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(54) **LOW RESISTANCE FEEDTHROUGH CELL WITH CONTACTED POLY PITCH BY METAL GATE CONNECTED TO FEEDTHROUGH VIA**

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Publication Classification

(51) **Int. Cl.**

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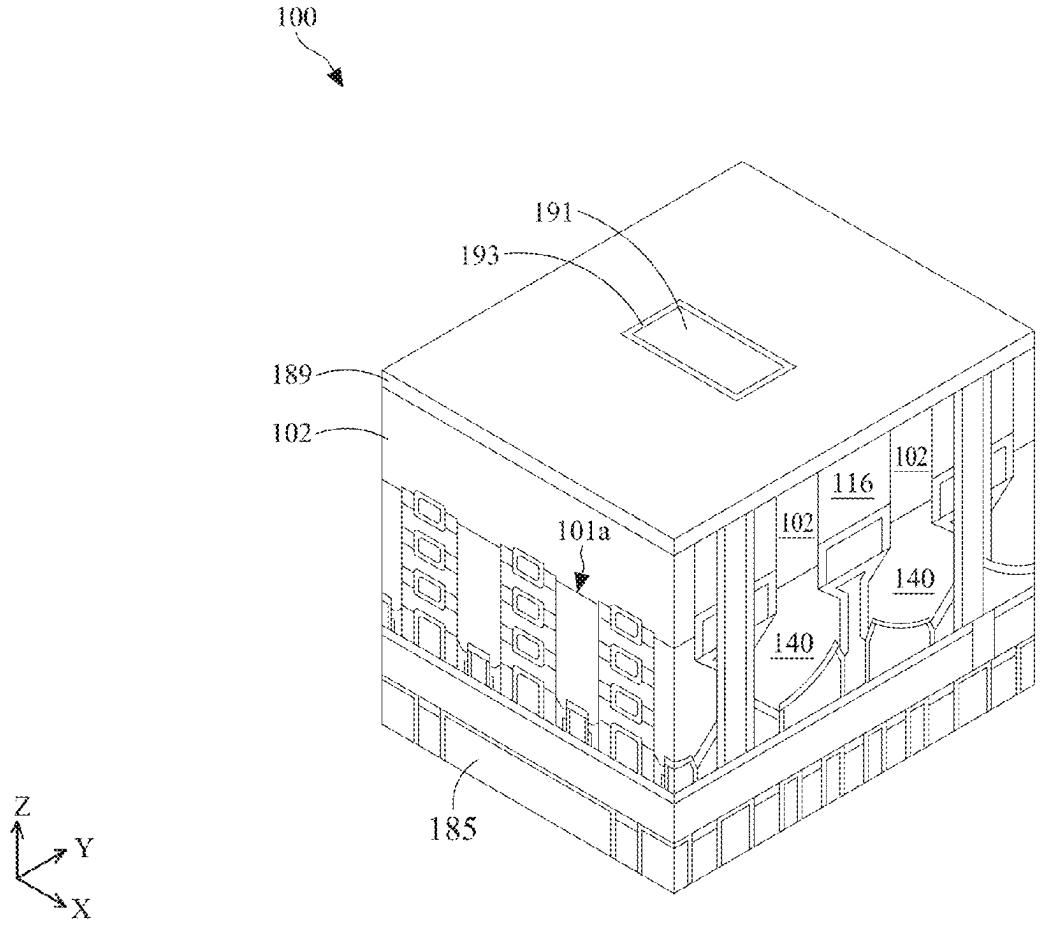
H01L 23/528	(2006.01)
H01L 27/088	(2006.01)
H01L 29/06	(2006.01)
H01L 29/423	(2006.01)
H01L 29/66	(2006.01)
H01L 29/775	(2006.01)
H01L 29/786	(2006.01)

(52) **U.S. Cl.**

CPC ***H10D 84/038*** (2025.01); ***H01L 21/76898*** (2013.01); ***H01L 23/5226*** (2013.01); ***H01L 23/5286*** (2013.01); ***H10D 64/017*** (2025.01); ***H10D 84/0149*** (2025.01); ***H10D 84/83*** (2025.01); *H10D 30/014* (2025.01); *H10D 30/43* (2025.01); *H10D 30/6735* (2025.01); *H10D 30/6757* (2025.01); *H10D 62/121* (2025.01)

(57) **ABSTRACT**

An integrated circuit includes a feedthrough via structure includes a dummy transistor with a dummy gate metal. The dummy transistor is positioned between a first transistor and a second transistor. The dummy gate metal is a different material than the gate metal of the first and second transistors. The feedthrough via structure and electrically connects a backside metal line with a front side metal line. The first and second transistors are positioned between the front side of backside metal lines.



