(19) United States
(12) Patent Application Publication
Burke et al.
(10) Pub. No.: US 2013/0341712 A1
(43) Pub. Date: Dec. 26, 2013

(54) TRENCH SHIELDING STRUCTURE FOR SEMICONDUCTOR DEVICE AND METHOD

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(21) Appl. No.: **13/970,566**

(22) Filed: **Aug. 19, 2013**

Related U.S. Application Data

(63) Continuation of application No. 12/271,068, filed on Nov. 14, 2008, now Pat. No. 8,552,535.

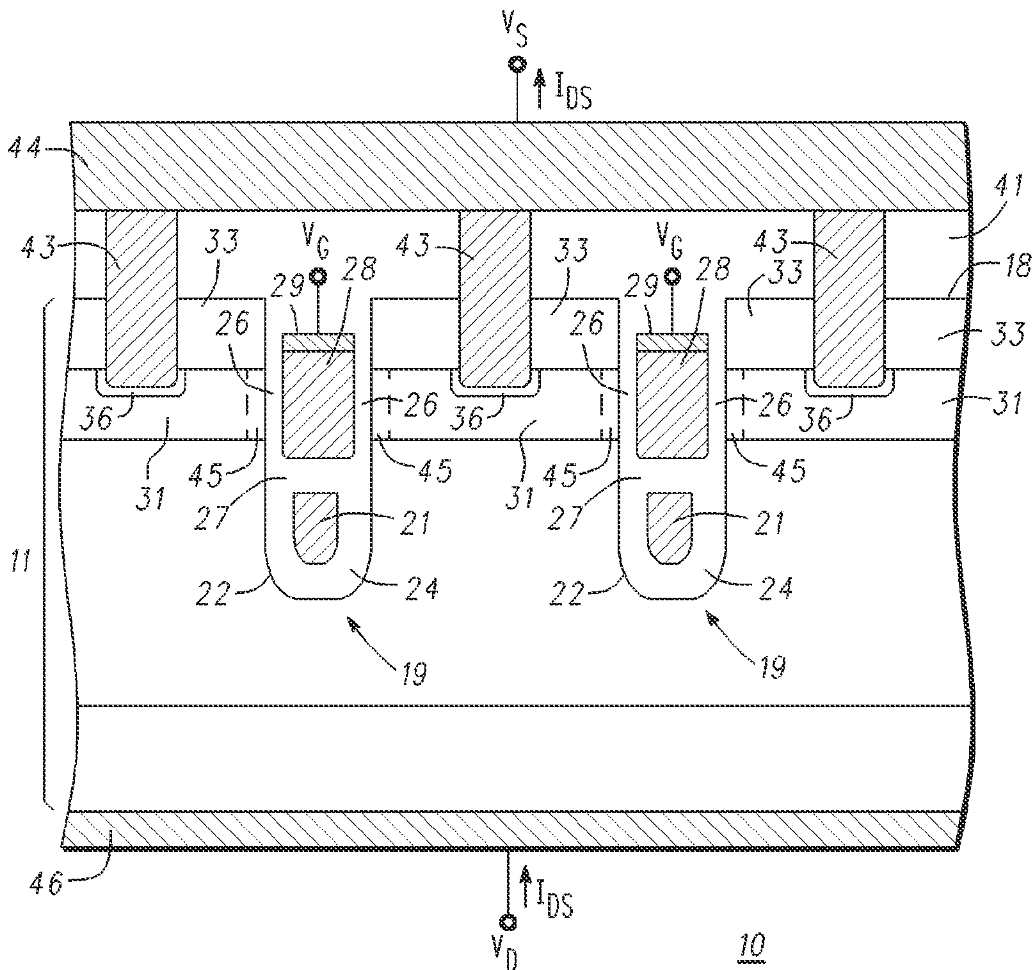
Publication Classification

(51) **Int. Cl.**
H01L 29/40 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 29/407*** (2013.01); ***H01L 29/401*** (2013.01)
USPC **257/333**; 438/589

(57) **ABSTRACT**

A shielding structure for a semiconductor device includes a plurality of trenches. The trenches include passivation liners and shield electrodes, which are formed therein. In one embodiment, the shielding structure is placed beneath a control pad. In another embodiment, the shielding structure is placed beneath a control runner.



