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### REDUCED AREA STANDARD CELL ABUTMENT CONFIGURATIONS

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#### Abstract

A method of designing a semiconductor device includes: analyzing, in a first layout design, a first abutment between a first cell block and a second cell block having a topographic mismatch in one or more of cell height, line width, or line spacing between the first and second cell blocks; selecting a modified first cell block reducing the topographic mismatch; replacing the first cell block with the modified first cell block to obtain a modified first layout design having a second abutment between the modified first cell block and the second cell block, wherein, in the modified first layout design, the second abutment includes a first abutment region having a continuous active region along a first axis parallel to an edge of the first abutment region; generating a tape-out for the modified first layout design; and manufacturing a semiconductor device according to the tape-out for the modified first layout design.

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## Background/Summary

**PRIORITY CLAIM [0001]** This application is a continuation of U.S. application Ser. No. 18/447,187, filed Aug. 9, 2023, now U.S. Pat. No. 12,299,373, issued May 13, 2025, which is a continuation of U.S. application Ser. No. 17/558,157, filed Dec. 21, 2021, now U.S. Pat. No. 11,768,989, issued Sep. 26, 2023, which is a continuation of U.S. application Ser. No. 16/664,242, filed Oct. 25, 2019, now U.S. Pat. No. 11,216,608, issued Jan. 4, 2022, which claims priority from U.S. Provisional Application No. 62/753,678, filed Oct. 31, 2018, which are incorporated by reference herein in their entireties.

### BACKGROUND

[0002] The semiconductor integrated circuit (IC) industry has continued to experience rapid growth with technological advances in IC materials and design producing successive generations of ICs, each new generation having smaller geometries and more complex circuits than the previous generation. The complexity of the associated layout, device structures, and manufacturing processes for producing each new generation of ICs has increased correspondingly in order to provide the designed functional density.

[0003] The performance of advanced patterning and etching processes is affected by density gradient effects (DGE) associated with the particular IC device layout configuration being manufactured. Consideration and adjustment of the relative placement, height, and density of the functional and non-functional structures during IC device layout mitigate some of the DGE and improve the uniformity and performance of the resulting ICs and allow for reductions in chip area and increases in chip density.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

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

[0005] FIG. 1 is a plan view of an initial integrated circuit layout including two standard cell block regions.

[0006] FIGS. 2A and 2B are cross-sectional views of portions of the N-type and P-type standard cell block boundary configurations of FIG. 1 according to some embodiments.

[0007] FIGS. 3A-3C are cross-sectional views of various N-type boundary configurations according to some embodiments.

[0008] FIGS. 4A-4C are cross-sectional views of various P-type boundary configurations

according to some embodiments.

[0009] FIG. 5 is a plan view of an embodiment of an initial integrated circuit layout including two modified standard cell block regions.

[0010] FIG. 6A is a plan view of an embodiment of a standard cell block with modified top and bottom regions and FIG. 6B is an enlarged plan view of the standard cell block structure.

[0011] FIG. 7A is a plan view of an embodiment of a standard cell block with modified top and bottom regions and FIG. 7B is an enlarged plan view of the standard cell block structure.

[0012] FIG. 8A is a plan view of an embodiment of a standard cell block with modified top and bottom regions and FIG. 8B is an enlarged plan view of the standard cell block structure.

[0013] FIG. 9A is a plan view of an embodiment of a standard cell block with modified top and bottom regions vertically abutting a non-standard cell block and FIG. 9B is an enlarged plan view of the abutting structures.

[0014] FIG. 10A is a plan view of an embodiment of a standard cell block with modified top and bottom regions horizontally abutting a non-standard cell block and FIG. 10B is an enlarged plan view of the abutting structures.

[0015] FIG. 11A is a plan view of an embodiment of a first standard cell block with modified top and bottom regions vertically abutting a second standard cell block and FIG. 11B is an enlarged plan view of the abutting structures.

[0016] FIG. 12A is a plan view of an embodiment of a first standard cell block with modified top and bottom regions horizontally abutting a second standard cell block and FIG. 12B is an enlarged plan view of the abutting structures.

[0017] FIG. 13 is a flow diagram of a method, according to some embodiments, for modifying an IC design layout to include modified standard cell blocks in accordance with some embodiments.

[0018] FIG. 14 is a schematic view of an electronic process control (EPC) system useful in the operation of an IC design layout modification in accordance with some embodiments.

[0019] FIG. 15 is a flow diagram of a manufacturing process for an integrated circuit in accordance with some embodiments.

[0020] FIG. 16A is a plan view of an initial integrated circuit layout including two standard cell block regions and FIG. 16B is a plan view of an initial integrated circuit layout including two modified standard cell block regions.

#### DETAILED DESCRIPTION

[0021] The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components, values, operations, materials, arrangements, or the like, are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. Other components, values, operations, materials, arrangements, or the like, are contemplated. 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.

[0022] 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.

[0023] Modifying the structure of the boundary regions of standard cells in accordance with some embodiments will tend to reduce density gradient effects (DGE) and improve yield, process performance, and layout operations. In accordance with some embodiments, the boundary regions of standard cells are designed to incorporate and/or compensate for the various types of active regional abutment variations found between two adjacent active areas on IC layout designs.

Incorporating standard cells having modified boundary regions according to some embodiments helps to improve a transition between adjacent active regions (AR) while decreasing the use of open area (white space) and/or transition or dummy cells between active regions. This helps to reduce the overall size of devices including the standard cells having modified boundary regions.

[0024] FIG. 1 is a plan view of an initial integrated circuit layout including two standard cell blocks **102a**, **102b**. The upper standard cell block **102a** includes a peripheral boundary region **104** and upper and lower abutment regions **106**. The upper standard cell block **102a** is separated from the lower standard cell block **102b** by non-functional space or “white” space **1080**. In some embodiments, the white space **1080** is free of any devices. In some embodiments, the white space **1080** includes dummy devices. The lower standard cell block **102b** is arranged around a non-standard cell, e.g., an SRAM **120**, and includes both an outer peripheral boundary region **1040** and an inner peripheral boundary region **104i**. The lower standard cell block **102** also includes upper and lower outer abutment regions **1060** as well as upper and lower inner abutment regions **106i**. The non-standard cell **120** is also offset from the surrounding lower standard cell block **102b** by non-functional white space **108i**. The inclusion of the white space **1080**, **108i**, tends to reduce the device density of the resulting integrated circuit layout.

[0025] FIGS. 2A and 2B are cross-sectional views of N-type **200A** and P-type **200B** standard cell block boundary configurations according to some embodiments.

[0026] In FIG. 2A, in some embodiments, the cross-section taken along line 2A in FIG. 1, of the N-type standard cell block boundary configurations **200A** include an active region **212n**, substrate region **214n**, and an upper border region, e.g., a PP/VT\_P region, **216n**. The combination **204n'** of the active region **212n** and the substrate region **214n** correspond to the standard cell height while the height **204n''** of the upper border region **216n** results in a standard cell block boundary configuration having a height **204n** that exceeds the height of the bulk of the adjacent standard cell region.

[0027] In FIG. 2B, in some embodiments, the cross-section taken along line 2B in FIG. 1, the P-type standard cell block boundary configurations **200B** include an active region **212p**, substrate region **214p**, and an upper border region, e.g., a NP/VT\_N region, **216p**. The combination **204p'** of the active region **212p** and the substrate region **214p** correspond to the standard cell height while the height **204p''** of the upper border region **216p** results in a standard cell block boundary configuration height **204p** that exceeds the height of the bulk of the adjacent standard cell region. In some instances, the portions of the standard cells blocks that extend beyond the cell block boundary inhibit direct abutting of standard cells, which reduces the ability to reduce the size of devices includes N-type **200A** and P-type **200B** standard cell blocks.

