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Akutsu et al.

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(54) **NON-VOLATILE SEMICONDUCTOR
MEMORY DEVICE AND MANUFACTURING
METHOD THEREOF**

(56) **References Cited**

U.S. PATENT DOCUMENTS

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8,008,710 B2 * 8/2011 Fukuzumi G11C 5/02
257/326

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8,338,882 B2 12/2012 Tanaka et al.
8,530,956 B2 9/2013 Lee

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2007/0252201 A1 * 11/2007 Kito H01L 21/8221
257/331

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U.S.C. 154(b) by 0 days.

2008/0173928 A1 * 7/2008 Arai H01L 29/7926
257/316

2011/0002178 A1 * 1/2011 Hwang H01L 27/11578
365/189.011

2013/0009235 A1 1/2013 Yoo
2015/0364488 A1 * 12/2015 Pachamuthu H01L 29/665
257/314

FOREIGN PATENT DOCUMENTS

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JP 2011-187794 9/2011
JP 2012-142558 7/2012
JP 2013-21322 1/2013

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* cited by examiner

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H01L 27/115 (2006.01)

H01L 23/522 (2006.01)

H01L 21/768 (2006.01)

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

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(2013.01); **H01L 23/5226** (2013.01); **H01L**
27/11578 (2013.01)

(58) **Field of Classification Search**

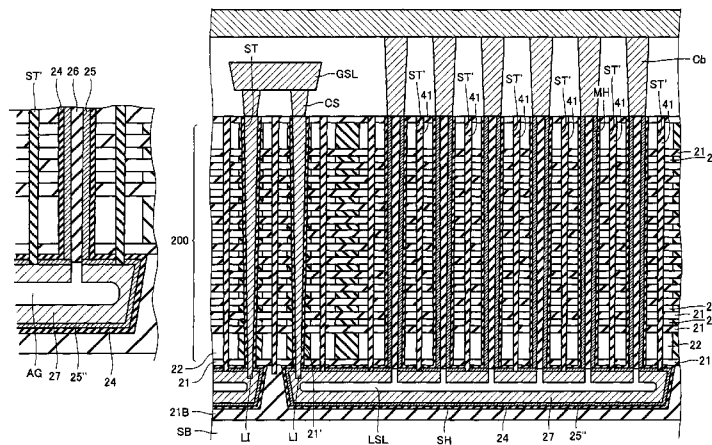
CPC H01L 27/1157; H01L 27/11578;
H01L 21/76889; H01L 23/5226

See application file for complete search history.

(57) **ABSTRACT**

This non-volatile semiconductor memory device includes a memory cell array including NAND cell units formed in a first direction vertical to a surface of a semiconductor substrate. A local source line is electrically coupled to one end of the NAND cell unit formed on the surface of the substrate. The memory cell array includes: a laminated body where plural conductive films, which are to be control gate lines of memory cells or selection gate lines of selection transistors, are laminated sandwiching interlayer insulating films; a semiconductor layer that extends in the first direction; and an electric charge accumulating layer sandwiched between: the semiconductor layer and the conductive film. The local source line includes a silicide layer. The electric charge accumulating layer is continuously formed from the memory cell array to cover a peripheral area of the silicide layer.