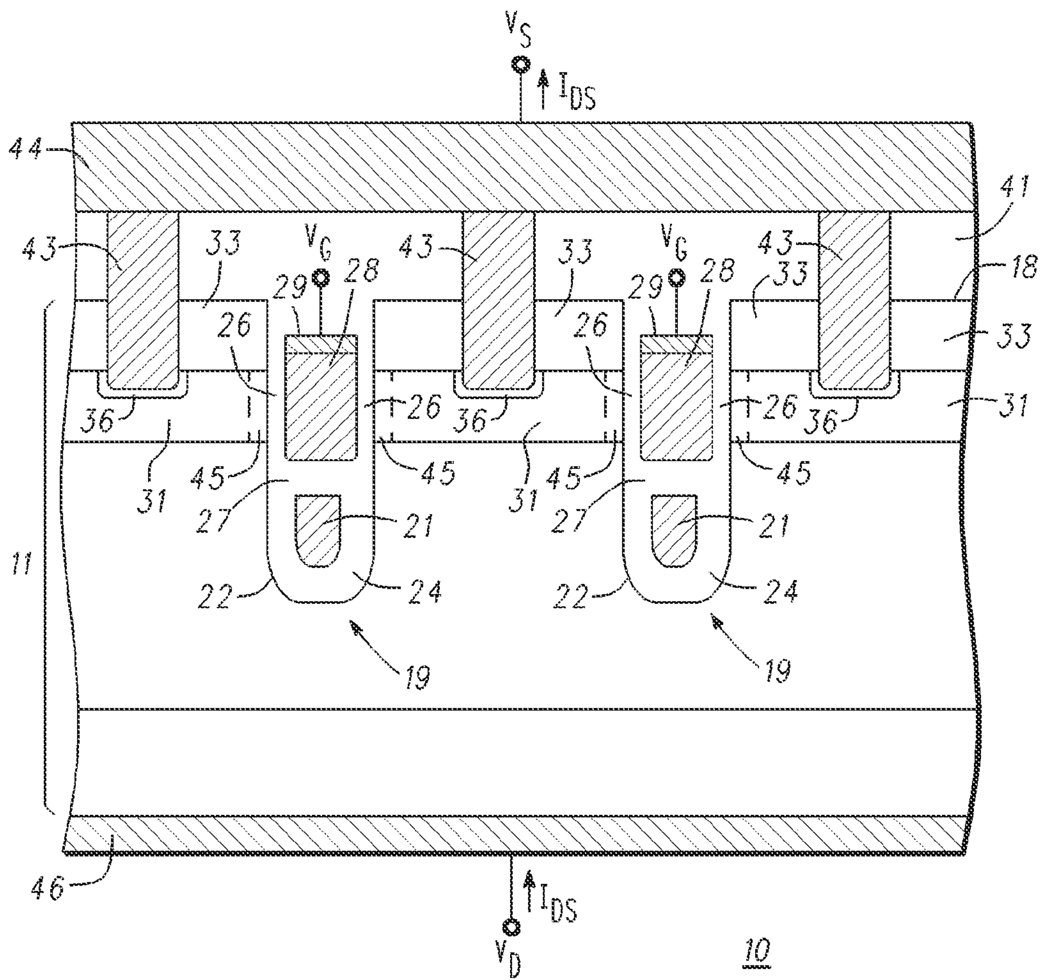


Fig. 1

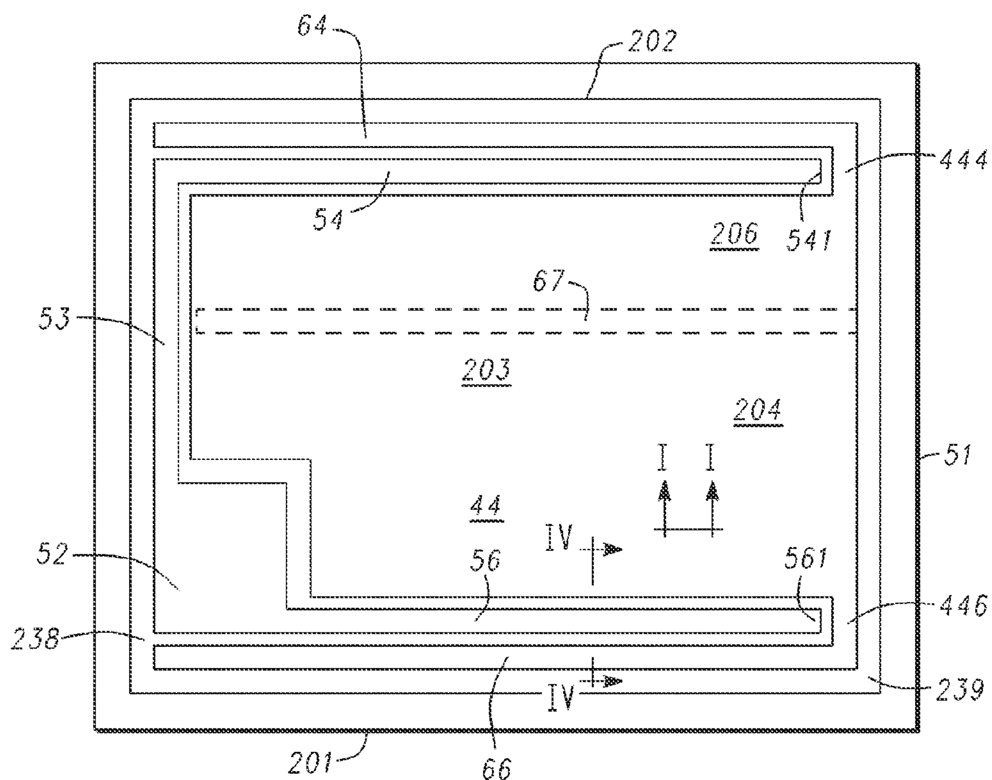


Fig. 2

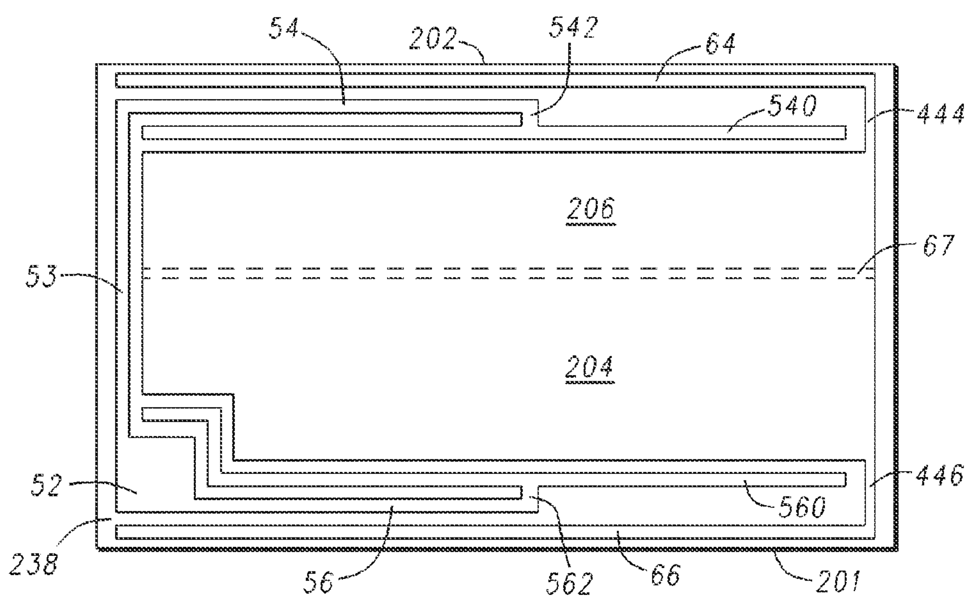


Fig. 3

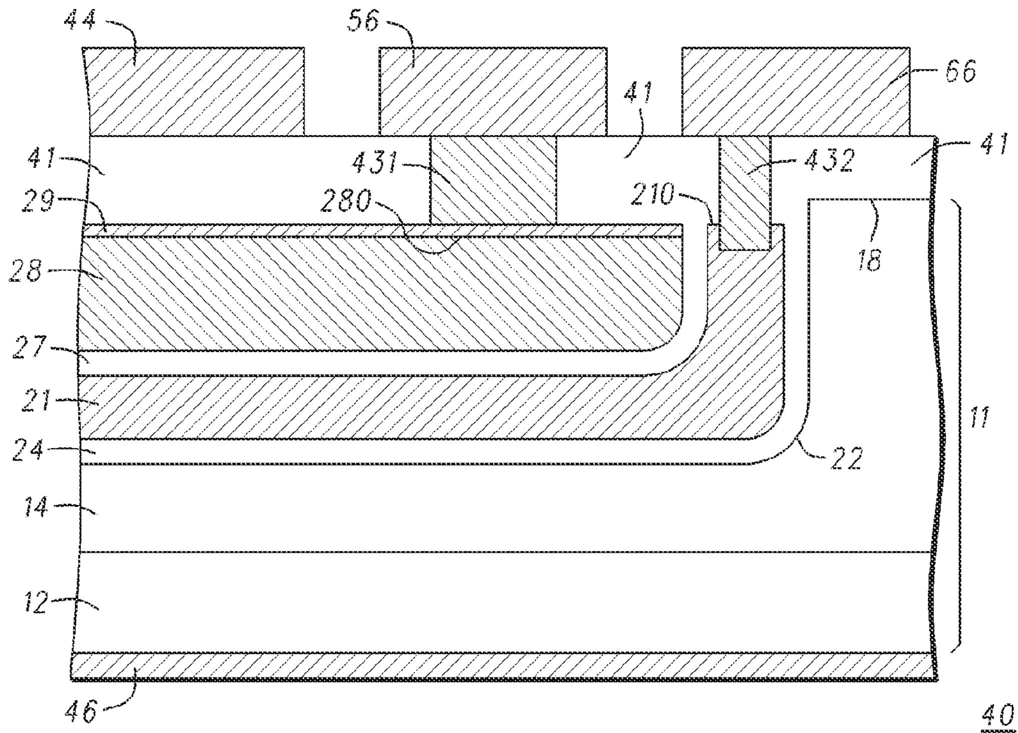


Fig. 4

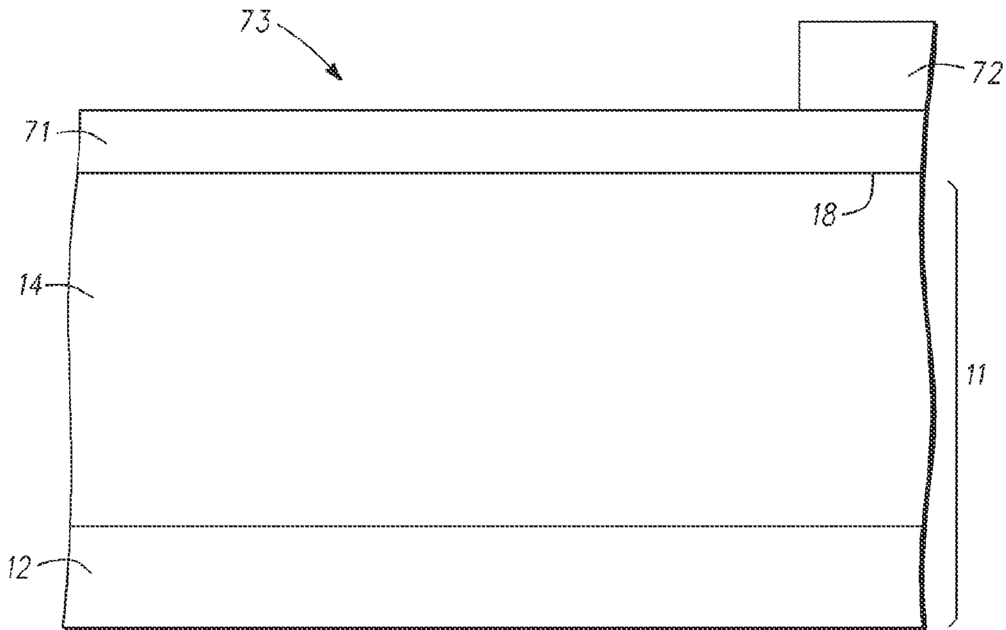


Fig. 5

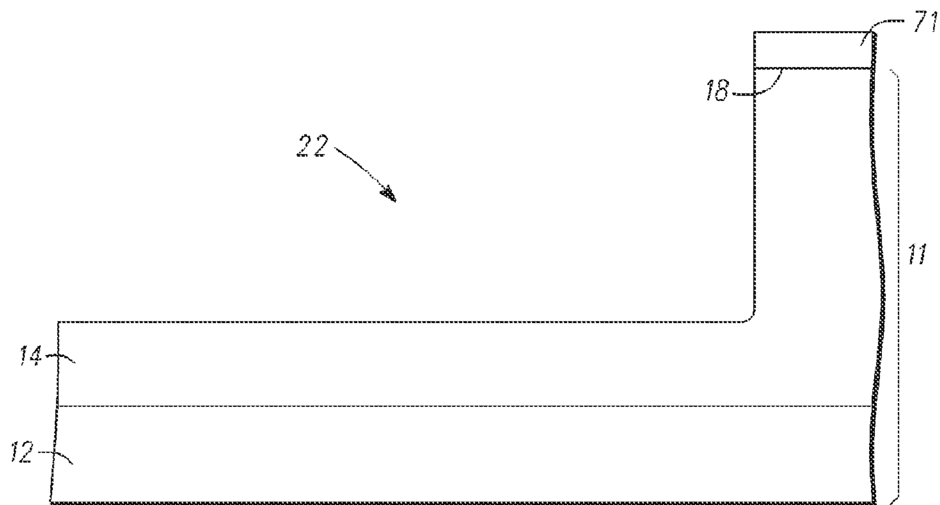


Fig. 6

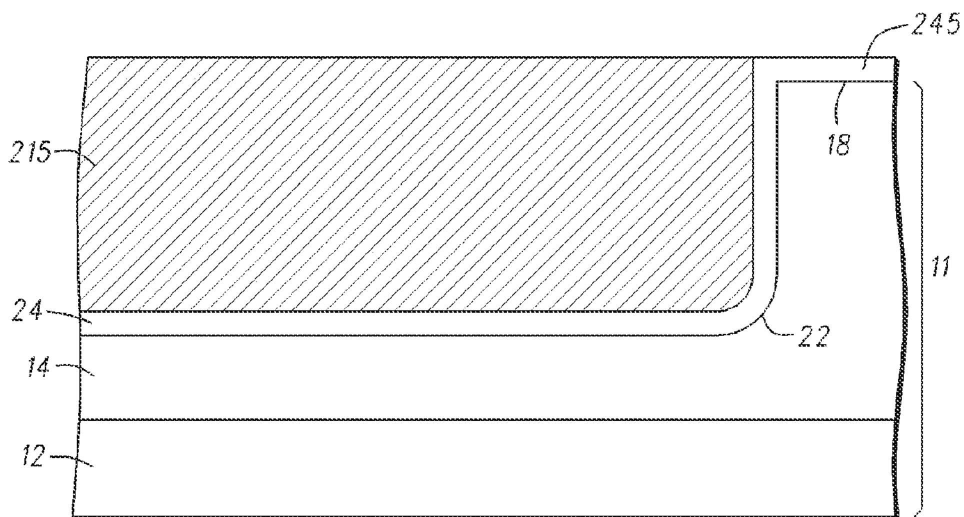


Fig. 7

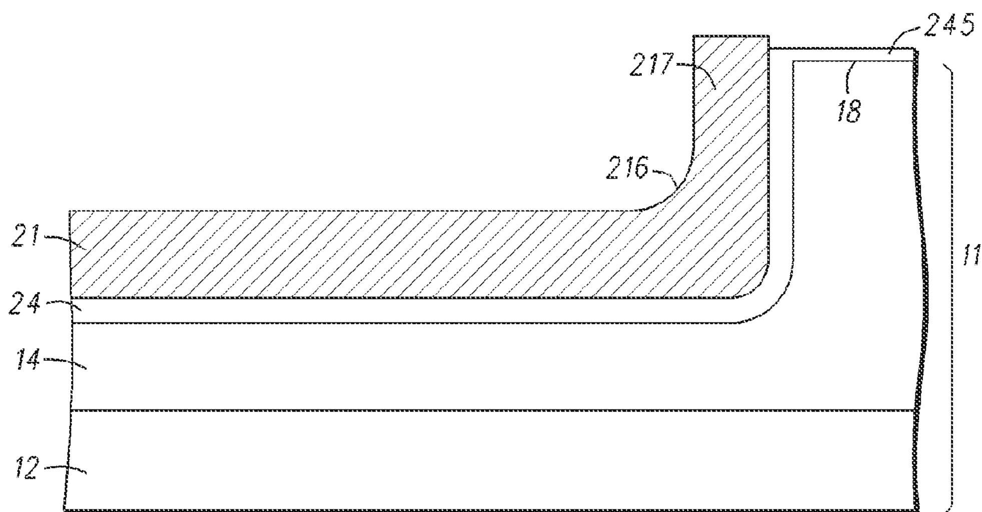


Fig. 8

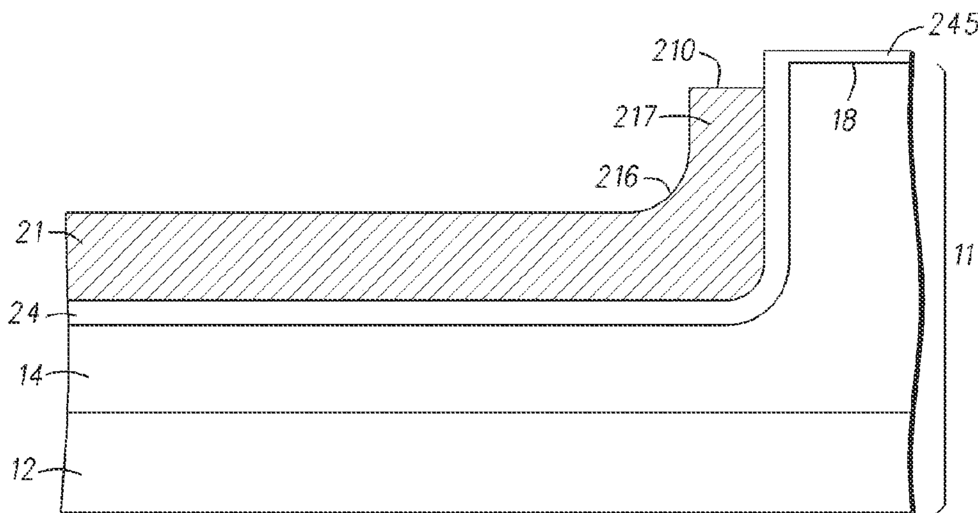


Fig. 9

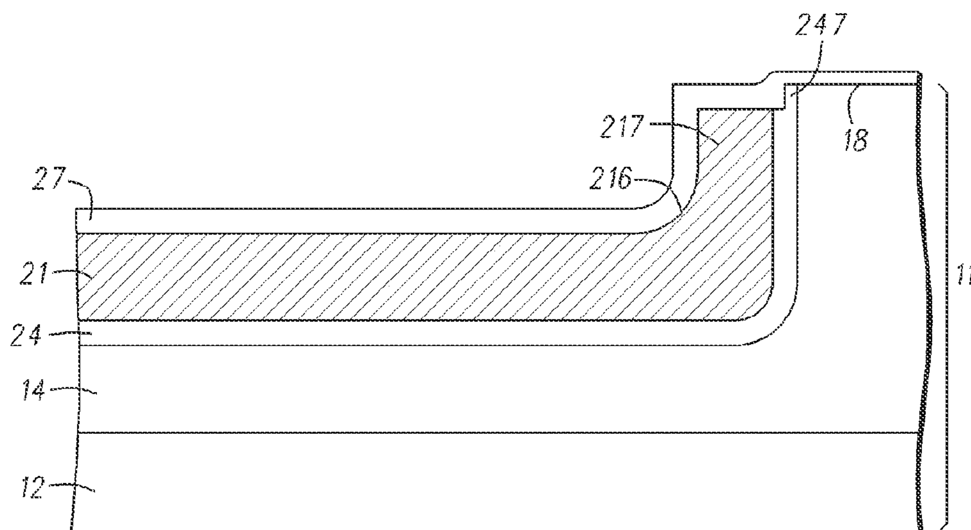


Fig. 10

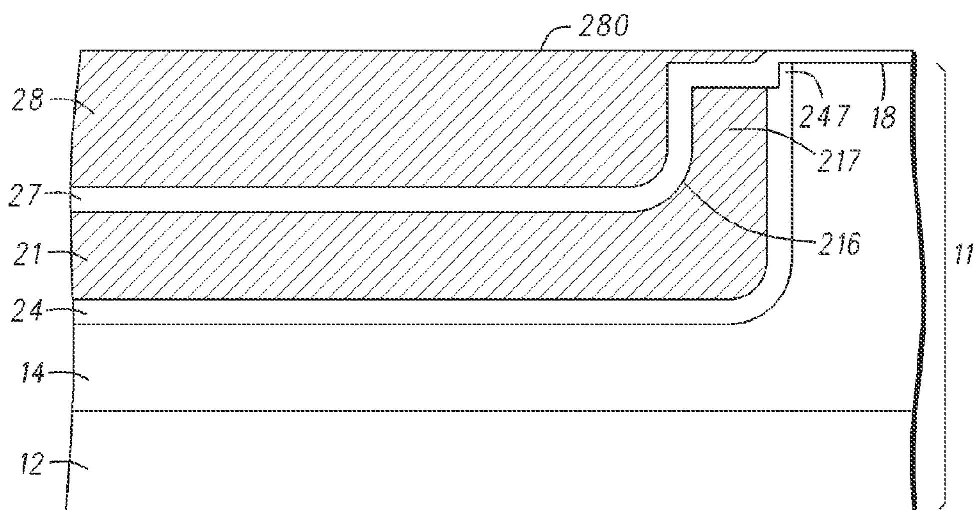