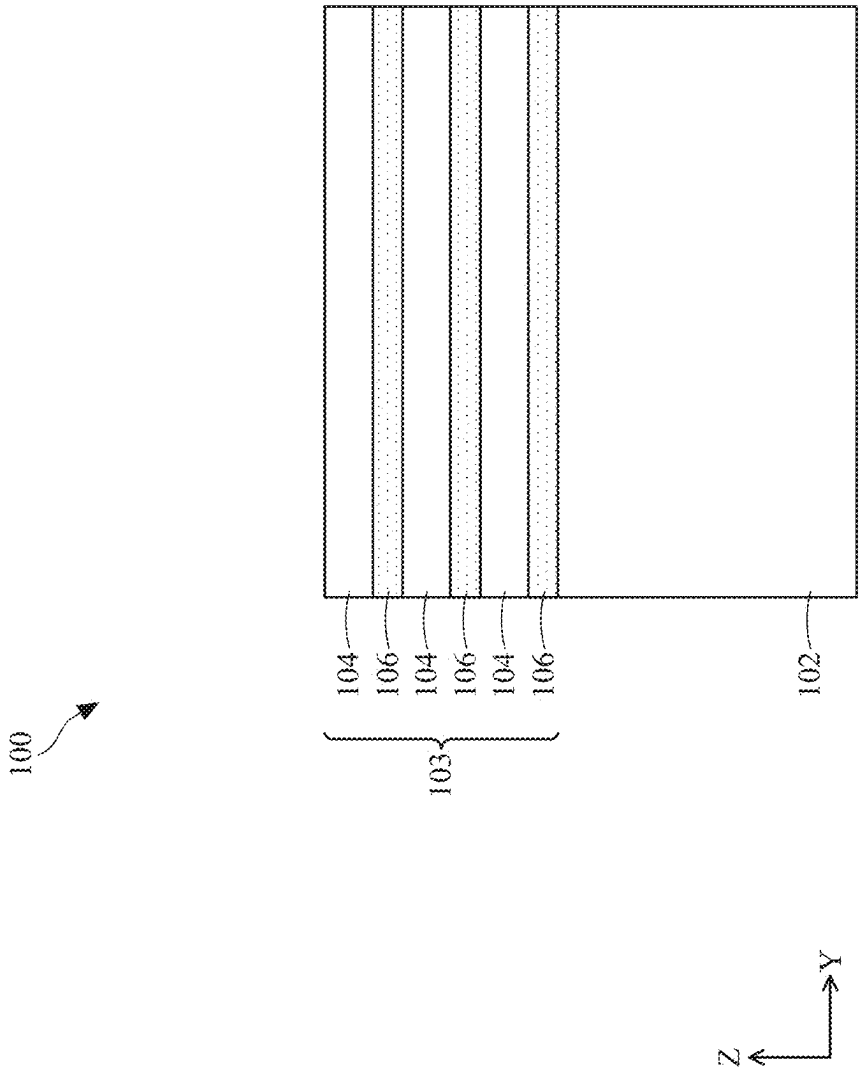


FIG. 1

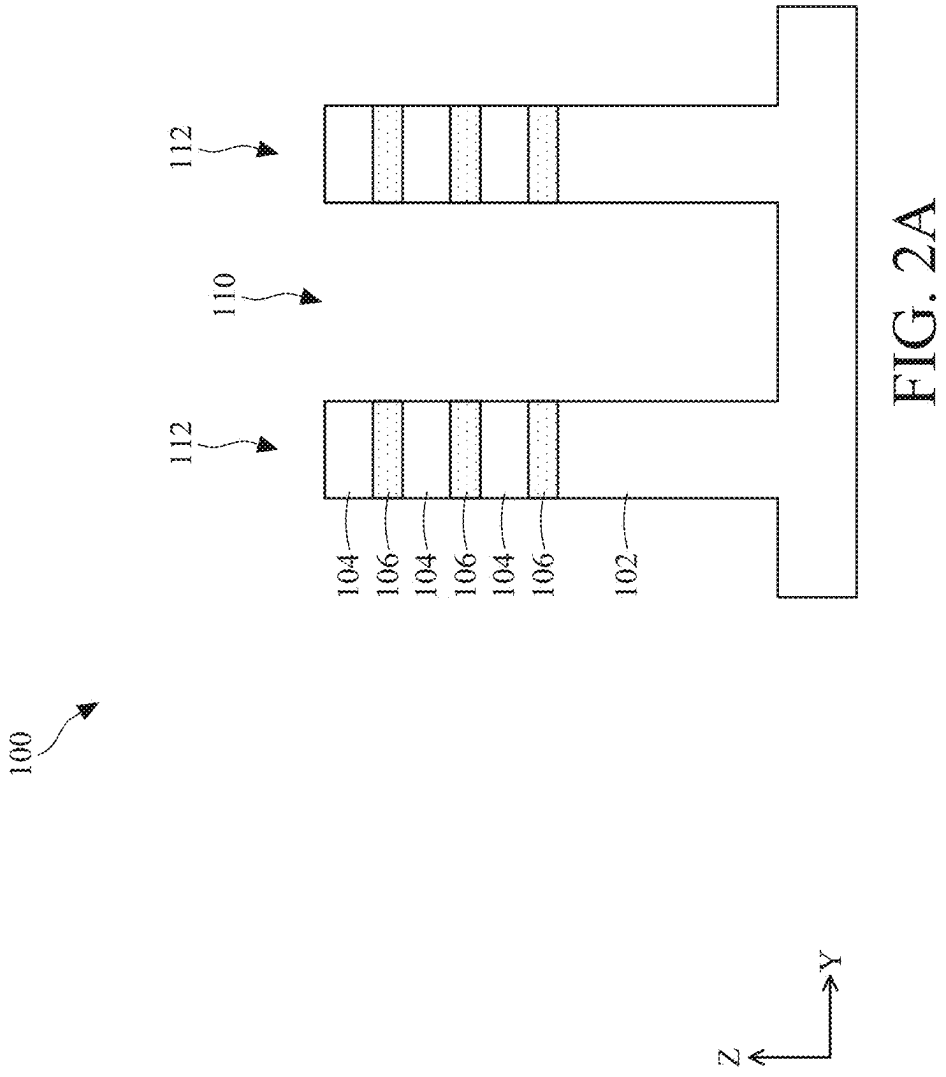


FIG. 2A

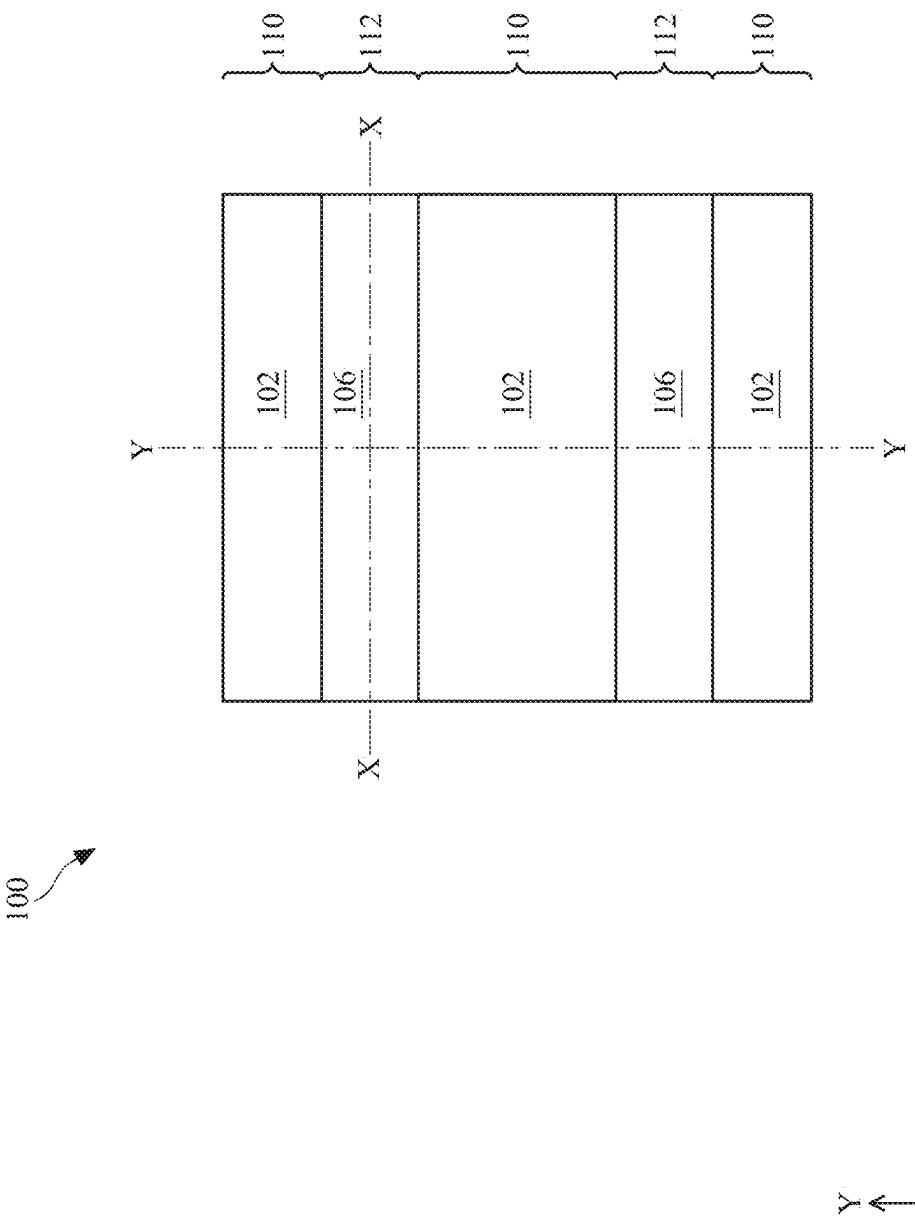


FIG. 2B

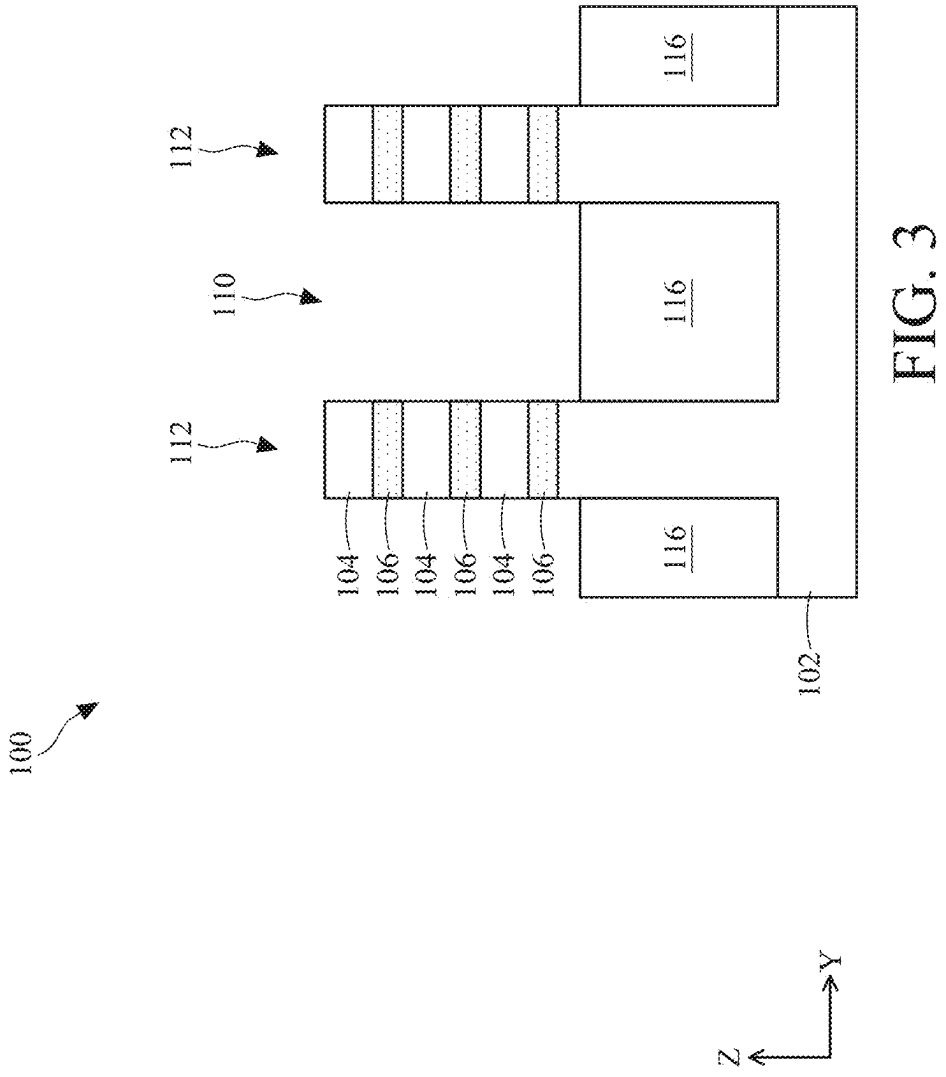


FIG. 3

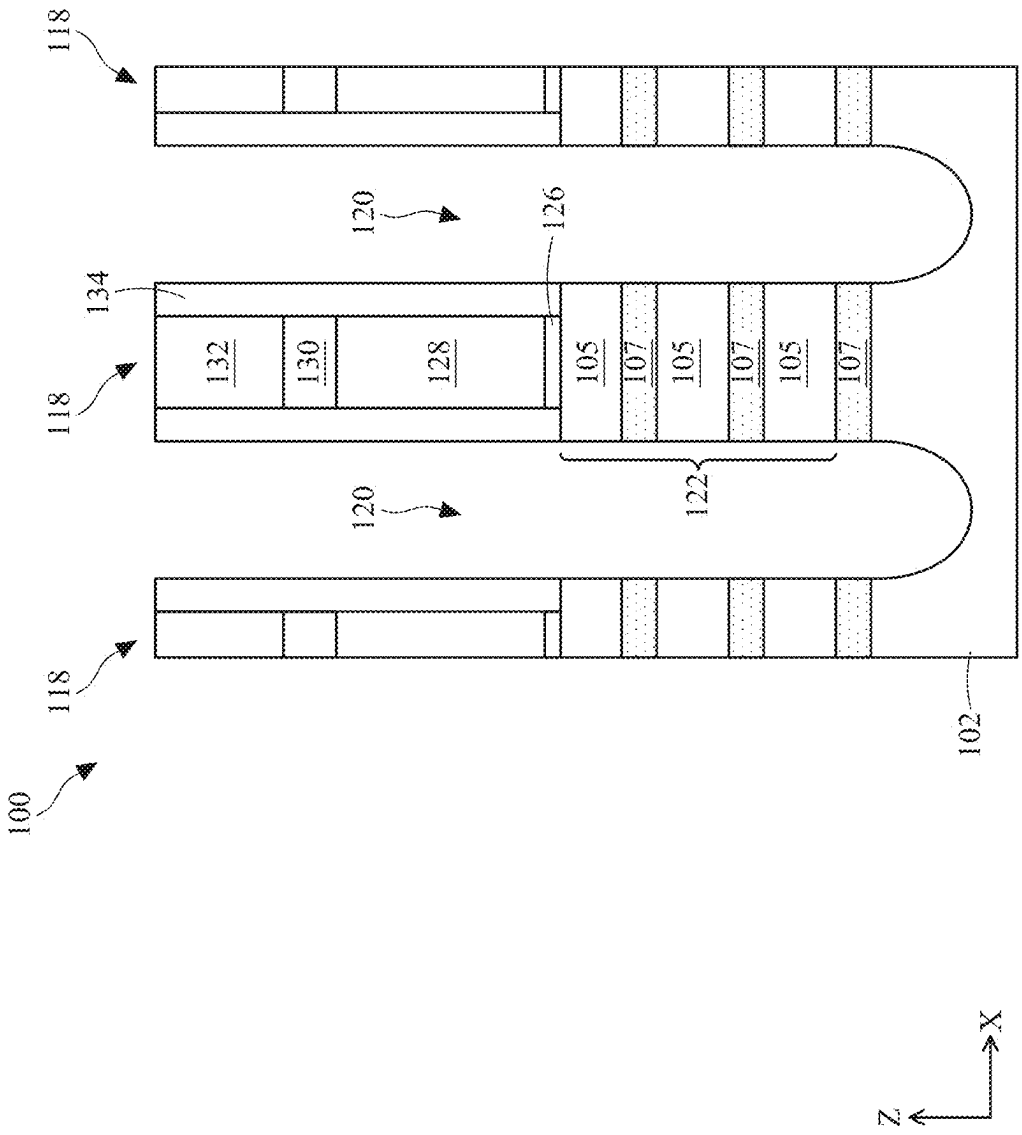
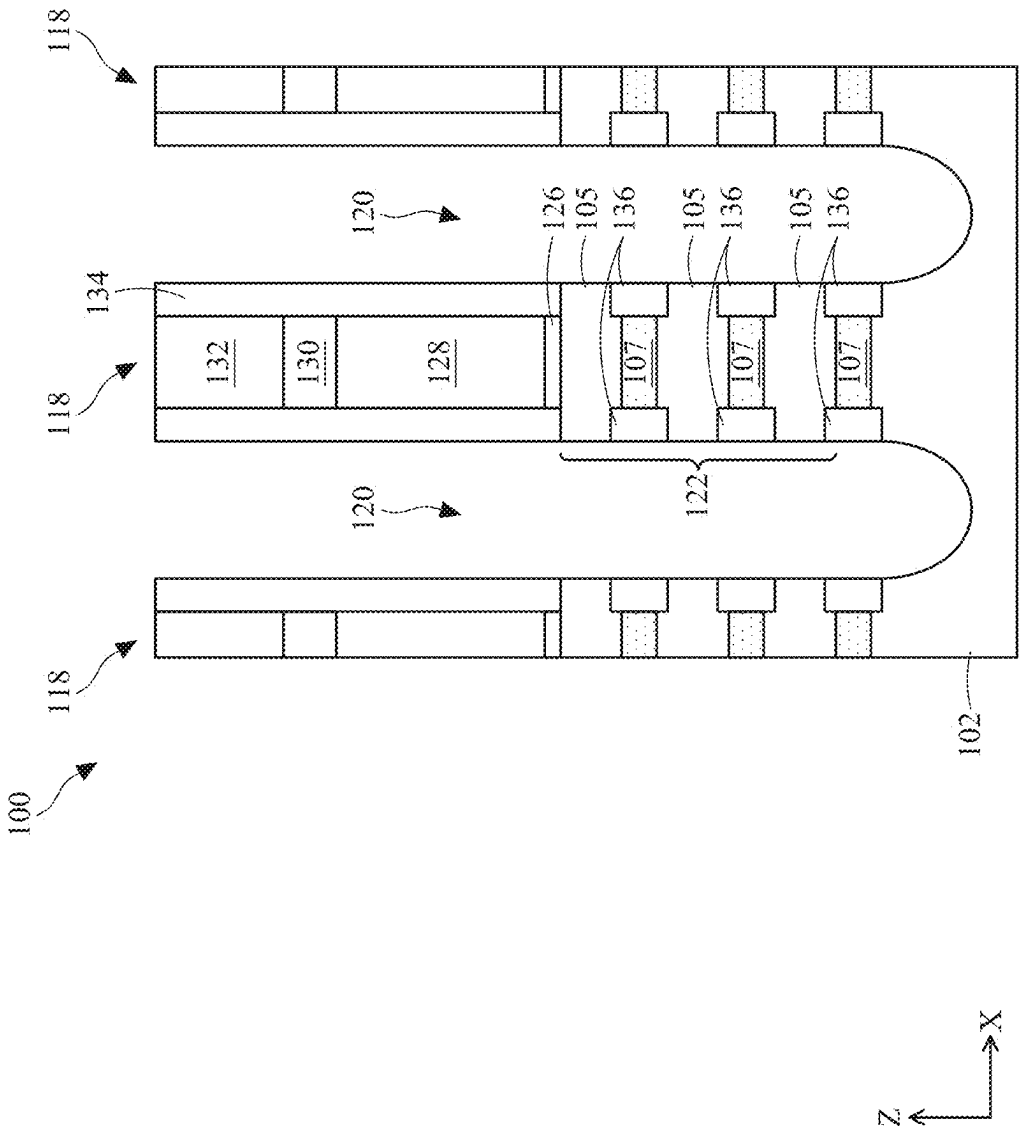

118
120
126
134
132
130
128
105
107
105
107
105
107
118
122
120
118
100
102
Z
X

FIG. 4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120
126
105
136
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136
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136
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132
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128
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107
107
118
122
120
118
102
100
Z
X

FIG. 5

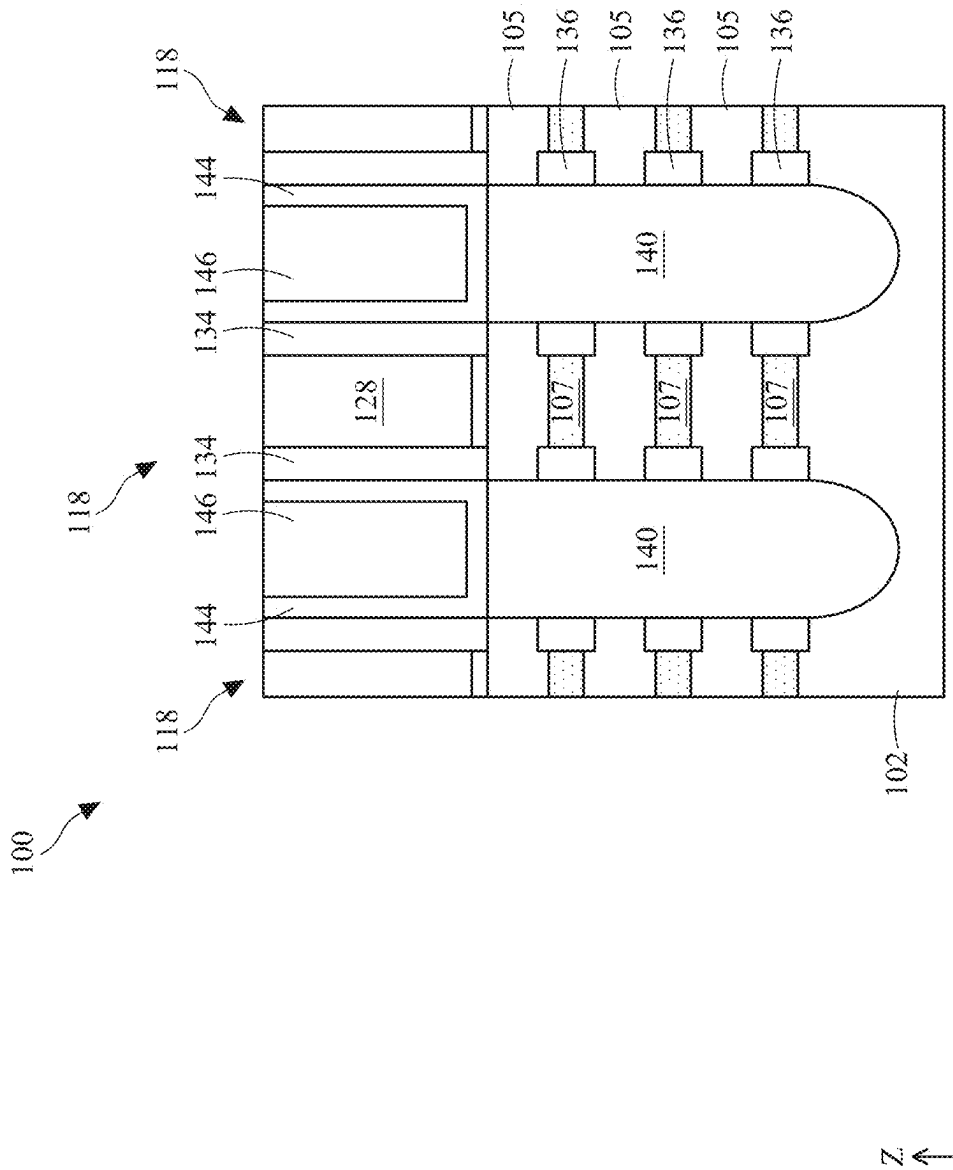
100
118
118
118
144
146
134
128
134
146
144
105
136
105
136
105
136
140
140
107
107
107
102
Z
X

FIG. 6

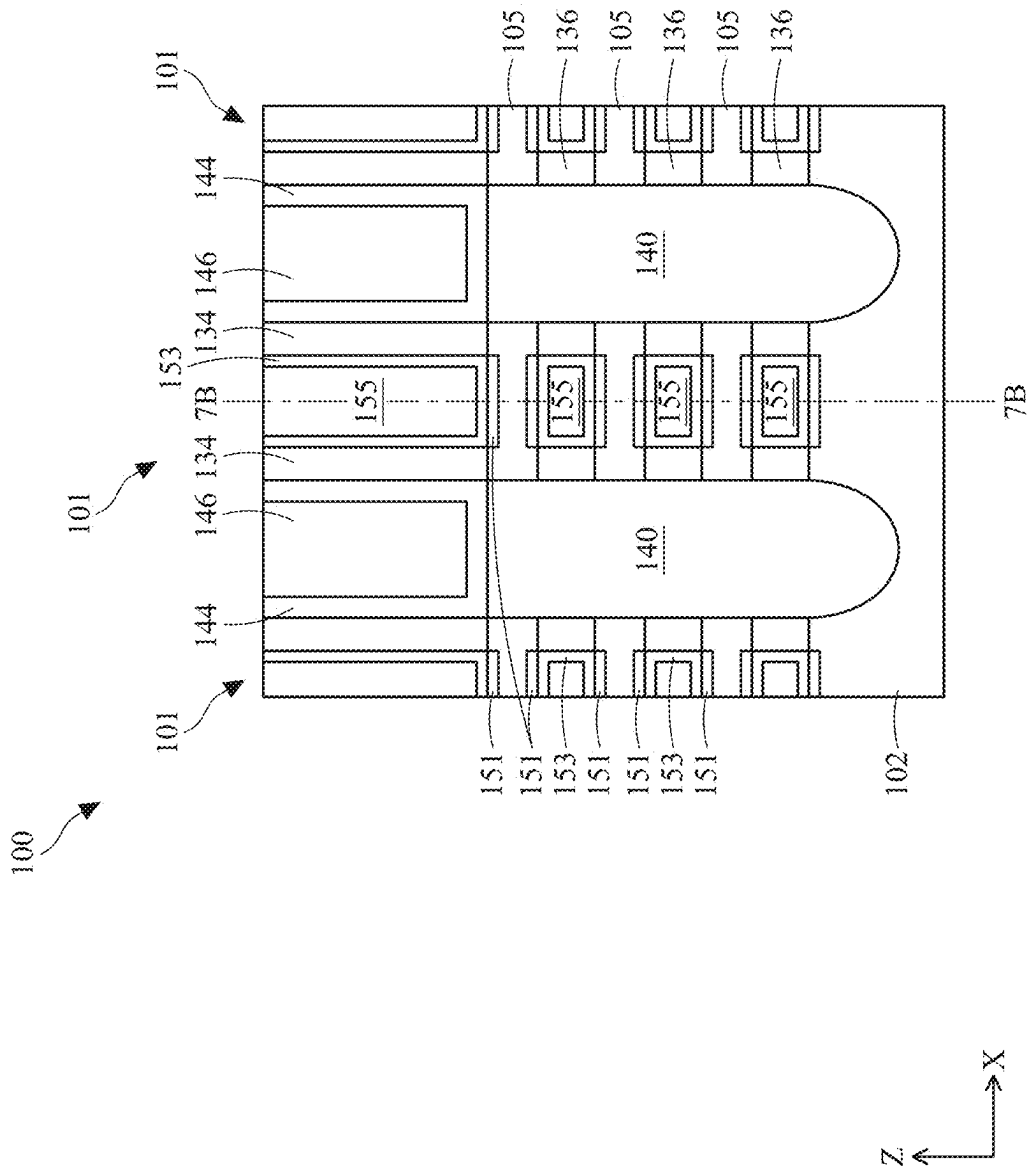
100
101
101
101
105
136
105
136
105
136
144
146
134
153
7B
155
155
155
155
7B
134
146
144
140
140
151
151
153
151
151
153
151
102
Z
X

FIG. 7A

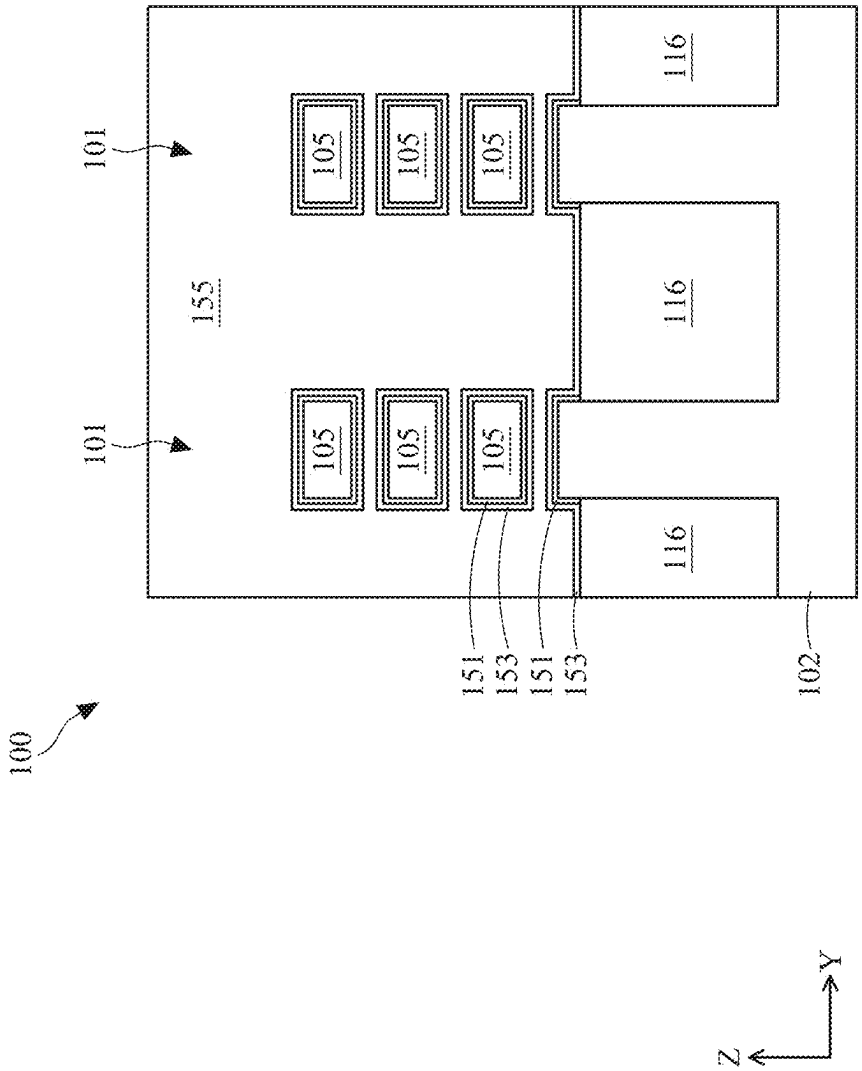
100
101
101
155
105
105
105
105
105
105
116
116
116
151
153
151
153
102
Y
Z

FIG. 7B

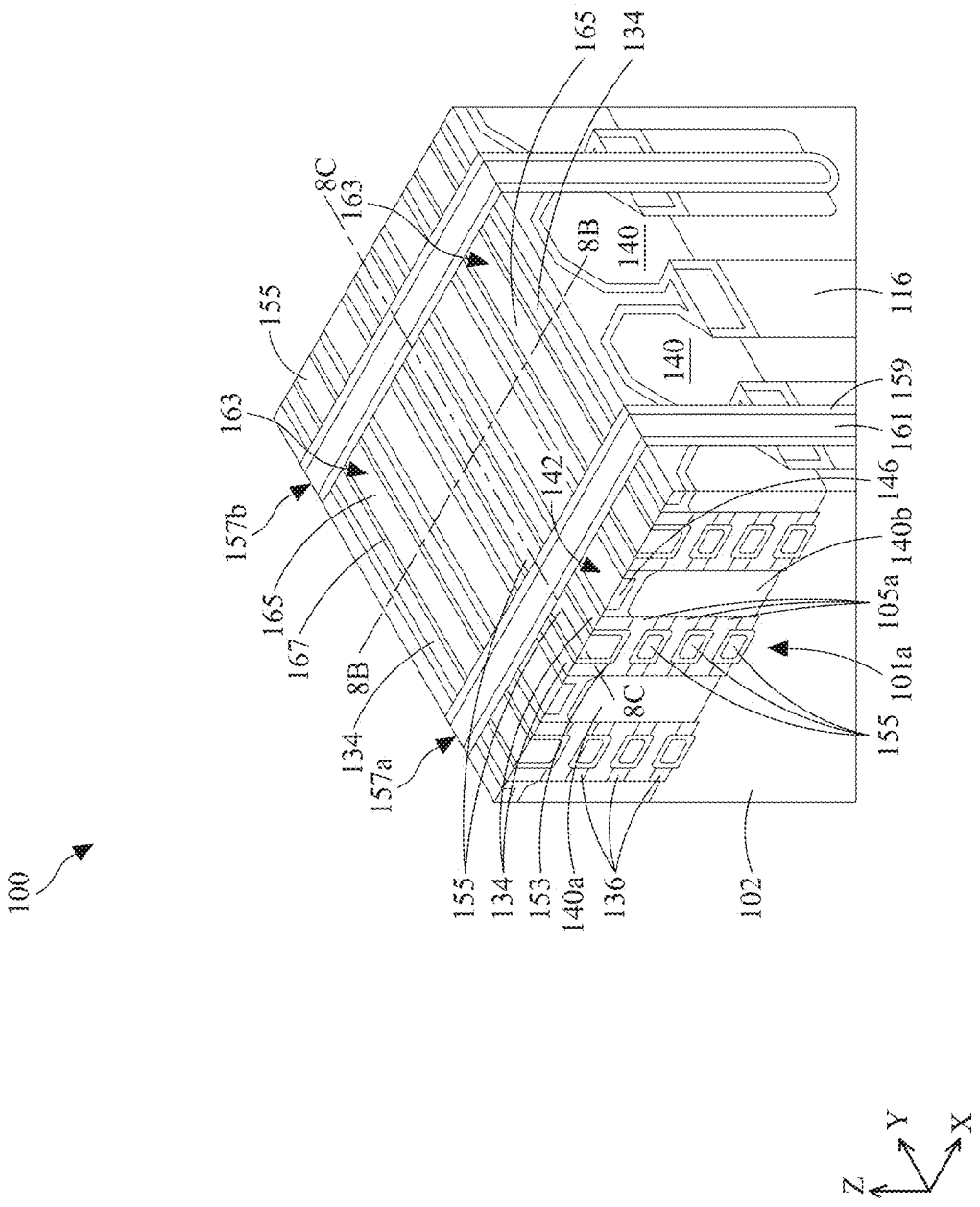
100
155
134
153
140a
136
102
157a
134
8B
167
165
157b
163
155
8C
163
165
134
8B
140
140
116
159
161
146
142
140b
105a
101a
155
8C
Z
Y
X

FIG. 8A

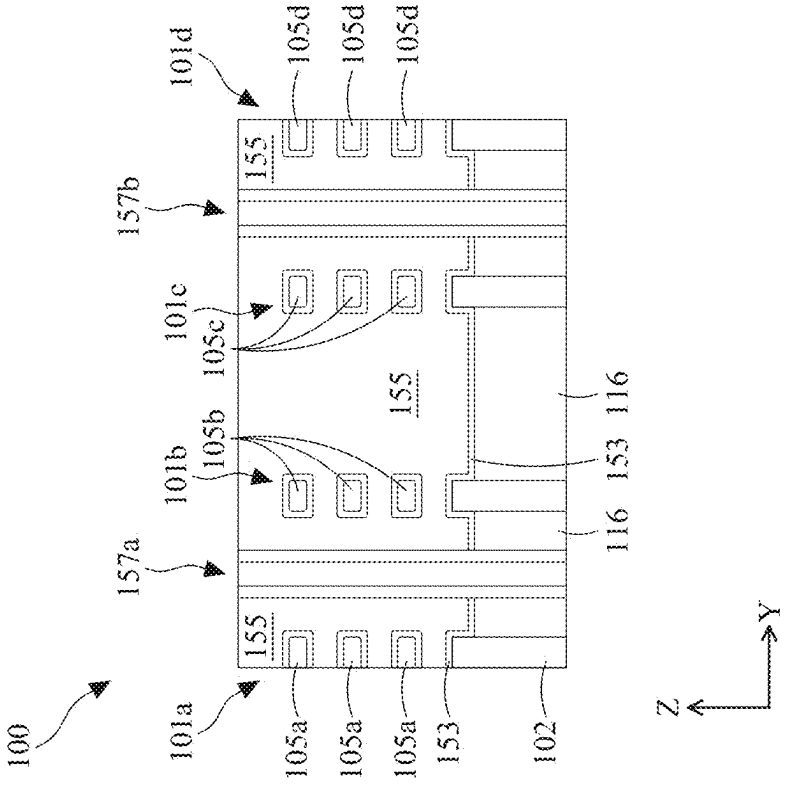
100
101a
101b
101c
101d
105a
105b
105c
105d
153
155
157a
157b
102
116
Z
Y

