



- (51) International Patent Classification:
H01L 27/088 (2006.01) *H01L 29/423* (2006.01)
H01L 29/417 (2006.01) *H01L 21/768* (2006.01)
- (21) International Application Number:
PCT/US2017/025463
- (22) International Filing Date:
31 March 2017 (31.03.2017)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
62/316,518 31 March 2016 (31.03.2016) US
62/316,519 31 March 2016 (31.03.2016) US
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: BODY CONTACTS FOR FIELD-EFFECT TRANSISTORS

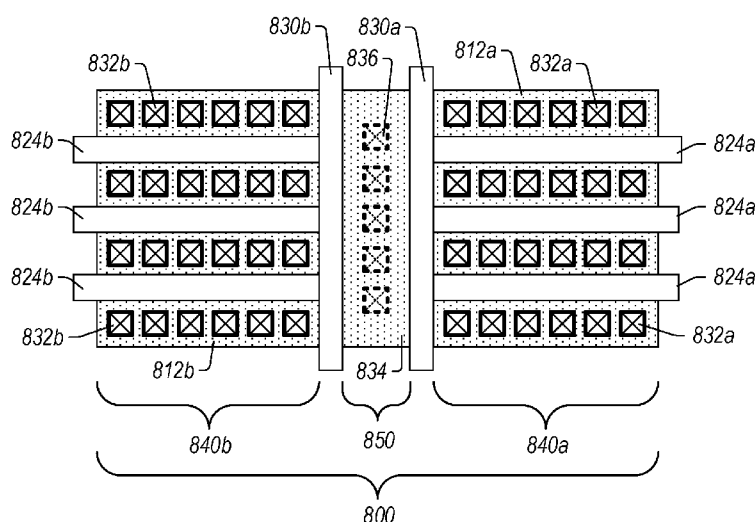


FIG. 9

(57) Abstract: Field-effect transistor (FET) devices are described herein that include one or more body contacts implemented near source, gate, drain (S/G/D) assemblies to improve the influence of a voltage applied at the body contact on the S/G/D assemblies. For example, body contacts can be implemented between S/G/D assemblies rather than on the ends of such assemblies. This can advantageously improve body contact influence on the S/G/D assemblies while maintaining a targeted size for the FET device.



Declarations under Rule 4.17:

Published:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))* — *with international search report (Art. 21(3))*

BODY CONTACTS FOR FIELD-EFFECT TRANSISTORS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Prov. App. No. 62/316,518 filed March 31, 2016, entitled “Body Contacts for Field-Effect Transistors,” and U.S. Prov. App. No. 62/316,519 filed March 31, 2016, entitled “Body Contacts for Field-Effect Transistors,” each of which is expressly incorporated by reference herein in its entirety for all purposes.

BACKGROUND

Field

[0002] The present disclosure generally relates to field-effect transistor (FET) devices and more particularly to body contacts for such FET devices.

Description of Related Art

[0003] In electronics applications, field-effect transistors (FETs) can be utilized as switches and in amplifiers. Switches can allow, for example, routing of radio-frequency (RF) signals in wireless devices. Amplifiers can amplify signals for transmission or amplify received signals.

SUMMARY

[0004] According to a number of implementations, the present disclosure relates to a field-effect transistor (FET) that includes a first assembly of source, gate, and drain implemented on a first active region; a second assembly of source, gate, and drain implemented on a second active region; and a first body contact implemented between the first assembly and the second assembly.

[0005] In some embodiments, the FET includes a silicon-on-insulator (SOI) substrate. In some embodiments, the first assembly and the second assembly are dimensioned substantially the same and the first body contact is positioned at approximately the center of the FET.

[0006] In some embodiments, the FET also includes a third assembly of source, gate, and drain implemented on a third active region, and a second body contact implemented between the second assembly and the third assembly. In further embodiments, the first assembly and the third assembly are dimensioned substantially the same such that the first body contact and the second body contact are positioned substantially symmetrically about a center line of the FET.

[0007] In some embodiments, each of the first and second assemblies of respective source, gate, and drain is implemented in a finger configuration with gate fingers extending in a direction to provide a folded T-shaped body contact configuration for the first body contact and the gate fingers of the first and second assemblies. In further embodiments, the finger configuration of each of the first and second assemblies results in source and drain fingers being interleaved with the gate fingers. In yet further embodiments, the source fingers and the drain fingers are arranged in alternating rows. In yet further embodiments, a particular source finger of the first assembly is electrically connected to a source finger of the second assembly that is positioned on the same row as the particular source finger of the first assembly. In yet further embodiments, a particular drain finger of the first assembly is electrically connected to a drain finger of the second assembly that is positioned on the same row as the particular drain finger of the first assembly. In further embodiments, a particular source finger of the first assembly is electrically connected to a source finger of the second assembly that is offset by one row from the particular source finger of the first assembly. In yet further embodiments, a particular drain finger of the first assembly is electrically connected to a drain finger of the second assembly that is offset by one row from the particular drain finger of the first assembly.

[0008] In some embodiments, the first body contact further includes a first connecting metal extending along a width of the first body contact on a first side and a second connecting metal extending along a width of the first body contact on a second side opposite the first side. In further embodiments, a first plurality of gate fingers electrically coupled to the first connecting metal that extends away from the first connecting metal over the first active region and a second plurality of gate fingers electrically coupled to the second connecting metal that extends away from the

second connecting metal over the second active region. In yet further embodiments, the FET also includes a third connecting metal that electrically couples the first connecting metal and the second connecting metal to electrically connect the first plurality of gate fingers and the second plurality of gate fingers.

[0009] According to a number of implementations, the present disclosure relates to a radio-frequency (RF) module that includes a packaging substrate configured to receive a plurality of devices. The RF module also includes a die mounted on the packaging substrate, the die including a field-effect transistor (FET) having a first assembly of source, gate, and drain implemented on a first active region, the FET further including a second assembly of source, gate, and drain implemented on a second active region, the FET further including a body contact implemented between the first assembly and the second assembly.

[0010] In some embodiments, the RF module is a switch module. In some embodiments, the die is a silicon-on-insulator (SOI) die.

[0011] According to a number of implementations, the present disclosure relates to a wireless device that includes a transceiver configured to process radio-frequency (RF) signals. The wireless device also includes an RF module in communication with the transceiver, the RF module including a switching device having a field-effect transistor (FET), the FET including a first assembly of source, gate, and drain implemented on a first active region, the FET further including a second assembly of source, gate, and drain implemented on a second active region, the FET further including a body contact implemented between the first assembly and the second assembly. The wireless device also includes an antenna in communication with the RF module, the antenna configured to facilitate transmitting and/or receiving of the RF signals.

[0012] In some embodiments, the RF module is a switch module.

[0013] According to a number of implementations, the present disclosure relates to a field-effect transistor (FET) that includes an assembly of source, gate, and drain implemented on an active region; a first body contact implemented on a first side of the assembly; and a second body contact implemented on a second side of the assembly, the second side opposite the first side of the assembly.

[0014] In some embodiments, the FET also includes a plurality of gate fingers, a first connecting metal, and a second connecting metal that together form a gate contact for the FET device. In further embodiments, the plurality of gate fingers is coupled to the first connecting metal and to the second connecting metal. In yet further embodiments, the first connecting metal is implemented between the first body contact and the assembly and the second connecting metal is implemented between the second body contact and the assembly. In some embodiments, the first active region of the assembly includes a plurality of conductive features in rows between the plurality of gate fingers to form alternating strips of source and drain. In further embodiments, the conductive features include conductive vias.

[0015] In some embodiments, each of the first body contact and the second body contact includes a plurality of conductive features.

[0016] According to a number of implementations, the present disclosure relates to a method for fabricating a radio-frequency (RF) device, the method including forming a field-effect transistor (FET) over a substrate layer; electrically connecting the substrate layer to a substrate node; and coupling a non-grounding circuit to the substrate node to adjust RF performance of the FET.

[0017] According to a number of implementations, the present disclosure relates to a method for fabricating a field-effect transistor (FET), the method including forming or providing a substrate; implementing a first assembly of source, gate, and drain on a first active region of the substrate; implementing a second assembly of source, gate, and drain on a second active region of the substrate; and forming a first body contact between the first assembly and the second assembly.

[0018] In some embodiments, the substrate is a silicon-on-insulator (SOI) substrate.

[0019] According to a number of implementations, the present disclosure relates to a method for fabricating a radio-frequency (RF) device, the method includes forming a field-effect transistor (FET) using the method of the above implementations; electrically connecting the substrate to a substrate node; and coupling a non-grounding circuit to the substrate node to adjust RF performance of the FET.

[0020] According to a number of implementations, the present disclosure relates to a field-effect transistor (FET) that includes a first assembly of source, gate, and drain implemented on a first active region, the first assembly having a first width and a first length; a second assembly of source, gate, and drain implemented on a second active region, the second assembly having a second width and a second length, such that the first width is greater than the second width and the first length is not equal to the second length; and a body contact implemented between the first assembly and the second assembly such that the body contact is away from a center of the FET.

[0021] In some embodiments, the FET includes a silicon-on-insulator (SOI) substrate. In some embodiments, the FET also includes a plurality of gate fingers, a first connecting metal, and a second connecting metal that together form a gate contact for the FET device. In further embodiments, the first active region of the assembly includes a plurality of conductive features in rows between the plurality of gate fingers to form alternating strips of source and drain.

[0022] In some embodiments, the body contact further includes a first connecting metal extending along a width of the body contact on a first side and a second connecting metal extending along a width of the body contact on a second side opposite the first side. In further embodiments, the FET also includes a first plurality of gate fingers electrically coupled to the first connecting metal that extends away from the first connecting metal over the first active region and a second plurality of gate fingers electrically coupled to the second connecting metal that extends away from the second connecting metal over the second active region, the number of gate fingers of the first plurality of gate fingers being different from the number of gate fingers of the second plurality of gate fingers.

[0023] In some embodiments, each of the first and second assemblies of respective source, gate, and drain is implemented in a finger configuration with gate fingers extending in a direction to provide a folded T-shaped body contact configuration for the first body contact and the gate fingers of the first and second assemblies.

[0024] According to a number of implementations, the present disclosure relates to a field-effect transistor (FET) that includes a first assembly of source, gate, and drain implemented on a first active region; a second assembly of source, gate, and drain implemented on a second active region, the second assembly aligned with the first assembly in a first row; a third assembly of source, gate, and drain implemented on a second active region, the third assembly aligned with the first assembly in a first column; a fourth assembly of source, gate, and drain implemented on a second active region, the fourth assembly aligned with the second assembly in a second column and with the third assembly in a second row; and a body contact assembly implemented between the first assembly, the second assembly, the third assembly, and the fourth assembly.

[0025] In some embodiments, the FET includes a silicon-on-insulator (SOI) substrate. In some embodiments, the body contact assembly is positioned between the first row and the second row and between the first column and the second column. In further embodiments, the body contact assembly forms a cross shape.

[0026] In some embodiments, the body contact assembly includes a first body contact implemented between the first and second assemblies and a second body contact implemented between the third and fourth assemblies. In some embodiments, the body contact assembly includes a first body contact implemented between the first and third assemblies and a second body contact implemented between the second and fourth assemblies. In some embodiments, the body contact assembly includes a first body contact implemented between the first and second assemblies, a second body contact implemented between the third and fourth assemblies, a third body contact implemented between the first and third assemblies, and a fourth body contact implemented between the second and fourth assemblies.

[0027] In some embodiments, each of the first, second, third, and fourth assemblies of respective source, gate, and drain is implemented in a finger configuration with gate fingers extending over the first, second, third, and fourth active regions to provide alternating rows of source and drain interleaved with the gate fingers. In some embodiments, the first assembly has a first width and a first length and the second assembly has a second width and a second length such that the first

width is greater than the second width. In further embodiments, the first length is greater than the second length.

[0028] According to a number of implementations, the present disclosure relates to a radio-frequency (RF) module that includes a packaging substrate configured to receive a plurality of devices. The RF module also includes a die mounted on the packaging substrate, the die including a field-effect transistor (FET) having a first assembly of source, gate, and drain implemented on a first active region, the first assembly having a first width and a first length, the die further including a second assembly of source, gate, and drain implemented on a second active region, the second assembly having a second width and a second length, such that the first width is greater than the second width and the first length is not equal to the second length, and the die further including a body contact implemented between the first assembly and the second assembly such that the body contact is away from a center of the FET.

[0029] In some embodiments, the RF module is a switch module. In some embodiments, the die is a silicon-on-insulator (SOI) die.

[0030] For purposes of summarizing the disclosure, certain aspects, advantages and novel features have been described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment. Thus, one or more of the disclosed features may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. 1 illustrates a terminal representation of a FET having nodes associated with a gate, a source, a drain and a body.

[0032] FIG. 2 illustrates a FET having a body contact configuration as well as a substrate node.

[0033] FIGS. 3A and 3B respectively illustrate side sectional and plan views of an example SOI FET device having an active FET implemented over a substrate such as a silicon substrate associated with a handle wafer.

[0034] FIG. 4 illustrates an example of a FET device having a T-shaped body contact configuration.

[0035] FIG. 5 illustrates a block diagram of the FET of FIG. 4.

[0036] FIG. 6 illustrates an example of a FET device having an H-shaped body contact configuration.

[0037] FIG. 7 illustrates a block diagram of the FET of FIG. 6.

[0038] FIG. 8 illustrates a block diagram of a FET device having a folded T-shaped body contact configuration.

[0039] FIG. 9 illustrates an example configuration of the FET device of FIG. 8.

[0040] FIG. 10 illustrates a block diagram of a FET device having a double-folded T-shaped body contact configuration.

[0041] FIG. 11 illustrates an example configuration of the FET device of FIG. 10.

[0042] FIG. 12 illustrates an example configuration of a FET device with source and drain connections that alternate rows in a folded T-shaped body contact configuration.