Fig. 11

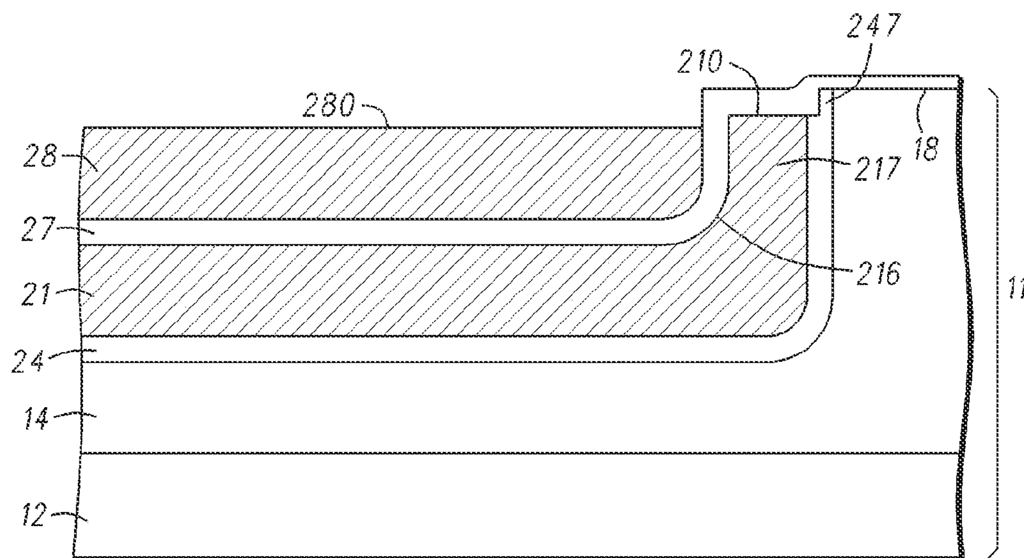


Fig. 12

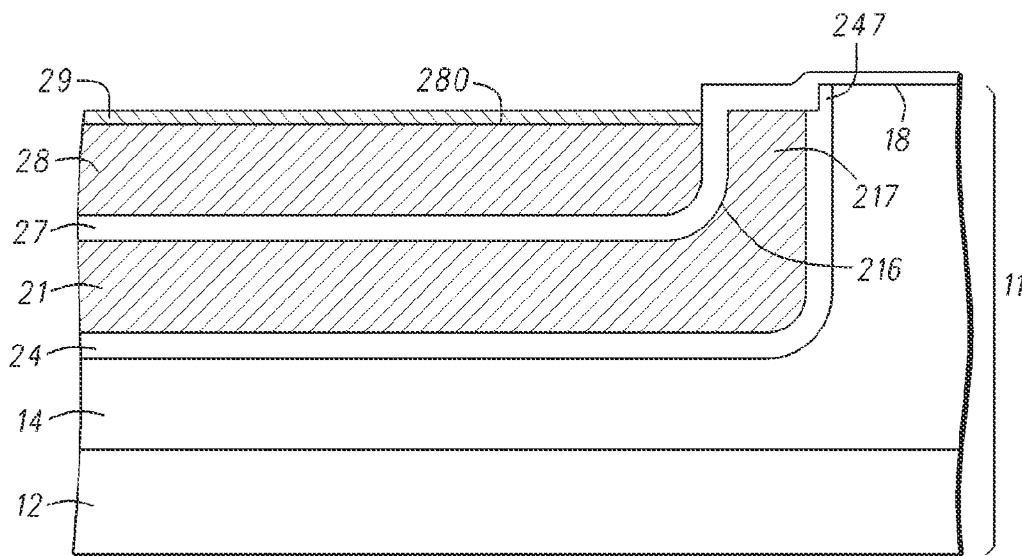


Fig. 13

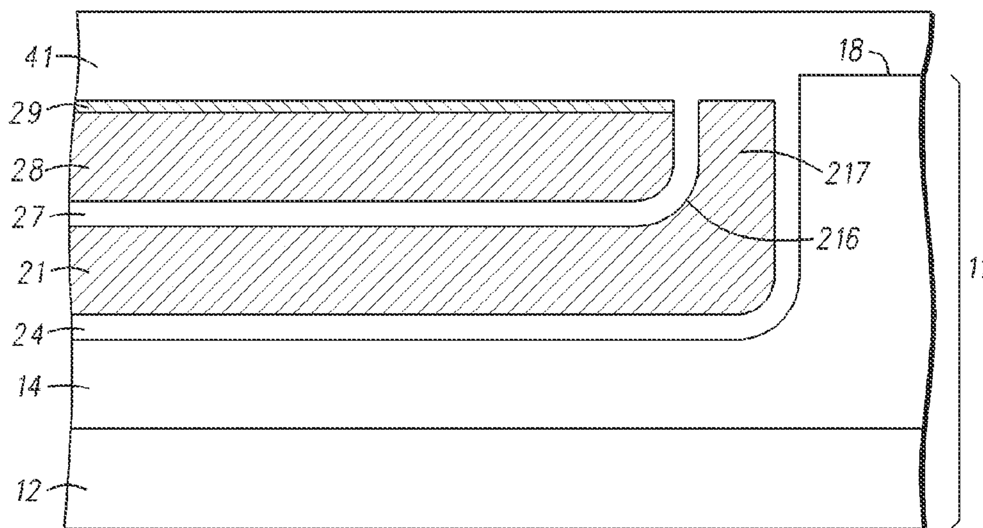


Fig. 14

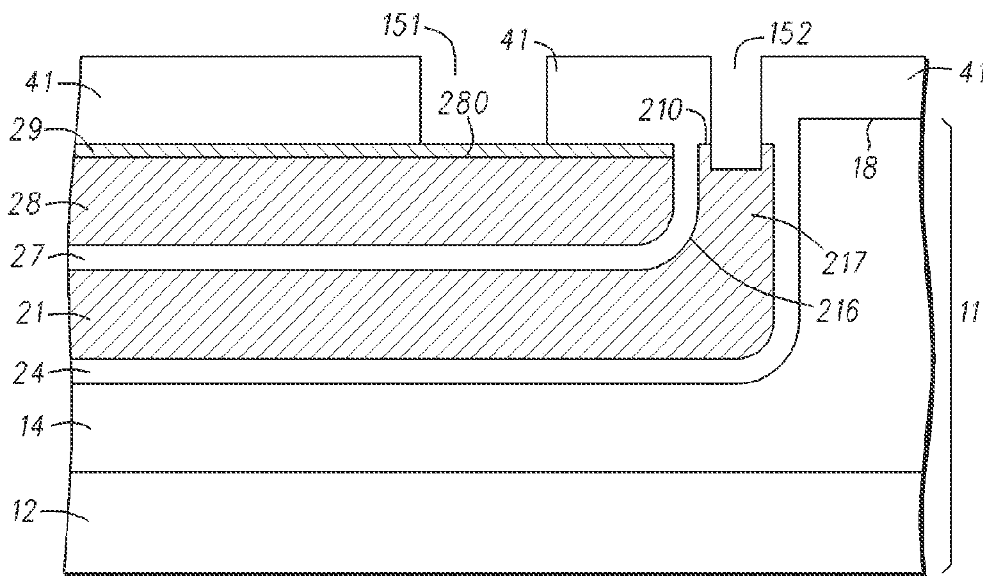


Fig. 15

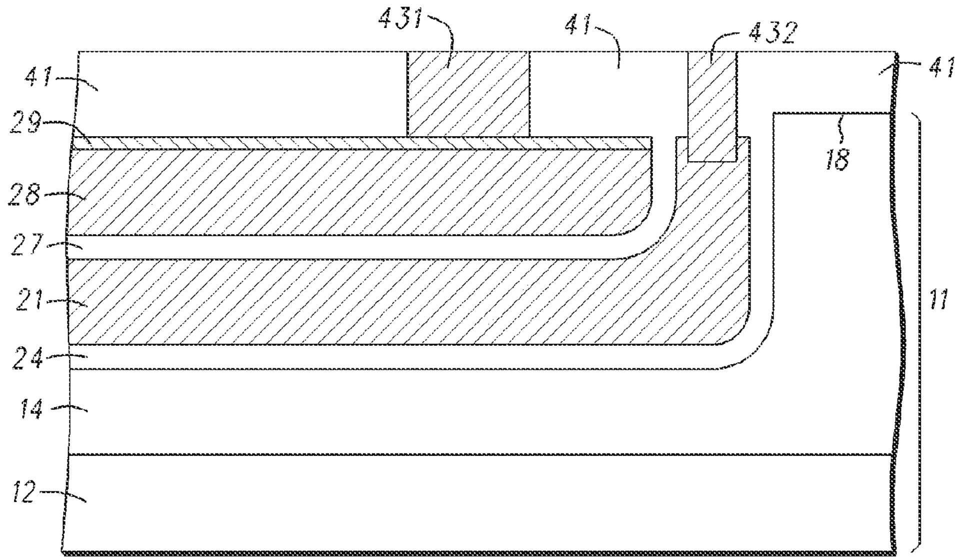


Fig. 16

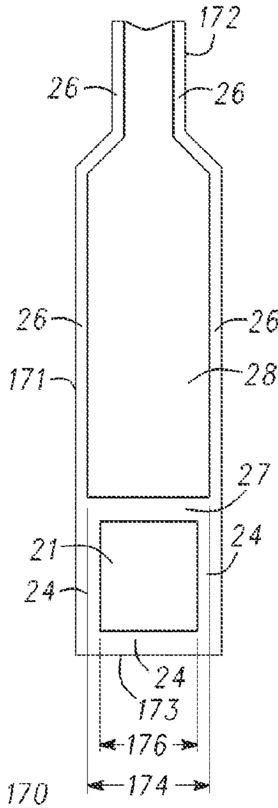


Fig. 17

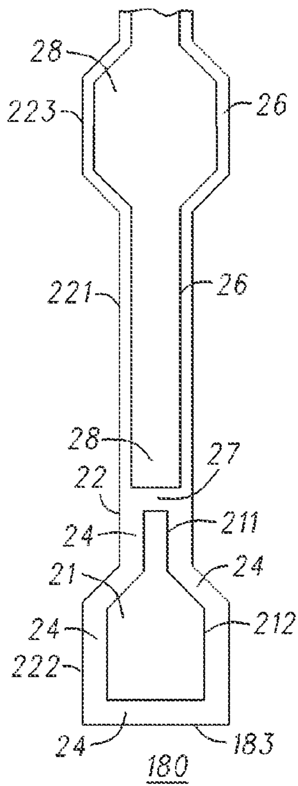


Fig. 18

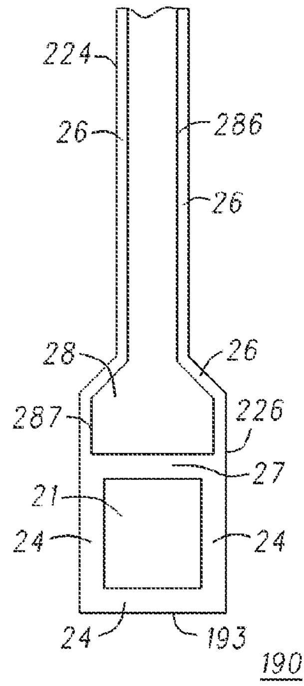


Fig. 19

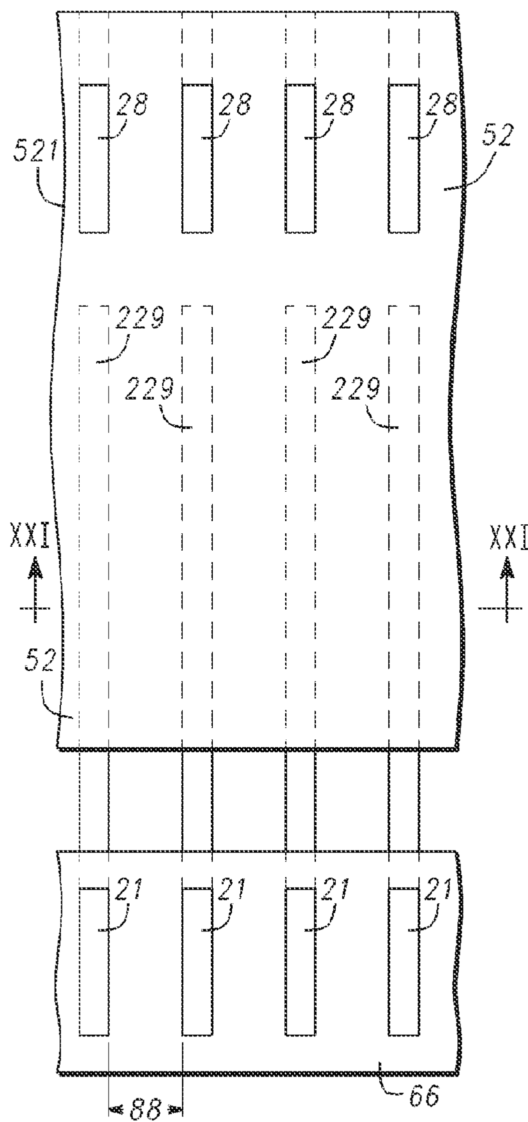


Fig. 20

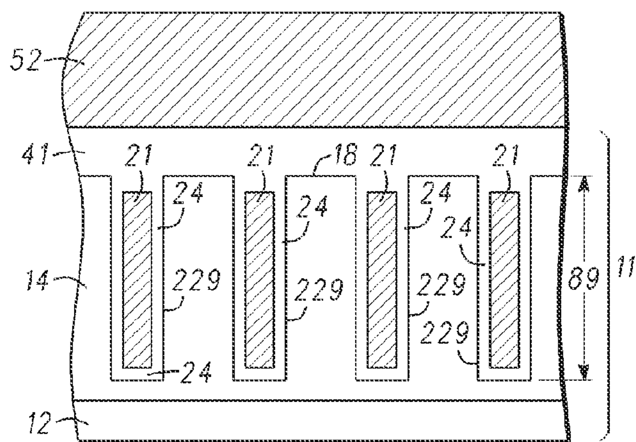


Fig. 21