FIG. 8C

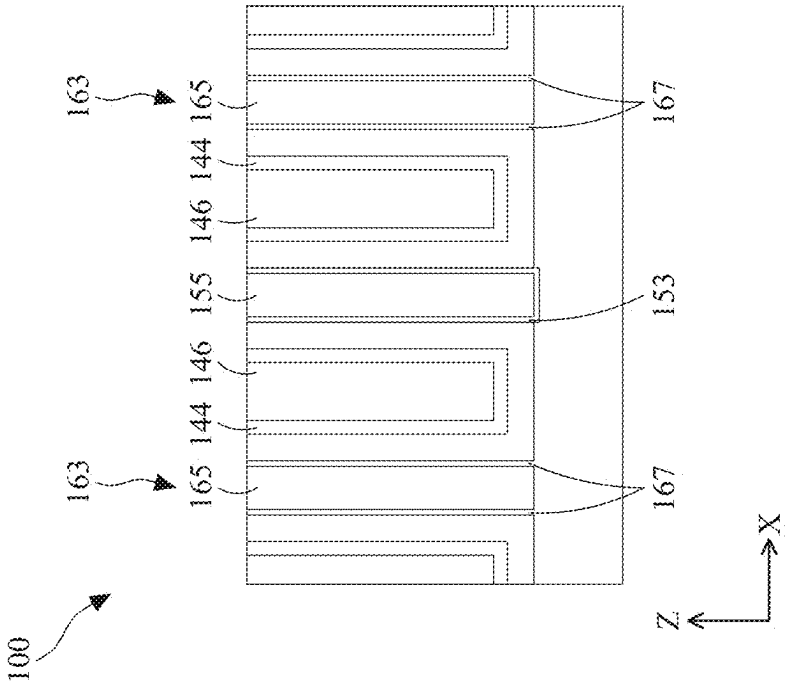
100
163
165
167
144
146
153
155
Z
X

FIG. 8B

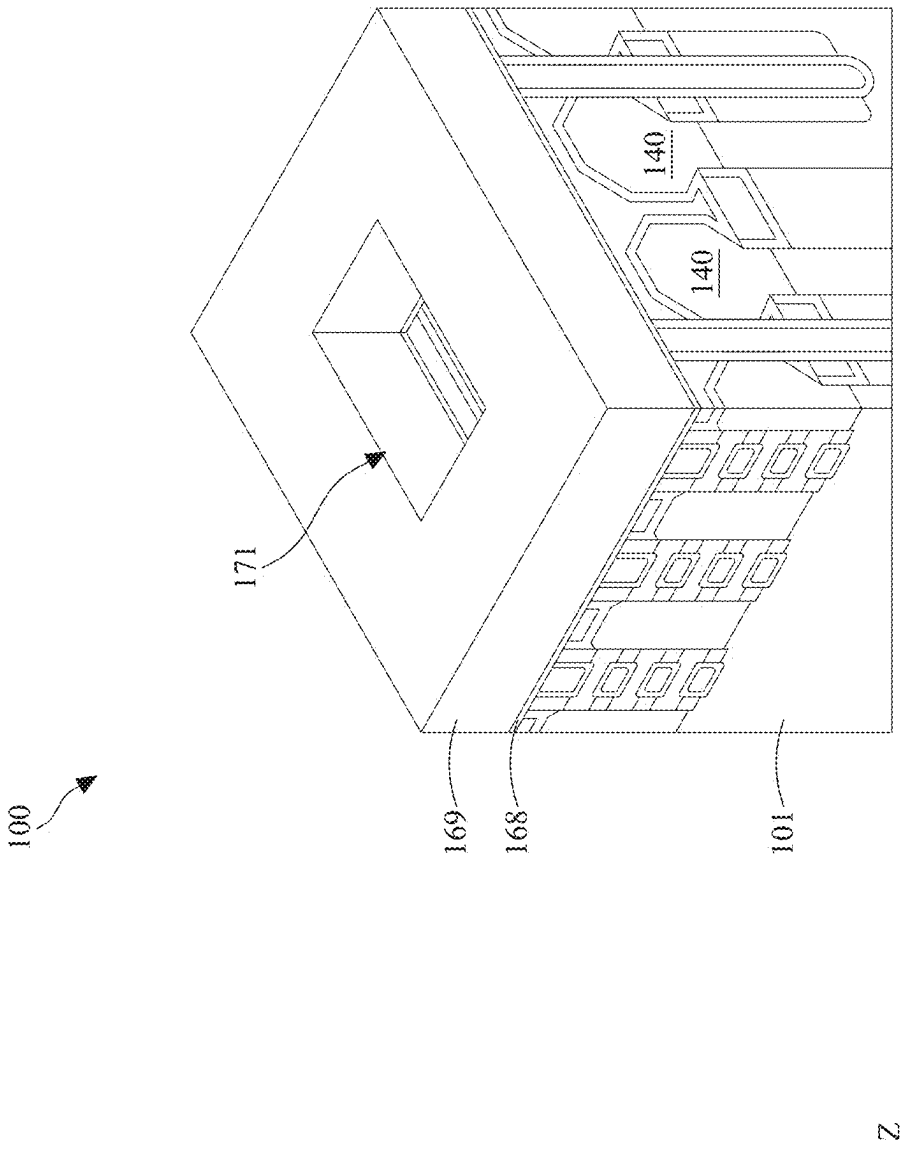

FIG. 9A

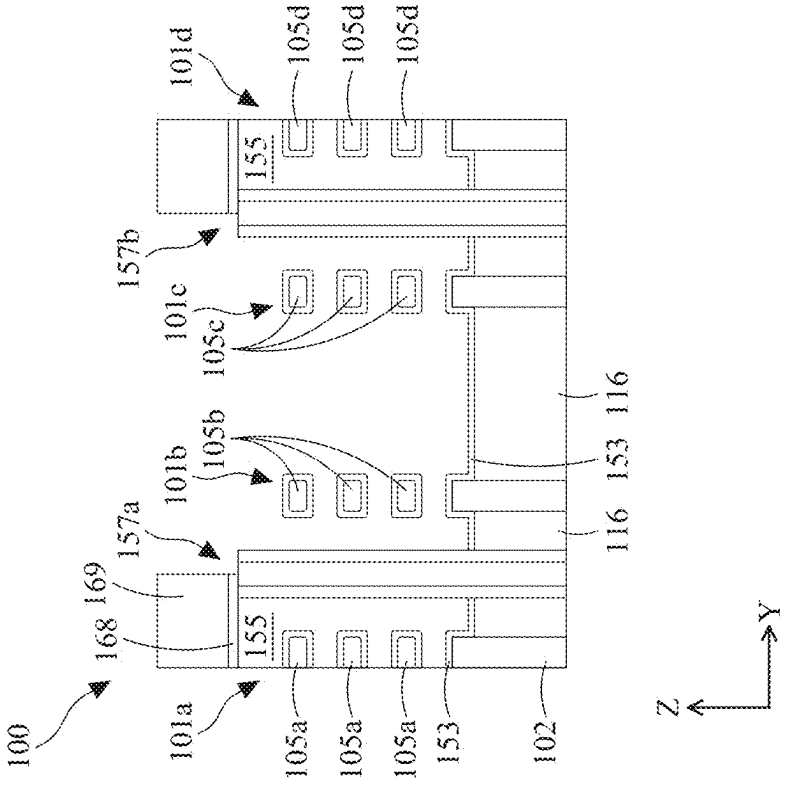
100
101a
101b
101c
101d
102
105a
105b
105c
105d
116
153
155
157a
157b
168
169
Y
Z