[0043] FIG. 13 illustrates an example configuration of a FET device with source and drain connections that alternate rows in a double-folded T-shaped body contact configuration.

[0044] FIG. 14 illustrates an example configuration of a FET device with source and drain connections that connect offset rows in a folded T-shaped body contact configuration.

[0045] FIG. 15 illustrates an example configuration of a FET device with source and drain connections that connect offset rows in a double-folded T-shaped body contact configuration.

[0046] FIG. 16 illustrates an example configuration of a FET device wherein an active region has been shifted.

[0047] FIG. 17 illustrates an example configuration of a FET device wherein a polysilicon contact has been shifted.

[0048] FIG. 18 illustrates a block diagram of a non-symmetric FET device wherein source, gate, drain assemblies have different design parameters.

[0049] FIG. 19 illustrates a block diagram of a FET device that arranges source, gate, drain assemblies in two dimensions separated by one or more body contacts.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

[0050] The headings provided herein, if any, are for convenience only and do not necessarily affect the scope or meaning of the claimed invention.

[0051] Disclosed herein are various examples related to body contacts for field-effect transistors (FETs). FETs, such as those having silicon-on-insulator (SOI) process technology, are utilized in many radio-frequency (RF) circuits, including those involving high performance, low loss, high linearity switches. In such RF switching circuits, performance advantage typically results from building a transistor in silicon, which sits on an insulator such as an insulating buried oxide (BOX). The BOX typically sits on a handle wafer, typically silicon, but can be glass, borosilicon glass, fused quartz, sapphire, silicon carbide, or any other electrically-insulating material.

[0052] In various examples herein, FETs are sometimes described in the context of such SOI technology. However, it will be understood that one or more features of the present disclosure can also be implemented in other types of FETs.

[0053] FIG. 1 illustrates a terminal representation of a FET 100 having nodes associated with a gate, a source, a drain and a body. Examples related to contacts for such a body are described herein in greater detail.

[0054] FIG. 2 illustrates that, in some embodiments, a FET 100 having a body contact configuration as described herein can also include a substrate node. Among others, U.S. Pat. Pub. No. 2016/0322385 published Nov. 3, 2016 and entitled "Substrate bias for field-effect transistor devices," which is expressly incorporated herein by reference in its entirety, discloses additional details about how such a substrate node can be biased and/or coupled to one or more other nodes of the

transistor to, for example, improve both linearity and loss performance of the transistor.

[0055] U.S. Pat. Pub. No. 2016/0322385 also discloses examples of how FET devices having one or more features as described herein can be fabricated as wafers, as well as various applications that utilize such FET devices. U.S. Pat. Pub. No. 2016/0322385 also discloses examples of various products that can include such FET devices.

[0056] FIGS. 3A and 3B respectively illustrate side sectional and plan views of an example SOI FET device 10 having an active FET implemented over a substrate such as a silicon substrate associated with a handle wafer 16. Although described in the context of such a handle wafer, it will be understood that the substrate does not necessarily need to have functionality associated with a handle wafer.

[0057] An insulator layer such as a BOX layer 14 can be formed over the handle wafer 16, and the active FET can be formed based on an active silicon device 12 over the BOX layer 14. In various examples described herein, and as illustrated in FIGS. 3A and 3B, the active FET can be configured as an NPN or PNP device.

[0058] In the example of FIGS. 3A and 3B, terminals for the gate 24, source 20, drain 22 and body 26 can be configured and provided to allow operation of the FET. It will be understood that in some embodiments, the source and the drain can be interchanged.

[0059] Referring to FIGS. 3A and 3B, a contact feature 28 provides an electrical contact with the body 26. It is noted that in the example of FIGS. 3A and 3B, such a body contact feature 28 is located at one end of the FET device 10.

[0060] In general, a body contact is typically utilized to control a voltage potential associated with the FET body. If the body contact is implemented at an end of a given FET device, such as in the example of FIGS. 3A and 3B, such voltage controlling influence provided by the body contact may weaken significantly at locations relatively far away from the body contact.

[0061] For example, FIG. 4 illustrates an example of a FET device 400 having a T-shaped body contact configuration. More particularly, a plurality of conductive features 436 such as conductive vias can be implemented on a region of

a body 434 to generally form a body contact 450. In the example of FIG. 4, such a body contact 450 generally forms a “T” shape along with the direction of a plurality of gate fingers 424.

[0062] In the example of FIG. 4, the gate fingers 424 and a connecting metal 430 can collectively form a gate contact for the FET device 400. Portions of an active region 412 between the gate fingers 424 can be provided with a plurality of conductive features 432 such as conductive vias to form alternating strips of source and drain for the FET device 400.

[0063] In the example of FIG. 4, the foregoing configuration generally results in an assembly of source, gate and drain generally occupying a region indicated as 440, and the body contact occupying a region indicated as 450. To facilitate the description herein, the region 440 may be referred to as an assembly of source, gate and drain, or simply as S/G/D, an S/G/D region, or an S/G/D assembly. Similarly, the region 450 may be referred to herein as a body contact, a body, or the like.

[0064] FIG. 5 illustrates a block diagram of the example FET device 400 of FIG. 4. Such a FET device can have an overall dimension of $D1 \times D2$. The S/G/D region 440 has a width of $W0$, and a length of $L0$. The body contact 450 can be positioned on one end of the width ($W0$) dimension.

[0065] Depicted in the S/G/D region 440 are examples of influence contour lines 542, 544 that can result from, for example, application of a voltage at the body contact 450. Generally, such an influence from the body contact 450 decreases as distance increases. Accordingly, the body contact influence in a first example region between the body contact 450 and the first influence contour line 542 is generally stronger than the body contact influence in a second example region between the first influence contour line 542 and the second influence contour line 544. Similarly, the body contact influence beyond the second influence contour line 544 is generally weaker than the body contact influence in the second region. Accordingly, a relatively weak control of the body can result in FET devices such as that of FIGS. 4 and 5. For example, the region to the left of the second influence contour line 544 (when viewed

as depicted in FIG. 5) can have a relatively weak body control when compared to the region to the right of the first influence contour line 542.

[0066] FIGS. 6 and 7 illustrate another example FET device 600 having a configuration similar to the example FET device 400 of FIGS. 4 and 5, but with an additional body contact implemented on the opposite end of an S/G/D region 640. More particularly, the S/G/D region 640 can include a plurality of gate fingers 624, and strips of source and drain about such gate fingers. The gate fingers 624 can be connected by first and second connecting metals 630a, 630b to form a gate contact for the FET device 600.

[0067] A first body contact 650a can be implemented on the first end of the FET device 600 (e.g., the right side in the example FET device 600). Similarly, a second body contact 650b can be implemented on the second end of the FET device 600. Accordingly, the two body contacts 650a, 650b and the direction of the gate fingers 624 generally form an “H” shape.

[0068] To merely facilitate the description of the FET device 600, suppose that the S/G/D region 640 is dimensioned ($L_0 \times W_0$) similar to the example of FIGS. 4 and 5. In such a configuration, the first body contact 650a can exert its influence as depicted by first and second influence contour lines 742a, 744a. Similarly, the second body contact 650b can exert its influence as depicted by first and second influence contour lines 742b, 744b.

[0069] Accordingly, the weak body contact influence region (e.g., on the left side) in the example of FIGS. 4 and 5 is now strongly influenced by the second body contact 650b. However, such a dual body contact configuration involves addition of the second body contact. Still assuming the same S/G/D region dimensions ($L_0 \times W_0$) among the examples of FIGS. 4 and 5 and FIGS. 6 and 7, such a second body contact may increase the overall dimensions of the FET device 600. For example, the D_2 dimension of the example FET device of FIGS. 4 and 5 is increased to a dimension of D_3 .

[0070] In some embodiments, a FET device can include a body contact that can be implemented between a first S/G/D region and a second S/G/D region. Such a configuration can address at least some of the foregoing issues described with

reference to FIGS. 4-7, as well as provide additional advantageous features described herein.

[0071] FIG. 8 illustrates a block diagram of a FET device 800 having a body contact 850 implemented between a first S/G/D assembly 840a implemented on a first active region 812a and a second S/G/D assembly 840b implemented on a second active region 812b. The first assembly 840a and the second assembly 840b can be dimensioned such that the body contact 850 is positioned so that it bridges the center of the FET device 800. In some embodiments, the body contact 850 can be positioned at approximately the center of the FET device 800. Such an arrangement of the first S/G/D assembly 840a, the body contact 850, and the second S/G/D assembly 840b can be along a direction of gate fingers 824a, 824b. An example of such an arrangement is illustrated in FIG. 9.

[0072] In the example of FIG. 9, the body contact 850 includes a plurality of conductive features 836 implemented to provide an electrical contact with a body 850. The first S/G/D assembly 840a includes a plurality of gate fingers 824a implemented over a first active region 812a to define strips or rows of the first active region 812a. A plurality of conductive features 832a are implemented for such strips to form source and drains. When connected appropriately such strips with corresponding conductive features can function as alternating source and drain strips or rows. The gate fingers 824a of the first S/G/D assembly 840a can be interconnected by a connecting metal 830a.

[0073] Similarly, the second S/G/D assembly 840b includes a plurality of gate fingers 824b implemented over a second active region 812b to define strips or rows of the second active region 812b. A plurality of conductive features 832b are implemented for such strips to form source and drains. When connected appropriately such strips with corresponding conductive features can function as alternating source and drain strips. The gate fingers 824b of the second S/G/D assembly 840b can be interconnected by a connecting metal 830b.

[0074] The connecting metal 830a for the first gate fingers 824a and the connecting metal 830b for the second gate fingers 824b may or may not be interconnected. In the example of FIG. 9, the conductive features 836 associated with

the body contact 850 and the conductive features 832a, 832b associated with the source and drain strips can include, for example, conductive vias, conductive trenches, or some combination thereof.

[0075] The following observations can be made comparing the example of FIGS. 8 and 9 with the example of FIGS. 4 and 5. Merely for the purpose of such a comparison, suppose that the length dimension of each of the first and second S/G/D assemblies 840a, 840b of FIGS. 8 and 9 is L_0 , approximately the same as that of the S/G/D assembly 440 of FIGS. 4 and 5. Further, suppose that the overall width dimension of the first S/G/D assembly 840a, the body contact 850, and the second S/G/D assembly 840b ($W_1 + \text{body contact width} + W_1$) of FIGS. 8 and 9 is similar to the overall width dimension of the body contact 450 and the S/G/D assembly 440 ($\text{body contact width} + W_0$) of FIGS. 4 and 5. In such a comparison, the width W_1 can be approximately half of the width W_0 .

[0076] In such a configuration of FIGS. 8 and 9, it is apparent that most of each of the first and second S/G/D assemblies 840a, 840b is strongly influenced by the common body contact 850. More particularly, the first influence contour line 842a on the right side of the body contact 850 covers much of the first S/G/D assembly 840a. Similarly, the first influence contour line 842b on the left of the body contact 850 covers much of the second S/G/D assembly 840b.

[0077] In the foregoing comparison of the FET device 400 of FIGS. 4 and 5 and the FET device 800 of FIGS. 8 and 9, one can see that improved body contact influence can be obtained with the configuration of FIGS. 8 and 9 while utilizing a single body contact and maintaining a similar area for S/G/D functionality.

[0078] The following observations can be made when the example of FIGS. 8 and 9 is compared to the example of FIGS. 6 and 7. Merely for the purpose of such a comparison, suppose again that the length dimension of each of the first and second S/G/D assemblies 840a, 840b of FIGS. 8 and 9 is L_0 , approximately same as that of the S/G/D assembly 640 of FIGS. 6 and 7. Further, suppose that the overall width dimension of the first S/G/D assembly 840a, the body contact 850, and the second S/G/D assembly 840b is $W_1 + \text{body contact width} + W_1$ in FIGS. 8 and 9, and that the overall width dimension of the first body contact 650a, the S/G/D assembly

640, and the second body contact 650b is body contact width + W_0 + body contact width in FIGS. 6 and 7.

[0079] In such a comparison, if the width W_1 is assumed to be approximately half of the width W_0 , the foregoing overall width dimension in the example of FIGS. 6 and 7 is greater than the overall width dimension in the example of FIGS. 8 and 9 by approximately one body contact width. Accordingly, one can see that while the body contact influence is relatively strong in both examples (of FIGS. 6 and 7 and of FIGS. 8 and 9), the configuration in the example of FIGS. 8 and 9 can achieve a relatively strong influence with one less body contact and less overall area.

[0080] To facilitate the discussion herein, the example configuration of FIGS. 8 and 9 can be referred to as a folded configuration, with the common body contact 850 generally defining a fold line. Such a common body contact forms a T-shaped configuration with the first gate fingers 824a. The same common body contact 850 also forms a T-shaped configuration with the second gate fingers 824b. Accordingly, the example configuration of FIGS. 8 and 9 can also be referred to as a folded T-shaped body contact configuration. For example, the first gate fingers 824a and the second gate fingers 824b extend in a direction substantially perpendicular to the respective connecting metals 830a, 830b, forming the T-shaped configuration. The configuration of the respective gate fingers 824a, 824b also results in source and drain fingers being interleaved with the gate fingers 824a, 824b on each of the first assembly 840a and the second assembly 840b. In some embodiments, the source and drain fingers of the respective assemblies 840a, 840b are arranged in alternating strips or rows.

[0081] FIGS. 10 and 11 illustrate that, in some embodiments, two body contacts can be implemented within a FET device 1000. A first body contact 1050a can be implemented between a first S/G/D assembly 1040a implemented on a first active region 1012a and a second S/G/D assembly 1040b implemented on a second active region 1012b, and a second body contact 1050b can be implemented between the second S/G/D assembly 1040b and a third S/G/D assembly 1040c implemented on a third active region 1012c. In some embodiments, the first assembly 1040a and the third assembly 1040c are dimensioned substantially the same such that the first

body contact 1050a and the second body contact 1050b are positioned substantially symmetrically about a center line of the FET device 1000.

