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Nakajima et al.

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(54) **SEMICONDUCTOR DEVICE AND METHOD OF MANUFACTURING THE SAME**

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H01L 23/532	(2006.01)
H01L 23/535	(2006.01)
H01L 27/11556	(2017.01)
H01L 27/11582	(2017.01)

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

CPC ***H01L 23/5226*** (2013.01); ***H01L 23/535*** (2013.01); ***H01L 23/53295*** (2013.01); *H01L 27/11556* (2013.01); *H01L 27/11582* (2013.01)

(58) **Field of Classification Search**

CPC H01L 23/5226; H01L 23/535; H01L 27/11556; H01L 27/11582

See application file for complete search history.

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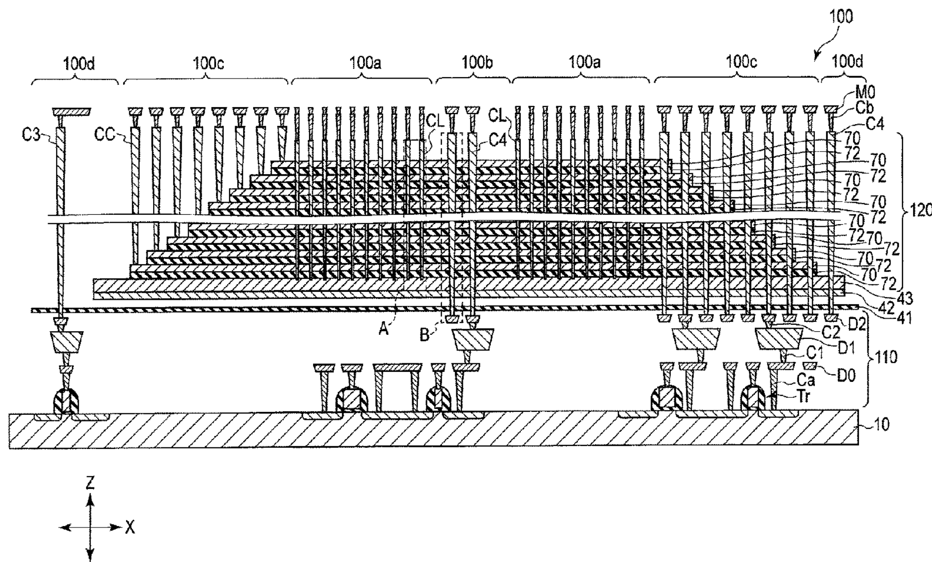
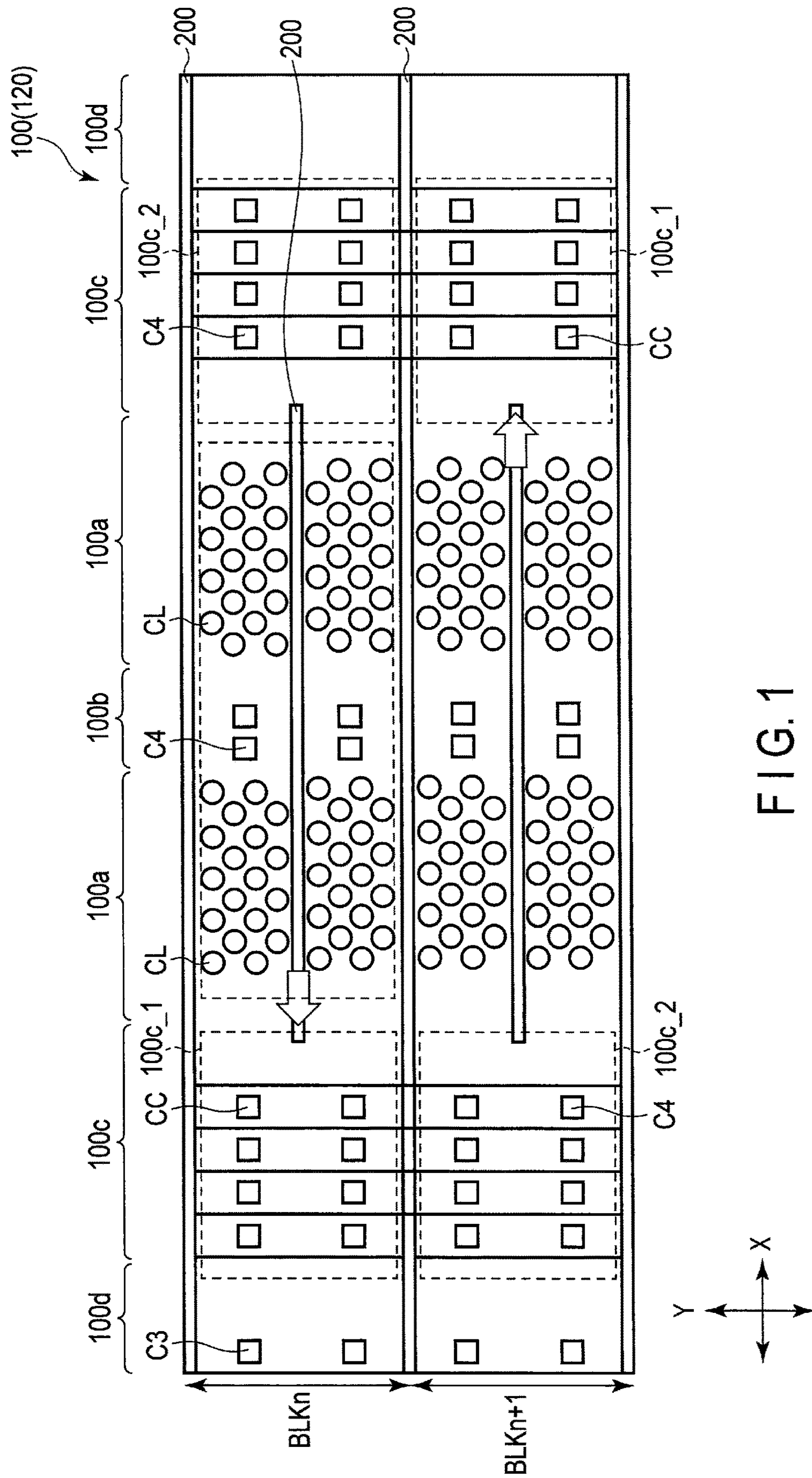
(57) **ABSTRACT**

According to one embodiment, a semiconductor device includes a substrate, an interconnect layer, a layer stack, and a first silicon nitride layer. The interconnect layer includes a transistor provided on the substrate and a first interconnect electrically coupled to the transistor and is provided above the transistor. The layer stack is provided above the interconnect layer and includes conductive layers stacked with an insulation layer interposed between two of conductive layers of each pair of conductive layers. The first silicon nitride layer is provided between the interconnect layer and the layer stack.

15 Claims, 34 Drawing Sheets





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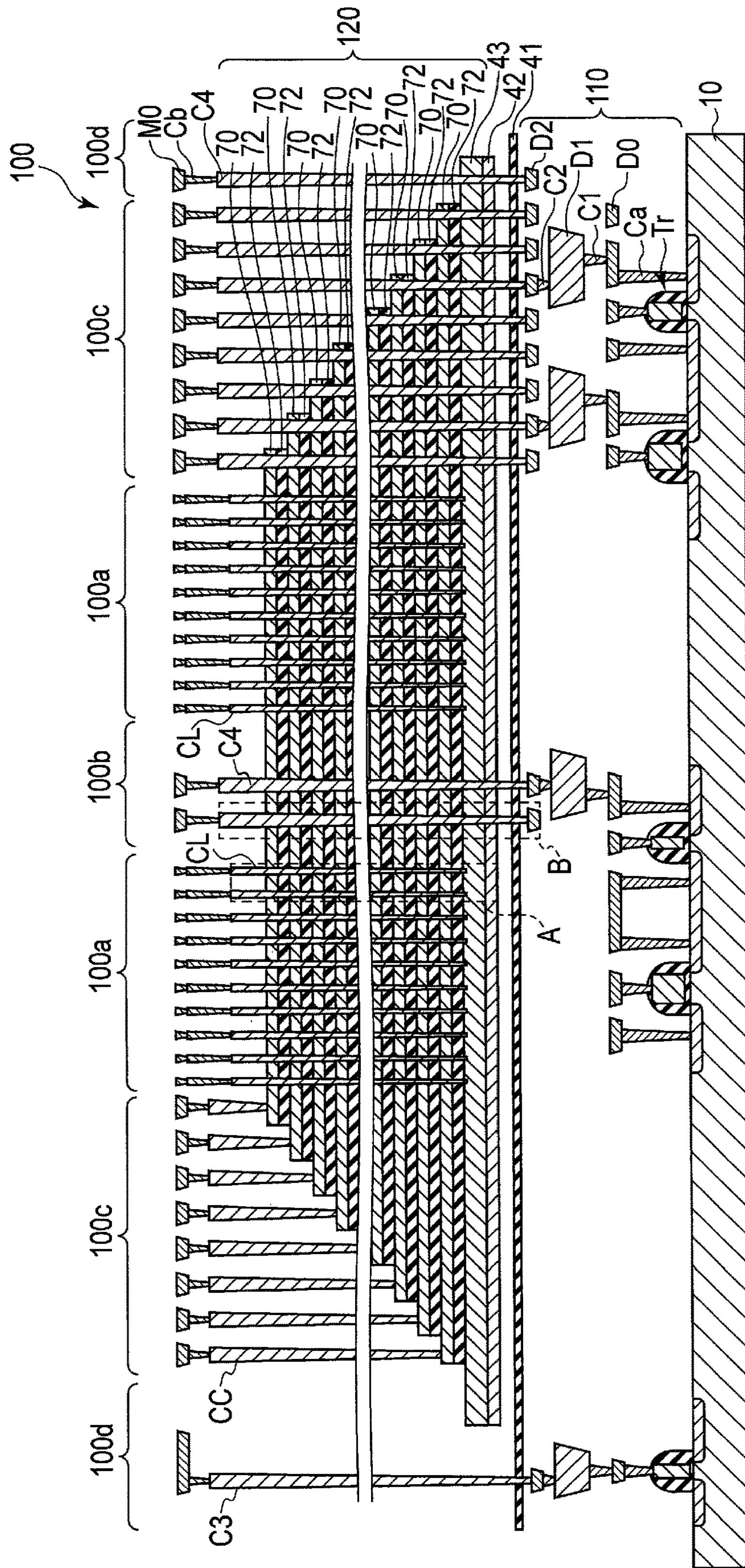

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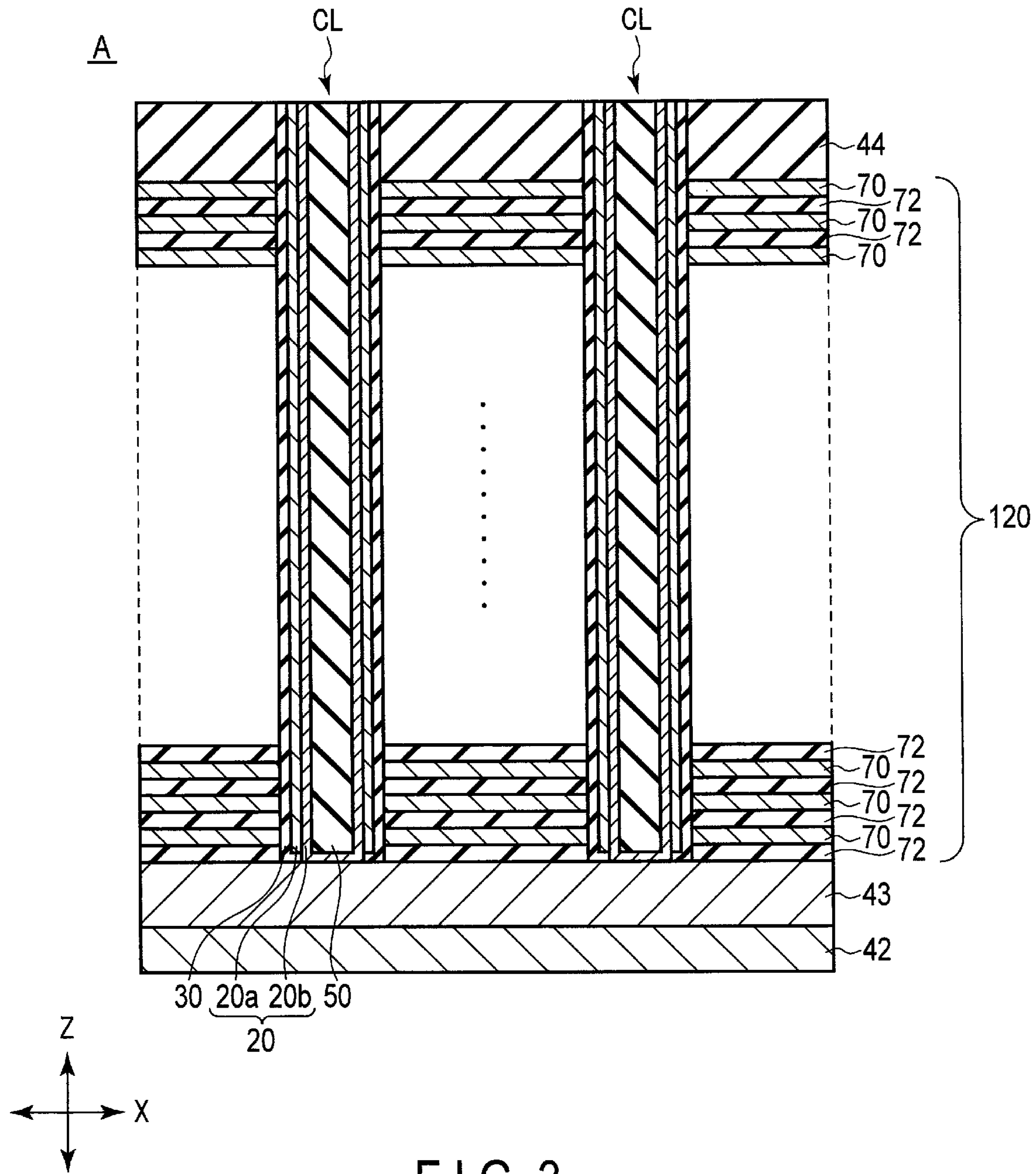

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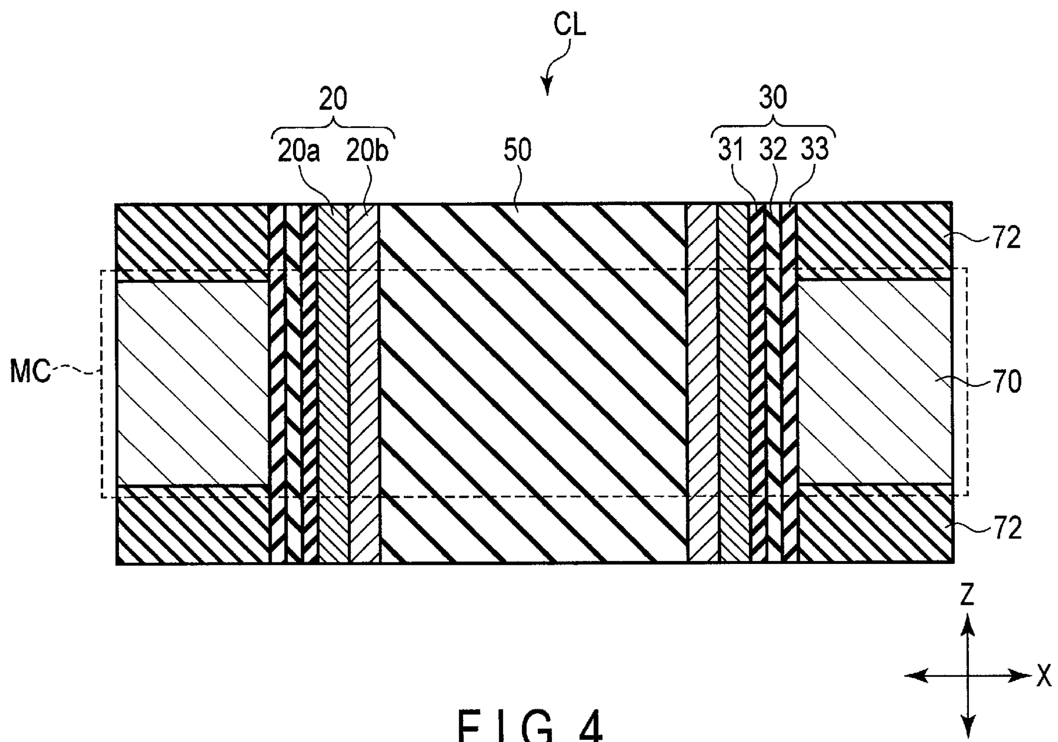

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B

C4 Cb 64 44 70 72 70 72 70 82 81 120 72 70 72 70 72 70 72 43 63 42 62 41 61 D2 Z X

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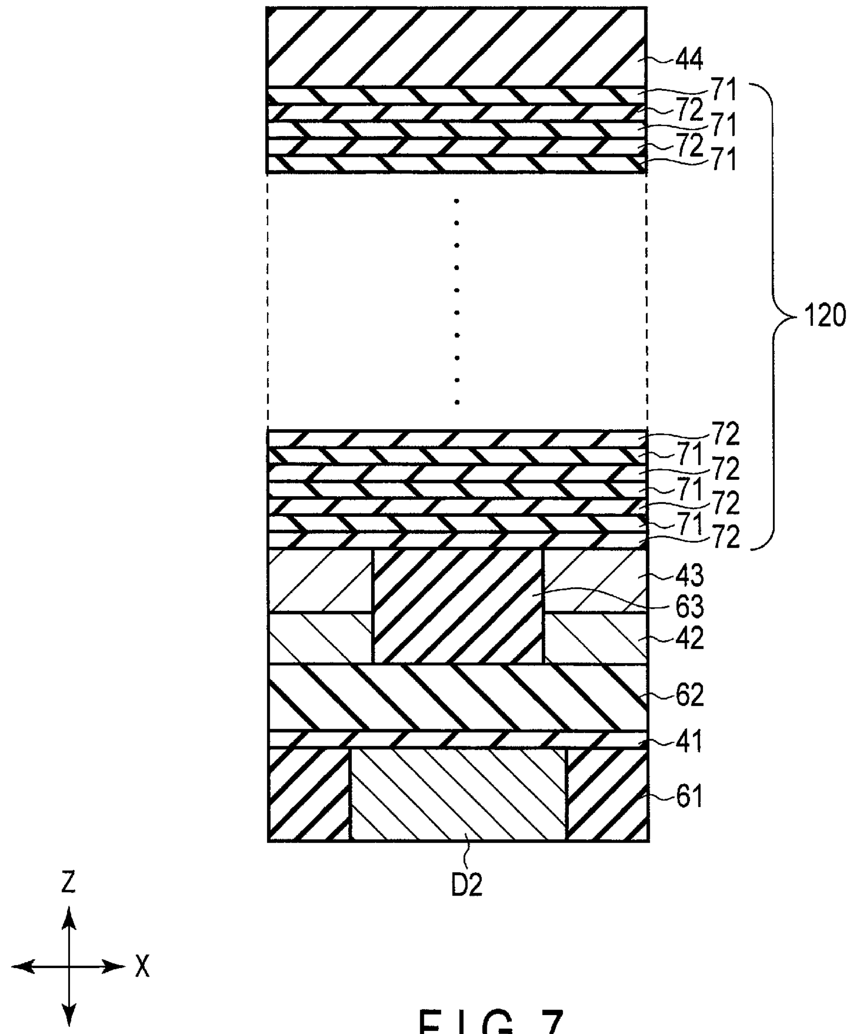

