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GAP PATTERNING FOR METAL-TO-SOURCE/DRAIN PLUGS IN A SEMICONDUCTOR DEVICE

Abstract

A method may include forming a mask layer on top of a first dielectric layer formed on a first source/drain and a second source/drain, and creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain. The method may include filling the opening with a metal layer that covers the exposed portions of the first source/drain and the second source/drain, and forming a gap in the metal layer to create a first metal contact and a second metal contact. The first metal contact may electrically couple to the first source/drain and the second metal contact may electrically couple to the second source/drain. The gap may separate the first metal contact from the second metal contact by less than nineteen nanometers.

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Background/Summary

RELATED APPLICATIONS [0001] This application is a divisional of U.S. patent application Ser. No. 18/507,138, filed Nov. 13, 2023, which is a continuation of U.S. patent application Ser. No. 17/662,752, filed May 10, 2022 (now U.S. Pat. No. 11,842,930), which is a divisional of U.S. patent application Ser. No. 16/878,005, filed May 19, 2020 (now U.S. Pat. No. 11,355,399), the contents of which are incorporated herein by reference in their entireties.

BACKGROUND

[0002] A fin field-effect transistor (finFET) is a multi-gate device that includes a metal-oxide-semiconductor field-effect transistor (MOSFET) built on a substrate. A gate is placed on two, three, or four sides of a channel or wrapped around the channel, forming a double gate structure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] 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.

[0004] FIG. 1 is a diagram of an example implementation of semiconductor processing tools described herein.

[0005] FIGS. 2A-2N are diagrams of one or more example operations involved in manufacturing an example semiconductor device described herein.

[0006] FIGS. 3A-3P are diagrams of another one or more example operations involved in manufacturing the example semiconductor device described herein.

[0007] FIG. 4 is a diagram of the example semiconductor device described herein.

[0008] FIG. 5 is a diagram of example components of one or more devices of FIG. 1.

[0009] FIGS. 6 and 7 are flowcharts of example processes for manufacturing the example semiconductor device based on gap patterning for metal-to-source/drain plugs in the example semiconductor device.

DETAILED DESCRIPTION

[0010] 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.

[0011] 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.

[0012] In some instances, a semiconductor device, such as a finFET, includes metal-to-source/drain plugs (e.g., a source/drain epitaxial layer) that are electrically coupled to other components of the semiconductor device using an island patterning technique. The island patterning technique includes patterning a photoresist layer between the metal-to-source/drain plugs to create openings that expose the metal-to-source/drain plugs. The openings are filled with metal contacts that electrically couple with corresponding metal-to-source/drain plugs. In the island patterning technique, the metal contacts are separated by at least a minimum distance (e.g., at least nineteen (19) nanometers (nm)). However, some semiconductor designs may indicate that the metal contacts are to be separated by less than the minimum distance provided by the island patterning technique. Furthermore, the island patterning technique may result in a less of an interface between a source/drain and the corresponding metal-to-source/drain plugs, which may cause unwanted increases in resistance of the corresponding metal-to-source/drain plugs.

[0013] According to some implementations described herein, a first method for manufacturing a semiconductor device (e.g., a finFET) is based on gap patterning for metal-to-source/drain plugs in the semiconductor device. For example, the first method may include forming a mask layer on top of a first dielectric layer formed on a first source/drain plug and a second source/drain plug, and creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain plug and the second source/drain plug. The first method may include filling the opening with a metal layer that covers the exposed portions of the first source/drain plug and the second source/drain plug, and forming a gap in the metal layer to create a first metal contact and a second metal contact. The first metal contact may electrically couple to the first source/drain plug and the second metal contact may electrically couple to the second source/drain plug. The gap may separate the first metal contact from the second metal contact by less than nineteen nanometers. The first method may include filling the gap with a material used for the first dielectric layer.

[0014] According to some implementations described herein, a second method for manufacturing a semiconductor device (e.g., a finFET) is based on gap patterning for metal-to-source/drain plugs in the semiconductor device. For example, the second method may include forming a mask layer on top of a first dielectric layer formed on a first source/drain plug and a second source/drain plug, and creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain plug and the second source/drain plug. The second method may include filling the opening with a sacrificial layer that covers the exposed portions of the first source/drain plug and the second source/drain plug, and forming a gap in the sacrificial layer. The second method may include filling the gap with a material used for the first dielectric layer to form a spacer, and removing the sacrificial layer to create a first opening that exposes a portion of the first source/drain plug and a second opening that exposes a portion of the second source/drain plug. The

second method may include filling the first opening with a metal to form a first metal contact, and filling the second opening with a metal to form a second metal contact. The first metal contact may electrically couple to the first source/drain plug and the second metal contact may electrically couple to the second source/drain plug. The spacer may separate the first metal contact from the second metal contact by less than nineteen nanometers.

[0015] In this way, the first and second methods for manufacturing a semiconductor device may be based on gap patterning for metal-to-source/drain plugs in the semiconductor device. The first and second methods enable metal contacts electrically coupled to corresponding metal-to-source/drain plugs of the semiconductor device to be separated by less than the minimum distance (e.g., less than nineteen nm) provided by the island patterning technique. Thus, the first and second methods may be utilized for the semiconductor designs that indicate that metal contacts are to be separated by less than a particular distance (e.g., nineteen nm). Furthermore, the first and second methods provide a more of an interface between a source/drain and the corresponding metal-to-source/drain plugs (e.g., relative to the island patterning technique), which reduces resistance of the corresponding metal-to-source/drain plugs (e.g., relative to the island patterning technique).

[0016] FIG. 1 is a diagram of an example implementation **100** of semiconductor processing tools described herein. As shown, a tool configuration may include one or more deposition (depo) tools, one or more photoresist (photo) tools, one or more etch tools, one or more metal tools, one or more chemical-mechanical polishing (CMP) tools, and/or the like. Semiconductor devices may be provided to one or more of the aforementioned tools via a handler device (e.g., a robotic arm, multiple robotic arms, and/or the like). Although FIG. 1 shows different modules (e.g., deposition, photolithography, etch, and/or the like) in same tool configuration, the different modules may be provided in different tool configurations. FIG. 1 is provided to explain process sequences. In some implementations, the tool configuration is utilized to produce a semiconductor device described below in connection with FIGS. 2A-4.

[0017] The deposition tool may include a tool that deposits materials on the semiconductor device, such as an insulation layer, a dielectric layer, a mask layer, a metal layer, and/or the like.

Deposition is any process that grows, coats, or otherwise transfers a material onto a semiconductor device. The deposition tool may include a tool that forms a thin film of material on a semiconductor device by physical vapor deposition (PVD), chemical vapor deposition (CVD), atomic layer deposition (ALD), molecular beam epitaxy (MBE), electrochemical deposition (ECD), and/or the like. In some implementations, the deposition includes a chamber that enables deposition of layers on the semiconductor device. The chamber may be filled with a gas (e.g., an argon gas) that is maintained at a particular temperature, is provided at a particular flow rate, is maintained at a particular pressure, and/or the like, depending on the material deposited on the semiconductor device.

[0018] The photoresist tool may include a tool that removes materials from or provides materials to a semiconductor device based on a photoresist layer (e.g., a photoresist mask) applied to the semiconductor device. A photoresist is a light-sensitive material used in several processes (e.g., photolithography, photoengraving, and/or the like) to form a patterned coating on a surface of a semiconductor device. The photoresist tool may coat the semiconductor device with a photo-sensitive organic material, and may apply a patterned mask to the semiconductor device to block light, so that only unmasked regions of the photo-sensitive organic material will be exposed to light. The photoresist tool or another tool (e.g., the etch tool) may apply a solvent, called a developer, to the semiconductor device. In the case of a positive photoresist, the photo-sensitive organic material is degraded by light and the developer dissolves away regions that are exposed to light, leaving behind a coating where the mask is placed. In the case of a negative photoresist, the photo-sensitive organic material is strengthened (e.g., either polymerized or cross-linked) by light, and the developer dissolves away only regions that are not exposed to light, leaving behind a coating in areas where the mask is not placed.