[0028] FIGS. 3A-3C are cross-sectional views of various N-type boundary configurations according to some embodiments. In some embodiments according to FIG. 3A, the N-type standard cell block boundary configurations **300A** include an active region **312n**, substrate region **314n**, and a modified upper border region, e.g., a logic operation transfer layer (NPVT\_Transform), **318n**. The NPVT\_Transform designation represents a marker layer used in Graphic Database Systems (GDS) for designating a reconfigurable region on a standard cell block for which the final structure is determined by the configuration of the integrated circuit layout. For N-type boundaries on a standard cell block, if there is no abutting structure, the NPVT\_Transform region is configured and processed as PP/VT\_P structures or, when there is an abutting structure, the NPVT\_Transform region will not include a functional structure. Conversely, for P-type boundaries on a standard cell block, if there is no abutting structure, the NPVT\_Transform region is configured and processed as

NP/VT\_N structures or, when there is an abutting structure, the NPVT\_Transform region will not include a functional structure. The consistent use of a logic operation transfer layer, **318n**, in all modified standard cell blocks helps to ensure that the topography, i.e., cell heights, cell voltages, and/or cell densities, is the same (or at least a better match) for both of the abutting boundary regions. The combination of the active region **312n** and the substrate region **314n** correspond to the standard cell height while the height of the modified upper border region **318n** results in a standard cell block boundary configuration that exceeds the height of the bulk of the adjacent standard cell region.

[0029] In some embodiments according to FIG. 3B, the N-type standard cell block boundary configurations **300B** include an active region **312n**, substrate region **314n**, and an upper border region, e.g., a PP/VT\_P layer **316n**. The combination of the active region **312n** and the substrate region **314n** correspond to the standard cell height while the height of the upper border region **316n** results in a standard cell block boundary configuration that exceeds the height of the bulk of the adjacent standard cell region.

[0030] In some embodiments according to FIG. 3C, the N-type standard cell block boundary configurations **300C** includes only an active region **312n** and substrate region **314n**. The combination of the active region **312n** and the substrate region **314n** corresponds to the standard cell height.

[0031] FIGS. 4A-4C are cross-sectional views of various P-type boundary configurations according to some embodiments. In some embodiments according to FIG. 4A, the N-type standard cell block boundary configurations **400A** include an active region **412p**, substrate region **414p**, and a modified upper border region, e.g., a logic operation transfer layer (NPVT\_Transform), **418p**. The consistent use of a logic operation transfer layer, **418p**, in all modified standard cell blocks helps to ensure that the topography, i.e., cell heights, is the same for both of the abutting boundary regions. The combination of the active region **412p** and the substrate region **414p** corresponds to the standard cell height while the height of the modified upper border region **418p** results in a standard cell block boundary configuration that exceeds the height of the bulk of the adjacent standard cell region.

[0032] In some embodiments according to FIG. 4B, the P-type standard cell block boundary configurations **400B** include an active region **412p**, substrate region **414p**, and an upper border region, e.g., a PP/VT\_P layer **416p**. The combination of the active region **412p** and the substrate region **414p** correspond to the standard cell height while the height of the upper border region **416p** results in a standard cell block boundary configuration that exceeds the height of the bulk of the adjacent standard cell region.

[0033] In some embodiments according to FIG. 4C, the P-type standard cell block boundary configurations **400C** includes only an active region **412p** and substrate region **414p**. The combination of the active region **412p** and the substrate region **414p** corresponds to the standard cell height.

[0034] FIG. 5 is a plan view of an initial integrated circuit layout including two modified standard cell block regions in which the two standard cell blocks **502a**, **502b** incorporate standard cell block boundary configurations that have been modified to include a logic operation transfer layer (NPVT\_Transform) border region having a continuous peripheral active region to create a modified standard cell that allows for the elimination or reduction of the “white” space utilized in previous abutment region configurations, thereby reducing the area required for the IC design layout. The upper standard cell block **502a** includes a peripheral boundary region **504** and vertical abutment regions **506**. By utilizing the modified upper border region, however, non-functional void or “white” space is reduced or avoided between the abutment region **506** of the upper **502a** standard cell block and the outer abutment region **5060** of the lower standard cell block **502b**. Further, by utilizing the modified upper border region in the inner abutment regions **506i**, non-functional void or “white” space is reduced or avoided between the inner periphery of the lower standard cell block

**502b** and any non-standard cell **520**, e.g., an SRAM. The elimination or reduction of the white space **1080**, **108i**, in comparison with the IC design layout **100** of FIG. **1** to obtain the reduced area IC design layout of FIG. **5** tends to reduce the size and increase the density of the resulting IC design layout.

[0035] FIG. **6A** is a plan view of a standard cell block **602** that has been modified with top and bottom abutment regions **606a**, **606b** which include a modified upper border region, e.g., a logic operation transfer layer (NPVT\_Transform) having a continuous peripheral active region to create a modified standard cell **600A**. FIG. **6B** is an enlarged plan view **600B** of portions of the modified standard cell block structure of FIG. **6A** to provide greater detail regarding the configuration of the modified upper border region.

[0036] The modified upper border regions utilized in top and bottom abutment regions **606a**, **606b** include at least one continuous peripheral active region **608a**, **608b** (also referred to as oxide defined (OD) regions, active areas (AA), diffusion regions (DR), or source/drain regions (S/D) in some instances) at the outer periphery (or outer edge) of the corresponding abutment regions of the modified standard cell blocks. Continuous peripheral active regions **608a** and **608b** extend across substantially an entirety of the standard cell block **602**. Inward from the continuous peripheral active regions, some embodiments of the modified upper border regions include at least one row of elongated active regions **610a** and, inward from the elongated active regions **610a**, at least one row of abbreviated active regions **612a**. Elongated active regions **610** have a length greater than abbreviated active regions **612a**, but shorter than the continuous peripheral active regions **608a** and **680b**. In some embodiments, rows of elongated active regions **610a** are alternated with rows of abbreviated active regions **612a**. In some embodiments, a plurality of strap active regions **608a** are configured with a plurality of rows of elongated active regions **610a** spaced inward of the continuous peripheral active regions **608a** with a plurality of rows of abbreviated active regions **612a** spaced inward of the elongated active regions **610a**.

[0037] FIG. **7A** is a plan view of a standard cell block **702** that has been modified with top and bottom abutment regions **706a**, **706b** having modified cell block boundary configurations that include a modified upper border region, e.g., a logic operation transfer layer (NPVT\_Transform) having a continuous peripheral active region to create a modified standard cell **700A**. FIG. **7B** is an enlarged plan view **700B** of portions of the standard cell block structure of FIG. **7A** to provide greater detail regarding the configuration of the modified upper border region.

[0038] The modified upper border regions utilized in modified abutment regions **706a**, **706b** include at least one continuous peripheral oxide defined active region **708a**, **708b** at the outer periphery of the corresponding abutment regions provided on the modified standard cell blocks. Inward from the continuous peripheral active regions, some embodiments of the modified upper border regions include at least one row of elongated active regions **710a** and, inward from the elongated active regions **710a**, at least one row of abbreviated active regions **712a**. In some embodiments, rows of elongated active regions **710a** are alternated with rows of abbreviated active regions **712a**. In some embodiments, a plurality of strap active regions **708a** are configured with a plurality of rows of elongated active regions **710a** spaced inward of the continuous peripheral active regions **708a** with a plurality of rows of abbreviated active regions **712a** spaced inward of the elongated active regions **710a**.