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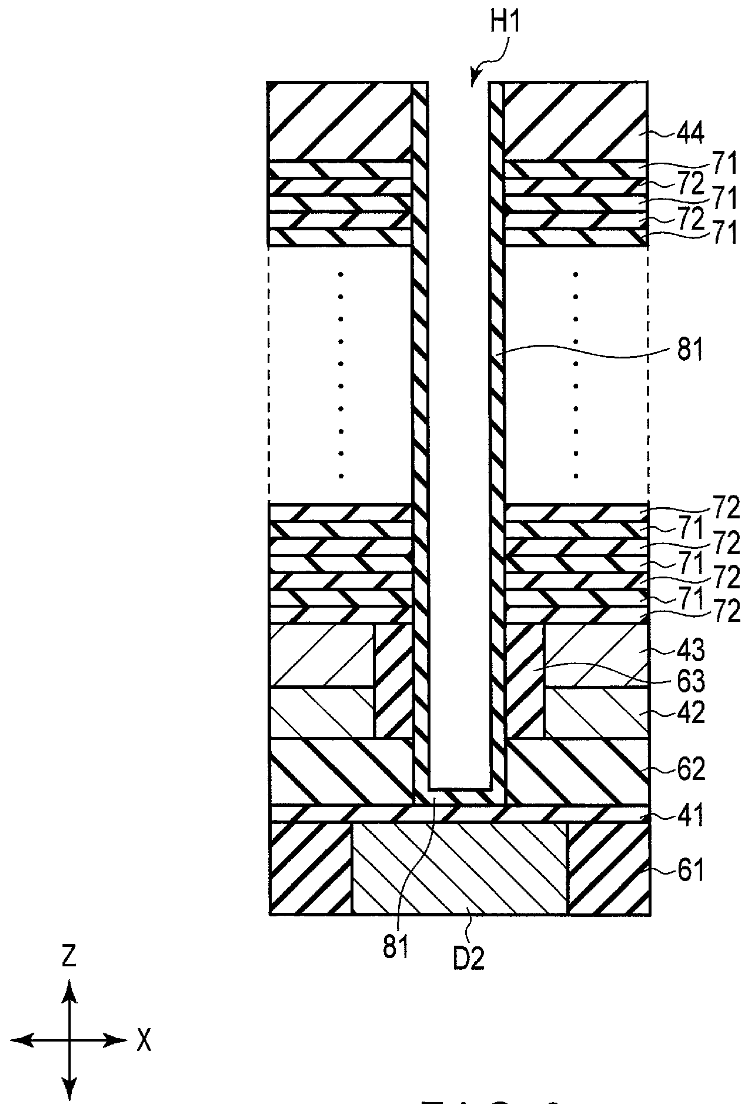

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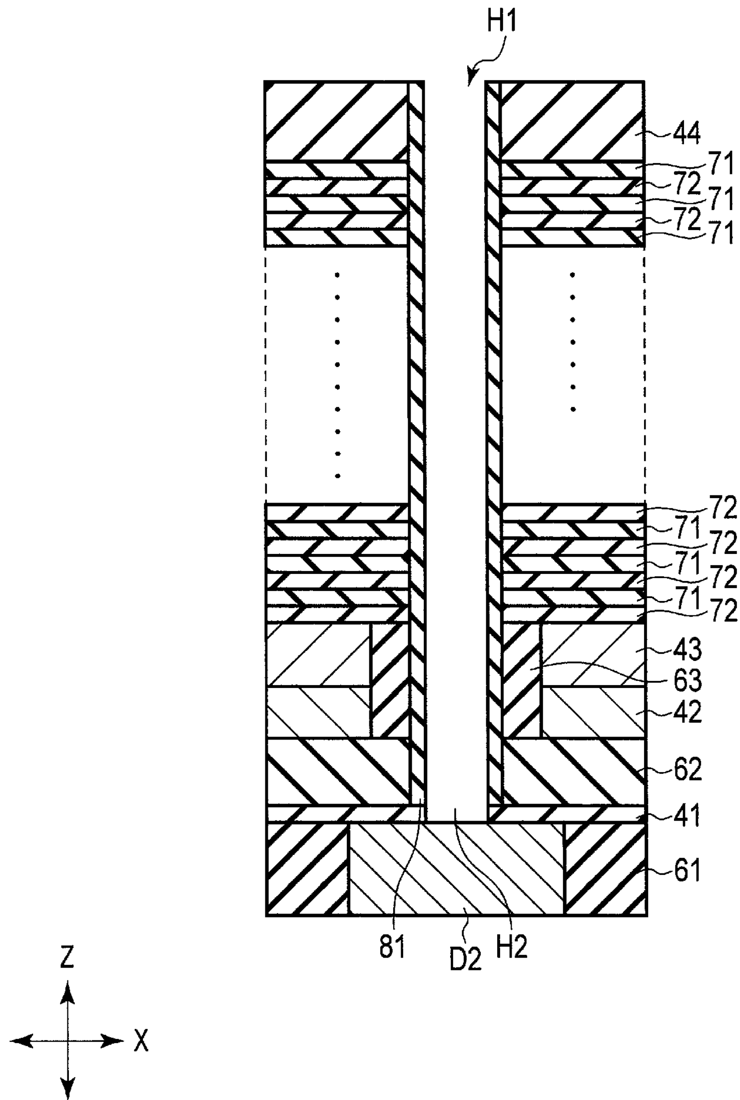

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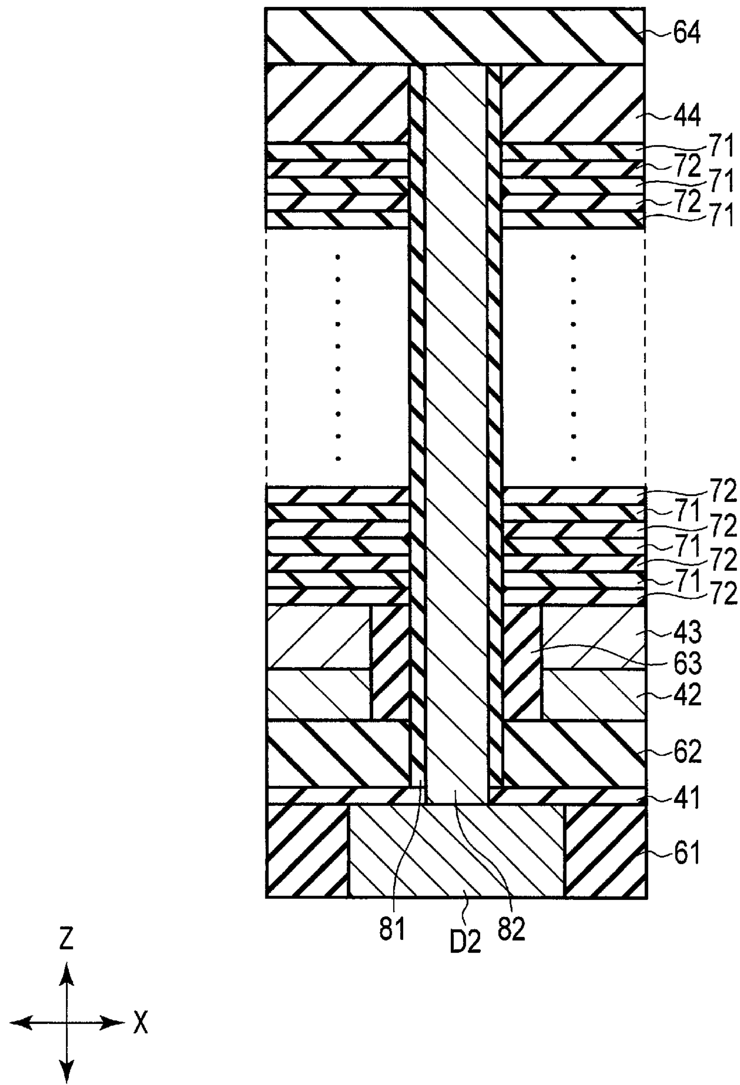

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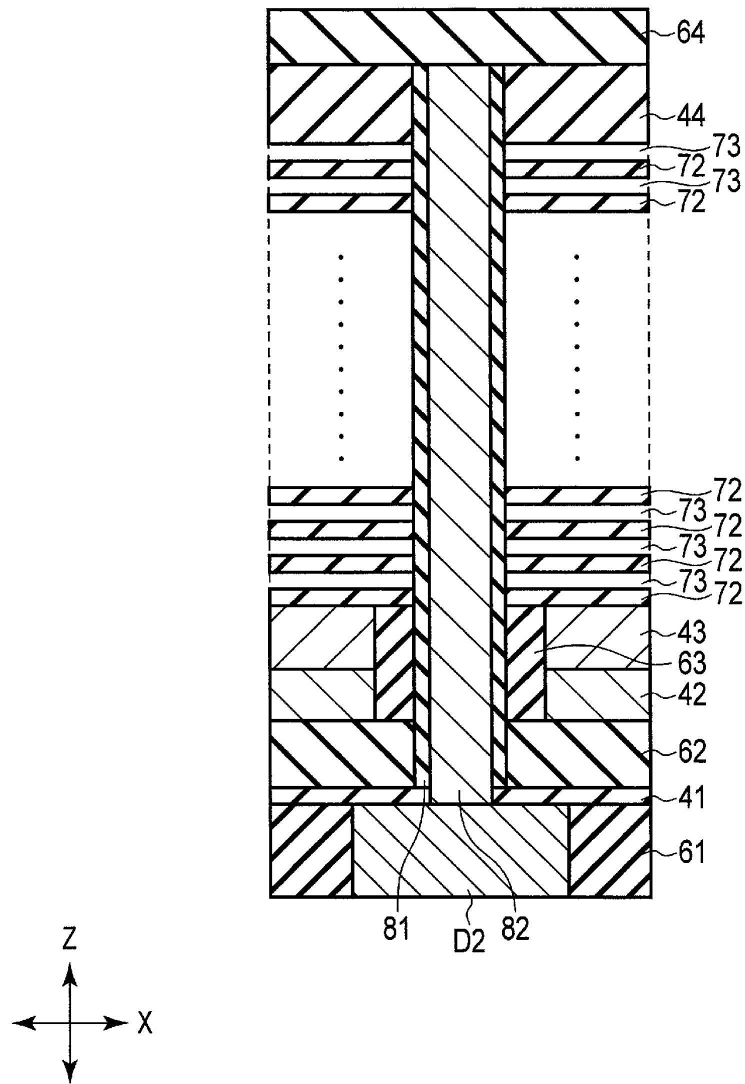

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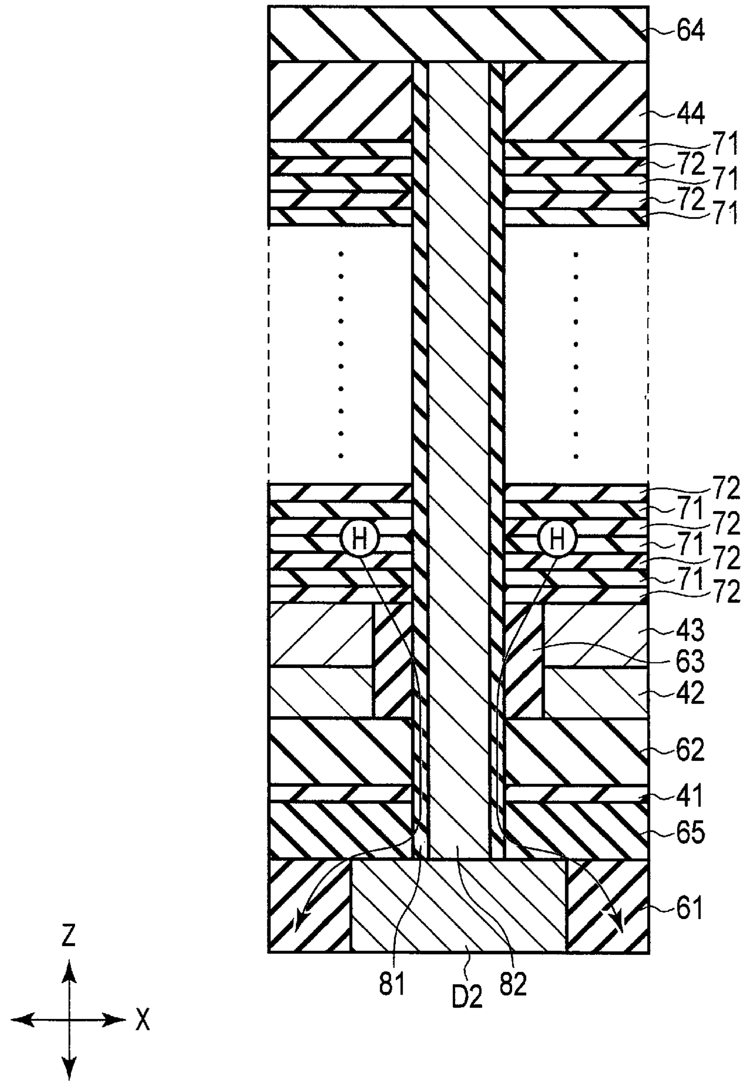
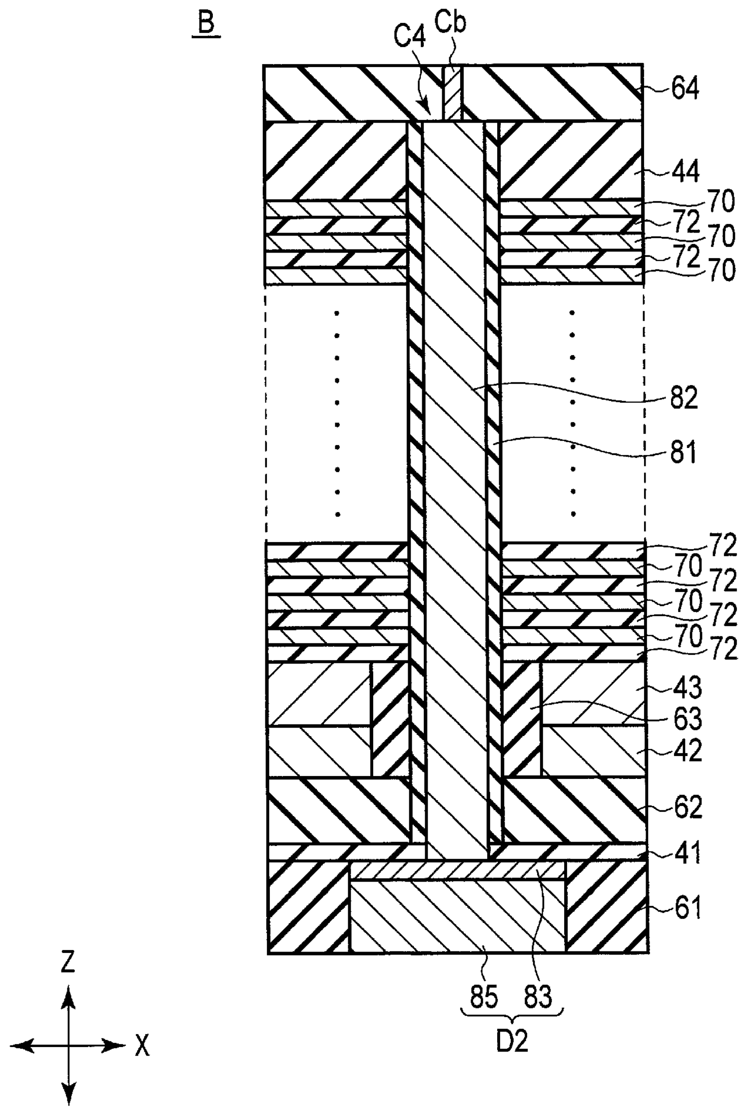


FIG. 13



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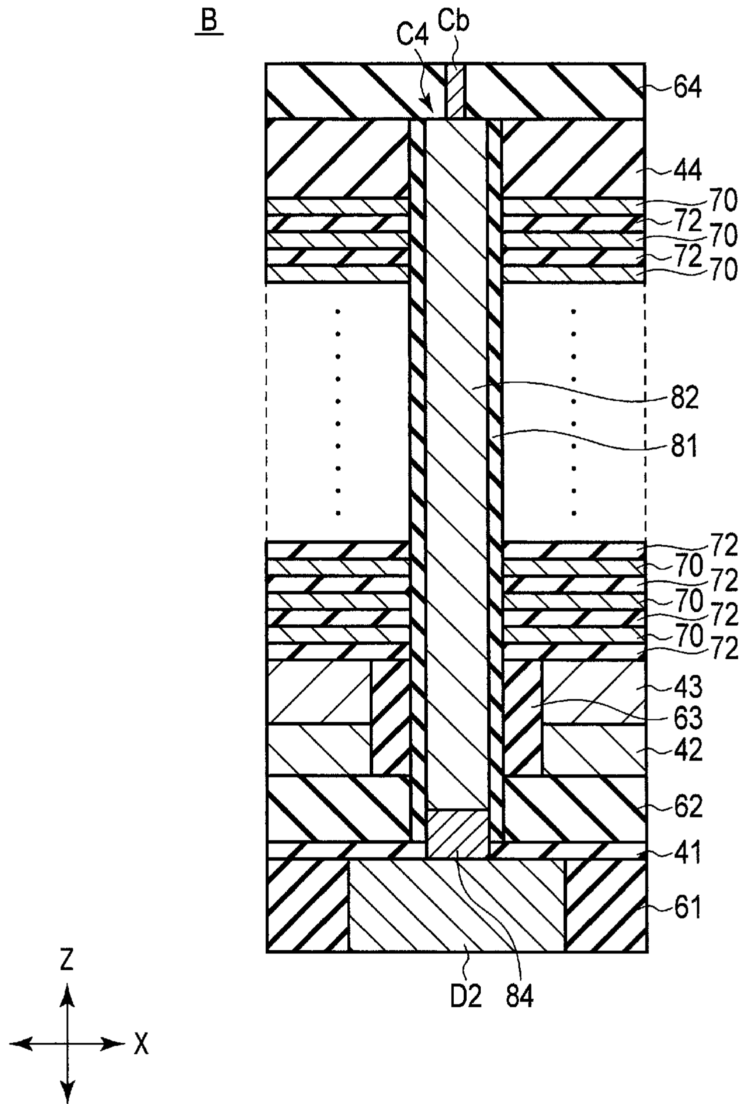
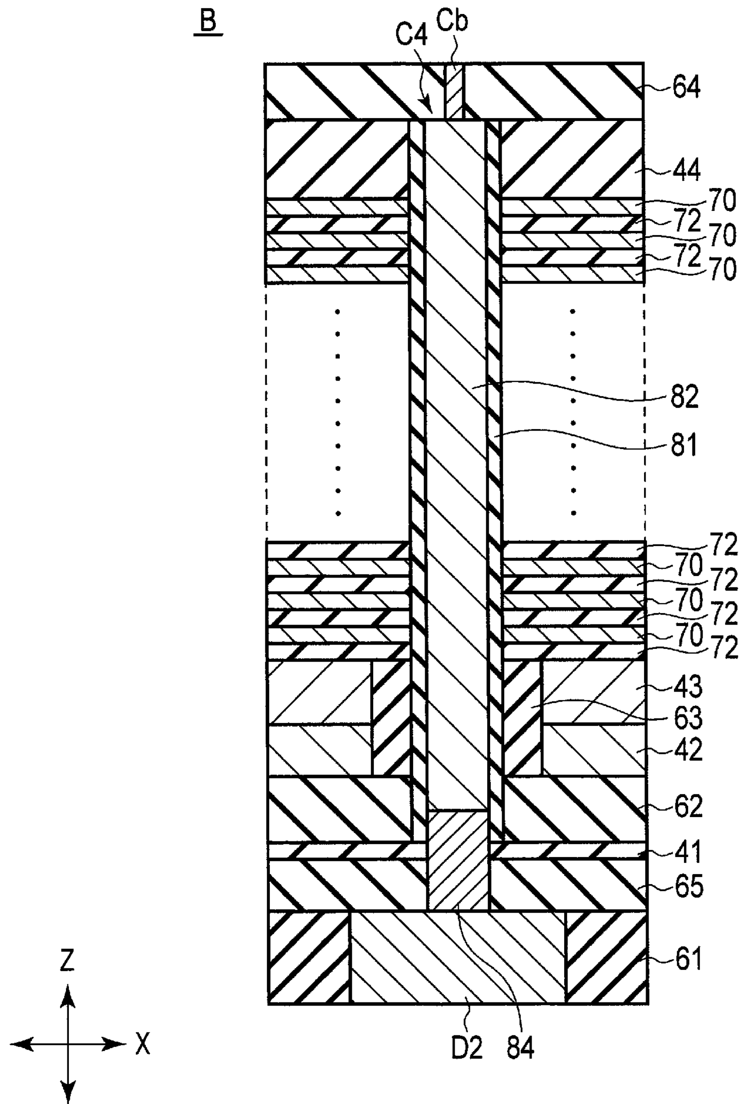