[0082] The first body contact 1050a includes a plurality of first conductive features 1036a implemented to provide an electrical contact with a first body 1034a. Similarly, the second body contact 1050b includes a plurality of second conductive features 1036b implemented to provide an electrical contact with a second body 1034b.

[0083] Referring to FIG. 11, the first S/G/D assembly 1040a includes a plurality of gate fingers 1024a implemented over a first active region 1012a to define strips or rows of the first active region 1012a. A plurality of conductive features 1032a can be implemented for such strips to form source and drains. When connected appropriately, such strips with corresponding conductive features can function as alternating source and drain strips or rows. The gate fingers 1024a of the first S/G/D assembly 1040a can be interconnected by a connecting metal 1030a.

[0084] The second S/G/D assembly 1040b includes a plurality of gate fingers 1024b implemented over a second active region 1012b to define strips or rows of the second active region 1012b. A plurality of conductive features 1032b can be implemented for such strips or rows to form source and drains. When connected appropriately such strips with corresponding conductive features can function as alternating source and drain strips or rows. The gate fingers 1024b of the second S/G/D assembly 1040b can be interconnected by a connecting metal 1030b on one end and a connecting metal 1030c on the other end.

[0085] The third S/G/D assembly 1040c includes a plurality of gate fingers 1024c implemented over a third active region 1012c to define strips or rows of the third active region 1012c. A plurality of conductive features 1032c can be implemented for such strips or rows to form source and drains. When connected appropriately such strips with corresponding conductive features can function as alternating source and drain strips or rows. The gate fingers 1024c of the third S/G/D assembly 1040c can be interconnected by a connecting metal 1030d.

[0086] In the example of FIG. 11, the connecting metal 1030a for the first gate fingers 1024a and the connecting metal 1030b for the second gate fingers 1024b

may or may not be interconnected. Similarly, the connecting metal 1030c for the second gate fingers 1024b and the connecting metal 1030d for the third gate fingers 1024c may or may not be interconnected.

[0087] In the example of FIG. 11, the conductive features 1036a, 1036b associated with the first and second body contacts 1050a, 1050b, and the conductive features 1032a, 1032b, 1032c associated with the source and drain strips can include, for example, conductive vias, conductive trenches, or some combination thereof.

[0088] The following observations can be made when comparing the example of FIGS. 10 and 11 with the example of FIGS. 6 and 7. Merely for the purpose of such a comparison, suppose that the length dimension of each of the first, second and third S/G/D assemblies 1040a, 1040b, 1040c of FIGS. 10 and 11 is L_0 , approximately the same as that of the S/G/D assembly 40 of FIGS. 6 and 7. Further, suppose that the overall width dimension of the first S/G/D assembly 1040a, the first body contact 1050a, the second S/G/D assembly 1040b, the second body contact 1050b, and the third S/G/D assembly 1040c ($W_2 + \text{body contact width} + 2 \times W_2 + \text{body contact width} + W_2$) of FIGS. 10 and 11 is similar to the overall width dimension of the first body contact 650a, the S/G/D assembly 640, and the second body contact 650b ($\text{body contact width} + W_0 + \text{body contact width}$) of FIGS. 6 and 7. In such a comparison, the width W_2 can be approximately a quarter of the width W_0 .

[0089] In such a configuration of FIGS. 10 and 11, the farthest distance from a body contact (e.g., body contacts 1050a, 1050b) to any location on the S/G/D assemblies (e.g., S/G/D assemblies 1040a, 1040b, 1040c) is approximately W_2 (e.g., a quarter of W_0). In the configuration of FIGS. 6 and 7, however, the farthest distance from a body contact (e.g., body contacts 650a, 650b) to any location on the S/G/D assembly (e.g., S/G/D assembly 640) is approximately half of W_0 . Accordingly, the two body contacts 1050a, 1050b of FIGS. 10 and 11 being distributed differently than the two body contacts 650a, 650b of FIGS. 6 and 7 results in stronger body contact influence for the S/G/D assemblies of the former. For example, the first influence contour line 1042a associated with the first body contact 1050a can cover substantially all the first S/G/D assembly 1040a as well as most of the second S/G/D assembly 1040b. Similarly, the first influence contour line 1042b associated with the second

body contact 1050b can cover substantially all the third S/G/D assembly 1040c as well as most of the second S/G/D assembly 1040b. It is apparent that the overlapping coverage of the first influence lines 1042a and 1042b results in the second S/G/D assembly 1040b being strongly influenced by the first and second body contacts 1050a, 1050b.

[0090] Merely for descriptive purposes, the example configuration of FIGS. 10 and 11 can be referred to as a double-folded configuration, with the two body contacts 1050a, 1050b generally defining two fold lines. The first body contact 1050a forms a T configuration with the first gate fingers 1024a and forms a T configuration with the second gate fingers 1024b. Similarly, the second body contact 1050b forms a T configuration with the third gate fingers 1024c and forms a T configuration with the second gate fingers 1024b. Accordingly, the example configuration of FIGS. 10 and 11 can also be referred to as a double-folded T-shaped body contact configuration.

[0091] In some embodiments, one or more additional body contacts can be introduced to provide further reduction in body contact-to-body contact spacing and thereby increase the body contact influence at various locations of a FET device. In some embodiments, such reduction in body contact-to-body contact spacing can be balanced with any introduction or increase in narrow-width effects.

[0092] FIGS. 12–15 illustrate examples of how source and drain connections can be implemented for the example FET devices 800, 1000 of FIGS. 9 and 11. More particularly, FIG. 12 illustrates a FET device 1200 that is similar to the FET device 800 of FIG. 9. In the example of FIG. 12, the connecting metal 1230a for the first gate fingers 1224a and the connecting metal 1230b for the second gate fingers 1224b can be interconnected by a connecting metal 1221 to electrically connect the gate fingers on both sides of the body contact 1250.

[0093] Similarly, FIG. 13 illustrates a FET device 1300 that is similar to the FET device 1000 of FIG. 11. In the example of FIG. 13, the four connecting metals 1330a, 1330b, 1330c, 1330d can be interconnected by a connecting metal 1321 to electrically connect the gate fingers.

[0094] Referring to the example of FIG. 12, the alternating strips or rows of conductive features (e.g., conductive features 832a and 832b in FIG. 9) can be

electrically coupled or connected by a first metal, and the other alternating rows of conductive features can be connected by a second metal. For example, conductive features of the first row at the top and the third row from the top can be connected by a first metal (e.g., using a first metal M1) to form a source connection 1260. Similarly, conductive features of the second row from the top and the fourth row from the top can be connected by the second metal (e.g., using a second metal M2) to form a drain connection 1262. In some embodiments, a particular source finger of a first assembly 1240a can be electrically connected to a source finger of a second assembly 1240b that is positioned on the same row as the particular source finger of the first assembly. Similarly, a particular drain finger of the first assembly 1240a can be electrically connected to a drain finger of the second assembly 1240b that is positioned on the same row as the particular drain finger of the first assembly.

[0095] Referring to the example of FIG. 13, the alternating rows of conductive features (e.g., conductive features 1032a, 1032b and 1032c in FIG. 11) can be connected by a first metal, and the other alternating rows of conductive features can be connected by a second metal. For example, conductive features of the first row at the top and the third row from the top can be connected by the first metal (e.g., M1) to form a source connection 1360. Similarly, conductive features of the second row from the top and the fourth row from the top can be connected by the second metal (e.g., M2) to form a drain connection 1362.

[0096] FIG. 14 illustrates a FET device 1400 having a gate configuration similar to the example of FIG. 12. The FET device 1400 can include a connecting metal 1421 configured to connect a first connecting metal 1430a to a second connecting metal 1430b to electrically connect gate fingers 1424a, 1424b on both sides of the body contact 1450. In the example of FIG. 14, however, a source connection 1460 can be made by connecting conductive features of a given strip or row in the first S/G/D assembly 1440a with conductive features of an offset strip or row in the second S/G/D assembly 1440b. For example, conductive features of the first row at the top of the second S/G/D assembly 1440b can be connected with conductive features of the second row from the top of the first S/G/D assembly 1440a. Similarly, conductive features of the third row from the top of the second S/G/D

assembly 1440b can be connected with conductive features of the fourth row from the top of the first S/G/D assembly 1440a. Such two connections can be joined to form a source connection 1460 (e.g., using a first metal M1).

[0097] Similarly, conductive features of the first row at the top of the first S/G/D assembly 1440a can be connected with conductive features of the second row from the top of the second S/G/D assembly 1440b. Similarly, conductive features of the third row from the top of the first S/G/D assembly 1440a can be connected with conductive features of the fourth row from the top of the second S/G/D assembly 1440b. Such two connections can be joined to form a drain connection 1462 (e.g., using a second metal M2).

[0098] In some embodiments, a particular source finger of the first assembly 1440a can be electrically connected to a source finger of the second assembly 1440b that is positioned on a row that is offset by one row from the particular source finger of the first assembly 1440a. Similarly, a particular drain finger of the first assembly 1440a can be electrically connected to a drain finger of the second assembly 1440b that is positioned on a row that is offset by one row from the particular drain finger of the first assembly 1440a.

[0099] FIG. 15 illustrates a FET device 1500 having a gate configuration similar to the example of FIG. 13. In the example of FIG. 15, however, a source connection 1560 can be made by connecting conductive features of a given row in a S/G/D assembly with conductive features of an offset row in the neighboring S/G/D assembly. For example, conductive features of the first row at the top of the first S/G/D assembly 1540a can be connected with conductive features of the second row from the top of the second S/G/D assembly 1540b and conductive features of the first row at the top of the third S/G/D assembly 1540c. Similarly, conductive features of the third row from the top of the first S/G/D assembly 1540a can be connected with conductive features of the fourth row from the top of the second S/G/D assembly 1540b and conductive features of the third row from the top of the third S/G/D assembly 1540c. Such two connections can be joined to form a source connection 1560 (e.g., using a first metal M1).

[0100] Similarly, conductive features of the second row from the top of the first S/G/D assembly 1540a can be connected with conductive features of the first row at the top of the second S/G/D assembly 1540b and conductive features of the second row from the top of the third S/G/D assembly 1540c. Similarly, conductive features of the fourth row from the top of the first S/G/D assembly 1540a can be connected with conductive features of the third row from the top of the second S/G/D assembly 1540b and conductive features of the fourth row from the top of the third S/G/D assembly 1540c. Such two connections can be joined to form a drain connection 1562 (e.g., using a second metal M2).

[0101] In some embodiments, the offset arrangement of source and drain connections in neighboring S/G/D assemblies can provide a number of advantages. For example, impact from undesirable process variations such as source/drain mismatch and/or active region (RX)/polysilicon contact (PC) misalignment can be reduced or mitigated.

[0102] For example, suppose that in the example of FIGS. 4 and 5, the active region (RX) 412 of the FET device 400 is shifted to the left by an amount ΔW relative to the S/G/D assembly 440. In such a situation, the effective width of the S/G/D assembly 440 is then $W_0 - \Delta W$.

[0103] As illustrated in FIG. 16, suppose that a FET device 1600 configured in the same manner as the FET device 1400 in the example of FIG. 14 (which is based on the example of FIGS. 8 and 9), is shifted with the same amount of RX shift (ΔW), resulting in an original RX position 1670 and a shifted RX position 1672. In the original RX position 1670, and referring to the dimensions of FIG. 8, the total width associated with the S/G/D assemblies 1640a, 1640b is approximately $W_1 + W_1 = 2 \times W_1$. In the shifted RX position 1672, the width of the first S/G/D assembly 1640a is decreased by an amount ΔW , and width of the second S/G/D assembly 1640b is increased by an amount ΔW . Accordingly, the total width associated with the S/G/D assemblies 1640a, 1640b is approximately $(W_1 - \Delta W) + W_1 + \Delta W = 2 \times W_1$. Thus, one can see that for embodiments of FET devices having an even number of S/G/D assemblies, an impact in device parameter (e.g., S/G/D width) resulting from a shift in RX can be substantially canceled or reduced.

[0104] In another example, and as illustrated in FIG. 17, suppose that a FET device 1700 (configured in a manner similar to the FET device 1400 described herein with reference to FIG. 14) includes a polysilicon contact (PC) that is shifted downward (as illustrated in FIG. 17) from an original PC position 1774 to a shifted PC position 1776. For the second S/G/D assembly 1740b, two rows of source contacts can be farther away from the shifted PC position 1776, while for the first S/G/D assembly 1740a, two rows of drain contacts can be farther away from the shifted PC position 1776. Accordingly, when the source and drain are connected respectively as indicated in FIG. 17, source/drain asymmetry resulting from a PC shift can be reduced.

[0105] In the various examples described herein with reference to FIGS. 8–17, it is assumed that S/G/D assemblies, as well as one or more body contacts in a given FET device are configured to form a generally symmetric FET device. It will be understood that, in some embodiments, a FET device having one or more features as described herein can be configured in non-symmetric manners with respect to one or more design parameters.

[0106] For example, FIG. 18 illustrates a FET device 1800 having a body contact 1850 implemented between a first S/G/D assembly 1840a and a second S/G/D assembly 1840b, similar to the example FET device 800 of FIG. 8. In the example of FIG. 18, however, one or more design parameters of the FET device 1800 can be different between the first and second S/G/D assemblies 1840a, 1840b.

[0107] For example, either or both of L and W dimensions can be different among the first and second S/G/D assemblies 1840a, 1840b. In FIG. 18, the first S/G/D assembly 1840a has dimensions $L1 \times W1$, and the second S/G/D assembly 1840b has dimensions $L2 \times W2$. The values of $L1$ and $L2$ may or may not be the same. Similarly, the values of $W1$ and $W2$ may or may not be the same.

