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(54) **SEMICONDUCTOR SUBSTRATE, PRODUCTION METHOD THEREOF AND SEMICONDUCTOR DEVICE**

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(57) **ABSTRACT**

[Problem to be Solved] An object is to provide an art for preventing an element formative layer (active layer) from peeling off from a buried insulating film (intermediate insulating layer) with regard to production method of a semiconductor substrate having trench construction.

[Solution] Production method of a semiconductor substrate, constructed by laminating a support substrate **53**, a buried insulating film **52** and an element formative layer **51** in this order and having a trench **56** in the element formative layer **51** for separating an element, comprises a process forming one or plural trenches **56** in the element formative layer **51** along an outer perimeter of an element formative area E so as to connect the element formative area E of the element formative layer **51** to an outer peripheral part thereof at a part thereof at least; a process oxidizing a part of the element formative layer **51** connecting the element formative area E to the outer peripheral part thereof; and a process filling up the trenches **56** with an insulator, thereby forming the trenches **56** in the element formative layer **51** so as to make the element formative area E not independent.

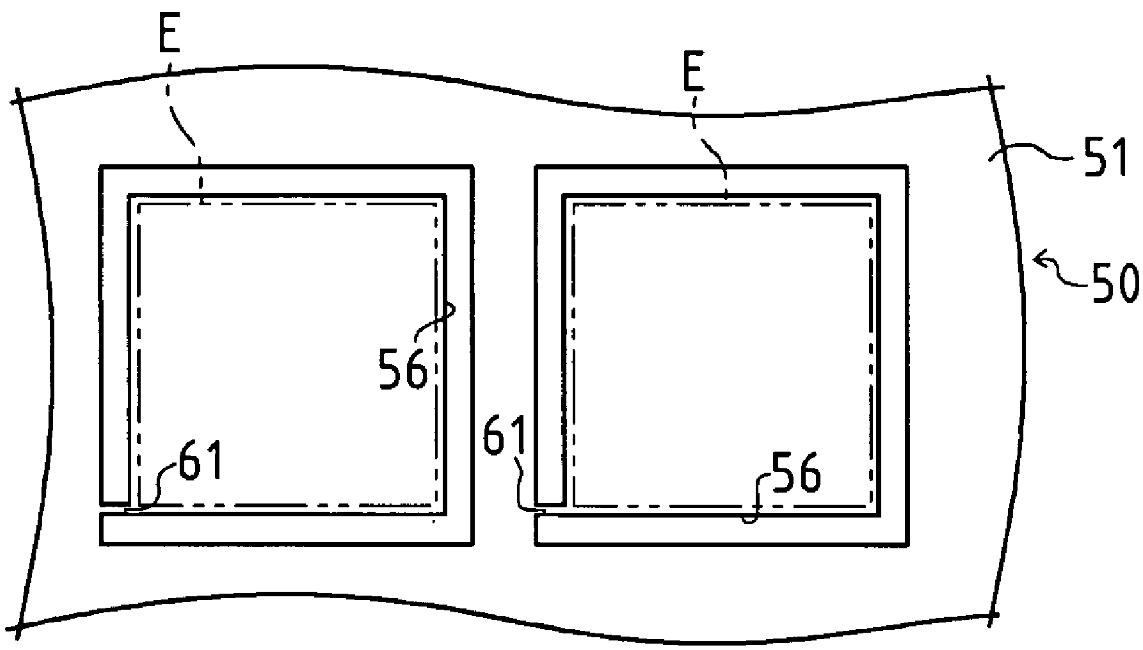
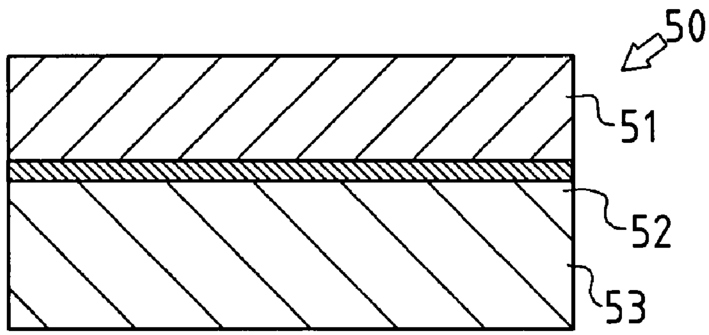