FIG. 15



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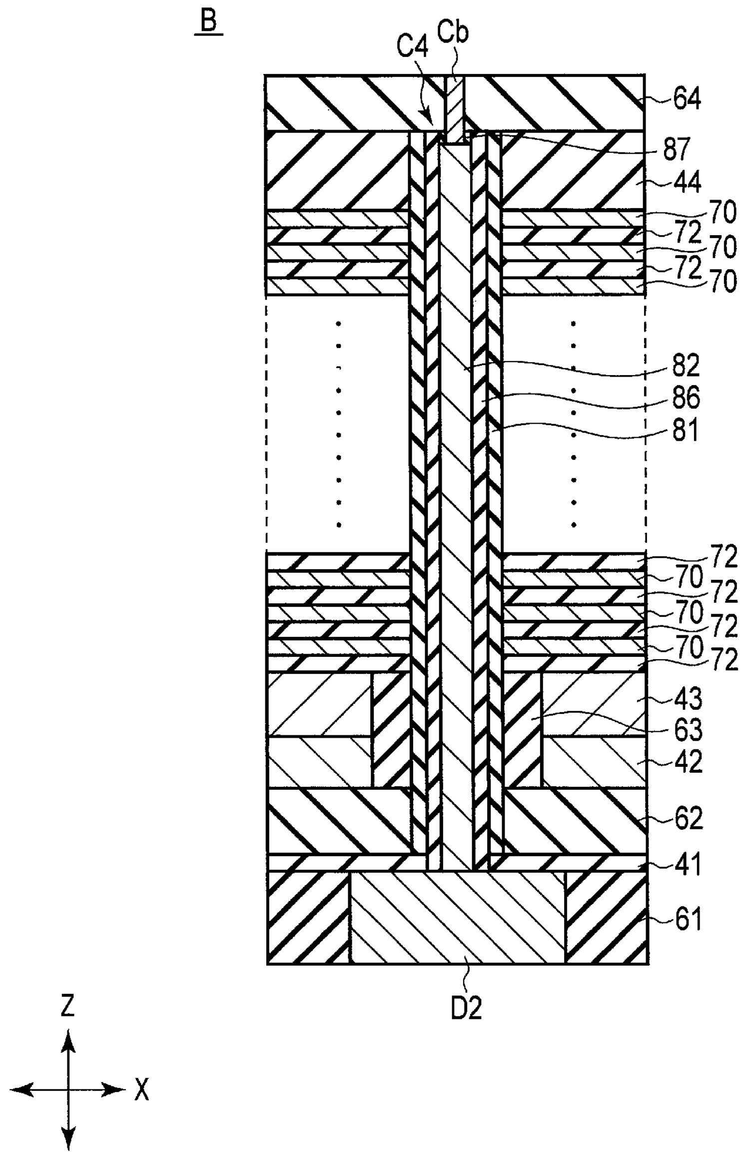

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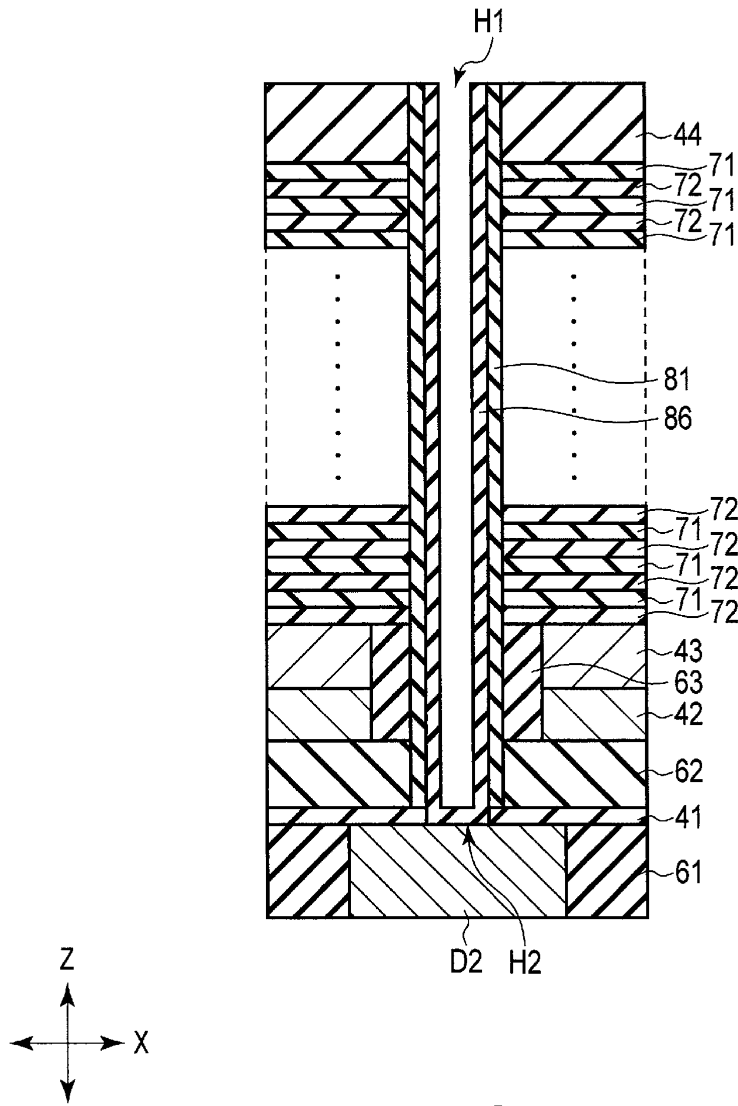

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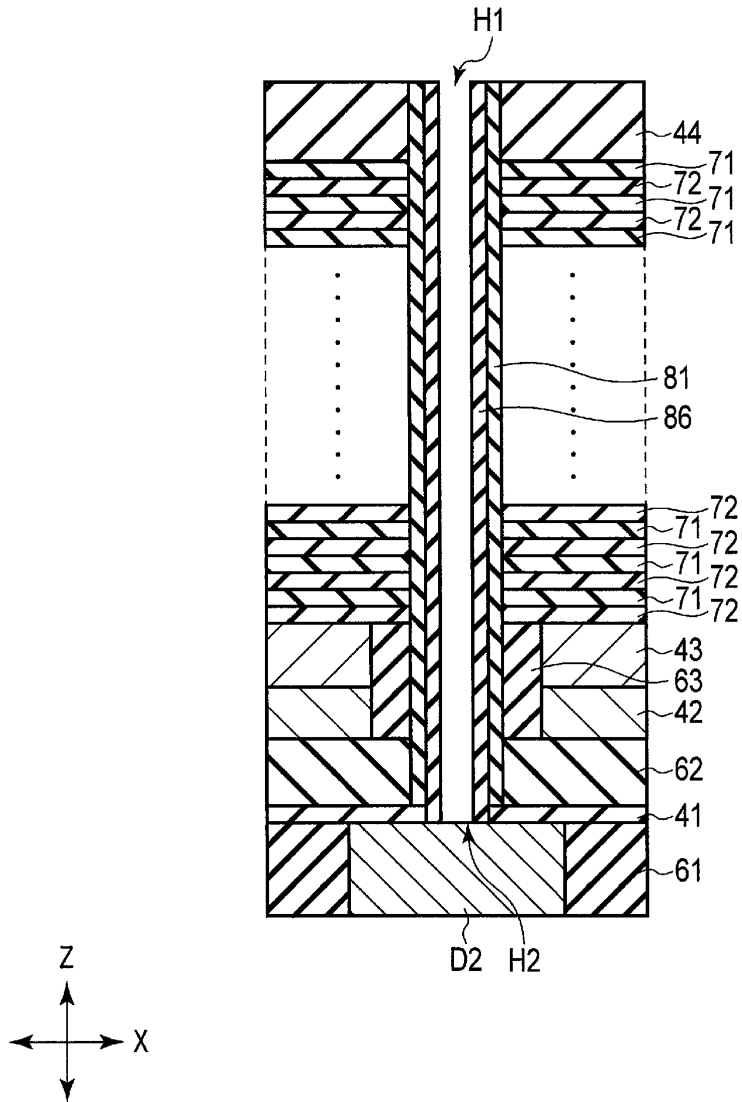

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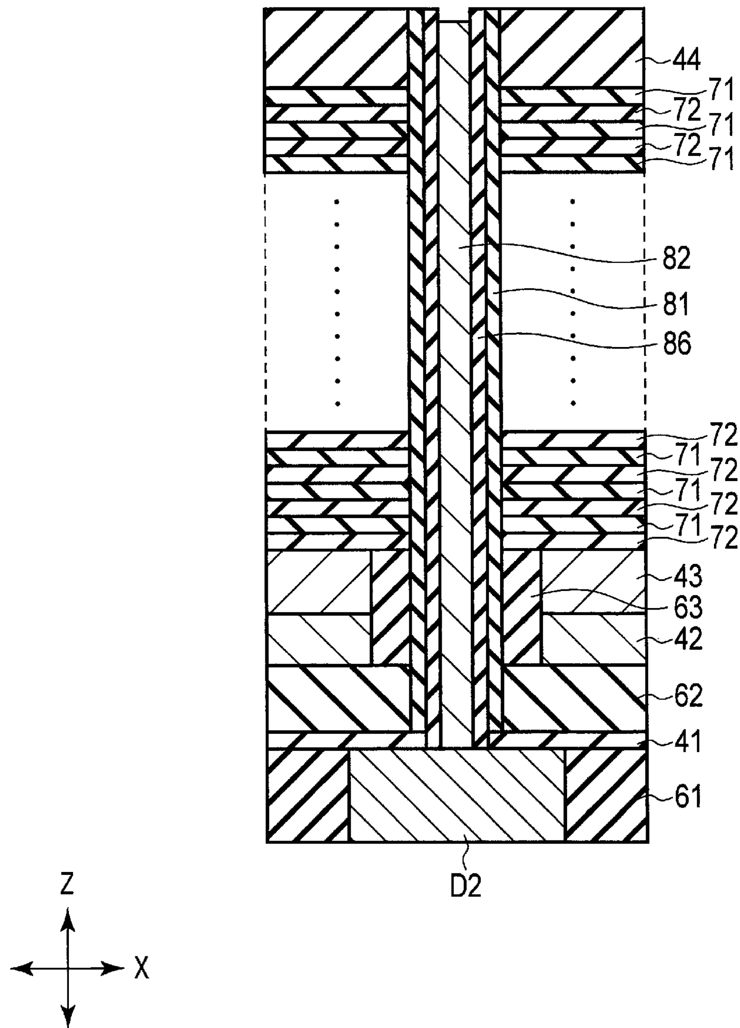

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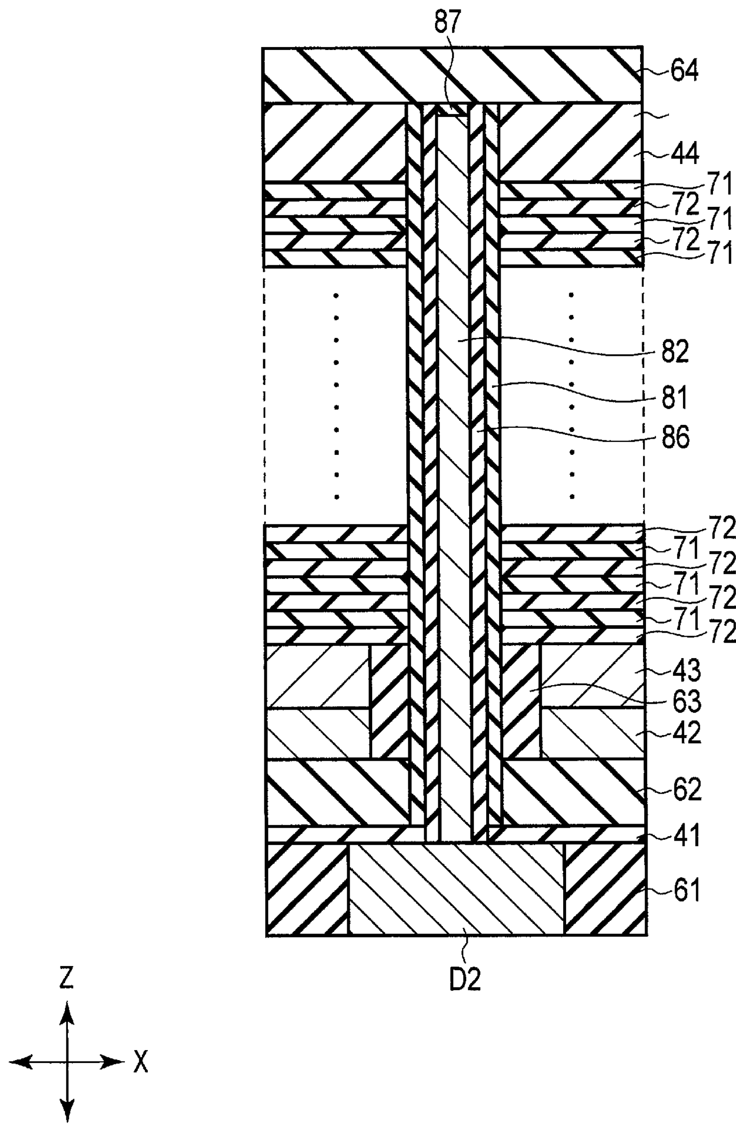

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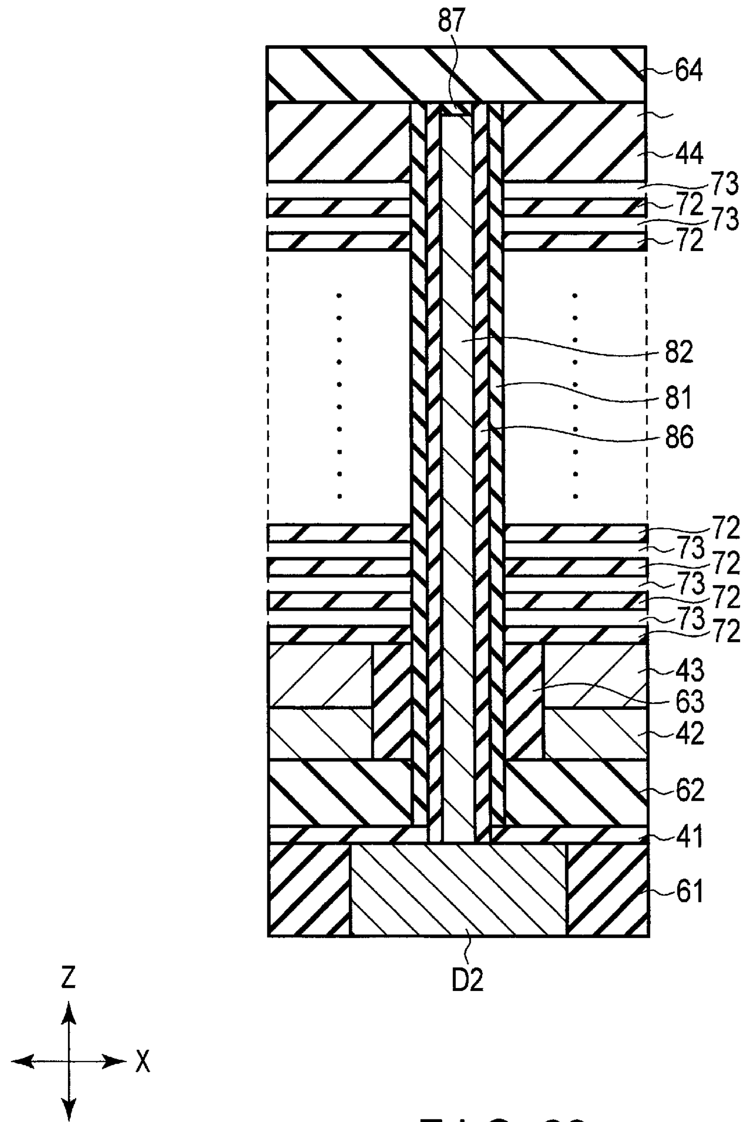

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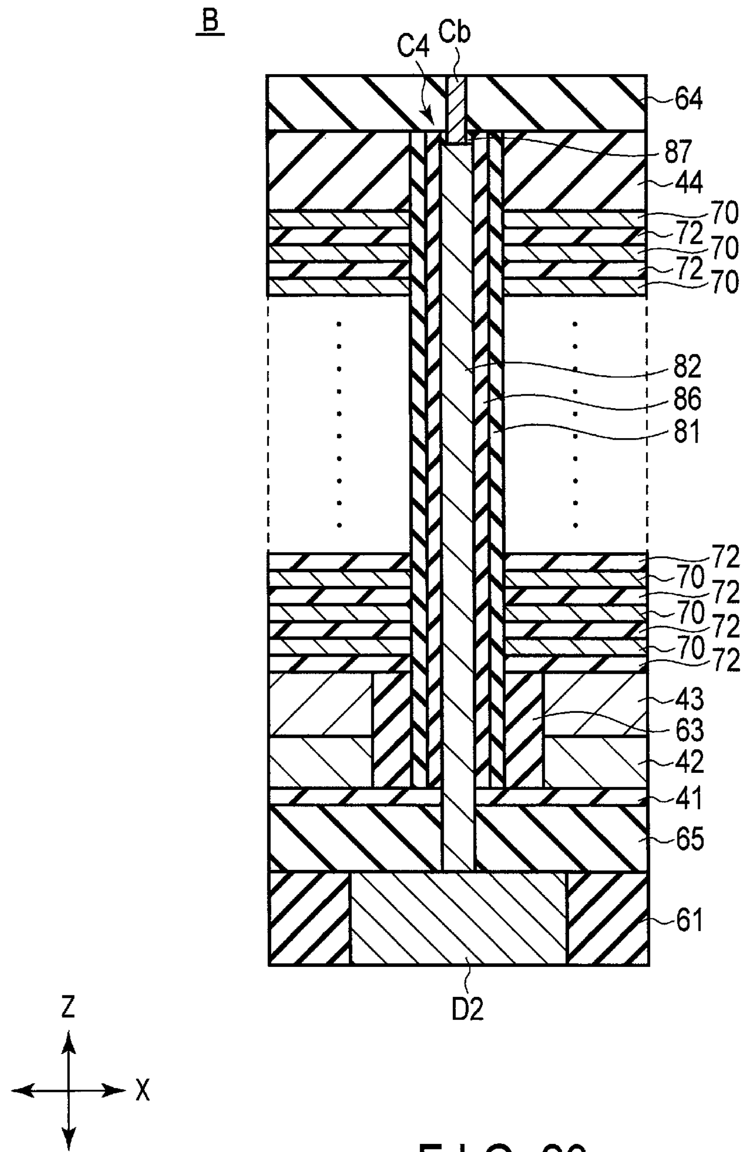

