed earlier and isolates the fins.

[0052] The gate layer **240** includes gate structures having gate dielectric layer(s) and gate electrode layer(s). The gate dielectric layer(s) may include silicon dioxide, silicon oxynitride, and/or a high-k dielectric material such as HfO<sub>2</sub>, HfSiO, HfSiO<sub>2</sub>, HfSiON, HfLaO, HfTaO, HfTiO, HfZrO, HfAlO<sub>x</sub>, ZrO, ZrO<sub>2</sub>, ZrSiO<sub>2</sub>, AlO, AlSiO, Al<sub>2</sub>O<sub>3</sub>, TiO, TiO<sub>2</sub>, LaO, LaSiO, Ta<sub>2</sub>O<sub>3</sub>, Ta<sub>2</sub>O<sub>5</sub>, Y<sub>2</sub>O<sub>3</sub>, SrTiO<sub>3</sub>, BaZrO, BaTiO<sub>3</sub> (BTO), (Ba, Sr)TiO<sub>3</sub> (BST), Si<sub>3</sub>N<sub>4</sub>, hafnium dioxide-alumina (HfO<sub>2</sub>—Al<sub>2</sub>O<sub>3</sub>) alloy, other suitable high-k dielectric material, or combinations thereof. High-k dielectric material generally refers to dielectric materials having a high dielectric constant, for example, greater than that of silicon oxide ( $k \approx 3.9$ ). The gate electrode layer(s) may include titanium, aluminum, tantalum carbide, tantalum carbide nitride, tantalum silicon nitride, titanium nitride, tantalum nitride, ruthenium, molybdenum, tungsten, platinum, tungsten, cobalt, copper, and/or other suitable materials. In an embodiment, functional patterns **410** are also formed in the gate layer, in the form of gate dielectric layer(s) and gate electrode layer(s).

[0053] Each of the gate via layer **242**, contact layer (not shown), via layer (not shown), the via layers **252**, and the metal layers **251** may include titanium, tantalum, tungsten, cobalt, molybdenum, ruthenium, or a conductive nitride such as titanium nitride, titanium aluminum nitride, tungsten nitride, tantalum nitride, or combinations thereof, and may be formed by CVD, PVD, ALD, and/or other suitable processes. In an embodiment, functional patterns **410** are also formed in one or more of the layers mentioned above and using the same material and process that form the corresponding features in the circuit regions **150**.

[0054] Although not intended to be limiting, embodiments of the present disclosure provide one or more of the following advantages. For example, embodiments of the present disclosure provide a semiconductor structure with a dual seal ring structure. The dual seal ring structure includes an outer seal ring enclosing two or more inner seal rings. Each inner seal ring encloses a circuit region. The semiconductor structure can be used to form connected dies or individual dies flexibly.

Redundant regions between the outer seal ring and the inner seal rings are provided with functional patterns to further utilize the wafer area. The functional patterns may perform various monitoring, testing, or other functions. Embodiments of the present disclosure can be readily integrated into existing semiconductor manufacturing processes.

[0055] In one example aspect, the present disclosure is directed to a semiconductor structure. The semiconductor structure includes a first circuit region; a first inner seal ring at least partially surrounding the first circuit region; and an outer seal ring at least partially surrounding the first inner seal ring. The outer seal ring includes a first corner and a substantially triangular corner seal ring (CSR) structure at the first corner. The first inner seal ring includes a second corner adjacent to and spaced away from the CSR structure. The semiconductor structure further includes a first region between a first side of the first corner and a first side of the second corner that is parallel to the first side of the first corner, and multiple functional patterns in the first region.

[0056] In an embodiment of the semiconductor structure, a common line bisects an interior angle of the first corner and an interior angle of the second corner. In another embodiment, a bisector of an interior angle of the first corner and a bisector of an interior angle of the second corner are parallel to each other and spaced away from each other. In a further embodiment, the semiconductor structure further includes a second region between a second side of the first corner and a second side of the second corner that is parallel to the second side of the first corner, wherein a first distance between the first side of the first corner and the first side of the second corner is greater than a second distance between the second side of the first corner and the second side of the second corner.

[0057] In an embodiment of the semiconductor structure, a width of the first region as measured along a direction that is perpendicular to the first side of the first corner is in a range from about 30  $\mu\text{m}$  to about 200  $\mu\text{m}$ . In an embodiment, the functional patterns include one or more test lines. In another embodiment, the functional patterns include a passivation crack monitor circuit, a low noise seal ring pattern, an inductance monitor, a capacitance monitor, a resistance monitor, an inline critical dimension monitor, an overlay monitor, a film thickness monitor, or a combination thereof.