[0039] In addition to the various configurations of active regions provided on various embodiments of the modified abutment regions **706a**, **706b** according to FIG. **7B**, in some embodiments the modified abutment regions **706a**, **706b** also include a transition region **716** in which at least some of the inwardly located elongated active regions **710a** and abbreviated active regions **712a** are replaced by a plurality of conductive structures **714**, e.g., polysilicon structures, that are arranged perpendicularly to the remaining portions of the rows of the various active regions **710a**, **712a**. In some embodiments, the overall width of the transition region containing the conductive structures is between 2 and 3 times the cell poly pitch (CPP). The CPP value for a particular IC design layout

is determined by the applicable design rules for the manufacturing process that is to be utilized to manufacture ICs corresponding to a final IC design layout. Regardless of the configuration of the transition region, however, at least the outermost continuous peripheral active region **708a** is maintained and extends, uninterrupted, across the transition region.

[0040] FIG. **8A** is a plan view of a non-rectangular standard cell block having first and second standard cell block regions **802a**, **802b** with each of the standard cell block regions **802a**, **802b** including modified top and bottom abutment regions **806a**, **806b**, **806c**. Each of the modified abutment regions **806a**, **806b**, **806c** include a modified standard cell block boundary configuration that includes a modified upper border region, e.g., a logic operation transfer layer

(NPVT\_Transform) having a continuous peripheral active region to create a modified standard cell **800A**. FIG. **8B** is an enlarged plan view **800B** of portions of the standard cell block structure of FIG. **8A** to provide greater detail regarding the configuration of the modified upper border regions.

[0041] The modified upper border regions utilized in modified abutment regions **806a**, **806b**, **806c** include at least one continuous peripheral active region **808a**, **808b**, **808c** at the outer periphery of the corresponding abutment regions provided on the modified standard cell blocks. Inward from the continuous peripheral active regions, some embodiments of the modified upper border regions include at least one row of elongated active regions **810a** and, inward from the elongated active regions **810a**, at least one row of abbreviated active regions **812a**. In some embodiments, rows of elongated active regions **810a** alternate with rows of abbreviated active regions **812a**. In some embodiments, a plurality of continuous peripheral active regions **808a** are configured with a plurality of rows of elongated active regions **810a** spaced inward of the continuous peripheral active regions **808a** with a plurality of rows of abbreviated active regions **812a** spaced inward of the elongated active regions **810a**.

[0042] In addition to the various configurations of active regions provided on various embodiments of the modified abutment regions **806a**, **806b** according to FIG. **8B**, in some embodiments the modified abutment regions **806a**, **806b** also include a transition region **816** extending between the standard cell block regions **802a**, **802b** in which at least some of the inwardly located elongated active regions **810a** and abbreviated active regions **812a** are replaced by a plurality of conductive structures **814**, e.g., polysilicon structures, that are arranged perpendicularly to the remaining portions of the rows of the various active regions **810a-c**, **812a-c**. In some embodiments, the overall width of the transition region containing the conductive structures is between 2 and 4 times the cell poly pitch (CPP). Regardless of the configuration of the transition region, however, at least the outermost strap active regions **808a-c** are maintained and extend to the transition region in those embodiment in which the transition region **816** terminates one or more continuous, but offset, active regions **808a**, **808b** and uninterrupted, across the transition region(s) in those embodiments in which the transition region **816** is in a medial position relative to the strap active region(s) **808c**. In some embodiments, the transition region **816** defines a vertical boundary adjacent the upper portion of the standard cell block regions **802a**, while in other embodiments, the transition region **816** extends only between the lower portion of the first standard cell block region **802a** and the adjacent vertical boundary of the second standard cell block region **802b** (not shown).

[0043] FIG. **9A** is a plan view **900A** of a standard cell block vertically abutting a non-standard cell block and FIG. **9B** is an enlarged plan view **900B** of the abutting structures. Embodiments according to FIG. **9A** include a standard cell block **902** modified to include at least one modified abutment region **906** vertically abutting a non-standard cell block **908**, e.g., a logic operation transfer layer (NPVT\_Transform) having a continuous peripheral active region to create a modified standard cell. FIG. **9B** is an enlarged plan view **900B** of the abutting structures of region **912** according to some embodiments.

[0044] The modified upper border regions utilized in modified abutment region **906** include at least one continuous peripheral active region **917a**, **917b** at the outer periphery of the modified abutment region **906** provided on the modified standard cell block **902**. In some embodiments, the widths

**918a**, **918b** of the strap active region(s) is about 2-3 fin widths. The fin width value for the IC design layout under development is determined by the applicable design rules for the manufacturing process that are to be utilized to manufacture ICs corresponding to a final IC design layout. Inward from the strap active regions, some embodiments of the modified upper border regions include at least one row of elongated active regions (not shown) and, inward from the continuous peripheral active region **917a**, **917b** and/or elongated active regions, at least one row of abbreviated active regions **917c**.

[0045] Opposite the modified standard cell block **902** is non-standard cell block **908** having a border region including a series of active regions **911a**, **911b**, **911c** located at the outer periphery of the abutment region on the non-standard cell block **908**. In some embodiments, the spacings **914a**, **914b** of the active region(s) on the non-standard cell block **908** is at least about 2 fin widths. The fin width value for the IC design layout under development is determined by the applicable design rules for the manufacturing process that are to be utilized to manufacture ICs corresponding to a final IC design layout. In some embodiments, the modified standard cell block **902** is spaced from the non-standard cell block **908** by a separation distance **916** that is on the order of about 0.3  $\mu\text{m}$ .

[0046] FIG. **10A** is a plan view **1000A** of a standard cell block horizontally abutting a non-standard cell block and FIG. **10B** is an enlarged plan view **1000B** of the abutting structures. Embodiments according to FIG. **10A** include a modified standard cell block **1002** horizontally abutting a non-standard cell block **1008**.

[0047] FIG. **10B** is an enlarged plan view **1000B** of the abutting structures of region **1012** according to some embodiments in which the modified standard cell block includes a transition region **1016** in which at least some of the inwardly located strap active regions **1017a**, elongated active regions **1017b** and/or abbreviated active regions **1017c** are replaced by a plurality of conductive structures **1014a**, e.g., polysilicon structures, that are arranged perpendicularly to the remaining portions of the rows of the various active regions **1017a-c**. In some embodiments, the overall width of the transition region **1016** containing the conductive structures is between 2 and 6 times the cell poly pitch (CPP) depending upon the portion of the transition region provided on the modified standard cell block **1002**.

[0048] Opposite the modified standard cell block **1002** is non-standard cell block **1008** having a border region including a series of active regions **1011a**, **1011b**, located at the outer periphery of the abutment region on the non-standard cell block **1008**. In some embodiments, non-standard cell block **1008** includes at least a portion of a transition region **1016** in which at least some of the active regions **1011a**, **1011b** are replaced by a plurality of conductive structures **1014b**, e.g., polysilicon structures, that are arranged perpendicularly to the remaining portions of the rows of the various active regions **1011a-b**. In some embodiments, the overall width of the transition region **1016** containing the conductive structures is between 2 and 6 times the cell poly pitch (CPP) depending upon the portion of the transition region provided on the non-standard cell block **1008**. In some embodiments, the full width of the transition region **1016** is apportioned evenly between the modified standard cell block **1002** and the non-standard cell block **1008**. In other embodiments, the total width of the transition region **1016** comprises unequal transition region contributions from the modified standard cell block **1002** and the non-standard cell block **1008**, e.g., 4:1 to 1:4 ratios of the respective contributions.

[0049] FIG. **11A** is a plan view **1100A** of a first standard cell block with modified top and bottom regions that include a logic operation transfer layer (NPVT\_Transform) having a continuous peripheral active region to create a modified standard cell vertically abutting a second standard cell block and FIG. **11B** is an enlarged plan view of the abutting structures. Embodiments according to FIG. **11A** include a pair of upper and lower modified standard cell blocks **1102a**, **1102b** with at least one modified abutment region **1106** vertically abutting the other modified standard cell block **1108**. FIG. **11B** is an enlarged plan view **1100B** of the abutting structures of region **1112** according to some embodiments.