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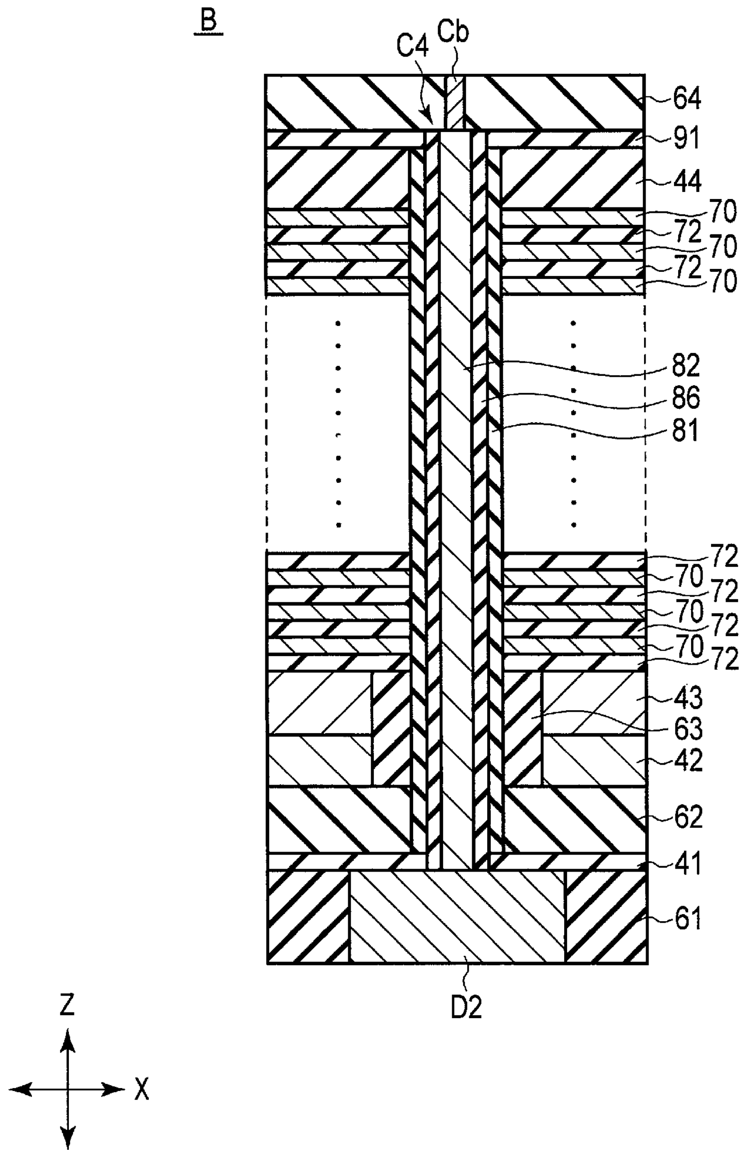

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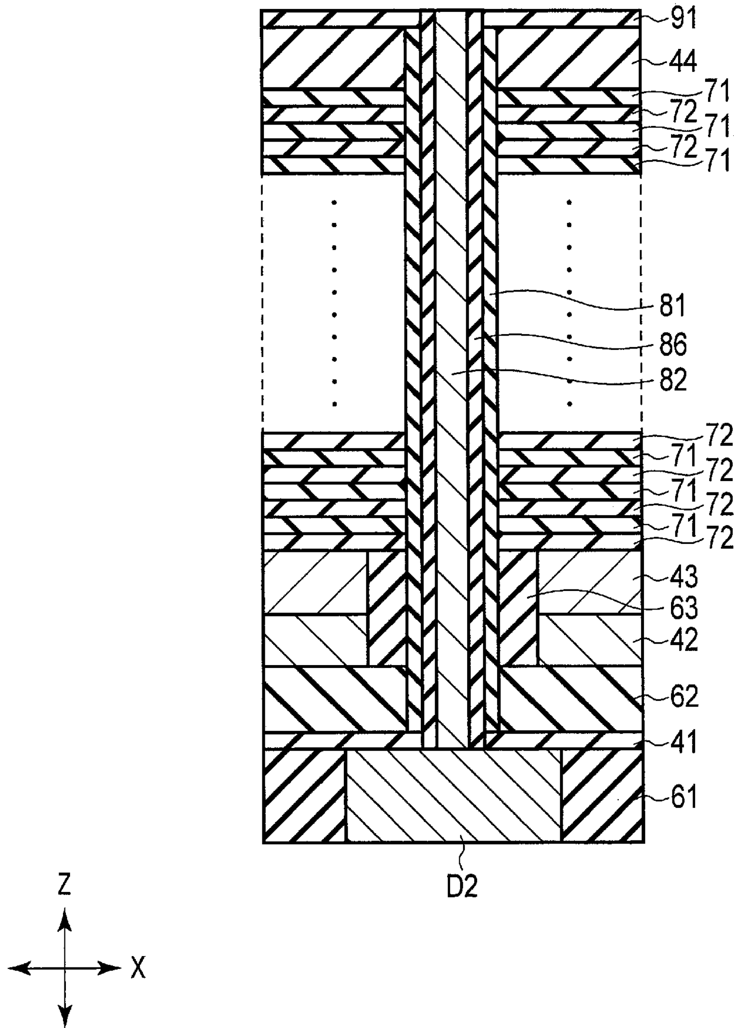

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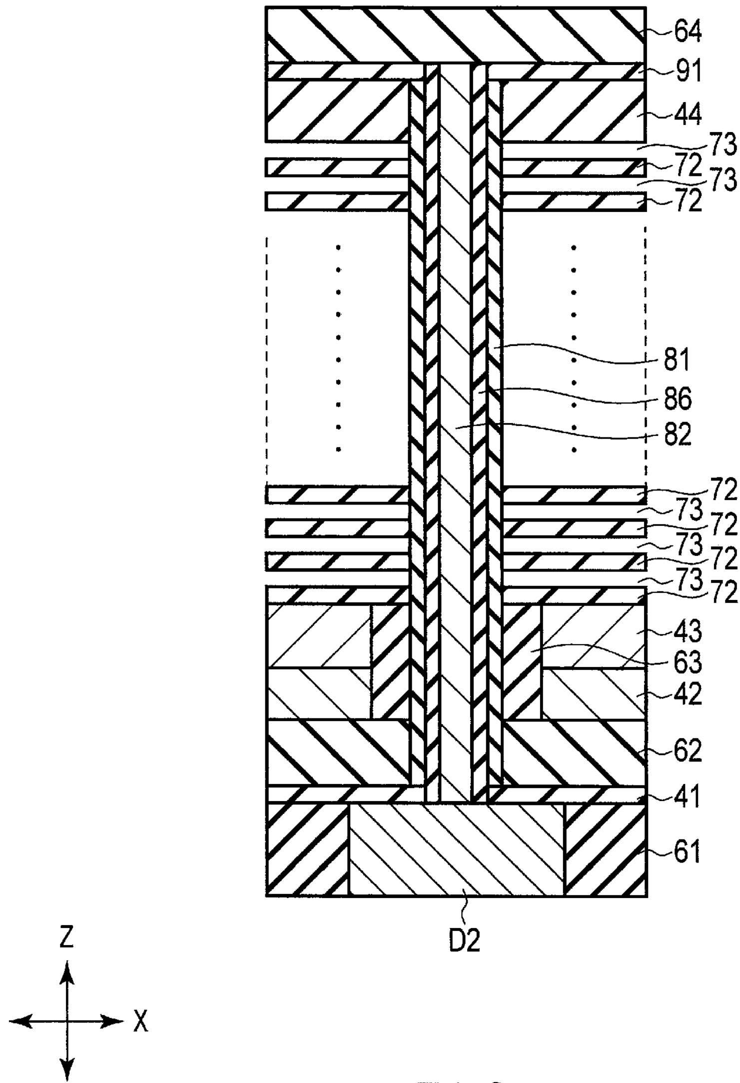

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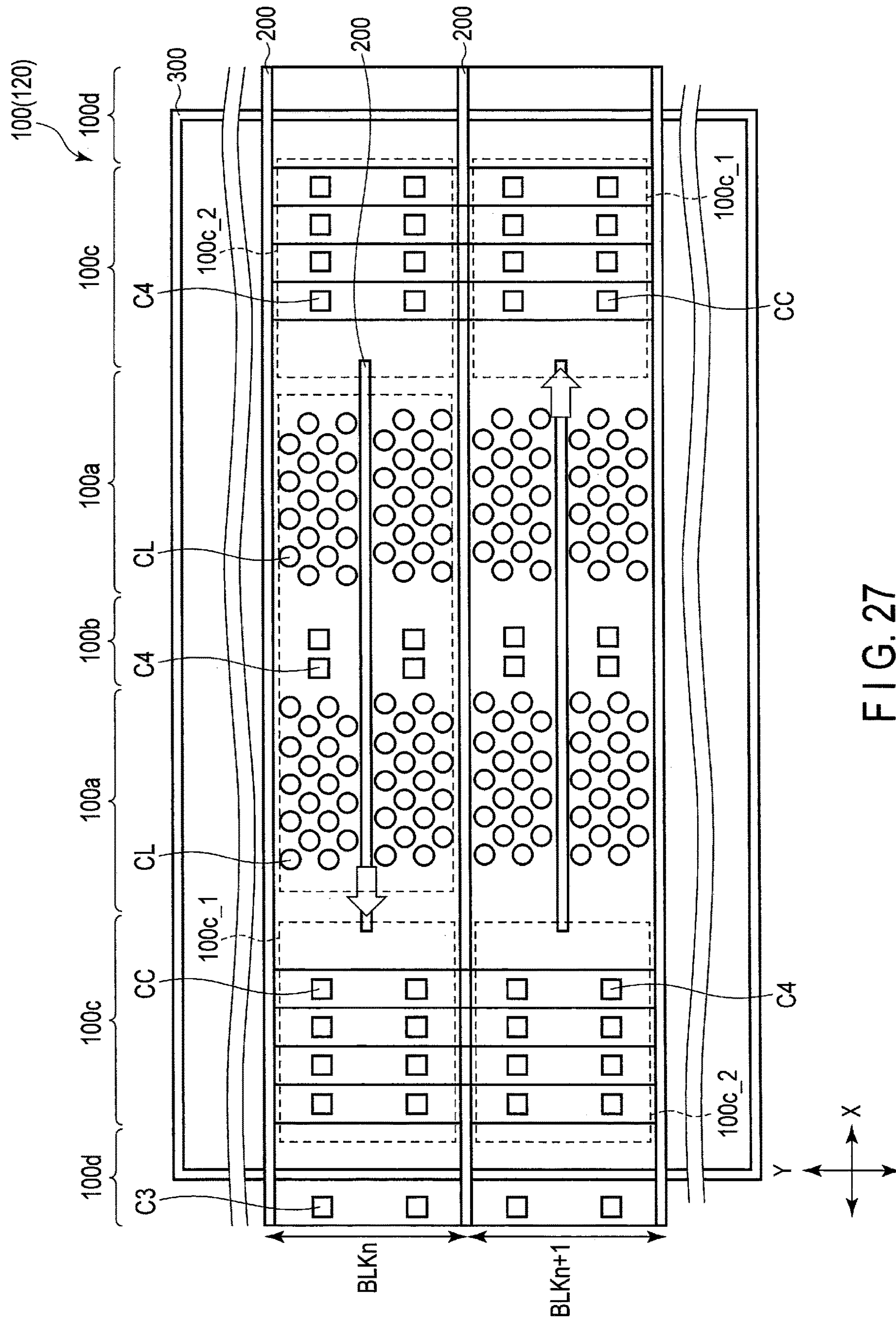
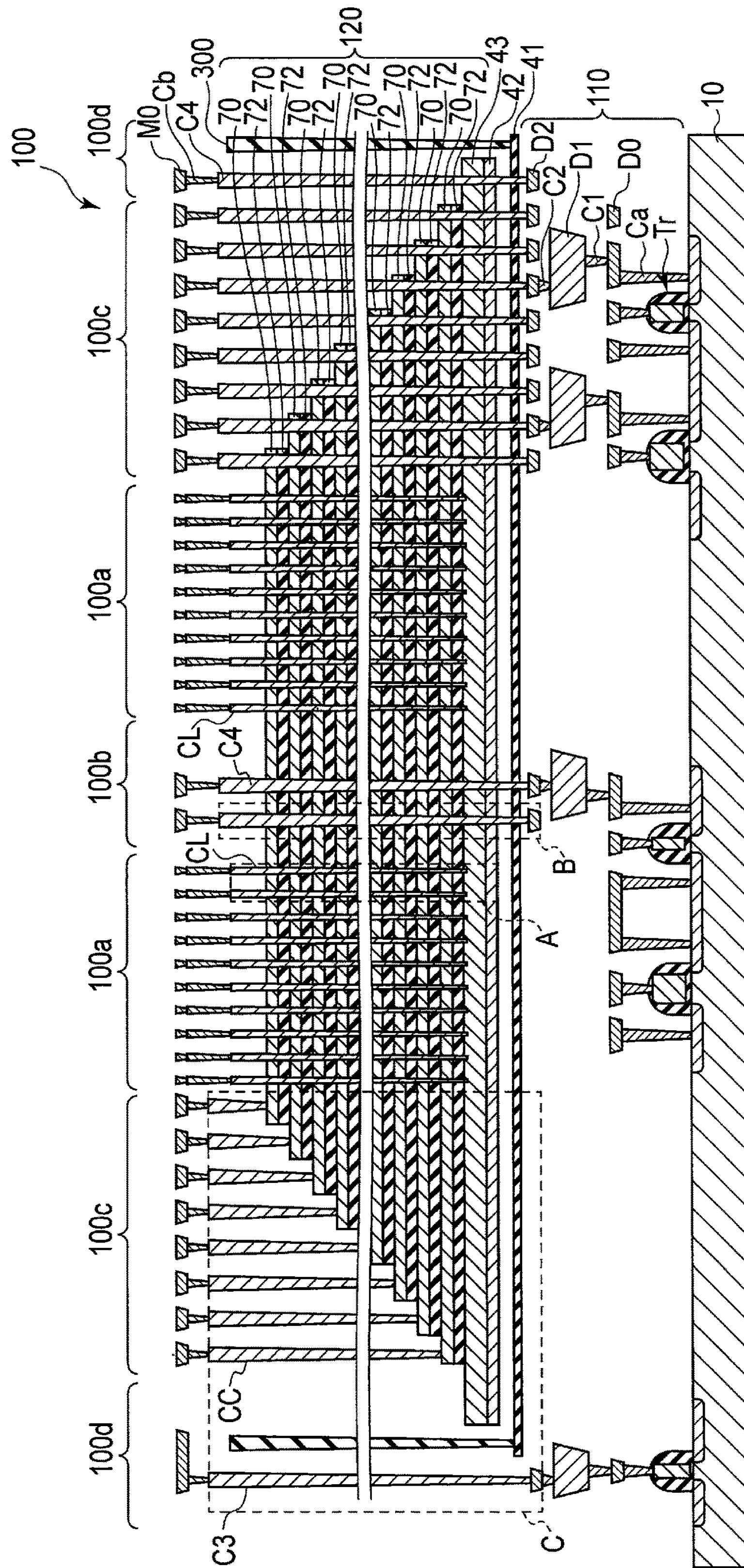


FIG. 27



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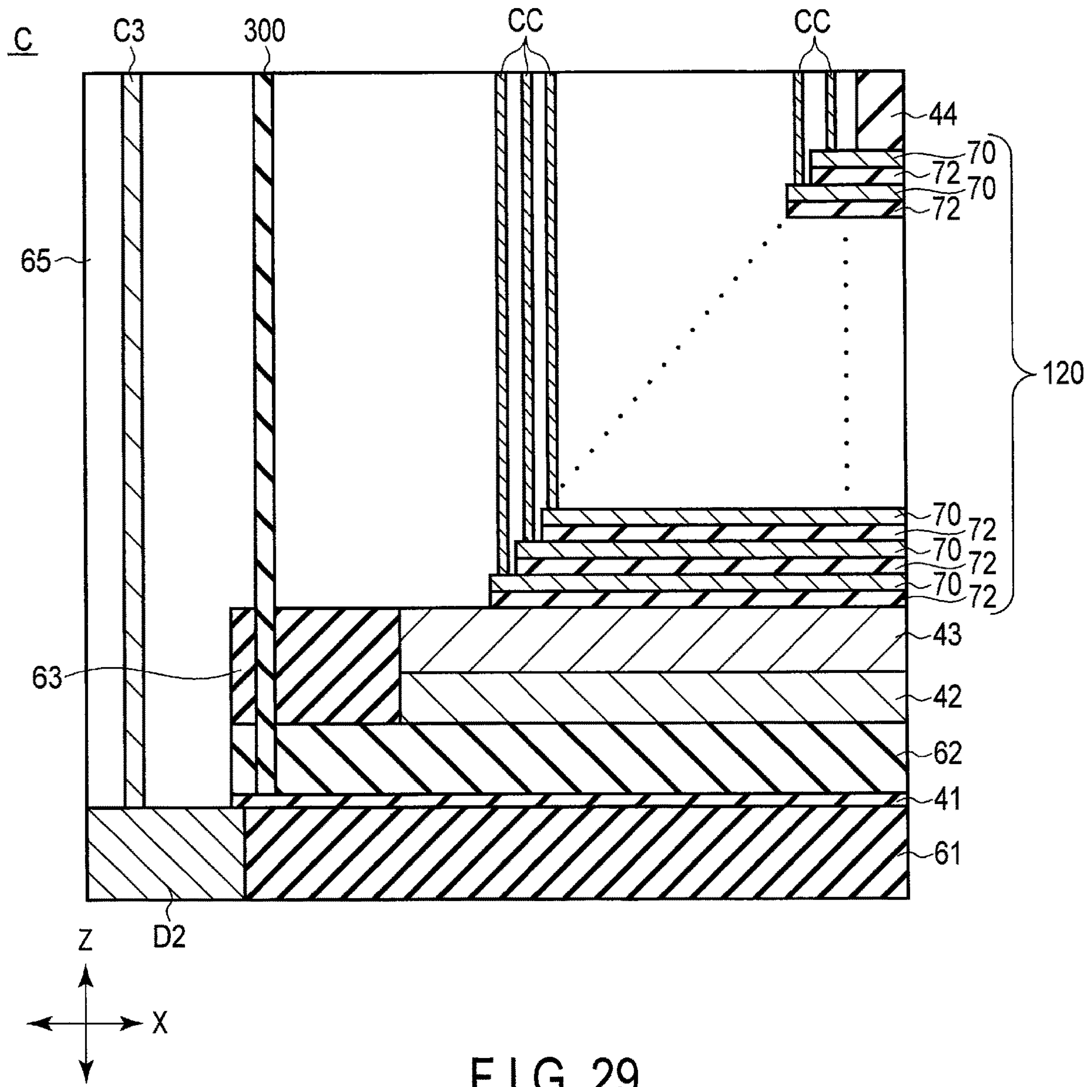

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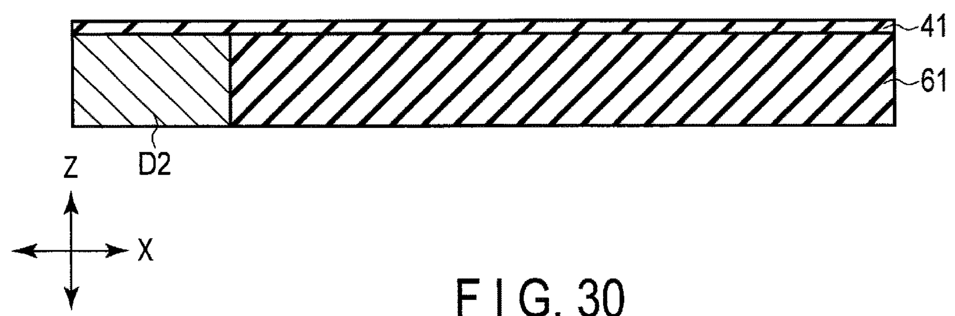