Fig. 1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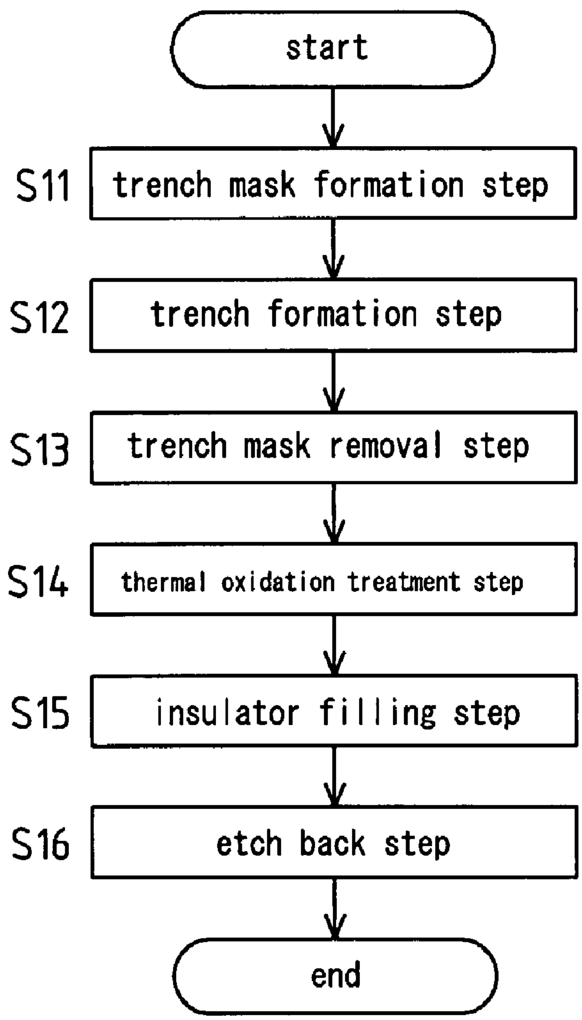
51
52
53

Fig. 2


start
S11
trench mask formation step
S12
trench formation step
S13
trench mask removal step
S14
thermal oxidation treatment step
S15
insulator filling step
S16
etch back step
end