[0050] The modified upper border regions utilized in modified abutment regions **1106a**, **1106b** include at least one strap active region **1108a**, **1108b** at the outer periphery of the modified abutment regions **1106** provided on the modified standard cell block **1102**. In some embodiments, the widths of the strap active region(s) are about 2-3 fin widths. The fin width value for the IC design layout is determined by the applicable design rules for the manufacturing process that is to be utilized to manufacture ICs corresponding to a final IC design layout.

[0051] Inward from the strap active regions, some embodiments of the modified upper border regions include at least one row of elongated active regions (not shown) and, inward from the continuous **1108a**, **1108b** and/or elongated active regions, at least one row of abbreviated active regions **1108c**. In some embodiments, the increased compatibility between the abutting edges of the modified standard cell blocks **1102**, **1108** permits the non-standard cell blocks to be separated by a separation distance **1116** that is on the order of about 0.1-0.03  $\mu\text{m}$ .

[0052] FIG. **12A** is a plan view **1200A** of an embodiment of a standard cell block horizontally abutting another standard cell block and FIG. **12B** is an enlarged plan view **1200B** of the abutting structures. Embodiments according to FIG. **12A** include modified standard cell blocks **1202a**, **1202b** in a horizontally abutting configuration.

[0053] FIG. **12B** is an enlarged plan view **1200B** of the abutting structures of region **1212** according to some embodiments in which the modified standard cell blocks **1202a**, **1202b** include a transition region **1216** in which at least some of the inwardly located strap active regions **1217a**, elongated active regions (not shown) and/or abbreviated active regions **1217c** are replaced by a plurality of conductive structures **1214a**, **1214b**, e.g., polysilicon structures, that are arranged perpendicularly to the remaining portions of the rows of the various active regions **1217a-b**. In some embodiments, the overall width of the transition region **1216** containing the conductive structures is between 2 and 3 times the cell poly pitch (CPP) depending upon the portion of the transition region provided on each of the modified standard cell blocks **1202a**, **1202b**. In some embodiments, the full width of the transition region **1216** is apportioned evenly between the modified standard cell blocks **1202a**, **1202b** and in other embodiments, the total width of the transition region **1216** comprises unequal transition region contributions from each of the modified standard cell blocks **1202a**, **1202b**, e.g., 4:1 to 1:4 ratios of the respective contributions.

[0054] FIG. **13** is a flowchart of a method **1300** according to some embodiments for improving the uniformity of the boundary structures between abutting structures on two adjacent cell blocks and reducing the degrading effects of the density gradient effect (DGE) resulting from mismatched structural densities in adjacent regions of the IC design layout, i.e., structures that have significantly higher or lower structural densities or structural configurations, e.g., cell heights, line widths, and/or line spacing (collectively topography) that are situated within an impact area (an area over which patterning, etching, and/or deposition effects are known or expected to occur) associated with vertical and/or horizontal abutment structures and adjacent cell regions.

[0055] Evaluating the relative structural densities and topography of peripheral structures will, in some embodiments, allow for mitigation of the DGE using one or more modified standard cell blocks. By recognizing and compensating for the DGE and other effects associated with mismatched structural densities and/or topography, the IC design layout modification and associated improvement in structural density and topographic uniformity, according to some embodiments, will improve the uniformity of the processing and/or the active structures of the resulting semiconductor device, thereby increasing the likelihood that the semiconductor device will meet or exceed design specification.

[0056] In some embodiments of methods **1300** according to FIG. **13**, in operation **1302**, a preliminary IC design layout including both standard cell blocks and other (non-standard) cellblocks is retrieved for evaluation. In operation **1304**, the preliminary IC design file is evaluated to identify vertical abutments (VA) including at least one standard cell block. Operation **1306** involves a query regarding the extent to which the vertical abutments have been successfully

identified. If fewer than all the vertical abutments have been identified, method **1300** branches from operation **1306** to operation **1308** in order to identify the next vertical abutment for evaluation. When all the vertical abutments have been identified, method **1300** branches to operation **1310** for analyzing the identified vertical abutments to identify topographic mismatches. For those identified vertical abutments that are identified as including a topographic mismatch exceeding a predetermined design threshold in operation **1310**, method **1300** proceeds to operation **1312** during which a modified standard cell block incorporating a logic operation transfer layer (NPVT\_Transform) border region having a continuous peripheral active region is selected for substitution into the IC design file. The alternative standard cell block selected in operation **1312** provides the same functionality as the standard cell block that is being replaced while simultaneously reducing the topographic mismatch between the alternative standard cell block and the abutting cell block.

[0057] In some embodiments, libraries of alternative standard cell blocks are available for a designer's selection and/or modification for use in an IC layout design. Each of the modified standard cell blocks available in a library has passed complex advanced technology rule checks (DRC) and will be useful in addressing at least one of the types of standard cell block abutment differences found in the IC layout design. Modified standard cell blocks according to some embodiments provide a range of options for matching and/or approximating one or more parameters of the adjacent active areas, e.g., gate length, gate density, and/or operating voltage (VDD) types for placement between various combinations of active areas.

[0058] In some embodiments, IC designs including, for example, decoupling capacitor (DCAP) regions, alternative standard cell blocks provide a range of options for matching and/or approximating one or more parameters of the adjacent active areas, e.g., cell height, gate length, gate density, different doping, structures, Lg, gate density, Vt and/or operating voltage (VDD)) types in the abutment region(s). Using alternative standard cell blocks according to some embodiments allows a designer to achieve better matching of poly/active area densities across the abutment regions of an IC layout design. This improved configuration matching, in turn, reduces DGE within at least the abutment regions and improves the yields and/or reliability of the resulting devices manufactured from such modified designs.

[0059] Because embodiments of the alternative standard cell blocks incorporate specific design rules for known and/or anticipated types of abutment differences, DRC update revisions and node-to-node porting are simplified and able to be made efficiently across a family or a library of alternative standard cell block designs. In some embodiments, the library of modified standard cell block designs, e.g., those designs that are modified to incorporate logic operation transfer layer (NPVT\_Transform) abutment regions having a continuous peripheral active region, will include modified standard cell blocks suitable for use in abutment regions adjacent core, input/output, and/or DCAP active areas as well as active areas utilizing different operating voltages. For example, in some embodiments IC layout designs incorporate a standard threshold voltage (SVT), a low threshold voltage (LVT), and/or an ultralow threshold voltage (ULVT) regions or standard cell blocks configured for providing structures adapted for the various threshold voltages. The configuration of the alternative standard cell blocks according to some embodiments would be modified whereby an alternative standard cell block is available for each of the types of operating voltage abutments between a first and second active area as reflected below in TABLE 1.

TABLE-US-00001 TABLE 1 Second Active Area First Active Area Operating Voltage Operating Voltage SVT LVT ULVT SVT SVT SVT/LVT SVT/ULVT LVT LVT/SVT LVT LVT/ULVT ULVT ULVT/SVT ULVT/LVT ULVT

Turning to TABLE 1, for example, if a first active area is configured for low voltage operation (LVT) and an abutting second active area is configured for ultralow voltage operation (ULVT), a modified standard cell block interposed between the first and second active areas in some embodiments would have a combination of both LVT structures and ULVT structures, i.e., a

LVT/ULVT configuration, with the modified standard cell block having an abutment region configured to be suitable adjacent both LVT and ULVT regions.