[0058] In an embodiment of the semiconductor structure, at least one of the functional patterns is electrically connected to the first circuit region. In another embodiment, at least one of the functional patterns is electrically connected to the first inner seal ring. In an embodiment, the semiconductor structure further includes a second circuit region; a second inner seal ring at least partially surrounding the second circuit region; and interconnects that go through the first and the second inner seal rings and electrically connect the first and the second circuit regions, wherein the outer seal ring surrounds the first and the second circuit regions, the first and the second inner seal rings, and the interconnects.

[0059] In another example aspect, the present disclosure is directed to a semiconductor structure. The semiconductor structure includes first and second circuit regions and first and second inner seal rings at least partially surrounding the first and the second circuit regions, respectively, and spaced out by a first region. The semiconductor structure further includes openings in the first and the second inner seal rings; interconnects in the first region and going through the openings and electrically connecting the first and the second circuit regions; an outer seal ring surrounding the first and the second inner seal rings and the first region; a second region that is inside the outer seal ring and outside of the first and the second inner seal rings and is different from the first region; and multiple functional patterns in the second region.

[0060] In an embodiment of the semiconductor structure, the functional patterns include one or more test lines, a passivation crack monitor circuit, a low noise seal ring pattern, an inductance monitor, a capacitance monitor, a resistance monitor, an inline critical dimension monitor, an overlay monitor, a film thickness monitor, or a combination thereof.

[0061] In an embodiment, at least one of the functional patterns is electrically connected to the first circuit region. In another embodiment, at least one of the functional patterns is electrically

connected to the first inner seal ring. In another embodiment, the second region has a length in a range from about 10 mm to about 26 mm and a width in a range from about 30  $\mu\text{m}$  to about 200  $\mu\text{m}$ . In yet another embodiment, the outer seal ring includes a first corner, the first inner seal ring includes a second corner adjacent to the first corner and spaced away from the outer seal ring, a bisector of an interior angle of the first corner and another bisector of an interior angle of the second corner are parallel to each other and spaced away from each other.

[0062] In yet another example aspect, the present disclosure is directed to a semiconductor structure that includes first and second circuit regions; first and second inner seal rings at least partially surrounding the first and the second circuit regions, respectively; and an outer seal ring surrounding the first and the second inner seal rings, thereby defining multiple substantially rectangular regions between the outer seal ring and the first and the second inner seal rings. The semiconductor structure further includes functional patterns in at least one of the substantially rectangular regions, wherein the functional patterns include one or more test lines, a passivation crack monitor circuit, a low noise seal ring pattern, an inductance monitor, a capacitance monitor, a resistance monitor, an inline critical dimension monitor, an overlay monitor, a film thickness monitor, or a combination thereof.

[0063] In an embodiment of the semiconductor structure, at least one of the functional patterns is electrically connected to the first circuit region. In another embodiment, at least one of the functional patterns is electrically connected to the first inner seal ring. In yet another embodiment, the outer seal ring includes a first corner, the first inner seal ring includes a second corner adjacent to the first corner and spaced away from the outer seal ring, a bisector of an interior angle of the first corner and a bisector of an interior angle of the second corner are parallel to each other and spaced away from each other.

[0064] The foregoing outlines features of several embodiments so that those of ordinary skill in the art may better understand the aspects of the present disclosure. Those of ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those of ordinary skill in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

## Claims

1. A semiconductor structure, comprising: a first circuit region; an inner seal ring at least partially surrounding the first circuit region; an outer seal ring at least partially surrounding the inner seal ring; a first region between a first side of the outer seal ring and a first side of the inner seal ring that is parallel to the first side of the outer seal ring; a second region between a second side of the outer seal ring and a second side of the inner seal ring that is parallel to the second side of the outer seal ring, wherein a first shortest distance between the first side of the outer seal ring and the first side of the inner seal ring is greater than a second shortest distance between the second side of the outer seal ring and the second side of the inner seal ring; and multiple functional patterns in the first region or the second region.
2. The semiconductor structure of claim 1, wherein the outer seal ring has an outer rectangular periphery and includes four corner seal ring (CSR) structures at four interior corners of the outer rectangular periphery, wherein the inner seal ring has an inner rectangular periphery and includes four CSR structures at four interior corners of the inner rectangular periphery, wherein the CSR structures of the outer seal ring has a greater size than the CSR structures of the inner seal ring.
3. The semiconductor structure of claim 1, wherein the first region includes more functional patterns than the second region.