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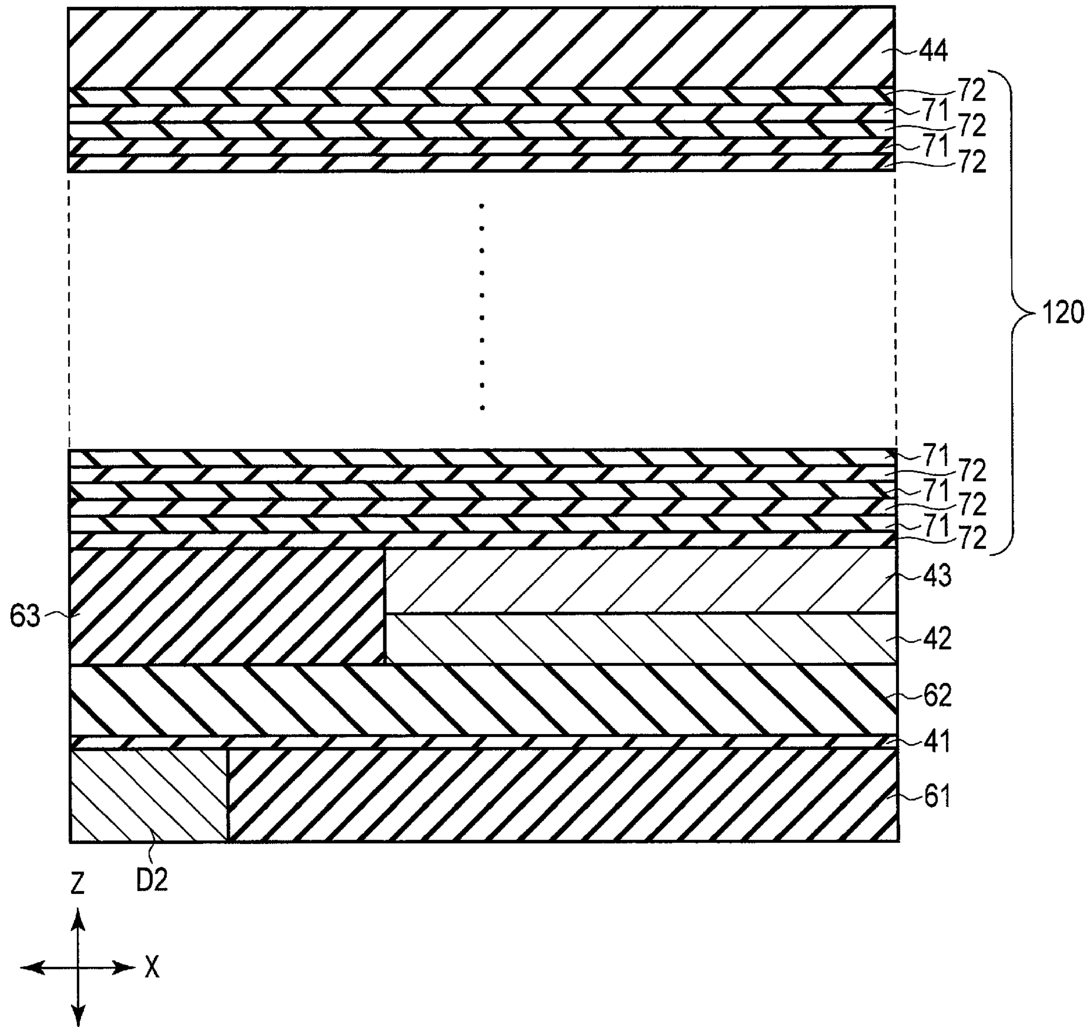

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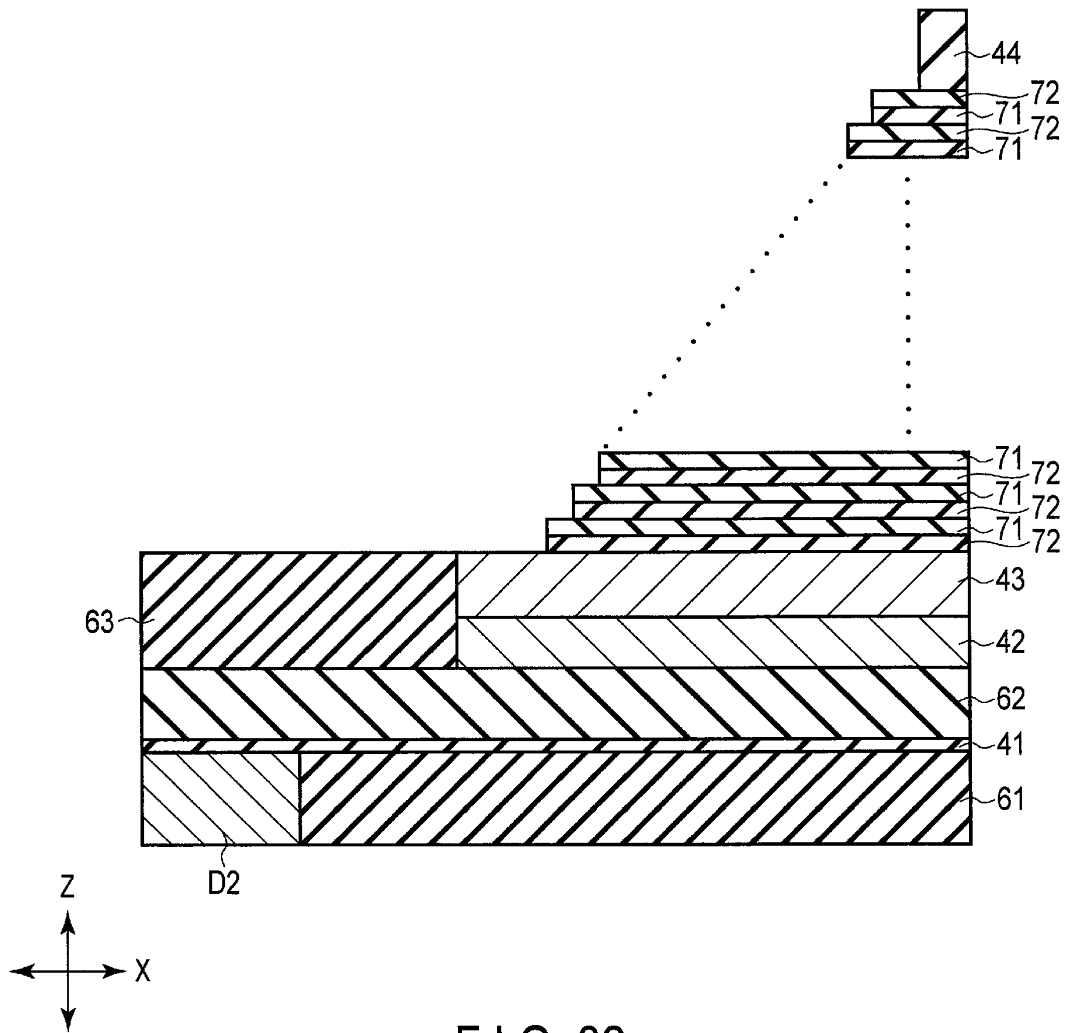

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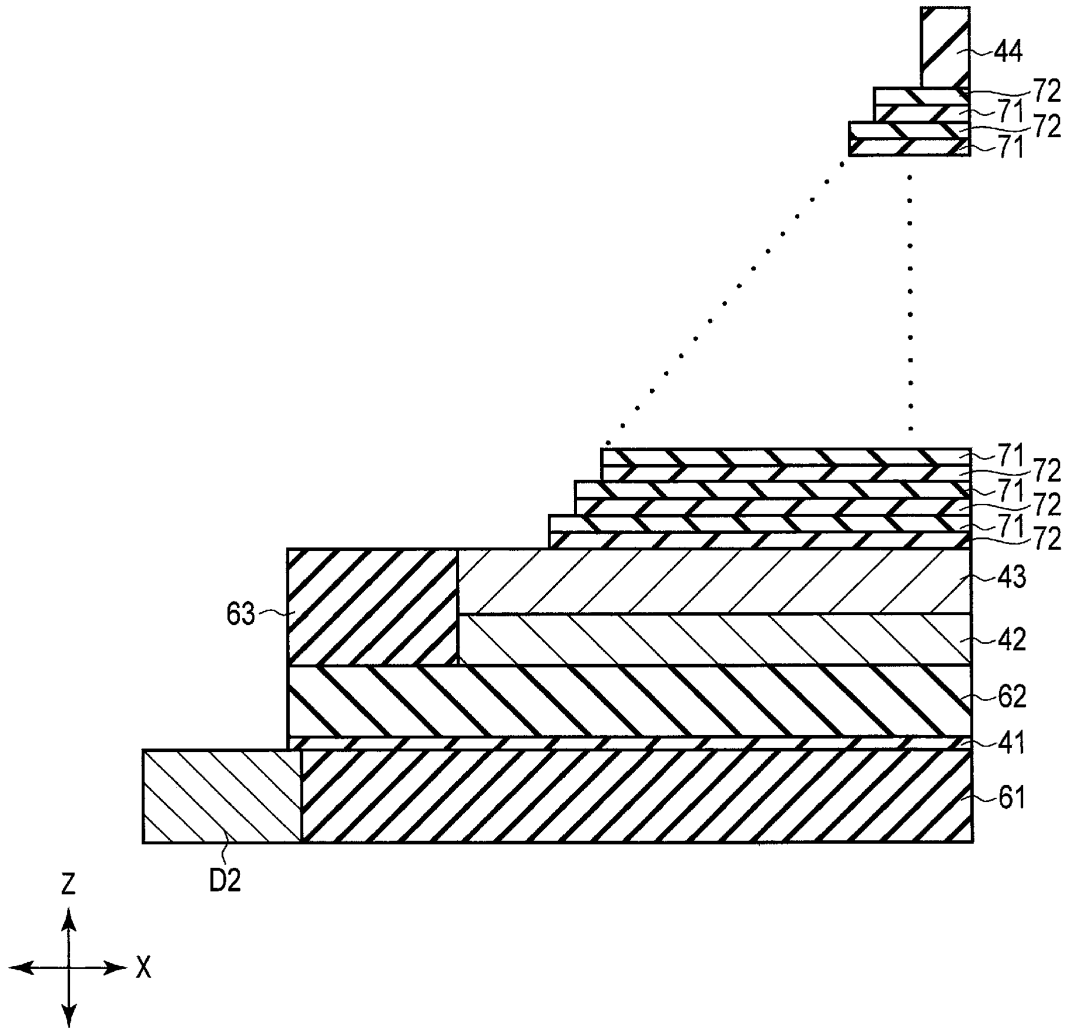
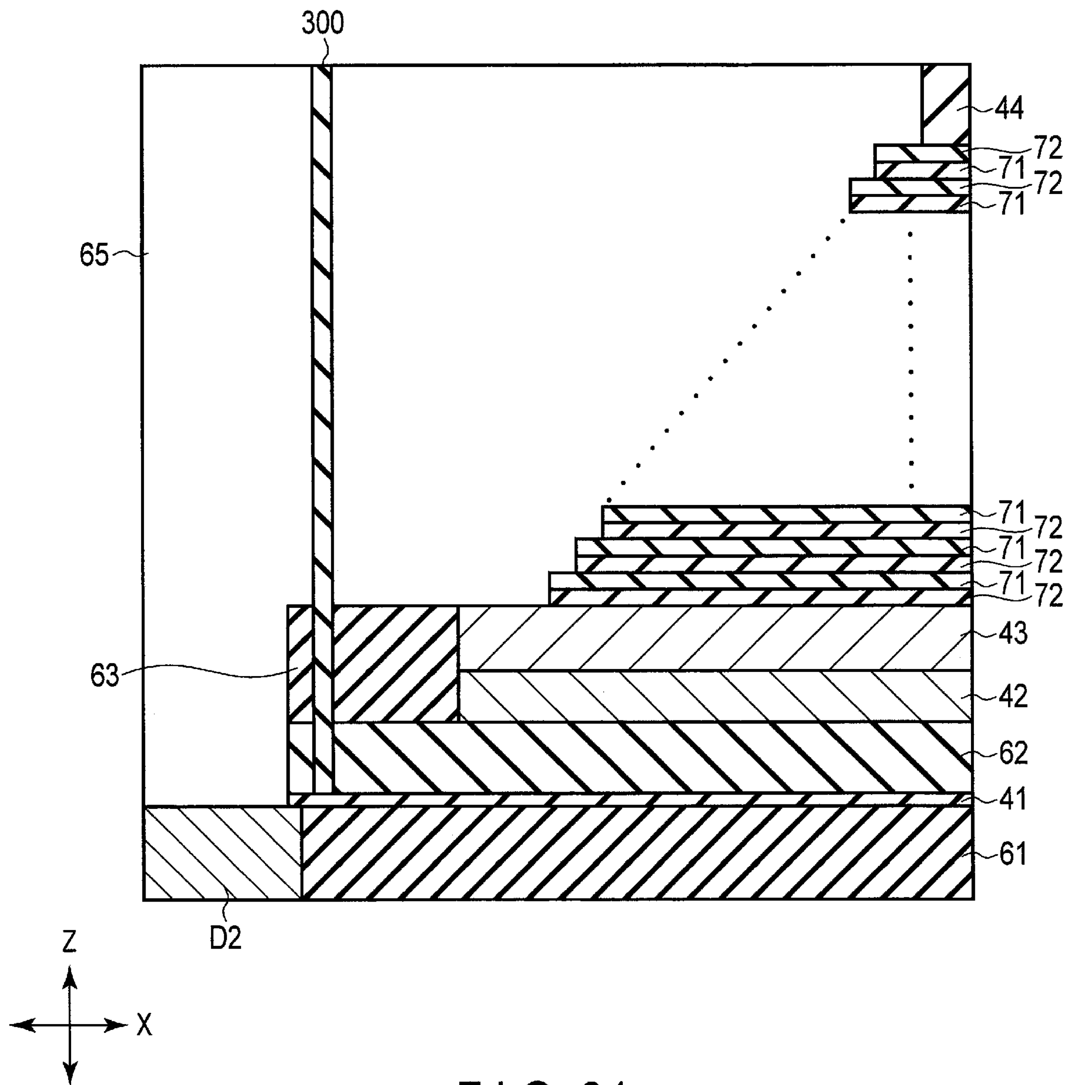


FIG. 33



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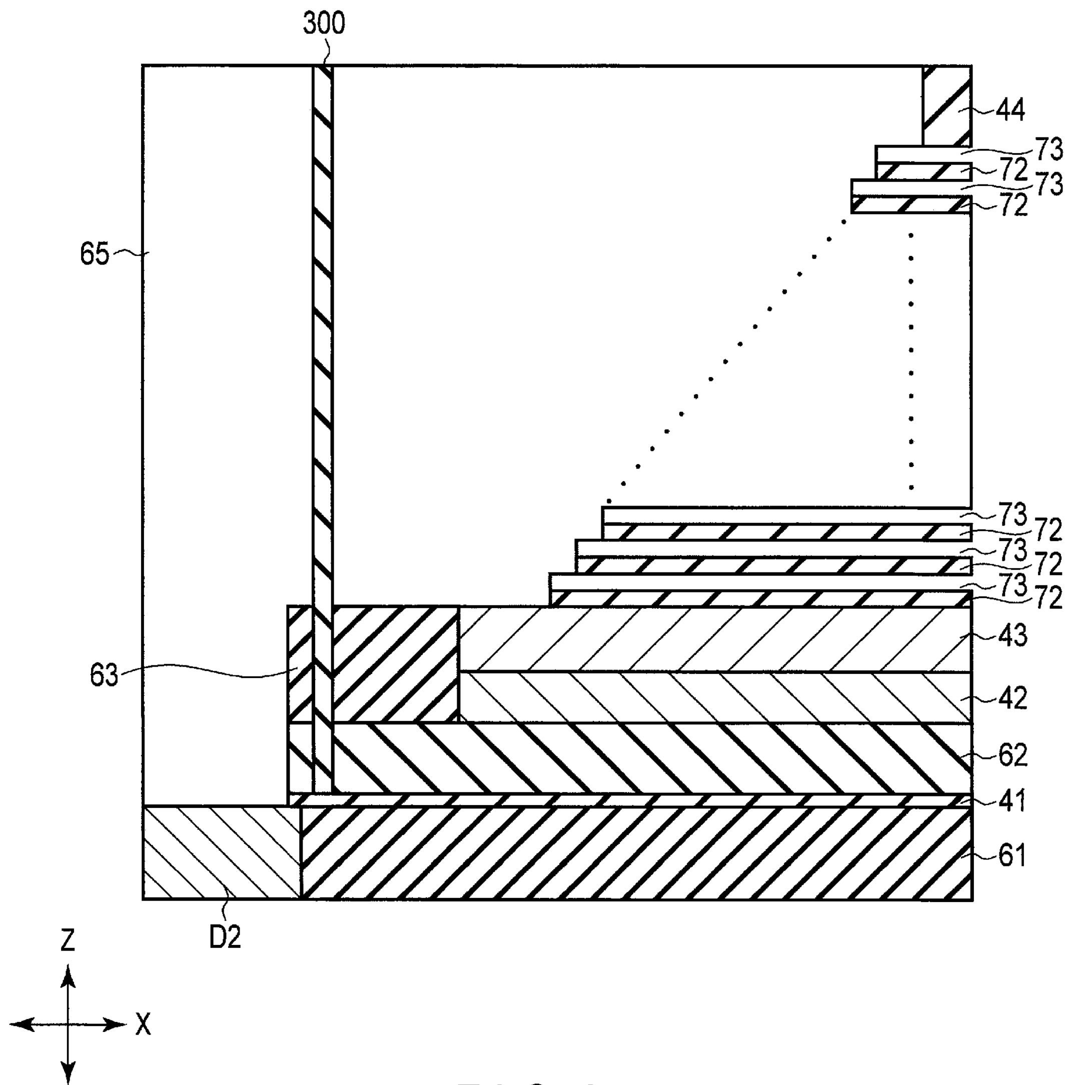

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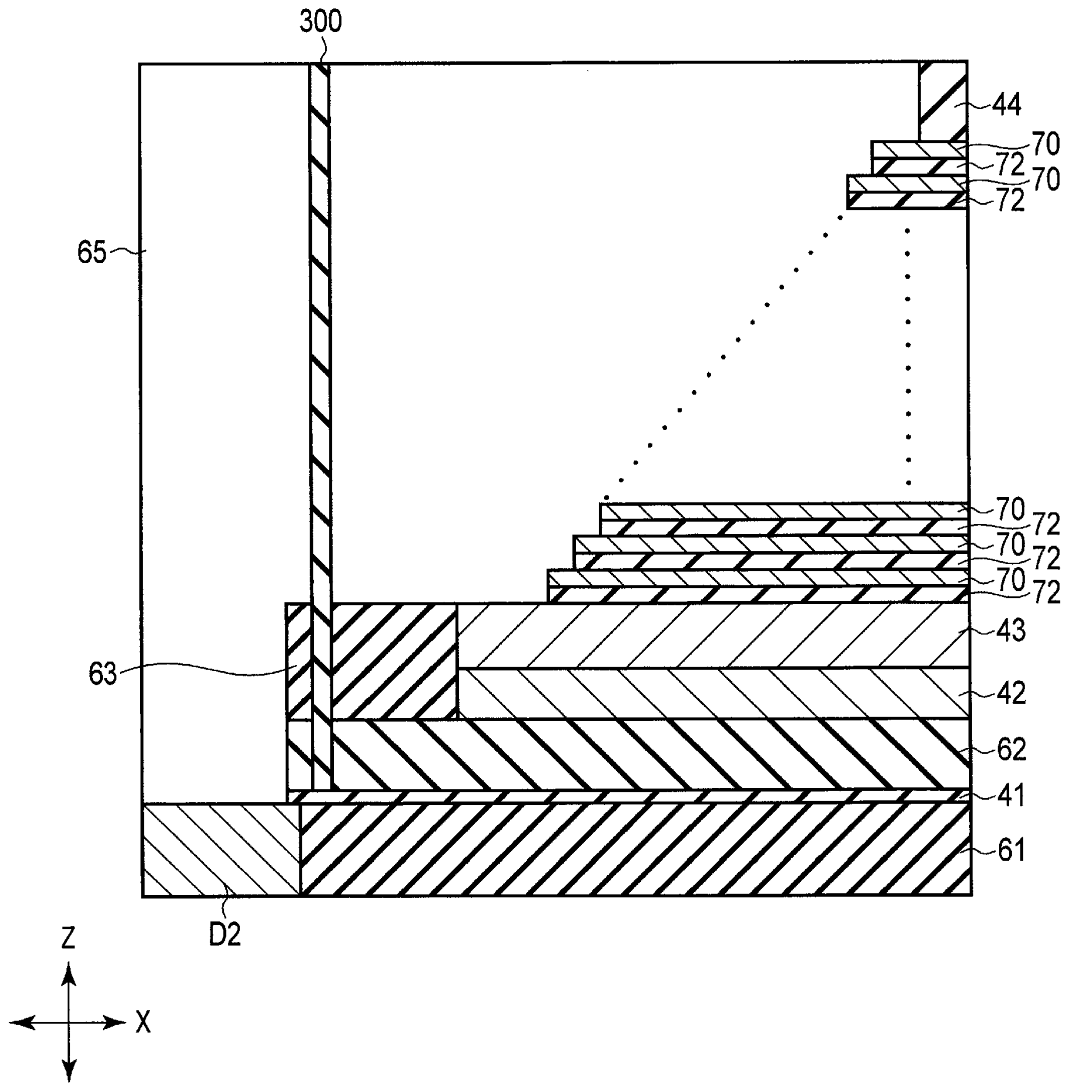

F I G. 36

SEMICONDUCTOR DEVICE AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2018-49280, filed Mar. 16, 2018, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a semiconductor device and a method of manufacturing the same.