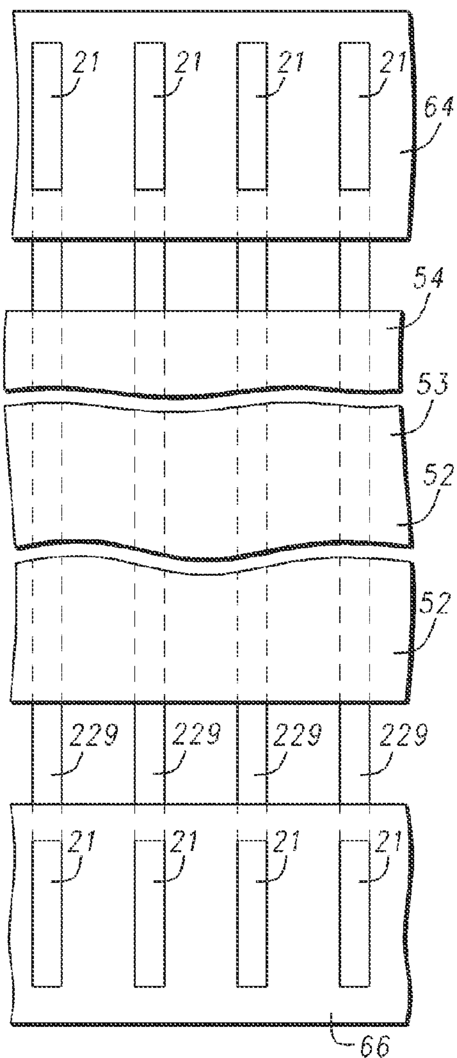


Fig. 22

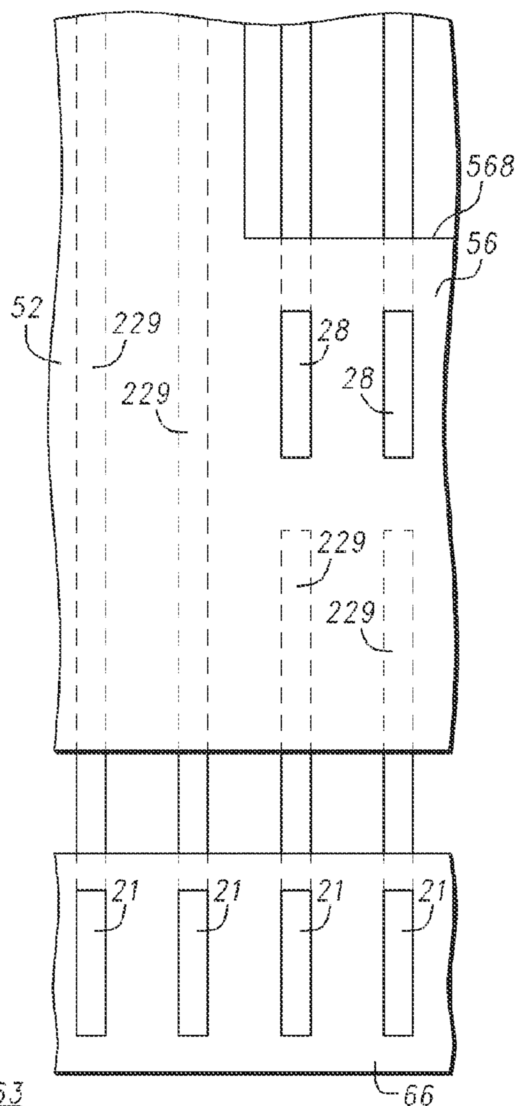


Fig. 23

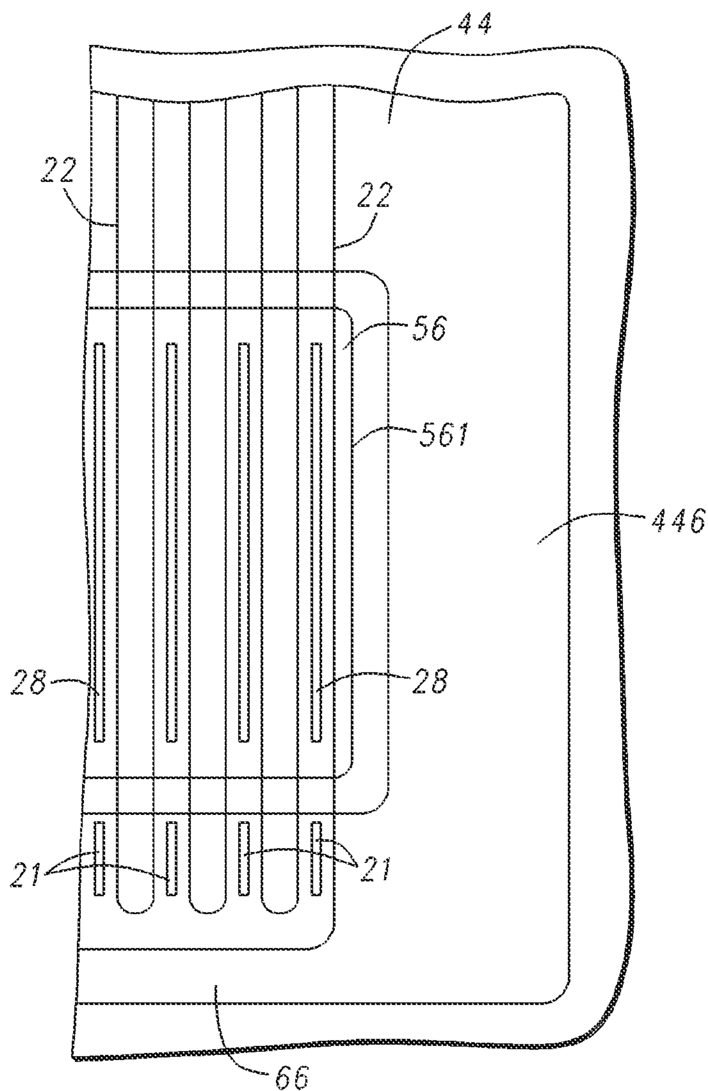


Fig. 24

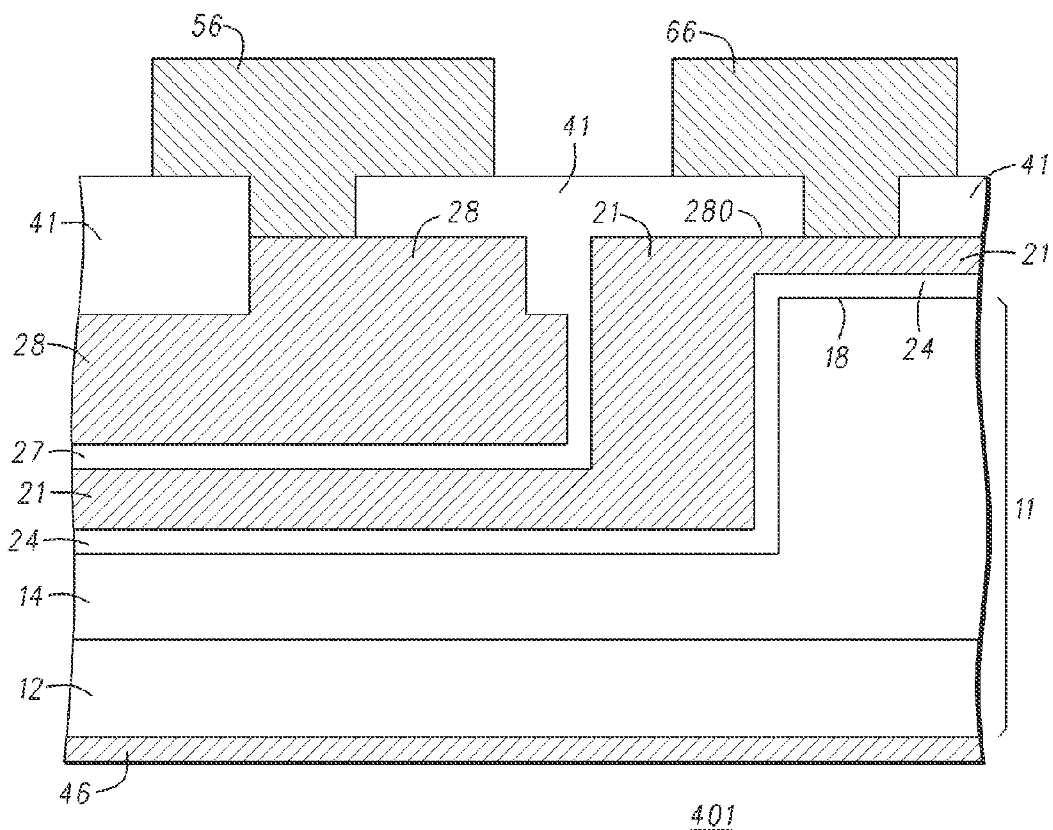


Fig. 25

TRENCH SHIELDING STRUCTURE FOR SEMICONDUCTOR DEVICE AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation of U.S. application Ser. No. 12/271,068 entitled TRENCH SHIELDING STRUCTURE FOR SEMICONDUCTOR DEVICE AND METHOD filed Nov. 14, 2008, which is incorporated herein by reference in its entirety to provide continuity of disclosure.