F i g. 3

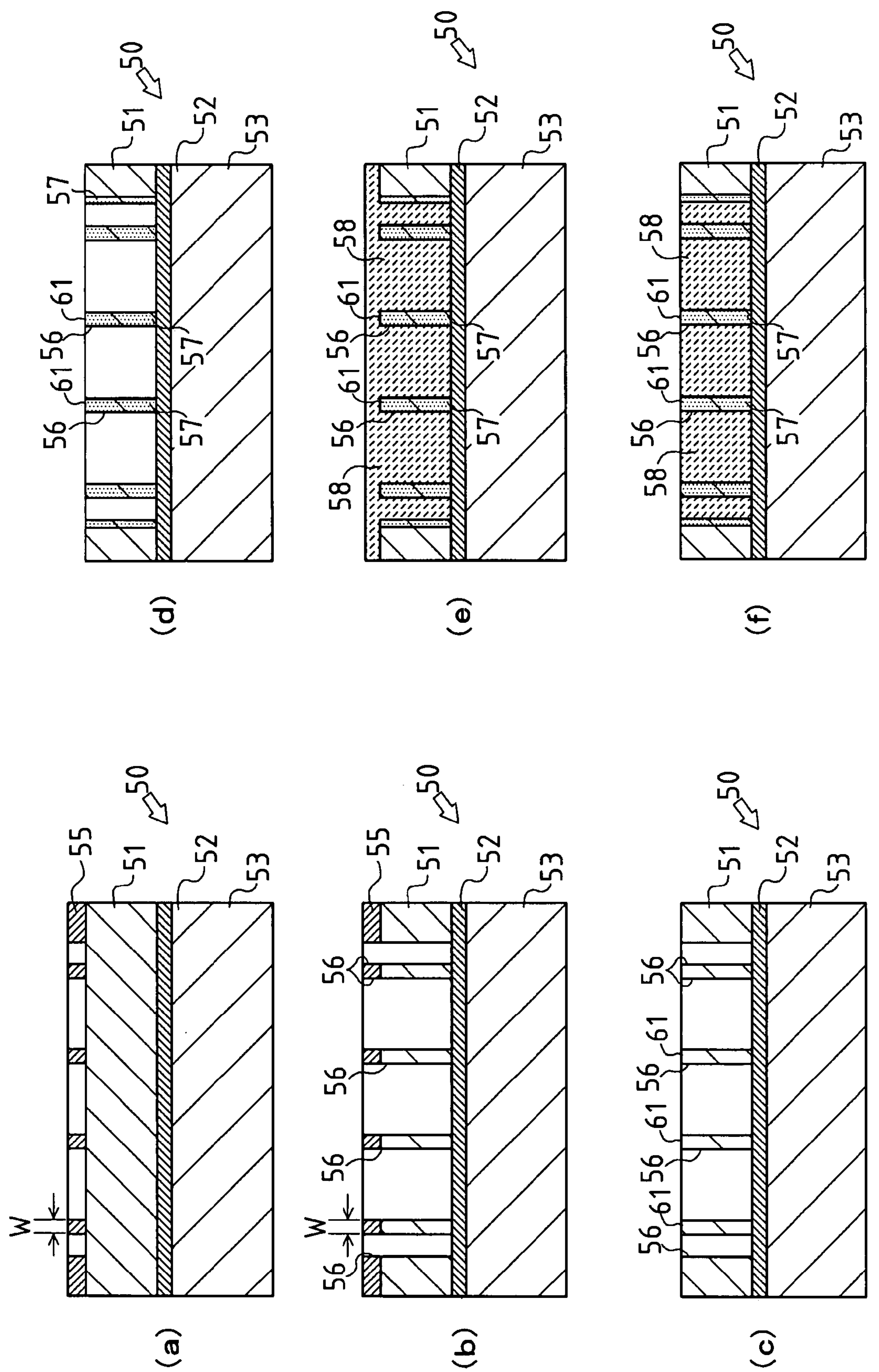


Fig. 4