[0019] The etch tool may include a tool that removes materials from a surface of a semiconductor device. In some implementations, a portion of the semiconductor device is protected from an etchant by a masking material that resists etching. For example, the masking material may include a photoresist that is patterned using photolithography. The etch tool may perform a wet etching process or a dry (e.g., plasma) etching process on the semiconductor device. In the wet etching process, the semiconductor device may be immersed in a batch of a liquid-phase (e.g., wet) etchant, which may be agitated to achieve process control. For example, a buffered hydrofluoric acid (BHF) may be used to etch silicon dioxide over a silicon substrate. The plasma etching process may operate in several modes based on adjusting parameters of the plasma. For example, the plasma etching process may operate at a pressure in a range from approximately 0.01 Torr to approximately 5 Torr. The plasma produces energetic free radicals, that are neutrally charged and that react at a surface of the semiconductor device. Plasma etching may be isotropic (e.g., exhibiting a lateral undercut rate on a patterned surface approximately the same as a downward etch rate) or anisotropic (e.g., exhibiting a smaller lateral undercut rate than the downward etch rate). A source gas for the plasma may include small molecules rich in chlorine or fluorine. For example, carbon tetra fluorine may be utilized to etch silicon and chlorine may be utilized to etch aluminum, trifluoro methane may be used to etch silicon dioxide and silicon nitride, and/or the like. The plasma may also include oxygen that is used to oxidize photoresist and facilitate removal of the photoresist.

[0020] The metal tool may include a tool that forms metal layers on the semiconductor device. In some implementations, the metal tool includes a chamber that enables deposition of the metal layers on the semiconductor device. The chamber may be filled with a gas (e.g., an argon gas) that is maintained at a particular temperature (e.g., 510° C., 530° C., and/or the like) and is provided at a particular flow rate (e.g., 20, 25, 30 and/or the like standard cubic centimeters per minute (sccm)). In some implementations, the metal tool may include a heater component, a target component, and a magnetron that are provided within the chamber of the metal tool. The heater component may include a support pad that is sized and shaped to support the semiconductor device. The support pad may include one or more heating elements that generate heat that is transferred to the semiconductor device based on the semiconductor device contacting the support pad. The target component may include a material that is used to create metal layers on the semiconductor device, via a technique known as thin film deposition. For example, the target component may include an aluminum material, a copper material, an aluminum copper material, and/or the like. The magnetron may include multiple magnetic columns that generate a magnetic field when the magnetron is rotated.

[0021] In operation, since the magnetron is located behind the target component, plasma generated from the target component may be confined to a target surface of the semiconductor device. Rotation of the magnetron may generate a magnetic field that forms a closed-loop annular path acting as an electron trap that reshapes trajectories of secondary electrons ejected from the target component into a cycloidal path, which increases a probability of ionization of a sputtering gas within the chamber. Inert gases (e.g., argon) may be employed as the sputtering gas because inert gases tend not to react with the target component or combine with any process gases and because inert gases produce higher sputtering and deposition rates due to high molecular weight. Positively charged argon ions from the plasma may be accelerated toward the negatively biased target component, resulting in material being dislodged from a surface of the target component and onto the semiconductor device.

[0022] The CMP tool may include a tool that smooths surfaces of a semiconductor device with a combination of chemical and mechanical forces (e.g., chemical etching and free abrasive polishing). The CMP tool may utilize an abrasive and corrosive chemical slurry in conjunction with a polishing pad and retaining ring (e.g., typically of a greater diameter than the semiconductor device). The polishing pad and the semiconductor device are pressed together by a dynamic

polishing head and held in place by the retaining ring. The dynamic polishing head is rotated with different axes of rotation to remove material and even out any irregular topography of the semiconductor device, making the semiconductor device flat or planar.

[0023] As indicated above, FIG. 1 is provided merely as one or more examples. Other examples may differ from what is described with regard to FIG. 1.

[0024] FIGS. 2A-2N are diagrams of one or more example operations **200** involved in manufacturing an example semiconductor device (e.g., a logic device, a memory device, a finFET, a MOSFET, and/or the like). As shown in FIG. 2A, the semiconductor device may include a substrate layer with multiple fins, an insulation layer, a source/drain epitaxial layer, and a first dielectric layer. The substrate layer and the multiple fins may include a conductive or semi-conductive material, such as silicon, aluminum, copper, and/or the like. The insulation layer may include a material that insulates the substrate layer and the multiple fins, such as tantalum nitride, silicon oxide, silicate glass, silicon oxycarbide, and/or the like. In some implementations, the insulation layer is formed by shallow trench isolation to prevent electric current leakage between adjacent fins of the substrate layer. The source/drain epitaxial layer may include a silicon germanium formed via epitaxial growth. In some implementations, the source/drain epitaxial layer may form a first source/drain plug that is electrically coupled to a first pair of fins of the substrate layer, and a second source/drain plug that is electrically coupled to a second pair of fins of the substrate layer. The first dielectric layer may include a material that electrically insulates the first source/drain plug and the second source/drain plug from each other and from other components of the semiconductor device. For example, the first dielectric layer may include, silicon nitride, silicon oxide, a low-k material and/or the like.

[0025] As further shown in FIG. 2A, and by reference number **205**, a mask layer may be formed on the semiconductor device. For example, the mask layer may be formed on top of the first dielectric layer of the semiconductor device. The mask layer may include a metal oxide, titanium nitride (TiN), tungsten carbide (WC), and/or the like. In some implementations, the deposition tool and/or the metal tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the mask layer on top of the first dielectric layer.

[0026] As shown in FIG. 2B, and by reference number **210**, a first bottom layer may be formed on top of the mask layer, a first middle layer may be formed on top of the first bottom layer, and a first photoresist layer may be formed on portions of the first middle layer. The first bottom layer may include an organic material, such as carbon, oxygen, hydrogen, a thermosetting polyarene ether, and/or the like. The first middle layer may include an antireflective coating (ARC) material, such as silicon, oxygen, nitrogen, silicon oxide, a silicon-containing ARC material, and/or the like. The first photoresist layer may include a photoresist material, such as a photopolymeric photoresist (e.g., methyl methacrylate), a photodecomposing photoresist (e.g., diazonaphthaquinone), a photocrosslinking photoresist, and/or the like. In some implementations, the photoresist layer is patterned on the portions of the first middle layer so that an opening may be formed to expose the first source/drain plug and the second source/drain plug, as described below. In some implementations, the photoresist tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the first bottom layer on top of the mask layer, to form the first middle layer on top of the first bottom layer, and to form the first photoresist layer on the portions of the first middle layer.

[0027] As shown in FIG. 2C, and by reference number **215**, the first bottom layer, the first middle layer, the first photoresist layer, and a portion of the mask layer may be removed based on formation of the first photoresist layer on the portions of the first middle layer. Such removal transfers the pattern to mask layer and portions of the mask layer to remain on top of the first dielectric layer, as shown in FIG. 2C. In some implementations, one or more photolithography and/or etching operations may be performed to remove the first bottom layer, the first middle layer, the first photoresist layer, and the portion of the mask layer. For example, one or more

photolithographic operations may be performed to remove portions of the first bottom layer, the first middle layer, and the mask layer not formed under the first photoresist layer. One or more etching operations may be performed to remove remaining portions of the first bottom layer, the first middle layer, and the first photoresist layer from the semiconductor device. For example, a dry etching operation may be performed, utilizing carbon tetrafluoride gas, CF_3H gas, and/or the like to etch the first middle layer; SO_2 , O_2 gas, and/or the like to etch the first bottom layer; carbon tetrafluoride gas, C_4F_6 gas, and/or the like to etch the first mask layer, after the first photoresist pattern is transferred to the first mask layer. In some implementations, the photoresist tool and/or the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to etch the first bottom layer, the first middle layer, the first photoresist layer, and the portion of the mask layer based on formation of the first photoresist layer on the portions of the first middle layer.

[0028] As shown in FIG. 2D, and by reference number **220**, the first dielectric layer not formed below the portion of the mask layer may be removed to form an opening that exposes the source/drain epitaxial layer (e.g., the first source/drain plug and the second source/drain plug). In some implementations, one or more etching operations may be performed to remove the first dielectric layer not formed below the portion of the mask layer and to form the opening that exposes the source/drain epitaxial layer. For example, a dry etching operation, utilizing carbon tetrafluoride gas, hexafluorocyclobutane gas, octafluorocyclobutane gas, oxygen gas, and/or the like, may be performed to remove the first dielectric layer not formed below the portion of the mask layer and to form the opening that exposes the source/drain epitaxial layer (e.g., the first source/drain plug and the second source/drain plug). In some implementations, there may be a CESL (e.g., a SiN, etch stop layer) layer deposited before the first dielectric layer. In some implementations, the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the first dielectric layer not formed below the portion of the mask layer and to form the opening that exposes the source/drain epitaxial layer.