FIG. 9C

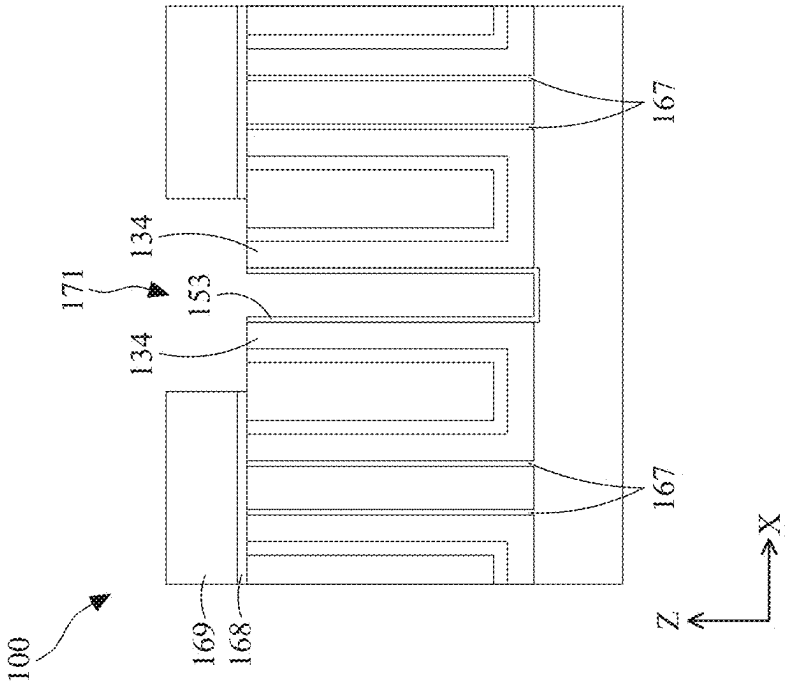
100
134
153
167
168
169
171
X
Z

FIG. 9B

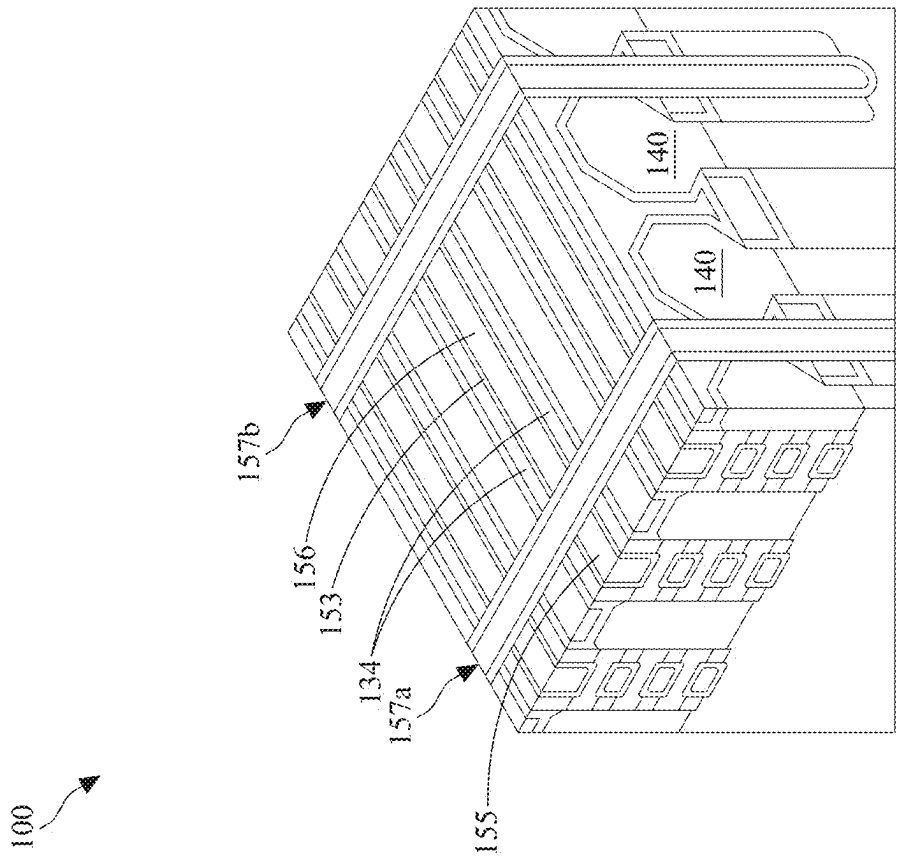

FIG. 10A

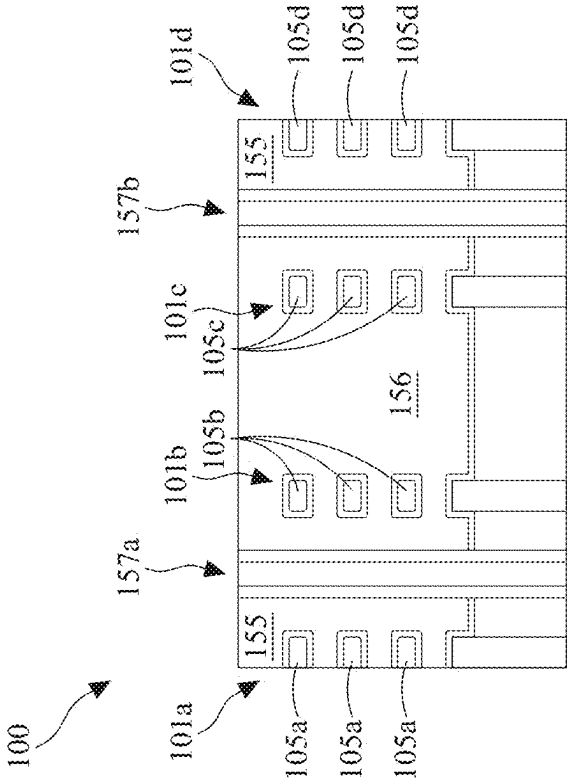

FIG. 10C

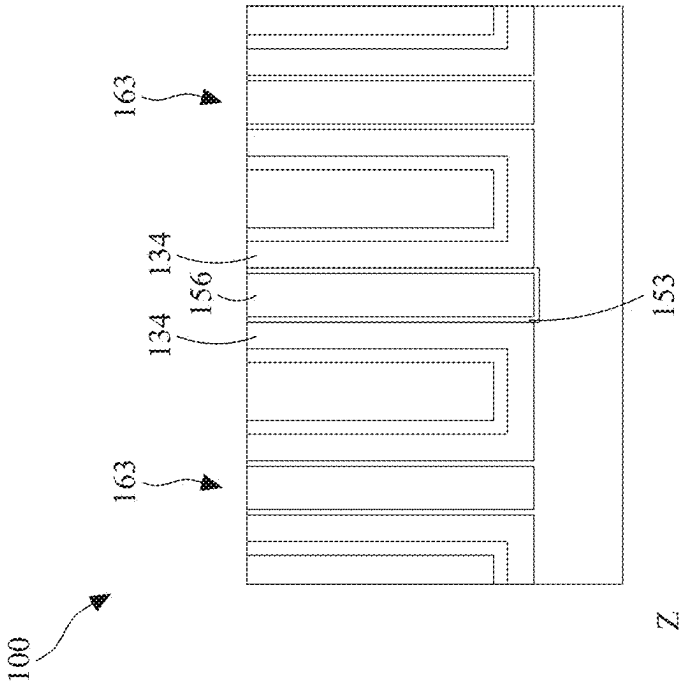

FIG. 10B

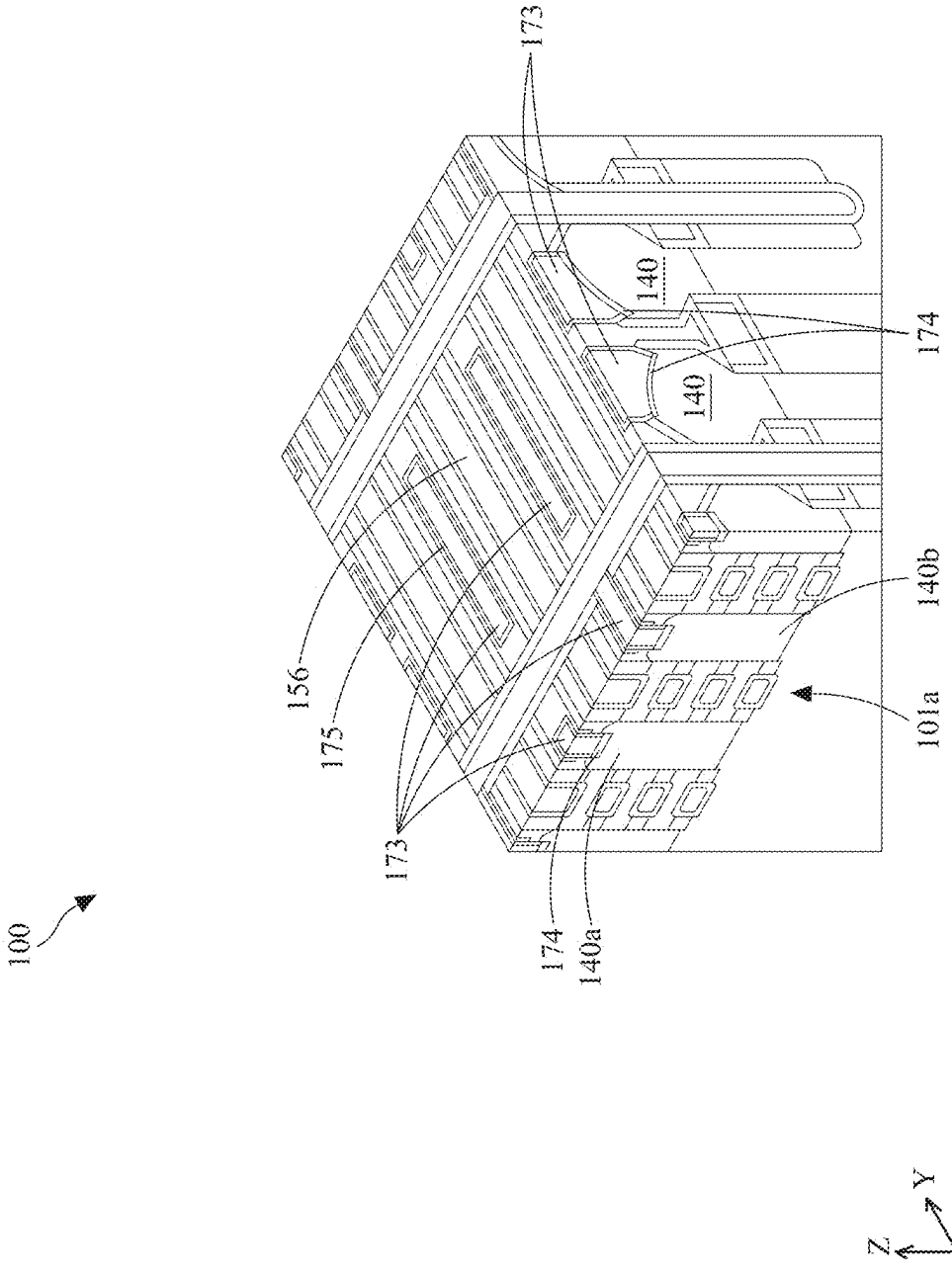

FIG. 11A

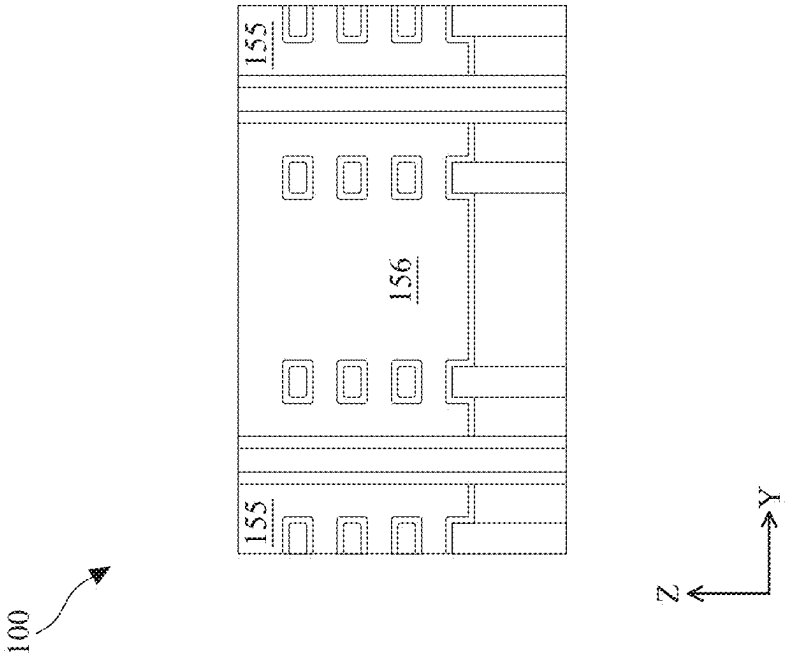

FIG. 11C

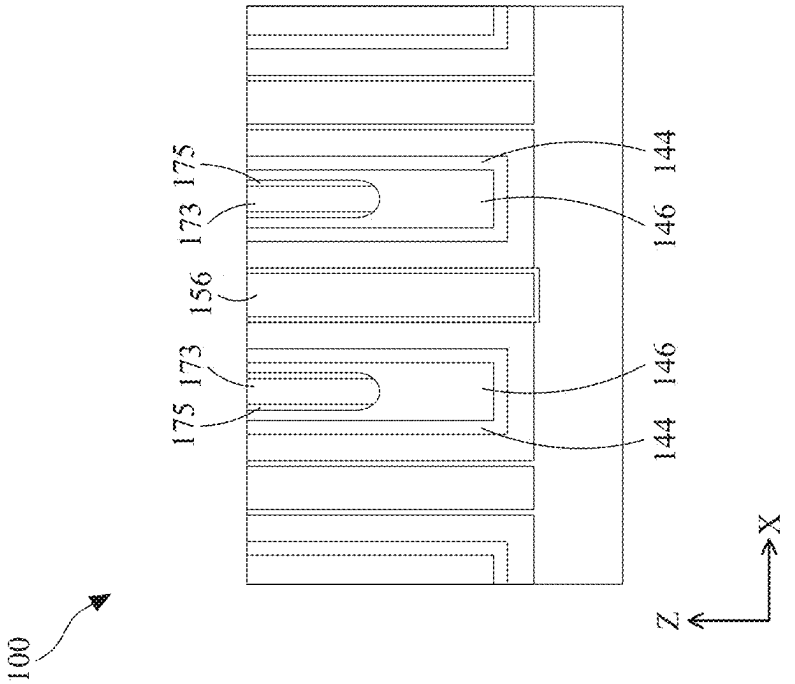

FIG. 11B

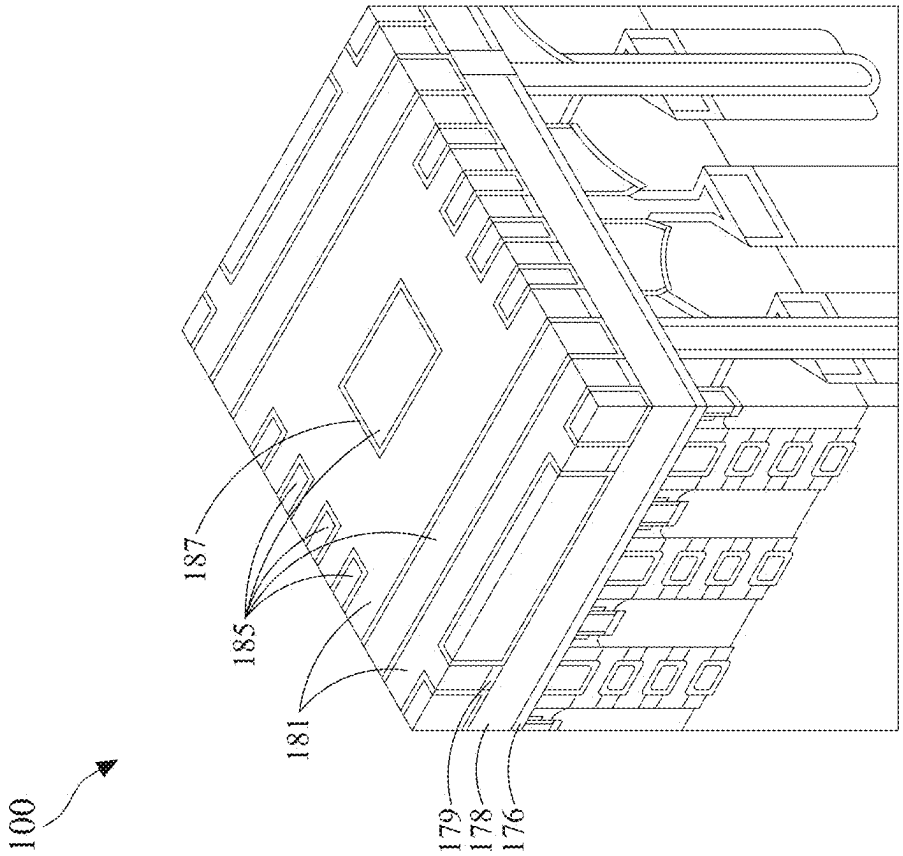

FIG. 12A

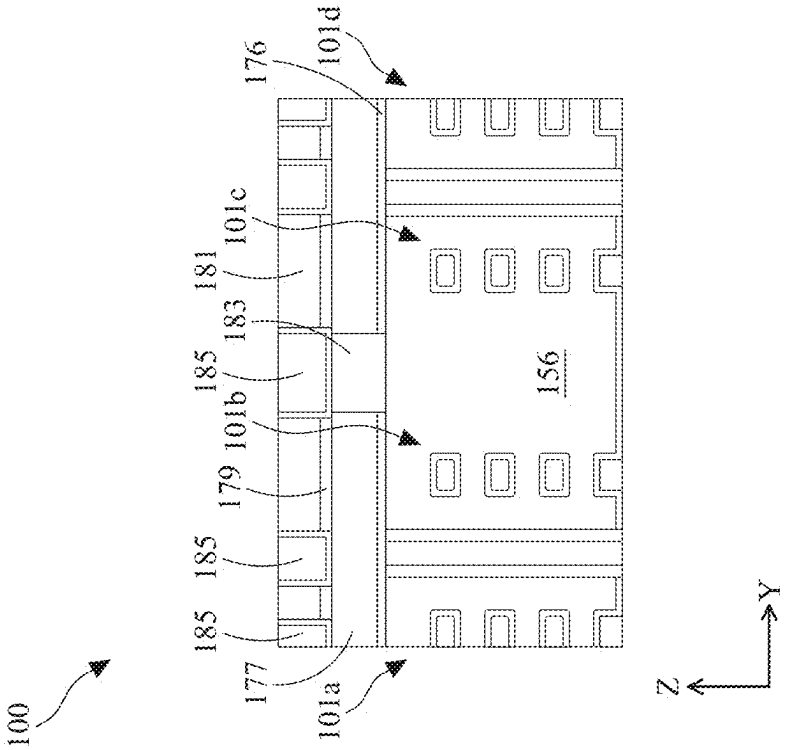

FIG. 12C

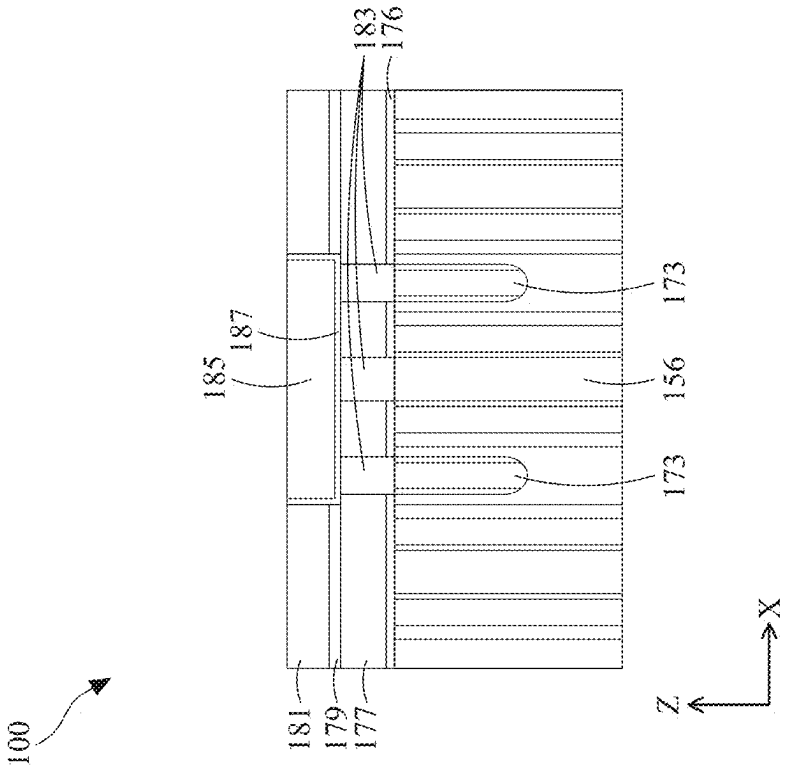

FIG. 12B