10 Claims, 21 Drawing Sheets



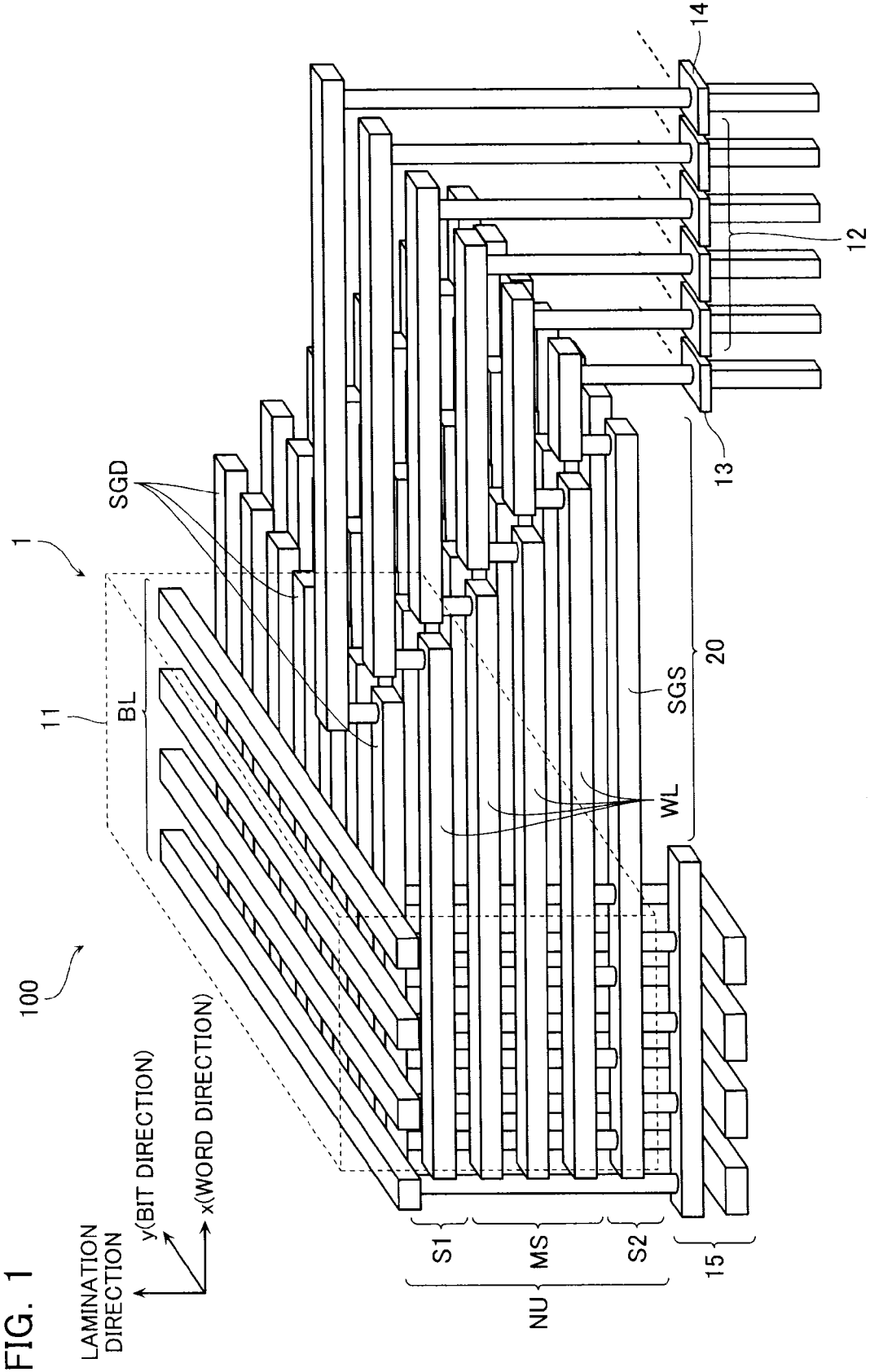


FIG. 1

FIG. 2

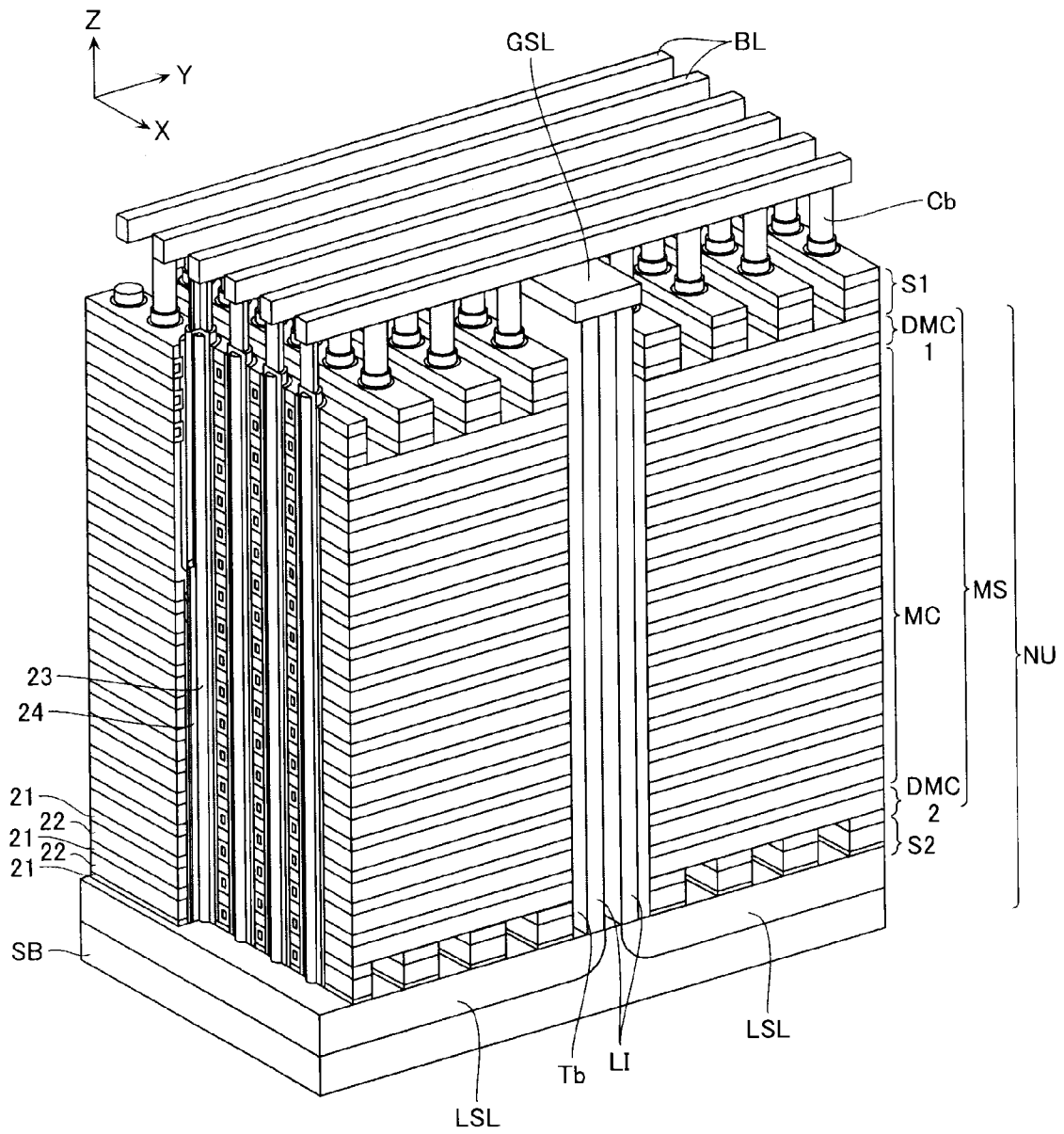


FIG. 3A

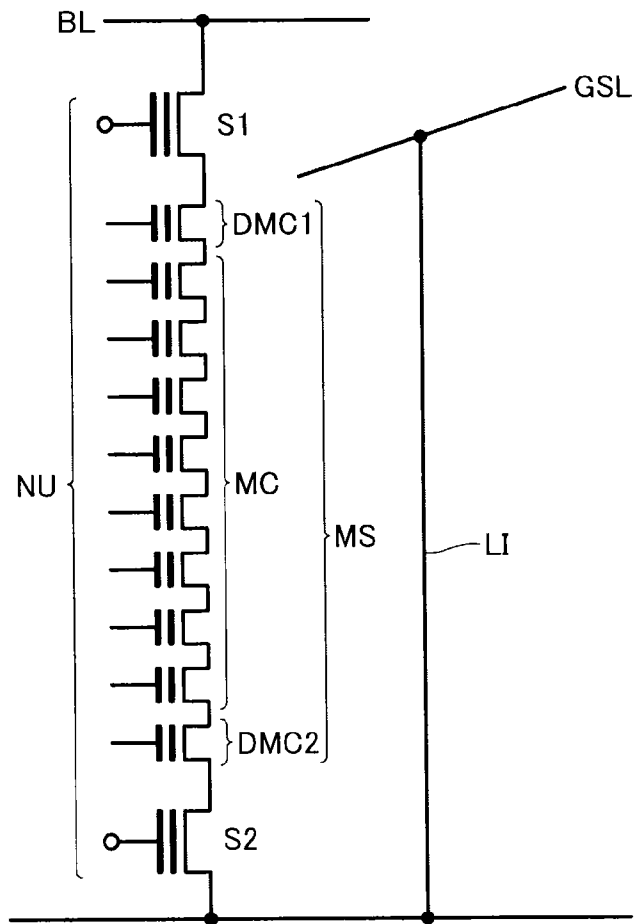


FIG. 3B

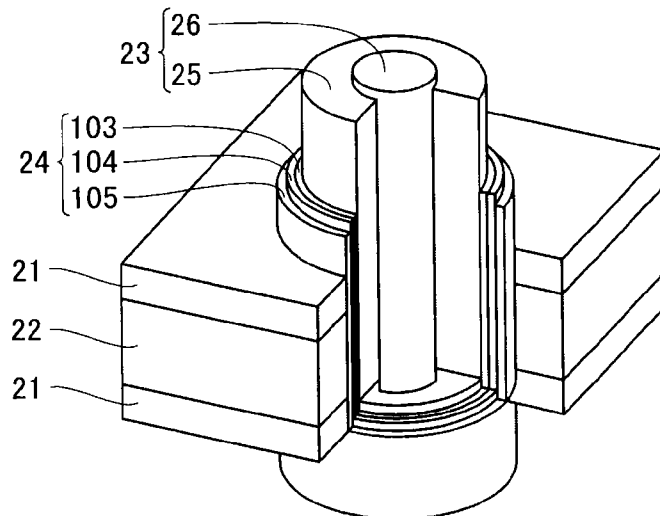


FIG. 4

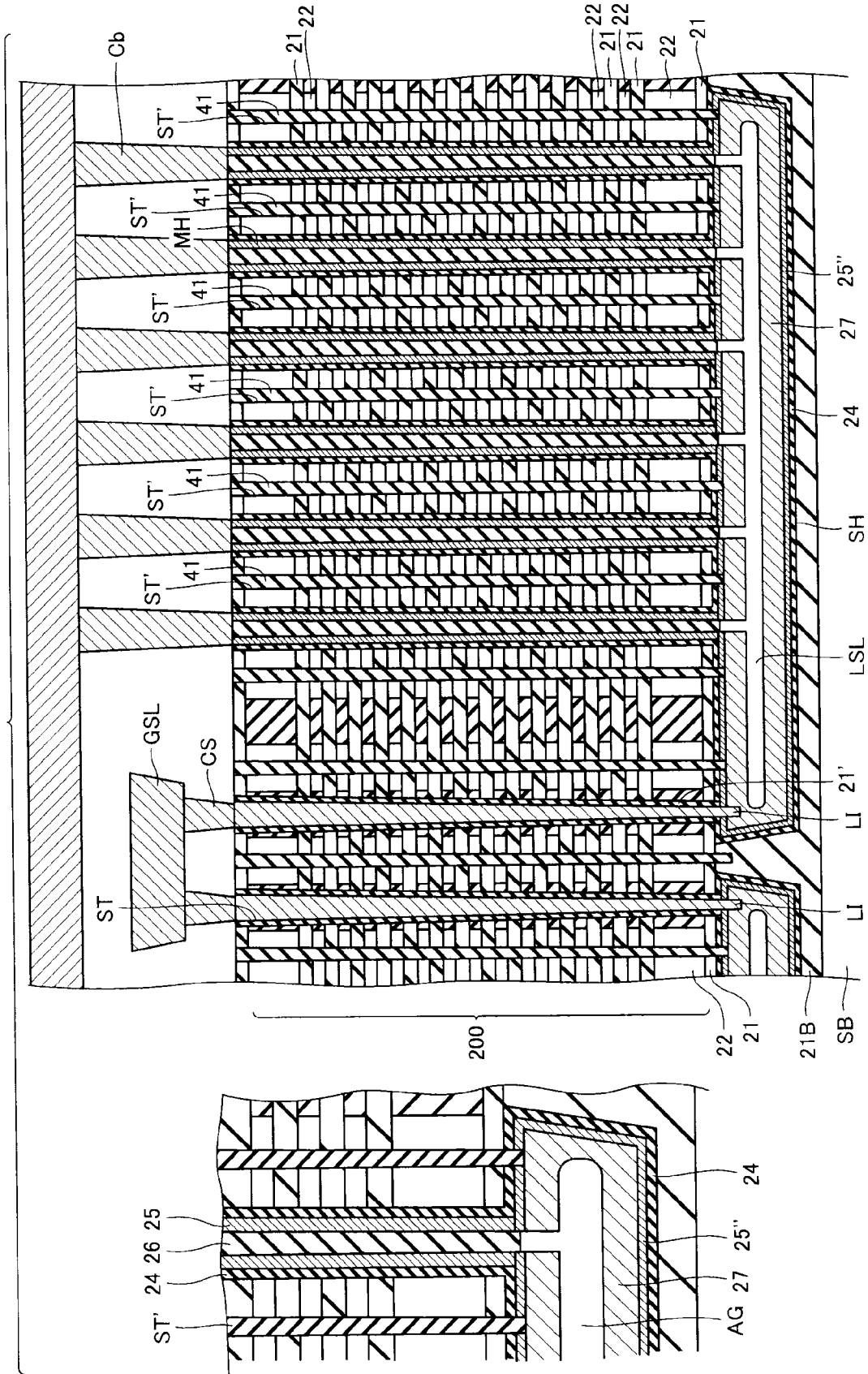
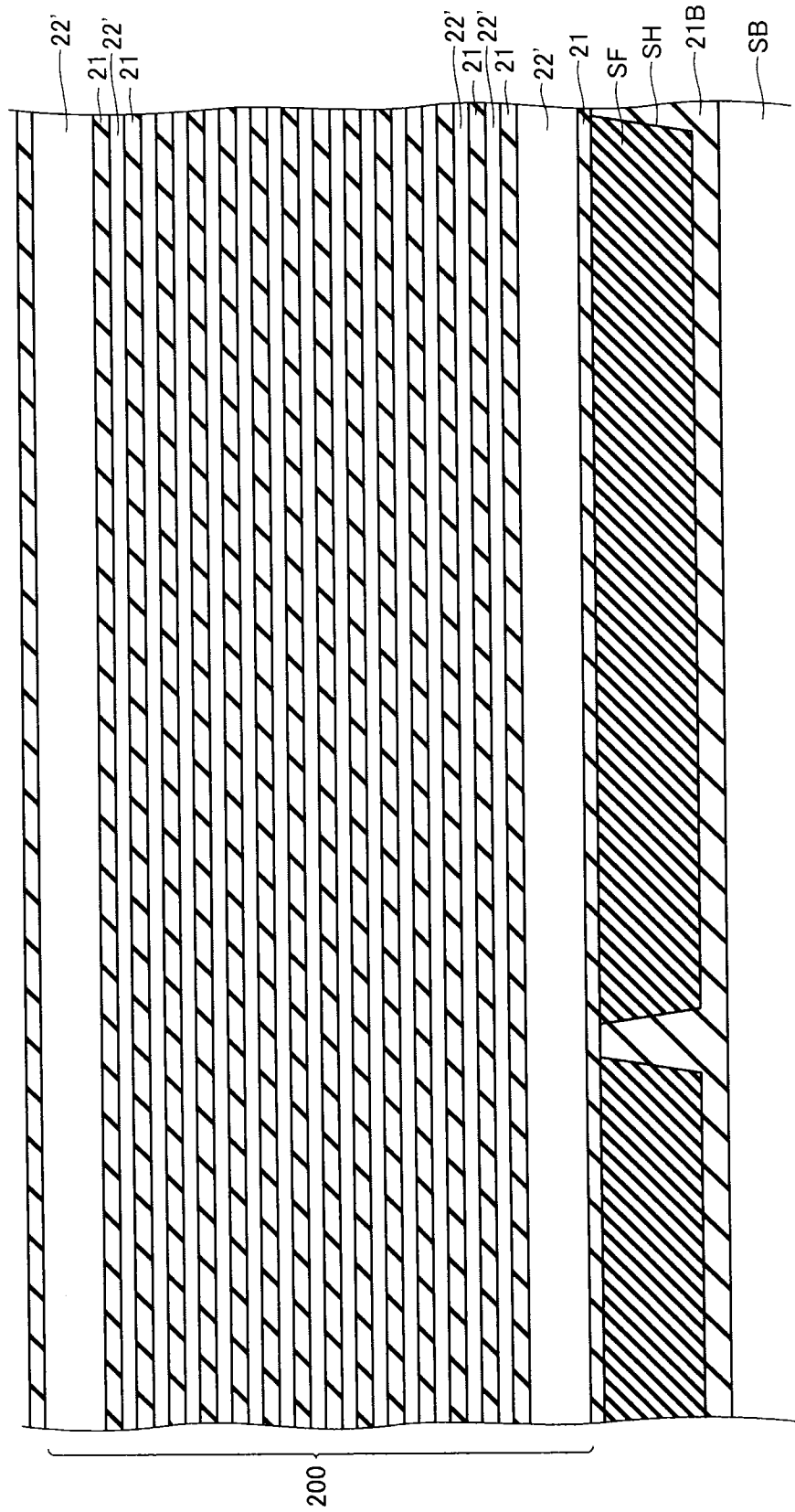


FIG. 5



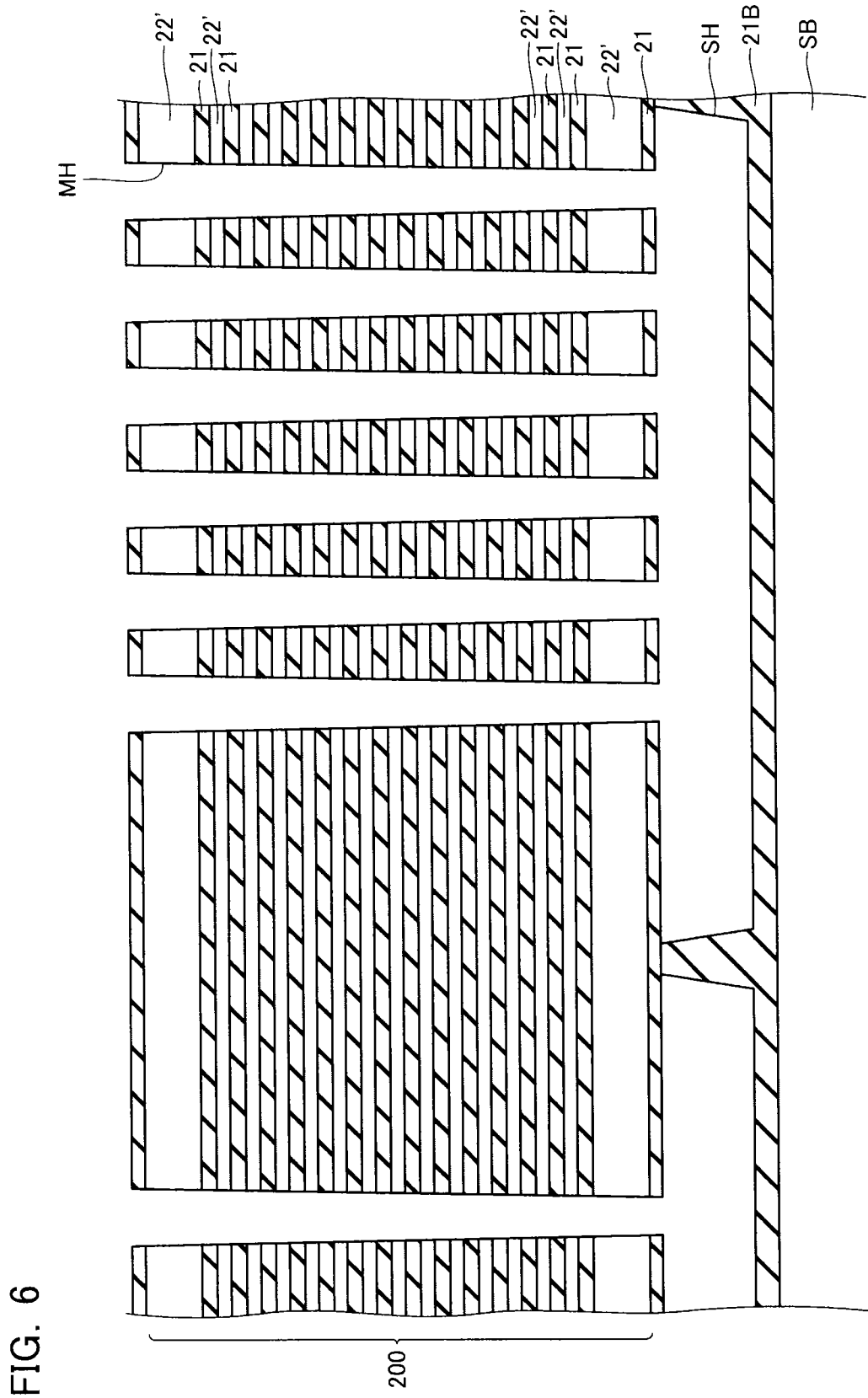
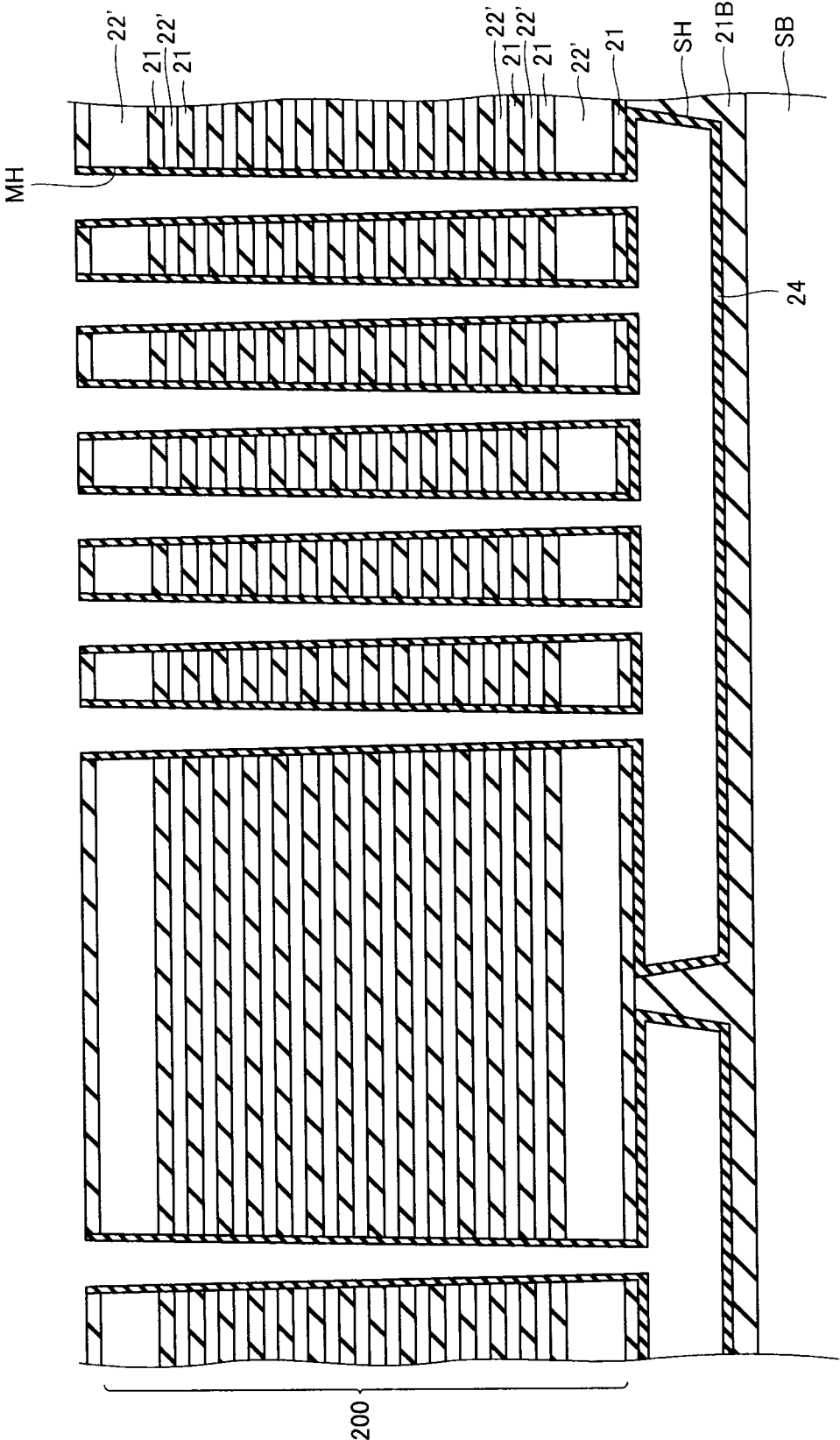