4. The semiconductor structure of claim 1, wherein first functional patterns in the first region extend lengthwise parallel to the first side of the inner seal ring, and second functional patterns in the second region extend lengthwise parallel to the second side of the inner seal ring, wherein there are one or more rows of the first functional patterns between the first side of the inner seal ring and the first side of the outer seal ring and one or more columns of the second functional patterns between the second side of the inner seal ring and the second side of the outer seal ring, wherein there are more rows than columns.
5. The semiconductor structure of claim 1, wherein first functional patterns in the first region extend lengthwise parallel to the first side of the inner seal ring, and second functional patterns in the second region extend lengthwise parallel to the second side of the inner seal ring, wherein there are one or more columns of the first functional patterns between the first side of the inner seal ring and the first side of the outer seal ring and one or more rows of the second functional patterns between the second side of the inner seal ring and the second side of the outer seal ring, wherein there are more columns than rows.
6. The semiconductor structure of claim 1, wherein the outer seal ring includes a first corner, the inner seal ring includes a second corner adjacent to the first corner and spaced away from the outer seal ring, a bisector of an interior angle of the first corner and a bisector of an interior angle of the second corner are parallel to each other and spaced away from each other.
7. The semiconductor structure of claim 1, wherein a width of the first region as measured along a direction that is perpendicular to the first side is in a range from about 80  $\mu\text{m}$  to about 200  $\mu\text{m}$ , and a width of the second region as measured along a direction that is perpendicular to the second side is in a range from about 30  $\mu\text{m}$  to about 200  $\mu\text{m}$ .
8. The semiconductor structure of claim 1, wherein the functional patterns include one or more test lines.
9. The semiconductor structure of claim 1, wherein the functional patterns include a passivation crack monitor circuit, a low noise seal ring pattern, an inductance monitor, a capacitance monitor, a resistance monitor, an inline critical dimension monitor, an overlay monitor, a film thickness monitor, or a combination thereof.
10. The semiconductor structure of claim 1, wherein at least one of the functional patterns is electrically connected to the first circuit region.
11. The semiconductor structure of claim 1, wherein at least one of the functional patterns is electrically connected to the inner seal ring.
12. A semiconductor structure, comprising: first and second circuit regions; first and second inner seal rings fully surrounding the first and the second circuit regions, respectively, and spaced out by a first region; an outer seal ring surrounding the first and the second inner seal rings and the first region; a second region that is inside the outer seal ring and outside of the first and the second inner seal rings and is different from the first region; and multiple functional patterns in the second region, wherein at least one of the functional patterns is electrically connected to the first circuit region.
13. The semiconductor structure of claim 12, wherein the functional patterns include one or more test lines, a passivation crack monitor circuit, a low noise seal ring pattern, an inductance monitor, a capacitance monitor, a resistance monitor, an inline critical dimension monitor, an overlay monitor, a film thickness monitor, or a combination thereof.
14. The semiconductor structure of claim 12, wherein the second region has a length in a range from about 10 mm to about 26 mm and a width at least greater than about 40  $\mu\text{m}$ .
15. The semiconductor structure of claim 12, wherein at least one of the functional patterns is electrically connected to the first inner seal ring.
16. The semiconductor structure of claim 11, wherein the outer seal ring includes multiple sub seal rings.
17. The semiconductor structure of claim 16, wherein the multiple sub seal rings includes a main

sub seal ring and an edge sub seal ring, wherein the main sub seal ring is wider than the edge sub seal ring, and the main sub seal ring is closer to the inner seal rings than the edge sub seal ring.

**18.** A semiconductor structure, comprising: a first circuit region; an inner seal ring surrounding the first circuit region; an outer seal ring at least partially surrounding the inner seal ring, wherein the outer seal ring has an outer rectangular periphery and includes four CSR structures at four interior corners of the outer rectangular periphery; a first region between a first side of the outer seal ring and a first side of the inner seal ring that is parallel to the first side of the outer seal ring; a second region between a second side of the outer seal ring and a second side of the inner seal ring that is parallel to the second side of the outer seal ring; a third region between each of the four CSR structures of the outer seal ring and a corresponding exterior corner of the inner seal ring, wherein a distance between each of the four CSR structures of the outer seal ring and the corresponding exterior corner of the inner seal ring is greater than 1  $\mu\text{m}$ ; and multiple functional patterns in the first region or the second region.

**19.** The semiconductor structure of claim 18, wherein at least one of the functional patterns is electrically connected to the first circuit region or the inner seal ring.

**20.** The semiconductor structure of claim 11, wherein the inner seal ring includes multiple sub seal rings.

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