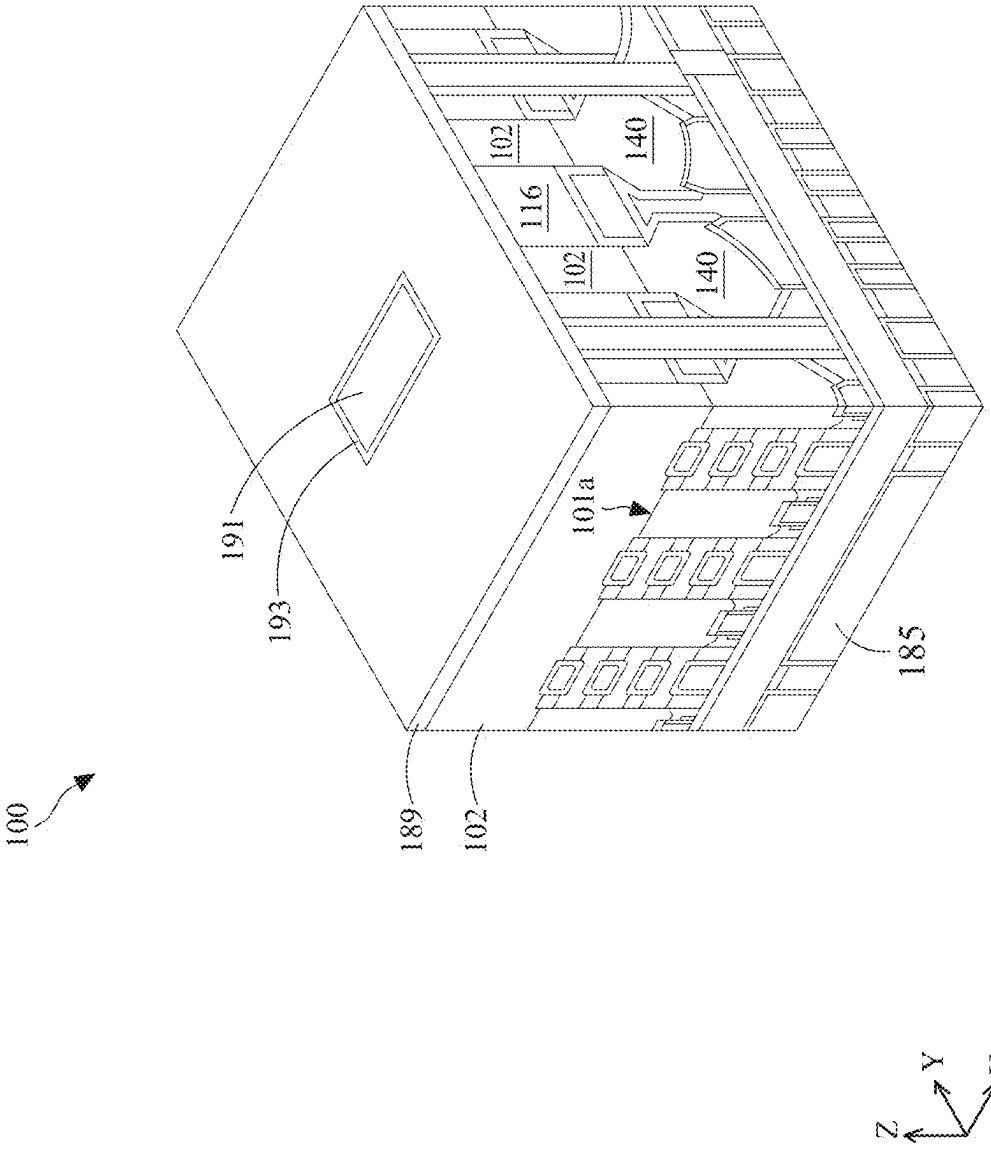

FIG. 13A

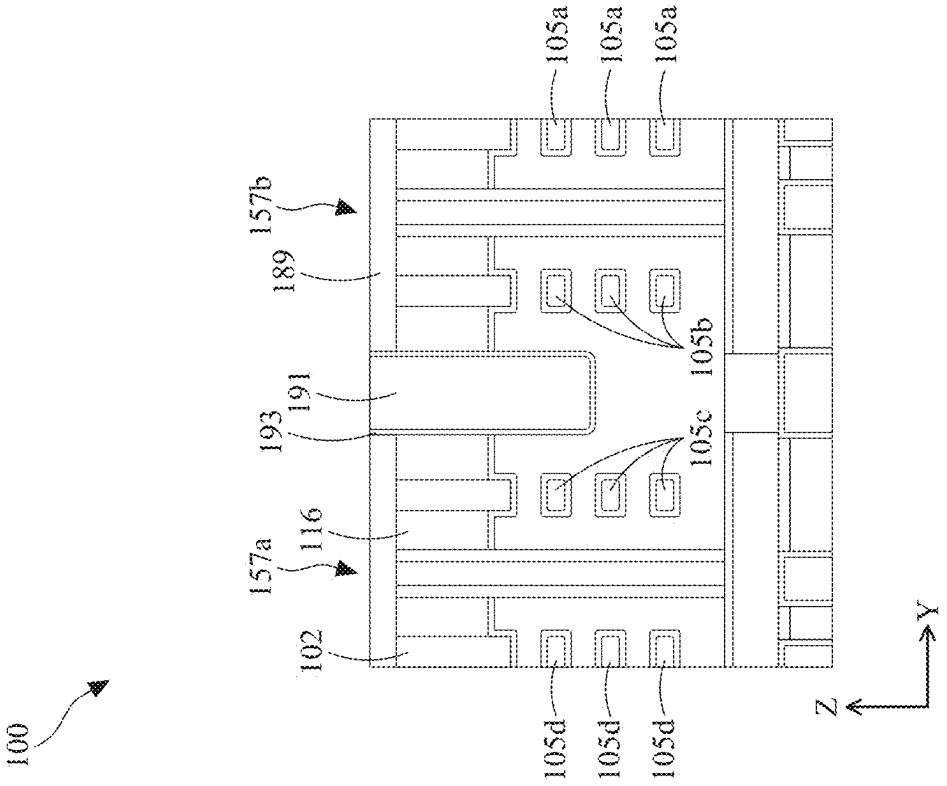

FIG. 13C

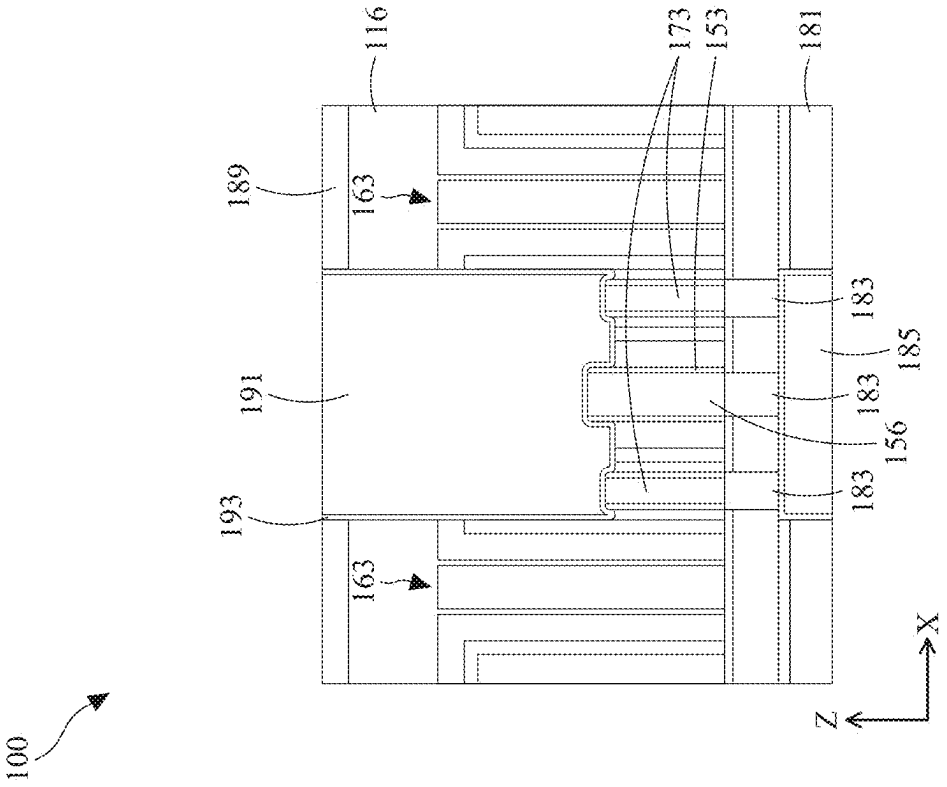

FIG. 13B

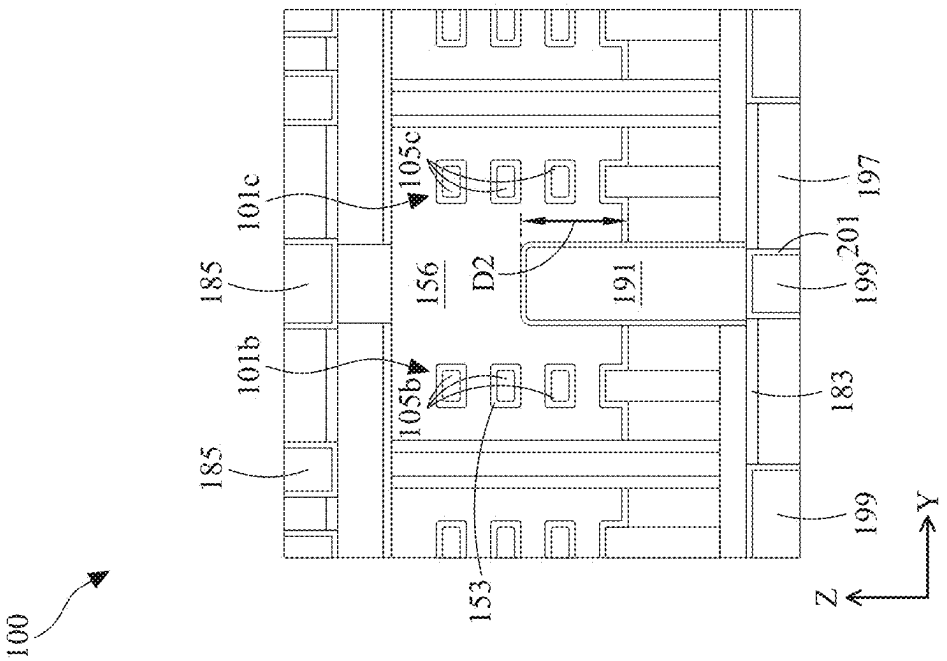

FIG. 14B

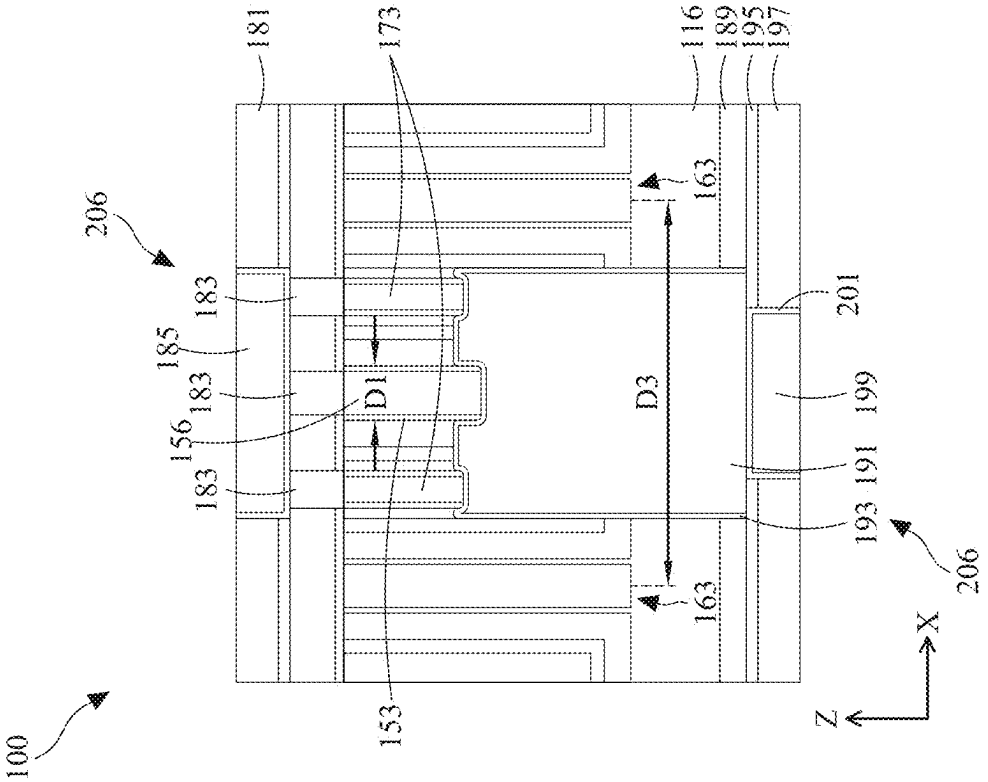

FIG. 14A

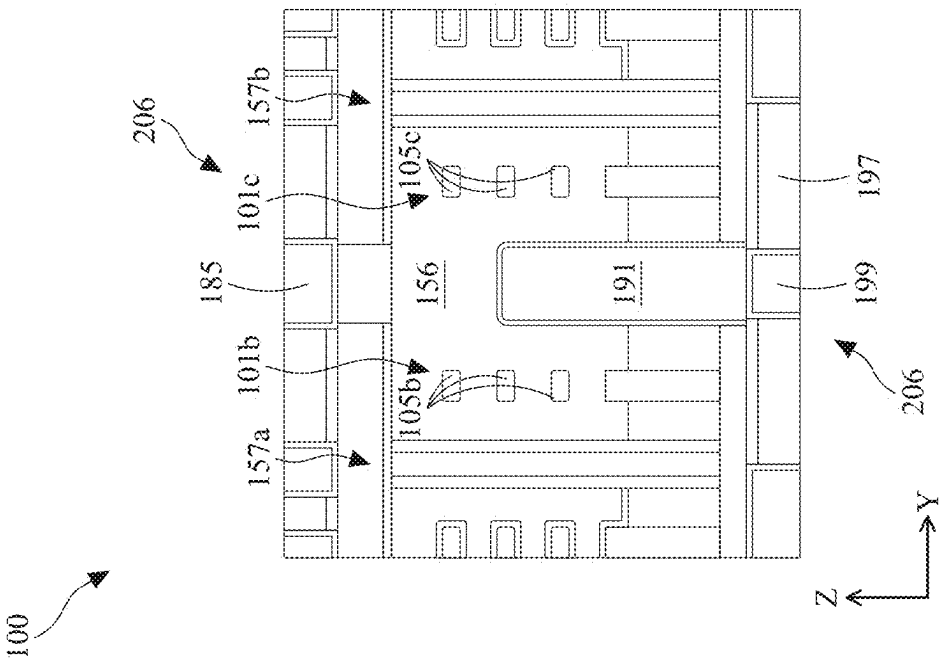

FIG. 15B

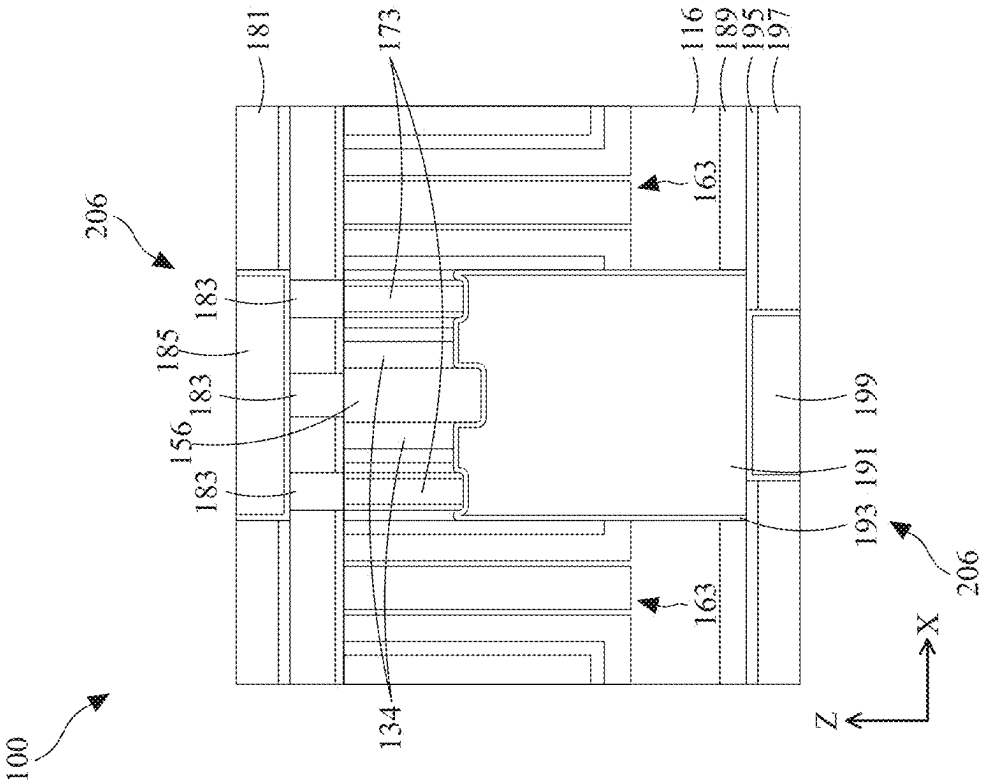

FIG. 15A

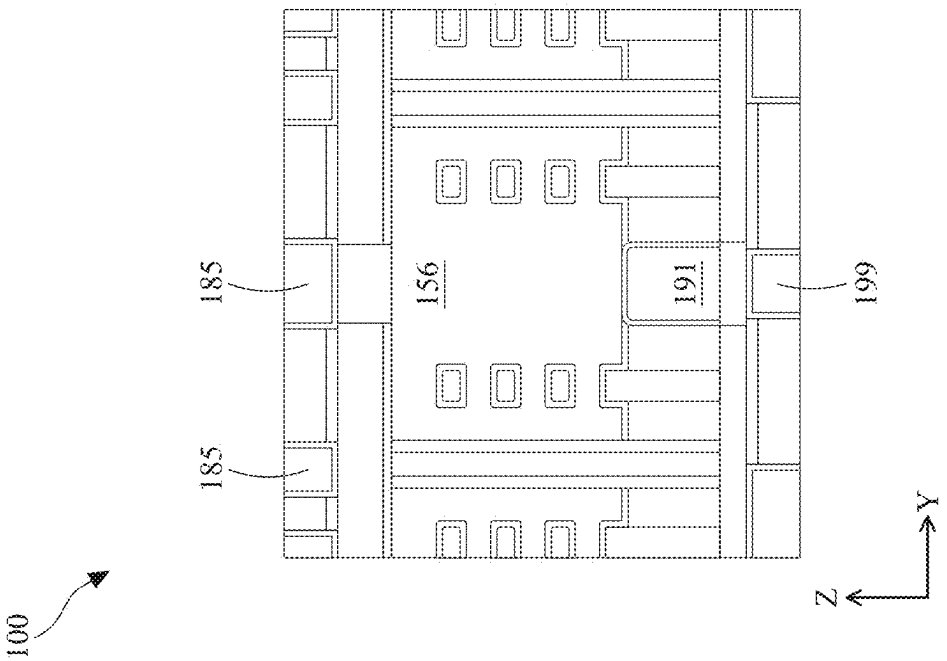

FIG. 16B

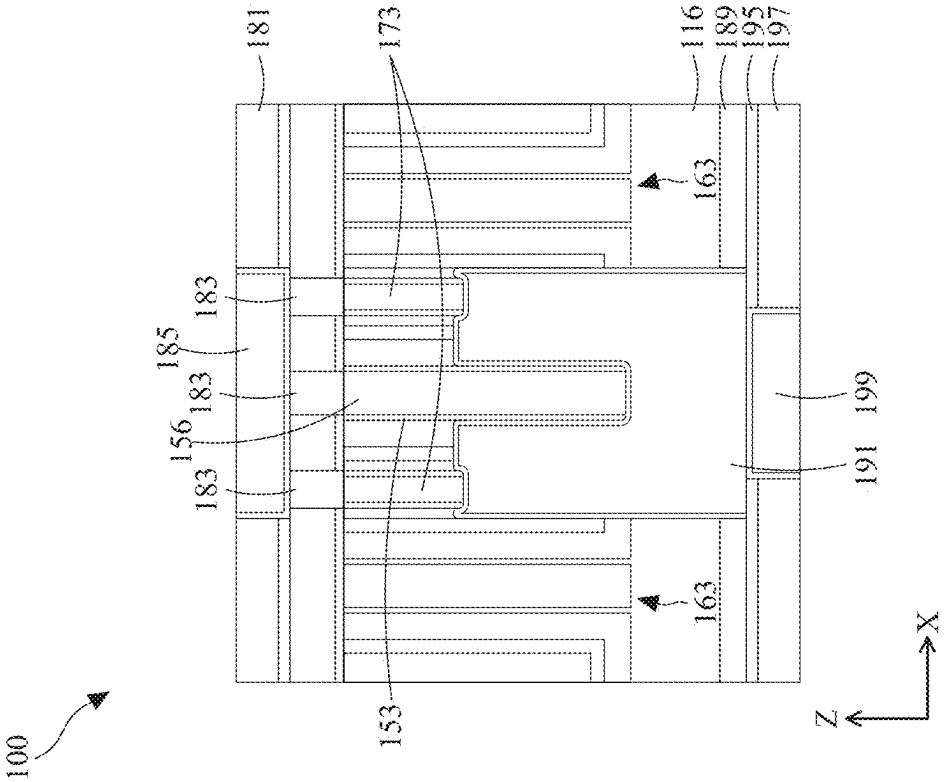

FIG. 16A

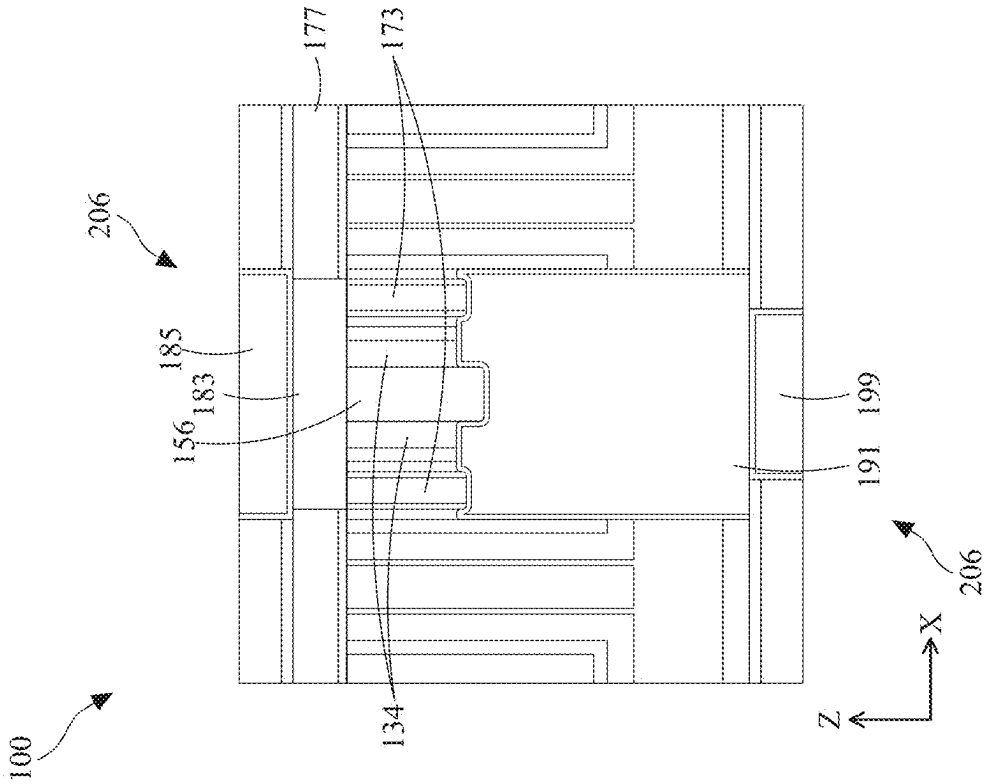
177
173
206
185
183
156
199
191
206
X
Z
134
100