FIG. 7



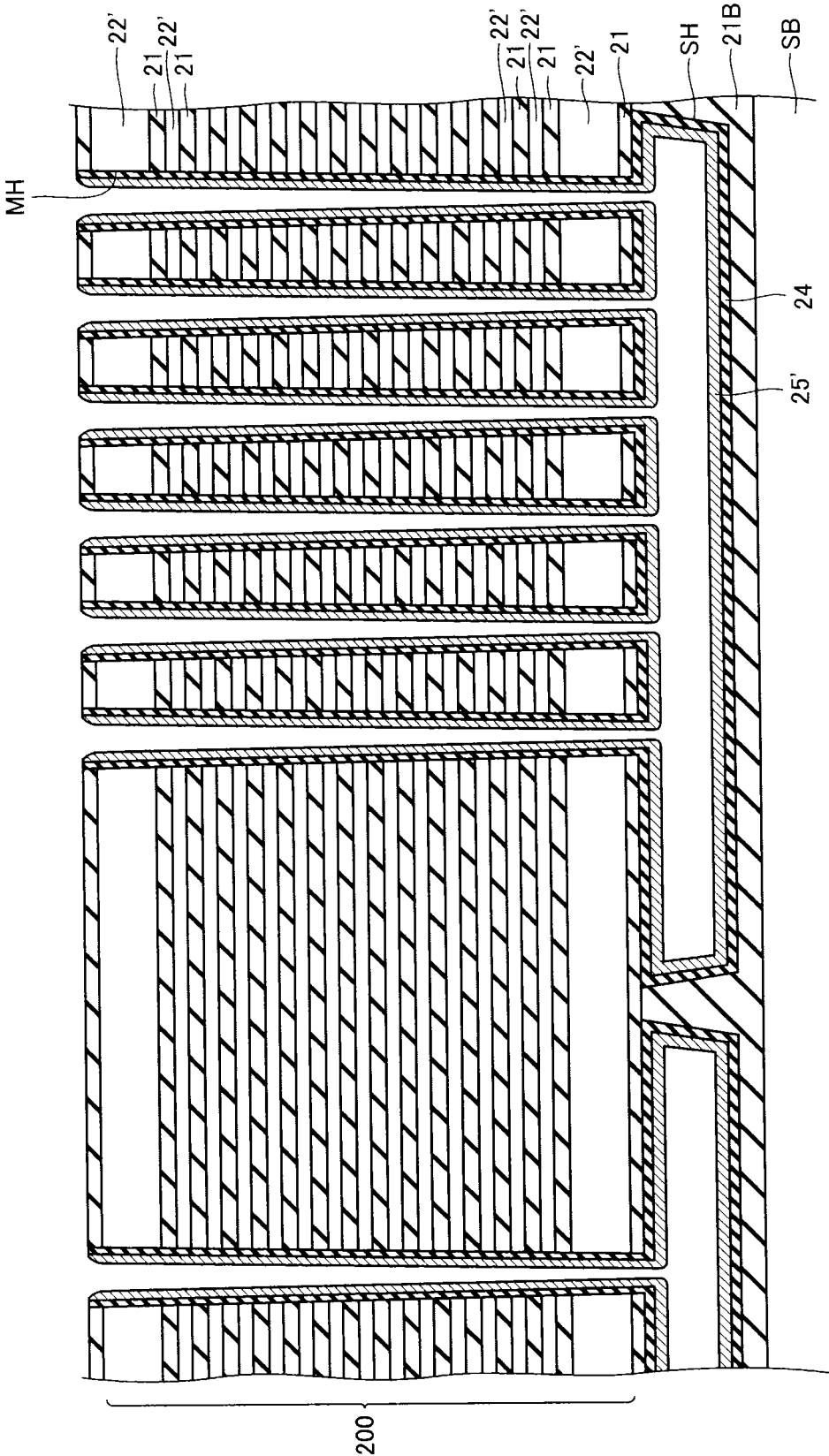


FIG. 8

FIG. 9

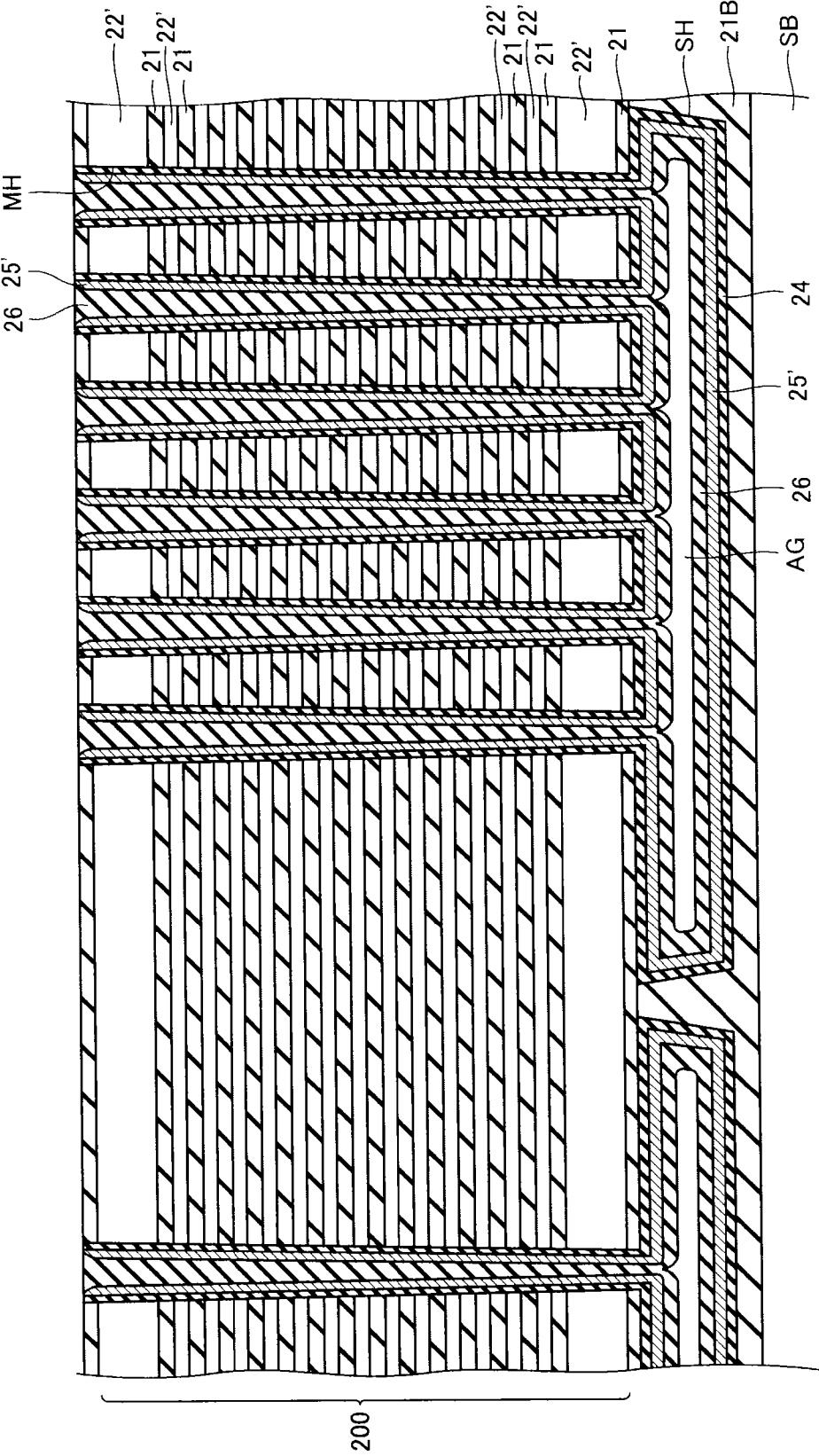
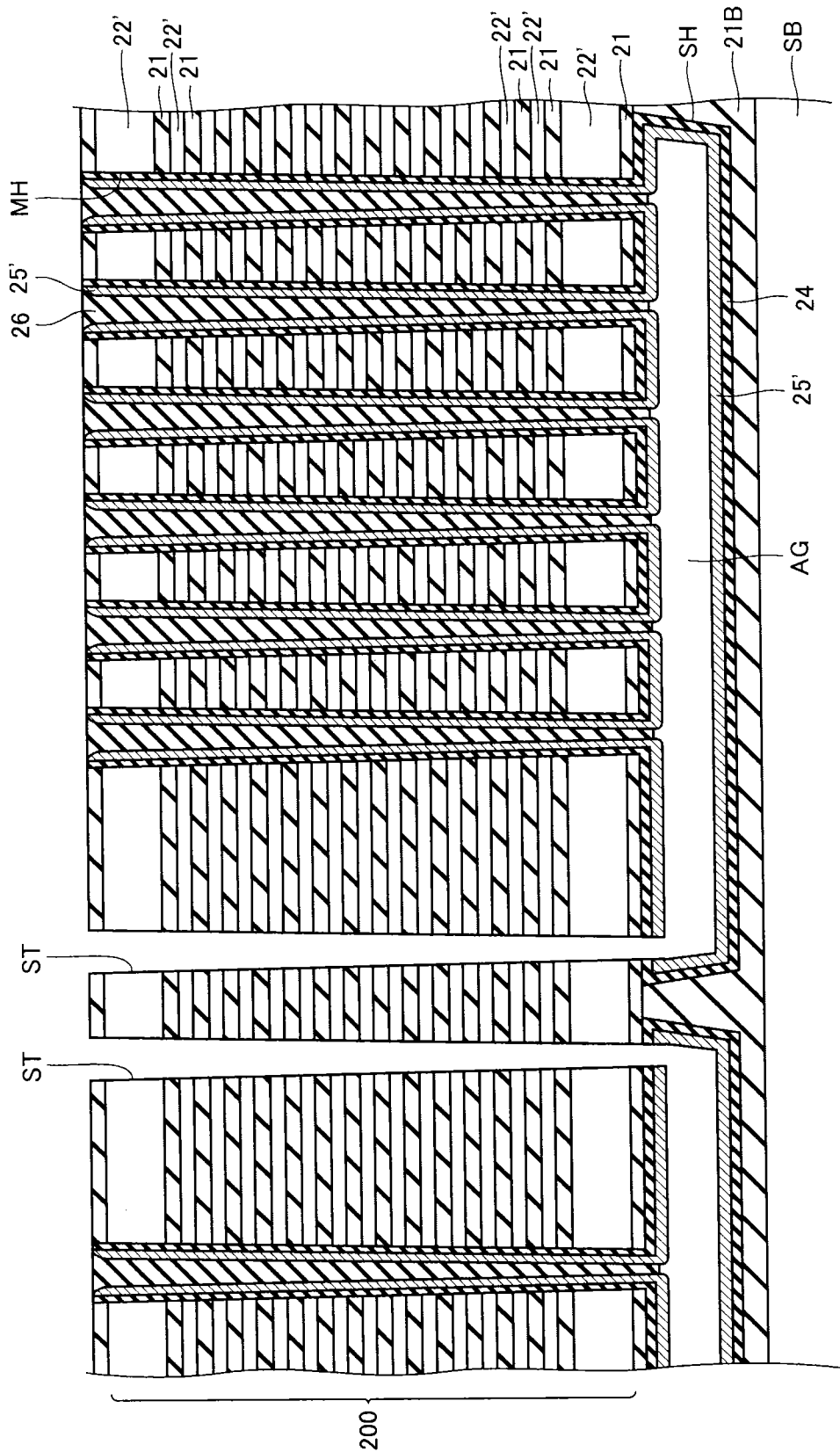