[0060] In operation **1314**, the modified IC design layout is evaluated for overall structural/device density uniformity. Operation **1316** involves a query regarding the extent to which the uniformity evaluation of operation **1314** meets a predetermined uniformity target value. If the uniformity evaluation score is below the uniformity target value, method **1300** branches back to operation **1312** to improve the selection of the alternative standard cell blocks by selectively replacing those alternative standard cell blocks defining abutments that are contributing a relatively greater share to the total reduction in the uniformity evaluation score.

[0061] For those modified IC design layouts that pass the uniformity evaluation, method **1300** includes an optional operation **1318**, in some embodiments, during which a tape out data file corresponding to the passing modified IC design layout is generated. For those modified IC design layouts for which a tape out data file is generated, the tape out data file will be used to manufacture a semiconductor device according to the passing modified IC design layout in optional operation **1320**.

[0062] In some embodiments, the modified device layout will be evaluated for structural density and topographic uniformity in the abutment regions. In those instances in which a structural density and/or topographic uniformity target value is met, the modified IC design layout will be approved for tape out and, ultimately, the optional manufacture of the corresponding IC device. In some embodiments, in those instances in which the structural density and/or topographic uniformity target value is not met, the performance of the individual alternative standard cell blocks will be evaluated to identify the lowest performing alternative standard cell blocks. These low performing alternative standard cell blocks are then modified or replaced in order to improve the overall structural density and/or topographic uniformity performance of the IC design layout.

[0063] FIG. **14** is a block diagram of an electronic process control (EPC) system **1400**, in accordance with some embodiments. Methods described herein of generating cell layout diagrams, in accordance with one or more embodiments, are implementable, for example, using EPC system **1400**, in accordance with some embodiments. In some embodiments, EPC system **1400** is a general purpose computing device including a hardware processor **1402** and a non-transitory, computer-readable storage medium **1404**. Computer-readable storage medium **1404**, amongst other things, is encoded with, i.e., stores, computer program code (or instructions) **1406**, i.e., a set of executable instructions. Execution of computer program code **1406** by hardware processor **1402** represents (at least in part) an EPC tool which implements a portion of, or all, the methods described herein in accordance with one or more (hereinafter, the noted processes and/or methods).

[0064] Hardware processor **1402** is electrically coupled to computer-readable storage medium **1404** via a bus **1418**. Hardware processor **1402** is also electrically coupled to an I/O interface **1412** by bus **1418**. A network interface **1414** is also electrically connected to hardware processor **1402** via bus **1418**. Network interface **1414** is connected to a network **1416**, so that hardware processor **1402** and computer-readable storage medium **1404** are connected to external elements via network **1416**. Hardware processor **1402** is configured to execute computer program code **1406** encoded in computer-readable storage medium **1404** in order to cause EPC system **1400** to be usable for performing a portion of, or all, the noted processes and/or methods. In one or more embodiments, hardware processor **1402** is a central processing unit (CPU), a multi-processor, a distributed processing system, an application specific integrated circuit (ASIC), and/or a suitable processing unit.

[0065] In one or more embodiments, computer-readable storage medium **1404** is an electronic, magnetic, optical, electromagnetic, infrared, and/or a semiconductor system (or apparatus or device). For example, computer-readable storage medium **1404** includes a semiconductor or solid-state memory, a magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk, and/or an optical disk. In one or more

embodiments using optical disks, computer-readable storage medium **1404** includes a compact disk-read only memory (CD-ROM), a compact disk-read/write (CD-R/W), and/or a digital video disc (DVD).

[0066] In one or more embodiments, computer-readable storage medium **1404** stores computer program code **1406** configured to cause EPC system **1400** (where such execution represents (at least in part) the EPC tool) to be usable for performing a portion of, or all, the noted processes and/or methods. In one or more embodiments, computer-readable storage medium **1404** also stores information which facilitates performing a portion of, or all, the noted processes and/or methods. In one or more embodiments, computer-readable storage medium **1404** stores process control data **1408** including, in some embodiments, control algorithms, active area data, transition cell data, uniformity algorithms, layout data, and constants, target ranges, set points, and code for enabling statistical process control (SPC) and/or model predictive control (MPC) based control of the various processes.

[0067] EPC system **1400** includes I/O interface **1412**. I/O interface **1412** is coupled to external circuitry. In one or more embodiments, I/O interface **1412** includes a keyboard, keypad, mouse, trackball, trackpad, touchscreen, and/or cursor direction keys for communicating information and commands to hardware processor **1402**.

[0068] EPC system **1400** also includes network interface **1414** coupled to hardware processor **1402**. Network interface **1414** allows EPC system **1400** to communicate with network **1416**, to which one or more other computer systems are connected. Network interface **1414** includes wireless network interfaces such as BLUETOOTH, WIFI, WIMAX, GPRS, or WCDMA; or wired network interfaces such as ETHERNET, USB, or IEEE-1364. In one or more embodiments, a portion of, or all, noted processes and/or methods, is implemented in two or more EPC systems **1400**.

[0069] EPC system **1400** is configured to receive information through I/O interface **1412**. The information received through I/O interface **1412** includes one or more of instructions, data, design rules, process performance histories, target ranges, set points, and/or other parameters for processing by hardware processor **1402**. The information is transferred to hardware processor **1402** via bus **1418**. EPC system **1400** is configured to receive information related to a user interface (UI) through I/O interface **1412**. The information is stored in computer-readable storage medium **1404** as user interface (UI) **1410**.

[0070] In some embodiments, a portion of, or all, the noted processes and/or methods is/are implemented as a standalone software application for execution by a processor. In some embodiments, a portion of, or all, the noted processes and/or methods is/are implemented as a software application that is a part of an additional software application. In some embodiments, a portion of, or all, the noted processes and/or methods is/are implemented as a plug-in to a software application. In some embodiments, at least one of the noted processes and/or methods is implemented as a software application that is a portion of an EPC tool. In some embodiments, a portion of, or all, the noted processes and/or methods is implemented as a software application that is used by EPC system **1400**.

[0071] In some embodiments, the processes are realized as functions of a program stored in a non-transitory computer readable recording medium. Examples of a non-transitory computer readable recording medium include, but are not limited to, external/removable and/or internal/built-in storage or memory unit, e.g., one or more of an optical disk, such as a DVD, a magnetic disk, such as a hard disk, a semiconductor memory, such as a ROM, a RAM, a memory card, and the like.

[0072] FIG. **15** is a block diagram of an integrated circuit (IC) manufacturing system **1500**, and an IC manufacturing flow associated therewith, in accordance with some embodiments. In some embodiments, based on a layout diagram, at least one of (A) one or more semiconductor masks or (B) at least one component in a layer of a semiconductor integrated circuit is fabricated using IC manufacturing system **1500**.

[0073] In FIG. 15, IC manufacturing system **1500** includes entities, such as a design house **1520**, a mask house **1530**, and an IC manufacturer/fabricator (“fab”) **1550**, that interact with one another in the design, development, and manufacturing cycles and/or services related to manufacturing an IC device **1560**. The entities in IC manufacturing system **1500** are connected by a communications network. In some embodiments, the communications network is a single network. In some embodiments, the communications network is a variety of different networks, such as an intranet and the Internet. The communications network includes wired and/or wireless communication channels. Each entity interacts with one or more of the other entities and provides services to and/or receives services from one or more of the other entities. In some embodiments, two or more of design house **1520**, mask house **1530**, and IC fab **1550** is owned by a single larger company. In some embodiments, two or more of design house **1520**, mask house **1530**, and IC fab **1550** coexist in a common facility and use common resources.