BACKGROUND

NAND-type flash memories having three-dimensionally arranged memory cells are known.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plane view of a semiconductor device according to a first embodiment.

FIG. **2** is a cross-sectional view of the semiconductor device according to the first embodiment.

FIG. **3** is a partially enlarged cross-sectional view of the semiconductor device according to the first embodiment.

FIG. **4** is a partially enlarged cross-sectional view showing a pillar structure of the semiconductor device according to the first embodiment.

FIG. **5** is a partially enlarged cross-sectional view of the semiconductor device according to the first embodiment.

FIGS. **6** to **12** are cross-sectional views showing a process for manufacturing the semiconductor device according to the first embodiment.

FIG. **13** is a cross-sectional view showing a comparative example of the process for manufacturing the semiconductor device according to the first embodiment.

FIG. **14** is a partially enlarged cross-sectional view of a first modification of the semiconductor device according to the first embodiment.

FIG. **15** is a partially enlarged cross-sectional view of a second modification of the semiconductor device according to the first embodiment.

FIG. **16** is a partially enlarged cross-sectional view of the second modification of the semiconductor device according to the first embodiment.

FIG. **17** is a partially enlarged cross-sectional view of a semiconductor device according to a second embodiment.

FIGS. **18** to **22** are cross-sectional views showing a process for manufacturing the semiconductor device according to the second embodiment.

FIG. **23** is a partially enlarged cross-sectional view of a comparative example of the semiconductor device according to the second embodiment.

FIG. **24** is a partially enlarged cross-sectional view of a semiconductor device according to a third embodiment.

FIGS. **25** and **26** are cross-sectional views showing a process for manufacturing the semiconductor device according to the third embodiment.

FIG. **27** is a plane view of a semiconductor device according to a fourth embodiment.

FIG. **28** is a cross-sectional view of the semiconductor device according to the fourth embodiment.

FIG. **29** is a partially enlarged cross-sectional view of the semiconductor device according to the fourth embodiment.

FIGS. **30** to **36** are cross-sectional views showing a process for manufacturing the semiconductor device according to the fourth embodiment.

DETAILED DESCRIPTION

According to one embodiment, a semiconductor device includes a substrate, an interconnect layer, a layer stack, and a first silicon nitride layer. The interconnect layer includes a transistor provided on the substrate and a first interconnect electrically coupled to the transistor and is provided above the transistor. The layer stack is provided above the interconnect layer and includes conductive layers stacked with an insulation layer interposed between two of conductive layers of each pair of conductive layers. The first silicon nitride layer is provided between the interconnect layer and the layer stack.

Hereinafter, the embodiments will be described with reference to the accompanying drawings. In the drawings, the same parts are given the same reference signs.

First Embodiment

A semiconductor device **100** according to the first embodiment will be described below with reference to FIGS. **1** to **16**. In this embodiment, a three-dimensionally-stacked type NAND flash memory will be described as an example of the semiconductor device.

[Configuration of First Embodiment]

FIG. **1** is a plane view of the semiconductor device **100** according to the first embodiment.

As shown in FIG. **1**, the semiconductor device **100** includes blocks BLK (BLKn to BLKn+1) that are arranged along the Y-direction. In each block BLK, an isolation section **200** extending in the X-direction is provided in its central part that is positioned in its center along the X-direction. The isolation section **200** is also provided between the blocks BLK.

Each block BLK includes two memory cell array areas **100***a*, a contact area **100***b*, two staircase areas **100***c*, and two peripheral areas **100***d*.

The two memory cell array areas **100***a* and the contact area **100***b* are provided in a central portion of a layer stack **120**. The contact area **100***b* is provided between the two memory cell array areas **100***a*. The two staircase areas **100***c* are provided at ends of the layer stack **120**. Namely, the two memory cell array areas **100***a* and the contact area **100***b* are provided between the two staircase areas **100***c*. In addition, the peripheral area **100***d* is provided on each of the outer sides of the two staircase areas **100***c* (outer sides of the layer stack **120**).

The memory cell array area **100***a* includes pillar structures CL. The pillar structures CL are arranged in the X-direction and the Y-direction. Also, two pillar structures CL that are adjacent to each other in the X-direction (or Y-direction) are provided so as to be shifted by half a pitch in the Y-direction (or X-direction). Namely, the pillar structures CL are arranged in a staggered pattern in the X-direction and the Y-direction. The arrangement of the pillar structures CL is not limited thereto. The pillar structures CL may be provided in a matrix. Also, the shape of the pillar structures CL is a substantially circular shape in FIG. **1**, as viewed in the Z-direction. However, the shape is not limited thereto.

The contact area **100***b* includes contacts C**4**. A contact C**4** couples an interconnect in an upper layer of the layer stack

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120 and an interconnect in a lower layer of the layer stack **120** with each other, as will be described later.

The staircase area **100***c* includes steps and terraces that are arranged in the X-direction. The staircase area **100***c* also includes steps and terraces (not shown in the drawings) that are arranged in the Y-direction. In this embodiment, a terrace is an upper surface of a part of a conductive layer **70** (which will be described later) that does not have another conductive layer **70** disposed directly thereabove, and is substantially parallel to the XY plane. Also, a step is a perpendicular surface or an inclined surface between two terraces that are adjacent to each other in the X-direction. A step is a surface formed of a side surface (end surface) of one conductive layer **70** and an end surface of one insulation layer **72**, and is substantially parallel to a plane including the Y-direction.

The staircase area **100***c* on one side with respect to a central part (or, the two memory cell array areas **100***a* and the contact area **100***b*) includes a first contact group **100***c*_**1**. The first contact group **100***c*_**1** includes contacts CC. Each contact CC is coupled to each terrace, and draws a word line corresponding to each layer.

The staircase area **100***c* on the other side with respect to the central part includes a second contact group **100***c*_**2**. The second contact group **100***c*_**2** includes contacts C**4**. In a manner similar to the contact C**4** of the contact area **100***b*, a contact C**4** of the staircase area **100***c* couples an interconnect in an upper layer of the layer stack **120** and an interconnect in a lower layer of the layer stack **120** with each other.

In the blocks BLK that are adjacent to each other in the Y-direction, the arrangement of the first contact group **100***c*_**1** and the second contact group **100***c*_**2** in the staircase areas **100***c* on one side with respect to the central part is opposite to that in the staircase areas **100***c* on the other side with respect to the central part. More specifically, in the block BLKn, the first contact group **100***c*_**1** is provided in the staircase area **100***c* on one side with respect to the central part of the block BLKn (e.g., left side in FIG. **1**), and the second contact group **100***c*_**2** is provided in the staircase area **100***c* on the other side (e.g., right side in FIG. **1**). In the block BLKn+1, the second contact group **100***c*_**2** is provided in the staircase area **100***c* on one side with respect to the central part of the block BLKn+1 (e.g., left side in FIG. **1**), and the first contact group **100***c*_**1** is provided in the staircase area **100***c* on the other side (e.g., right side in FIG. **1**).

Namely, the staircase area **100***c* has word lines alternately drawn on both sides by the contacts CC in units of blocks. The contacts C**4** are provided in the staircase area **100***c* where the contacts CC for drawing the word lines are not provided.

The arrangement of the first contact group **100***c*_**1** and the second contact group **100***c*_**2** is not limited thereto, but may be discretionarily set. For example, the arrangement of the first contact group **100***c*_**1** and the second contact group **100***c*_**2** with respect to the central part may be reversed for every two blocks BLK or more.

The peripheral area **100***d* includes contacts C**3**. In a manner similar to the contact C**4**, a contact C**3** couples an interconnect in the upper layer of the layer stack **120** and an interconnect in the lower layer of the layer stack **120** with each other, as will be described later.

The shape of the contacts CC, C**3**, and C**4** is a rectangular shape in FIG. **1**, as viewed in the Z-direction. However, the shape of the contacts CC, C**3**, and C**4** is not limited thereto, but may be a substantially circular shape.

FIG. **2** is a cross-sectional view of the semiconductor device **100** according to the first embodiment. In FIG. **2**, an interlayer insulation layer is omitted, as appropriate.

In the descriptions provided below, a direction perpendicular to the X-direction and the Y-direction is defined as the Z-direction (stacking direction). Also, in the Z-direction, a direction from a substrate **10** toward the layer stack **120** is referred to as "upward," and a direction from the layer stack **120** toward the substrate **10** is referred to as "downward." The terms are used for convenience, and are unrelated to the direction of gravity.

The semiconductor device **100** includes an interconnect layer **110** and the layer stack **120** that are provided above the substrate **10**, as shown in FIG. **2**.

The substrate **10** is a semiconductor substrate, and is, for example, a silicon substrate mainly containing silicon.

The interconnect layer **110** is provided on the substrate **10**. The interconnect layer **110** includes a transistors Tr, contacts Ca, C**1**, and C**2**, and interconnects D**0**, D**1**, and D**2**, and forms a control circuit. The transistors Tr are provided on the substrate **10**. A source/drain region and a gate of a transistor Tr are coupled, via a contact Ca, to an interconnect D**0** disposed thereabove. An interconnect D**0** is coupled, via a contact C**1**, to an interconnect D**1** disposed thereabove. An interconnect D**1** is coupled, via a contact C**2**, to an interconnect D**2** disposed thereabove.

A silicon nitride layer **41** is provided above the interconnect layer **110** (interconnects D**2**). The silicon nitride layer **41** extends in the X-direction and the Y-direction, and is provided over the entire region. A tungsten silicide layer **42** and a polysilicon layer **43** are provided above the silicon nitride layer **41** in the mentioned order. A source line is constituted by a layer stack formed of the tungsten silicide layer **42** and the polysilicon layer **43**.

The layer stack **120** is provided above the polysilicon layer **43**. The layer stack **120** includes conductive layers **70** and insulation layers **72**. The conductive layers **70** and the insulation layers **72** are alternately stacked.

The pillar structures CL are provided in the layer stack **120** in the memory cell array area **100***a*. The pillar structures CL extends in the stacking direction (Z-direction) in the layer stack **120**. An upper end of a pillar structure CL is coupled to an interconnect M**0**, which is a bit line, via a contact Cb.

A contact CC is coupled to each terrace of the layer stack **120** in the staircase area **100***c* on one side. An upper end of a contact CC is coupled to an interconnect M**0** via a contact Cb.

The contacts C**4** are provided in the layer stack **120** in the staircase area **100***c* on the other side and in the contact area **100***b*. The contacts C**4** extend in the layer stack **120** and in the tungsten silicide layer **42**, polysilicon layer **43**, and silicon nitride layer **41**, in the stacking direction. A lower end of a contact C**4** is coupled to an interconnect D**2**. An upper end of a contact C**4** is coupled to an interconnect M**0** via a contact Cb.

Also, the contacts C**3** are provided in the peripheral area **100***d*. A lower end of a contact C**3** is coupled to an interconnect D**2**. An upper end of a contact C**3** is coupled to an interconnect M**0** via a contact Cb.

FIG. **3** is a partially enlarged cross-sectional view of the semiconductor device **100** according to the first embodiment, and is a cross-sectional view showing a part indicated by the broken line A (memory cell array area **100***a*) in FIG. **2**.

The layer stack **120** is provided on the polysilicon layer **43**, as shown in FIG. **3**. The layer stack **120** includes

conductive layers **70** and insulation layers **72**. The conductive layers **70** are stacked in a direction (Z-direction) perpendicular to a main surface of the substrate **10**, while having an insulation layer (insulator) **72** between two conductive layers **70** of each pair of conductive layers **70**. Namely, the conductive layers **70** and the insulation layers **72** are alternately stacked. An insulation layer **44** is provided on the layer stack **120**.

The conductive layers **70** are, for example, metal layers. The conductive layers **70** are, for example, tungsten layers including tungsten as a main component, or molybdenum layers including molybdenum as a main component. The insulation layers **44** and **72** are, for example, silicon oxide layers including silicon oxide as a main component.

The pillar structures CL continuously extend in the insulation layer **44** and in the layer stack **120** in the stacking direction (Z-direction). The pillar structures CL include a core layer **50**, a semiconductor layer **20**, and a memory layer **30**, which are provided in the mentioned order from the center.

The core layer **50** is provided as a central portion in a pillar structure CL. The core layer **50** is, for example, a silicon oxide layer including silicon oxide as a main component.

A semiconductor layer **20** is provided around the core layer **50** in a pillar structure CL. Namely, the semiconductor layer **20** is provided between the core layer **50** and the memory layer **30**. The semiconductor layer **20** includes a body layer **20***b* provided around the core layer **50**, and a cover layer **20***a* provided around the body layer **20***b*. A lower end of the body layer **20***b* contacts the polysilicon layer **43**.

The memory layer **30** is provided around the semiconductor layer **20** in a pillar structure CL. Namely, the memory layer **30** is provided between the semiconductor layer **20** and the layer stack **120** as well as the insulation layer **44**.

FIG. **4** is a partially enlarged cross-sectional view showing the pillar structure CL of the semiconductor device **100** according to the first embodiment.

The memory layer **30** includes a tunnel insulation layer **31**, a charge trap layer **32**, and a block insulation layer **33**, as shown in FIG. **4**.

The tunnel insulation layer **31** is provided between the semiconductor layer **20** and the charge trap layer **32**. The charge trap layer **32** is provided between the tunnel insulation layer **31** and the block insulation layer **33**. The block insulation layer **33** is provided between the charge trap layer **32** and the conductive layer **70** (and the insulation layer **72**).

The semiconductor layer **20**, the memory layer **30**, and the conductive layer **70** constitute a memory cell MC. The memory cell MC has a vertical transistor structure in which the conductive layer **70** surrounds the semiconductor layer **20** via the memory layer **30**. A plurality of memory cells MC are provided in the layer stack **120**.

In the memory cell MC having the vertical transistor structure, the semiconductor layer **20** functions as a channel, and the conductive layer **70** functions as a control gate (word line). The charge trap layer **32** functions as a data storage layer that stores electric charge injected from the semiconductor layer **20**.

The memory cell MC is, for example, a charge-trap-type memory cell. The charge trap layer **32** includes a number of trap sites to trap electric charge in an insulative layer. Also, the charge trap layer **32** is, for example, a silicon nitride layer including silicon nitride as a main component. Alternatively, the charge trap layer **32** may be a floating gate having conductivity and surrounded with an insulator.

The tunnel insulation layer **31** serves as a potential barrier when electric charge is injected from the semiconductor layer **20** into the charge trap layer **32**, or when the electric charge stored in the charge trap layer **32** is discharged to the semiconductor layer **20**. The tunnel insulation layer **31** is, for example, a silicon oxide layer including silicon oxide as a main component.

The block insulation layer **33** prevents the electric charge stored in the charge trap layer **32** from being discharged to the conductive layer **70**. The block insulation layer **33** also prevents back tunneling of the electric charge from the conductive layer **70** to the pillar structure CL.

The block insulation layer **33** is, for example, a silicon oxide layer including silicon oxide as a main component. Also, the block insulation layer **33** may be a layer stack of a silicon oxide layer and a metal oxide layer. In this case, the silicon oxide layer is provided between the charge trap layer **32** and the metal oxide layer, and the metal oxide layer is provided between the silicon oxide layer and the conductive layer **70**. Examples of the metal oxide layer include an aluminum oxide layer including aluminum oxide as a main component, a zirconium oxide layer including zirconium oxide as a main component, and a hafnium oxide layer including hafnium oxide as a main component.

FIG. **5** is a partially enlarged cross-sectional view of the semiconductor device **100** according to the first embodiment, and is a cross-sectional view showing a part indicated by the broken line B (contact area **100***b*) in FIG. **2**.

The interconnect D**2** is provided in an insulation layer **61**, as shown in FIG. **5**. The interconnect D**2** is a metal layer, and is, for example, a tungsten layer. The silicon nitride layer **41** is provided on the interconnect D**2** and the insulation layer **61**. An insulation layer **62** is provided on the silicon nitride layer **41**, and the tungsten silicide layer **42** and the polysilicon layer **43** are provided on this insulation layer **62** in the mentioned order. An insulation layer **63** is provided in a contact formation area on the same level as the tungsten silicide layer **42** and the polysilicon layer **43**. The layer stack **120** is formed on the polysilicon layer **43** and the insulation layer **63**. Also, the insulation layer **44** is provided on the layer stack **120**, and an insulation layer **64** is provided on the insulation layer **44**. The insulation layers **61**, **62**, **63** and **64** are, for example, silicon oxide layers including silicon oxide.

The contact C**4** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction. The contact C**4** includes a metal layer **82** and a silicon oxide layer **81**, which are provided in the mentioned order from the center. The lower end of the contact C**4** is coupled to the interconnect D**2**, and the upper end of the contact C**4** is coupled to the contact Cb provided in the insulation layer **64**.

The metal layer **82** is provided as a central portion of the contact C**4**. The metal layer **82** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction. The metal layer **82** is, for example, a tungsten layer that includes tungsten. A lower end of the metal layer **82** is coupled to the interconnect D**2**, and an upper end of the metal layer **82** is coupled to the contact Cb provided in the insulation layer **64**.