[0029] As shown in FIG. 2E, and by reference number **225**, the opening in the first dielectric layer and the mask layer may be filled with a first metal layer that covers the source/drain epitaxial layer (e.g., the first source/drain plug and the second source/drain plug). The first metal layer may include a metal, such as cobalt, tungsten, aluminum, copper, and/or the like. In some implementations, a metal deposition operation may be performed to fill the opening in the first dielectric layer and the mask layer with the first metal layer that covers the source/drain epitaxial layer. For example, PVD, CVD, ALD, MBE, ECD, and/or the like may be performed to fill the opening in the first dielectric layer and the mask layer with the first metal layer that covers the source/drain epitaxial layer. In some implementations, the deposition tool and/or the metal tool of the tool configuration, described above in connection with FIG. 1, may be utilized to fill the opening in the first dielectric layer and the mask layer with the first metal layer that covers the source/drain epitaxial layer. In some implementations, there may be a barrier layer (e.g. TaN, TiN, and/or the like) deposited before metal filling. In some implementations, the first metal layer provides a better interface with the source/drain epitaxial layer (e.g., the first source/drain plug and second source/drain plug), relative to the island patterning technique, which reduces resistance between the first metal layer and the source/drain epitaxial layer, relative to the island patterning technique.

[0030] As shown in FIG. 2F, and by reference number **230**, the first metal layer may be polished to be substantially planar with and/or under the first dielectric layer and to remove the mask layer. In some implementations, a CMP operation may be performed to polish the first metal layer to be substantially planar with the first dielectric layer and to remove the mask layer. In some implementations, the CMP tool of the tool configuration, described above in connection with FIG. 1, may be utilized to polish the first metal layer to be substantially planar with/or under the first dielectric layer and to remove the mask layer.

[0031] As shown in FIG. 2G, and by reference number **235**, a second bottom layer may be formed on top of the first metal layer and the first dielectric layer, a second middle layer may be formed on top of the second bottom layer, and a second photoresist layer may be formed on portions of the second middle layer. The second bottom layer may include an organic material, such as carbon, oxygen, hydrogen, a thermosetting polyarene ether, and/or the like. The second middle layer may include an ARC material, such as silicon, oxygen, nitrogen, silicon oxide, a silicon-containing ARC material, and/or the like. The second photoresist layer may include a photoresist material, such as a photopolymeric photoresist, a photodecomposing photoresist, a photocrosslinking photoresist, and/or the like. In some implementations, the second photoresist layer is patterned on the portions of the second middle layer so that a gap may be formed in the first metal layer, as described below. In some implementations, the photoresist tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the second bottom layer on top of the first metal layer and the first dielectric layer, to form the second middle layer on top of the second bottom layer, and to form the second photoresist layer on the portions of the second middle layer.

[0032] As shown in FIG. 2H, and by reference number **240**, the second bottom layer, the second middle layer, the second photoresist layer may be removed and a portion of the first metal layer may be removed and transfer the pattern to form a gap in the first metal layer. For example, the first metal layer not formed below the second photoresist layer may be removed to form the gap in the first metal layer. In some implementations, one or more photolithography and/or etching operations may be performed to an etch on the second bottom layer, the second middle layer, and the second photoresist layer and to form the gap in the first metal layer. For example, one or more photolithographic operations may be performed to remove portions of the second bottom layer and the second middle layer not formed under the second photoresist layer. One or more etching operations may be performed to remove remaining portions of the second bottom layer, the second middle layer, and the second photoresist layer from the semiconductor device.

[0033] In some implementations, one or more etching operations may be performed to remove the first metal layer not formed below the second photoresist layer and to form the gap in the first metal layer. For example, when the first metal layer is made from cobalt, a dry etching operation, utilizing chlorine and hydrogen gases, chlorine and oxygen gases, and/or the like, may be performed to remove the first metal layer not formed below the second photoresist layer and to form the gap in the first metal layer. In another example, when the first metal layer is made from tungsten, a dry etching operation, utilizing carbon tetrafluoride gas, nitrogen trifluoride gas, sulfur hexafluoride gas, and/or the like, may be performed to remove the first metal layer not formed below the second photoresist layer and to form the gap in the first metal layer. In some implementations, the photoresist tool and/or the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to etch the second bottom layer, the second middle layer, the second photoresist layer, and/or the portion of the first metal layer that forms the gap in the first metal layer. In some implementations, the gap creates a first metal contact and a second metal contact, as shown in FIG. 2H. The first metal contact may electrically couple to the first source/drain plug, and the second metal contact may electrically couple to the second source/drain plug. In some implementations, the gap separates the first metal contact from the second metal contact by less than nineteen nanometers, such as a gap of approximately eight nanometers, a gap in a range from approximately eight nanometers to less than nineteen nanometers, and/or the like.

[0034] As shown in FIG. 2I, and by reference number **245**, the gap in the first metal layer may be filled with material utilized for the first dielectric layer. For example, the gap may be filled with, silicon nitride, silicon oxide, a low-k material, and/or the like then with a CMP to planarize the surface. The dielectric material filled in the gap may electrically isolate the first metal contact from the second metal contact. In some implementations, the deposition tool of the tool configuration, described above in connection with FIG. 1, may be utilized to fill the gap in the first metal layer with the material utilized for the first dielectric layer.

[0035] As shown in FIG. 2J, and by reference number **250**, a second dielectric layer may be formed on the first metal layer (e.g., the first metal contact and the second metal contact) and the first dielectric layer. The second dielectric layer may include a material that electrically insulates the first metal layer and the first dielectric layer from other components of the semiconductor device. For example, the second dielectric layer may include, silicon nitride, silicon oxide, a low-k material, and/or the like. In some implementations, the deposition tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the second dielectric layer on the first metal layer and the first dielectric layer.

[0036] As shown in FIG. 2K, and by reference number **255**, a third bottom layer may be formed on top of the second dielectric layer, a third middle layer may be formed on top of the third bottom layer, and a third photoresist layer may be formed on portions of the third middle layer. The third bottom layer may include an organic material, such as carbon, oxygen, hydrogen, a thermosetting polyarene ether, and/or the like. The third middle layer may include an ARC material, such as silicon, oxygen, nitrogen, silicon oxide, a silicon-containing ARC material, and/or the like. The third photoresist layer may include a photoresist material, such as a photopolymeric photoresist, a photodecomposing photoresist, a photocrosslinking photoresist, and/or the like. In some implementations, the third photoresist layer is patterned on the portions of the third middle layer so that vias may be formed in the second dielectric layer, as described below. In some implementations, the photoresist tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the third bottom layer on top of the second dielectric layer, to form the third middle layer on top of the third bottom layer, and to form the third photoresist layer on the portions of the third middle layer.

[0037] As shown in FIG. 2L, and by reference number **260**, the third bottom layer, the third middle layer, and the third photoresist layer may be etched and the pattern transferred to the second dielectric layer and portions of the second dielectric layer may be removed to form vias in the second dielectric layer based on the formation of the third photoresist layer on the portions of the third middle layer. In some implementations, one or more photolithography and/or etching operations may be performed to remove the third bottom layer, the third middle layer, and the third photoresist layer and to form the vias in the second dielectric layer. For example, one or more photolithographic operations may be performed to remove portions of the third bottom layer and the third middle layer not formed under the third photoresist layer. One or more etching operations may be performed to remove remaining portions of the third bottom layer, the third middle layer, and the third photoresist layer from the semiconductor device.

[0038] In some implementations, one or more etching operations may be performed to remove the second dielectric layer not formed below the third photoresist layer and to form the vias in the second dielectric layer. For example, a dry etching operation, utilizing chlorine and hydrogen gases, chlorine and oxygen gases, carbon tetrafluoride gas, nitrogen trifluoride gas, sulfur hexafluoride gas, and/or the like, may be performed to remove the second dielectric layer not formed below the third photoresist layer and to form the vias in the second dielectric layer. In some implementations, the photoresist tool and/or the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the third bottom layer, the third middle layer, and the third photoresist layer and to form the vias in the second dielectric layer.

[0039] As shown in FIG. 2M, and by reference number **265**, a second metal layer may be formed on the second dielectric layer to fill the vias in the second dielectric layer with the second metal layer and so that the second metal layer contacts portions of the first metal layer (e.g., the first metal contact and the second metal contact). The second metal layer may include a metal, such as cobalt, tungsten, aluminum, copper, and/or the like. In some implementations, a metal deposition operation may be performed to form the second metal layer on the second dielectric layer and to fill the vias in the second dielectric layer with the second metal layer. For example, PVD, CVD, ALD, MBE, ECD, and/or the like may be performed to form the second metal layer on the second

dielectric layer and to fill the vias in the second dielectric layer with the second metal layer. In some implementations, the deposition tool and/or the metal tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the second metal layer on the second dielectric layer and to fill the vias in the second dielectric layer with the second metal layer.