[0074] Design house (or design team) **1520** generates an IC design layout diagram **1522**. IC design layout diagram **1522** includes various geometrical patterns designed for an IC device **1560**. The geometrical patterns correspond to patterns of metal, oxide, or semiconductor layers that make up the various components of IC device **1560** to be fabricated. The various layers combine to form various IC features. For example, a portion of IC design layout diagram **1522** includes various IC features, such as an active region, gate electrode, source and drain, metal lines or vias of an interlayer interconnection, and openings for bonding pads, to be formed in a semiconductor substrate (such as a silicon wafer) and various material layers disposed on the semiconductor substrate. Design house **1520** implements a proper design procedure to form IC design layout diagram **1522**. The design procedure includes one or more of logic design, physical design or place and route. IC design layout diagram **1522** is presented in one or more data files having information of the geometrical patterns. For example, IC design layout diagram **1522** is expressed in a GDSII file format or DFII file format, according to some embodiments.

[0075] In some embodiments, the configuration of a modified IC design layout diagram is adjusted, such as by method **1300**, in order to improve the compatibility of abutting edges and thereby reduce the device area of the final IC design layout when compared with an unmodified IC design layout, the modified IC design layout diagram reflecting the result(s) of modifying the boundary structures and/or the positions of standard cell blocks within the IC design layout diagram.

[0076] Mask house **1530** includes mask data preparation **1532** and mask fabrication **1544**. Mask house **1530** uses IC design layout diagram **1522** to manufacture one or more masks **1545** to be used for fabricating the various layers of IC device **1560** according to IC design layout diagram **1522**. Mask house **1530** performs mask data preparation **1532**, where IC design layout diagram **1522** is translated into a representative data file (“RDF”). Mask data preparation **1532** provides the RDF to mask fabrication **1544**. Mask fabrication **1544** includes a mask writer. A mask writer converts the RDF to an image on a substrate, such as a mask (reticle) **1545** or a semiconductor wafer **1553**. The IC design layout diagram **1522** is manipulated by mask data preparation **1532** to comply with the characteristics of the mask writer and/or requirements of IC fab **1550**. In FIG. 15, mask data preparation **1532** and mask fabrication **1544** are illustrated as separate elements. In some embodiments, mask data preparation **1532** and mask fabrication **1544** are collectively referred to as mask data preparation.

[0077] In some embodiments, mask data preparation **1532** includes optical proximity correction (OPC) which uses lithography enhancement techniques to compensate for image errors, such as those that arise from diffraction, interference, other process effects and the like. OPC adjusts IC design layout diagram **1522**. In some embodiments, mask data preparation **1532** includes further resolution enhancement techniques (RET), such as off-axis illumination, sub-resolution assist features, phase-shifting masks, other suitable techniques, and the like or combinations thereof. In some embodiments, inverse lithography technology (ILT) is also used, which treats OPC as an inverse imaging problem.

[0078] In some embodiments, mask data preparation **1532** includes a mask rule checker (MRC) that checks the IC design layout diagram **1522** that has undergone processes in OPC with a set of mask creation rules which contain certain geometric and/or connectivity restrictions to ensure sufficient margins, to account for variability in semiconductor manufacturing processes, and the like. In some embodiments, the MRC modifies the IC design layout diagram **1522** to compensate for limitations during mask fabrication **1544**, which undoes part of the modifications performed by OPC in order to meet mask creation rules.

[0079] In some embodiments, mask data preparation **1532** includes lithography process checking (LPC) that simulates processing that will be implemented by IC fab **1550** to fabricate IC device **1560**. LPC simulates this processing based on IC design layout diagram **1522** to create a simulated manufactured device, such as IC device **1560**. In some embodiments, the processing parameters in LPC simulation include parameters associated with various processes of the IC manufacturing cycle, parameters associated with tools used for manufacturing the IC, and/or other aspects of the manufacturing process. LPC accounts for various factors, such as aerial image contrast, depth of focus (“DOF”), mask error enhancement factor (“MEEF”), other suitable factors, and the like or combinations thereof. In some embodiments, after a simulated manufactured device has been created by LPC, if the simulated device is not close enough in shape to satisfy design rules, OPC, and/or MRC are repeated to produce a further refined IC design layout diagram **1522**.

[0080] One of ordinary skill in the art would understand that the above description of mask data preparation **1532** has been simplified for the purposes of clarity. In some embodiments, mask data preparation **1532** includes additional features such as a logic operation (LOP) to modify the IC design layout diagram **1522** according to manufacturing rules. Additionally, the processes applied to IC design layout diagram **1522** during mask data preparation **1532** is executed in a variety of different orders, according to some embodiments.

[0081] After mask data preparation **1532** and during mask fabrication **1544**, a mask **1545** or a group of masks **1545** are fabricated based on the modified IC design layout diagram **1522**. In some embodiments, mask fabrication **1544** includes performing one or more lithographic exposures based on IC design layout diagram **1522**. In some embodiments, an electron-beam (e-beam) or a mechanism of multiple e-beams is used to form a pattern on a mask (photomask or reticle) **1545** based on the modified IC design layout diagram **1522**. In some embodiments, mask **1545** is formed in various technologies. In some embodiments, mask **1545** is formed using binary technology. In some embodiments, a mask pattern includes opaque regions and transparent regions. A radiation beam, such as an ultraviolet (UV) beam, used to expose the image sensitive material layer (e.g., photoresist) which has been coated on a wafer, is blocked by the opaque region and transmits through the transparent regions. In one example, a binary mask version of mask **1545** includes a transparent substrate (e.g., fused quartz) and an opaque material (e.g., chromium) coated in the opaque regions of the binary mask.

[0082] In another example, mask **1545** is formed using a phase shift technology. In a phase shift mask (PSM) version of mask **1545**, various features in the pattern formed on the phase shift mask are configured to have proper phase difference to enhance the resolution and imaging quality. In various examples, the phase shift mask is attenuated PSM or alternating PSM. The mask(s) generated by mask fabrication **1544** is used in a variety of processes. For example, such a mask(s) is used in an ion implantation process to form various doped regions in semiconductor wafer **1553**, in an etching process to form various etching regions in semiconductor wafer **1553**, and/or in other suitable processes.

[0083] IC fab **1550** includes wafer fabrication **1552**. IC fab **1550** is an IC fabrication business that includes one or more manufacturing facilities for the fabrication of a variety of different IC products. In some embodiments, IC fab **1550** is a semiconductor foundry. For example, according to some embodiments, a manufacturing facility for the front end fabrication of a plurality of IC products (front-end-of-line (FEOL) fabrication), while a second manufacturing facility is provided

the back end fabrication for the interconnecting and packaging of the IC products (back-end-of-line (BEOL) fabrication), and a third manufacturing facility is provided other services for the foundry business.

[0084] In some embodiments of the present disclosure, fin dimensional adjustment includes operations associated with making an array of fins across an entirety of the fin-containing functional areas of the integrated circuit, followed by modification of fin dimensions in at least one fin-containing functional area of the integrated circuit. In some embodiments of the present disclosure, the fins of different fin-containing functional areas are formed to a final fin shape or fin dimensional profile separately, in a single fin-formation manufacturing flow for each fin-containing functional area of the IC. In some embodiments, the fin dimension adjustment occurs by forming fins in a layer of fin material, or fin substrate, by applying mask layer to a top surface of the fin material, patterning the mask layer with a pattern that corresponds to the locations of fins in one or more of the fin-containing functional areas, exposing a top surface of the fin material through the mask layer, and etching the fin material to form fins in the fin substrate. In some embodiments, the fins are formed in a single functional area of the IC with a final fin dimension, the selected fin dimension (or, fin height) as described above.

[0085] A patterned layer of mask material formed on a semiconductor substrate is made of a mask material that includes one or more layers of photoresist, polyimide, silicon oxide, silicon nitride (e.g., Si.sub.3N.sub.4), SION, SiC, SiOC, mixtures, or combinations thereof. In some embodiments, masks include a single layer of mask material. In some embodiments, a mask includes multiple layers of mask materials.