The silicon oxide layer **81** is provided around the metal layer **82** in the contact C**4**. The silicon oxide layer **81** is provided between the metal layer **82** and the insulation layers **44**, **62**, and **63** as well as the layer stack **120**. On the other hand, the silicon oxide layer **81** is not provided between the metal layer **82** and the silicon nitride layer **41**. Therefore, a side surface of the metal layer **82** is in contact

with the silicon nitride layer **41**. Accordingly, the interconnect layer **110** and the layer stack **120** are separated from each other by the interconnect D**2** and the silicon nitride layer **41**.

[Manufacturing Method of First Embodiment]

FIGS. **6** to **12** are cross-sectional views showing a process of manufacturing the semiconductor device **100** according to the first embodiment. A process of manufacturing the contact C**4** will be described below.

First, the interconnect D**2** is formed in the insulation layer **61**, as shown in FIG. **6**. The insulation layer **61** is, for example, a silicon oxide layer. The interconnect D**2** is a metal layer, and is, for example, a tungsten layer. The interconnect D**2** is formed by, for example, the damascene method. The silicon nitride layer **41** is formed on the interconnect D**2** and the insulation layer **61**. The silicon nitride layer **41** is formed by, for example, the low pressure (LP)-chemical vapor deposition (CVD) method.

Next, the insulation layer **62** is formed on the silicon nitride layer **41**, as shown in FIG. **7**. The tungsten silicide layer **42** is formed on the insulation layer **62**, and the polysilicon layer **43** is further formed on the tungsten silicide layer **42**. The insulation layer **63** is formed in a contact formation area in the tungsten silicide layer **42** and the polysilicon layer **43**.

Next, the insulation layers **72** and sacrifice layers **71** are alternately stacked on the polysilicon layer **43** and the insulation layer **63**. The step of alternately stacking the insulation layer **72** and the sacrifice layer **71** is repeated, so that the layer stack **120** that includes the sacrifice layers **71** and the insulation layers **72** is formed. Furthermore, the insulation layer **44** is formed on the layer stack **120**. For example, the sacrifice layers **71** are silicon nitride layers, and the insulation layers **44**, **62**, **63**, and **72** are silicon oxide layers. The sacrifice layers **71** being silicon nitride layers are formed by, for example, the P (plasma)-CVD method.

Next, a hole H**1** extending in the Z-direction is formed in the insulation layers **44**, **62**, and **63**, and the layer stack **120**, as shown in FIG. **8**. The hole H**1** is formed by, for example, reactive ion etching (RIE) using a mask layer not shown in the drawing. The hole H**1** penetrates the insulation layers **44**, **62**, and **63**, and the layer stack **120**, to reach the silicon nitride layer **41**.

Next, the silicon oxide layer **81** is formed on the inner surfaces of the layer stack **120** and the insulation layers **44**, **62**, and **63** in the hole H**1**, and on the silicon nitride layer **41**, as shown in FIG. **9**. The silicon oxide layer **81** is conformally formed along the bottom and the side surface of the hole H**1**.

Next, as shown in FIG. **10**, a portion of the silicon oxide layer **81** that is located at the bottom of the hole H**1** is removed by, for example, RIE using a mask layer not shown in the drawing, so that the silicon nitride layer **41** is exposed. Furthermore, a portion of the silicon nitride layer **41** that is exposed to the bottom of the hole H**1** is removed, so that a hole H**2** is formed in the silicon nitride layer **41**. The hole H**2** penetrates the silicon nitride layer **41**, to reach the interconnect D**2**. At this time, a diameter of the hole H**2** is smaller than a diameter of the hole H**1** by the layer thickness of the silicon oxide layer **81** provided on the side surface of the hole H**1**.

Next, the metal layer **82** is formed on the inner surface of the silicon oxide layer **81** in the hole H**1**, and the inner surface of the silicon nitride layer **41** in the hole H**2**, as shown in FIG. **11**. Thereby, the holes H**1** and H**2** are filled. The interconnect layer **110** and the layer stack **120** are now separated from each other by the interconnect D**2** and the silicon nitride layer **41**. As a result, even if a thermal step is performed in the subsequent steps, diffusion of hydrogen included in the layer stack **120** into the interconnect layer **110** can be suppressed.

Thereafter, a portion of the silicon oxide layer **81** and a portion of the metal layer **82** that are provided outside the hole H**1** are removed by, for example, the chemical mechanical polishing (CMP) method. Then, the insulation layer **64** is formed on the insulation layer **44**, the silicon oxide layer **81**, and the metal layer **82**.

Next, although not shown in the drawing, slits are formed in the layer stack **120** by the RIE method using a mask layer. The slits penetrate the insulation layers **44** and **64** and the layer stack **120**, to reach the polysilicon layer **43**.

Then, the sacrifice layers **71** are removed by an etching liquid or an etching gas supplied through the slits, as shown in FIG. **12**. For example, an etching liquid including phosphoric acid is used as the etching liquid. Thereby, a gap **73** is formed between every two insulation layers **72** that are vertically adjacent to each other. The gap **73** is also formed between the insulation layer **44** and the uppermost insulation layer **72** of the layer stack **120**.

The insulation layers **72** of the layer stack **120** are in contact with the side surfaces of the pillar structures CL in such a manner to surround the side surfaces of the pillar structures CL. The insulation layers **72** are supported by physical joints with such pillar structures CL, and thereby the gaps **73** between the insulation layers **72** are maintained.

Next, the conductive layers **70** are formed in the gaps **73** by, for example, the CVD method, as shown in FIG. **5**. At this time, a source gas is supplied to the gaps **73** through the slits.

Thereafter, an insulation layer is formed on the side surface and at the bottom of the slits, although not shown in the drawing. Thereby, the slits are filled, and the isolation section **200** shown in FIG. **1** is formed.

Furthermore, the contact Cb is formed in the insulation layer **64**, and the contact Cb is coupled to the contact C**4**.

In this manner, the semiconductor device **100** of the first embodiment is formed.

[Advantageous Effect of First Embodiment]

In a NAND flash memory that includes three-dimensionally arranged memory cells, the layer stack **120**, in which silicon oxide layers (insulation layers **72**) and silicon nitride layers (sacrifice layers **71**) are alternately stacked, is formed above the interconnect layer **110**. When a thermal step is performed after the layer stack **120** is formed, hydrogen included in the layer stack **120** (in particular, silicon nitride layers) is diffused. The diffused hydrogen enters the interconnect layer **110** arranged below the layer stack **120**, and negatively affects the properties of the transistors Tr, etc., in the interconnect layer **110**. Thereby, the electrical properties of the interconnect layer **110** deteriorate.

In contrast, in the first embodiment described above, the silicon nitride layer **41** is provided between the interconnect layer **110** and the layer stack **120**. This silicon nitride layer **41** functions as a barrier layer that prevents intrusion of the hydrogen. Thereby, it is possible to prevent the hydrogen diffused from the layer stack **120** from entering the interconnect layer **110** in the thermal step in the manufacturing process. As a result, it is possible to suppress deterioration of the electrical properties of the interconnect layer **110**.

Whereas the silicon nitride layers (sacrifice layers) **71** in the layer stack **120** are formed by the P-CVD method, the silicon nitride layer **41** is formed by the LP-CVD method. The silicon nitride layer **41** formed by the LP-CVD method

does not diffuse hydrogen into the interconnect layer **110**, and functions as a barrier layer.

FIG. **13** is a cross-sectional view showing a comparative example of the process for manufacturing the semiconductor device **100** according to the first embodiment.

Even if the silicon nitride layer **41** as a barrier layer is formed, hydrogen from the layer stack **120** may diffuse into the interconnect layer **110** when the contact C**4** is formed, as shown in the comparative example of FIG. **13**. For example, in the comparative example, an insulation layer **65** made of a silicon oxide layer is provided between the silicon nitride layer **41** and the interconnect D**2**. Also, the silicon oxide layer **81** serving as a sidewall spacer of the contact C**4** is formed in the silicon nitride layer **41**. The silicon oxide layer cannot prevent intrusion of hydrogen from the layer stack **120**. Therefore, in the comparative example, although the silicon nitride layer **41** is formed, hydrogen from the layer stack **120** enters the interconnect layer **110** via the silicon oxide layer **81** and the insulation layer **65** (silicon oxide layer) when the contact C**4** is formed.

In contrast, in the first embodiment described above, the silicon oxide layer **81** is not formed in the silicon nitride layer **41**. Namely, the metal layer **82** and the silicon nitride layer **41** are formed in contact with each other. Also, the silicon nitride layer **41** is formed directly on the interconnect D**2** (in contact with the interconnect D**2**). Thereby, in the first embodiment described above, a pathway of intrusion of hydrogen by the silicon oxide layers (silicon oxide layer **81** and insulation layer **65**) shown in the comparative example is blocked. Accordingly, it is possible to prevent the hydrogen diffused from the layer stack **120** from entering the interconnect layer **110** when the contact C**4** is formed.

[Modification of First Embodiment]

FIG. **14** is a partially enlarged cross-sectional view showing a first modification of the semiconductor device **100** according to the first embodiment, and is a cross-sectional view showing a modification of the part indicated by the broken line B (contact area **100***b*) in FIG. **2**.

In the first modification, the interconnect D**2** includes a metal layer **85** and a polysilicon layer **83**, as shown in FIG. **14**. The polysilicon layer **83** is provided on the metal layer **85**. The metal layer **85** is, for example, a tungsten layer. A barrier metal layer (not shown in the drawing) that is a titanium or titanium nitride layer is provided between the metal layer **85** and the polysilicon layer **83**. The silicon nitride layer **41** is provided on the interconnect D**2** and the insulation layer **61**. The metal layer **82** of the contact C**4** is provided in a manner contacting the polysilicon layer **83** of the interconnect D**2**.

In the first modification, the polysilicon layer **83** is provided on the metal layer **85** as the interconnect D**2**. Thereby, the interconnect layer **110** and the layer stack **120** are separated from each other by the polysilicon layer **83** and the silicon nitride layer **41**. The polysilicon layer **83** functions as a barrier layer that prevents intrusion of hydrogen. Thereby, it is possible to prevent the hydrogen diffused from the layer stack **120** from entering the interconnect layer **110** in the thermal step in the manufacturing process. As a result, deterioration of the electrical properties of the interconnect layer **110** can be suppressed.

FIG. **15** is a partially enlarged cross-sectional view showing a second modification of the semiconductor device **100** according to the first embodiment, and is a cross-sectional view showing a modification of the part indicated by the broken line B (contact area **100***b*) in FIG. **2**.

In the second modification, the contact C**4** includes the metal layer **82** and the silicon oxide layer **81**, which are provided in the mentioned order from the center, as shown in FIG. **15**. Also, the contact C**4** includes a polysilicon layer **84** in place of a part of a lower end portion of the metal layer **82**. The polysilicon layer **84** is provided so as to be continuous with the metal layer **82**, and is provided on the inner surface of the silicon oxide layer **81** in a manner similar to the metal layer **82**. The polysilicon layer **84** is also formed in the silicon nitride layer **41**, and a lower end of the polysilicon layer **84** is coupled to the interconnect D**2**. A barrier metal layer (not shown in the drawing) that is a titanium or titanium nitride layer is provided between the metal layer **82** and the polysilicon layer **84**.

After the hole H**2** is formed in the silicon nitride layer **41** (i.e., after the step shown in FIG. **10**), the polysilicon layer **84** is formed at the bottom of the holes H**1** and H**2**. The polysilicon layer **84** may be formed by being etched back after the holes H**1** and H**2** are filled by the polysilicon layer **84**.

In the second modification, the polysilicon layer **84** is provided below the metal layer **82**. Thereby, the interconnect layer **110** including the interconnect D**2** and the layer stack **120** are separated from each other by the polysilicon layer **84** and the silicon nitride layer **41**. The polysilicon layer **84** functions as a barrier layer that prevents intrusion of hydrogen. Thereby, it is possible to prevent the hydrogen diffused from the layer stack **120** from entering the interconnect layer **110** in the thermal step in the manufacturing process. As a result, deterioration of the electrical properties of the interconnect layer **110** can be suppressed.

The insulation layer **65** made of a silicon oxide layer may be provided between the silicon nitride layer **41** and the interconnect D**2**, as shown in FIG. **16**. In this case, an upper end of the polysilicon layer **84** is located at a position higher than an upper end of the insulation layer **65**.

Second Embodiment

A semiconductor device **100** according to the second embodiment will be described below with reference to FIGS. **17** to **23**. The second embodiment is an example in which silicon nitride layers **86** and **87** are provided in a manner to cover the side surface and upper surface of the metal layer **82** in the contact C**4**. The second embodiment will be detailed below.

In the second embodiment, descriptions of the same points as the above first embodiment will be omitted, and mainly the different points will be described.

[Configuration of Second Embodiment]

FIG. **17** is a partially enlarged cross-sectional view of the semiconductor device **100** according to the second embodiment, and is a cross-sectional view showing the part indicated by the broken line B (contact area **100***b*) in FIG. **2**.

The contact C**4** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction. The contact C**4** includes the metal layer **82**, the silicon nitride layer **86**, and the silicon oxide layer **81**, which are provided in the mentioned order from the center. The contact C**4** also includes the silicon nitride layer **87** that covers the upper surface (upper end) of the metal layer **82**.

The metal layer **82** is provided as a central portion of the contact C**4**. The metal layer **82** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction. The metal layer **82** is, for example, a tungsten layer that includes tungsten. The lower end of the metal layer **82** is connected

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to the interconnect D2, and the upper end of the metal layer **82** is connected to the contact Cb provided in the insulation layer **64**.

The silicon nitride layer **86** is provided around the metal layer **82** in the contact C**4**. The silicon nitride layer **86** is provided between the metal layer **82** and the silicon oxide layer **81**, and between the metal layer **82** and the silicon nitride layer **41**. The silicon nitride layer **86** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction.

The silicon nitride layer **87** is provided in a manner to cover the upper surface of the metal layer **82** in the contact C**4**. The silicon nitride layer **87** is provided in an area where a part of the upper end portion of the metal layer **82** has been removed. Therefore, the silicon nitride layer **86** is provided around the silicon nitride layer **87**, and the side surface of the silicon nitride layer **87** is in contact with the silicon nitride layer **86**. The contact Cb continuously extends in the silicon nitride layer **87** in the stacking direction, to be coupled to the metal layer **82**.

The silicon oxide layer **81** is provided around the silicon nitride layer **86** in the contact C**4**. The silicon oxide layer **81** is provided between the silicon nitride layer **86** and the insulation layers **44**, **62**, and **63** as well as the layer stack **120**. On the other hand, the silicon oxide layer **81** is not provided between the silicon nitride layer **86** and the silicon nitride layer **41**. Therefore, the side surface of the silicon nitride layer **86** is in contact with the silicon nitride layer **41**. Accordingly, the silicon nitride layers **41**, **86**, and **87** are consecutively provided. As a result, the interconnect layer **110** and the layer stack **120** are separated from each other by the silicon nitride layers **41**, **86**, and **87**.

[Manufacturing Method of Second Embodiment]

FIGS. **18** to **22** are cross-sectional views showing a process of manufacturing the semiconductor device **100** according to the second embodiment. A process of manufacturing the contact C**4** will be described below.

First, the steps until the step shown in FIG. **10** of the first embodiment are performed. Namely, after the silicon oxide layer **81** is formed inside the hole H**1**, the hole H**2** is formed in the silicon nitride layer **41**.

Next, the silicon nitride layer **86** is formed on the inner surface of the silicon oxide layer **81** in the hole H**1**, and inner surface of the silicon nitride layer **41** in the hole H**2**, as shown in FIG. **18**. The silicon nitride layer **86** is coformally formed along the bottom and the side surface of the holes H**1** and H**2**. The silicon nitride layer **86** is formed by the LP-CVD method.

Next, a portion of the silicon nitride layer **86** that is located at the bottom of the hole H**2** is removed by, for example, RIE using a mask layer not shown in the drawing, so that the interconnect D**2** is exposed, as shown in FIG. **19**.

Next, the metal layer **82** is formed on the inner surface of the silicon nitride layer **86** in the holes H**1** and H**2**, as shown in FIG. **20**. Thereby, the holes H**1** and H**2** are filled. Thereafter, a part of the upper end portion of the metal layer **82** in the hole H**1** is removed by etch-back processing.

Next, the silicon nitride layer **87** is formed in an area in the hole H**1** where the metal layer **82** has been removed, as shown in FIG. **21**. The silicon nitride layer **87** is formed by the LP-CVD method. The interconnect layer **110** and the layer stack **120** are now separated from each other by the silicon nitride layers **41**, **86**, and **87**. As a result, even if a thermal step is performed in the subsequent steps, diffusion of hydrogen included in the layer stack **120** into the interconnect layer **110** can be suppressed.

Thereafter, a portion of the silicon oxide layer **81**, a portion of the silicon nitride layers **86** and **87**, and a portion of the metal layer **82** that are located outside the hole H**1** are removed by, for example, the CMP method. Then, the insulation layer **64** is formed on the insulation layer **44**, the silicon oxide layer **81**, the silicon nitride layers **86** and **87**, and the metal layer **82**.

Next, although not shown in the drawing, slits are formed in the layer stack **120** by the RIE method using a mask layer. The slits penetrate the insulation layers **44** and **64** and the layer stack **120**, to reach the polysilicon layer **43**. Then, the sacrifice layers **71** are removed by an etching liquid or an etching gas supplied through the slits, as shown in FIG. **22**. Thereby, the gap **73** is formed between every two insulation layers **72** that are vertically adjacent to each other. The gap **73** is also formed between the insulation layer **44** and the uppermost insulation layer **72** of the layer stack **120**.

Next, the conductive layers **70** are formed in the gaps **73** by, for example, the CVD method, as shown in FIG. **17**. At this time, a source gas is supplied to the gaps **73** through the slits. Thereafter, an insulation layer is formed on the side surface and at the bottom of the slits, although not shown in the drawing. Thereby, the slits are filled, and the isolation section **200** shown in FIG. **1** is formed.

Furthermore, the contact Cb is formed in the insulation layer **64** and the silicon nitride layer **87**. The contact Cb reaches the metal layer **82** to be coupled thereto.

In this manner, the semiconductor device **100** of the second embodiment is formed.

[Advantageous Effect of Second Embodiment]

In the second embodiment described above, the silicon nitride layer **86** is provided in a manner to cover the side surface of the metal layer **82**, and the silicon nitride layer **87** is provided in a manner to cover the upper surface of the metal layer **82**, in the contact C**4**. Thereby, the interconnect layer **110** and the layer stack **120** are separated from each other by the silicon nitride layers **41**, **86**, and **87**. Thereby, it is possible to prevent the hydrogen diffused from the layer stack **120** from entering the interconnect layer **110** in the thermal step in the manufacturing process. As a result, deterioration of the electrical properties of the interconnect layer **110** can be suppressed.

The insulation layer **62** may not be formed and the silicon nitride layer **41** may be provided directly below the tungsten silicide layer **42**, as shown in FIG. **23**. Also, the insulation layer **65** made of a silicon oxide layer may be provided between the silicon nitride layer **41** and the interconnect D**2**.

Third Embodiment

A semiconductor device **100** according to the third embodiment will be described below with reference to FIGS. **24** to **26**. The third embodiment is an example in which the silicon nitride layer **86** is provided in a manner to cover the side surface of the metal layer **82** in the contact C**4**, and a silicon oxide layer **91** that includes impurities is provided on the insulation layer **44**. The third embodiment will be detailed below.

In the third embodiment, descriptions of the same points as the above first embodiment will be omitted, and mainly the different points will be described.

[Configuration of Third Embodiment]

FIG. **24** is a partially enlarged cross-sectional view of the semiconductor device **100** according to the third embodiment, and is a cross-sectional view showing the part indicated by the broken line B (contact area **100***b*) in FIG. **2**.

The contact C**4** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction. The contact C**4** includes the metal layer **82**, silicon nitride layer **86**, and silicon oxide layer **81**, which are provided in the mentioned order from the center.