[0040] As shown in FIG. 2N, and by reference number **270**, the second metal layer may be polished to be substantially planar with the second dielectric layer. In some implementations, a CMP operation may be performed to polish the second metal layer to be substantially planar with the second dielectric layer. In some implementations, the CMP tool of the tool configuration, described above in connection with FIG. 1, may be utilized to polish the second metal layer to be substantially planar with the second dielectric layer. As further shown in FIG. 2N, the second metal layer formed in the vias of the second dielectric layer may form a third metal contact and a fourth metal contact. In some implementations, the third metal contact electrically couples to the first metal contact, and the fourth metal contact electrically couples to the second metal contact.

[0041] In this way, the method for manufacturing a semiconductor device, described in connection with FIGS. 2A-2N, enables metal contacts electrically coupled to corresponding metal-to-source/drain plugs of the semiconductor device to be separated by less than nineteen nanometers, in range from approximately eight nanometers to less than nineteen nanometers, and/or the like. Thus, the method may be utilized for the semiconductor designs that indicate that metal contacts are to be separated by less than nineteen nanometers. Furthermore, the method provides a more of an interface between a source/drain and the corresponding metal-to-source/drain plugs (e.g., relative to the island patterning technique), which reduces resistance of the corresponding metal-to-source/drain plugs (e.g., relative to the island patterning technique).

[0042] As indicated above, FIGS. 2A-2N are provided merely as one or more examples. Other examples may differ from what is described with regard to FIGS. 2A-2N.

[0043] FIGS. 3A-3P are diagrams of one or more example operations **300** involved in manufacturing an example semiconductor device (e.g., a logic device, a memory device, a finFET, a MOSFET, and/or the like). As shown in FIG. 3A, the semiconductor device may include a substrate layer with multiple fins, an insulation layer, a source/drain epitaxial layer, and a first dielectric layer. The substrate layer, the multiple fins, the insulation layer, the source/drain epitaxial layer (e.g., the first source/drain plug and the second source/drain plug), and the first dielectric layer of FIG. 3A may include the features described above in connection with FIG. 2A.

[0044] As further shown in FIG. 3A, and by reference number **305**, a mask layer may be formed on the semiconductor device. For example, the mask layer may be formed on top of the first dielectric layer of the semiconductor device. The mask layer may include a metal oxide, titanium nitride, tungsten carbide, and/or the like. In some implementations, the deposition tool and/or the metal tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the mask layer on top of the first dielectric layer.

[0045] As shown in FIG. 3B, and by reference number **310**, a first bottom layer may be formed on top of the mask layer, a first middle layer may be formed on top of the first bottom layer, and a first photoresist layer may be formed on portions of the first middle layer. The first bottom layer may include an organic material, such as carbon, oxygen, hydrogen, a thermosetting polyarene ether, and/or the like. The first middle layer may include an ARC material, such as silicon, oxygen, nitrogen, silicon oxide, a silicon-containing ARC material, and/or the like. The first photoresist layer may include a photoresist material, such as a photopolymeric photoresist, a photodecomposing photoresist, a photocrosslinking photoresist, and/or the like. In some implementations, the photoresist layer is patterned on the portions of the first middle layer so that an opening may be formed to expose the first source/drain plug and the second source/drain plug, as described below. In some implementations, the photoresist tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the first bottom layer on top of the mask layer, to form the first middle layer on top of the first bottom layer, and to form the first

photoresist layer on the portions of the first middle layer.

[0046] As shown in FIG. 3C, and by reference number **315**, the first bottom layer, the first middle layer, the first photoresist layer, and a portion of the mask layer may be removed based on formation of the first photoresist layer on the portions of the first middle layer. Such removal may cause portions of the mask layer to remain on top of the first dielectric layer, as shown in FIG. 3C. In some implementations, one or more photolithography and/or etching operations may be performed to remove the first bottom layer, the first middle layer, the first photoresist layer, and the portion of the mask layer. For example, one or more photolithographic operations may be performed to remove portions of the first bottom layer, the first middle layer, and the mask layer not formed under the first photoresist layer. One or more etching operations may be performed to remove remaining portions of the first bottom layer, the first middle layer, and the first photoresist layer from the semiconductor device. For example, a dry etching operation may be performed, utilizing carbon tetrafluoride gas, a CF_3H gas, and/or the like to etch the first middle layer; SO_2 , O_2 gas, and/or the like to etch the first bottom layer; carbon tetrafluoride gas, C_4F_6 gas, and/or the like to etch first mask layer, after the first photoresist pattern is transferred to the first mask layer. In some implementations, the photoresist tool and/or the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the first bottom layer, the first middle layer, the first photoresist layer, and the portion of the mask layer based on formation of the first photoresist layer on the portions of the first middle layer.

[0047] As shown in FIG. 3D, and by reference number **320**, the first dielectric layer not formed below the portion of the mask layer may be removed to form an opening that exposes the source/drain epitaxial layer (e.g., the first source/drain plug and the second source/drain plug). In some implementations, one or more etching operations may be performed to remove the first dielectric layer not formed below the portion of the mask layer and to form the opening that exposes the source/drain epitaxial layer. For example, a dry etching operation, utilizing carbon tetrafluoride gas, hexafluorocyclobutane gas, octafluorocyclobutane gas, oxygen gas, and/or the like, may be performed to remove the first dielectric layer not formed below the portion of the mask layer and to form the opening that exposes the source/drain epitaxial layer. In some implementations, the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the first dielectric layer not formed below the portion of the mask layer and to form the opening that exposes the source/drain epitaxial layer.

[0048] As shown in FIG. 3E, and by reference number **325**, the opening in the first dielectric layer and the mask layer may be filled with a sacrificial layer that covers the source/drain epitaxial layer (e.g., the first source/drain plug and the second source/drain plug). The sacrificial layer may include material that is subsequently removed from the semiconductor device, such as silicon, silicon nitride, hafnium oxide, and/or the like. In some implementations, a deposition operation may be performed to fill the opening in the first dielectric layer and the mask layer with the sacrificial layer that covers the source/drain epitaxial layer. For example, PVD, CVD, ALD, MBE, ECD, and/or the like may be performed to fill the opening in the first dielectric layer and the mask layer with the sacrificial layer that covers the source/drain epitaxial layer. In some implementations, the deposition tool of the tool configuration, described above in connection with FIG. 1, may be utilized to fill the opening in the first dielectric layer and the mask layer with the sacrificial layer that covers the source/drain epitaxial layer. If silicon is utilized for the sacrificial layer and the first dielectric layer, a liner layer (e.g., other than silicon) may be formed on walls and a bottom of the opening prior to the deposition of the sacrificial layer in the opening.

[0049] As shown in FIG. 3F, and by reference number **330**, the sacrificial layer may be polished to be substantially planar with the first dielectric layer and to remove the mask layer. In some implementations, a CMP operation may be performed to polish the sacrificial layer to be substantially planar with the first dielectric layer and to remove the mask layer. In some

implementations, the CMP tool of the tool configuration, described above in connection with FIG. 1, may be utilized to polish the sacrificial layer to be substantially planar with the first dielectric layer and to remove the mask layer.

[0050] As shown in FIG. 3G, and by reference number 335, a second bottom layer may be formed on top of the sacrificial layer and the first dielectric layer, a second middle layer may be formed on top of the second bottom layer, and a second photoresist layer may be formed on portions of the second middle layer. The second bottom layer may include an organic material, such as carbon, oxygen, hydrogen, a thermosetting polyarene ether, and/or the like. The second middle layer may include an ARC material, such as silicon, oxygen, nitrogen, silicon oxide, a silicon-containing ARC material, and/or the like. The second photoresist layer may include a photoresist material, such as a photopolymeric photoresist, a photodecomposing photoresist, a photocrosslinking photoresist, and/or the like. In some implementations, the second photoresist layer is patterned on the portions of the second middle layer so that a gap may be formed in the sacrificial layer, as described below. In some implementations, the photoresist tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the second bottom layer on top of the sacrificial layer and the first dielectric layer, to form the second middle layer on top of the second bottom layer, and to form the second photoresist layer on the portions of the second middle layer.

[0051] As shown in FIG. 3H, and by reference number 340, the second bottom layer, the second middle layer, and the second photoresist layer may be removed and a portion of the sacrificial layer may be removed to form a gap in the sacrificial layer. For example, the sacrificial layer not formed below the second photoresist layer may be removed to form the gap in the sacrificial layer. In some implementations, one or more photolithography and/or etching operations may be performed to remove the second bottom layer, the second middle layer, and the second photoresist layer and to form the gap in the sacrificial layer. For example, one or more photolithographic operations may be performed to remove portions of the second bottom layer and the second middle layer not formed under the second photoresist layer. One or more etching operations may be performed to remove remaining portions of the second bottom layer, the second middle layer, and the second photoresist layer from the semiconductor device.