FIELD OF THE INVENTION

[0002] This document relates generally to semiconductor devices, and more specifically to insulated gate structures and methods of formation.

BACKGROUND OF THE INVENTION

[0003] Metal oxide field effect transistor (MOSFET) devices are used in many power switching applications such as dc-dc converters. In a typical MOSFET, a gate electrode provides turn-on and turn-off control with the application of an appropriate gate voltage. By way of example, in an n-type enhancement mode MOSFET, turn-on occurs when a conductive n-type inversion layer (i.e., channel region) is formed in a p-type body region in response to the application of a positive gate voltage, which exceeds an inherent threshold voltage. The inversion layer connects n-type source regions to n-type drain regions and allows for majority carrier conduction between these regions.

[0004] There is a class of MOSFET devices where the gate electrode is formed in a trench that extends downward from a major surface of a semiconductor material such as silicon. Current flow in this class of devices is primarily vertical and, as a result, device cells can be more densely packed. All else being equal, this increases the current carrying capability and reduces on-resistance of the device.

[0005] In certain applications, high frequency switching characteristics are important and certain design techniques have been used to reduce capacitive effects thereby improving switching performance. By way of example, it is previously known to incorporate an additional electrode below the gate electrode in trench MOSFET devices and to connect this additional electrode to the source electrode or another bias source. This additional electrode is often referred to as a "shield electrode" and functions, among other things, to reduce gate-to-drain capacitance. Shield electrodes have been previously used as well in planar MOSFET devices.

[0006] Although shield electrodes improve device performance, challenges still exist to more effectively integrate them with other device structures. These challenges include avoiding additional masking steps, addressing non-planar topographies, and avoiding excessive consumption of die area. These challenges impact, among other things, cost and manufacturability. Additionally, opportunities exist to provide devices having shield electrodes with more optimum and reliable performance.

[0007] Accordingly, structures and methods of manufacture are needed to effectively integrate shield electrode structures with other device structures and to provide more optimum and reliable performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** illustrates a partial cross-sectional view of a first embodiment of a semiconductor structure taken along reference line I-I of FIG. **2**;

[0009] FIG. **2** illustrates a top plan view of a first embodiment of a semiconductor device including the structure of FIG. **1**;

[0010] FIG. **3** illustrates a top plan view of a second embodiment of a semiconductor device;

[0011] FIG. **4** illustrates a partial cross-sectional view of a portion of the semiconductor device of FIG. **2** taken along reference line IV-IV;

[0012] FIGS. **5-16** illustrate partial cross-sectional views of the portion of FIG. **4** at various stages of fabrication;

[0013] FIG. **17** illustrates a partial top plan view of a contact structure in accordance with a first embodiment;

[0014] FIG. **18** illustrates a partial top plan view of a contact structure in accordance with a second embodiment;

[0015] FIG. **19** illustrates a partial top plan view of a contact structure in accordance with a third embodiment;

[0016] FIG. **20** illustrates a partial top plan view of the semiconductor device of FIG. **2** including a first embodiment of a shielding structure;

[0017] FIG. **21** illustrates a cross-sectional view of the shielding structure of FIG. **20** taken along reference line XXI-XXI;

[0018] FIG. **22** illustrates a partial top plan view of the semiconductor device of FIG. **2** including a second embodiment of a shielding structure;

[0019] FIG. **23** illustrates a partial top plan view of the semiconductor device of FIG. **2** including a third embodiment of a shielding structure;

[0020] FIG. **24** illustrates a partial top plan view of a portion of the semiconductor device of FIG. **2**; and

[0021] FIG. **25** illustrates a cross-sectional view of another embodiment of a semiconductor device.

[0022] For simplicity and clarity of illustration, elements in the figures are not necessarily drawn to scale, and the same reference numbers in different figures denote generally the same elements. Additionally, descriptions and details of well-known steps and elements may be omitted for simplicity of the description. As used herein current-carrying electrode means an element of a device that carries current through the device such as a source or a drain of an MOS transistor or an emitter or a collector of a bipolar transistor or a cathode or anode of a diode, and a control electrode means an element of the device that controls current through the device such as a gate of a MOS transistor or a base of a bipolar transistor. Although the devices are explained herein as certain N-channel devices, a person of ordinary skill in the art will appreciate that P-channel devices and complementary devices are also possible in accordance with the present description. For clarity of the drawings, doped regions of device structures are illustrated as having generally straight-line edges and precise angular corners. However, those skilled in the art understand that due to the diffusion and activation of dopants, the edges of doped regions are generally not straight lines and the corners are not precise angles.

[0023] In addition, structures of the present description may embody either a cellular base design (where the body regions are a plurality of distinct and separate cellular or stripe regions) or a single base design (where the body region is a single region formed in an elongated pattern, typically in a serpentine pattern or a central portion with connected

appendages). However, one embodiment of the present description will be described as a cellular base design throughout the description for ease of understanding. It should be understood that it is intended that the present disclosure encompass both a cellular base design and a single base design.

DETAILED DESCRIPTION OF THE DRAWINGS

[0024] In general, the present description pertains to a shielding structure for a semiconductor device. In one embodiment, the shielding structure is formed in a plurality of closely spaced trenches and includes an insulator layer, a shield electrode in each trench and an interlayer dielectric overlying the trenches. In one embodiment, the shield electrodes are configured to be connected to a ground potential. In one embodiment, the shielding structure is placed beneath at least a portion of a control pad structure. In another embodiment, the shielding structure is placed beneath at least a portion of a control runner configuration.

[0025] FIG. **1** shows a partial cross-sectional view of a semiconductor device or cell **10** having a shield electrode or electrodes **21**. The cross-section is taken, for example, along reference line I-I from active area **204** of device **20** shown in FIG. **2**. In this embodiment, device **10** comprises a MOSFET structure, but it is understood that this description applies as well to insulated gate bipolar transistors (IGBT), MOS-gated thyristors, and the like.

[0026] Device **10** includes a region of semiconductor material, semiconductor material, or semiconductor region **11**, which comprises for example, an n-type silicon substrate **12** having a resistivity in a range from about 0.001 ohm-cm to about 0.005 ohm-cm. Substrate **12** can be doped with phosphorous or arsenic. In the embodiment shown, substrate **12** provides a drain contact or a first current carrying contact for device **10**. A semiconductor layer, drift region, or extended drain region **14** is formed in, on, or overlying substrate **12**. In one embodiment, semiconductor layer **14** is formed using conventional epitaxial growth techniques. Alternatively, semiconductor layer **14** is formed using conventional doping and diffusion techniques. In an embodiment suitable for a 50 volt device, semiconductor layer **14** is n-type with a dopant concentration of about 1.0×10^{16} atoms/cm^3 and has a thickness from about 3 microns to about 5 microns. The thickness and dopant concentration of semiconductor layer **14** is increased or decreased depending on the desired drain-to-source breakdown voltage (BVDss) rating of device **10**. It is understood that other materials may be used for semiconductor material **11** or portions thereof including silicon-germanium, silicon-germanium-carbon, carbon-doped silicon, silicon carbide, or the like. Additionally, in an alternate embodiment, the conductivity type of substrate **12** is switched to be opposite the conductivity type of semiconductor layer **14** to form, for example, an IGBT embodiment.

[0027] Device **10** also includes a body, base, PHV, or doped region or regions **31** extending from a major surface **18** of semiconductor material **11**. Body regions **31** have a conductivity type that is opposite to the conductivity type of semiconductor layer **14**. In this example, body regions **31** are p-type conductivity. Body regions **31** have a dopant concentration suitable for forming inversion layers that operate as conduction channels or channel regions **45** of device **10**. Body regions **31** extend from major surface **18** to a depth, for example, from about 0.5 microns to about 2.0 microns. N-type source regions, current conducting regions, or current carrying regions **33** are formed within, in, or overlying body regions **31** and extend from major surface **18** to a depth, for example, from about 0.1 microns to about 0.5 microns. A p-type body contact or contact region **36** can be formed in body regions **31**, and is configured to provide a lower contact resistance to body regions **31**.

[0028] Device **10** further includes trench control, trench gate, or trench structures **19**, which extend in a substantially vertical direction from major surface **18**. Alternatively, trench control structures **19** or portions thereof have a tapered shape. Trench structures **19** include trenches **22**, which are formed in semiconductor layer **14**. For example, trenches **22** have a depth from about 1.5 microns to about 2.5 microns or deeper. In one embodiment, trenches **22** extend all the way through semiconductor layer **14** into substrate **12**. In another embodiment, trenches **22** terminate within semiconductor layer **14**.

[0029] Passivating layers, insulator layers, field insulator layers or regions **24** are formed on lower portions of trenches **22** and comprise, for example, an oxide, a nitride, combinations thereof, or the like. In one embodiment, insulator layers **24** are silicon oxide and have a thickness from about 0.1 microns to about 0.2 microns. Insulator layers **24** can be uniform in thickness or variable thickness. Additionally, the thickness of layer **24** may be varied, depending on the desired drain-to-source breakdown voltage (BVDss). Shield electrodes **21** are formed overlying insulator layers **24** in substantially centrally located lower portions of trenches **22**. In one embodiment, shield electrodes **21** comprise polycrystalline semiconductor material that can be doped. In another embodiment, shield electrodes **21** can comprise other conductive materials. In contact structure embodiments described below, portions of trenches **22** in the contact structure areas have insulator layers **24** along upper sidewall portions as well.

[0030] Passivating, dielectric, or insulator layers **26** are formed along upper sidewall portions of trenches **22** and are configured as gate dielectric regions or layers. By way of example, insulator layers **26** comprise oxide, nitride, tantalum pentoxide, titanium dioxide, barium strontium titanate, combinations thereof, or the like. In one embodiment, insulator layers **26** are silicon oxide and have a thickness from about 0.01 microns to about 0.1 microns. In one embodiment, insulator layers **24** are thicker than insulator layers **26**. Passivating, dielectric, or insulator layers **27** are formed overlying shield electrodes **21**, and in one embodiment insulator layers **27** have a thickness between the thickness of insulator layers **24** and insulator layers **26**. In one embodiment, insulator layers **27** have a thickness greater than the thickness of insulator layer **26**, which improves oxide breakdown voltage performance.

[0031] Trench structures **19** further include control electrodes or gate electrodes **28**, which are formed overlying insulator layers **26** and **27**. In one embodiment, gate electrodes **28** comprise doped polycrystalline semiconductor material such as polysilicon doped with an n-type dopant. In one embodiment, trench structures **19** further include a metal or silicide layer **29** formed adjoining gate electrode **28** or upper surfaces thereof. Layer **29** is configured to reduce gate resistance.

[0032] An interlayer dielectric (ILD), dielectric, insulator, or passivating layer **41** is formed overlying major surface **18** and above trench structures **19**. In one embodiment, dielectric layer **41** comprises a silicon oxide and has a thickness from about 0.4 microns to about 1.0 micron. In one embodiment,

dielectric layer **41** comprises a deposited silicon oxide doped with phosphorous or boron and phosphorous. In one embodiment, dielectric layer **41** is planarized to provide a more uniform surface topography, which improves manufacturability.

[0033] Conductive regions or plugs **43** are formed through openings or vias in dielectric layer **41** and portions of semiconductor layer **14** to provide for electrical contact to source regions **33** and body regions **31** through contact regions **36**. In one embodiment, conductive regions **43** are conductive plugs or plug structures. In one embodiment, conductive regions **43** comprise a conductive barrier structure or liner plus a conductive fill material. In one embodiment, the barrier structure includes a metal/metal-nitride configuration such as titanium/titanium-nitride or the like. In another embodiment, the barrier structure further includes a metal-silicide structure. In one embodiment, the conductive fill material includes tungsten. In one embodiment, conductive regions **43** are planarized to provide a more uniform surface topography.