[0108] It is noted that in a configuration where the values of $W1$ and $W2$ are different, the position of the body contact 1850 is generally away from the middle.

[0109] In another example, the first and second S/G/D assemblies 1840a, 1840b can have different numbers of fingers. In FIG. 18, the first S/G/D assembly 1840a has $N1$ fingers, and the second S/G/D assembly 1840b has $N2$ fingers. The values of $N1$ and $N2$ may or may not be the same.

[0110] In the various examples described herein with reference to FIGS. 8–17, it is assumed that S/G/D assemblies, as well as one or more body contacts in a given FET device are arranged along a single direction. For example, various S/G/D assemblies and respective body contact(s) are arranged along a horizontal direction.

[0111] FIG. 19 illustrates that, in some embodiments, one or more features of the present disclosure can be implemented to provide a plurality of S/G/D assemblies arranged in two dimensions and separated by one or more body contacts. For example, four S/G/D assemblies 1940a, 1940b, 1940c, 1940d can be implemented for a FET device 1900, and such S/G/D assemblies can be separated by a cross-shaped body contact assembly indicated as 1950. It will be understood that such a body contact assembly can have one or more body contacts.

[0112] For example, the body contact assembly 1950 can include a first body contact implemented between the first and second assemblies 1940a, 1940b and a second body contact implemented between the third and fourth assemblies 1940c, 1940d. As another example, the body contact assembly 1950 can include a first body contact implemented between the first and third assemblies 1940a, 1940c and a second body contact implemented between the second and fourth assemblies 1940b, 1940d. As a further example, the body contact assembly 1950 can include a first body contact implemented between the first and second assemblies 1940a, 1940b, a second body contact implemented between the third and fourth assemblies 1940c, 1940d, a third body contact implemented between the first and third assemblies 1940a, 1940c, and a fourth body contact implemented between the second and fourth assemblies 1940b, 1940d.

[0113] The present disclosure describes various features, no single one of which is solely responsible for the benefits described herein. It will be understood that various features described herein may be combined, modified, or omitted, as would be apparent to one of ordinary skill. Other combinations and sub-combinations than those specifically described herein will be apparent to one of ordinary skill, and are intended to form a part of this disclosure. Various methods are described herein in connection with various flowchart steps and/or phases. It will be understood that in many cases, certain steps and/or phases may be combined such that multiple steps

and/or phases illustrated in the flowcharts can be performed as a single step and/or phase. Also, certain steps and/or phases can be broken into additional sub-components to be performed separately. In some instances, the order of the steps and/or phases can be rearranged and certain steps and/or phases may be omitted entirely. Also, the methods described herein are to be understood to be open-ended, such that additional steps and/or phases to those illustrated and described herein can also be performed.

[0114] Some aspects of the systems and methods described herein can advantageously be implemented using, for example, computer software, hardware, firmware, or any combination of computer software, hardware, and firmware. Computer software can comprise computer executable code stored in a computer readable medium (e.g., non-transitory computer readable medium) that, when executed, performs the functions described herein. In some embodiments, computer-executable code is executed by one or more general purpose computer processors. A skilled artisan will appreciate, in light of this disclosure, that any feature or function that can be implemented using software to be executed on a general-purpose computer can also be implemented using a different combination of hardware, software, or firmware. For example, such a module can be implemented completely in hardware using a combination of integrated circuits. Alternatively or additionally, such a feature or function can be implemented completely or partially using specialized computers designed to perform the particular functions described herein rather than by general purpose computers.

[0115] Multiple distributed computing devices can be substituted for any one computing device described herein. In such distributed embodiments, the functions of the one computing device are distributed (e.g., over a network) such that some functions are performed on each of the distributed computing devices.

[0116] Some embodiments may be described with reference to equations, algorithms, and/or flowchart illustrations. These methods may be implemented using computer program instructions executable on one or more computers. These methods may also be implemented as computer program products either separately, or as a component of an apparatus or system. In this regard, each equation,

algorithm, block, or step of a flowchart, and combinations thereof, may be implemented by hardware, firmware, and/or software including one or more computer program instructions embodied in computer-readable program code logic. As will be appreciated, any such computer program instructions may be loaded onto one or more computers, including without limitation a general-purpose computer or special purpose computer, or other programmable processing apparatus to produce a machine, such that the computer program instructions which execute on the computer(s) or other programmable processing device(s) implement the functions specified in the equations, algorithms, and/or flowcharts. It will also be understood that each equation, algorithm, and/or block in flowchart illustrations, and combinations thereof, may be implemented by special purpose hardware-based computer systems which perform the specified functions or steps, or combinations of special purpose hardware and computer-readable program code logic means.

[0117] Furthermore, computer program instructions, such as embodied in computer-readable program code logic, may also be stored in a computer readable memory (e.g., a non-transitory computer readable medium) that can direct one or more computers or other programmable processing devices to function in a particular manner, such that the instructions stored in the computer-readable memory implement the function(s) specified in the block(s) of the flowchart(s). The computer program instructions may also be loaded onto one or more computers or other programmable computing devices to cause a series of operational steps to be performed on the one or more computers or other programmable computing devices to produce a computer-implemented process such that the instructions which execute on the computer or other programmable processing apparatus provide steps for implementing the functions specified in the equation(s), algorithm(s), and/or block(s) of the flowchart(s).

[0118] Some or all of the methods and tasks described herein may be performed and fully automated by a computer system. The computer system may, in some cases, include multiple distinct computers or computing devices (e.g., physical servers, workstations, storage arrays, etc.) that communicate and interoperate over a network to perform the described functions. Each such computing device typically

includes a processor (or multiple processors) that executes program instructions or modules stored in a memory or other non-transitory computer-readable storage medium or device. The various functions disclosed herein may be embodied in such program instructions, although some or all of the disclosed functions may alternatively be implemented in application-specific circuitry (e.g., ASICs or FPGAs) of the computer system. Where the computer system includes multiple computing devices, these devices may, but need not, be co-located. The results of the disclosed methods and tasks may be persistently stored by transforming physical storage devices, such as solid state memory chips and/or magnetic disks, into a different state.

[0119] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise,” “comprising,” and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to.” The word “coupled”, as generally used herein, refers to two or more elements that may be either directly connected, or connected by way of one or more intermediate elements. Additionally, the words “herein,” “above,” “below,” and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the above Detailed Description using the singular or plural number may also include the plural or singular number respectively. The word “or” in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list. The word “exemplary” is used exclusively herein to mean “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other implementations.

[0120] The disclosure is not intended to be limited to the implementations illustrated and described herein. Various modifications to the implementations described in this disclosure may be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other implementations without departing from the spirit or scope of this disclosure. The teachings of the invention provided herein can be applied to other methods and systems, and are not limited to

the methods and systems described above, and elements and acts of the various embodiments described above can be combined to provide further embodiments. Accordingly, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the disclosure. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the disclosure.

WHAT IS CLAIMED IS:

1. A field-effect transistor (FET) comprising:
a first assembly of source, gate, and drain implemented on a first active region;
a second assembly of source, gate, and drain implemented on a second active region; and
a first body contact implemented between the first assembly and the second assembly.
2. The FET of claim 1 wherein the FET includes a silicon-on-insulator (SOI) substrate.
3. The FET of claim 1 wherein the first assembly and the second assembly are dimensioned substantially the same and the first body contact is positioned at approximately the center of the FET.
4. The FET of claim 1 further comprising a third assembly of source, gate, and drain implemented on a third active region, and a second body contact implemented between the second assembly and the third assembly.
5. The FET of claim 4 wherein the first assembly and the third assembly are dimensioned substantially the same such that the first body contact and the second body contact are positioned substantially symmetrically about a center line of the FET.
6. The FET of claim 1 wherein each of the first and second assemblies of respective source, gate, and drain is implemented in a finger configuration with gate fingers extending in a direction to provide a folded T-shaped body contact configuration for the first body contact and the gate fingers of the first and second assemblies.

7. The FET of claim 6 wherein the finger configuration of each of the first and second assemblies results in source and drain fingers being interleaved with the gate fingers.

8. The FET of claim 7 wherein the source fingers and the drain fingers are arranged in alternating rows.

9. The FET of claim 8 wherein a particular source finger of the first assembly is electrically connected to a source finger of the second assembly that is positioned on the same row as the particular source finger of the first assembly.

10. The FET of claim 9 wherein a particular drain finger of the first assembly is electrically connected to a drain finger of the second assembly that is positioned on the same row as the particular drain finger of the first assembly.

11. The FET of claim 8 wherein a particular source finger of the first assembly is electrically connected to a source finger of the second assembly that is offset by one row from the particular source finger of the first assembly.

12. The FET of claim 11 wherein a particular drain finger of the first assembly is electrically connected to a drain finger of the second assembly that is offset by one row from the particular drain finger of the first assembly.

13. The FET of claim 1 wherein the first body contact further includes a first connecting metal extending along a width of the first body contact on a first side and a second connecting metal extending along a width of the first body contact on a second side opposite the first side.

14. The FET of claim 13 further comprising a first plurality of gate fingers electrically coupled to the first connecting metal that extends away from the first connecting metal over the first active region and a second plurality of gate fingers electrically coupled to the second connecting metal that extends away from the second connecting metal over the second active region.

15. The FET of claim 14 further comprising a third connecting metal that electrically couples the first connecting metal and the second connecting metal to electrically connect the first plurality of gate fingers and the second plurality of gate fingers.

16. A radio-frequency (RF) module comprising:
a packaging substrate configured to receive a plurality of devices; and
a die mounted on the packaging substrate, the die including a field-effect transistor (FET) having a first assembly of source, gate, and drain implemented on a first active region, the FET further including a second assembly of source, gate, and drain implemented on a second active region, the FET further including a body contact implemented between the first assembly and the second assembly.

17. The RF module of claim 16 wherein the RF module is a switch module.

18. The RF module of claim 16 wherein the die is a silicon-on-insulator (SOI) die.

19. A wireless device comprising:
a transceiver configured to process radio-frequency (RF) signals;
an RF module in communication with the transceiver, the RF module including a switching device having a field-effect transistor (FET), the FET including a first assembly of source, gate, and drain implemented on a first active region, the FET further including a second assembly of source, gate, and drain implemented on a second active region, the FET further including a body contact implemented between the first assembly and the second assembly; and
an antenna in communication with the RF module, the antenna configured to facilitate transmitting and/or receiving of the RF signals.

20. The wireless device of claim 19 wherein the RF module is a switch module.

21. A field-effect transistor (FET) comprising:

a first assembly of source, gate, and drain implemented on a first active region, the first assembly having a first width and a first length;

a second assembly of source, gate, and drain implemented on a second active region, the second assembly having a second width and a second length, such that the first width is greater than the second width and the first length is not equal to the second length; and

a body contact implemented between the first assembly and the second assembly such that the body contact is away from a center of the FET.

22. The FET of claim 21 wherein the FET includes a silicon-on-insulator (SOI) substrate.

23. The FET of claim 21 further comprising a plurality of gate fingers, a first connecting metal, and a second connecting metal that together form a gate contact for the FET device.

24. The FET of claim 23 wherein the first active region of the assembly includes a plurality of conductive features in rows between the plurality of gate fingers to form alternating strips of source and drain.

25. The FET of claim 21 wherein the body contact further includes a first connecting metal extending along a width of the body contact on a first side and a second connecting metal extending along a width of the body contact on a second side opposite the first side.

26. The FET of claim 25 further comprising a first plurality of gate fingers electrically coupled to the first connecting metal that extends away from the first connecting metal over the first active region and a second plurality of gate fingers electrically coupled to the second connecting metal that extends away from the second connecting metal over the second active region, the number of gate fingers of the first plurality of gate fingers being different from the number of gate fingers of the second plurality of gate fingers.

27. The FET of claim 21 wherein each of the first and second assemblies of respective source, gate, and drain is implemented in a finger configuration with gate fingers extending in a direction to provide a folded T-shaped body contact configuration for the first body contact and the gate fingers of the first and second assemblies.

28. A field-effect transistor (FET) comprising:

- a first assembly of source, gate, and drain implemented on a first active region;

- a second assembly of source, gate, and drain implemented on a second active region, the second assembly aligned with the first assembly in a first row;

- a third assembly of source, gate, and drain implemented on a second active region, the third assembly aligned with the first assembly in a first column;

- a fourth assembly of source, gate, and drain implemented on a second active region, the fourth assembly aligned with the second assembly in a second column and with the third assembly in a second row; and

- a body contact assembly implemented between the first assembly, the second assembly, the third assembly, and the fourth assembly.

29. The FET of claim 28 wherein the FET includes a silicon-on-insulator (SOI) substrate.

30. The FET of claim 28 wherein the body contact assembly is positioned between the first row and the second row and between the first column and the second column.

31. The FET of claim 30 wherein the body contact assembly forms a cross shape.

32. The FET of claim 28 wherein the body contact assembly includes a first body contact implemented between the first and second assemblies and a second body contact implemented between the third and fourth assemblies.

33. The FET of claim 28 wherein the body contact assembly includes a first body contact implemented between the first and third assemblies and a second body contact implemented between the second and fourth assemblies.

34. The FET of claim 28 wherein the body contact assembly includes a first body contact implemented between the first and second assemblies, a second body contact implemented between the third and fourth assemblies, a third body contact implemented between the first and third assemblies, and a fourth body contact implemented between the second and fourth assemblies.

35. The FET of claim 28 wherein each of the first, second, third, and fourth assemblies of respective source, gate, and drain is implemented in a finger configuration with gate fingers extending over the first, second, third, and fourth active regions to provide alternating rows of source and drain interleaved with the gate fingers.

36. The FET of claim 28 wherein the first assembly has a first width and a first length and the second assembly has a second width and a second length such that the first width is greater than the second width.