FIG. 10



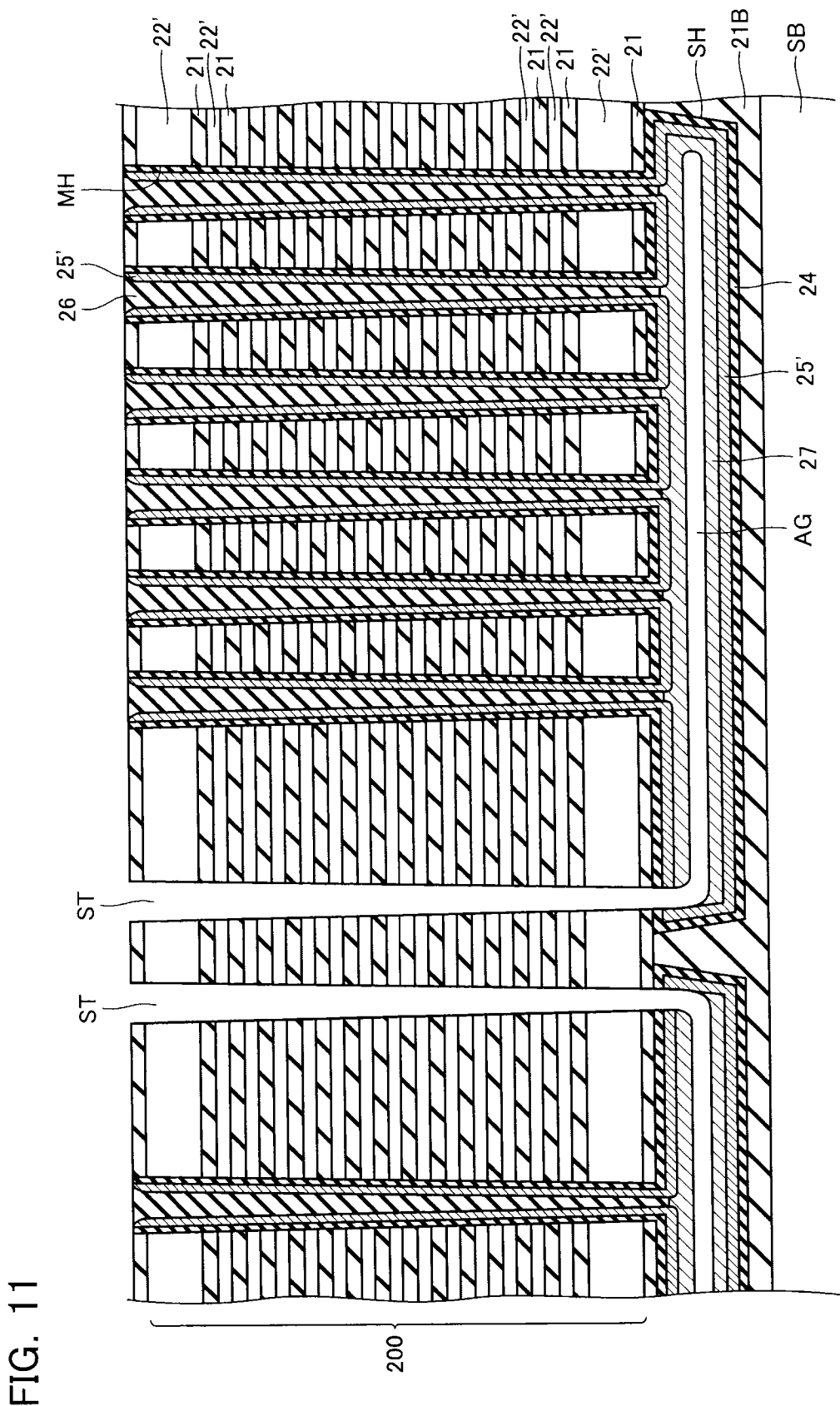
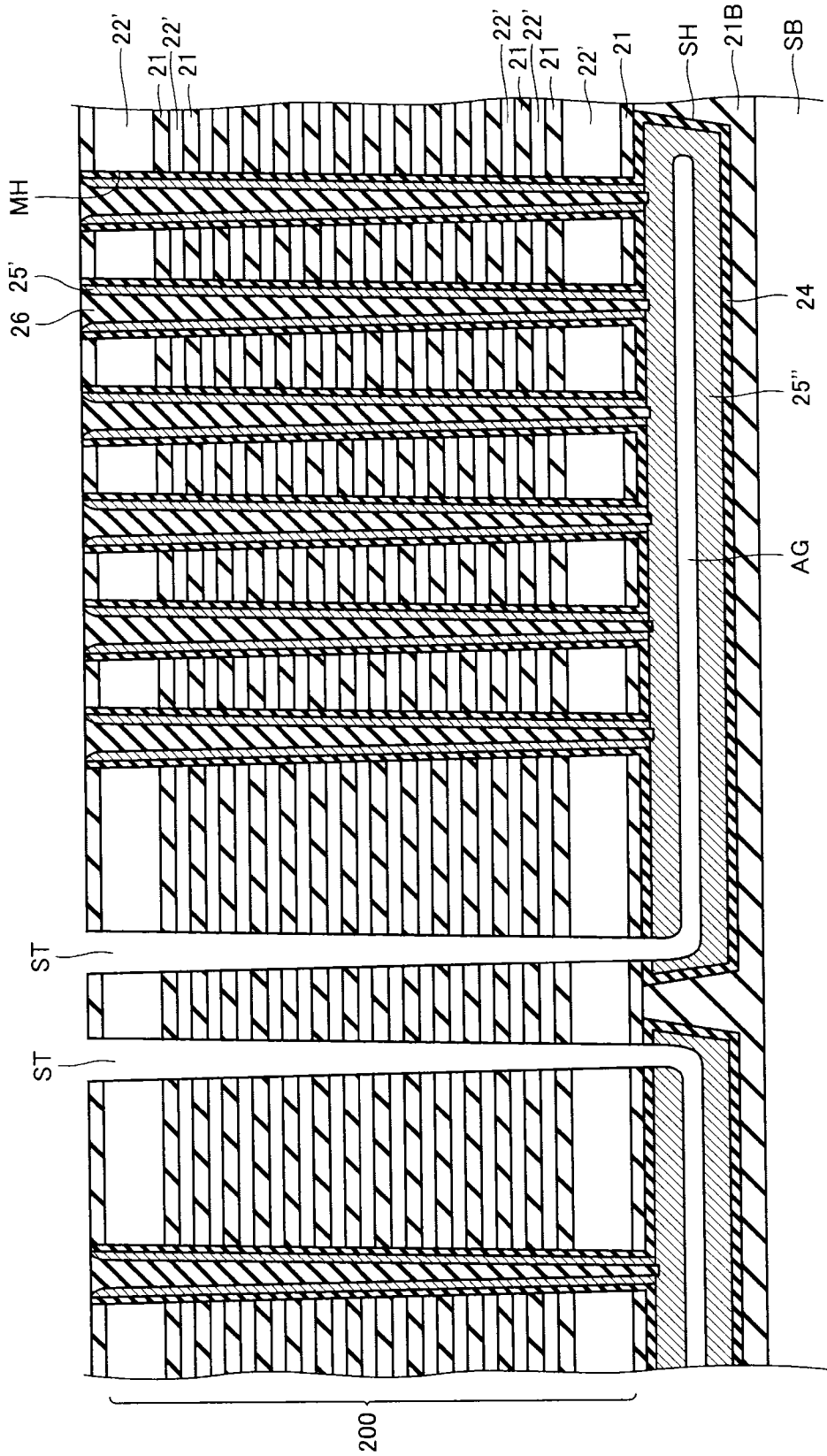