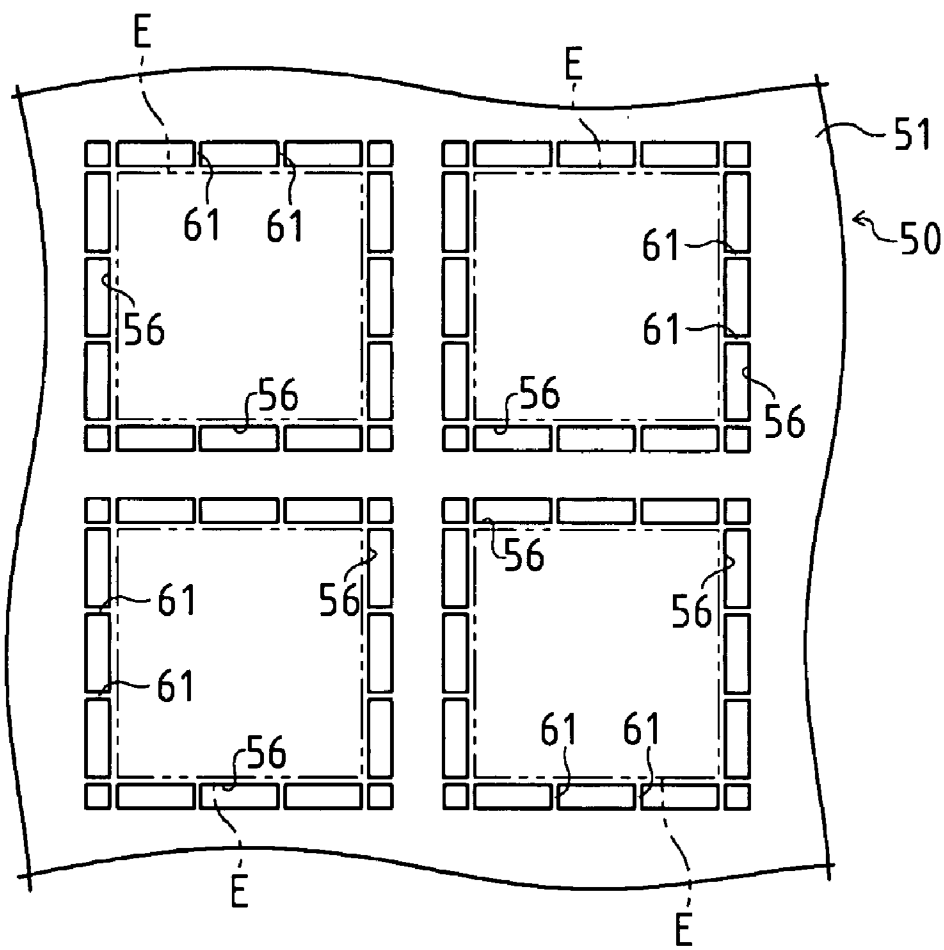
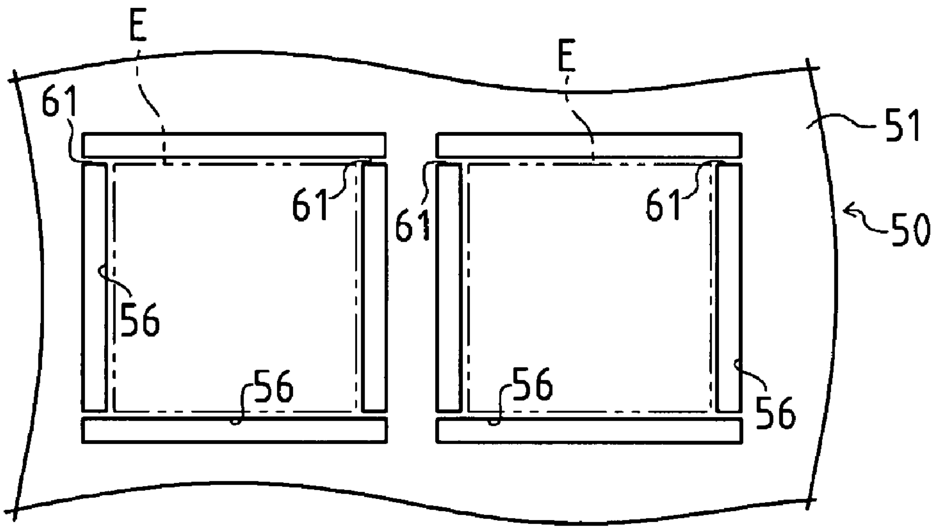