The metal layer **82** is provided as a central portion of the contact C**4**. The metal layer **82** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction. The metal layer **82** is, for example, a tungsten layer that includes tungsten. The lower end of the metal layer **82** is connected to the interconnect D**2**, and the upper end of the metal layer **82** is connected to the contact Cb provided in the insulation layer **64**.

The silicon nitride layer **86** is provided around the metal layer **82** in the contact C**4**. The silicon nitride layer **86** is provided between the metal layer **82** and the silicon oxide layer **81** and between the metal layer **82** and the silicon nitride layer **41**. The silicon nitride layer **86** continuously extends in the silicon nitride layer **41**, in the insulation layers **44**, **62**, and **63**, and in the layer stack **120**, in the stacking direction.

The silicon oxide layer **81** is provided around the silicon nitride layer **86** in the contact C**4**. The silicon oxide layer **81** is provided between the silicon nitride layer **86** and the insulation layers **44**, **62**, and **63** as well as the layer stack **120**. On the other hand, the silicon oxide layer **81** is not provided between the silicon nitride layer **86** and the silicon nitride layer **41**. Therefore, the side surface of the silicon nitride layer **86** is in contact with the silicon nitride layer **41**.

The silicon oxide layer **91** is provided on the insulation layer **44** and the silicon oxide layer **81**. The silicon oxide layer **91** includes at least one of phosphorus, carbon, arsenic, or argon, as impurities. The silicon oxide layer **91** is an area formed by injecting impurities into the upper end portion of the silicon oxide layer **81** and the insulation layer **44** made of a silicon oxide layer. Namely, an impurity concentration of the silicon oxide layer **91** is higher than an impurity concentration of the insulation layer **44** and the silicon oxide layer **81**.

The silicon oxide layer **91** and the silicon nitride layers **41** and **86** are consecutively provided. As a result, the interconnect layer **110** and the layer stack **120** are separated from each other by the silicon oxide layer **91** and the silicon nitride layers **41** and **86**.

[Manufacturing Method of Third Embodiment]

FIGS. **25** and **26** are cross-sectional views showing a process for manufacturing the semiconductor device **100** according to the third embodiment. A process of manufacturing the contact C**4** will be described below.

First, the steps until the step shown in FIG. **10** of the first embodiment are performed. Namely, after the silicon oxide layer **81** is formed inside the hole H**1**, the hole H**2** is formed in the silicon nitride layer **41**.

Next, the silicon nitride layer **86** is formed on the inner surface of the silicon oxide layer **81** in the hole H**1**, and the inner surface of the silicon nitride layer **41** in the hole H**2**, as shown in FIG. **25**. The silicon nitride layer **86** is conformally formed along the bottom and the side surface of the holes H**1** and H**2**. The silicon nitride layer **86** is formed by the LP-CVD method.

Next, a portion of the silicon nitride layer **86** that is located at the bottom of the hole H**2** is removed by, for example, RIE using a mask layer not shown in the drawing, so that the interconnect D**2** is exposed. Thereafter, the metal layer **82** is formed on the inner surface of the silicon nitride layer **86** in the holes H**1** and H**2**. Thereby, the holes H**1** and H**2** are filled. Then, a portion of the silicon oxide layer **81**, a portion of the silicon nitride layer **86**, and a portion of the metal layer **82** that are provided outside the hole H**1** are removed by, for example, the CMP method.

Furthermore, impurities are injected into the upper end portion of the silicon oxide layer **81** and the insulation layer **44** made of a silicon oxide layer by the ion implantation method. Thereby, the silicon oxide layer **91** that includes impurities is formed on the upper end portion of the silicon oxide layer **81** and the insulation layer **44** made of a silicon oxide layer. The silicon oxide layer **91** includes at least one of phosphorus, carbon, arsenic, or argon, as impurities.

Next, the insulation layer **64** is formed on the silicon oxide layer **91**, the silicon nitride layer **86**, and the metal layer **82**, as shown in FIG. **26**.

The interconnect layer **110** and the layer stack **120** are now separated from each other by the silicon nitride layers **41** and **86**, and the silicon oxide layer **91** containing impurities. As a result, even if a thermal step is performed in the subsequent steps, diffusion of hydrogen included in the layer stack **120** into the interconnect layer **110** can be suppressed. On the other hand, hydrogen included in the interconnect layer **110** is released into the air using the metal layer **82** and the insulation layer **64** as diffusion pathways. This can suppress the interconnect layer **110** from being steamed by the hydrogen included therein.

Next, although not shown in the drawing, slits are formed in the layer stack **120** by the RIE method using a mask layer. The slits penetrate the insulation layers **44** and **64** and the layer stack **120**, to reach the polysilicon layer **43**. Then, the sacrifice layers **71** are removed by an etching liquid or an etching gas supplied through the slits. Thereby, the gap **73** is formed between every two insulation layers **72** that are vertically adjacent to each other. The gap **73** is also formed between the insulation layer **44** and the uppermost insulation layer **72** of the layer stack **120**.

Next, the conductive layers **70** are formed in the gaps **73** by, for example, the CVD method, as shown in FIG. **24**. At this time, a source gas is supplied to the gaps **73** through the slits. Thereafter, an insulation layer is formed on the side surface and at the bottom of the slits, although not shown in the drawing. Thereby, the slits are filled, and the isolation section **200** shown in FIG. **1** is formed.

Furthermore, the contact Cb is formed in the insulation layer **64**. The contact Cb reaches the metal layer **82** to be coupled thereto.

In this manner, the semiconductor device **100** of the third embodiment is formed.

[Advantageous Effect of Third Embodiment]

In the third embodiment, the upper part of the contact C**4** is not covered with a silicon nitride layer when the contact C**4** is formed. Therefore, the interconnect layer **110** is not completely covered with a silicon nitride layer. Thereby, hydrogen included in the interconnect layer **110** is released into the air using the metal layer **82** and the insulation layer **64** as diffusion pathways. Therefore, it is possible to suppress the interconnect layer **110** from being steamed by the hydrogen included therein in the thermal step in the manufacturing process. As a result, it is possible to suppress deterioration of the electrical properties of the interconnect layer **110**.

On the other hand, the interconnect layer **110** and the layer stack **120** are separated from each other by the silicon nitride layers **41** and **86**, and the silicon oxide layer **91** containing impurities. Thereby, even if the thermal step is performed in

the subsequent steps, diffusion of hydrogen included in the layer stack **120** into the interconnect layer **110** can be inhibited.

Fourth Embodiment

A semiconductor device **100** according to the fourth embodiment will be described below with reference to FIGS. **27** to **36**. The fourth embodiment is an example in which a silicon nitride layer **300** is provided in a manner to cover the perimeter of the layer stack **120**. The fourth embodiment will be detailed below.

In the fourth embodiment, descriptions of the same points as the above first embodiment will be omitted, and mainly the different points will be described.

[Configuration of Fourth Embodiment]

FIG. **27** is a plane view of the semiconductor device **100** according to the fourth embodiment.

The semiconductor device **100** includes the silicon nitride layer **300**, as shown in FIG. **27**. The silicon nitride layer **300** is provided in a manner to cover the perimeter of the memory cell array area **100***a*, the contact area **100***b*, and the staircase area **100***c*. Namely, the silicon nitride layer **300** includes two parts extending in the X-direction and the Z-direction, and two parts extending in the Y-direction and the Z-direction. The respective end portions of these four parts are connected to one another, thereby forming the silicon nitride layer **300** in a rectangular shape, as viewed in the Z-direction. The silicon nitride layer **300** is provided in the peripheral area **100***d* as viewed in the X-direction. Also, the silicon nitride layer **300** is provided closer to the inner side than the contact C**3** as viewed in the X-direction.

FIG. **28** is a cross-sectional view of the semiconductor device **100** according to the fourth embodiment. In FIG. **28**, an interlayer insulation layer is omitted, as appropriate.

The silicon nitride layer **300** is provided around the layer stack **120**, as shown in FIG. **28**. The silicon nitride layer **300** includes two parts extending in the Y-direction and the Z-direction, and two parts extending in the X-direction and the Z-direction (not shown in the drawings). A lower end of the silicon nitride layer **300** is coupled to the silicon nitride layer **41**. Namely, a lower side and lateral side of the layer stack **120** are surrounded by the silicon nitride layers **41** and **300**. In other words, the silicon nitride layer **300** and the silicon nitride layer **41** are provided in a U-shape, as viewed in the Y-direction.

FIG. **29** is a partially enlarged cross-sectional view of the semiconductor device **100** according to the fourth embodiment, and is a cross-sectional view showing a part indicated by the broken line C (staircase area **100***c* and peripheral area **100***d*) in FIG. **28**.

The interconnect D**2** is provided in the insulation layer **61**, as shown in FIG. **29**. The silicon nitride layer **41** is provided on the interconnect D**2** and the insulation layer **61**. The insulation layer **62** is provided on the silicon nitride layer **41**, and the tungsten silicide layer **42** and the polysilicon layer **43** are provided on this insulation layer **62** in the mentioned order. The insulation layer **63** is provided in a contact formation area on the same level as the tungsten silicide layer **42** and the polysilicon layer **43**. The end portions of the silicon nitride layer **41** and the insulation layers **62** and **63** in the X-direction are located closer to the inner side (i.e., closer to the memory cell array area **100***a*) than the end portion of the interconnect D**2** in the X-direction.

The layer stack **120** is formed on the polysilicon layer **43** and the insulation layer **63**. The layer stack **120** includes insulation layers **72** and conductive layers **70**, which are alternately stacked. One insulation layer **72** and one conductive layer **70** form a set, and a staircase (step and terrace) is formed for each set at the end portion as viewed in the X-direction. The insulation layer **44** is provided on the layer stack **120**, and the insulation layer (silicon oxide layer) **65** is further provided on an entire surface thereof.

The contact CC is connected to each terrace of the layer stack **120**. Also, the contact C**3** is coupled to the interconnect D**2**. The end portions of the silicon nitride layer **41** and the insulation layers **62** and **63** as viewed in the X-direction are located closer to the inner side than the contact C**3**. The silicon nitride layer **300** is provided between the contact C**3** and the layer stack **120**. The silicon nitride layer **300** is provided in the insulation layers **62**, **63**, and **65** so as to extend in the Y-direction and the Z-direction. The lower end of the silicon nitride layer **300** is connected to the silicon nitride layer **41**.

[Manufacturing Method of Fourth Embodiment]

FIGS. **30** to **36** are cross-sectional views showing a process of manufacturing the semiconductor device **100** according to the fourth embodiment. Hereinafter, mainly a process of manufacturing the silicon nitride layer **300** will be described.

First, the interconnect D**2** is formed in the insulation layer **61**, as shown in FIG. **30**. The insulation layer **61** is, for example, a silicon oxide layer. The interconnect D**2** is formed by, for example, the damascene method. The silicon nitride layer **41** is formed on the interconnect D**2** and the insulation layer **61**. The silicon nitride layer **41** is formed by, for example, the LP-CVD method.

Next, the insulation layer **62** is formed on the silicon nitride layer **41**, as shown in FIG. **31**. The tungsten silicide layer **42** is formed on the insulation layer **62**, and the polysilicon layer **43** is further formed on the tungsten silicide layer **42**. The insulation layer **63** is formed in a contact formation area in the tungsten silicide layer **42** and the polysilicon layer **43**.

Next, the insulation layers **72** and the sacrifice layers **71** are alternately stacked on the polysilicon layer **43** and the insulation layer **63**. The step of alternately stacking the insulation layer **72** and the sacrifice layer **71** is repeated, so that the layer stack **120** that includes sacrifice layers **71** and insulation layers **72** is formed. Furthermore, the insulation layer **44** is formed on the layer stack **120**. For example, the sacrifice layers **71** are silicon nitride layers, and the insulation layers **44**, **62**, **63**, and **72** are silicon oxide layers. The sacrifice layers **71** being a silicon nitride layer are formed by, for example, the P-CVD method.

Next, as shown in FIG. **32**, as one insulation layer **72** and one sacrifice layer **71** as a set, a staircase (step and terrace) is formed for each set at the end portion as viewed in the X-direction. This staircase is formed by repeating the step of slimming a resist pattern (not shown in the drawing) and the step of etching one insulation layer **72** and one sacrifice layer **71** using the resist pattern as a mask layer.

Next, the end portions of the insulation layers **62** and **63** and the silicon nitride layer **41** are removed by, for example, RIE using a mask layer not shown in the drawing, as shown in FIG. **33**. Thereby, the end portions of the silicon nitride layer **41** and the insulation layers **62** and **63** as viewed in the X-direction are located closer to the inner side than the end portion of the interconnect D**2** as viewed in the X-direction.

Next, the insulation layer **65** is formed on the entire surface, as shown in FIG. **34**. The insulation layer **65** is, for example, a silicon oxide layer. Next, a hole not shown in the drawing is formed in the insulation layers **62**, **63**, and **65** so as to cover the perimeter of the layer stack **120**. The hole is

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formed by, for example, RIE using a mask layer not shown in the drawing. The hole penetrates the insulation layers **62**, **63**, and **65**, to reach the silicon nitride layer **41**.

Thereafter, the silicon nitride layer **300** is formed in the hole. The silicon nitride layer **300** is formed by, for example, the LP-CVD method. Thereby, the hole is filled. In the end portion (peripheral area **100***d*), the interconnect layer **110** and the layer stack **120** are now separated from each other by the silicon nitride layers **41** and **300**. As a result, even if a thermal step is performed in the subsequent steps, diffusion of hydrogen included in the layer stack **120** from the end portion side into the interconnect layer **110** can be suppressed. On the other hand, hydrogen included in the interconnect layer **110** is released into the air through the end portion side as a diffusion pathway. This can suppress the interconnect layer **110** from being steamed by the hydrogen included therein.

Next, slits are formed in the layer stack **120** by the RIE method using a mask layer, although not shown in the drawing. The slits penetrate the insulation layer **44** and the layer stack **120**, to reach the polysilicon layer **43**.

Then, the sacrifice layers **71** are removed by an etching liquid or an etching gas supplied through the slits, as shown in FIG. **35**. For example, an etching liquid including phosphoric acid is used as the etching liquid. Thereby, the gap **73** is formed between every two insulation layers **72** that are vertically adjacent to each other. The gap **73** is also formed between the insulation layer **44** and the uppermost insulation layer **72** of the layer stack **120**.

Next, the conductive layers **70** are formed in the gaps **73** by, for example, the CVD method, as shown in FIG. **36**. At this time, a source gas is supplied to the gaps **73** through the slits. Thereafter, an insulation layer is formed on the side surface and at the bottom of the slits, although not shown in the drawing. Thereby, the slits are filled, and the isolation section **200** shown in FIG. **1** is formed.

Next, holes for the contacts CC and C**3** are formed in the silicon oxide layer **65** by the RIE method using a mask layer, as shown in FIG. **29**. The holes for the contacts CC penetrate the silicon oxide layer **65**, to reach each terrace. The hole for the contact C**3** penetrates the silicon oxide layer **65**, to reach the interconnect D**2**. Thereafter, a metal layer is formed in the holes by, for example, the CVD method, and the contacts CC and C**3** are formed.

In this manner, the semiconductor device **100** of the fourth embodiment is formed.

[Advantageous Effect of Fourth Embodiment]

According to the fourth embodiment described above, in the end portion (peripheral area **100***d*), the interconnect layer **110** and the layer stack **120** are separated from each other by the silicon nitride layers **41** and **300**. Thereby, even if a thermal step is performed in the subsequent steps, diffusion of hydrogen included in the layer stack **120** from the end portion side into the interconnect layer **110** can be suppressed.

Also, according to the fourth embodiment, the end portion of the silicon nitride layer **41** is removed to such an extent that the silicon nitride layer **41** is connected to the silicon nitride layer **300**. Thereby, the end portion of the interconnect layer **110** is not covered with the silicon nitride layer **41** as a barrier layer. Therefore, hydrogen included in the interconnect layer **110** is released into the air through the end portion side as a diffusion pathway. Therefore, it is possible to suppress the interconnect layer **110** from being steamed by the hydrogen included therein in the thermal step in the manufacturing process.

Also, according to the fourth embodiment, the end portion of the silicon nitride layer **41** is removed so as to be located closer to the inner side than the contact C**3**. Thereby, when the hole for the contact C**3** is formed, it does not need to penetrate the silicon nitride layer **41**. Namely, only the silicon oxide layer **65** is etched, which makes processing easy.

While certain embodiments 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 embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments 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.

What is claimed is:

1. A semiconductor device comprising:
- a substrate;
- a transistor provided on the substrate;
- a first interconnect layer provided above the transistor and electrically coupled to the transistor;
- a first conductive layer provided above the first interconnect layer;
- a layer stack provided above the first interconnect layer, the layer stack comprising a plurality of second conductive layers separated from each other;
- a pillar extending through the layer stack in a first direction and including a semiconductor layer, the first direction being a stacking direction of the second conductive layers, the semiconductor layer electrically coupled to the first conductive layer; and
- a first silicon nitride layer provided between the first interconnect layer and the first conductive layer, the first conductive layer contacting an end of the pillar.

2. The semiconductor device according to claim **1**, further comprising a first contact that extends in the layer stack and in the first silicon nitride layer in the first direction and is electrically coupled to the first interconnect layer.

3. The semiconductor device according to claim **2**, wherein the first contact comprises:
- a first metal layer continuously extending in the layer stack and in the first silicon nitride layer in the first direction; and
- a first silicon oxide layer provided between the first metal layer and the layer stack.

4. The semiconductor device according to claim **3**, further comprising:
- a second silicon oxide layer, wherein the first silicon nitride layer is located on the second silicon oxide layer and on the first interconnect layer.

5. The semiconductor device according to claim **4**, wherein a lower end of the first silicon oxide layer is located on the first silicon nitride layer.

6. The semiconductor device according to claim **5**, further comprising a third silicon oxide layer provided between the first silicon nitride layer and the layer stack and between the first interconnect layer and the layer stack.

7. The semiconductor device according to claim **6**, wherein the first silicon oxide layer is in contact with the layer stack.

8. The semiconductor device according to claim **7**, wherein the third silicon oxide layer is in contact with the layer stack.

9. The semiconductor device according to claim 8, wherein the first silicon oxide layer is in contact with the third silicon oxide layer.

10. The semiconductor device according to claim 9, further comprising:

a semiconductor layer provided above the third silicon oxide layer, wherein the layer stack is provided on the semiconductor layer.

11. The semiconductor device according to claim 2, wherein the first interconnect layer comprises:

a second metal layer; and

a first silicon layer provided between the second metal layer and the first contact.

12. The semiconductor device according to claim 2, wherein the first contact comprises:

a first metal layer continuously extending in the layer stack in the first direction;

a second silicon layer that continuously extends in the first silicon nitride layer in the first direction and is connected to the first metal layer; and

a first silicon oxide layer provided between the first metal layer and the layer stack.

13. A method of manufacturing a semiconductor device, the method comprising:

forming a transistor on a substrate; and

forming a first interconnect layer above the transistor, the first interconnect layer being electrically coupled to the transistor;

forming a first silicon nitride layer above the first interconnect layer;

forming a first conductive layer above the first silicon nitride layer;

forming a layer stack above the first conductive layer, the layer stack comprising a plurality of second conductive layers separated from each other;

forming a pillar extending through the layer stack in a first direction and including a semiconductor layer, the first direction being a stacking direction of the second conductive layers, the semiconductor layer electrically coupled to the first conductive layer; and

forming a first silicon nitride layer between the first interconnect layer and the first conductive layer, the first conductive layer contacting an end of the pillar.

14. The method according to claim 13, wherein the first silicon nitride layer is formed by an LP-CVD method.

15. The device according to claim 1, wherein the first silicon nitride layer extends in a second direction that intersects with the first direction.

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