37. The FET of claim 36 wherein the first length is greater than the second length.

38. A radio-frequency (RF) module comprising:
a packaging substrate configured to receive a plurality of devices; and
a die mounted on the packaging substrate, the die including a field-effect transistor (FET) having a first assembly of source, gate, and drain implemented on a first active region, the first assembly having a first width and a first length, the die further including a second assembly of source, gate, and drain implemented on a second active region, the second assembly having a second width and a second length, such that the first width is greater than the second width and the first length is not equal to the second length, and the die further

including a body contact implemented between the first assembly and the second assembly such that the body contact is away from a center of the FET.

39. The RF module of claim 38 wherein the RF module is a switch module.

40. The RF module of claim 38 wherein the die is a silicon-on-insulator (SOI) die.

41. A method for fabricating a radio-frequency (RF) device, the method comprising:

- forming a field-effect transistor (FET) over a substrate layer;
- electrically connecting the substrate layer to a substrate node; and
- coupling a non-grounding circuit to the substrate node to adjust RF performance of the FET.

42. A method for fabricating a field-effect transistor (FET), the method comprising:

- forming or providing a substrate;
- implementing a first assembly of source, gate, and drain on a first active region of the substrate;
- implementing a second assembly of source, gate, and drain on a second active region of the substrate; and
- forming a first body contact between the first assembly and the second assembly.

43. The method of claim 42 wherein the substrate is a silicon-on-insulator (SOI) substrate.

44. A method for fabricating a radio-frequency (RF) device, the method comprising:

- forming a field-effect transistor (FET) using the method of claim 42;
- electrically connecting the substrate to a substrate node; and
- coupling a non-grounding circuit to the substrate node to adjust RF performance of the FET.

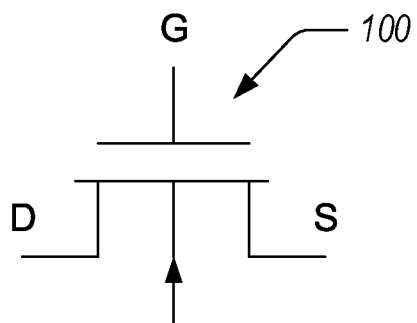


FIG. 1

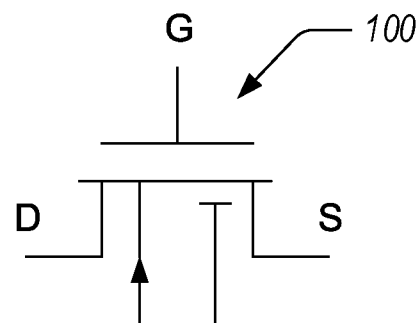


FIG. 2

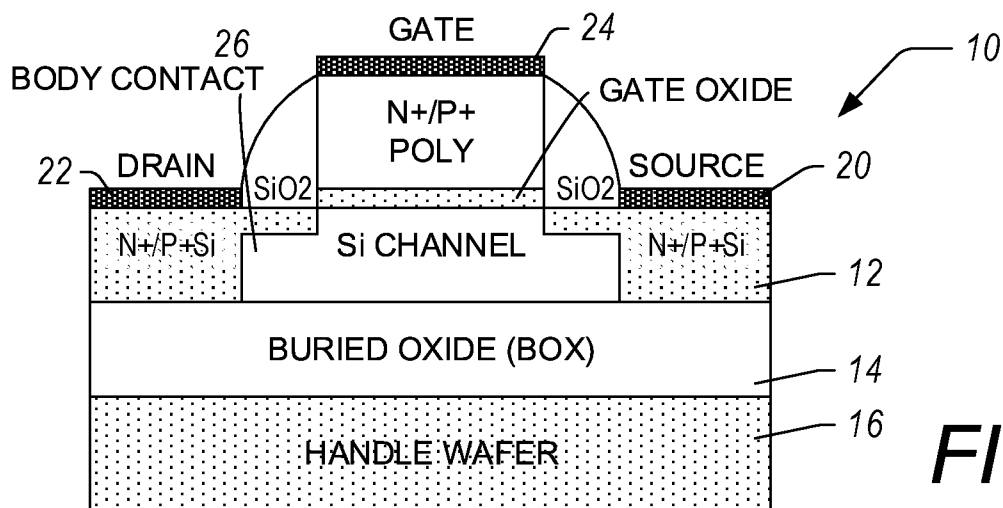


FIG. 3A

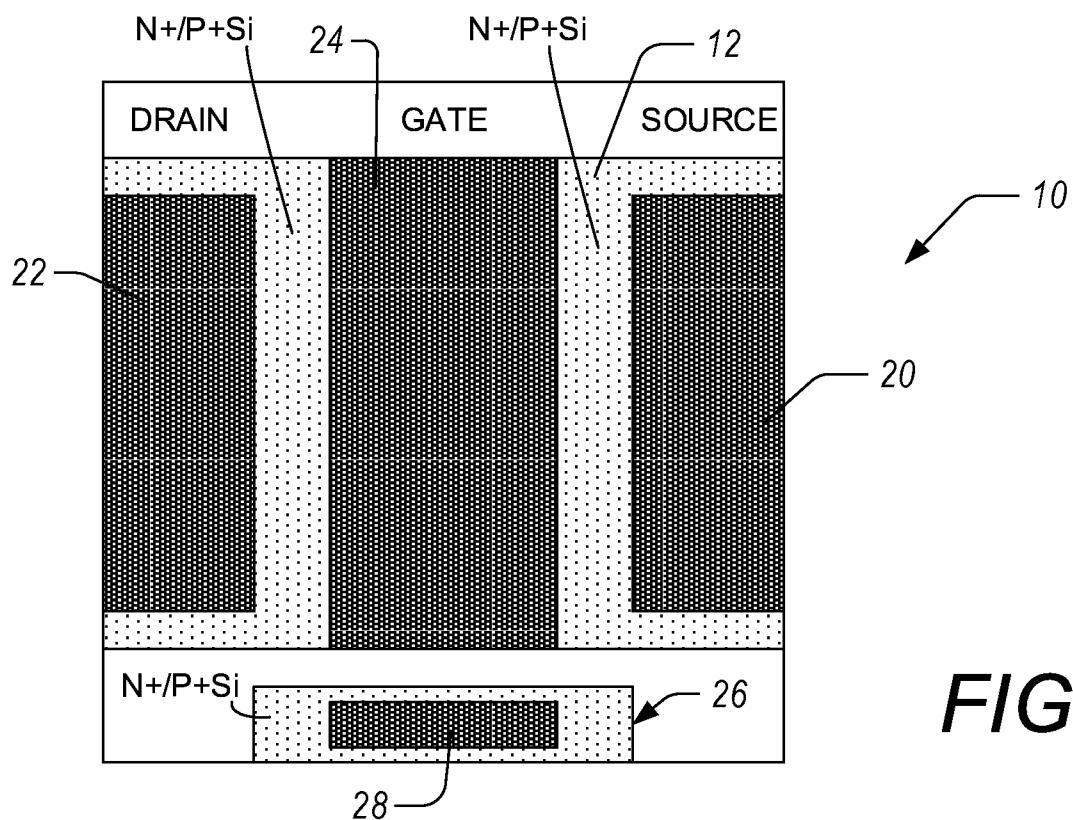
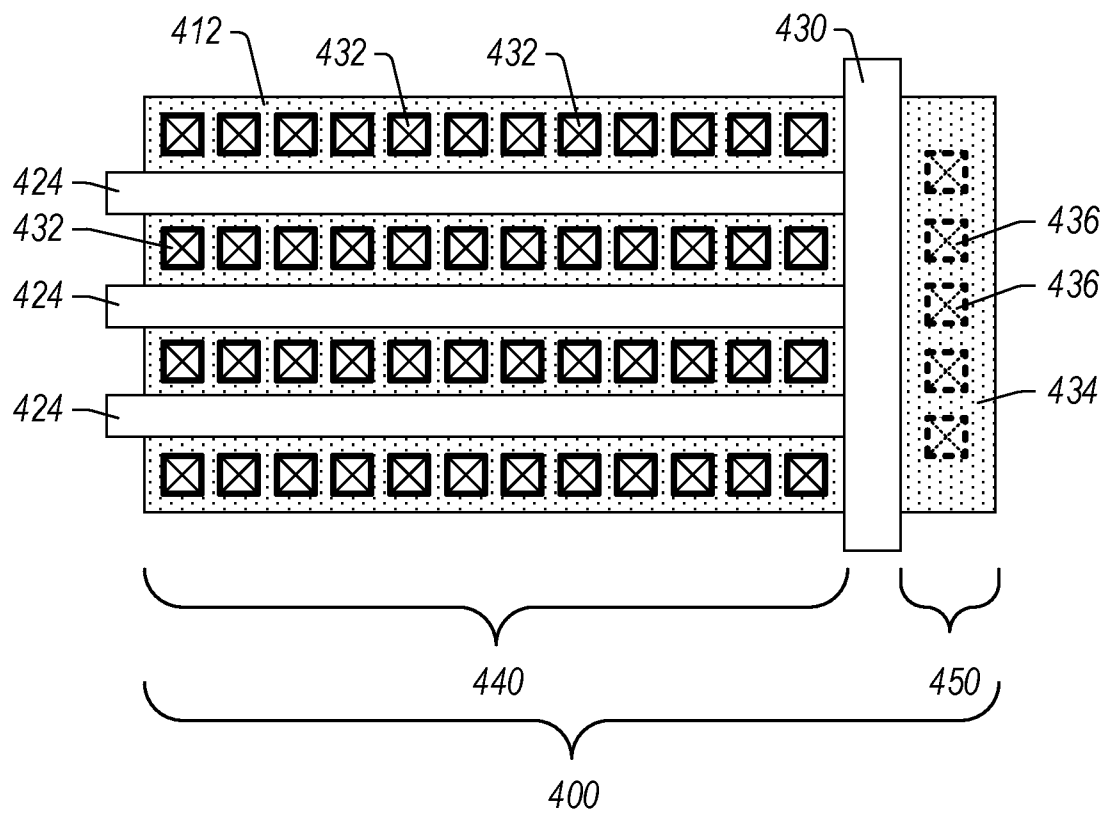
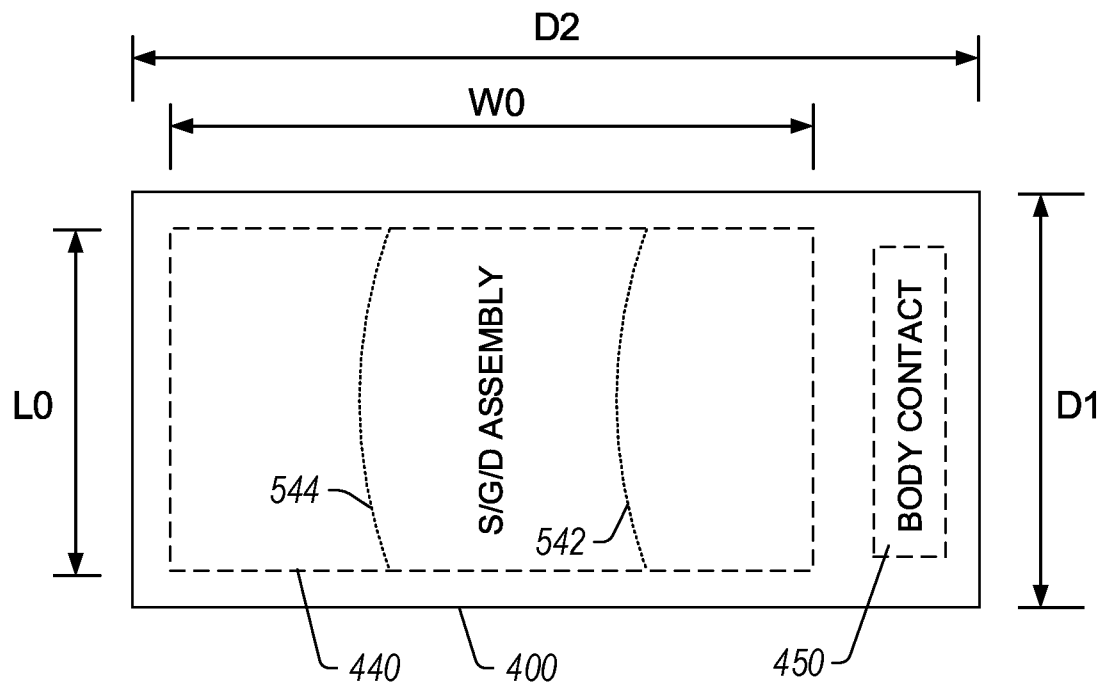
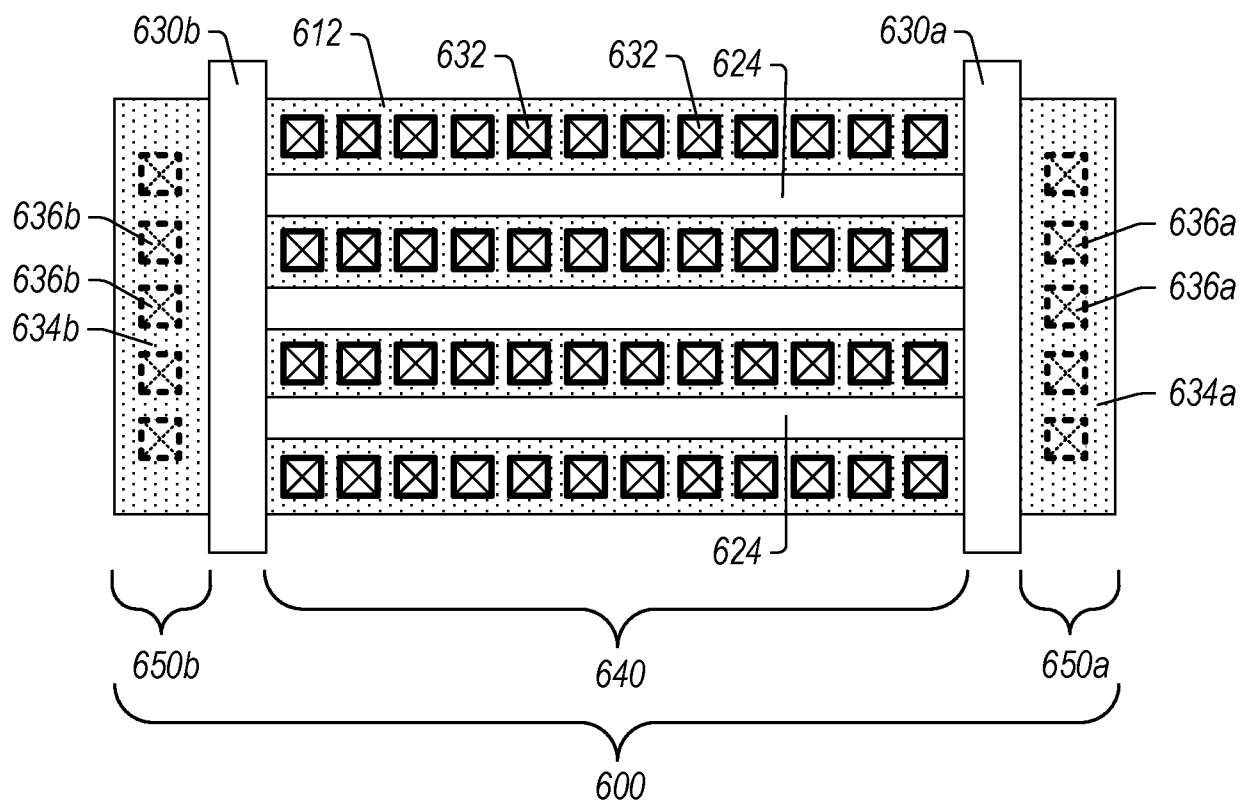
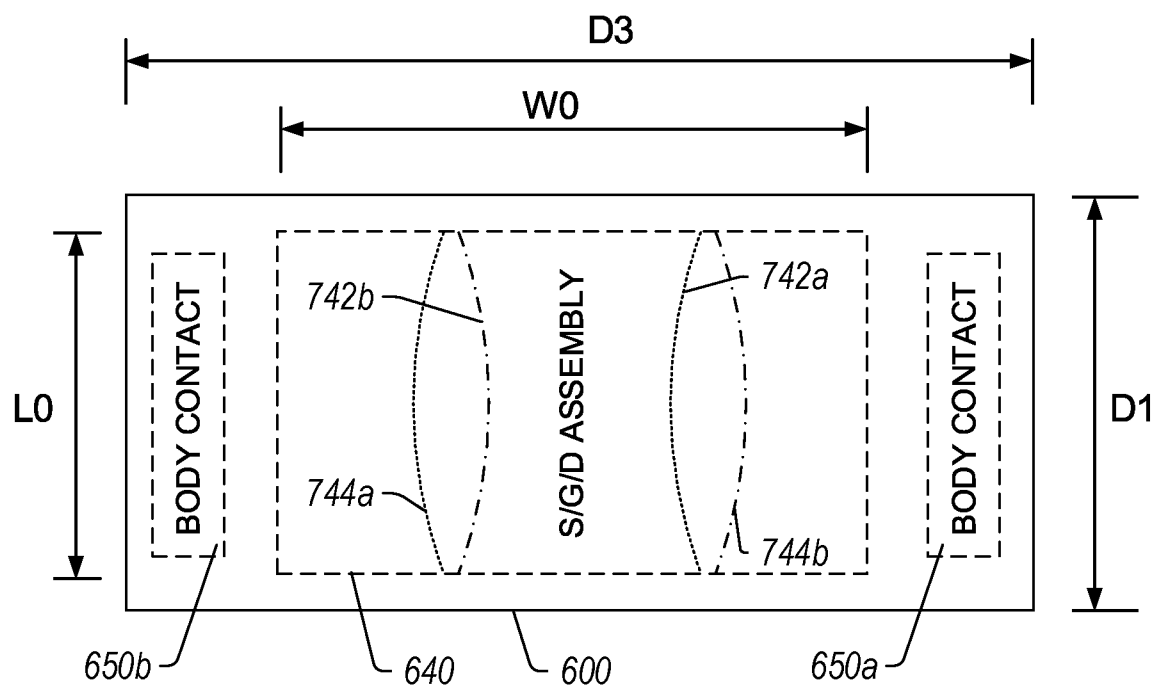