[0052] In some implementations, one or more etching operations may be performed to remove the sacrificial layer not formed below the second photoresist layer and to form the gap in the sacrificial layer. For example, a dry etching operation may be performed to remove the sacrificial layer not formed below the second photoresist layer and to form the gap in the sacrificial layer. In some implementations, the photoresist tool and/or the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the second bottom layer, the second middle layer, and the second photoresist layer and to form a gap in the sacrificial layer. In some implementations, the gap creates a spacer for a first metal contact and a second metal contact, as described below.

[0053] As shown in FIG. 3I, and by reference number 345, the gap in the sacrificial layer may be filled with material utilized for the first dielectric layer. For example, the gap may be filled with, silicon nitride, silicon oxide, and/or the like. The dielectric material filled in the gap may create a spacer that electrically isolates a first metal contact from a second metal contact, as described below. In some implementations, the deposition tool of the tool configuration, described above in connection with FIG. 1, may be utilized to fill the gap in the sacrificial layer with the material utilized for the first dielectric layer.

[0054] As shown in FIG. 3J, and by reference number 350, the sacrificial layer may be removed to form openings in the first dielectric layer that expose the source/drain epitaxial layer. In some implementations, one or more etching operations may be performed to remove the sacrificial layer and to form the openings in the first dielectric layer. For example, when the sacrificial layer is formed from silicon, a wet etching operation, utilizing ammonium hydroxide, may be performed to remove the sacrificial layer and to form the openings in the first dielectric layer. In another

example, when the sacrificial layer is formed from silicon nitride, a wet etching operation, utilizing phosphoric acid, may be performed to remove the sacrificial layer and to form the openings in the first dielectric layer. In some implementations, the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the sacrificial layer and to form the openings in the first dielectric layer.

[0055] As shown in FIG. 3K, and by reference number 355, the openings in the first dielectric layer may be filled with a first metal layer. The first metal layer may include a metal, such as cobalt, tungsten, aluminum, copper, and/or the like. In some implementations, a metal deposition operation may be performed to fill the openings in the first dielectric layer with the first metal layer that covers the source/drain epitaxial layer. For example, PVD, CVD, ALD, MBE, ECD, and/or the like may be performed to fill the openings in the first dielectric layer with the first metal layer that covers the source/drain epitaxial layer. In some implementations, the deposition tool and/or the metal tool of the tool configuration, described above in connection with FIG. 1, may be utilized to fill the openings in the first dielectric layer with the first metal layer that covers the source/drain epitaxial layer. As further shown in FIG. 3K, the spacer with the first dielectric material layer may divide the first metal layer into a first metal contact and a second metal contact. The first metal contact may electrically couple to the first source/drain plug, and the second metal contact may electrically couple to the second source/drain plug. In some implementations, the spacer separates the first metal contact from the second metal contact by less than nineteen nanometers. In some implementations, the first metal layer provides more of an interface with the source/drain epitaxial layer (e.g., the first source/drain plug and second source/drain plug), relative to the island patterning technique, which reduces resistance between the first metal layer and the source/drain epitaxial layer, relative to the island patterning technique.

[0056] The first metal layer may be polished to be substantially planar with the first dielectric layer. In some implementations, a CMP operation may be performed to polish the first metal layer to be substantially planar with the first dielectric layer. In some implementations, the CMP tool of the tool configuration, described above in connection with FIG. 1, may be utilized to polish the first metal layer to be substantially planar with the first dielectric layer and to form the first metal contact and the second metal contact.

[0057] As shown in FIG. 3L, and by reference number 360, a second dielectric layer may be formed on the first metal layer (e.g., the first metal contact and the second metal contact) and the first dielectric layer. The second dielectric layer may include a material that electrically insulates the first metal layer and the first dielectric layer from other components of the semiconductor device. For example, the second dielectric layer may include, silicon nitride, silicon oxide, and/or the like. In some implementations, the deposition tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the second dielectric layer on the first metal layer and the first dielectric layer.

[0058] As shown in FIG. 3M, and by reference number 365, a third bottom layer may be formed on top of the second dielectric layer, a third middle layer may be formed on top of the third bottom layer, and a third photoresist layer may be formed on portions of the third middle layer. The third bottom layer may include an organic material, such as carbon, oxygen, hydrogen, a thermosetting polyarene ether, and/or the like. The third middle layer may include an ARC material, such as silicon, oxygen, nitrogen, silicon oxide, a silicon-containing ARC material, and/or the like. The third photoresist layer may include a photoresist material, such as a photopolymeric photoresist, a photodecomposing photoresist, a photocrosslinking photoresist, and/or the like. In some implementations, the third photoresist layer is patterned on the portions of the third middle layer so that vias may be formed in the second dielectric layer, as described below. In some implementations, the photoresist tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the third bottom layer on top of the second dielectric layer, to form the third middle layer on top of the third bottom layer, and to form the third photoresist layer on the

portions of the third middle layer.

[0059] As shown in FIG. 3N, and by reference number **370**, the third bottom layer, the third middle layer, and the third photoresist layer may be removed and portions of the second dielectric layer may be removed to form vias in the second dielectric layer based on the formation of the third photoresist layer on the portions of the third middle layer. In some implementations, one or more photolithography and/or etching operations may be performed to remove the third bottom layer, the third middle layer, and the third photoresist layer and to form the vias in the second dielectric layer. For example, one or more photolithographic operations may be performed to remove portions of the third bottom layer and the third middle layer not formed under the third photoresist layer. One or more etching operations may be performed to remove remaining portions of the third bottom layer, the third middle layer, and the third photoresist layer from the semiconductor device.

[0060] In some implementations, one or more etching operations may be performed to remove the second dielectric layer not formed below the third photoresist layer and to form the vias in the second dielectric layer. For example, a dry etching operation, utilizing chlorine and hydrogen gases, chlorine and oxygen gases, carbon tetrafluoride gas, nitrogen trifluoride gas, sulfur hexafluoride gas, and/or the like, may be performed to remove the second dielectric layer not formed below the third photoresist layer and to form the vias in the second dielectric layer. In some implementations, the photoresist tool and/or the etch tool of the tool configuration, described above in connection with FIG. 1, may be utilized to remove the third bottom layer, the third middle layer, and the third photoresist layer and to form the vias in the second dielectric layer.

[0061] As shown in FIG. 3O, and by reference number **375**, a second metal layer may be formed on the second dielectric layer to fill the vias in the second dielectric layer with the second metal layer and so that the second metal layer contacts portions of the first metal layer (e.g., the first metal contact and the second metal contact). The second metal layer may include a metal, such as cobalt, tungsten, aluminum, copper, and/or the like. In some implementations, a metal deposition operation may be performed to form the second metal layer on the second dielectric layer and to fill the vias in the second dielectric layer with the second metal layer. For example, PVD, CVD, ALD, MBE, ECD, and/or the like may be performed to form the second metal layer on the second dielectric layer and to fill the vias in the second dielectric layer with the second metal layer. In some implementations, the deposition tool and/or the metal tool of the tool configuration, described above in connection with FIG. 1, may be utilized to form the second metal layer on the second dielectric layer and to fill the vias in the second dielectric layer with the second metal layer.

[0062] As shown in FIG. 3P, and by reference number **380**, the second metal layer may be polished to be substantially planar with the second dielectric layer. In some implementations, a CMP operation may be performed to polish the second metal layer to be substantially planar with the second dielectric layer. In some implementations, the CMP tool of the tool configuration, described above in connection with FIG. 1, may be utilized to polish the second metal layer to be substantially planar with the second dielectric layer. As further shown in FIG. 3P, the second metal layer formed in the vias of the second dielectric layer may form a third metal contact and a fourth metal contact. In some implementations, the third metal contact electrically couples to the first metal contact, and the fourth metal contact electrically couples to the second metal contact.

[0063] In this way, the method for manufacturing a semiconductor device, described in connection with FIGS. 3A-3P, enables metal contacts electrically coupled to corresponding metal-to-source/drain plugs of the semiconductor device to be separated by less than nineteen nanometers, in a range from approximately eight nanometers to less than nineteen nanometers, and/or the like. Thus, the method may be utilized for the semiconductor designs that indicate that metal contacts are to be separated by less than nineteen nanometers. Furthermore, the method provides a better interface between the metal contacts and the corresponding metal-to-source/drain plugs (e.g., relative to the island patterning technique), which reduces resistance between the metal contacts and the corresponding metal-to-source/drain plugs (e.g., relative to the island patterning technique).