FIG. 18

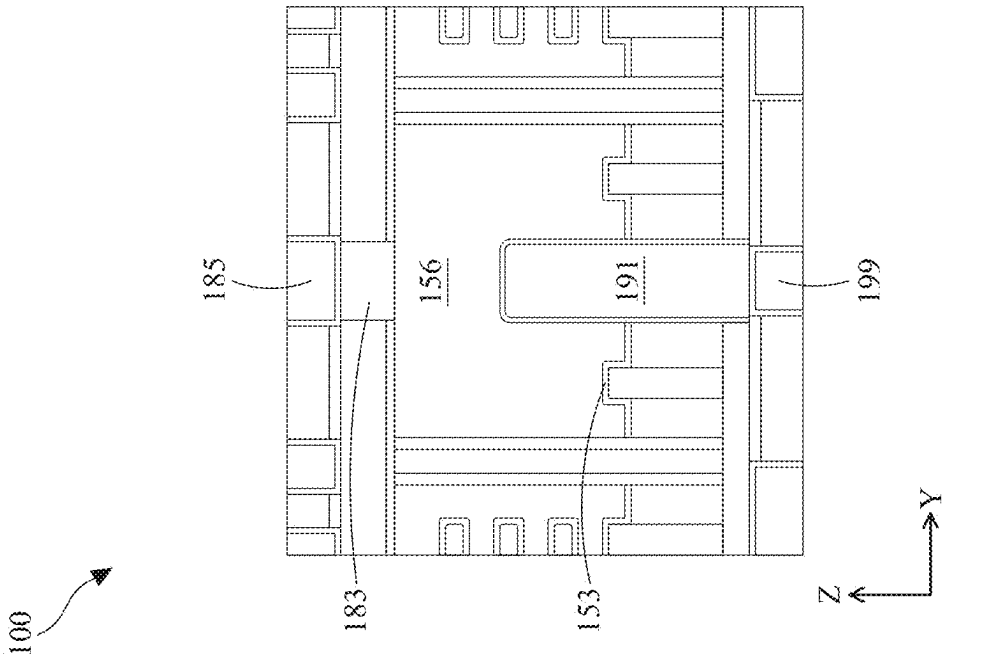
185
156
191
199
Y
Z
183
153
100

FIG. 17

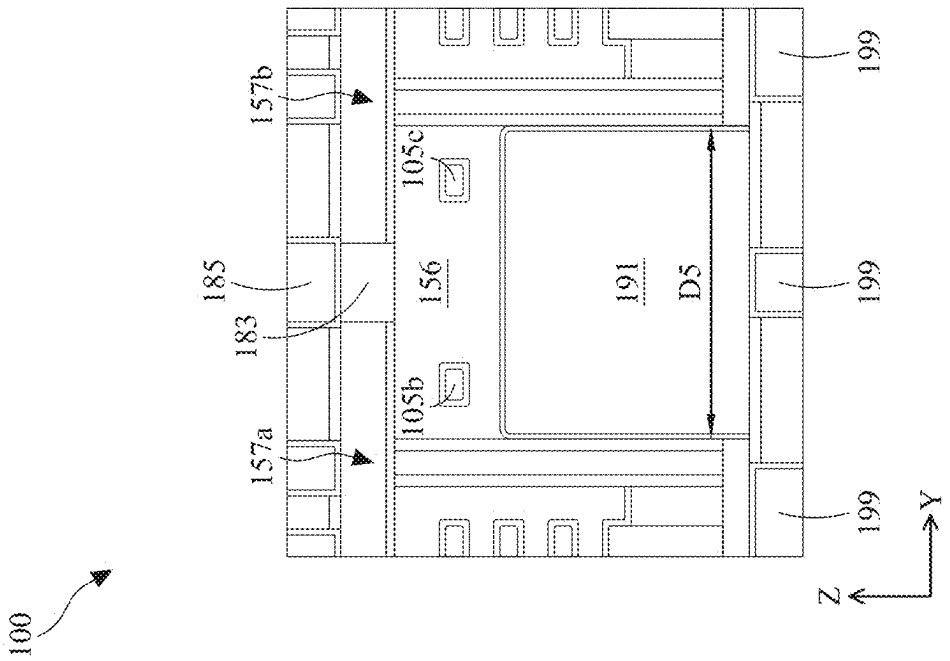

FIG. 19B

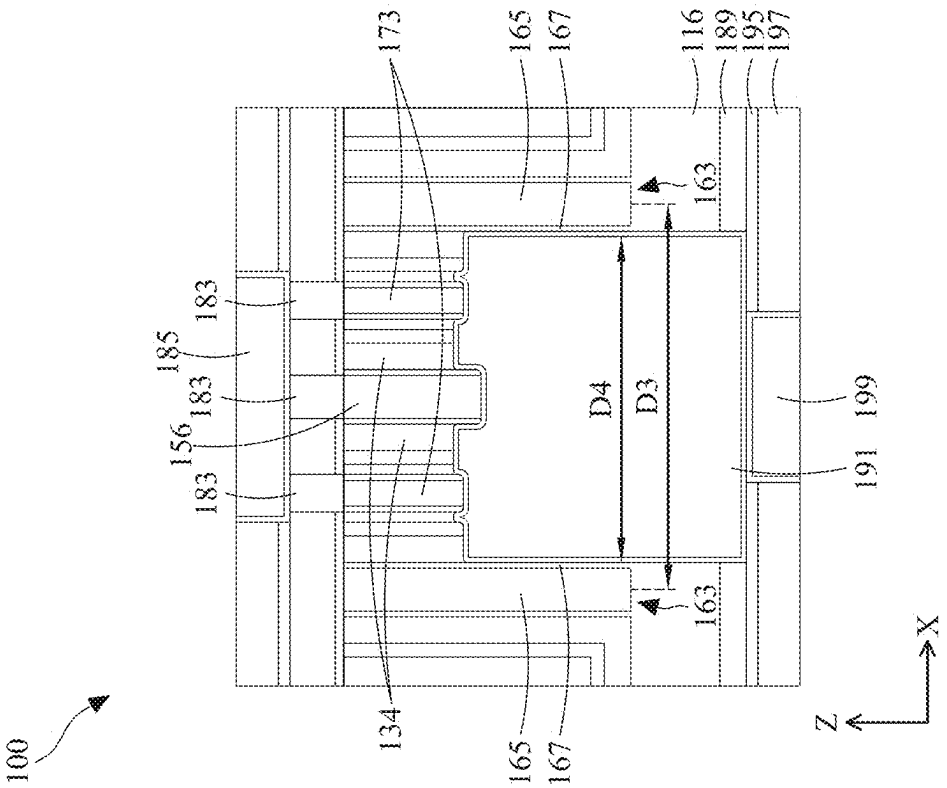

FIG. 19A

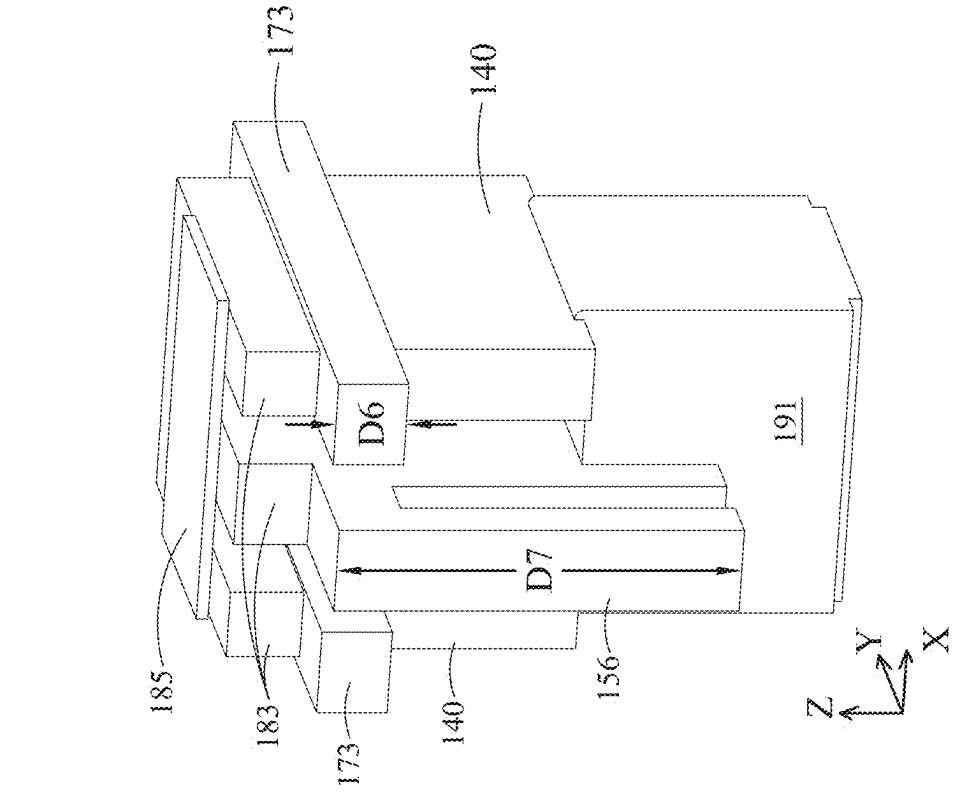

FIG. 20B

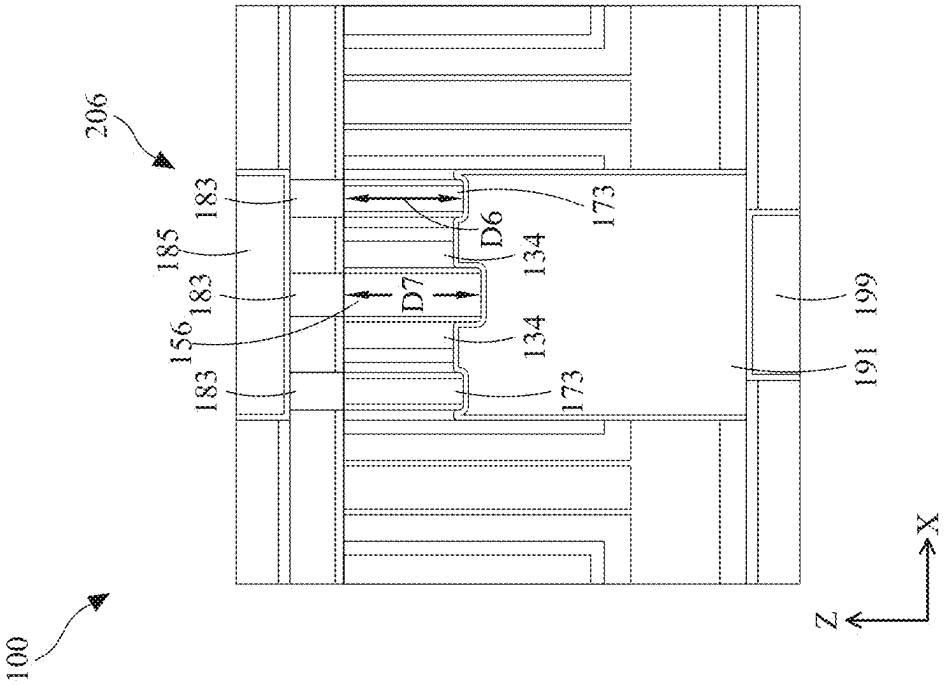

FIG. 20A

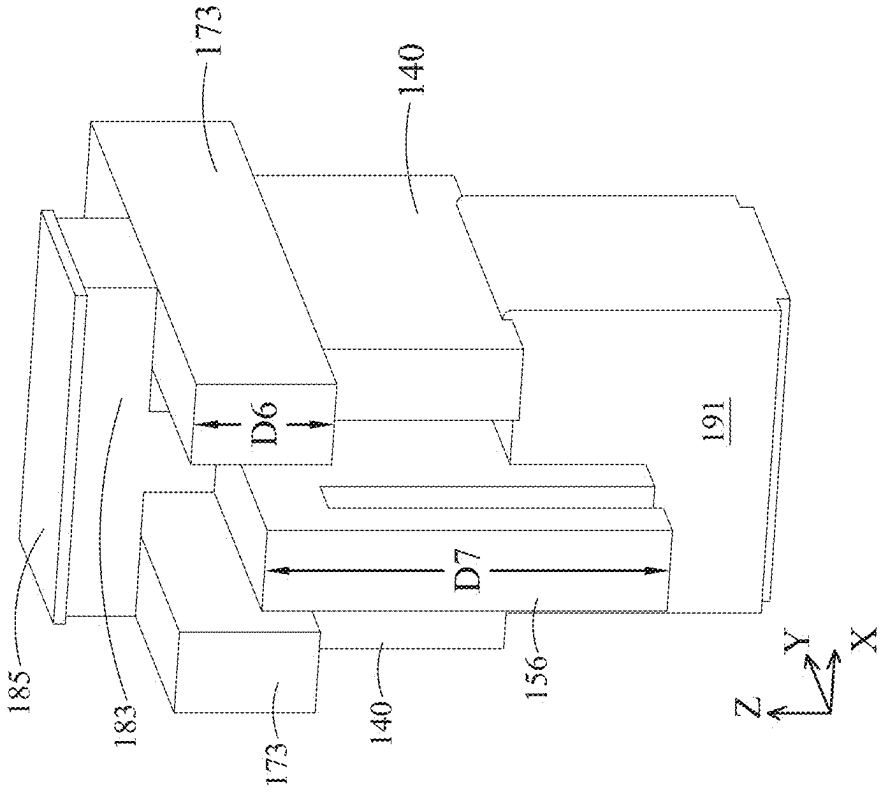

FIG. 21B

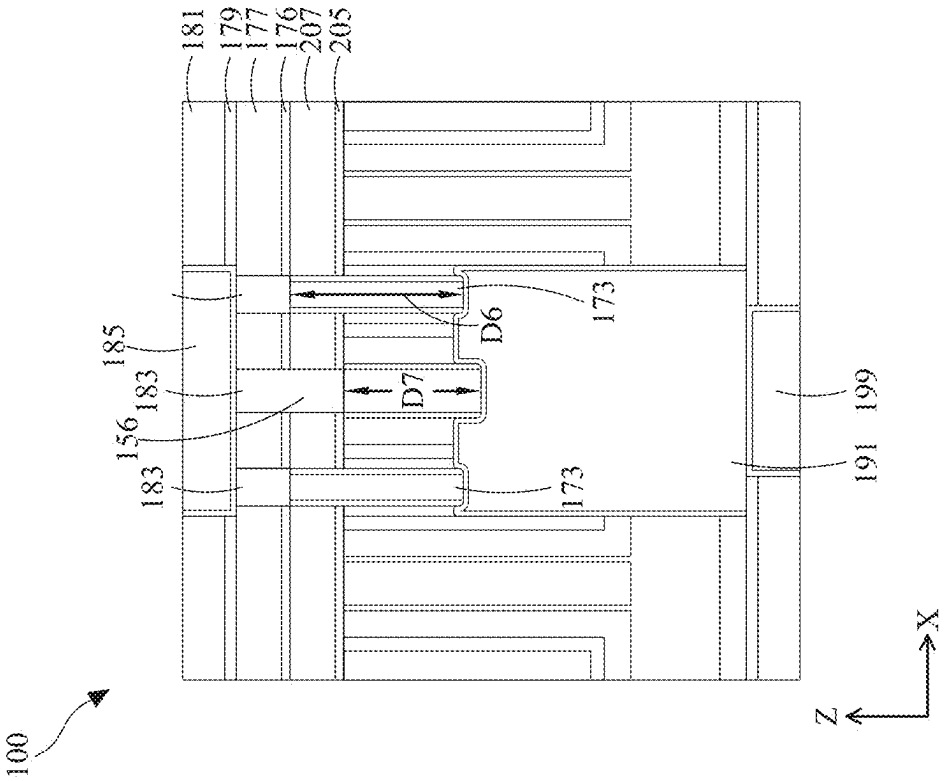

FIG. 21A

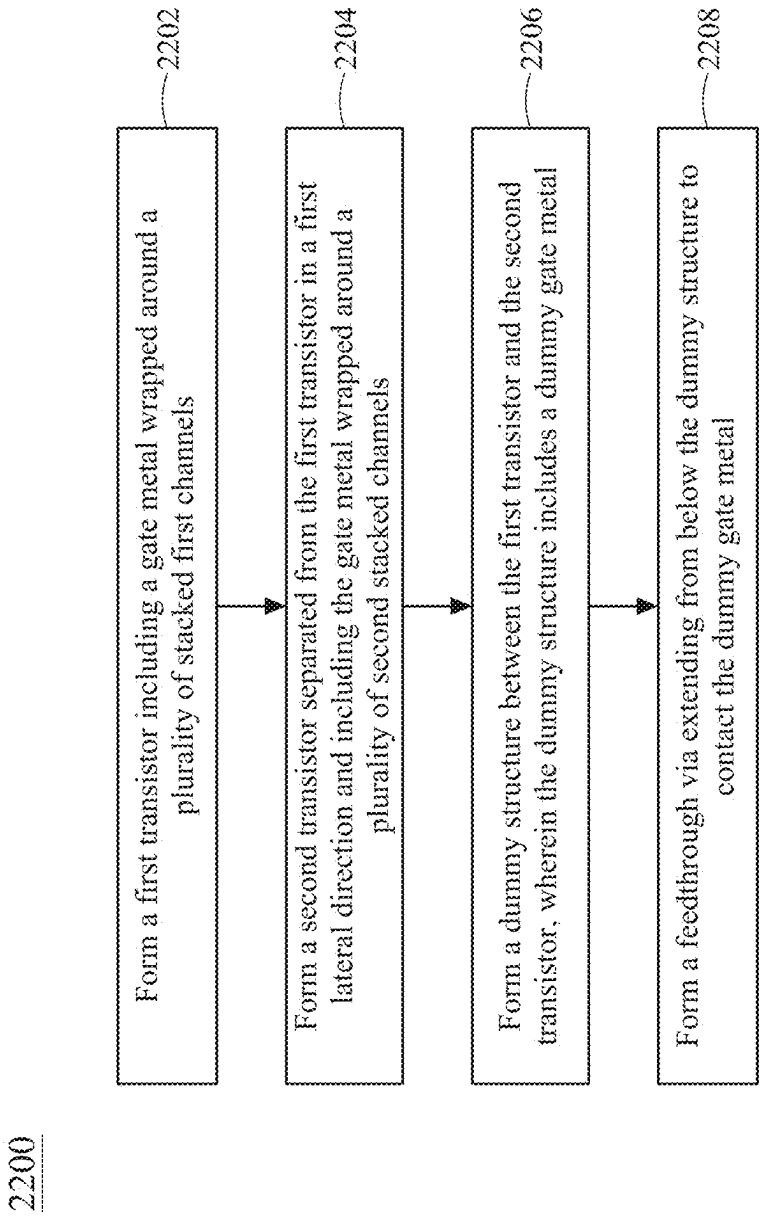
2200
2202
Form a first transistor including a gate metal wrapped around a plurality of stacked first channels
2204
Form a second transistor separated from the first transistor in a first lateral direction and including the gate metal wrapped around a plurality of second stacked channels
2206
Form a dummy structure between the first transistor and the second transistor, wherein the dummy structure includes a dummy gate metal
2208
Form a feedthrough via extending from below the dummy structure to contact the dummy gate metal

FIG. 22

LOW RESISTANCE FEEDTHROUGH CELL WITH CONTACTED POLY PITCH BY METAL GATE CONNECTED TO FEEDTHROUGH VIA

BACKGROUND

[0001] The semiconductor integrated circuit industry has experienced exponential growth. Technological advances in integrated circuit materials and design have produced generations of integrated circuits where each generation has smaller and more complex circuits than the previous generation. In the course of integrated circuit evolution, functional density (i.e., the number of interconnected devices per chip area) has generally increased while geometry size (i.e., the smallest component (or line) that can be created using a fabrication process) has decreased. This scaling down process generally provides benefits by increasing production efficiency and lowering associated costs. Such scaling down has also increased the complexity of processing and manufacturing integrated circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] 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.

[0003] FIG. **1-21**B are cross-sectional views, perspective, and top views of an integrated circuit at various stages of processing, in accordance with some embodiments.

[0004] FIG. **22** is a flow diagram of a method for operating an integrated circuit, in accordance with some embodiments.

DETAILED DESCRIPTION

[0005] The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0006] 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.

[0007] Terms indicative of relative degree, such as "about," "substantially," and the like, should be interpreted as one having ordinary skill in the art would in view of current technological norms.

[0008] The present disclosure is generally related to semiconductor devices, and more particularly to field-effect transistors (FETs), such as planar FETs, three-dimensional fin FETs (FinFETs), or nanostructure devices. Examples of nanostructure devices include gate-all-around (GAA) devices, nanosheet FETs (NSFETs), nanowire FETs (NWFETs), and the like. In advanced technology nodes, active area spacing between nanostructure devices is generally uniform, source/drain epitaxy structures are symmetrical, and a metal gate surrounds four sides of the nanostructures (e.g., nanosheets).

[0009] Embodiments of the disclosure provide an integrated circuit with a feedthrough via structure that provides an electrical connection between the backside metal lines and front side metal lines of the integrated circuit. The feedthrough via structure merges dummy source/drain contacts, a dummy metal, and source/drain conductive vias. The dummy metal is formed in place of a gate metal of a gate all around transistor structure positioned between two continuous poly diffusion edge (CPODE) structures. The result is a feedthrough cell with low area penalty and low resistance. This results in improved processing speeds and reduced power consumption.

[0010] The feedthrough via structure may be positioned between transistors. The transistors may be termed "nanostructure transistors" and the channels may be termed "semiconductor nanostructures". The nanostructure transistor structures may be patterned by any suitable method. For example, the structures may be patterned using one or more photolithography processes, including double-patterning or multi-patterning processes. Generally, double-patterning or multi-patterning processes combine photolithography and self-aligned processes, allowing patterns to be created that have, for example, pitches smaller than what is otherwise obtainable using a single, direct photolithography process. For example, in one embodiment, a sacrificial layer is formed over a substrate and patterned using a photolithography process. Spacers are formed alongside the patterned sacrificial layer using a self-aligned process. The sacrificial layer is then removed, and the remaining spacers may then be used to pattern the nanostructure transistor structure.

[0011] FIGS. **1-14**B are cross-sectional views, top views, and perspective views of an integrated circuit **100** fabricated in accordance with some embodiments of the present disclosure. The fabrication process results in a plurality of transistors **101**, as will be described in further detail below.

[0012] FIG. **1** is a perspective view of the integrated circuit **100** at an intermediate state of processing. The integrated circuit **100** includes a substrate **102**. The substrate **102** may be a semiconductor substrate, such as a bulk semiconductor, or the like, which may be doped (e.g., with a p-type or an n-type dopant) or undoped. The semiconductor material of the substrate **102** may include silicon; germanium; a compound semiconductor including silicon carbide, gallium arsenide, gallium phosphide, indium phosphide, indium arsenide, and/or indium antimonide; an alloy semiconductor including silicon-germanium, gallium

arsenide phosphide, aluminum indium arsenide, aluminum gallium arsenide, gallium indium arsenide, gallium indium phosphide, and/or gallium indium arsenide phosphide; or combinations thereof. Other substrates, such as single-layer, multi-layered, or gradient substrates may be used.

[0013] The integrated circuit **100** includes a semiconductor stack **103** including a plurality of semiconductor layers **104** and sacrificial semiconductor layers **106** alternating with each other. As will be set forth in further detail below, the semiconductor layers **104** will be patterned to form stacked channels of a plurality of transistors. As set forth in more detail below, the sacrificial semiconductor layers **106** will eventually be entirely removed and are utilized to enable forming gate metals and other structures around the semiconductor nanostructures. In FIG. **1**, Three semiconductor layers **104** and three sacrificial semiconductor layers **106** are illustrated. In some embodiments, the multi-layer stack **103** may include fewer or more layers than are shown in FIG. **1**.

[0014] In some embodiments, the semiconductor layers **104** may be formed of a first semiconductor material suitable, such as silicon, silicon carbide, or the like, and the sacrificial semiconductor layers **106** may be formed of a second semiconductor material, such as silicon germanium or the like. Each of the layers of the multi-layer stack **103** may be epitaxially grown using a process such as chemical vapor deposition (CVD), atomic layer deposition (ALD), vapor phase epitaxy (VPE), molecular beam epitaxy (MBE), or the like.

[0015] Due to high etch selectivity between the materials of the semiconductor layers **104** and the sacrificial semiconductor layers **106**, the sacrificial semiconductor layers **106** of the second semiconductor material may be removed without significantly etching the semiconductor layers **104** of the first semiconductor material, thereby allowing the semiconductor layers **104** to be released to form stacked channel regions of transistors, as will be set forth in more detail below.

[0016] In FIG. **2**A, trenches **110** have been formed in the stack **103** and in the substrate **102**. Though not shown in FIG. **1**, a hard mask layer is first formed and patterned on the stack **103**. The trenches **110** can be formed with an anisotropic etching process that etches in the downward direction in the presence of the patterned hard mask. The etching process defines semiconductor fins **112** by forming trenches **110** through the sacrificial semiconductor layers **106**, the semiconductor layers **104**, and the substrate **102**.

[0017] FIG. **2**B is a top view of the integrated circuit **100** of FIG. **2**A, in accordance with some embodiments. The top view of FIG. **2**B illustrates the fins **112** extending in the X direction and the trenches **110** between the fins **112**. The substrate **102** is visible in the trenches **110**. The top-most semiconductor layer **106** is visible atop the fins **112**. As set forth previously, in practice, a hard mask layer may be positioned on top of the top-most semiconductor layer **106**. FIG. **2**B also illustrates cut-lines X and Y. A cross-sectional view along the cut lines Y may be referred to as a "Y-view". A cross-sectional view along the cut lines X may be referred to as a "X-view".

[0018] FIG. **3** is a cross-sectional Y-view, in accordance with some embodiments. In FIG. **3**, shallow trench isolation regions **116** have been formed by depositing a dielectric material in the trenches **110** between fins **112**. The shell dielectric layer may be deposited by chemical vapor deposition (CVD), atomic layer deposition (ALD), physical vapor deposition (PVD), or other suitable deposition processes. In an exemplary embodiment, the dielectric material includes silicon oxide. However, the dielectric material can include SiN, SiCN, SiOC, SiOCN, or other dielectric materials without departing from the scope of the present disclosure. After deposition of the dielectric material, an etch-back process has been performed to recess the top of the shallow trench isolation regions **116** below the lowest sacrificial semiconductor layers **106**.

[0019] FIG. **4** is an X-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **4**, sacrificial gate structures **118** have been formed over the fins **112**. The sacrificial gate structures **118** extend in the Y direction, perpendicular to the fins **112**. Each sacrificial gate structure **118** crosses multiple fins **112**. The sacrificial gate structures **118** are also formed in the trenches **110**.

[0020] The sacrificial gate structures **118** include a dielectric layer **126**. In an exemplary embodiment, the dielectric layer **126** includes silicon oxide. However, alternatively, the dielectric layer **126** can include SiN, SiCN, SiOC, SiOCN, or other dielectric materials without departing from the scope of the present disclosure. In some embodiments, the dielectric layer **126** has a low K dielectric material. The dielectric layer **126** can be deposited by CVD, ALD, or PVD.

[0021] The sacrificial gate structures include a sacrificial gate layer **128** on the dielectric layer **126**. The sacrificial gate layer **128** can include materials that have a high etch selectivity with respect to the trench isolation regions **116**. In an exemplary embodiment, sacrificial gate layer **128** includes polysilicon. However, the sacrificial gate layer **128** may be a conductive, semiconductive, or non-conductive material and may be or include amorphous silicon, polycrystalline silicon-germanium (poly-SiGe), metallic nitrides, metallic silicides, metallic oxides, and metals. The sacrificial gate layer **128** may be deposited by physical vapor deposition (PVD), CVD, sputter deposition, or other techniques for depositing the selected material.

[0022] The sacrificial gate structures **118** include a dielectric layer **130** on the sacrificial gate layer **128** and a dielectric layer **132** of the dielectric layer **130**. The dielectric layers **130** and **132** may correspond to first and second mask layers. The dielectric layer **130** can include silicon nitride, silicon oxynitride, or other suitable dielectric materials. The dielectric layer **130** can include silicon nitride, silicon oxynitride or other suitable dielectric materials. The dielectric layers **130** and **132** are different materials from each other and can be deposited using CVD, ALD, PVD, or other suitable deposition processes. Other materials and deposition processes can be utilized for the dielectric layers **130** and **132** without departing from the scope of the present disclosure.

[0023] Gate spacer layers **134** have been formed on the sidewalls of the layers **126**, **128**, **130**, and **132**. The gate spacer layers **134** may also be formed on other exposed surfaces of the integrated circuit. The gate spacer layer **134** can be formed by PVD, CVD, ALD, or other suitable deposition processes. Following formation of the gate spacer layer **134**, horizontal portions (e.g., in the X-Y plane) of the gate spacer layer **134** may be removed by an anisotropic etching process, thereby exposing upper surfaces of the fins **112** and the dielectric layer **134**. After patterning of the gate spacer layers, vertically thicker portions of the gate spacer layers **134** remain, such as the portion shown in FIG. **4**. The

gate spacer layers **134** can include one or more of SiO, SiN, SiON, SiCN, SiOCN, SiOC, or other suitable dielectric materials.

[0024] After patterning of the gate spacer layers **134**, an etching process is performed to form source/drain trenches **120** in the fins **112**. One or more etching processes are performed to form the source/drain trenches **120** in the fins **112**. Forming the source/drain trenches **120** includes etching through each of the semiconductor layers **104** and sacrificial semiconductor layers **106**, and a portion of the substrate **102**. Accordingly, the removal operations may include suitable etch operations for removing materials of the semiconductor layers **104**, the sacrificial semiconductor layers **106**, and the substrate **102**. The etching processes can include reactive ion etching (RIE), neutral beam etching (NBE), atomic layer etching (ALE), or the like.

[0025] Formation of the source/drain trenches **120** results in formation of stacks of channels **105**. In particular, the portions of the semiconductor layers **104** after formation of the source/drain trenches **120** now correspond to channels of a transistor. Formation of the source/drain trenches **120** also results in formation of a plurality of sacrificial semiconductor nanostructures **107** from the sacrificial semiconductor layers **106**.

[0026] A large number of source/drain trenches **120** are formed in the fins **112**. A stack **122** of channels **105** is positioned between each source/drain layer. Each stack **122** of channels **105** corresponds to the stacked channels **105** of a transistor.

[0027] In FIG. **5**, inner spacers **136** have been formed. A selective etching process is performed to recess exposed end portions of the sacrificial semiconductor nanostructures **107** without substantially etching the sacrificial semiconductor nanostructures **107**. Next, the inner spacers **136** are formed by depositing a dielectric material to fill the recesses between the channels **105** formed by the previous selective etching process of the sacrificial semiconductor nanostructures **107**. The inner spacer **136** may be a suitable dielectric material, such as silicon carbon nitride (SiCN), silicon oxycarbonitride (SiOCN), or the like, formed by a suitable deposition method such as physical vapor deposition (PVD), CVD, ALD, or the like. An etching process, such as an anisotropic etching process, is performed to remove portions of the inner spacer **136** disposed outside the recesses in the sacrificial semiconductor nanostructures **107**. The remaining portions of the dielectric layer correspond to the inner spacers **136** shown in FIG. **5**.