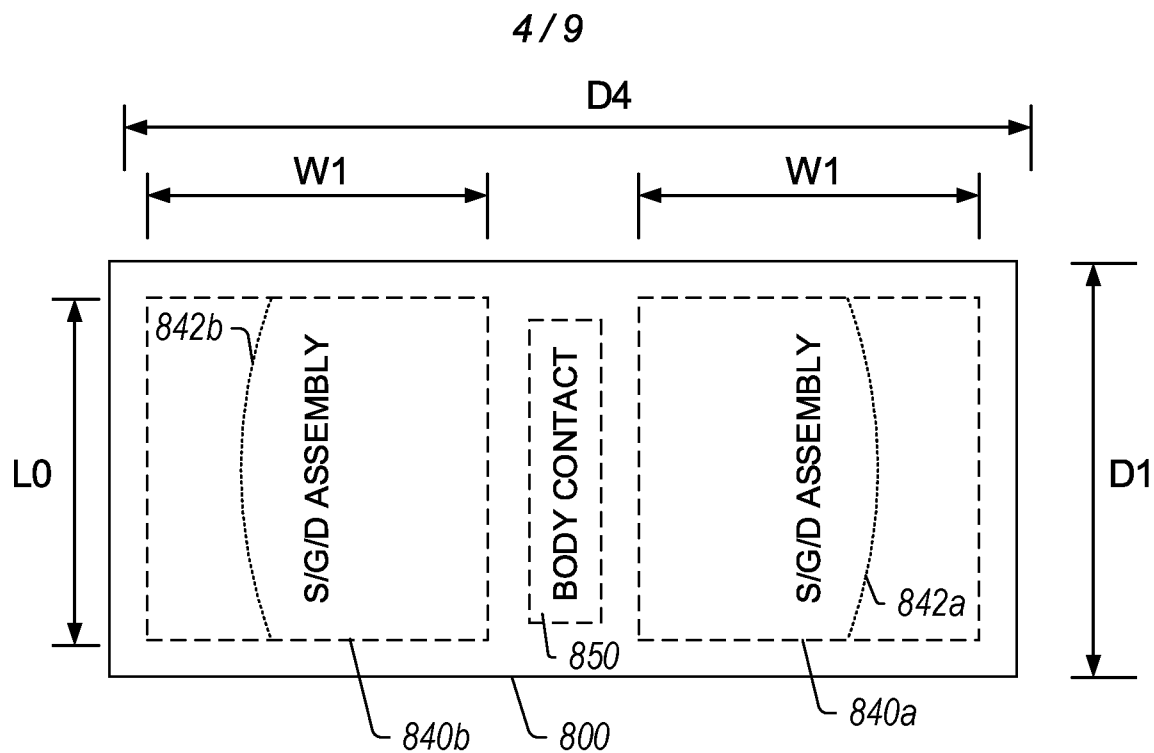
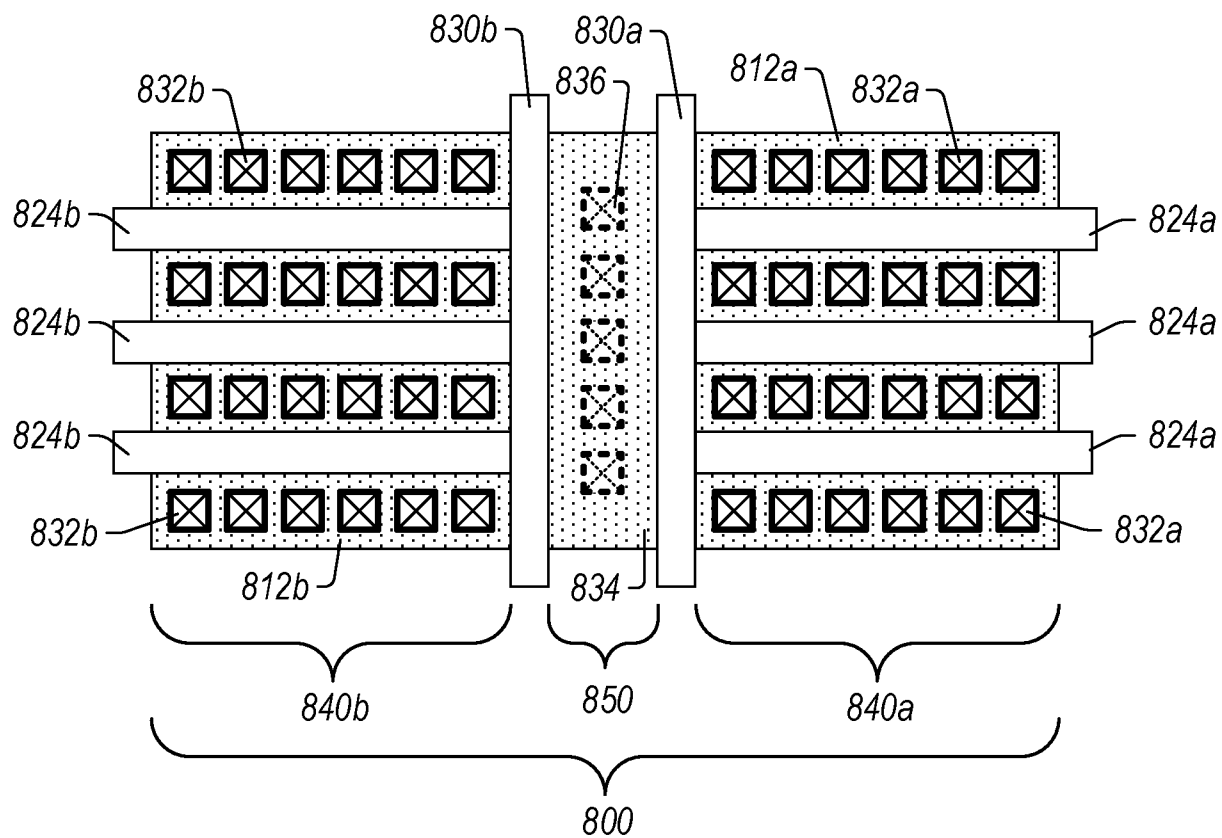
FIG. 3B

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**FIG. 4****FIG. 5**

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**FIG. 6****FIG. 7**

**FIG. 8****FIG. 9**

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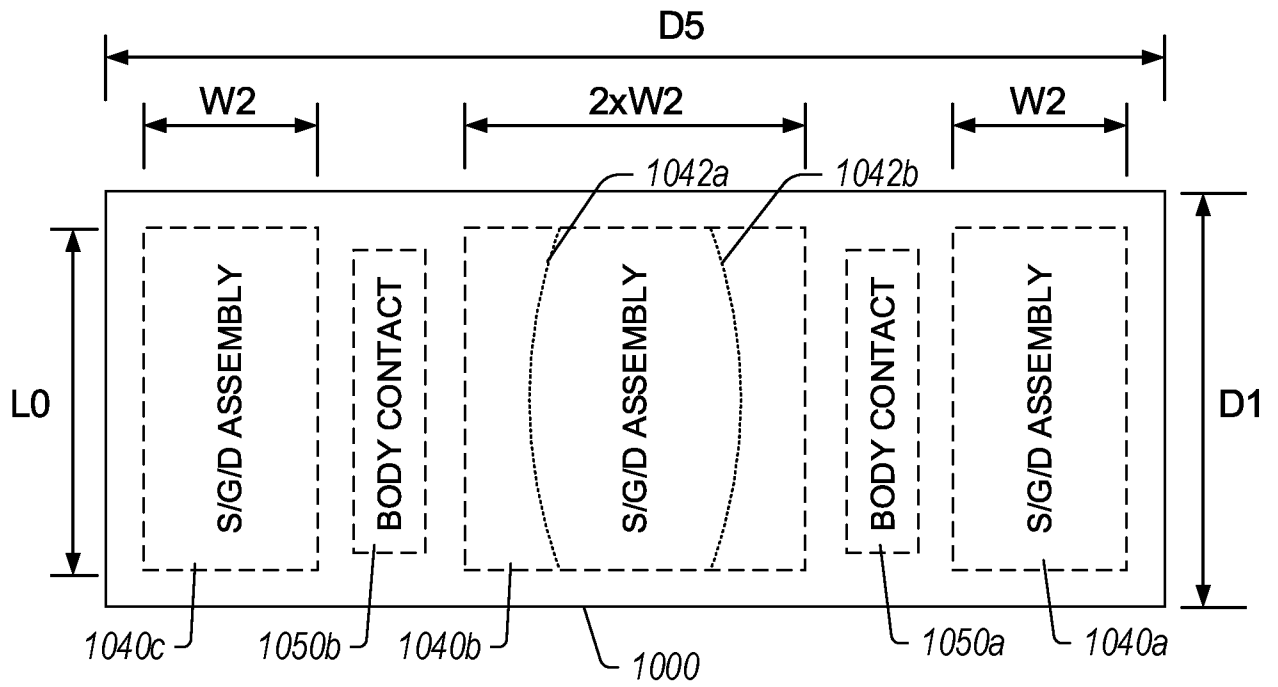