[0086] In some embodiments, the mask material is patterned by exposure to an illumination source. In some embodiments, the illumination source is an electron beam source. In some embodiments, the illumination source is a lamp that emits light. In some embodiments, the light is ultraviolet light. In some embodiments, the light is visible light. In some embodiments, the light is infrared light. In some embodiments, the illumination source emits a combination of different (UV, visible, and/or infrared) light.

[0087] Subsequent to mask patterning operations, fins of areas not covered by the mask, or fins in open areas of the pattern, are etched to modify a fin dimension. In some embodiments, the etching is performed on a top surface of fins with fin sides that are completely covered by adjoining dielectric support material deposited between fins in a previous manufacturing step. Etching of top surfaces of fins is performed with plasma etching, or with a liquid chemical etch solution, according to some embodiments. The chemistry of the liquid chemical etch solution includes one or more of etchants such as citric acid (C.sub.6H.sub.8O.sub.7), hydrogen peroxide (H.sub.2O.sub.2), nitric acid (HNO.sub.3), sulfuric acid (H.sub.2SO.sub.4), hydrochloric acid (HCl), acetic acid (CH.sub.3CO.sub.2H), hydrofluoric acid (HF), buffered hydrofluoric acid (BHF), phosphoric acid (H.sub.3PO.sub.4), ammonium fluoride (NH.sub.4F) potassium hydroxide (KOH), ethylenediamine pyrocatechol (EDP), TMAH (tetramethylammonium hydroxide), or a combination thereof. In some embodiments, etching the fins is performed by exposing an upper portion of fin material, extending above a top surface of a dielectric support medium deposited between fins and recessed below a top surface of the fin height in a prior manufacturing step, to a liquid chemical etch solution comprising one or more of the liquid chemical etchants described above. An upper portion of the fin material includes a top surface and sides of the fin material.

[0088] In some embodiments, the etching process is a dry-etch or plasma etch process. Plasma etching of a substrate material is performed using halogen-containing reactive gasses excited by an electromagnetic field to dissociate into ions. Reactive or etchant gases include CF.sub.4, SF6, NF3, Cl.sub.2, CCl2F2, SiCl.sub.4, BCl.sub.2, or a combination thereof, although other semiconductor-material etchant gases are also envisioned within the scope of the present disclosure. Ions are accelerated to strike exposed fin material by alternating electromagnetic fields or by fixed bias according to methods of plasma etching that are known in the art. In some embodiments, etching

processes include presenting the exposed portions of fins of the functional area in an oxygen-containing atmosphere to oxidize an outer portion of the fin material, followed by a chemical trimming process such as plasma-etching or liquid chemical etching, as described above, to remove the oxidized semiconductor fin material and leave a modified fin behind.

[0089] In some embodiments, fin oxidation followed by chemical trimming is performed to provide greater selectivity to the fin material and to reduce a likelihood of accidental fin material removal during a manufacturing process. In some embodiments, the exposed portions of fins of the functional area are top surfaces of the fins, the fins being embedded in a dielectric support medium covering the sides of the fins. In some embodiments, the exposed portions of the fins of the functional area are top surfaces and sides of the fins that are above a top surface of the dielectric support medium, where the top surface of the dielectric support medium has been recessed to a level below the top surface of the fins, but still covering a lower portion of the sides of the fins.

[0090] IC fab **1550** uses mask(s) **1545** fabricated by mask house **1530** to fabricate IC device **1560**. Thus, IC fab **1550** at least indirectly uses IC design layout diagram **1522** to fabricate IC device **1560**. In some embodiments, semiconductor wafer **1553** is fabricated by IC fab **1550** using mask(s) **1545** to form IC device **1560**. In some embodiments, the IC fabrication includes performing one or more lithographic exposures based at least indirectly on IC design layout diagram **1522**.

Semiconductor wafer **1553** includes a silicon substrate or other proper substrate having material layers formed thereon. Semiconductor wafer **1553** further includes one or more of various doped regions, dielectric features, multilevel interconnects, and the like (formed at subsequent manufacturing steps).

[0091] Details regarding an integrated circuit (IC) manufacturing system (e.g., IC manufacturing system **1500** of FIG. **15**), and an IC manufacturing flow associated therewith are found, e.g., in U.S. Pat. No. 9,256,709, granted Feb. 9, 2016, U.S. Pre-Grant Pub. No. 2015/0278429 A1, published Oct. 1, 2015, U.S. Pre-Grant Pub. No. 2014/0040838 A1, published Feb. 6, 2014, and U.S. Pat. No. 7,260,442, granted Aug. 21, 2007, each of which are hereby incorporated, in their entireties, by reference.

[0092] FIG. **16A** is a plan view of an initial integrated circuit layout including two standard cell block regions consuming an area **1502** (dashed line) and separated by white space **1504**. FIG. **16B** is a plan view of a modified integrated circuit layout including two, vertically abutted modified standard cell block regions that allow the standard cells to be positioned more closely, thereby freeing up surface areas **1506**, **1508**, and reducing or eliminating the white space **1504** between the standard cell blocks. Some embodiments are utilized in manufacturing IC devices using processing regimes broadly referred to as N5 and N3 processes while some embodiments are used in manufacturing IC devices under less challenging process parameters.

[0093] In some embodiments, a method of designing a semiconductor device includes: analyzing, in a first layout design, a first abutment between a first cell block and a second cell block having a topographic mismatch in one or more of a cell height, a line width, or a line spacing between the first cell block and the second cell block; selecting a modified first cell block that reduces the topographic mismatch; replacing the first cell block with the modified first cell block to obtain a modified first layout design having a second abutment between the modified first cell block and the second cell block, wherein, in the modified first layout design, the second abutment includes a first abutment region having a continuous active region along a first axis parallel to an edge of the first abutment region; generating a tape-out for the modified first layout design; and manufacturing a semiconductor device according to the tape-out for the modified first layout design.

[0094] In some embodiments, the method further includes selecting the second cell block from a library of standard cell blocks. In some embodiments, the method further includes selecting a modified second cell block that reduces the topographic mismatch and a first spacing between the modified first cell block and the second cell block, the modified second cell block including a second abutment region having a continuous active region along a second axis parallel to the edge



of the first abutment; and replacing the second cell block with the modified second cell block to obtain a twice modified first layout design having a third abutment. In some embodiments, the selecting the modified first cell block includes selecting the modified first cell block to include therein a second active region parallel to and inward from the continuous active region. In some embodiments, the selecting the modified first cell block includes selecting the modified first cell block to include therein a plurality of active regions parallel to and inward from the continuous active region. In some embodiments, the selecting the modified first cell block includes selecting the modified first cell block to include therein: a first discontinuous active region having an average active region length of  $L1$ ; and a second discontinuous active region arranged inwardly from the first discontinuous active region and having an average active region length of  $L2$ , wherein  $L1 \neq L2$ . In some embodiments, the selecting the modified first cell block includes selecting the modified first cell block to include therein a plurality of active regions parallel to and inward from the continuous active region, wherein at least one of the plurality of active regions is continuous. In some embodiments, the method further includes analyzing, in the modified first layout design, the second abutment between the modified first cell block and the second cell block and, in response to identifying a topographical mismatch between the modified first cell block and the second cell block: selecting a third cell block that reduces the topographical mismatch, the third cell block including a second abutment region having a continuous active region along a second axis parallel to the edge of the second abutment; and replacing the modified first cell block with the third cell block to obtain a twice modified first layout design having a third abutment. In some embodiments, the method further includes retrieving the first modified cell block from a cell block library; and outputting the modified first layout design to a tape out process for manufacture of the semiconductor device. In some embodiments, the method further includes selecting a modified first abutment region that reduces the topographical mismatch, the modified first abutment region including a continuous active region along a first axis parallel to an abutment edge; and replacing the first abutment region with the modified first abutment region. In some embodiments, the continuous active region in the first abutment region has a width of about two to times to about three times a width of an active region fin in the modified first layout design.