FIG. 12



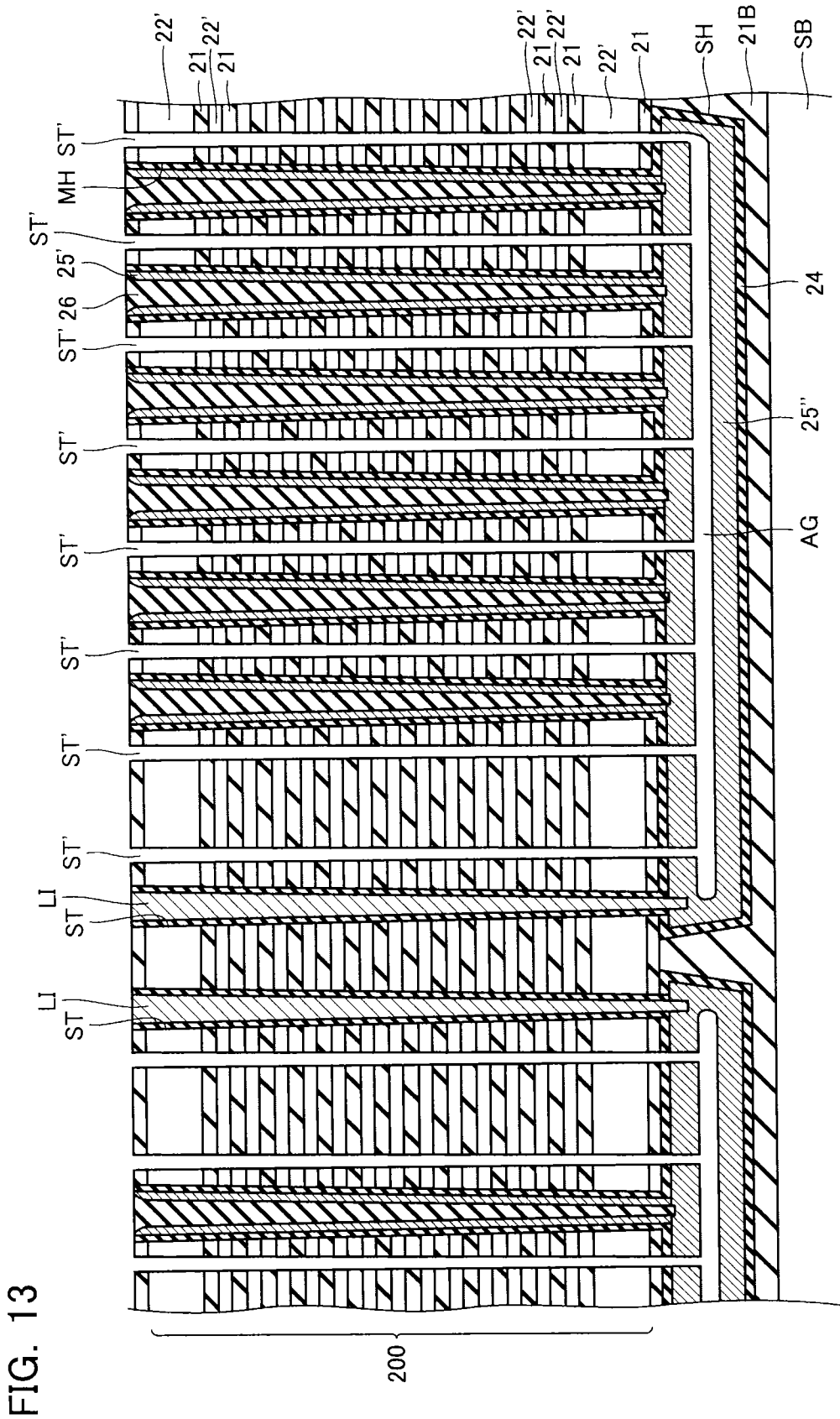


FIG. 13

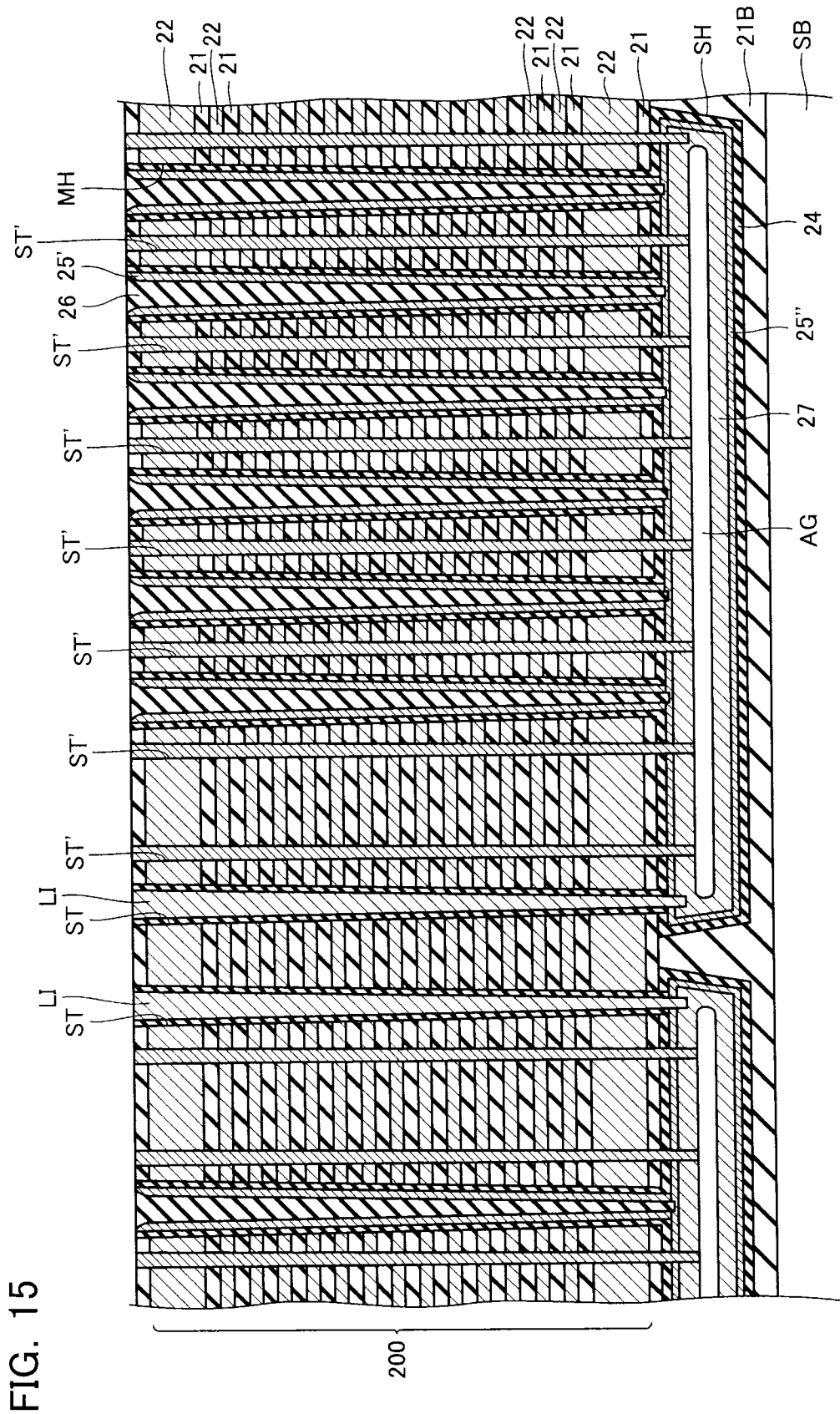


FIG. 15

FIG. 16

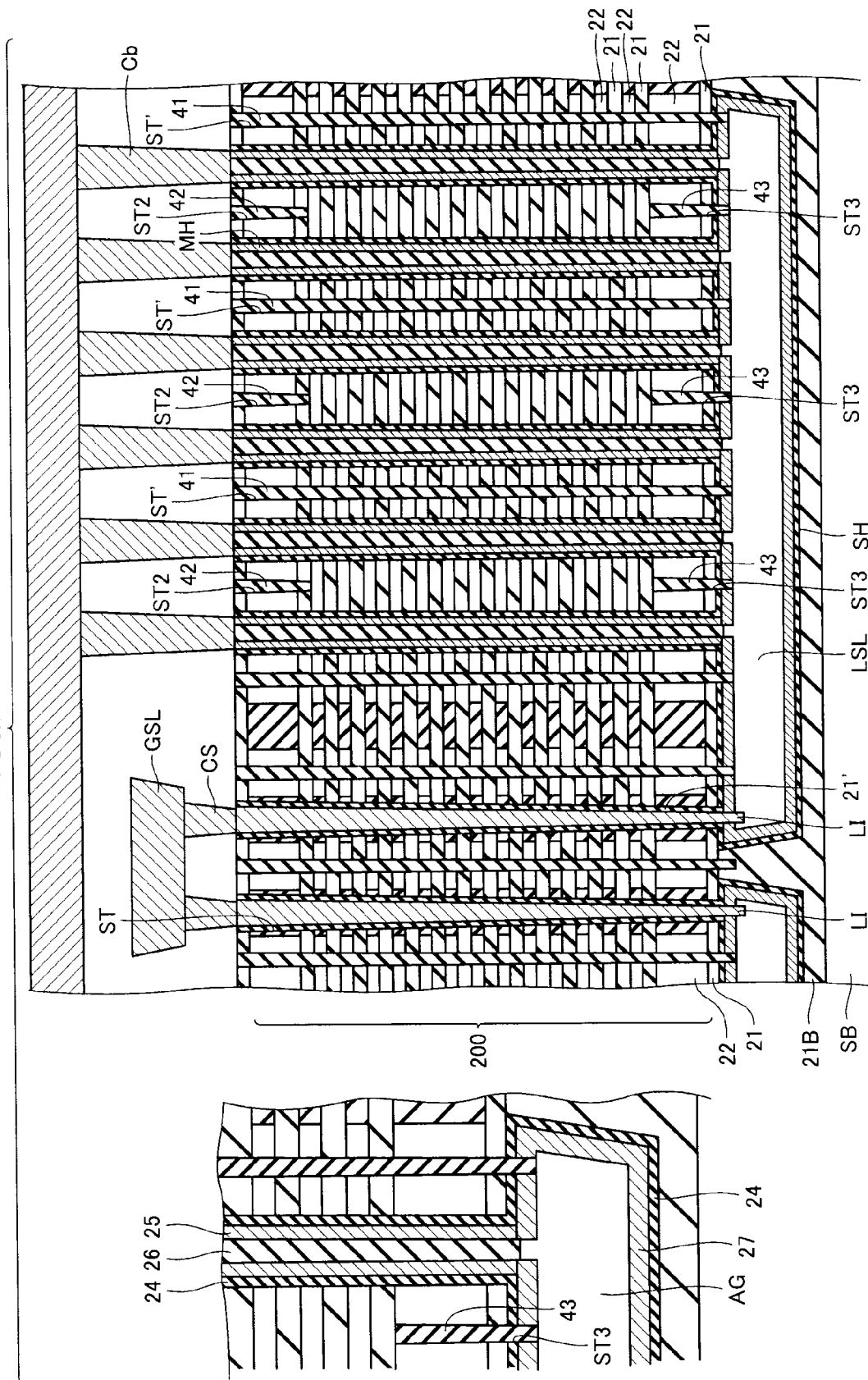


FIG. 17

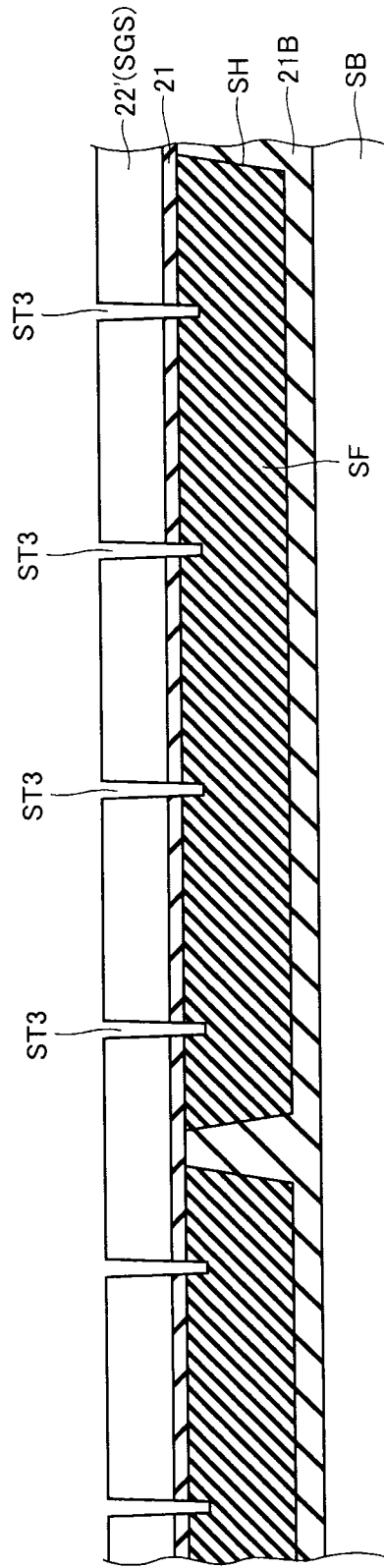


FIG. 18

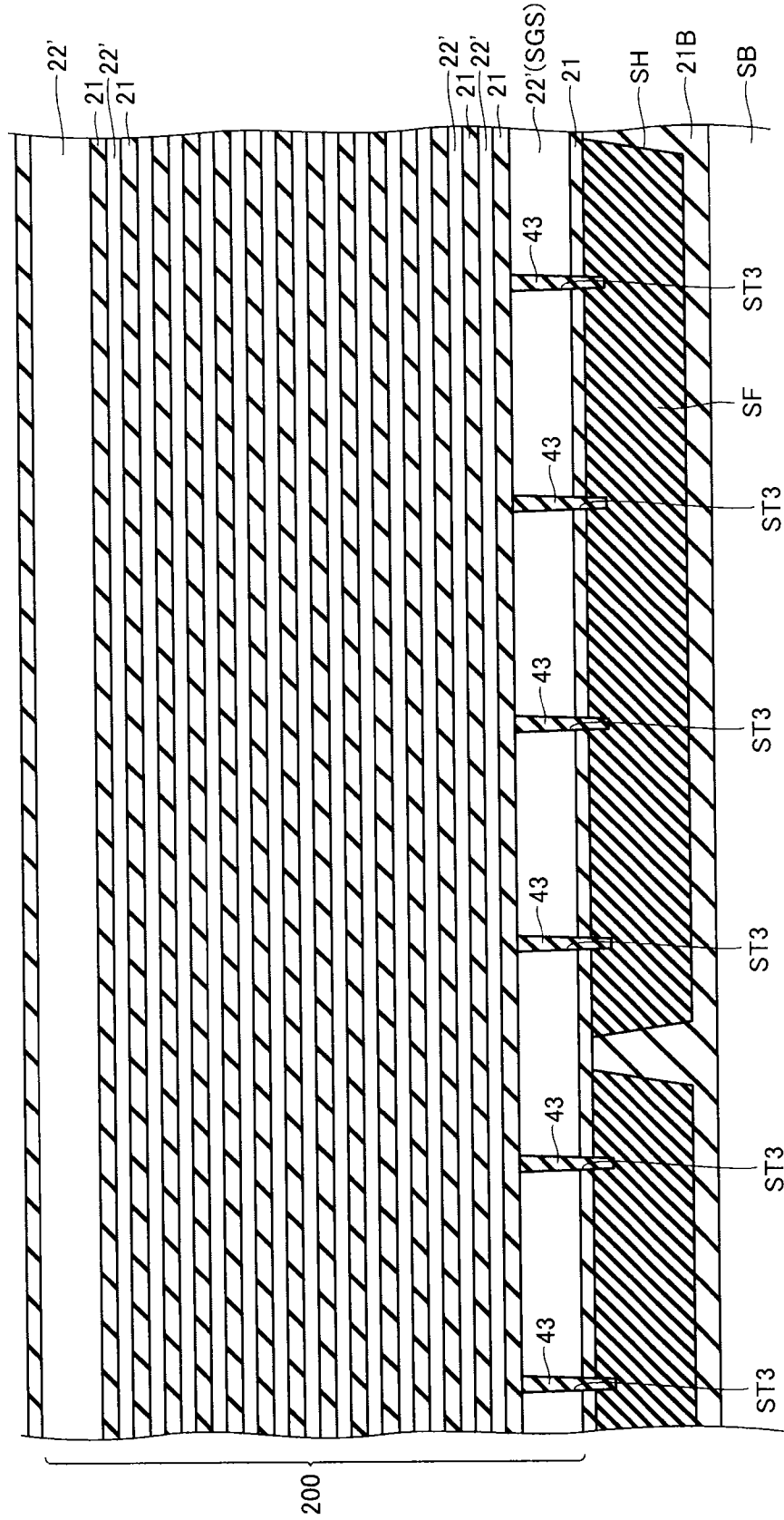


FIG. 19

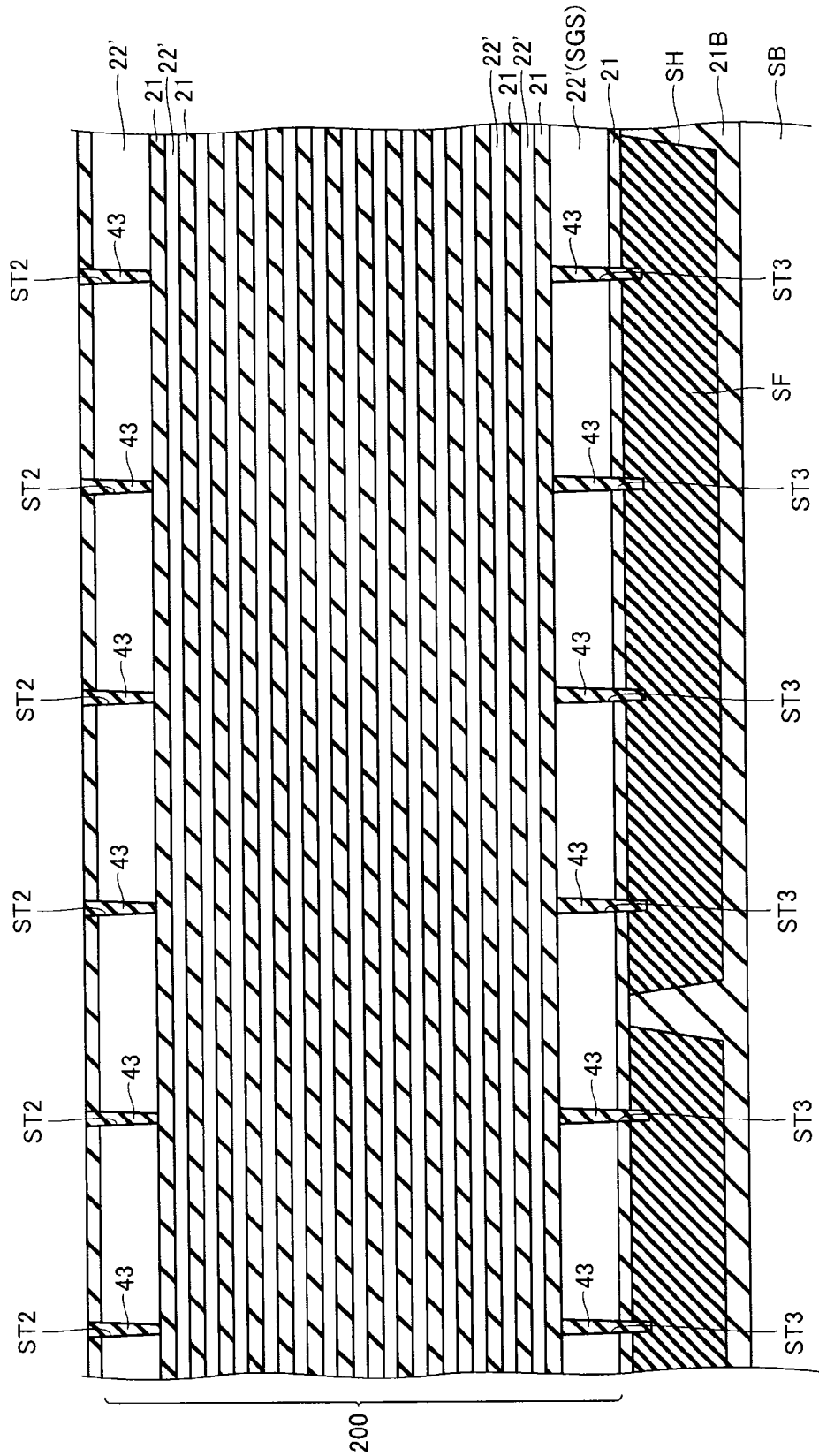


FIG. 20

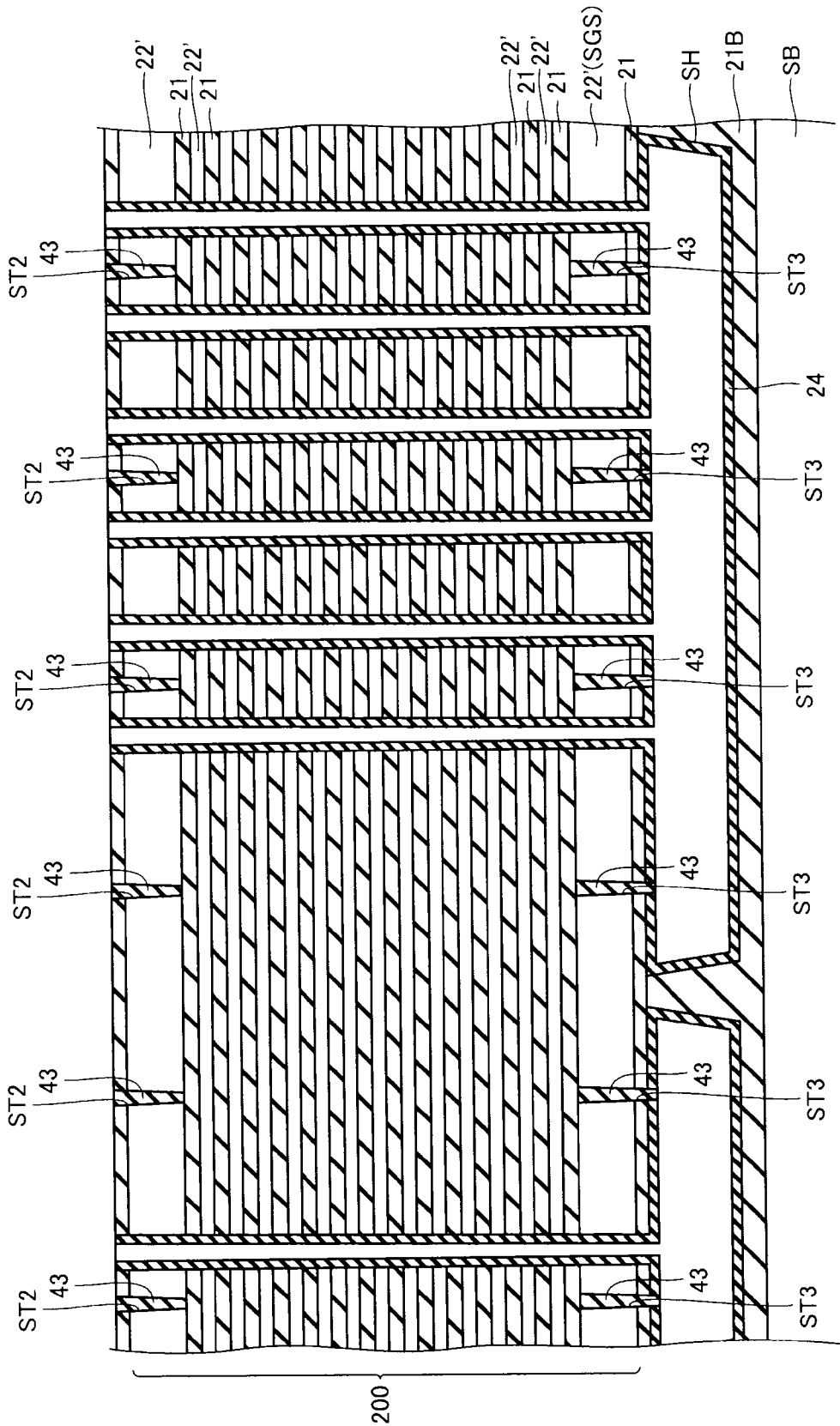
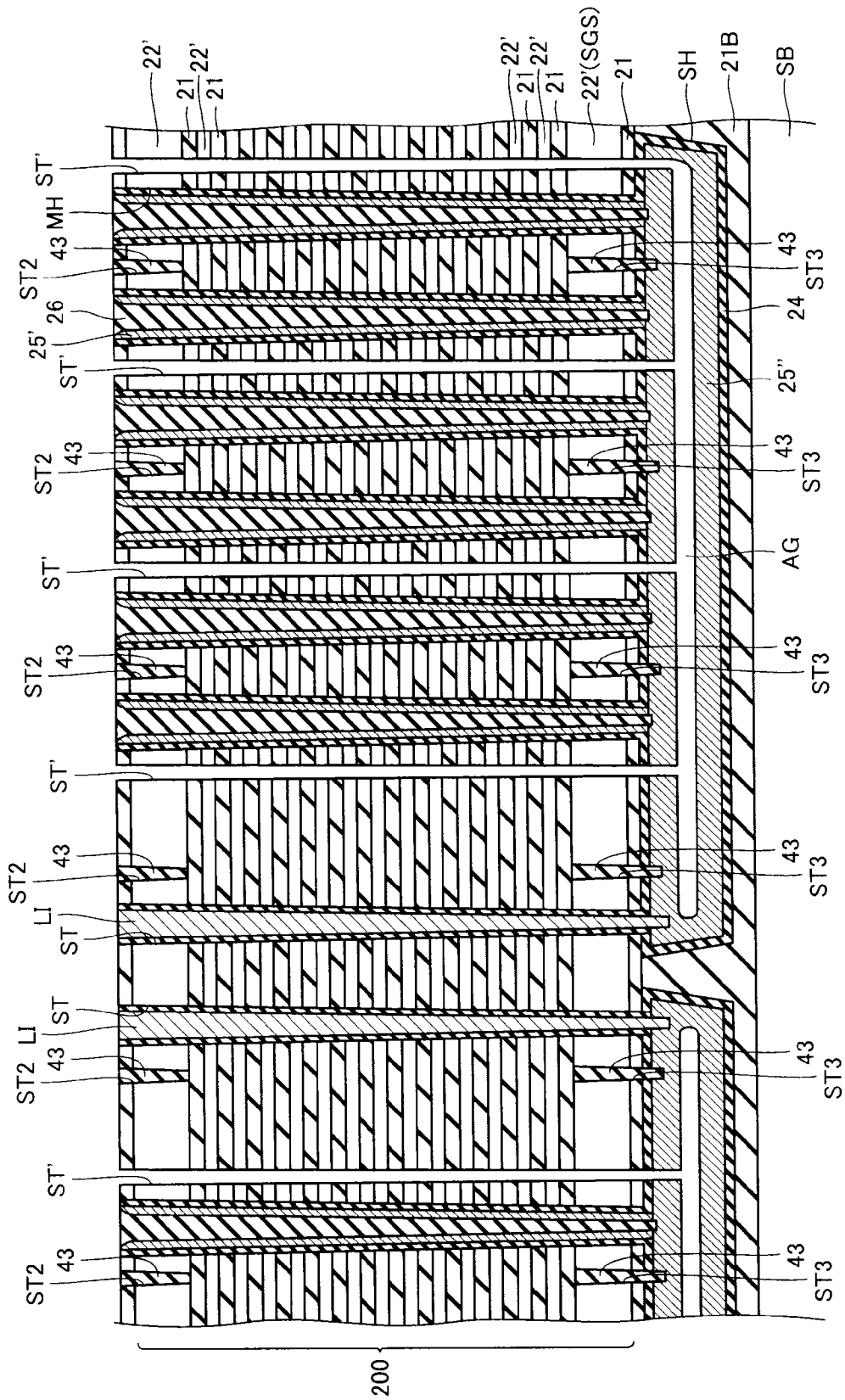


FIG. 21



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NON-VOLATILE SEMICONDUCTOR MEMORY DEVICE AND MANUFACTURING METHOD THEREOF

CROSS REFERENCE TO RELATED APPLICATIONS

This application is based on and claims the benefit of priority from prior U.S. Provisional Patent Application No. 62/049,017, filed on Sep. 11, 2014, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate to a non-volatile semiconductor memory device and a manufacturing method of the non-volatile semiconductor memory device.

BACKGROUND

Recently, in the field of NAND-type flash memories, attention has been focused on a laminated-type (three-dimensional) NAND-type flash memory as a device that can achieve high integration without being restricted by the limit of resolution of the lithography technology. This type of three-dimensional NAND-type flash memory includes a laminated body and a semiconductor layer. In the laminated body, a plurality of conductive films and interlayer insulating films are alternately laminated. The conductive film functions as word lines and selection gate lines. The semiconductor layer is formed to pass through these laminated films. This semiconductor layer functions as a body of a memory string. Between the semiconductor layer and the conductive film, a memory film that includes an electric charge accumulating layer is formed.

This three-dimensional NAND-type flash memory has a large number of wirings and contacts for coupling various wirings and an external circuit together. Accordingly, it is required to reduce the resistance values of these portions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view schematically illustrating an exemplary structure of a non-volatile semiconductor memory device **100** of a first embodiment;

FIG. 2 is a perspective view illustrating a part of a structure of a memory cell array **11**;

FIG. 3A is an equivalent circuit diagram of one NAND cell unit NU;

FIG. 3B is a perspective view illustrating one example of a specific structure of one of a memory cell MC or a dummy cell DMC;

FIG. 4 is a cross-sectional view for describing a detailed structure of the memory cell array **11** and a local source line LSL of the first embodiment;

FIG. 5 is a process diagram for describing a manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 6 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 7 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 8 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

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FIG. 9 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 10 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 11 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 12 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 13 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 14 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 15 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the first embodiment;

FIG. 16 is a cross-sectional view for describing a detailed structure of the memory cell array **11** and the local source line LSL of a second embodiment;

FIG. 17 is a process diagram for describing a manufacturing method of a non-volatile semiconductor memory device of the second embodiment;

FIG. 18 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the second embodiment;

FIG. 19 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the second embodiment;

FIG. 20 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the second embodiment; and

FIG. 21 is a process diagram for describing the manufacturing method of the non-volatile semiconductor memory device of the second embodiment.