[0064] As indicated above, FIGS. 3A-3P are provided merely as one or more examples. Other examples may differ from what is described with regard to FIGS. 3A-3P.

[0065] FIG. 4 is a diagram of an example semiconductor device **400** described herein. As shown, semiconductor device **400** may include a substrate layer **405** with multiple fins, an insulation layer **410**, source/drain plugs **415**, a first dielectric layer **420**, and metal contacts **425**. Substrate layer **405**, the multiple fins, insulation layer **410**, and first dielectric layer **420** may correspond to the substrate layer, the multiple fins, the insulation layer, and the first dielectric layer described above in connection with FIGS. 2A-3P. Source/drain plugs **415** may correspond to the first source/drain plug and the second source/drain plug described above in connection with FIGS. 2A-3P. Metal contacts **425** may correspond to the first metal contact and the second metal contact described above in connection with FIGS. 2A-3P. Semiconductor device **400** may be formed using the method of FIGS. 2A-2N or the method of FIGS. 3A-3P.

[0066] As further shown in FIG. 4, metal contacts **425** may be spaced apart by a distance (a) in a range from approximately eight (8) nanometers to less than nineteen (19) nanometers. In some implementations, the distance (a) may be approximately eight (8) nanometers. In some implementations, using this type of process for patterning may provide a distance (a) of more than nineteen (19) nanometers. A sidewall of one of metal contacts **425** may be spaced from a corresponding one of source/drain plugs **415** by a distance (b) in a range from approximately ten (10) nanometers to approximately sixty-six (66) nanometers. In some implementations, as shown in FIG. 4, the distance (b) may be less than ten (10) nanometers even with isolation material over the edge of the source/drain epitaxial layer. An angle (θ) formed based on a sidewall of one of metal contacts **425** and based on a top surface of insulation layer **410** may be in a range from approximately eighty-eight (88) degrees to approximately ninety-two (92) degrees. In contrast, with the island patterning technique, the distance (a) may be greater than nineteen (19) nanometers, the distance (b) may be in a range from approximately ten (10) nanometers to approximately fifty (50) nanometers, the angle (θ) may be in a range from approximately eighty-five (85) degrees to approximately eighty-eight (88) degrees. In this way, the dimensions of semiconductor device **400** enables metal contacts **425** electrically coupled to corresponding source/drain **415** of semiconductor device **400** to be separated by less than nineteen nanometers. Thus, semiconductor device **400** may be utilized for semiconductor designs that indicate that metal contacts are to be separated by less than nineteen nanometers. Furthermore, semiconductor device **400** provides more of an interface between metal contacts **425** and the corresponding source/drain **415** (e.g., relative to the island patterning technique), which reduces resistance between metal contacts **425** and the corresponding source/drain **415** (e.g., relative to the island patterning technique).

[0067] In this way, semiconductor device **400**, described in connection with FIG. 4, enables metal contacts **425** electrically coupled to corresponding metal-to-source/drain plugs **415** of semiconductor device **400** to be separated by less than nineteen nanometers, in range from approximately eight nanometers to less than nineteen nanometers, and/or the like. Thus, semiconductor device **400** may be utilized for the semiconductor designs that indicate that metal contacts **425** are to be separated by less than nineteen nanometers. Furthermore, semiconductor device **400** provides a better interface between metal contacts **425** and the corresponding metal-to-source/drain plugs **415** (e.g., relative to the island patterning technique), which reduces resistance between metal contacts **425** and source/drain **415** (e.g., relative to the island patterning technique).

[0068] FIG. 5 is a diagram of example components of a device **500**. Device **500** may correspond to the deposition tool, the photoresist tool, the etch tool, the metal tool, and/or the CMP tool. In some implementations, the deposition tool, the photoresist tool, the etch tool, the metal tool, and/or the CMP tool may include one or more devices **500** and/or one or more components of device **500**. As shown in FIG. 5, device **500** may include a bus **510**, a processor **520**, a memory **530**, a storage component **540**, an input component **550**, an output component **560**, and a communication interface **570**.

[0069] Bus **510** includes a component that permits communication among the components of device **500**. Processor **520** is implemented in hardware, firmware, or a combination of hardware and software. Processor **520** is a central processing unit (CPU), a graphics processing unit (GPU), an accelerated processing unit (APU), a microprocessor, a microcontroller, a digital signal processor (DSP), a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), or another type of processing component. In some implementations, processor **520** includes one or more processors capable of being programmed to perform a function. Memory **530** includes a random access memory (RAM), a read only memory (ROM), and/or another type of dynamic or static storage device (e.g., a flash memory, a magnetic memory, and/or an optical memory) that stores information and/or instructions for use by processor **520**.

[0070] Storage component **540** stores information and/or software related to the operation and use of device **500**. For example, storage component **540** may include a hard disk (e.g., a magnetic disk, an optical disk, a magneto-optic disk, and/or a solid state disk), a compact disc (CD), a digital versatile disc (DVD), a floppy disk, a cartridge, a magnetic tape, and/or another type of non-transitory computer-readable medium, along with a corresponding drive.

[0071] Input component **550** includes a component that permits device **500** to receive information, such as via user input (e.g., a touch screen display, a keyboard, a keypad, a mouse, a button, a switch, and/or a microphone). Additionally, or alternatively, input component **550** may include a sensor for sensing information (e.g., a global positioning system (GPS) component, an accelerometer, a gyroscope, and/or an actuator). Output component **560** includes a component that provides output information from device **500** (e.g., a display, a speaker, and/or one or more LEDs).

[0072] Communication interface **570** includes a transceiver-like component (e.g., a transceiver and/or a separate receiver and transmitter) that enables device **500** to communicate with other devices, such as via a wired connection, a wireless connection, or a combination of wired and wireless connections. Communication interface **570** may permit device **500** to receive information from another device and/or provide information to another device. For example, communication interface **570** may include an Ethernet interface, an optical interface, a coaxial interface, an infrared interface, an RF interface, a universal serial bus (USB) interface, a wireless local area interface, a cellular network interface, and/or the like.

[0073] Device **500** may perform one or more processes described herein. Device **500** may perform these processes based on processor **520** executing software instructions stored by a non-transitory computer-readable medium, such as memory **530** and/or storage component **540**. A computer-readable medium is defined herein as a non-transitory memory device. A memory device includes memory space within a single physical storage device or memory space spread across multiple physical storage devices.

[0074] Software instructions may be read into memory **530** and/or storage component **540** from another computer-readable medium or from another device via communication interface **570**. When executed, software instructions stored in memory **530** and/or storage component **540** may cause processor **520** to perform one or more processes described herein. Additionally, or alternatively, hardwired circuitry may be used in place of or in combination with software instructions to perform one or more processes described herein. Thus, implementations described herein are not limited to any specific combination of hardware circuitry and software.

[0075] The number and arrangement of components shown in FIG. 5 are provided as an example. In practice, device **500** may include additional components, fewer components, different components, or differently arranged components than those shown in FIG. 5. Additionally, or alternatively, a set of components (e.g., one or more components) of device **500** may perform one or more functions described as being performed by another set of components of device **500**.

[0076] FIG. 6 is a flow chart of an example process **600** for manufacturing an example semiconductor device based on gap patterning for metal-to-source/drain plugs in the example semiconductor device. In some implementations, one or more process blocks of FIG. 6 may be

performed by a tool configuration (e.g., the tool configuration of FIG. 1). In some implementations, one or more process blocks of FIG. 6 may be performed by another device or a group of devices separate from or including the tool configuration.

[0077] As shown in FIG. 6, process **600** may include forming a mask layer on top of a first dielectric layer formed on a first source/drain and a second source/drain (block **610**). For example, the tool configuration may form a mask layer on top of a first dielectric layer formed on a first source/drain and a second source/drain, as described above.

[0078] As further shown in FIG. 6, process **600** may include creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain (block **620**). For example, the tool configuration may create an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain, as described above.

[0079] As further shown in FIG. 6, process **600** may include filling the opening with a metal layer that covers the exposed portions of the first source/drain and the second source/drain (block **630**). For example, the tool configuration may fill the opening with a metal layer that covers the exposed portions of the first source/drain and the second source/drain, as described above.