FIG. 10

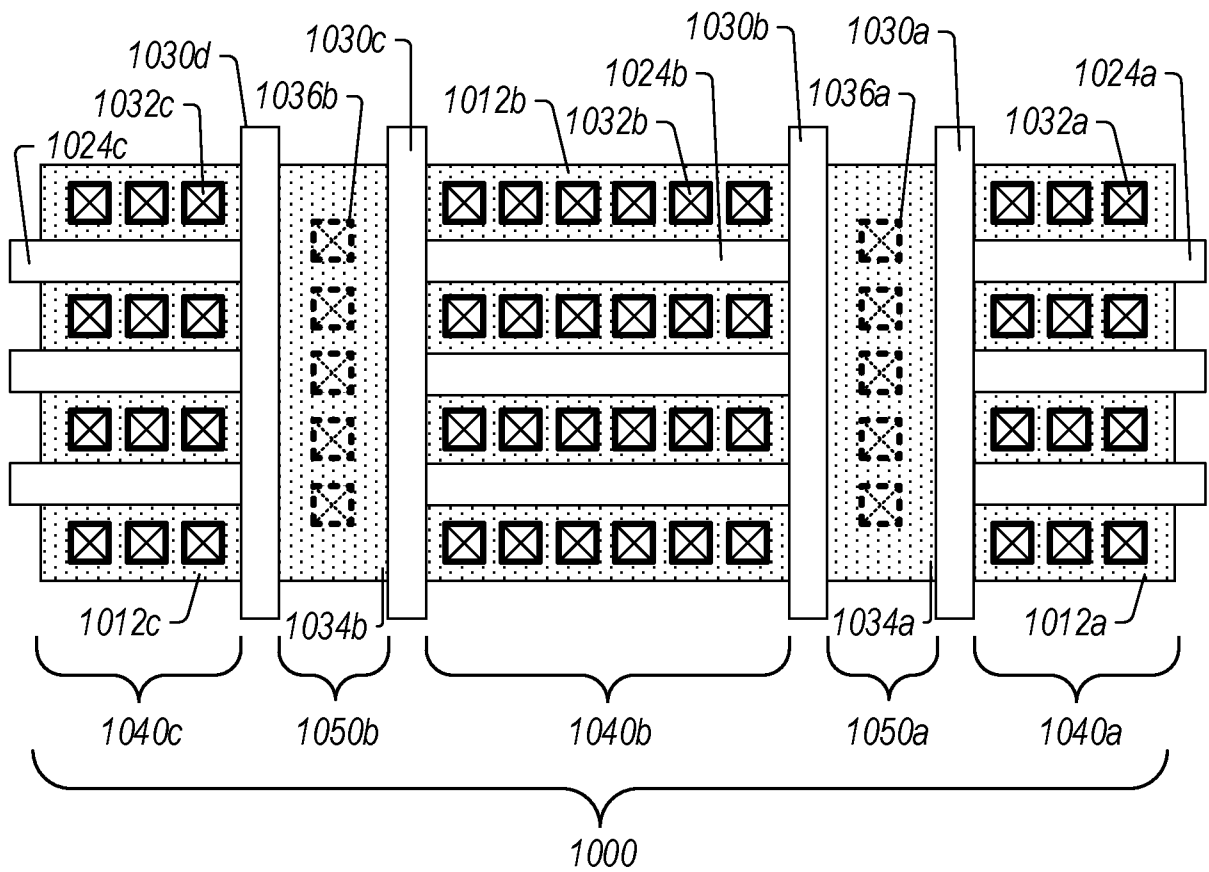


FIG. 11

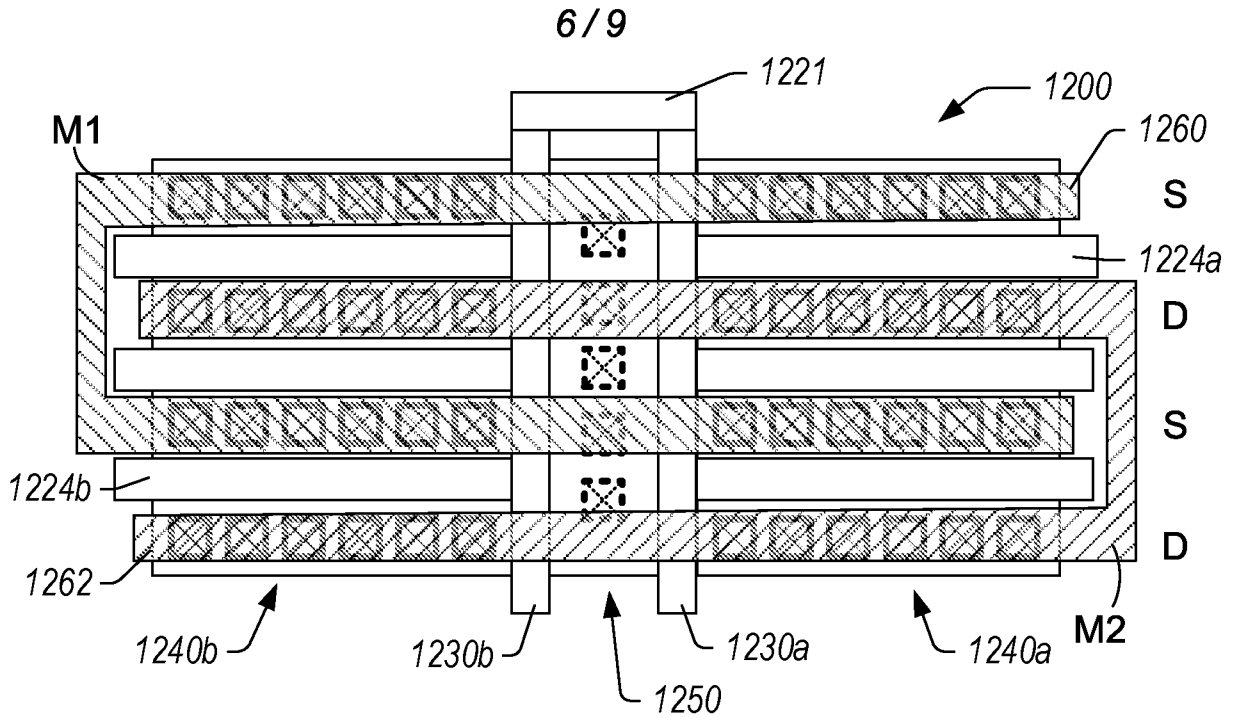


FIG. 12

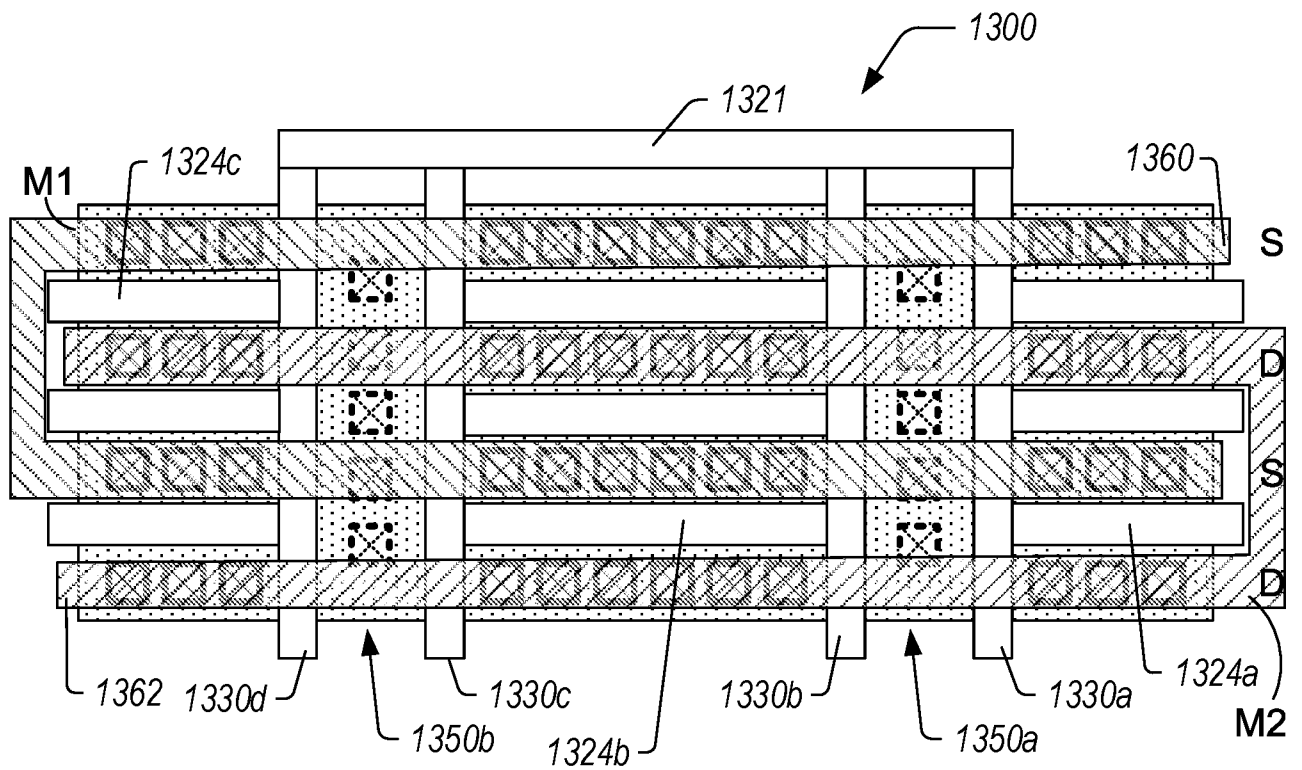
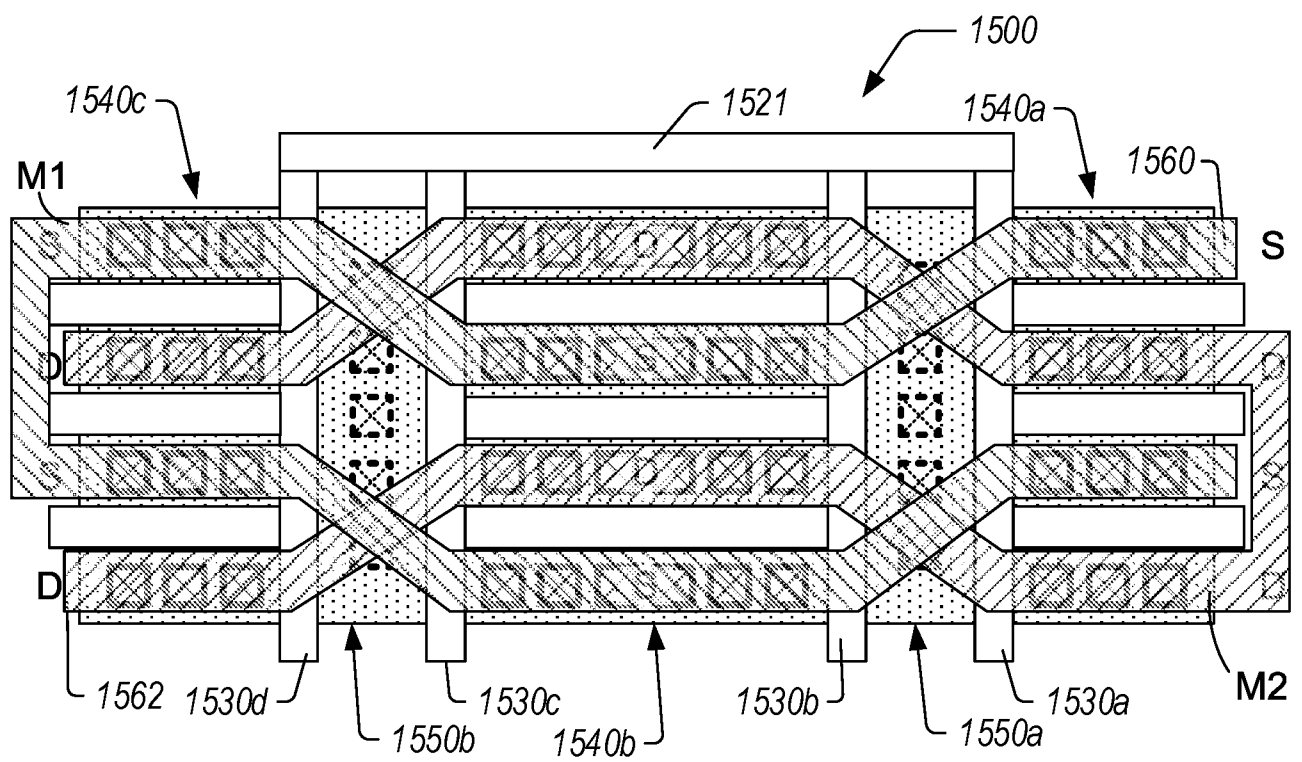
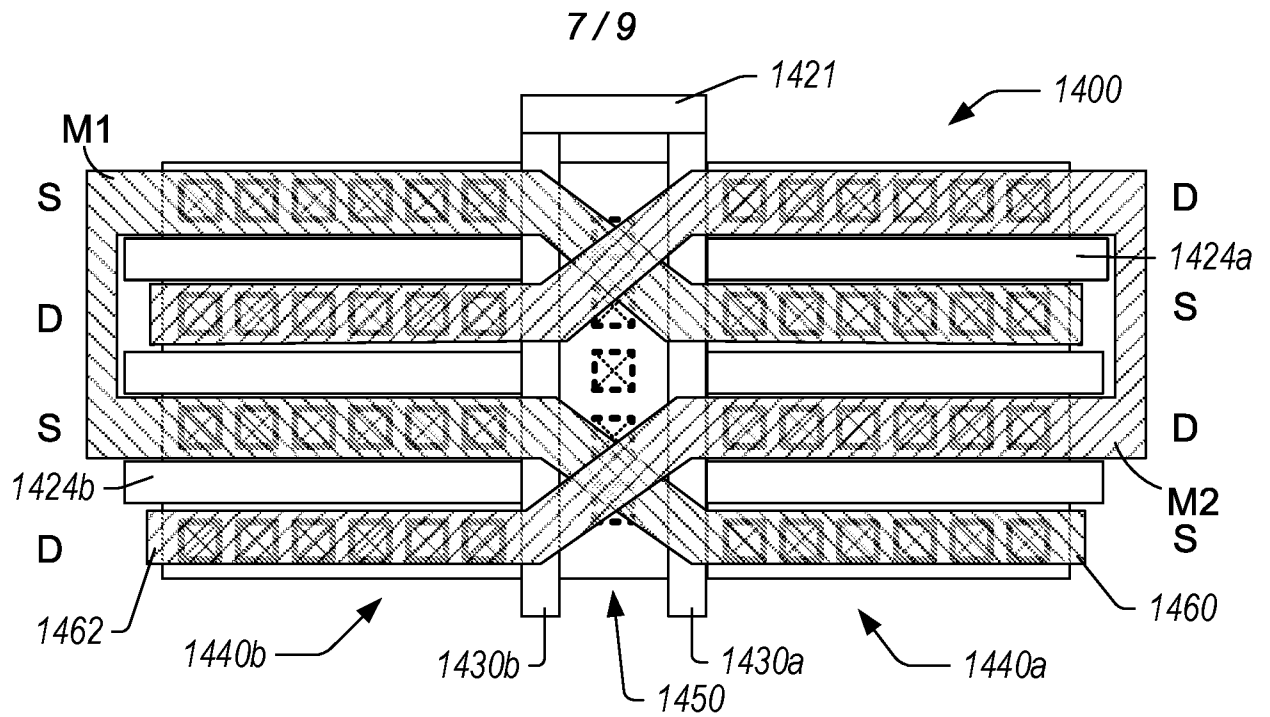
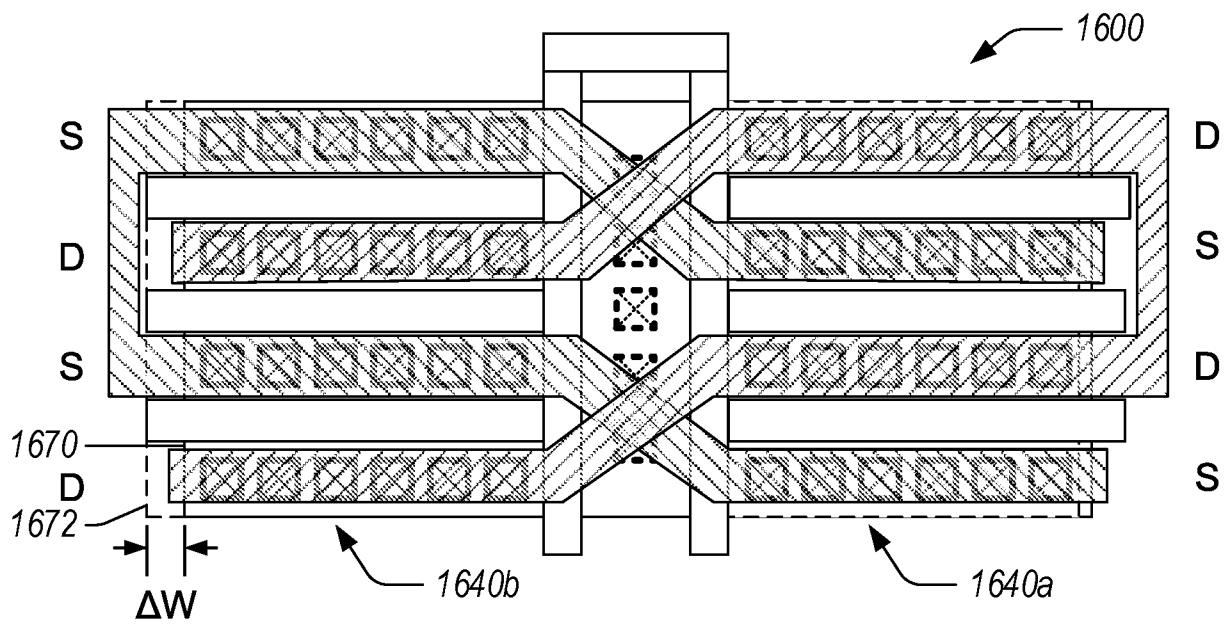
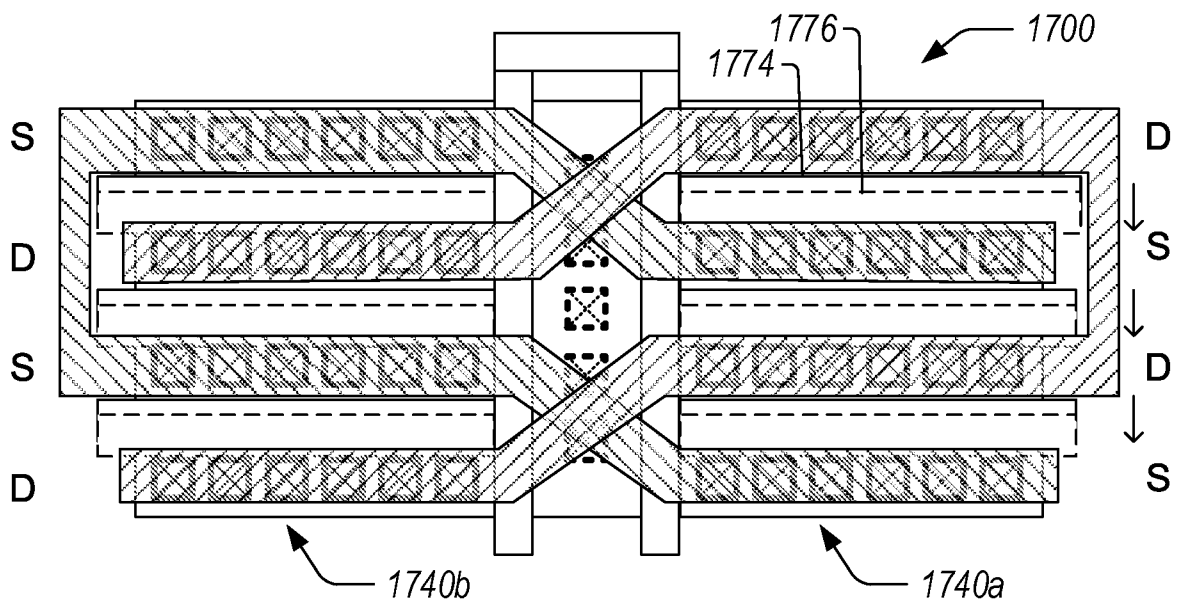