Fig. 5

(a)



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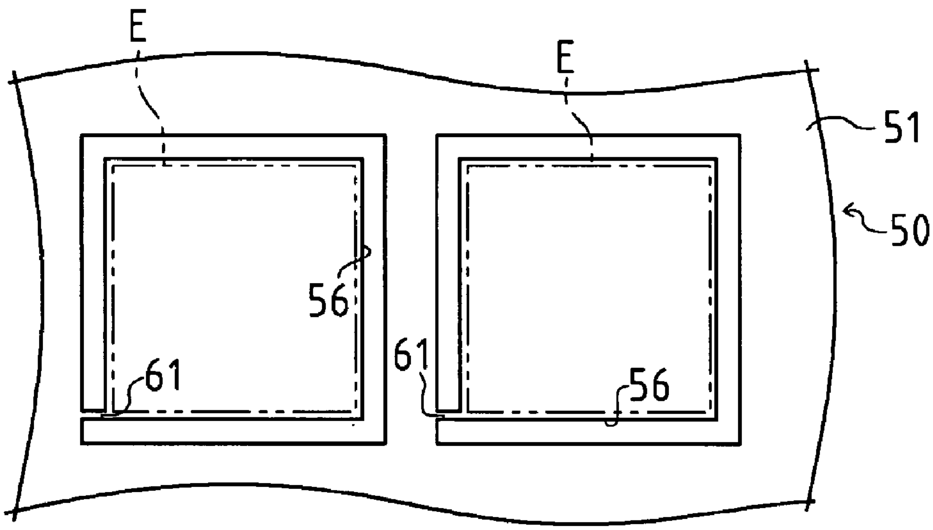