[0080] As further shown in FIG. 6, process **600** may include forming a gap in the metal layer to create a first metal contact and a second metal contact, wherein the first metal contact is electrically coupled to the first source/drain and the second metal contact is electrically coupled to the second source/drain, and wherein the gap separates the first metal contact from the second metal contact by less than nineteen nanometers (block **640**). For example, the tool configuration may form a gap in the metal layer to create a first metal contact and a second metal contact, as described above. In some implementations, the first metal contact is electrically coupled to the first source/drain and the second metal contact is electrically coupled to the second source/drain. In some implementations, the gap separates the first metal contact from the second metal contact by less than nineteen nanometers.

[0081] As further shown in FIG. 6, process **600** may include filling the gap with a material used for the first dielectric layer (block **650**). For example, the tool configuration may fill the gap with a material used for the first dielectric layer (or with materials used for other types of dielectric layers), as described above.

[0082] Process **600** may include additional implementations, such as any single implementation or any combination of implementations described below and/or in connection with one or more other processes described elsewhere herein.

[0083] In a first implementation, process **600** includes forming a second dielectric layer on top of the first dielectric layer, the first metal contact, and the second metal contact; creating a first via in the second dielectric layer to expose a portion of the first metal contact; creating a second via in the second dielectric layer to expose a portion of the second metal contact; filling the first via to create a third metal contact that is electrically coupled to the first metal contact; and filling the second via to create a fourth metal contact that is electrically coupled to the second metal contact.

[0084] In a second implementation, alone or in combination with the first implementation, creating the opening in the mask layer and the first dielectric layer includes forming a photoresist layer above portions of the mask layer and the first dielectric layer, and performing one or more etching operations to remove portions of the mask layer and the first dielectric layer other than the portions of the mask layer and the first dielectric layer formed below the photoresist layer, where the removed portions of the mask layer and the first dielectric layer correspond to the opening that exposes portions of the first source/drain and the second source/drain.

[0085] In a third implementation, alone or in combination with one or more of the first and second implementations, process **600** includes polishing the metal layer to be substantially planar with the first dielectric layer and to remove the mask layer, prior to forming the gap in the metal layer.

[0086] In a fourth implementation, alone or in combination with one or more of the first through

third implementations, forming the gap in the metal layer includes forming a photoresist layer above portions of the metal layer and the first dielectric layer except a portion of the metal layer associated with the gap, and performing one or more etching operations to remove the portion of metal layer, where the removed portion of the metal layer corresponds to the gap in the metal layer. [0087] In a fifth implementation, alone or in combination with one or more of the first through fourth implementations, forming the gap in the metal layer includes forming a bottom layer on top of the metal layer and the first dielectric layer; forming a middle layer on top of the bottom layer; forming a photoresist layer above portions of the metal layer, the first dielectric layer, the bottom layer, and the middle layer, except a portion of the metal layer associated with the gap; and performing one or more etching operations to remove the portion of metal layer, the entire photoresist layer, the entire bottom layer, and the entire middle layer, where the removed portion of the metal layer corresponds to the gap in the metal layer.

[0088] In a sixth implementation, alone or in combination with one or more of the first through fifth implementations, creating the opening in the mask layer and the first dielectric layer includes forming a bottom layer on top of the mask layer; forming a middle layer on top of the bottom layer; forming a photoresist layer above portions of the first dielectric layer, the mask layer, the bottom layer, and the middle layer; and performing one or more etching operations to remove the entire photoresist layer, the entire bottom layer, the entire middle layer, and portions of the mask layer and the first dielectric layer other than the portions of the mask layer and the first dielectric layer formed below the photoresist layer, where the removed portions of the mask layer and the first dielectric layer correspond to the opening that exposes portions of the first source/drain and the second source/drain.

[0089] In a seventh implementation, alone or in combination with one or more of the first through sixth implementations, the semiconductor device includes a substrate with fins and an insulation layer formed on top of the substrate, where one or more first fins electrically couple to the first source/drain and one or more second fins electrically couple to the second source/drain.

[0090] Although FIG. 6 shows example blocks of process **600**, in some implementations, process **600** may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in FIG. 6. Additionally, or alternatively, two or more of the blocks of process **600** may be performed in parallel.

[0091] FIG. 7 is a flow chart of an example process **700** for manufacturing an example semiconductor device based on gap patterning for metal-to-source/drain plugs in the example semiconductor device. In some implementations, one or more process blocks of FIG. 7 may be performed by a tool configuration (e.g., the tool configuration of FIG. 1). In some implementations, one or more process blocks of FIG. 7 may be performed by another device or a group of devices separate from or including the tool configuration.

[0092] As shown in FIG. 7, process **700** may include forming a mask layer on top of a first dielectric layer formed on a first source/drain and a second source/drain (block **710**). For example, the tool configuration may form a mask layer on top of a first dielectric layer formed on a first source/drain and a second source/drain, as described above.

[0093] As further shown in FIG. 7, process **700** may include creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain (block **720**). For example, the tool configuration may create an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain, as described above.

[0094] As further shown in FIG. 7, process **700** may include filling the opening with a sacrificial layer that covers the exposed portions of the first source/drain and the second source/drain (block **730**). For example, the tool configuration may fill the opening with a sacrificial layer that covers the exposed portions of the first source/drain and the second source/drain, as described above.

[0095] As further shown in FIG. 7, process **700** may include forming a gap in the sacrificial layer

(block **740**). For example, the tool configuration may form a gap in the sacrificial layer, as described above.

[0096] As further shown in FIG. 7, process **700** may include filling the gap with a material used for the first dielectric layer to form a spacer (block **750**). For example, the tool configuration may fill the gap with a material used for the first dielectric layer to form a spacer (or with materials used for other types of dielectric layers), as described above.

[0097] As further shown in FIG. 7, process **700** may include removing the sacrificial layer to create a first opening that exposes a portion of the first source/drain and a second opening that exposes a portion of the second source/drain (block **760**). For example, the tool configuration may remove the sacrificial layer to create a first opening that exposes a portion of the first source/drain and a second opening that exposes a portion of the second source/drain, as described above.

[0098] As further shown in FIG. 7, process **700** may include filling the first opening with a metal to form a first metal contact (block **770**). For example, the tool configuration may fill the first opening with a metal to form a first metal contact, as described above.

[0099] As further shown in FIG. 7, process **700** may include filling the second opening with a metal to form a second metal contact, wherein the first metal contact is electrically coupled to the first source/drain and the second metal contact is electrically coupled to the second source/drain, and wherein the spacer separates the first metal contact from the second metal contact by less than nineteen nanometers (block **780**). For example, the tool configuration may fill the second opening with a metal to form a second metal contact, as described above. In some implementations, the first metal contact is electrically coupled to the first source/drain and the second metal contact is electrically coupled to the second source/drain. In some implementations, the spacer separates the first metal contact from the second metal contact by less than nineteen nanometers.

[0100] Process **700** may include additional implementations, such as any single implementation or any combination of implementations described below and/or in connection with one or more other processes described elsewhere herein.

[0101] In a first implementation, process **700** includes forming a second dielectric layer on top of the first dielectric layer, the first metal contact, and the second metal contact; creating a first via in the second dielectric layer to expose a portion of the first metal contact; creating a second via in the second dielectric layer to expose a portion of the second metal contact; filling the first via to form a third metal contact that is electrically coupled to the first metal contact; and filling the second via to form a fourth metal contact that is electrically coupled to the second metal contact.

[0102] In a second implementation, alone or in combination with the first implementation, creating the opening in the mask layer and the first dielectric layer includes forming a photoresist layer above portions of the mask layer and the first dielectric layer, and performing one or more etching operations to remove portions of the mask layer and the first dielectric layer other than the portions of the mask layer and the first dielectric layer formed below the photoresist layer, where the removed portions of the mask layer and the first dielectric layer correspond to the opening that exposes portions of the first source/drain and the second source/drain.

[0103] In a third implementation, alone or in combination with one or more of the first and second implementations, process **700** includes polishing the sacrificial layer to be substantially planar with the first dielectric layer and to remove the mask layer, prior to forming the gap in the sacrificial layer.

[0104] In a fourth implementation, alone or in combination with one or more of the first through third implementations, forming the gap in the sacrificial layer includes forming a photoresist layer above portions of the sacrificial layer and the first dielectric layer except a portion of the sacrificial layer associated with the gap, and performing one or more etching operations to remove the portion of sacrificial layer, where the removed portion of the sacrificial layer corresponds to the gap in the sacrificial layer.

[0105] In a fifth implementation, alone or in combination with one or more of the first through

fourth implementations, forming the gap in the sacrificial layer includes forming a bottom layer on top of the sacrificial layer and the first dielectric layer; forming a middle layer on top of the bottom layer; forming a photoresist layer above portions of the sacrificial layer, the first dielectric layer, the bottom layer, and the middle layer, except a portion of the sacrificial layer associated with the gap; and performing one or more etching operations to remove the portion of sacrificial layer, the entire photoresist layer, the entire bottom layer, and the entire middle layer, where the removed portion of the sacrificial layer corresponds to the gap in the sacrificial layer.