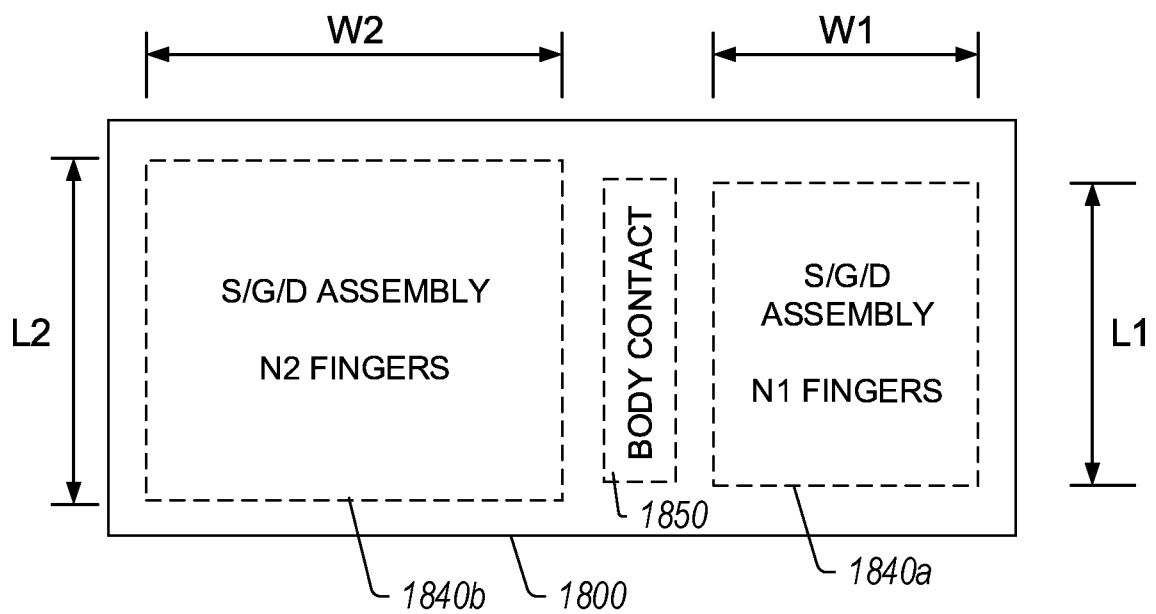
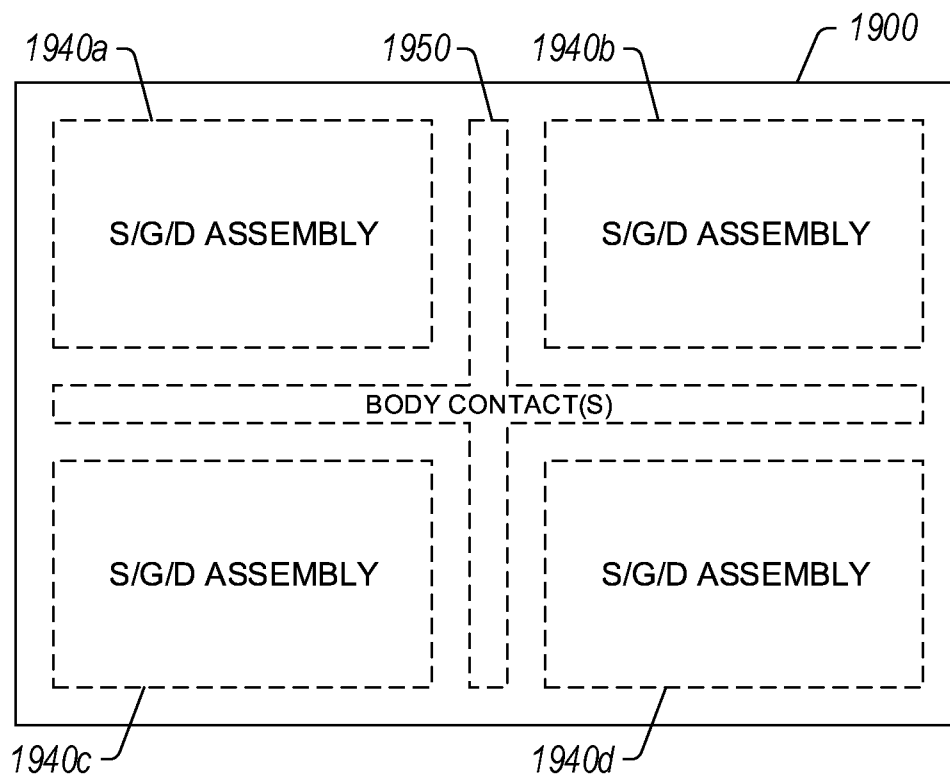
FIG. 13



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**FIG. 16****FIG. 17**

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**FIG. 18****FIG. 19**

A. CLASSIFICATION OF SUBJECT MATTER**H01L 27/088(2006.01)i, H01L 29/417(2006.01)i, H01L 29/423(2006.01)i, H01L 21/768(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 27/088; H01L 31/0392; H01L 27/118; G06F 17/50; H03K 17/16; H01L 27/092; H01L 27/12; H01L 29/417; H01L 29/423; H01L 21/768

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: transistor, active region, body contact, finger

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009-0315080 A1 (PAUL RONALD STRIBLEY et al.) 24 December 2009 See paragraphs [0003]-[0056] and figures 1-2.	1-5, 13-14, 28-35 , 42-43
Y		6-8, 15-25, 27, 36-40 , 44
A		9-12, 26, 41
Y	US 2007-0241402 A1 (YUICHI HIRANO) 18 October 2007 See paragraphs [0127]-[0140] and figure 14.	6-8, 15, 27
Y	US 2014-0009213 A1 (SKYWORKS SOLUTIONS INC.) 09 January 2014 See paragraphs [0014], [0037]-[0103] and figures 1-15.	16-20, 38-40
Y	US 2011-0031535 A1 (TOSHIKI IWAMATSU) 10 February 2011 See paragraphs [0037]-[0089], [0160]-[0161] and figures 1-4, 7.	21-25, 27, 36-40
X	US 2012-0104496 A1 (ALAN B. BOTULA et al.) 03 May 2012 See paragraphs [0008], [0073]-[0110], [0153] and figures 1-9.	41
Y		44



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

12 July 2017 (12.07.2017)

Date of mailing of the international search report

13 July 2017 (13.07.2017)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/025463

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009-0315080 A1	24/12/2009	GB 2439759 A US 8455955 B2 WO 2008-001142 A2 WO 2008-001142 A3	09/01/2008 04/06/2013 03/01/2008 25/09/2008
US 2007-0241402 A1	18/10/2007	JP 2007-287718 A JP 5042518 B2 US 2010-0314686 A1 US 7804132 B2	01/11/2007 03/10/2012 16/12/2010 28/09/2010
US 2014-0009213 A1	09/01/2014	None	
US 2011-0031535 A1	10/02/2011	JP 2007-287720 A JP 5052813 B2 US 2007-0241365 A1 US 7834377 B2 US 8110852 B2	01/11/2007 17/10/2012 18/10/2007 16/11/2010 07/02/2012
US 2012-0104496 A1	03/05/2012	TW 201108396 A US 2010-0244934 A1 US 8133774 B2 US 8866226 B2 WO 2010-108807 A1	01/03/2011 30/09/2010 13/03/2012 21/10/2014 30/09/2010