Fig. 6

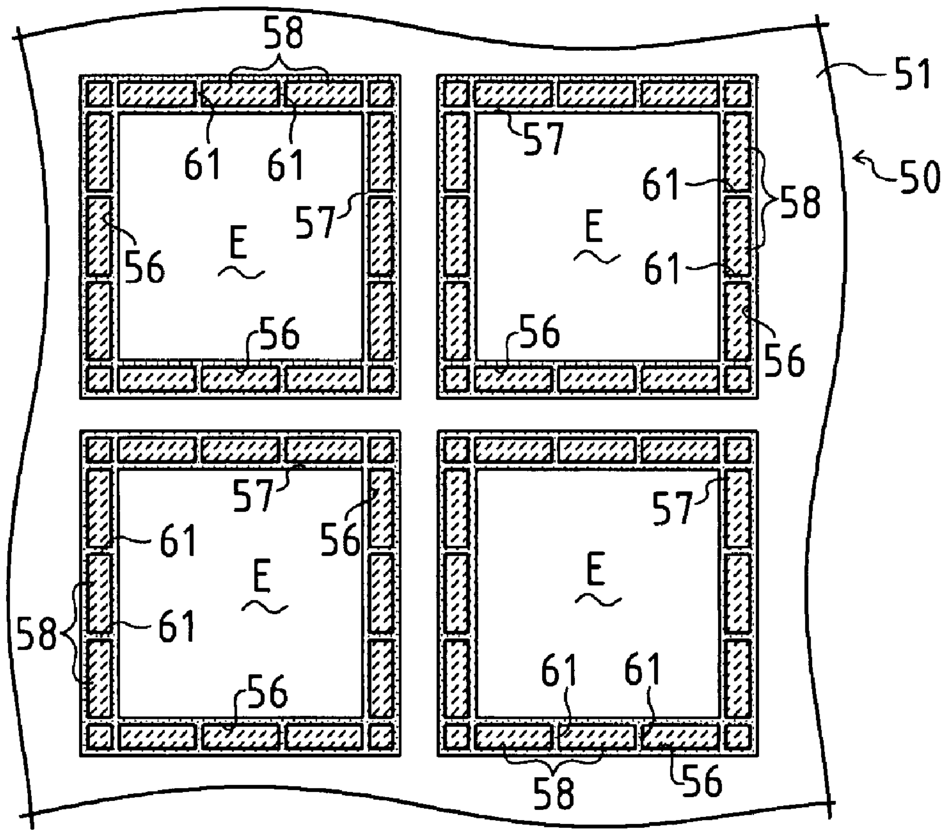

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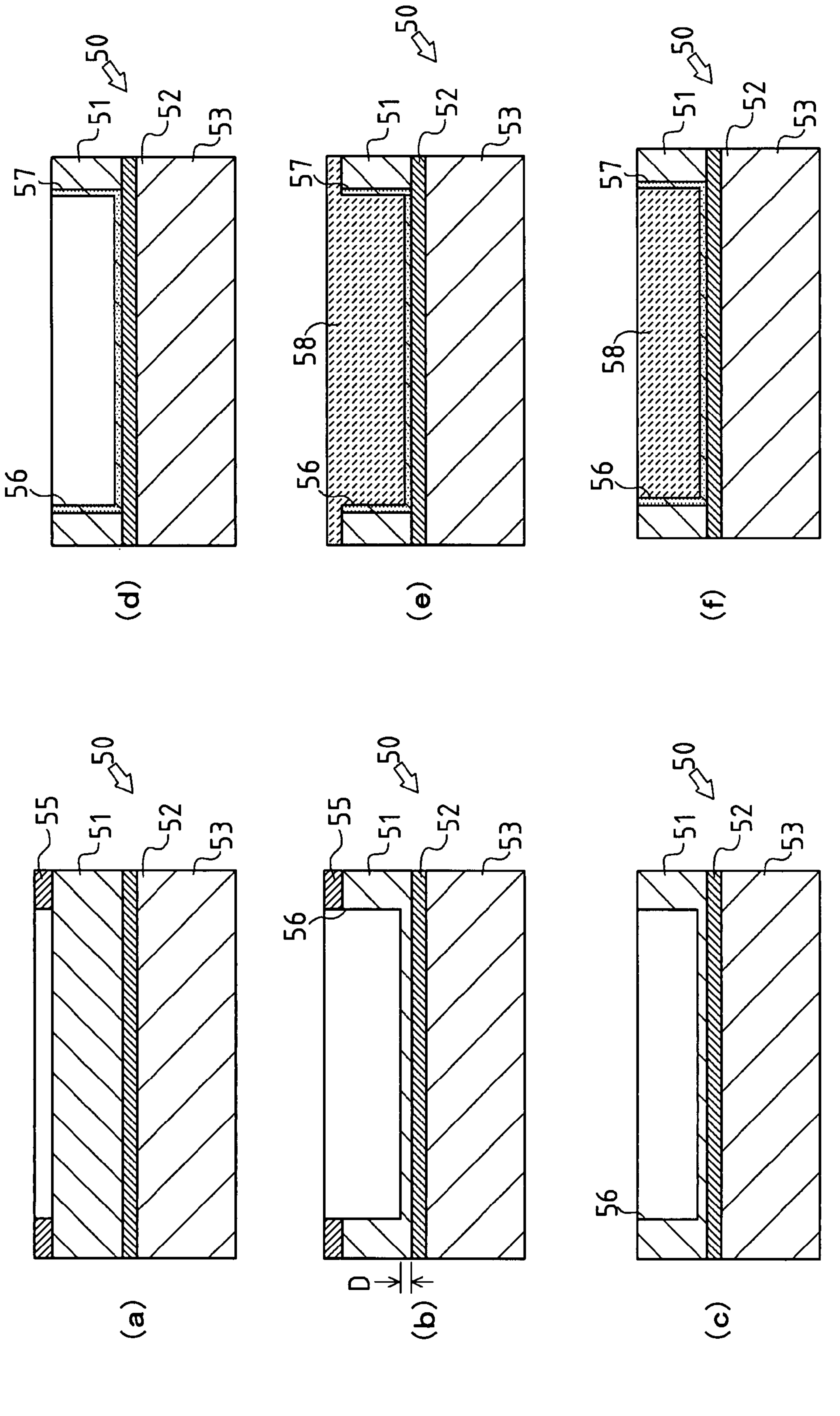
Fig. 7