[0106] In a sixth implementation, alone or in combination with one or more of the first through fifth implementations, creating the opening in the mask layer and the first dielectric layer includes forming a bottom layer on top of the mask layer; forming a middle layer on top of the bottom layer; forming a photoresist layer above portions of the first dielectric layer, the mask layer, the bottom layer, and the middle layer; and performing one or more etching operations to remove the entire photoresist layer, the entire bottom layer, the entire middle layer, and portions of the mask layer and the first dielectric layer other than the portions of the mask layer and the first dielectric layer formed below the photoresist layer, where the removed portions of the mask layer and the first dielectric layer correspond to the opening that exposes portions of the first source/drain and the second source/drain.

[0107] In a seventh implementation, alone or in combination with one or more of the first through sixth implementations, an angle formed based on a sidewall of the first metal contact or the second metal contact and based on a top surface of the insulation layer is in a range from approximately eighty-eight degrees to approximately ninety-two degrees.

[0108] In an eighth implementation, alone or in combination with one or more of the first through seventh implementations, a distance from a sidewall of the first metal contact to the first source/drain is in a range from approximately ten nanometers to approximately sixty-six nanometers.

[0109] In a ninth implementation, alone or in combination with one or more of the first through eighth implementations, a distance from a sidewall of the first metal contact to a sidewall of the second metal contact is in a range from approximately eight nanometers to nineteen nanometers.

[0110] Although FIG. 7 shows example blocks of process **700**, in some implementations, process **700** may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in FIG. 7. Additionally, or alternatively, two or more of the blocks of process **700** may be performed in parallel.

[0111] In this way, a method for manufacturing semiconductor device **400** may be based on gap patterning for metal-to-source/drain plugs **415** in semiconductor device **400**. The method enables metal contacts **425** electrically coupled to corresponding source/drain **415** of semiconductor device **400** to be separated by less than a minimum distance (e.g., less than nineteen nm) provided by the island patterning technique. Thus, the method may be utilized for semiconductor designs. Furthermore, the method provides more of an interface between metal contacts **425** and the corresponding source/drain—**415** (e.g., relative to the island patterning technique), which reduces resistance between metal contacts **425** and the corresponding source/drain **415** (e.g., relative to the island patterning technique).

[0112] As described in greater detail above, some implementations described herein provide a method for manufacturing a semiconductor device. The method may include providing a mask layer on top of a first dielectric layer provided on a first source/drain and a second source/drain, and creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain. The method may include filling the opening with a metal layer that covers the exposed portions of the first source/drain and the second source/drain, and forming a gap in the metal layer to create a first metal contact and a second metal contact. The first metal contact may electrically couple to the first source/drain and the second metal contact may electrically couple to the second source/drain. The gap may separate the first metal contact

from the second metal contact by less than nineteen nanometers. The method may include filling the gap with a material used for the first dielectric layer.

[0113] As described in greater detail above, some implementations described herein provide a method for manufacturing a semiconductor device. The method may include providing a mask layer on top of a first dielectric layer provided on a first source/drain and a second source/drain, and creating an opening in the mask layer and the first dielectric layer that exposes portions of the first source/drain and the second source/drain. The method may include filling the opening with a sacrificial layer that covers the exposed portions of the first source/drain and the second source/drain, and forming a gap in the sacrificial layer. The method may include filling the gap with a material used for the first dielectric layer to form a spacer, and removing the sacrificial layer to create a first opening that exposes a portion of the first source/drain and a second opening that exposes a portion of the second source/drain. The method may include filling the first opening with a metal to form a first metal contact, and filling the second opening with a metal to form a second metal contact. The first metal contact may electrically couple to the first source/drain and the second metal contact may electrically couple to the second source/drain. The spacer may separate the first metal contact from the second metal contact by less than nineteen nanometers.

[0114] As described in greater detail above, some implementations described herein provide a semiconductor device with a substrate layer that includes a plurality of fins, and an insulation layer formed on top of the substrate layer. The semiconductor device may include a first source/drain electrically coupled to one or more first fins of the plurality of fins, and a second source/drain spaced from the first source/drain and electrically coupled to one or more second fins of the plurality of fins. The semiconductor device may include a first metal contact electrically coupled to the first source/drain, a second metal contact electrically coupled to the second source/drain, and a dielectric layer to separate the first metal contact from the second metal contact by less than nineteen nanometers.

[0115] 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 those skilled in the art may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

Claims

1. A semiconductor device, comprising: a substrate layer that includes a plurality of fins; a first source/drain electrically coupled to one or more first fins of the plurality of fins; a second source/drain spaced from the first source/drain and electrically coupled to one or more second fins of the plurality of fins; a first metal contact electrically coupled to the first source/drain; a second metal contact electrically coupled to the second source/drain; and a dielectric layer to separate the first metal contact from the second metal contact by less than nineteen nanometers.
2. The semiconductor device of claim 1, wherein an angle formed based on a sidewall of the first metal contact or the second metal contact and based on a top surface of an insulation layer, above the substrate layer, is in a range from approximately eighty-eight degrees to approximately ninety-two degrees.
3. The semiconductor device of claim 1, wherein a distance from a sidewall of the first metal contact to the first source/drain is in a range from approximately ten nanometers to approximately sixty-six nanometers.
4. The semiconductor device of claim 1, further comprising: a third metal contact formed on top of

and electrically coupled to the first metal contact; and a fourth metal contact formed on top of and electrically coupled to the second metal contact.

5. The semiconductor device of claim 4, wherein the dielectric layer is a first dielectric layer; and wherein the semiconductor device further comprises: a second dielectric layer between the third metal contact and the fourth metal contact.

6. The semiconductor device of claim 1, wherein a distance from a sidewall of the first metal contact to a sidewall of the second metal contact is in a range from approximately eight nanometers to nineteen nanometers.

7. The semiconductor device of claim 1, wherein the dielectric layer is in contact with the first metal contact and the second metal contact.

8. A semiconductor device, comprising: a substrate layer that includes a first set of fins and a second set of fins; a first source/drain electrically coupled to the first set of fins; a second source/drain electrically coupled to the second set of fins; a first metal contact electrically coupled to the first source/drain; a second metal contact electrically coupled to the second source/drain; and dielectric material between the first metal contact and the second metal contact, wherein the dielectric material is in contact with the first metal contact and the second metal contact.

9. The semiconductor device of claim 8, wherein a width of the dielectric material between the first metal contact and the second metal contact is less than nineteen nanometers.

10. The semiconductor device of claim 9, wherein the width is approximately eight nanometers.

11. The semiconductor device of claim 8, further comprising: an insulation layer between the substrate layer and the first metal contact.

12. The semiconductor device of claim 11, wherein an angle formed based on a sidewall of the first metal contact and based on a top surface of the insulation layer is in a range from approximately eighty-eight degrees to approximately ninety-two degrees.

13. The semiconductor device of claim 12, wherein a distance between a sidewall of the second metal contact and the second source/drain is in a range from approximately ten nanometers to approximately sixty-six nanometers.

14. The semiconductor device of claim 11, wherein an angle formed based on a sidewall of the first metal contact and based on a top surface of the insulation layer is in a range from approximately eighty-five degrees to approximately eighty-eight degrees.

15. A semiconductor device, comprising: a substrate layer that includes a first set of fins and a second set of fins; a first source/drain coupled to the first set of fins; a second source/drain coupled to the second set of fins; a first metal contact covering the first source/drain; a second metal contact covering the second source/drain; an insulation layer between the substrate layer and the first metal contact; and a spacer between the first metal contact and the second metal contact, wherein the spacer is in contact with the first metal contact and the second metal contact.

16. The semiconductor device of claim 15, wherein the insulation layer is between the substrate layer and the second metal contact.

17. The semiconductor device of claim 15, wherein a width of the spacer is in a range from approximately eight nanometers to less than nineteen nanometers.

18. The semiconductor device of claim 15, wherein a distance between a sidewall of the first metal contact and the first source/drain is in a range from approximately ten nanometers to approximately sixty-six nanometers.

19. The semiconductor device of claim 15, further comprising: a third metal contact formed on the first metal contact; and a fourth metal contact formed on the second metal contact.

20. The semiconductor device of claim 15, wherein an angle formed based on a sidewall of the first metal contact and based on a top surface of the insulation layer is in a range from approximately eighty-eight degrees to approximately ninety-two degrees.