[0034] A conductive layer **44** is formed overlying major surface **18** and a conductive layer **46** is formed overlying a surface of semiconductor material **11** opposite major surface **18**. Conductive layers **44** and **46** are configured to provide electrical connection between the individual device components of device **10** and a next level of assembly. In one embodiment, conductive layer **44** is titanium/titanium-nitride/aluminum-copper or the like and is configured as a source electrode or terminal. In one embodiment, conductive layer **46** is a solderable metal structure such as titanium-nickel-silver, chromium-nickel-gold, or the like and is configured as a drain electrode or terminal. In one embodiment, a further passivation layer (not shown) is formed overlying conductive layer **44**. In one embodiment, shield electrodes **21** are connected (in another plane) to conductive layer **44** so that shield electrodes **21** are configured to be at the same potential as source regions **33** when device **10** is in use. In another embodiment, shield electrodes **21** are configured to be independently biased.

[0035] In one embodiment, the operation of device **10** proceeds as follows. Assume that source electrode (or input terminal) **44** and shield electrodes **21** are operating at a potential V_S of zero volts, gate electrodes **28** receive a control voltage V_G of 2.5 volts, which is greater than the conduction threshold of device **10**, and drain electrode (or output terminal) **46** operates at a drain potential VD of 5.0 volts. The values of V_G and V_S cause body region **31** to invert adjacent gate electrodes **28** to form channels **45**, which electrically connect source regions **33** to semiconductor layer **14**. A device current I_{DS} flows from drain electrode **46** and is routed through source regions **33**, channels **45**, and semiconductor layer **14** to source electrode **44**. In one embodiment, I_{DS} is on the order of 1.0 amperes. To switch device **10** to the off state, a control voltage V_G of less than the conduction threshold of device **10** is applied to gate electrodes **28** (e.g., V_G<2.5 volts). This removes channels **45** and I_{DS} no longer flows through device **10**.

[0036] Shield electrodes **21** are configured to control the width of the depletion layer between body region **31** and semiconductor layer **14**, which enhances source-to-drain breakdown voltage. Also, shield electrodes **21** help reduce gate-to-drain charge of device **10**. Additionally, because there is less overlap of gate electrode **28** with semiconductor layer **14** compared to other structures, the gate-to-drain capacitance of device **10** is reduced. These features enhance the switching characteristics of device **10**.

[0037] FIG. **2** shows a top plan view of a semiconductor device, die or chip **20** that includes device **10** of FIG. **1**. For perspective, FIG. **2** is generally looking down at major surface **18** of semiconductor material **11** shown in FIG. **1**. In this embodiment, device **20** is bounded by a die edge **51**, which can be the center of a scribe line used to separate chip **20** from other devices when in wafer form. Device **20** includes a control pad, gate metal pad or gate pad **52**, which is configured to electrically contact gate electrodes **28** (shown in FIG. **1**) through gate metal runners or gate runners or feeds **53**, **54**, and **56**. In this embodiment, gate metal pad **52** is placed in a corner portion **238** of device **20**. In one embodiment, gate runner **54** is adjacent to an edge **202** of device **20**, and gate runner **56** is adjacent another edge **201** of device **20**, which is opposite to edge **202**. In one embodiment, trenches **22** extend in a direction from edge **201** to edge **202**. In one embodiment, central portion **203** of device **20** is absent any gate runner(s). That is, in one embodiment the gate runners are placed in only peripheral or edge portions of device **20**.

[0038] Conductive layer **44**, which is configured in this embodiment as a source metal layer, is formed over active portions **204** and **206** of device **20**. In one embodiment, portion **444** of conductive layer **44** wraps around end portion **541** of gate runner **54**. A portion **446** of conductive layer **44** wraps around end portion **561** of gate runner **56** and is designated as structure **239**. Structure **239** is further shown in more detail in FIG. **24**. Conductive layer **44** is further configured to form shield electrode contacts, runners, or feeds **64** and **66**, which in this embodiment provide contact to shield electrodes **21**. In this configuration, conductive layer **44** is connected to shield electrodes **21**. In the wrap around configuration described above, conductive layer **44**, portions **444** and **446**, shield electrode runners **64** and **66** and gate runners **54** and **56** are in the same plane and do not overlap each other. This configuration provides for the use of a single metal layer, which simplifies manufacturing.

[0039] In one embodiment, shield electrode runner **66** is placed between edge **201** of device **20** and gate runner **56**, and shield electrode runner **64** is placed between edge **202** of device **20** and gate runner **54**. In one embodiment, additional contact is made to shield electrodes **21** in shield contact region, contact region or stripe **67**, which separates the active area of device **20** into portions **204** and **206**. Contact region **67** is another location on device **20** where contact between conductive layer **44** and shield electrodes **21** are made. Contact region **67** is configured to divide gate electrodes **28** into two portions within device **20**. The two portions include one portion that feeds from gate runner **54** and another portion that feeds from gate runner **56**. In this configuration, gate electrode material **28** is absent from contact region **67**. That is, gate electrodes **28** do not pass through contact region **67**.

[0040] In embodiments that place gate pads **52** in a corner (e.g., corner **23**) of device **20**, the effects of gate resistance can be more optimally distributed through a selected or predetermined placement of contact region **67** within device **20**. This predetermined placement provides more uniform switching characteristics. In one embodiment, contact region **67** is offset from center **203** so that contact region **67** is closer to edge **202** than edge **201** with gate pad **52** in corner portion **238** adjacent to edge **201**. That is, contact region **67** is placed closer to the edge opposite to the corner and edge where gate pad **52** is placed. This configuration decreases the length of

gate electrodes **28** in active area **206** and increases the length of gate electrodes **28** in active area **204**, which provides for a more efficient distribution of the gate resistance load.

[0041] In one embodiment, contact region **67** is placed in an offset location on device **20** to reduce gate resistance in active area **206** by about one half the resistance of gate runner **53**, and to increase gate resistance in active area **204** by about one half the resistance of gate runner **53**. In this embodiment, the gate resistance of active area **206** is given by:

$$2Rg_{FET206}+R_{53}-(R_{53}/2)$$

where Rg_{FET206} is the resistance of gate electrodes **28** in active area **206** when contact region **67** is placed in the center of device **20**, and R_{53} is the resistance of metal runner **53**. The gate resistance of active area **204** is given by:

$$2Rg_{FET204}+R_{53}/2$$

where Rg_{FET204} is the resistance of gate electrodes **28** in active area **204** when contact region **67** is placed in the center of device **20**. This is an example of a predetermined placement of contact region **67** that optimizes the distribution of gate resistance.

[0042] In another embodiment, shield contact region **67** is the only shield contact used to make contact to shield electrodes **21** and is placed in an interior portion of device **20**. That is, in this embodiment shield electrode runners **64** and **66** are not used. This embodiment is appropriate, for example, when switching speeds are not as critical, but where the resurf effect of the shield electrode is desired. In one embodiment, shield contact region **67** is placed in the center of device **20**. In another embodiment, shield contact region **67** is placed offset from center of device **20**. In these embodiments, shield contact region **67** provides contact to shield electrodes **21** within or inside of trenches **22** while control electrode runners **54** and **56** make contact to control electrodes **28** within or inside trenches **22** near edges **201** and **202**. This embodiment further saves on space within device **20**. In another embodiment, control electrodes **28** extend and overlap onto major surface **18** and control electrode runners **54** and **56** make contact to control electrodes outside of trenches **22**.

[0043] FIG. **3** is a top view of another embodiment of a semiconductor device, die or chip **30**. In this embodiment, gate pad **52** is placed in corner portion **238** of device **30** similar to device **20**. Device **30** is similar to device **20** except that gate runners **54** and **56** are configured to decrease the left-to-right non-uniformity of gate resistance. In one embodiment, gate runner **56** feeds, connects, or links into an additional gate runner **560** at a substantially central location **562**. Gate runner **560** then connects to gate electrodes **28** (shown in FIG. **1**) in active area **204**. In another embodiment, gate runner **54** feeds, connects, or links into gate runner **540** at a substantially central location **542**. Gate runner **540** then connects to gate electrodes **28** (shown in FIG. **1**) in active area **206**. It is understood that one or both of gate runners **54** and **56** can be configured this way. Also, if used shield contact region **67** can be offset in device **30** as shown in FIG. **2**. In one embodiment, shield electrode runner **66** is placed between gate runners **56** and **560** and edge **201**, and shield electrode runner **64** is placed between gate runners **54** and **540** and edge **202**. The gate runner configuration of FIG. **3** can be used as well in devices that do not include shield electrodes to reduce left-to-right non-uniformity of gate resistance.

[0044] FIG. **4** shows an enlarged cross-sectional view of a gate/shield electrode contact structure, connective structure, or contact structure or region **40**, which is taken along reference line IV-IV in FIG. **2**. In general, structure **40** is a contact area where contact is made between gate electrodes **28** and gate runners **54** and **56**, and where contact is made between shield electrodes **21** and shield electrode runners **64** and **66**. In previously known gate/shield electrode contact structures, a double stack of polysilicon or other conductive material is placed on top of the major surface of a substrate in peripheral or field regions of the device to enable contact to be made. Such double stacks of material can add in excess of 1.2 microns to surface topography. The double stacks of material on the major surface create several problems that include a surface topography that is non-planar, which affects subsequent photolithography steps and manufacturability. These previously known structures also increase die size.

[0045] Structure **40** is configured to address, among other things, the double polysilicon stack problem with previously known devices. Specifically, upper surface **210** of shield electrode **21** and upper surface **280** of gate electrode **28** are both recessed below major surface **18** of semiconductor material **11** so that contact is made to shield electrodes **21** and gate electrodes **28** within or directly inside of trenches **22**. That is, in one embodiment gate electrodes **28** and shield electrodes **21** do not overlap or extend on to major surface **18**. A conductive structure **431** connects gate runner **56** to gate electrode **28**, and a conductive structure **432** connects shield electrode runner **66** to shield electrode **21**. Conductive structures **431** and **432** are similar to conductive structures **43** as described in conjunction with FIG. **1**. Structure **40** uses planarized dielectric layer **41** and planarized conductive structures **431** and **432** to provide a more planar topography. This structure enables deep submicron lithography and global planarization in power device technology. In addition, this configuration enables portion **444** of conductive layer **44** to wrap around end portion **541** of gate runner **54** (as shown in FIG. **2**), and portion **446** to wrap around end portion **561** of gate runner **56** (as shown in FIG. **2**) and to do so without consuming too much die area.

[0046] In another embodiment, shield electrode **21** overlaps onto major surface **18** and contact to shield electrode **21** is made there while gate electrode **28** remains within trenches **22** without overlapping upper surface **210** of shield layer **21** or major surface **18** and contact to gate electrode **28** is made within or above trenches **22**. This embodiment is shown in FIG. **25**, which is cross-sectional view of a structure **401**, which is similar to structure **40** except shield electrode **21** overlaps major surface **18** as described above. In this embodiment, shield electrodes **21** and conductive layer **44** wrap-around end portions **541** and **561** (shown in FIG. **2**) and source metal **44** makes contact to shield electrodes **21** through openings in dielectric layer **41**.

[0047] Another feature of structure **40** is that insulator layers **24** and **27**, which are thicker than insulator layer **26** (shown in FIG. **1**), surround and overly shield electrode **21** even where shield electrode **21** approaches major surface **18**. In previously known structures, a thinner gate oxide separates the gate electrode from the shield electrode in the field or peripheral regions. In previously known structures oxide is also thinner at the top surface-to-trench interface where both gate shield routing is made. However, such structures, where gate or shield oxides are thinned, are susceptible to oxide breakdown and device failure. Structure **40** reduces this susceptibility by using thicker insulator layers **24** and **27**. This feature is further shown in FIGS. **17-18**.