[0028] In FIG. **6** source/drain regions **140** have been formed. In the illustrated embodiment, the source/drain regions **140** are epitaxially grown from the channels **105**. The source/drain regions **140** are grown on exposed portions of the fins **112** and contact the channels **105**. For each stack **122** of channels **105**, there are two source/drain regions **140**. Some stacks **122** of channels **105** may share a source/drain **140** with a stack **122** of channels **105** that is adjacent in the X direction.

[0029] Though not shown, dielectric support elements corresponding to remnants of the gate spacer layers **134** on the trench isolation regions **116** may laterally confine the growth of source/drain regions **140**. In some embodiments, the source/drain regions **140** exert stress in the respective channels **105**, thereby improving performance. The source/drain regions **140** are formed such that each sacrificial gate structure **118** is disposed between respective neighboring pairs of the source/drain regions **140**. In some embodiments, the spacer layer **134** and the inner spacers **136** separate the source/drain regions **140** from the sacrificial gate layer **128** by an appropriate lateral distance (e.g., in the X-axis direction) to prevent electrical bridging to subsequently formed gates of the resulting device.

[0030] The source/drain regions **140** may include any acceptable material, such as appropriate for n-type or p-type devices. For n-type devices, the source/drain regions **140** include materials exerting a tensile strain in the channel regions, such as silicon, SiC, SiCP, SiP, or the like, in some embodiments. When p-type devices are formed, the source/drain regions **140** include materials exerting a compressive strain in the channel regions, such as SiGe, SiGeB, Ge, GeSn, or the like, in accordance with certain embodiments. The source/drain regions **140** may have surfaces raised from respective surfaces of the fins and may have facets. Neighboring source/drain regions **140** may merge in some embodiments to form a singular source/drain region **140** over two neighboring fins of the fins **112**.

[0031] The source/drain regions **140** may be implanted with dopants followed by an annealing process. The source/drain regions **140** may have an impurity concentration of between about 10^{19} cm^{-3} and about 10^{21} cm^{-3}. N-type and/or p-type impurities for source/drain regions **140** may be any of the impurities previously discussed. In some embodiments, the source/drain regions **140** are in situ doped during growth.

[0032] In FIG. **6**, a contact etch stop layer (CESL) **144** and an interlayer dielectric (ILD) **146** have been formed above the source/drain regions **140** and between adjacent sacrificial gate structures. The CESL layer **144** can include a thin dielectric layer can formally deposited on exposed surfaces of the source/drain regions **140** and on other exposed surfaces. The CESL layer **144** can include SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The CESL **144** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0033] The dielectric layer **146** covers the CESL **144**. The dielectric layer **146** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **146** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0034] In FIG. **6**, a CMP process has been performed to reduce the height of the sacrificial gate structures **118**. The result of the CMP process is that the dielectric layers **130** and **132** are entirely removed. The heights of the sacrificial gate layer **128**, the gate spacer layers **134**, the CESL layer **144**, and the dielectric layer **146** have been reduced and the top surfaces have been planarized.

[0035] FIG. **7**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **7**A, the sacrificial gate structures **118** have been removed from between the gate spacer layers **134**. In particular, the dielectric layer **126** and the sacrificial gate layer **128** have been entirely removed from between the gate spacer layers **134**.

[0036] In some embodiments, the sacrificial gate layer **128** is removed by an anisotropic dry etch process. For example, the etching process may include a dry etch process using reaction gases that selectively etch the sacrificial gate layer **128** without etching the spacer layer **134**. The dielectric layer **126**, when present, may be used as an etch stop layer

when the sacrificial gate layer **128** is etched. The dielectric layer **126** may then be removed after the removal of the sacrificial gate layer **128**.

[0037] Removal of the sacrificial gate layer **128** and the dielectric layer **126** results in the formation of a void between the gate spacer layers **134** above the channels **105**. As will be set forth in more detail below, an upper portion of a gate metal or gate electrode will be formed in the void. Accordingly, the sacrificial gate layer **128** is sacrificial in the sense that the upper portion of the gate metal will eventually be formed in its place.

[0038] In FIG. **7**A, channels **105** are released by removal of the sacrificial semiconductor nanostructures **107**. The sacrificial semiconductor nanostructures **107** can be removed by a selective etching process using an etchant that is selective to the material of the sacrificial semiconductor nanostructures **107**, such that the sacrificial semiconductor nanostructures **107** are removed without substantially etching the channels **105**. In some embodiments, the etching process is an isotropic etching process using an etching gas, and optionally, a carrier gas, where the etching gas comprises F2 and HF, and the carrier gas may be an inert gas such as Ar, He, N2, combinations thereof, or the like. In some embodiments, the sacrificial semiconductor nanostructures **107** are removed and the channels **105** are patterned to form channel regions of both PFETs and NFETs. Removal of the sacrificial semiconductor nanostructures **107** results in the formation of voids between the channels **105**.

[0039] After release of the channels **105**, an interfacial gate dielectric layer **151** has been deposited. The interfacial gate dielectric layer **151** is deposited on all exposed surfaces of the channels **105**. The interfacial gate dielectric layer **151** is wrapped around the channels **105**. The interfacial gate dielectric layer **151** can include a dielectric material such as silicon oxide, silicon nitride, or other suitable dielectric materials. The interfacial gate dielectric layer **151** can include a comparatively low-K dielectric with respect to high-K dielectric such as hafnium oxide or other high-K dielectric materials that may be used in gate dielectrics of transistors. High-K dielectrics can include dielectric materials with a dielectric constant higher than the dielectric constant of silicon oxide. The interfacial gate dielectric layer **151** can be formed by a thermal oxidation process, a chemical vapor deposition (CVD) process, or an atomic layer deposition (ALD) process. The interfacial gate dielectric layer **151** can have a thickness between 0.5 nm and 2 nm. Other materials, deposition processes, and thicknesses can be utilized for the interfacial gate dielectric layer **151** without departing from the scope of the present disclosure.

[0040] A high-K dielectric layer **153** has been deposited. The high-K dielectric layer **153** is deposited in a conformal deposition process. The conformal deposition process deposits the high-K dielectric layer **153** on the interfacial gate dielectric layer **151**, on the hard mask structure **109**, on the substrate **102**, on the trench isolation regions **116**, and on the gate spacer layers **134**. The high-K gate dielectric layer **153** is wrapped around the channels **105**. The high-K gate dielectric layer **153** has a thickness between 1 nm and 3 nm. The high-K dielectric layer includes one or more layers of a dielectric material, such as HfO_2, HfSiO, HfSiON, HfTaO, HfTiO, HfZrO, zirconium oxide, aluminum oxide, titanium oxide, hafnium dioxide-alumina (HfO_2—Al_2O_3) alloy, other suitable high-K dielectric materials, and/or combinations thereof. The high-K dielectric layer **153** may be formed by CVD, ALD, or any suitable method. Other thicknesses, deposition processes, and materials can be utilized for the high-K dielectric layer **153** without departing from the scope of the present disclosure.

[0041] A gate metal **155** has been deposited. The gate metal **155** is deposited on all exposed surfaces of the high-K dielectric layer **153**. The gate metal **155** is wrapped around the channels **105**. Although the gate metal **155** is shown as a single layer in FIG. **7**, in practice, the gate metal **155** can include one or more conductive liner layers, work function layers, and gate fill layers that collectively make up the gate metal. The gate metal can include one or more of Ti, TiN, Ta, TaN, Al, Cu, Co, Ru, W, Au, or other suitable conductive materials. The gate metal **155** can be deposited by PVD, ALD, or CVD. Other configurations, materials, and deposition processes can be utilized for the gate metal **155** without departing from the scope of the present disclosure. The gate metal **155** acts as a gate electrode surrounding the channels **105**.

[0042] At the stage of processing shown in FIGS. **7**A and **7**B, the transistors **101** are substantially complete. Each transistor **101** includes a stack **122** of channels **105** extending between the source/drain regions **140** and acting as stacked channels of the transistor **101**. As set forth in more detail below, source/drain contacts and cut metal gate structures have not yet been formed.

[0043] FIG. **7**B is a Y-view of the integrated circuit **100** at the stage of processing of FIG. **7**A, taken along cut lines **7**B, in accordance with some embodiments. FIG. **7**B illustrates that of the current stage of processing there are no breaks in the gate metal **155** between transistors **101** adjacent to each other in the Y direction. Accordingly, the gate electrodes of adjacent transistors **101** in the Y direction are shorted together.

[0044] FIG. **8**A is a perspective view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **8**A, gate isolation structures **157***a* and **157***b* have been formed. In some instances herein, reference numbers may include a suffix "a", "b", "c", or "d". The gate isolation structures **157***a* and **157***b* are one example of this. Throughout the specification, the suffix "a", "b", "c", or "d" may be omitted when reference is not particular to a specific structure. For example, when description applies to both the gate isolation structures **157***a* and **157***b*, the description may simply refer to the gate isolation structures **157** without the suffix "a" or "b". This applies to other reference numbers with suffixes. The gate isolation structures **157** may also be termed "cut metal gate" (CMG) structures. The gate isolation structures **157** electrically isolate the gate electrodes of transistors **101** adjacent to each other in the Y direction.

[0045] The gate isolation structures **157** include a dielectric layer **159**. The dielectric layer **159** corresponds to a dielectric liner layer and can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **159** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0046] The gate isolation structures include a dielectric layer **161**. The dielectric layer **161** fills the gaps between the adjacent portions of the dielectric liner layer **159**. The dielectric layer **161** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **161** can be deposited by CVD, ALD, PVD, or other suitable deposition processes. In an exemplary

embodiment, the dielectric layer **159** includes silicon nitride and the dielectric layer **161** include silicon oxide.

[0047] The gate isolation structures **157** can be formed by forming trenches in the integrated circuit **100** in locations at which the gate isolation structures **157** are to be formed. The trenches extend into the trench isolation regions **116** and etch entirely through the gate metal **155** so that the gate metals **155** of transistors adjacent in the Y direction are electrically isolated from each other. After formation of the trenches, the dielectric layers **159** and **161** can be formed as described above, resulting in formation of the gate isolation structures **157**.

[0048] In FIG. **8**A, a transistor **101***a* is indicated, in accordance with some embodiments. The transistor **101***a* includes a plurality of channels **105***a* each extending in the X direction between a source/drain region **140***a* and a source/drain region **140***b*. The gate metal **155** wraps around the channels **105***a*. In FIG. **8**A, the interfacial dielectric layer **151** is not shown (though still present). FIG. **8**A and subsequent figures illustrate only the high-K dielectric layer **153**. The inner spacers **136** electrically isolate the gate metal **155** from the source/drain regions **140**. The high-K dielectric layer **153** is a gate dielectric layer.

[0049] In FIG. **8**A, continuous poly on diffusion edge (CPODE) structures **163** have been formed in place of the gate metal **155** at some locations between adjacent gate isolation structures **157***a* and **157***b*. The CPODE structures **163** include a polysilicon layer **165** and a dielectric layer **167**. The dielectric layer **167** is a dielectric liner layer positioned on sidewalls of the gate spacer layers **134**. The dielectric layer **167** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **159** can be deposited by CVD, ALD, PVD, or other suitable deposition processes. A CMP process has been performed to planarize the top surface of the integrated circuit **100**.

[0050] FIG. **8**A illustrates cut lines **8**B extending in the X direction. FIG. **8**A also illustrates cut lines **8**C extending in the Y direction. In subsequent figures, X-view figures are taken along cut lines **8**B. Y-view figures are taken along cut lines **8**C.

[0051] FIG. **8**B is a cross-sectional X-view of the integrated circuit **100** of FIG. **8**A, in accordance with some embodiments. FIG. **8**B illustrates the CPODE structures **163**, the CESL layer **144** and the interlevel dielectric layer **146**, and the gate electrode **155**, in accordance with some embodiments.

[0052] FIG. **8**C is a cross-sectional Y-view of the integrated circuit **100** of FIG. **8**A, in accordance with some embodiments. FIG. **8**C illustrates four stacks of channels **105***a-d* of four transistors **101***a-d*. The transistor **101***a* includes the channels **105***a* surrounded by the gate metal **105** on the left side of the gate isolation structure **157***a*. The transistor **101***b* includes the channels **101***b* surround by the gate metal **155** on the right side of the gate isolation structure **157***a*. The transistor **101***c* includes the channels **105***c* surrounded by the gate metal **155** on the left side of the gate isolation structure **157***b*. The transistor **101***d* includes the channels **105***d* surrounded by the gate metal **155** on the right side of the gate isolation structure **157***b*.

[0053] FIG. **8**C illustrates that the gate metals **155** of the transistors **101***b* and **101***c* are shorted. The gate isolation structure **157***a* electrically isolates the gate metal **155** of the transistor **101***a* from the gate metal **155** of the transistors **101***b* and **101***c*. The gate isolation structure **157***b* electrically isolates the gate metal **155** of the transistor **101***d* from the gate metal **155** of the transistors **101***b* and **101***c*.

[0054] FIG. **9**A is a perspective view of the integrated circuit **100**, in accordance with some embodiments In FIG. **9**A, a dielectric layer **168** has been deposited on a top surface of the integrated circuit **100** is shown in FIG. **8**A, in accordance with some embodiments. The dielectric layer **168** corresponds to a hard mask layer. The dielectric layer **168** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **168** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0055] In FIG. **9**A, a dielectric layer **169** has been formed on the dielectric layer **168**. The dielectric layer **169** corresponds to an interlevel dielectric layer. The dielectric layer **169** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **169** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0056] In FIG. **9**A, a photolithography process and a corresponding etching process have been performed to open a trench **171** in the dielectric layers **168** and **169**. Though not apparent in the view of FIG. **9**A, the trench **171** exposes the gate metal **155** between the gate isolation structures **157***a* and **157***b*. In particular, the trench **171** exposes the gate metal **155** surrounding the channels **105***b* and **105***c*.

[0057] In FIG. **9**A, though not apparent, an etching process has been performed to remove the gate metal **155** at the exposed locations. The etching process selectively etches the material of the gate metal **155** with respect to the material of exposed dielectric structures.

[0058] FIG. **9**B is an X-view of the integrated circuit **100** at the stage of processing of FIG. **9**A, in accordance with some embodiments. FIG. **9**C is a Y-view of the integrated circuit **100** at the stage of processing of FIG. **9**A, in accordance with some embodiments. FIGS. **9**B and **9**C illustrates that the gate metal **155** has been removed at locations exposed by the trench **171**. The high-K dielectric layer **153** is still present on the gate spacer layers **134** and the channels **101***b* and **101***c*. The gate metal **155** has been removed between the gate isolation structures **157***a* and **157***b*. The gate metal **155** still surrounds the channels **105***a* of the transistor **101***a* and the channels **105***d* of the transistor **101***d*.

[0059] FIG. **10**A is a perspective view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **10**A, a dummy gate metal **156** has been deposited in place of the gate metal **155** that was removed. The dummy gate metal **156** is a different material than the gate metal **155**. In some embodiments, the dummy gate metal **156** has a lower resistance than the gate metal **155**. The dummy gate metal **156** can be deposited by PVD, ALD, CVD, or other suitable deposition processes. The dummy gate metal can include tungsten, titanium, aluminum, tantalum, or other suitable conductive materials. In one example, the gate metal **155** includes titanium nitride of relatively high resistivity and the dummy gate metal **156** includes tungsten of significantly lower resistivity than the titanium nitride gate metal. Other combinations of metals can be utilized for the gate metal **155** and the dummy gate metal **156** without departing from the scope of the present disclosure. A lower resistance metal can be utilized for the dummy gate metal **156** based, in part, on the fact that there does not need to be consideration of using

a work function metal as the transistors **101***b* and **101***c* will be dummy transistors that do not function. The dummy gate metal **156** may be termed a filler metal, a second gate metal, or a substitute gate metal. The dummy transistors **101***b* and **101***c* may be termed dummy structures that have the form of transistors but that do not function.

[0060] FIG. **10**B is an X-view of the integrated circuit **100** of FIG. **10**A, in accordance with some embodiments. FIG. **10**C is a Y-view of the integrated circuit **100** of FIG. **10**A, in accordance with some embodiments. FIG. **10**B illustrates the dummy gate metal **156** on the high-K dielectric **153** between the gate spacer layers **134**. FIG. **10**C illustrates the dummy gate metal **156** wrapped around the channels **105***b* and **105***c* between the gate isolation structures **157***a* and **157***b*.

[0061] FIG. **11**A is a perspective view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **11**A, source/drain contacts **173** have been formed. Prior to formation of the source/drain contacts **173**, a photolithography process and corresponding etching process have been performed. The photolithography and etching process forms trenches that expose the source/drain regions **140** at selected locations.

[0062] After formation of the trenches for the source/drain contacts **173**, a silicide **174** is formed on the source/drain regions **140**. The silicide **174** can be formed after depositing the materials of the source/drain contacts **173**. In particular, after the materials of the source/drain contacts **173** are deposited, a thermal annealing process can be performed. The thermal annealing process results in formation of a silicide **174** at the interface between the semiconductor materials of the source/drain regions **140** and the metal of the source/drain contacts **173**.

[0063] In some embodiments, the source/drain contacts **173** can include tungsten, aluminum, titanium, titanium nitride, tantalum, tantalum nitride, molybdenum ruthenium, selenium, or other suitable conductive materials. The source/drain contacts **173** can be formed by PVD, ALD, CVD, or other suitable deposition processes.

[0064] In some embodiments, a dielectric liner layer **175** is formed in the trenches prior to deposition of the material for the source/drain contacts **173**. The dielectric layer **175** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **175** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0065] FIG. **11**B is an X-view of the integrated circuit **100** of FIG. **11**A, in accordance with some embodiments. FIG. **11**C is a Y-view of the integrated circuit **100** of FIG. **11**A, in accordance with some embodiments. FIG. **11**B illustrates the source/drain contacts **142** extending into the interlevel dielectric layer **146**. The source/drain contacts **173** are not apparent in FIG. **11**C.

[0066] FIG. **12**A is a perspective view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **12**A, a dielectric layer **176** has been deposited on a top surface of the integrated circuit **100** as shown in FIG. **11**A, in accordance with some embodiments. The dielectric layer **176** corresponds to a hard mask layer. The dielectric layer **176** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **176** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0067] In FIG. **12**A, a dielectric layer **177** has been formed on the dielectric layer **176**. The dielectric layer **177** corresponds to an interlevel dielectric layer. The dielectric layer **177** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **177** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0068] Though not apparent in view of FIG. **12**A, a photolithography process and a corresponding etching process have been performed to open trenches in the dielectric layers **176** and **177**. The trenches expose the source/drain contacts **173** and the dummy gate metal **156** at selected locations for conductive vias **183**. After formation of the trenches for the conductive vias **183**, the conductive vias **183** are formed by depositing a conductive material in the trenches. The conductive material can include tungsten, titanium, aluminum, titanium nitride, tantalum nitride, tantalum, ruthenium, selenium, or other suitable conductive materials. The conductive vias **183** can be formed by PVD, ALD, CVD, or other suitable deposition processes. A CMP process is performed after formation of the conductive vias **183** to remove excess metal material from the top surface of the dielectric layer **177**.

[0069] FIG. **12**B is an X-view of the integrated circuit **100** of FIG. **12**A, in accordance with some embodiments. FIG. **12**C is a Y-view of the integrated circuit **100** of FIG. **12**A, in accordance with some embodiments. FIG. **12**B illustrates the conductive vias **183** contacting the source/drain contacts **173** and the dummy gate metal **156**. FIG. **12**C illustrates a conductive via contacting the dummy gate metal **156**.

[0070] Returning to FIG. **12**A, a dielectric layer **179** has been deposited on the dielectric layer **177** after formation of the conductive vias **183**. The dielectric layer **179** corresponds to a hard mask layer. The dielectric layer **179** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **176** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0071] In FIG. **12**A, a dielectric layer **181** has been formed on the dielectric layer **179**. The dielectric layer **181** corresponds to an interlevel dielectric layer. The dielectric layer **181** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **181** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0072] After deposition of the dielectric layers **179** and **181**, a photolithography process and a corresponding etching process have been performed to open trenches in the dielectric layers **179** and **181** for formation of metal lines **185** in the front side metal **0** layer. The trenches expose the conductive vias **183** at selected locations. After formation of the trenches for the metal lines **185**, the metal lines **185** are formed by depositing a conductive material in the trenches. The conductive material can include tungsten, titanium, aluminum, titanium nitride, tantalum nitride, tantalum, ruthenium, selenium, or other suitable conductive materials. The metal lines **185** can be formed by PVD, ALD, CVD, or other suitable deposition processes.

[0073] In some embodiments, a conductive liner layer **187** is formed in the trenches prior to formation of the metal lines **185**. The conductive liner layer **187** can include titanium nitride, tantalum nitride or other suitable conductive materials. The conductive liner layer **187** can be formed by PVD, ALD, CVD, or other suitable deposition processes.