DETAILED DESCRIPTION

A non-volatile semiconductor memory device according to the embodiments described as follows includes a memory cell array including NAND cell units arranged therein. The NAND cell unit is configured to extend in a first direction vertical to a surface of a semiconductor substrate. The NAND cell unit includes a plurality of memory cells and selection transistors connected in series. A local source line is formed on the surface of the semiconductor substrate, and is electrically coupled to one end of the NAND cell unit. The memory cell array includes a laminated body, a semiconductor layer, and a memory film. In the laminated body, a plurality of conductive films are laminated sandwiching an interlayer insulating film. The conductive film becomes control gate lines of the memory cell or selection gate lines of the selection transistor. The semiconductor layer extends in the first direction. The memory film includes an electric charge accumulating layer sandwiched between the semiconductor layer and the conductive film. The local source line includes a silicide layer. The memory film is continuously formed from the memory cell array to cover a peripheral area of the silicide layer.

The following describes non-volatile semiconductor memory devices according to embodiments in detail with reference to the accompanying drawings. Here, these embodiments are only examples, and are not described for the

purpose of limiting the present invention. The respective drawings of the non-volatile semiconductor memory devices used in the following embodiments are schematically illustrated. The thickness, the width, the ratio, and similar parameter of the layer are different from actual parameters.

The following embodiments relate to a non-volatile semiconductor memory device in a structure where a plurality of metal-oxide-nitride-oxide-semiconductor (MONOS) type memory cells (transistors) is disposed in a height direction. The MONOS type memory cell includes: a semiconductor film disposed in a columnar shape vertical to the substrate as a channel, and a gate electrode film disposed on the side surface of the semiconductor film via an electric charge accumulating layer. However, this is not also intended to limit the present invention. The present invention is applicable to, for example, a semiconductor-oxide-nitride-oxide-semiconductor type (SONOS) memory cell or a floating-gate type memory cell.

First Embodiment

Overall Configuration

FIG. 1 is a perspective view schematically illustrating an exemplary structure of a non-volatile semiconductor memory device **100** of a first embodiment. The non-volatile semiconductor memory device **100** includes a memory cell array **11**, word-line driving circuits **12**, source-side selection-gate-line driving circuits **13**, drain-side selection-gate-line driving circuits **14**, a sense amplifier **15**, word lines WL, source-side selection gate lines SGS, drain-side selection gate lines SGD, bit lines BL, a wiring portion **20**, and the like.

The memory cell array **11** includes memory strings MS, drain-side selection transistors S1, and source-side selection transistors S2 on a semiconductor substrate (not illustrated in FIG. 1). The memory string MS is constituted such that a plurality of memory cells MC (memory transistors) are coupled together in series. The respective drain-side selection transistor S1 and source-side selection transistor S2 are coupled to both ends of the memory string MS. Here, the series circuit that includes: the memory string MS, and the drain-side selection transistor S1 and the source-side selection transistor S2 coupled to both ends of the memory string MS are hereinafter referred to as a "NAND cell unit NU."

As described later, the memory cell MC has the structure, where a control gate electrode (word line) is disposed on the side surface of a columnar semiconductor film **25**, becomes a channel via a memory film **24** including an electric charge accumulating layer. The drain-side selection transistor S1 and the source-side selection transistor S2 each have the structure where a selection gate electrode (selection gate line) is disposed on the side surface of a columnar semiconductor film **25** via the memory film **24** including an electric charge accumulating layer. For simplification of the illustration, FIG. 1 illustrates the case where three memory cells MC are disposed in one memory string MS as the example. Obviously, the number of the memory cells MC in one memory string MS is not limited to this.

The word line WL is coupled in common to the adjacent memory cells along the X direction (the word-line direction) in FIG. 1. The source-side selection gate line SGS is coupled in common to the adjacent source-side selection transistors S2 along the word-line direction. The drain-side selection gate line SGD is coupled in common to the adjacent drain-side selection transistor S1 along the word-line direction. Here, in the following description, the source-side selection gate line SGS and the drain-side selection gate line SGD are

collectively referred to simply as "selection gate lines" in some cases. The drain-side selection transistor S1 and the source-side selection transistor S2 are collectively referred to simply as "selection transistors" in some cases. Here, in the memory cells MC in the memory string MS, one or a plurality of the memory cells MC close to the source-side selection gate line SGS and the drain-side selection gate line SGD might be treated as a dummy cell that is not used for data storage. Also in the example described as follows, a description will be given of the example where one dummy cell is disposed at each of both ends of the memory string MS. This, however, should not be construed in a limiting sense. Two or more dummy cells may be disposed or the dummy cell may be omitted.

Furthermore, the bit lines BL are disposed to extend having the longitudinal direction in the Y direction (the bit-line direction) intersecting with the X direction (the word-line direction), and are collocated at a predetermined pitch in the X direction. The bit line BL is coupled to a plurality of the memory strings MS via the drain-side selection transistors S1. Global source lines GSL, which are omitted in FIG. 1, are disposed having the longitudinal direction in the X direction and coupled to the memory strings MS via the source-side selection transistors S2, local source lines LSL described later, and source line contacts LI.

The word-line driving circuit **12** is a circuit that controls the voltage to be applied to the word line WL. The source-side selection-gate-line driving circuit **13** is a circuit that controls the voltage to be applied to the source-side selection gate line SGS. The drain-side selection-gate-line driving circuit **14** is a circuit that controls the voltage to be applied to the drain-side selection gate line SGD. The sense amplifier **15** is a circuit for amplifying a signal (voltage) read out from a selected memory cell to the bit line BL.

The wiring portion **20** is a wiring portion for coupling the word lines WL and the selection gate lines SGD and SGS to the contacts. The word lines WL, the selection gate lines SGS and SGD have a structure processed in a staircase pattern such that the respective upper portions can independently be coupled to the contacts.

(Structure of Memory Cell Array 11)

The following describes the detail of the structure of the memory cell array **11** with reference to FIG. 2 and FIGS. 3A and 3B. FIG. 2 is a perspective view illustrating the structure of a part of the memory cell array **11**. FIGS. 3A and 3B are equivalent circuit diagrams of one NAND cell unit NU.

As illustrated in FIG. 2, the memory cell array **11** has a laminated body **200** where interlayer insulating films **21** and conductive films **22** are alternately laminated on a semiconductor substrate SB. These conductive films **22** function as control gate lines (word lines WL) of the memory cell MC, the source-side selection gate line SGS, and the drain-side selection gate line SGD. The interlayer insulating films **21** are disposed in the up-and-down direction of these conductive films **22** and disposed to electrically insulate the conductive films **22** from one another.

The conductive film **22** can be formed of, for example, tungsten (W), tungsten nitride (WN), tungsten silicide (WSix), tantalum (Ta), tantalum nitride (TaN), tantalum silicide (TaSix), palladium silicide (PdSix), erbium silicide (ErSix), yttrium silicide (YSix), platinum silicide (PtSix), hafnium silicide (HfSix), nickel silicide (NiSix), cobalt silicide (CoSix), titanium silicide (TiSix), vanadium silicide (VSix), chrome silicide (CrSix), manganese silicide (MnSix), iron silicide (FeSix), ruthenium (Ru), molybdenum (Mo), titanium (Ti), titanium nitride (TiN), vanadium (V), chrome (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni),

gold (Au), silver (Ag) or copper (Cu), or can be formed of a compound of these materials. The conductive film 22 may be formed of polysilicon with the addition of impurities.

To pass through this laminated body 200 of the interlayer insulating film 21 and the conductive film 22, semiconductor layers 23 having the longitudinal direction in the lamination direction (Z direction) are disposed at a predetermined pitch in the XY plane. Between: the semiconductor layer 23; and the conductive film 22 and the interlayer insulating film 21, the memory film 24 including an electric charge accumulating layer is formed. As described later, the memory film 24 is formed along the sidewall of a trench formed to pass through the laminated body 200 and can be formed by a laminated structure of: an electric charge accumulating layer such as a silicon nitride film, and an oxide film such as a silicon oxide film. Depending on the accumulation amount of the electric charge to this electric charge accumulating layer, the threshold voltage of the memory cell MC changes. The memory cell MC holds data corresponding to this threshold voltage.

The semiconductor layers 23 function as the channel regions (body) of the memory cell MC, the dummy cells DMC1 and DMC2, and the selection transistors S1 and S2 that are included in the NAND cell unit NU. These semiconductor layers 23 are coupled, on their upper ends, to the bit lines BL via contacts Cb. The bit lines BL having the longitudinal direction in the Y direction are collocated at a predetermined pitch along the X direction.

The lower end of the semiconductor layer 23 is coupled to the local source line LSL formed on the semiconductor substrate SB. The local source line LSL is coupled to the global source line GSL via the source line contact LI. The laminated body 200 of the interlayer insulating film 21 and the conductive film 22 in the memory cell array 11 are separated by blocks as the smallest unit of data erasure. At the boundary of the separation, a trench Tb is formed. In this trench Tb, an interlayer insulating film (not illustrated) is implanted. Further, the source line contact LI described above is formed passing through the interlayer insulating film. Here, the local source lines LSL may be divided by blocks, or may be disposed in a stripe shape at a predetermined pitch to have the longitudinal direction in the Y direction, similarly to the bit lines BL.

FIG. 3A is an equivalent circuit diagram of one NAND cell unit NU. In this memory cell array 11, one NAND cell unit NU includes the memory string MS constituted of a plurality of the memory cells MC and dummy cells DMC1 and DMC2. The one NAND cell unit NU also includes the drain-side selection transistor S1 and the source-side selection transistor S2. The drain-side selection transistor S1 is coupled between the upper end of the memory string MS and the bit line BL. The source-side selection transistor S2 is coupled between the lower end of the memory string MS and the local source line LSL.

FIG. 3B illustrates one example of a specific structure of one of the memory cell MC and the dummy cell DMC. The semiconductor layer 23 includes an oxide-film core 26 and the semiconductor film 25 that surrounds the peripheral area of the oxide-film core 26. The oxide-film core 26 is formed of, for example, a silicon oxide film (SiO₂). The semiconductor film 25 is formed of, for example, silicon (Si), silicon-germanium (SiGe), silicon carbide (SiC), germanium (Ge), or carbon (C).

In the peripheral area of this semiconductor film 25, a tunnel insulating film 103, an electric charge accumulating layer 104, and a block insulating film 105 are formed as the memory film 24 to surround this semiconductor film 25. The tunnel insulating film 103 and the block insulating film 105

are constituted of, for example, silicon oxide films (SiOx). The electric charge accumulating layer 104 is constituted of, for example, a silicon nitride film (SiN), and has a function that traps electrons injected from the semiconductor film 25 via the tunnel insulating film 103 by a write operation. In this example, the tunnel insulating film 103 and the electric charge accumulating layer 104 are illustrated to be formed on the entire side surface of the semiconductor film 25. This, however, should not be construed in a limiting sense. The tunnel insulating film 103 and the electric charge accumulating layer 104 can be formed only on the side surface of the word line WL. The memory film 24 need not surround the semiconductor film 25 over the whole circumference (360°), and may have a structure that only surrounds a part of the semiconductor film 25. On the side surface of the block insulating film 105, the interlayer insulating film 21 and the conductive film 22 described above are alternately laminated.

Here, the materials of the tunnel insulating film 103 and the block insulating film 105 can employ, for example, Al₂O₃, Y₂O₃, La₂O₃, Gd₂O₃, Ce₂O₃, CeO₂, Ta₂O₅, HfO₂, ZrO₂, TiO₂, HfSiO, HfAlO, ZrSiO, ZrAlO, and AlSiO other than the silicon oxide film (SiOx).

The following describes the detail of the structures of the memory cell array 11 and the local source line LSL with reference to a cross-sectional view of FIG. 4. FIG. 4 is a cross-sectional view of the portion including the memory cell array 11 and the local source line LSL along the Y direction. This cross-section structure illustrated in FIG. 4 is repeatedly formed in the X direction.

As illustrated in FIG. 4, an element isolation insulating film 21B is implanted on the surface of the semiconductor substrate SB. On the surface of this element isolation insulating film 21B, a trench SH is formed. In the trench SH, the above-described local source line LSL is implanted. The local source line LSL has an end portion coupled to a source line contact LI, and is coupled to the global source line GSL via this source line contact LI.

Here, the trench SH is divided by blocks in this illustration example. This, however, should not be construed in a limiting sense. For example, the trenches SH may have stripe shapes (line shapes) that extend in the Y direction and are collocated at a predetermined pitch in the X direction, similarly to the bit line BL. Here, the width in the lamination direction (the Z direction) of the trench SH is set to be larger than the width of a memory hole MH in the X and Y directions.

On the upper side of the semiconductor substrate SB, that is, on the upper side of the local source line LSL, the interlayer insulating films 21 and the conductive films 22 are alternately laminated so as to form the laminated body 200. The conductive film 22 is a conductive film that functions as the word lines WL, the selection gate line SGS, or the selection gate line SGD, and is formed of, for example, a silicide film. The interlayer insulating film 21 is formed of, for example, silicon oxide.