[0048] Turning now to FIGS. **5-16**, which are partial cross-sectional views, a method of manufacturing structure **40** of FIG. **4** is described. It is understood that the process steps used to form structure **40** can be the same steps used to form device **10** of FIG. **1** as well as the shielding structures described in FIGS. **20-23**. FIG. **5** shows structure **40** at an early step of fabrication. A dielectric layer **71** is formed over major surface **18** of semiconductor material **11**. In one embodiment, dielectric layer **71** is an oxide layer such as a low temperature deposited silicon oxide, and has a thickness from about 0.25 microns to about 0.4 microns. Next, a masking layer such as a patterned photoresist layer **72** is formed over dielectric layer **71** and then dielectric layer **71** is patterned to provide an opening **73**. In this embodiment, opening **73** corresponds to one of many trench openings for forming trenches **22**. The unmasked portion of dielectric layer **71** is then removed using conventional techniques and layer **72** is then removed.

[0049] FIG. **6** shows structure **40** after one of trenches **22** has been etched into semiconductor layer **14**. For perspective, this view is parallel to the direction that trenches **22** run on devices **20** and **30**. That is, in FIG. **6** trench **22** runs left to right. By way of example, trenches **22** are etched using plasma etching techniques with a fluorocarbon chemistry. In one embodiment, trenches **22** have a depth of about 2.5 microns, and a portion of dielectric layer **71** is removed during the process used to form trenches **22**. In one embodiment, trenches **22** have a width of about 0.4 microns and can taper or flare out to 0.6 microns where, for example, conductive structures **431** and **432** are formed to electrically connect gate electrodes **28** and shield electrodes **21** to gate runners **54** or **56** and shield electrode runners **56** or **66** respectively. Surfaces of trenches **22** can be cleaned using conventional techniques after they are formed.

[0050] FIG. **7** shows structure **40** after additional processing. A sacrificial oxide layer having a thickness of about 0.1 microns is formed overlying surfaces of trenches **22**. This process is configured to provide a thicker oxide towards the top of trenches **22** compared to lower portions of trenches **22**, which places a slope in the trench. This process also removes damage and forms curves along lower surfaces of trenches **22**. Next, the sacrificial oxide layer and dielectric layer **71** are removed. Insulator layer **24** is then formed over surfaces of trenches **22**. By way of example, insulator layer **24** is a silicon oxide and has a thickness from about 0.1 microns to about 0.2 microns. A layer of polycrystalline semiconductor material is then deposited overlying major surface **18** and within trenches **22**. In one embodiment, the polycrystalline semiconductor material comprises polysilicon and is doped with phosphorous. In one embodiment, the polysilicon has a thickness from about 0.45 microns to about 0.5 microns. In one embodiment, the polysilicon is annealed at an elevated temperature to reduce or eliminate any voids. The polysilicon is then planarized to form region **215**. In one embodiment, the polysilicon is planarized using a chemical mechanical planarization process that is preferentially selective to polysilicon. Region **215** is planarized to portion **245** of insulator layer **24**, which is configured as a stop layer.

[0051] FIG. **8** shows structure **40** after subsequent processing. A masking layer (not shown) is formed overlying structure **40** and patterned to protect those portions of region **215** that will not be etched such as portion **217**. Exposed portions of region **215** are then etched so that the etched portions are recessed below major surface **18** to form shield electrodes **21**. In one embodiment, region **215** is etched to about 0.8 microns below major surface **18**. In one embodiment, a selective isotropic etch is used for this step. The isotropic etch further provides a rounded portion **216** where shield electrode **21** transitions into portion **217**, which extends upward towards major surface **18**. This step further clears polycrystalline semiconductor material from exposed portions of the upper surfaces of trenches **22**. Any remaining masking materials can then be removed. In one embodiment, portion **245** of insulator layer **24** is exposed to an etchant to reduce its thickness. In one embodiment, about 0.05 microns are removed. Next, additional polycrystalline material is removed from shield electrode **21** so that upper surface **210** of shield electrode **21** including portion **217** is recessed below major surface **18** as shown in FIG. **9**. In one embodiment, about 0.15 microns of material is removed.

[0052] FIG. **10** shows structure **40** after still further processing. A portion of insulator layer **24** is removed where portion **217** of shield electrode **21** has been recessed. This forms an oxide stub structure **247**, which is configured to reduce stress effects during subsequent processing steps. After oxide stub structure **247** is formed, an oxide layer (not shown) is formed overlying shield electrode **21** and upper surfaces of trenches **22**. In one embodiment, a thermal silicon oxide growth process is used, which grows a thicker oxide overlying shield electrode **21** because shield electrode **21** is a polycrystalline material and a thinner oxide along exposed sidewalls of trenches **22** because these sidewalls are substantially monocrystalline semiconductor material. In one embodiment silicon oxide is grown and has a thickness of about 0.05 microns on sidewalls of trenches **22**. This oxide helps to smooth the upper surfaces of shield electrodes **21**. This oxide is then removed from the sidewalls of trenches **22** while leaving a portion of the oxide overlying shield electrode **21**. Next, insulator layer **26** is formed overlying the upper sidewalls of trenches **22**, which also increases the thickness of the dielectric material already overlying or formed on shield electrode **21** to form insulator layer **27** thereon. In one embodiment, a silicon oxide is grown to form insulator layers **26** and **27**. In one embodiment, insulator layer **26** has a thickness of about 0.05 microns, and insulator layer **27** has a thickness greater than about 0.1 microns.

[0053] FIG. **11** shows structure **40** after polycrystalline semiconductor material has been formed overlying major surface **18**. In one embodiment, doped polysilicon is used with phosphorous being a suitable dopant. In one embodiment about 0.5 microns of polysilicon is deposited overlying major surface **18**. In one embodiment, the polysilicon is then annealed at an elevated temperature to remove any voids. Any surface oxide is then removed using conventional techniques, and the polysilicon is then planarized to form gate electrodes **28**. In one embodiment, chemical mechanical planarization is used with the oxide overlying major surface **18** providing a stop layer.

[0054] Next, gate electrodes **28** are subjected to an etch process to recess upper surface **280** below major surface **18** as shown in FIG. **12**. In one embodiment, dry etching is used to recess upper surface **280** with a chemistry that is selective with respect to polysilicon and silicon oxide. In one embodiment, a chlorine chemistry, a bromine chemistry, or a mixture of the two chemistries is used for this step. It is convenient to use this etch step to remove polycrystalline semiconductor from the oxide layer above surface **210** of portion **217** so that when a silicide layer is used with gate electrode **28**, it does not

form above surface **210**, which would complicate the contacting of shield electrode **21** in subsequent process steps.

[0055] FIG. **13** shows structure **40** after silicide layer **29** has been formed overlying surface **280**. In one embodiment, silicide layer **29** is titanium. In another embodiment, silicide layer **29** is cobalt. In a further embodiment, a self-aligned silicide (salicide) process is used to form layer **29**. For example, in a first step, any residual oxide is removed from major surface **280**. Then, titanium or cobalt is deposited overlying structure **40**. Next, a lower temperature rapid thermal step (about 650 degrees Celsius) is used to react the metal and exposed polycrystalline semiconductor material. Structure **40** is then etched in a selective etchant to remove only unreacted titanium or cobalt. A second rapid thermal step at a higher temperature (greater than about 750 degrees Celsius) is then used to stabilize the film and lower its resistivity to form layer **29**.

[0056] In a next sequence of steps, ILD **41** is formed overlying structure **40** as shown in FIG. **14**. In one embodiment, about 0.5 microns of phosphorous doped silicon oxide is deposited using atmospheric pressure chemical vapor deposition. Next, about 0.5 microns of silane based plasma-enhanced chemical vapor deposited oxide is formed on or over the phosphorous doped oxide. The oxide layers are then planarized back to a final thickness of about 0.7 microns using, for example, chemical mechanical planarization to form ILD **41**. In FIG. **14**, insulator layer **27** and stub **247** are no longer shown within ILD **41** because they all comprise oxide in this embodiment, but it is understood that they can be present in the final structure.

[0057] FIG. **15** shows structure **40** after trench openings **151** and **152** have been formed in ILD **41** to expose a portion of silicide layer **29** and shield electrode **21**. Conventional photolithography and etch steps are used to form openings **151** and **152**. Next, exposed portions of shield electrode **21** are further etched to recess part of portion **217** below surface **210**.

[0058] Next, conductive structures or plugs **431** and **432** are formed within openings **151** and **152** respectively as shown in FIG. **16**. In one embodiment, conductive structures **431** and **432** are titanium/titanium-nitride/tungsten plug structures, and are formed using conventional techniques. In one embodiment, conductive structures **431** and **432** are planarized using, for example, chemical mechanical planarization so the upper surfaces of ILD **41** and conductive structures **431** and **432** are more uniform. Thereafter, a conductive layer is formed overlying structure **40** and patterned to form conductive gate runner **56**, shield electrode runner **66** and source metal layer **44** as shown in FIG. **4**. In one embodiment, conductive layer **44** is titanium/titanium-nitride/aluminum-copper or the like. A feature of this embodiment is that the same conductive layer is used to form source electrode **44**, gate runners **54** and **56**, and shield electrodes **56** and **66** as shown in FIG. **2**. Additionally, conductive layer **46** is formed adjacent substrate **12** as shown in FIG. **4**. In one embodiment, conductive layer **46** is a solderable metal structure such as titanium-nickel-silver, chromium-nickel-gold, or the like.

[0059] FIG. **17** is a partial top plan view of a contact or connective structure **170** according to a first embodiment that is configured to provide a contact structure for making contact to gate electrodes **28** and shield electrodes **21** within or inside of trenches **22**. That is, structure **170** is configured so that conductive contact to gate electrode **28** and shield electrode **21** can be made inside of or within trenches **22**. For perspective, connective structure **170** is one embodiment of a top view of structure **40** without conductive gate runner **56**, shield electrode runner **66**, conductive structures **431** and **432**, and ILD **41**. This view also shows insulator layer **26** adjacent gate electrode **28** as shown in FIG. **1**. Additionally, this view shows one advantage of this embodiment. In particular, shield electrode **21** in connective structure **170** is surrounded by insulator layers **24** and **27**, which are thicker than insulator layers **26**. This feature reduces the oxide breakdown problem with previously known structures, which provides a more reliable device. In this embodiment, structure **170** is striped shape and contact to both gate electrodes **28** and shield electrodes **21** is made within a wider or flared portion **171**. Structure **170** then tapers down to a narrower portion **172** as it approaches, for example, the active area of the device. As shown in FIG. **17**, gate electrode **28** has a width **174** within flared portion **171** that is wider than width **176** of shield electrode **21** within flared portion **171**. In this embodiment, end portion **173** of trench **22** terminates with a shield electrode **21**, which is surrounded by insulator layers **24** and **27**, which are thicker than insulator layer or gate dielectric layer **26**. In one embodiment, end portion **173** is adjacent to or in proximity to edge **201** or edge **202** of device **20** or device **30** shown in FIGS. **2** and **3**.

[0060] FIG. **18** is a partial top plan view of a contact connective structure **180** according to a second embodiment that is configured to provide a contact structure for making contact to gate electrodes **28** and shield electrodes **21** formed within or inside of trenches **22**. That is, structure **180** is configured so that conductive contact to gate electrode **28** and shield electrode **21** can be made inside of or within trenches **22**. In this embodiment, structure **180** includes a thin stripe portion **221** and a flared portion **222** that is wider than stripe portion **221**. In this embodiment, flared portion **222** provides a wider contact portion for making contact to shield electrode **21**. Structure **180** further includes another separate flared portion **223** that is wider than stripe portion **221** for making contact to gate electrode **28**. Like structure **170**, shield electrode **21** is surrounded by insulator layers **24** and **27**, which are thicker than insulator layers **26**. In one embodiment, shield electrode **21** includes a narrow portion **211** within stripe portion **221** and a wider portion **212** within flared portion **222**. In this embodiment, insulator layer **24** is within flared portion **222** and further extends into thin stripe portion **221**. In this embodiment insulator layer **26** is only within thin stripe portion **221** and flared portion **223**. In this embodiment, end portion **183** of trench **22** terminates with a shield electrode **21**, which is surrounded by thicker insulator layers **24** and **27**. In one embodiment, end portion **183** is adjacent to or in proximity to edge **201** or edge **202** of device **20** or device **30** shown in FIGS. **2** and **3**.