[0095] In some embodiments, a semiconductor device includes: a modified first cell block; a second cell block abutting the modified first cell block relative to a first direction; a first abutment region where the second cell block abuts the modified first cell block, the first abutment region extending in a second direction perpendicular to the first direction and including a continuous active region extending in the second direction; a third cell block abutting the modified first cell block relative to the second direction; and a second abutment region where the third cell block abuts the modified first cell block, the second abutment region extending in the first direction.

[0096] In some embodiments, the modified first cell block includes the continuous active region, and the second cell block a second continuous active region extending in the second direction. In some embodiments, the first abutment region includes a second active region parallel to the continuous active region and arranged closer to a center of the modified first cell block than the continuous active region. In some embodiments, the first abutment region includes a plurality of active regions that are shorter than the second active region and are arranged closer to the center of the modified first cell block than the second active region. In some embodiments, the first abutment region includes a discontinuous active region in which a second active region and a third active region are spaced apart along the second direction, and a first end of the second active region is spaced apart from a second end of the third active region by a distance that corresponds to a length of the continuous active region. In some embodiments, the semiconductor device further includes a plurality of active regions that are shorter than the second active region and are arranged closer to the center of the modified first cell block than the second active region. In some embodiments, the semiconductor device further includes a plurality of polysilicon structures that extend in the first direction and overlap the continuous active region. In some embodiments, the first abutment region

includes a discontinuous active region in which a second active region and a third active region are spaced apart by a gap along the second direction, and at least some of the plurality of polysilicon structures are in the gap and are free of overlap with the second active region and the third active region.

[0097] In some embodiments, a method of fabricating a semiconductor device includes: forming a modified first cell block; forming a second cell block abutting the modified first cell block relative to a first direction; forming a first abutment region where the second cell block abuts the modified first cell block, wherein the forming the first abutment region includes: forming the first abutment region to extend in a second direction perpendicular to the first direction, and forming a continuous active region to extend in the second direction; forming a third cell block abutting the modified first cell block relative to the second direction; and forming a second abutment region to extend in the first direction where the third cell block abuts the modified first cell block.

[0098] The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled 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 skilled 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 method of designing a semiconductor device, the method comprising: analyzing, in a first layout design, a first abutment between a first cell block and a second cell block having a topographic mismatch in one or more of a cell height, a line width, or a line spacing between the first cell block and the second cell block; selecting a modified first cell block that reduces the topographic mismatch; replacing the first cell block with the modified first cell block to obtain a modified first layout design having a second abutment between the modified first cell block and the second cell block, wherein, in the modified first layout design, the second abutment includes a first abutment region having a continuous active region along a first axis parallel to an edge of the first abutment region; generating a tape-out for the modified first layout design; and manufacturing a semiconductor device according to the tape-out for the modified first layout design.
2. The method of claim 1, further comprising: selecting the second cell block from a library of standard cell blocks.
3. The method of claim 1, further comprising: selecting a modified second cell block that reduces the topographic mismatch and a first spacing between the modified first cell block and the second cell block, the modified second cell block including a second abutment region having a continuous active region along a second axis parallel to the edge of the first abutment; and replacing the second cell block with the modified second cell block to obtain a twice modified first layout design having a third abutment.
4. The method of claim 1, wherein: the selecting the modified first cell block includes: selecting the modified first cell block to include therein a second active region parallel to and inward from the continuous active region.
5. The method of claim 1, wherein: the selecting the modified first cell block includes: selecting the modified first cell block to include therein a plurality of active regions parallel to and inward from the continuous active region.
6. The method of claim 5, wherein: the selecting the modified first cell block includes: selecting the modified first cell block to include therein: a first discontinuous active region having an average active region length of  $L_{sub.1}$ ; and a second discontinuous active region arranged inwardly from

the first discontinuous active region and having an average active region length of  $L_{sub.2}$ , wherein  $L_{sub.1} \neq L_{sub.2}$ .

**7.** The method of claim 1, wherein: the selecting the modified first cell block includes: selecting the modified first cell block to include therein a plurality of active regions parallel to and inward from the continuous active region, wherein at least one of the plurality of active regions is continuous.

**8.** The method of claim 1, further comprising: analyzing, in the modified first layout design, the second abutment between the modified first cell block and the second cell block and, in response to identifying a topographical mismatch between the modified first cell block and the second cell block: selecting a third cell block that reduces the topographical mismatch, the third cell block including a second abutment region having a continuous active region along a second axis parallel to the edge of the second abutment; and replacing the modified first cell block with the third cell block to obtain a twice modified first layout design having a third abutment.

**9.** The method of claim 1, further comprising: retrieving the first modified cell block from a cell block library; and outputting the modified first layout design to a tape out process for manufacture of the semiconductor device.

**10.** The method of claim 1, further comprising: selecting a modified first abutment region that reduces the topographical mismatch, the modified first abutment region including a continuous active region along a first axis parallel to an abutment edge; and replacing the first abutment region with the modified first abutment region.

**11.** The method of claim 1, wherein: the continuous active region in the first abutment region has a width of about two to times to about three times a width of an active region fin in the modified first layout design.

**12.** A semiconductor device comprising: a modified first cell block; a second cell block abutting the modified first cell block relative to a first direction; a first abutment region where the second cell block abuts the modified first cell block, the first abutment region extending in a second direction perpendicular to the first direction and including a continuous active region extending in the second direction; a third cell block abutting the modified first cell block relative to the second direction; and a second abutment region where the third cell block abuts the modified first cell block, the second abutment region extending in the first direction.

**13.** The semiconductor device of claim 12, wherein: the modified first cell block includes the continuous active region, and the second cell block a second continuous active region extending in the second direction.

**14.** The semiconductor device of claim 12, wherein: the first abutment region includes a second active region parallel to the continuous active region and arranged closer to a center of the modified first cell block than the continuous active region.

**15.** The semiconductor device of claim 14, wherein: the first abutment region includes a plurality of active regions that are shorter than the second active region and are arranged closer to the center of the modified first cell block than the second active region.

**16.** The semiconductor device of claim 12, wherein: the first abutment region includes a discontinuous active region in which a second active region and a third active region are spaced apart along the second direction, and a first end of the second active region is spaced apart from a second end of the third active region by a distance that corresponds to a length of the continuous active region.

**17.** The semiconductor device of claim 16, further comprising: a plurality of active regions that are shorter than the second active region and are arranged closer to the center of the modified first cell block than the second active region.

**18.** The semiconductor device of claim 12, further comprising: a plurality of polysilicon structures that extend in the first direction and overlap the continuous active region.

**19.** The semiconductor device of claim 18, wherein: the first abutment region includes a discontinuous active region in which a second active region and a third active region are spaced

apart by a gap along the second direction, and at least some of the plurality of polysilicon structures are in the gap and are free of overlap with the second active region and the third active region.

**20.** A method of fabricating a semiconductor device, the method comprising: forming a modified first cell block; forming a second cell block abutting the modified first cell block relative to a first direction; forming a first abutment region where the second cell block abuts the modified first cell block, wherein the forming the first abutment region includes: forming the first abutment region to extend in a second direction perpendicular to the first direction, and forming a continuous active region to extend in the second direction; forming a third cell block abutting the modified first cell block relative to the second direction; and forming a second abutment region to extend in the first direction where the third cell block abuts the modified first cell block.

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