As through-holes that pass through this laminated body 200 and reach the local source line LSL, the memory holes MH are formed in a matrix on the XY plane. In this memory hole MH, the above-described NAND cell unit NU is formed. Specifically, the memory film 24 (the tunnel insulating film 103, the electric charge accumulating layer 104, and the block insulating film 105) is formed along the inner wall of the memory hole MH. Further, the semiconductor film 25, which is the channel portion of the memory cell MC or similar member, and the oxide-film core 26 are formed along the memory film 24. The upper end of the semiconductor film 25 is coupled to the bit line BL via the contact Cb.

The local source line LSL includes a silicide film **27**. The silicide film **27** has an air gap AG inside. This air gap AG may be a simple air gap, or may be filled with another material such as a silicon oxide film. The outer periphery of the silicide film **27** in the local source line LSL is covered with a silicon film **25'** and the above-described memory film **24**. The memory film **24** is continuously formed without disconnection from the memory cell array side not only on the inner wall of the above-described memory hole MH but also on the inner wall of the trench SH.

Thus, the memory film **24** continues from the NAND cell unit NU without disconnection and reaches the local source line LSL, and is formed in the peripheral area of the silicide film **27** constituting the local source line LSL. This configuration eliminates the need for the process that etches and removes the memory film **24** formed in the bottom portion of the memory hole MH during formation of the NAND cell unit NU. Accordingly, the configuration of the device in the first embodiment allows reducing deterioration of the memory film **24**.

In the laminated body **200**, a trench ST is formed. The trench ST passes through the laminated body **200** and reaches the end portion of the trench SH. In this trench ST, the above-described source line contact LI is implanted via an interlayer insulating film **21'**.

Further, in the region of the memory cell array, trenches ST' are formed at approximately the same array pitch as the array pitch of the memory holes MH on both sides of the memory hole MH (the NAND cell unit NU). In this trench ST', an isolation insulating film **41** is implanted. In the local source line LSL, this isolation insulating film **41** passes through the memory film **24** and reaches the silicide film **27**. (Manufacturing Method)

The following describes a manufacturing method of this non-volatile semiconductor memory device of the first embodiment with reference to FIG. 5 to FIG. 15. Here, for ease of understanding, the dimensions of various members in FIG. 5 to FIG. 15 are set to be different from those in FIG. 4. Like reference numerals designate corresponding or identical elements throughout FIG. 4 to FIG. 15.

Firstly, as illustrated in FIG. 5, the element isolation insulating film **21B** is formed on the semiconductor substrate SB. Subsequently, the trench SH is formed on the surface of the element isolation insulating film **21B**. Then, in this trench SH, a sacrifice film SF, which is formed of a silicon nitride film (SiN), is implanted. Subsequently, the interlayer insulating films **21** (formed of, for example, silicon oxide films (SiO₂)) and conductive films **22'** (formed of, for example, polysilicon) are alternately deposited on the semiconductor substrate SB. Thus, the laminated body **200** is formed. The conductive film **22'** formed of, for example, polysilicon is silicidized in the subsequent process so as to be changed into the conductive film **22** formed of a silicide film as described later.

Subsequently, as illustrated in FIG. 6, the multiple memory holes MH are formed in a matrix on the XY plane so as to pass through the laminated body **200** and reach the trench SH. After the memory holes MH are formed, wet etching is performed to remove the sacrifice film SF.

Subsequently, as illustrated in FIG. 7, the above-described memory film **24** is formed along the inner walls of the memory holes MH and the trench SH. The memory film **24** is continuously formed without disconnection even at the boundary between the memory hole MH and the trench SH.

Subsequently, as illustrated in FIG. 8, a silicon film **25'** is deposited inside the memory holes MH and the trench SH via the memory film **24**. At this time, the film thickness of the

silicon film **25'** is adjusted such that the memory holes MH and the trench SH are not closed by the silicon film **25'** and leave air gaps inside them.

Subsequently, as illustrated in FIG. 9, the above-described oxide-film core **26** is formed inside the memory holes MH and the trench SH. The oxide-film core **26** closes the memory holes MH. In contrast, the trench SH with the width larger than that of the memory hole MH is not closed by this oxide film core **26**. The air gap AG is left inside the oxide-film core **26**.

Subsequently, as illustrated in FIG. 10, the trenches ST are formed. The trench ST passes through the laminated body **200** and reaches the end portion of the trench SH. The trench ST is formed to pass through the memory film **24**, the silicon film **25'** and the oxide-film core **26** that are already formed in the trench SH so as to reach the air gap AG left inside the oxide-film core **26**. Subsequently, wet etching is performed through this trench ST so as to remove the oxide-film core **26** formed inside the trench ST.

Subsequently, as illustrated in FIG. 11, the silicide film **27** with a high concentration of impurities (such as boron (B)) is formed along the silicon film **25'** inside the trench SH through the trench ST. In this state, a thermal process is performed such that the impurities in the silicide film **27** are diffused within the silicon film **25'**, so as to form the silicon film **25''** (diffusion layer) (see FIG. 12).

Subsequently, as illustrated in FIG. 13, the contact LI is formed in the trench ST. Subsequently, a plurality of trenches ST' are formed at approximately regular intervals along the Y direction. The trench ST' passes through the laminated body **200** and reaches the silicon film **25''** inside the trench SH. In this example, the trenches ST' are disposed at approximately the same array pitch as the array pitch of the memory holes MH so as to be sandwiched between the memory holes MH. This, however, should not be construed in a limiting sense.

After the trench ST' is formed, as illustrated in FIG. 14, a metal film **28** is deposited inside these trenches ST' and inside the trench SH. The metal film **28** is formed of, for example, nickel (Ni) or cobalt (Co). Subsequently, a silicidation process is performed to cause a reaction between the metal film **28** and the silicon film **25''** so as to form the silicide film **27** (see FIG. 15). Here, in the trench SH, a part of the silicon film **25''** is preferred not to be silicidized so as to be left as a silicon film. The left silicon film **25''** (diffusion layer) functions as a source/drain diffusion layer of the selection transistor S2, and is located between the memory film **24** and the silicide film **27**. By this silicidation process, polysilicon constituting the conductive film **22'** is also changed into the conductive film **22** formed of a silicide film.

After the silicidation process is terminated, the metal film **28** left in the trench ST' is removed by etching. The isolation insulating film **41** formed of a silicon oxide film or similar film is implanted in the trench ST' (see FIG. 4). Since the trench ST' is formed as described above, the isolation insulating film **41** is finally formed in the shape that passes through the memory film **24** and reaches the silicide film **27**. Subsequently, upper-layer wiring is formed with a known method so as to complete the structure in FIG. 4. (Effects)

As described above, the non-volatile semiconductor memory device of the first embodiment includes the local source line LSL, which is coupled to the lower end of the NAND cell unit NU formed in the memory hole MH. This local source line LSL includes the silicide film **27** having the hollow portion inside. The peripheral area of the local source line LSL is covered with the memory film **24** continuously

formed from the inside the NAND cell unit NU. The presence of the silicide film 27 causes reduction in resistance value of the local source line LSL.

Further, the memory film 24 is continuously formed from the memory cell array. Accordingly, after the memory film 24 is formed in the memory hole MH, it is not necessary to perform etching for peeling off the memory film 24 in the bottom portion (near the contact point between the memory hole MH and the trench SH) of the memory hole MH. This allows reducing the deterioration of the memory film 24, so as to improve the operating characteristics of the memory cell.

Second Embodiment

The following describes the non-volatile semiconductor memory device according to a second embodiment with reference to FIG. 16. The overall configuration of the device is approximately the same as that of the first embodiment. However, this second embodiment differs from the first embodiment (FIG. 4) in the cross-section structure of the memory cell array. Like reference numerals designate corresponding or identical configurations the first embodiment and FIG. 16, and therefore such configurations will not be further elaborated here.

As illustrated in FIG. 16, in the second embodiment, the array pitch of the trenches ST', which pass through the laminated body 200 and reach the trench SH, is doubled compared with the first embodiment. In other words, while the trench ST' is disposed on both sides of each memory hole MH in the first embodiment, the trench ST' is arranged only on one side of each memory hole MH in this second embodiment.

Instead, in the position where the trench ST' is omitted, a trench ST2 and a trench ST3 are disposed. The trench ST2 is formed for separating only the selection gate lines SGD (the conductive films 22 in the uppermost layer), which are coupled to the drain-side selection transistors S1, inside the laminated body 200. The trench ST3 is formed for separating only the selection gate lines SGS (the conductive films 22 in the lowermost layer), which are coupled to the source-side selection transistors S2, inside the laminated body 200. That is, the trench ST' and the trench ST2 (or ST3) are alternately disposed in the Y direction. Here, in the trenches ST', ST2, and ST3, respective isolation insulating films 41, 42, and 43 formed of silicon oxide films or similar film are implanted.

The following describes a manufacturing method of the non-volatile semiconductor memory device of this second embodiment with reference to FIG. 17 to FIG. 20.

Firstly, the trench SH and the sacrifice film SF are formed similarly to the first embodiment. Subsequently, on this trench SH, one interlayer insulating film 21 and one conductive film 22 for the source-side selection gate line SGS are deposited. Subsequently, the trenches ST3 are formed at approximately regular intervals. In the trench ST3, the isolation insulating film such as a silicon oxide film is implanted.

Subsequently, as illustrated in FIG. 18, the interlayer insulating films 21 and the conductive films 22 are alternately deposited so as to form the laminated body 200. Subsequently, as illustrated in FIG. 19, in the conductive film 22 in the uppermost layer, that is, the conductive film 22 for the drain-side selection gate line SGD, the trenches ST2 are formed at regular intervals from the trenches ST3 and immediately above the trenches ST3. Also in the trench ST2, the isolation insulating film is implanted.

Subsequently, similarly to the first embodiment, the memory holes MH are formed so as to form the NAND cell units NU in the similar manner of the first embodiment. Subsequently, as illustrated in FIG. 21, the trenches ST' are

formed so as to form the local source line LSL with the same method as that of the first embodiment. The other processes are similar to those in the first embodiment.

This second embodiment allows obtaining the same effects as those in the first embodiment.

OTHERS

While certain embodiments of the inventions have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

FIG. 1

LAMINATION DIRECTION

Y (BIT DIRECTION)

X (BIT DIRECTION)

What is claimed is:

1. A non-volatile semiconductor memory device, comprising:

a memory cell array including NAND cell units arranged therein, the NAND cell unit being configured to extend in a first direction vertical to a surface of a semiconductor substrate, the NAND cell unit being formed by coupling a plurality of memory cells and selection transistors in series; and

a local source line formed on the semiconductor substrate, the local source line being electrically coupled to one end of the NAND cell unit, wherein

the memory cell array includes:

a laminated body where a plurality of conductive films are laminated sandwiching an interlayer insulating film, the conductive film being a control gate line of the memory cell or a selection gate line of the selection transistor;

a semiconductor layer that extends in the first direction; and

an electric charge accumulating layer sandwiched between the semiconductor layer and the conductive film,

the local source line includes a silicide layer, and the electric charge accumulating layer is continuously formed from the memory cell array to cover a whole of a peripheral surface of the silicide layer.

2. The non-volatile semiconductor memory device according to claim 1, further comprising

an element isolation insulating film that extends in the first direction to separate a plurality of the conductive films in a position between a plurality of the NAND cell units, and

one end of the element isolation insulating film reaches the silicide layer.

3. The non-volatile semiconductor memory device according to claim 2, wherein

the element isolation insulating film includes:

a first element isolation insulating film that separates only the conductive films to be the selection gate lines of the selection transistors; and

a second element isolation insulating film that separates both the selection gate lines of the selection transistors and the control gate lines of the memory cells.

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- 4. The non-volatile semiconductor memory device according to claim 3, wherein the first element isolation insulating film and the second element isolation insulating film are alternately disposed along a second direction intersecting with the first direction. 5
- 5. The non-volatile semiconductor memory device according to claim 1, wherein the local source line is coupled to one end of a source-side contact that extends in the first direction, and another end of the source-side contact is coupled to a global source line. 10
- 6. The non-volatile semiconductor memory device according to claim 5, further comprising: an isolation insulating film that extends in the first direction to separate a plurality of the conductive films in a position between a plurality of the NAND cell units, and one end of the isolation insulating film reaches the silicide layer. 15
- 7. The non-volatile semiconductor memory device according to claim 6, wherein

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- the isolation insulating film includes:
 - a first isolation insulating film that separates only the conductive films to be the selection gate lines of the selection transistors; and
 - a second isolation insulating film that separates both the selection gate lines of the selection transistors and the control gate lines of the memory cells.
- 8. The non-volatile semiconductor memory device according to claim 7, wherein the first isolation insulating film and the second isolation insulating film are alternately disposed along a second direction intersecting with the first direction.
- 9. The non-volatile semiconductor memory device according to claim 1, wherein the silicide layer has a hollow portion inside.
- 10. The non-volatile semiconductor memory device according to claim 1, wherein the local source line includes a diffusion layer between the electric charge accumulating layer and the silicide layer.

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