[0061] FIG. **19** is a partial top plan view of a contact or connective structure **190** according to a third embodiment that is configured to provide a contact structure for making contact to gate electrode **28** and shield electrode **21** within or inside of trench **22**. That is, structure **90** is configured so that conductive contact to gate electrode **28** and shield electrode **21** is made inside of or within trenches **22**. In this embodiment, trench **22** includes a thin stripe portion **224** and a flared portion **226** that is wider than stripe portion **224**. In this embodiment, flared portion **226** provides a wider contact portion for making contact to both gate electrode **28** and shield electrode **21**. Shield electrode **21** is surrounded by thicker insulator layers **24** and **27**, which is thicker than insu-

lator layers **26**. In one embodiment, gate electrode **28** includes a narrow portion **286** within thin stripe portion **224** and a wider portion **287** within flared portion **226**. In this embodiment, insulator layer **26** is within thin stripe portion **224** and further extends into flared portion **226**. In this embodiment, thicker insulator layers **24** and **27** are only within flared portion **224**. In one embodiment, shield electrode **21** is within flared portion **226** only. It is understood that combinations of structures **170**, **180** and **190** or individual structures **170**, **180**, and **190** can be used in structure **40** with devices **20** and **30**. In this embodiment, end portion **193** of trench **22** terminates with a shield electrode **21**, which is surrounded by with thicker insulator layers **24** and **27**. In one embodiment, end portion **193** is adjacent to or in proximity to edge **201** or edge **202** of device **20** or device **30** shown in FIGS. **2** and **3**.

[0062] Turning now to FIGS. **20-23**, various shielding structure embodiments are described. FIG. **20** shows a partial top plan view of a trench shielding structure **261** according to a first embodiment. Shielding structure **261** is suitable for use with, for example, devices **20** and **30**, and is conveniently formed using the processing steps used to form device or cell **10** and structure **40** described previously. Shielding structure **261** is an embodiment of a shielding structure that runs at least partially below or underneath gate pad **52** to better isolate or insulate gate pad **52** from semiconductor layer **14**. Structure **261** includes a plurality of trenches **229**, which are formed at least in part underneath gate pad **52**. Trenches **229** are conveniently formed at the same time as trenches **22**. Portions of trenches **229** are shown in phantom to illustrate that they are underneath gate pad **52** and shield electrode runner **66**.

[0063] As further shown in FIG. **21**, which is a partial cross-sectional view of structure **261** taken along reference line XXI-XXI of FIG. **20**, in structure **261** trenches **229** are each lined with insulator layer **24** and include a shield electrode **21**. However, in one embodiment of structure **261** trenches **229** do not contain any gate electrode material **28**. That is, in this embodiment structure **261** does not include any gate or control electrodes. As shown in FIG. **20**, shield electrodes **21** are connected to shield electrode runner **66**, and in one embodiment are electrically connected to source metal **44**. In another feature of the present embodiment, ILD **41** separates shield electrodes **21** from gate pad **52** and there are no other intervening polycrystalline or other conductive layers overlying major surface **18** between gate pad **52** and structure **261**. That is, structure **261** is configured to better isolate gate pad **52** from semiconductor region **11** without adding more shielding layers overlying the major surface as used in previously known devices. This configuration helps to reduce gate-to-drain capacitance and does so without extra masking and/or processing steps. In one embodiment, spacing **88** between adjacent trenches **229** in structure **261** is less than about 0.3 microns. In another embodiment spacing **88** is less than one half the depth **89** (shown in FIG. **21**) of trenches **22** to provide a more optimum shielding. In one embodiment it was found that a spacing **88** of about 0.3 microns provides about a 15% reduction in gate-to-drain capacitance compared to a spacing **88** of 1.5 microns. In one embodiment of structure **261**, trenches **229** and shield electrodes **21** do not pass all of the way below gate pad **52**. In another embodiment, structure **261** and shield electrodes **21** pass all of the way the past gate pad **52**. In a still further embodiment, gate pad **52** contacts gate electrode **28** at an edge portion **521** of gate pad **52** as shown in FIG. **20**.

[0064] FIG. **22** shows a partial top plan view of a trench shielding structure **262** according to a second embodiment. Structure **262** is similar to structure **261** accept that structure **262** is placed to pass a plurality of trenches **229** and shield electrodes **21** below or underneath gate pad **52** and gate runner **53** to further isolate gate pad **52** and gate runner **53** from semiconductor layer **14**. In one embodiment of structure **262**, contact is made to shield electrodes **21** at both shield electrode runners **64** and **66** as shown in FIG. **22**, which are further connected to source metal **44**. Structure **262** is configured to better isolate gate pad **52** and gate runner **53** from semiconductor region **11**. In structure **262**, a portion of trenches **229** pass all the way past or underneath at least a portion of gate pad **52**. That is, in one embodiment at least one trench **229** extends from at least one edge or side of gate pad **52** to another opposing edge of gate pad **52**.

[0065] FIG. **23** shows a partial top plan view of a trench shielding structure **263** according to a third embodiment. Structure **263** is similar to structure **261** accept that structure **263** is placed to pass a plurality of trenches **229** and shield electrodes **21** below or underneath gate pad **52** and at least a portion of gate runner **56**. In one embodiment, a portion of trenches **229** and shield electrodes **21** below gate runner **56** pass all the way below or past gate runner **56**. In another embodiment, a portion of trenches **229** and shield electrodes **21** below gate runner **56** only pass a part of the way below gate runner **56**. In another embodiment, a portion of gate runner **56** makes contact to gate electrodes **28** at an edge portion **568** as shown in FIG. **23**. Structure **263** is configured to better isolate gate pad **52** and at least a portion of gate runner **56** from semiconductor layer **14**. It is understood that all, one or combinations of structures **261**, **262**, and **263** can be used with, for example, devices **20** and **30**.

[0066] FIG. **24** shows a partial top plan view of structure **239** from device **20** shown in FIG. **2**. As shown in FIG. **24**, conductive layer **44** includes portion **446**, which wraps around end **561** of gate runner **56** and connects to shield electrode runner **66** where contact is made to shield electrodes **21**. FIG. **24** further shows an example of the location of trenches **22** and gate electrodes **28** where contact is made between gate runner **56** and gate electrode **28**. Additionally, FIG. **24** shows trenches **22** having a striped shape and extending in a direction from the active area where conductive layer **44** is to the contact area where gate runner **56** and shield runner **66** are located. It is understood that the connective structures of FIGS. **17**, **18** and **19** can be used with structure **239** either individually or in combination. Structure **239** further illustrates an embodiment that provides for the use of one metal layer to connect the various structures.

[0067] In summary, a shielding structure for a semiconductor device has been described. The structure includes a plurality of trenches with passivation liners and shield electrodes, which are placed on or within the semiconductor device in locations to improve isolation and reduce capacitance effects. In one embodiment, the shielding structure is placed beneath a control pad. In another embodiment, the shielding structure is placed beneath a control runner. The shielding structure eliminates intervening conductive layers, which have been in previously known structures. This reduces manufacturing costs and complexity. The shielding structure uses structures similar to those used for form semiconductor devices with trench shield electrodes, which simplifies integration.

[0068] Although the invention has been described and illustrated with reference to specific embodiments thereof, it is not intended that the invention be limited to these illustrative embodiments. Those skilled in the art will recognize that modifications and variations can be made without departing from the spirit of the invention. Therefore, it is intended that this invention encompass all such variations and modifications as fall within the scope of the appended claims.

We claim:

1. A semiconductor device structure comprising:
- a region of semiconductor material having a first major surface;
- a first trench structure formed in an active area of the semiconductor device, wherein the first trench structure includes a first trench, a first control electrode, and a first shield electrode;
- a control pad formed overlying the first major surface and coupled to the first control electrode; and
- a second trench structure formed in the region of semiconductor material underlying at least a portion of the control pad, wherein the second trench structure includes a second trench, an insulator layer and a second shield electrode, and wherein the second shield electrode and the first shield electrode are coupled together, and wherein the second trench structure is configured as a shielding structure to isolate the control pad from the region of semiconductor material.

2. The structure of claim **1**, wherein the second trench structure includes a plurality of trenches, wherein the plurality of trenches has a trench spacing less than about 0.3 microns.

3. The structure of claim **1**, wherein the structure is absent any intervening conductive layers between the second trench structure and the control pad.

4. The structure of claim **1**, wherein the second trench structure is formed absent a control electrode.

5. The structure of claim **1** further comprising a first control runner connecting the control pad to the first control electrode, wherein the second trench structure is further formed underlying at least a portion of the first control runner.

6. The structure of claim **1**, wherein the second trench extends from a first side of the control pad to another side of the control pad opposite to the first side.

7. The structure of claim **1**, wherein the first and second shield electrodes are coupled together with a shield electrode runner overlying the first major surface.

8. The structure of claim **7**, wherein the second shield electrode does not overlap the first major surface, and wherein the shield electrode runner makes contact to the second shield electrode inside of the second trench.

9. The structure of claim **1**, wherein the second trench structure includes a plurality of trenches each having a depth, wherein the plurality of trenches are spaced a distance less than about one-half the depth.

10. The structure of claim **1**, wherein the control pad makes direct contact to the first control electrode underneath a portion of the control pad.

11. The structure of claim **1** further comprising a dielectric layer between the control pad and the second trench structure.

12. A semiconductor device structure comprising:
- a region of semiconductor material having a major surface and first and second opposing edges;
- a first trench formed in the region of semiconductor material extending in a direction from the first edge to the second edge;
- a first shield electrode formed in the first trench;
- a first control electrode formed in the first trench;
- a second trench formed in the region of semiconductor material;
- an insulator layer formed in the second trench;
- a second shield electrode formed in the second trench overlying the insulator layer;
- a control pad overlying at least a portion of the second trench, wherein the control pad is coupled to the first control electrode; and
- a first shield electrode runner formed overlying the major surface, wherein the first shield electrode runner is coupled to the second shield electrode.

13. The structure of claim **12**, wherein the first shield electrode is coupled to the second shield electrode adjacent the first edge, and wherein the structure further comprises a second shield electrode runner coupled to the second shield electrode adjacent the second edge.

14. The structure of claim **12** further comprising:
- a control electrode runner connecting the control pad to the first control electrode;
- a third trench formed in the region of semiconductor material below at least a portion of the control electrode runner; and
- a third shield electrode formed in the third trench, wherein the second and third trenches are formed absent control electrodes.

15. The structure of claim **14** further comprising a dielectric layer overlying the second and third trenches, wherein the control pad overlies the dielectric layer.

16. A semiconductor device structure comprising:
- a region of semiconductor material having a first major surface;
- a first trench structure formed in an active area of the semiconductor device, wherein the first trench structure includes a first trench, a first control electrode, and a first shield electrode;
- a control pad formed overlying the first major surface and coupled to the first control electrode;
- a second trench structure formed in the region of semiconductor material underlying at least a portion of the control pad, wherein the second trench structure includes a second trench, an insulator layer and a second shield electrode, and wherein the second shield electrode and the first shield electrode are coupled together, and wherein the second trench structure is formed absent a control electrode; and
- a dielectric layer formed between the control pad and the second trench structure.

17. The structure of claim **16**, wherein the second trench structure includes a plurality of trenches each having a depth, wherein the plurality of trenches are spaced a distance less than about one-half the depth.

18. The structure of claim **16** further comprising a first control runner connecting the control pad to the first control electrode, wherein the second trench structure is further formed underlying at least a portion of the first control runner.

19. The structure of claim **16**, wherein the structure is formed absent any conductive layers overlying the major surface between the control pad and the second trench structure.

20. The structure of claim **16**, wherein the first shield electrode is coupled to the second shield electrode with a first shield electrode runner adjacent the first edge, and wherein the structure further comprises a second shield electrode runner coupled to the second shield electrode adjacent the second edge.

21. A method of forming a semiconductor device comprising the steps of:

providing a region of semiconductor material having a major surface and first and second opposing edges;

forming a first trench in the region of semiconductor material extending in a direction from the first edge to the second edge;

forming a first shield electrode in the first trench;

forming a first control electrode in the first trench;

forming a second trench in the region of semiconductor material;

forming an insulator layer in the second trench;

forming a second shield electrode in the second trench overlying the insulator layer;

forming a control pad overlying at least a portion of the second trench, wherein the control pad is coupled to the first control electrode; and

forming a first shield electrode runner overlying the major surface, wherein the first shield electrode runner is coupled to the second shield electrode.

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