[0074] Returning to FIGS. **12**B and **12**C, FIG. **12**B illustrates a metal line **185** in contact with three conductive vias **183** that respectably contact source/drain contacts and the dummy gate metal **156**. FIG. **12**C illustrates a metal line **185** in contact with a conductive via **183** in contact with the dummy gate metal **156**. FIG. **12**C also illustrates a plurality of other metal lines **185** formed in the interlevel dielectric layer **181**.

[0075] FIG. **13**A is a perspective view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **13**A, the integrated circuit **100** has been flipped such that the substrate **102** is that the top and the metal lines **185** are at the bottom of the figure. The integrated circuit **100** has been flipped to facilitate formation of a feedthrough via **191** that electrically connects to the dummy gate metal **156** and adjacent source/drain contacts **173**. The feedthrough via **191** may also be described as a conductive backside via.

[0076] In FIG. **13**A, a dielectric layer **189** has been formed on the backside of the integrated circuit **100**. In particular, the dielectric layer **189** has been formed on the semiconductor substrate **102** and on the trench isolation regions **116**. In this case, the semiconductor substrate **102** and the trench isolation regions **116** may be collectively considered as a substrate. The dielectric layer **189** corresponds to a hard mask layer. The dielectric layer **189** can include SiO, SiON, SiN, SIC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **189** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0077] In FIG. **13**A, a photolithography process and the corresponding etching process has been performed to form a trench through the dielectric layer **189** and the substrate to expose the dummy gate metal **156** and selected source/drain contacts **173**. After formation of the trench, a conductive liner layer **193** is formed in the trench. The conductive liner layer **193** can include titanium nitride, tantalum nitride, or other suitable conductive materials. The conductive liner layer **193** can be formed by PVD, ALD, CVD, or other suitable deposition processes.

[0078] After formation of the conductive liner layer **193**, the feedthrough via **191** is formed by depositing a conductive material in the trench on the conductive liner layer **193**. The feedthrough via **191** can include tungsten, aluminum, titanium, titanium nitride, tantalum nitride, ruthenium, selenium, or other suitable conductive materials. The feedthrough via **191** can be formed by PVD, ALD, CVD, or other suitable deposition processes. A CMP process is performed after formation of the feedthrough via **191** to remove excess conductive material from the top surface of the dielectric layer **189**.

[0079] FIG. **13**B is an X-view of the integrated circuit **100** of FIG. **13**A, in accordance with some embodiments. FIG. **13**C is a Y-view of the integrated circuit **100** of FIG. **13**A, in accordance with some embodiments. FIG. **13**B illustrates the feedthrough via **191** contacting the source/drain contacts **173** and the dummy gate metal **156**. FIG. **13**C illustrates the feedthrough via **191** contacting the dummy gate metal **156**. FIG. **13**C also illustrates that the trench for the feature via **191** extends into the dummy gate metal **156** beyond at least one of the channels **105***b/c*.

[0080] FIG. **14**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. FIG. **14**B is a Y-view of the integrated circuit **100** at the stage of processing of FIG. **14**A, in accordance with some embodiments. Although the orientation of FIGS. **14**A and **14**B (as well as in subsequent figures) are returned so that the backside of the integrated circuit **100** is at the bottom of each figure, the backside processes described are performed with the orientation flipped as described in relation to FIGS. **13**A-**13**C.

[0081] In FIGS. **14**A and **14**B, a dielectric layer **195** has been formed on the backside of the integrated circuit **100**. In particular, the dielectric layer **195** has been formed on the dielectric layer **189**. The dielectric layer **195** corresponds to a hard mask layer. The dielectric layer **195** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **195** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0082] A dielectric layer **197** has been formed on the backside of the integrated circuit **100**. In particular, the dielectric layer **197** has been formed on the dielectric layer **195**. The dielectric layer **197** corresponds to a backside interlevel dielectric layer. The dielectric layer **197** can include SiO, SiON, SiN, SiC, SiOC, SiOCN, SiON, or other suitable dielectric materials. The dielectric layer **197** can be deposited by CVD, ALD, PVD, or other suitable deposition processes.

[0083] In FIGS. **14**A and **14**B, a photolithography process and a corresponding etching process have been performed to form trenches through the dielectric layers **195** and **197** to expose the feedthrough via **191** and that other selected locations. After formation of the trenches, a conductive liner layer **201** is formed in the trenches. The conductive liner layer **201** can include titanium nitride, tantalum nitride, or other suitable conductive materials. The conductive liner layer **201** can be formed by PVD, ALD, CVD, or other suitable deposition processes.

[0084] After formation of the conductive liner layer **201**, metal lines **199** of backside metal BO are formed by depositing a conductive material in the trenches on the conductive liner layer **201**. The metal lines **199** can include tungsten, aluminum, titanium, titanium nitride, tantalum nitride, ruthenium, selenium, or other suitable conductive materials. The metal lines **199** can be formed by PVD, ALD, CVD, or other suitable deposition processes. A CMP process is performed after formation of the feedthrough via **199** to remove excess conductive material from the top surface of the dielectric layer **197**.

[0085] At the stage of processing shown in FIGS. **14**A and **14**B, front side metal lines **185** and backside metal lines **199** have been formed. At least one of the front side metal lines **185** is electrically connected to at least one of the backside metal lines **199** by the feedthrough via **191**, the dummy gate metal **156**, and the conductive via **183**. The feedthrough via **191**, the gate structure including the dummy gate metal **156**, the source/drain contacts **173**, the conductive vias **183**, the front side metal line **185**, and the backside metal line **199** collectively correspond to a feedthrough via structure **206**. The feedthrough via structure **206** is bound by the low CPODE structures **163** in the X direction for low area penalty. The feedthrough via structure **206** is bound by the gate isolation structures **157***a/b* for larger length in the Y direction, resulting in low electrical resistance.

[0086] In some embodiments, the dummy gate metal **156** may also be termed a second gate metal. The second gate metal **156** is different from the gate metal **155** of other logic transistors **101**, such as the logic transistors **101***a* and **101***d*. The second gate metal **156** can include tungsten or other low resistance material such as ruthenium, molybdenum, copper,

iridium, or other suitable metals. Although not shown in FIGS. **14**A and **14**B, the second gate metal **156** can also include a conductive liner layer such as titanium nitride, tantalum nitride, or other suitable conductive liner materials.

[0087] In some embodiments, the high-K dielectric layer **153**, corresponding to a gate dielectric layer may be present between the dummy gate metal **156** and the channels **105***b/c*, as well as between the dummy gate metal **156** and the gate spacer layers **134**. The high-K dielectric layer **153** may have a thickness between zero point one nanometers and 5 nm and can include Si, O, C, N, Hf, or other suitable dielectric materials.

[0088] In some embodiments, the dummy gate metal **156** has a dimension D**1** in the X direction. D**1** can be between 8 nm and 54 nm, though other dimensions can be utilized without departing from the scope of the present disclosure. In some embodiments, the dummy gate metal **156** has the same profile or dimensions as the gate metal **155**.

[0089] In some embodiments, feedthrough via **191** protrudes into the dummy gate metal **156** a dimension D**2** corresponding to a distance between the bottom of the dummy gate metal **156** and the top of the feedthrough via **191** and the orientation shown in FIG. **14**B. The dimension D**2** can be between 0.1 nm and 70 nm, though other dimensions can be utilized without departing from the scope of the present disclosure. The dimension D**2** can be based, in part, on the rate at which the etching process to form the trench for the feedthrough via **191** etches the dummy gate metal **156**.

[0090] In some embodiments, a dimension D**3** corresponds to a pitch of between adjacent CPODE structures **163**. The dimension D**3** may correspond to twice the contact poly pitch (CPP). The dimension D**3** is greater than or equal to twice the width of the of the feedthrough via **191** in the X direction.

[0091] As described previously, the dummy gate metal **156** is formed between the gate all around transistors **101***a* and **101***d*. The dummy gate metal **156** surrounds channels **105***b* and **105***c* that have substantially the same dimensions and characteristics as the channels **105***a* and **105***d* of the transistors **101***a* and **101***d*. However, the channels **105***b* and **105***c* are no longer part of functioning transistors because the source/drain contacts **173** are merged or shorted with the dummy gate metal **156**.

[0092] In some embodiments, the transistors **101***b* and **101***c* correspond to dummy transistors that have the structure of a transistor, the do not function as a transistor. The channels **105***b* and **105***c* are dummy channels. The source/drain contacts **173** are dummy source/drain contacts **173**. In some embodiments, the dummy gate metal **156** may be termed a substitute gate metal or a second gate metal.

[0093] FIG. **15**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. FIG. **15**B is a Y-view of the integrated circuit **100** at the stage of processing of FIG. **15**A, in accordance with some embodiments. The integrated circuit **100** of FIGS. **15**A and **15**B is substantially similar to the integrated circuit **100** of FIGS. **14**A and **14**B. One difference is that in FIGS. **15**A and **15**B, the high-K dielectric layer **153** (and the interfacial dielectric layer **151**) are not present at the dummy gate metal **156**. Accordingly, the dummy gate metal **156** is in direct contact with the channels **105***b/c* and the gate spacer layers **134**. The gate dielectric layer can be removed during the removal of the gate metal **155** as described in relation to FIGS. **9**A-**9**C.

[0094] FIG. **16**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. FIG. **16**B is a Y-view of the integrated circuit **100** at the stage of processing of FIG. **16**A, in accordance with some embodiments. The integrated circuit **100** of FIGS. **15**A and **16**B is substantially similar to the integrated circuit **100** of FIGS. **14**A and **14**B. One difference is that in FIGS. **16**A and **16**B, the dummy gate metal **156** is not substantially recessed during formation of the feedthrough via **191**. Accordingly, the dimension D**2** described in relation to FIG. **14**B will be substantially zero in FIG. **16**B. This can be achieved by using an etching process to form the trenches for the feedthrough via **191** that does not substantially etch the dummy gate metal **156**.

[0095] FIG. **17** is a Y-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **17**, the channels **105***a/b* have been removed. The channels **105***a/b* can be removed during removal of the gate metal **155** as described in relation to FIGS. **9**A-**9**C. Accordingly, in FIG. **17**, the dummy gate metal **156** does not surround any channels **105**. This may further reduce the resistance of the feedthrough structure **206**.

[0096] FIG. **18** is an X-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **17**, a single large conductive via **183** is formed in contact with the source/drain regions **173** and the dummy gate metal **156**. This can be accomplished by patterning a single trench for the conductive vias **183** in the dielectric layer **177** at the stage of processing described in relation to FIGS. **12**A-**12**C. This can further reduce the resistance of the feedthrough via structure **206**.

[0097] FIG. **19**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **19**A, the feedthrough via **191** has a dimension D**4** in the X direction that is greater than in FIG. **14**A and FIG. **19**A, the etching process that forms the space for the feature via **191** etches a portion of the gate spacer layer **134** and corresponding liner layer. The result is that the feedthrough via **191** abuts the liner layer **167** of the CPODE structure **163**. The dimension D**4** is nearly equal to the dimension D**3**, corresponding to double the CPP. This results in a reduced resistance of the feedthrough via **191**.

[0098] FIG. **19**B is a Y-view of the integrated circuit **100** of FIG. **19**A, in accordance with some embodiments. FIG. **19**B illustrates that the width dimension D**5** of the feature via **191** in the Y direction is substantially equal to the distance between the gate isolation structures **157***a* and **157***b*. This results in an overall lower resistance of the feedthrough via **191**.

[0099] FIG. **20**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **20**A, the source/drain contacts **173** have a vertical dimension D**6**. The dummy gate metal **156** has a vertical dimension D**7**. In some embodiments, the vertical dimension D**7** is slightly greater than the vertical dimension D**6**. The metal filler **156** extends to a same height as the source/drain regions **173**. In some embodiments, the dimensions D**6** and D**7** are substantially equal. The conductive vias **183** can be merged into a single conductive via **183** as described in relation to FIG. **18**.

[0100] FIG. **20**B is a perspective view of the integrated circuit **100** of FIG. **20**A, in accordance with some embodiments. The perspective view does not illustrate dielectric layers present in the integrated circuit **100**. The perspective view of FIG. **20**B illustrates source/drain regions **140**, the

dummy gate metal **156**, source/drain contacts **173**, conductive vias **183**, the metal line **185**, and the feedthrough via **191**.

[0101] FIG. **21**A is an X-view of the integrated circuit **100**, in accordance with some embodiments. In FIG. **20** **1**A, dielectric layers **205** and **207** have been formed prior to formation of the source/drain contacts **173**. The dielectric layers **205** and **207** may be substantially similar in composition to the dielectric layers **176** and **177**, respectively. The conductive vias **183** are then formed through the dielectric layers **176** and **177**. The conductive via **183** that contacts the dummy gate metal **156** extends through the dielectric layers **207** and **205**. The result is that the vertical dimension D**6** of the source/drain contacts **173** is greater than the vertical dimension D**7** of the dummy gate metal **156**. Furthermore, the source/drain contacts **173** extends to a greater height than does the dummy gate metal **156**. The conductive vias **183** can be merged into a single conductive via **183** as described in relation to FIG. **18**.

[0102] FIG. **21**B is a perspective view of the integrated circuit **100** of FIG. **20**A, in accordance with some embodiments. The perspective view does not illustrate dielectric layers present in the integrated circuit **100**. The perspective view of FIG. **21**B illustrates source/drain regions **140**, the dummy gate metal **156**, source/drain contacts **173**, conductive vias **183**, the metal line **185**, and the feedthrough via **191**. In FIG. **21**B, the conductive vias **183** are merged into a single conductive via including a portion that protrudes downward to contact the dummy gate metal **156**.

[0103] FIG. **22** is a flow diagram of a method **2200** for forming an integrated circuit, in accordance with some embodiments. The method **2200** can utilize the structures, processes, and systems described in relation to FIGS. **1**-**21**B. At **2202**, the method **2200** includes forming a first transistor including a gate metal wrapped around a plurality of stacked first channels. One example of a first transistor is the transistor **101***a* of FIG. **14**A. One example of a gate metal is the gate metal **155** of FIG. **14**A. One example of stacked first channels are the channels **105***a* of FIG. **14**A. At **2204**, the method **2200** includes forming a second transistor separated from the first transistor in a first lateral direction and including the gate metal wrapped around a plurality of second stacked channels. One example of a second transistor is the transistor **101***d* of FIG. **14**A. One example of a gate metal is the gate metal **155** of FIG. **14**A. One example of stacked second channels are the channels **105***d* of FIG. **14**A. At **2206**, the method **2200** includes forming a dummy structure between the first transistor and the second transistor, wherein the dummy structure includes a dummy gate metal. One example of a dummy structure is the dummy structure **101***b* of FIG. **14**A. One example of a dummy gate metal is the dummy gate metal **156** of FIG. **14**A. At **2208**, the method **2200** includes forming a feedthrough via extending from below the dummy structure to contact the dummy gate metal. One example of the feedthrough via is the feedthrough via **191** of FIG. **14**A.

[0104] Embodiments of the disclosure provide an integrated circuit with a feedthrough via structure that provides an electrical connection between the backside metal lines and front side metal lines of the integrated circuit. The feedthrough via structure merges source/drain contacts, a gate dummy gate metal, and source/drain conductive vias. The gate dummy gate metal is formed in place of a gate metal of a gate all around transistor structure positioned between two continuous polysilicon on the fusion edge (CPODE) structures. The result is a feedthrough cell with low area penalty and low resistance. This results in improved processing speeds and reduced power consumption.

[0105] In some embodiments, a method includes forming a first transistor including a gate metal wrapped around a plurality of stacked first channels and forming a second transistor separated from the first transistor in a first lateral direction and including the gate metal wrapped around a plurality of second stacked channels. The method includes forming a dummy structure between the first transistor and the second transistor, wherein the dummy structure includes a dummy gate metal with a lower resistivity than the gate metal and forming a feedthrough via extending from below the dummy structure to contact the dummy gate metal.

[0106] In some embodiments, an integrated circuit includes a substrate and a dummy transistor. The dummy transistor includes a dummy gate metal, a first dummy source/drain contact, and a second dummy source/drain contact. The integrated circuit includes a feedthrough via extending through the substrate and contacting the dummy gate metal, the first dummy source/drain contact, and the second dummy source/drain contact.

[0107] In some embodiments, an integrated circuit includes a first transistor including a gate metal and a second transistor including the gate metal. The integrated circuit includes a dummy transistor positioned between the first transistor and the second transistor and including a plurality of semiconductor nanostructures and a dummy gate metal surrounding the semiconductor nanostructures. The integrated circuit includes a backside feedthrough via in contact with a bottom of the dummy gate metal and a first metal line above the dummy gate metal and electrically connected to the backside feedthrough via.

[0108] 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.

What is claimed is:

1. A method, comprising:

forming a first transistor including a gate metal wrapped around a plurality of stacked first channels;

forming a second transistor separated from the first transistor in a first lateral direction and including the gate metal wrapped around a plurality of second stacked channels;

forming a dummy structure between the first transistor and the second transistor, wherein the dummy structure includes a dummy gate metal; and

forming a feedthrough via extending from below the dummy structure to contact the dummy gate metal.

2. The method of claim **1**, wherein the dummy gate metal wraps around a plurality of stacked dummy channels.

3. The method of claim 1, wherein the forming the dummy structure includes:

depositing the gate metal around a plurality of stacked dummy channels of the dummy structure, around the first stacked channels, and around the second stacked channels;

removing the gate metal from the dummy structure; and

replacing the gate metal with the dummy metal at the dummy structure.

4. The method of claim 1, comprising:

forming a first dummy source/drain contact of the dummy structure;

forming a second dummy source/drain contact of the dummy structure; and

forming a first metal line over the dummy structure;

electrically shorting the first dummy source/drain contact, the second dummy source/drain contact, and the dummy gate metal to the first metal line.

5. The method of claim 4, wherein electrically shorting the first dummy source/drain contact, the second dummy source/drain contact, and the dummy gate metal to the first metal line includes forming a first conductive via coupled between the first dummy source/drain contact and the first metal line, forming a second conductive via coupled between the second dummy source/drain contact and the first metal line, and forming a third conductive via coupled between the dummy gate metal and the first metal line.

6. The method of claim 4, wherein electrically shorting the first dummy source/drain contact, the second dummy source/drain contact, and the dummy gate to the first metal line includes forming a conductive via in contact with the first dummy source/drain contact, the second dummy source/drain contact, the dummy gate metal, and the first metal line.

7. The method of claim 4, comprising forming a second metal line below and in contact with the feedthrough via.

8. The method of claim 4, wherein the feedthrough via is in contact with the first and second dummy source/drain structures.

9. The method of claim 1, comprising forming a gate isolation structure electrically isolating the gate metal of the first transistor and the dummy gate metal of the dummy structure.

10. The method of claim 1, comprising:

forming a first poly gate structure extending in the first lateral direction;

forming a second poly gate structure extending parallel to the first poly gate structure; and

forming the dummy gate metal and the feedthrough via between the first and second poly gate structures.

11. An integrated circuit, comprising:

a substrate;

a dummy structure including:

a dummy gate metal;

a first dummy source/drain contact; and

a second dummy source/drain contact; and

a feedthrough via extending through the substrate and contacting the dummy gate metal, the first dummy source/drain contact, and the second dummy source/drain contact.

12. The integrated circuit of claim 11, comprising:

a first transistor including a plurality of stacked first channels and a gate metal surrounding the stacked first channels; and

a second transistor separated from the first transistor in a first lateral direction including a plurality of stacked second channels and the gate metal surrounding the stacked second channels, the dummy structure being positioned between the first and second transistors, wherein the dummy gate metal has a lower resistivity than the gate metal.

13. The integrated circuit of claim 12, wherein the dummy gate transistor includes a plurality of stacked dummy channels, wherein the dummy gate metal wraps around the dummy channels.

14. The integrated circuit of claim 13, wherein the dummy gate metal is in direct contact with the dummy channels.

15. The integrated circuit of claim 11, wherein the dummy gate and the first and second dummy source/drain contacts extend to a same height.

16. The integrated circuit of claim 11, wherein the feedthrough via extends into the dummy gate metal.

17. The integrated circuit of claim 11, comprising:

a first metal line above the dummy structure;

a second metal line below and in contact with the feedthrough via; and

a conductive via between and in contact with the dummy gate metal and the first metal line.

18. An integrated circuit, comprising:

a first transistor including a gate metal;

a second transistor including the gate metal;

a dummy structure positioned between the first transistor and the second transistor and including a plurality of semiconductor nanostructures and a dummy gate metal surrounding the semiconductor nanostructures;

a backside feedthrough via in contact with a bottom of the dummy gate metal; and

a first metal line above the dummy gate metal and electrically connected to the backside feedthrough via.

19. The integrated circuit of claim 18, wherein the dummy structure includes first and second dummy source/drain contacts in contact with the backside feedthrough via.

20. The integrated circuit of claim 19, wherein the backside feedthrough via includes a U-shape in cross-section, wherein the dummy gate metal contacts the backside feedthrough via at a bottom of the U-shape, wherein the first and second dummy source/drain contacts contact the backside via at respective top ends of the U-shape.

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