(a)
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(b)
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D
(c)
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(f)
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Fig. 8

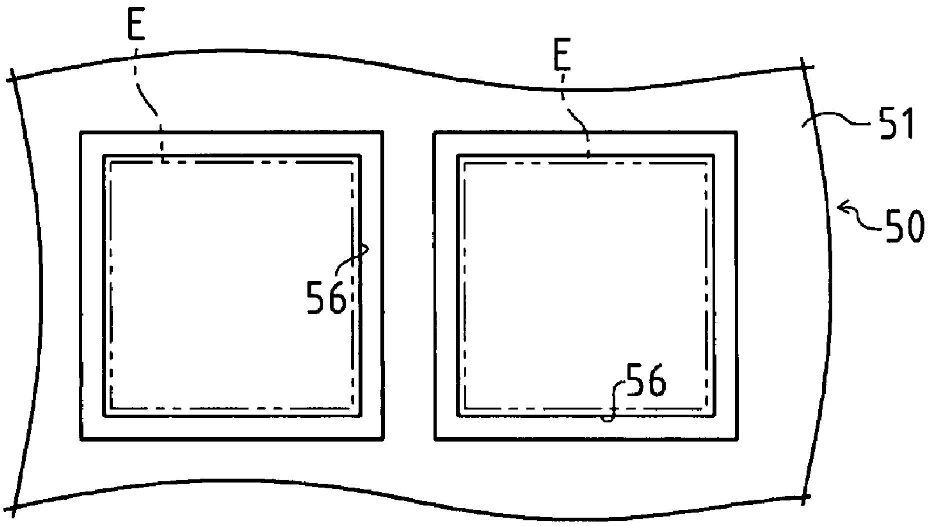


Fig. 9

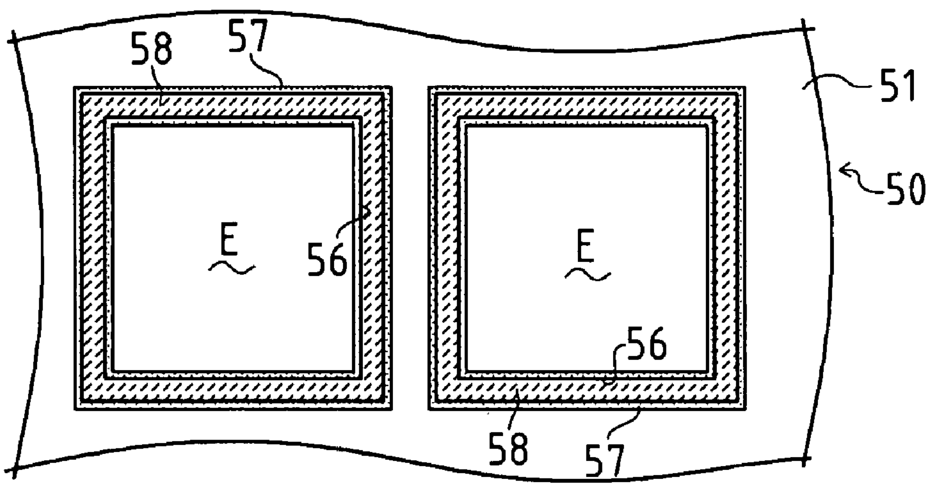


Fig. 10

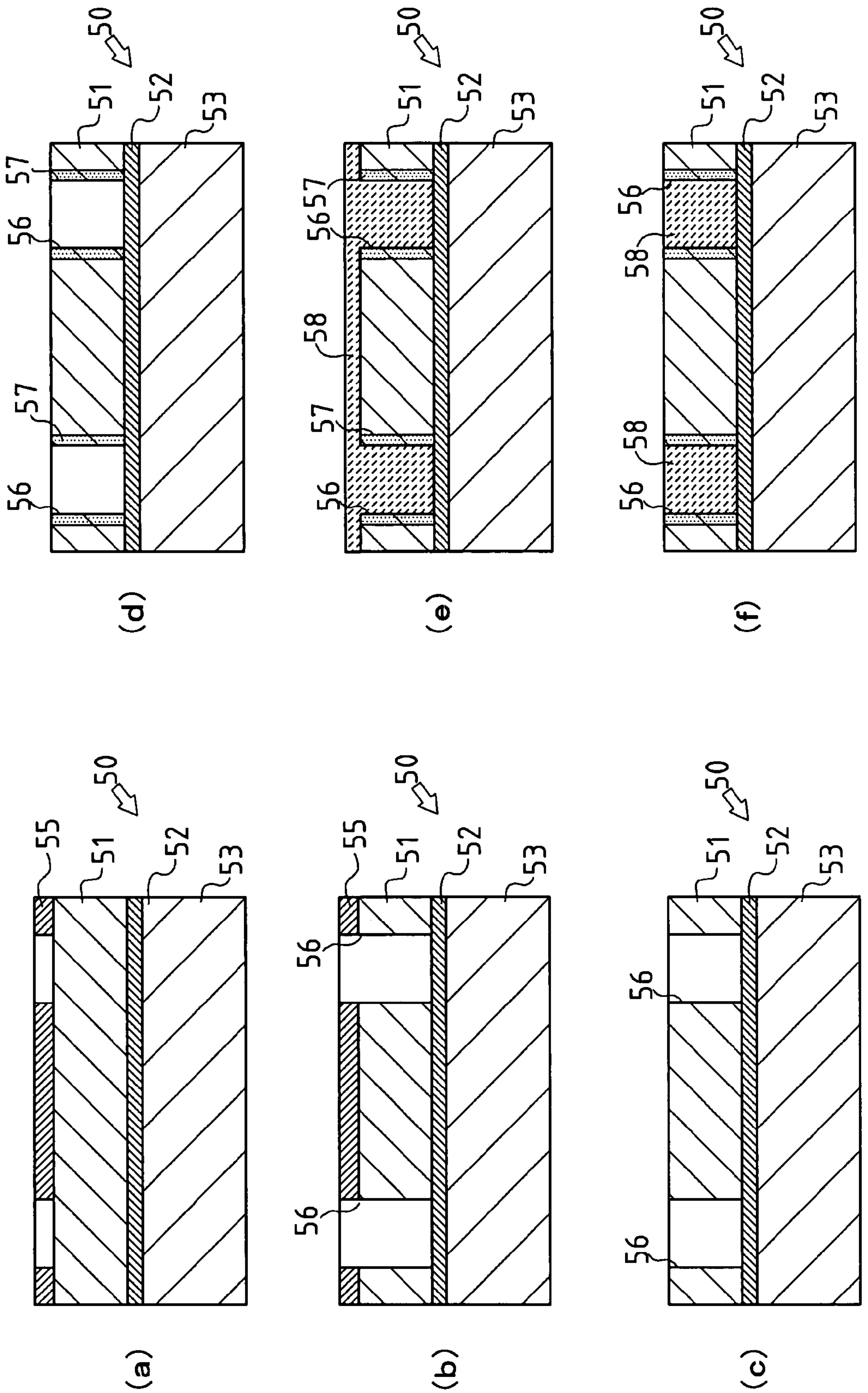
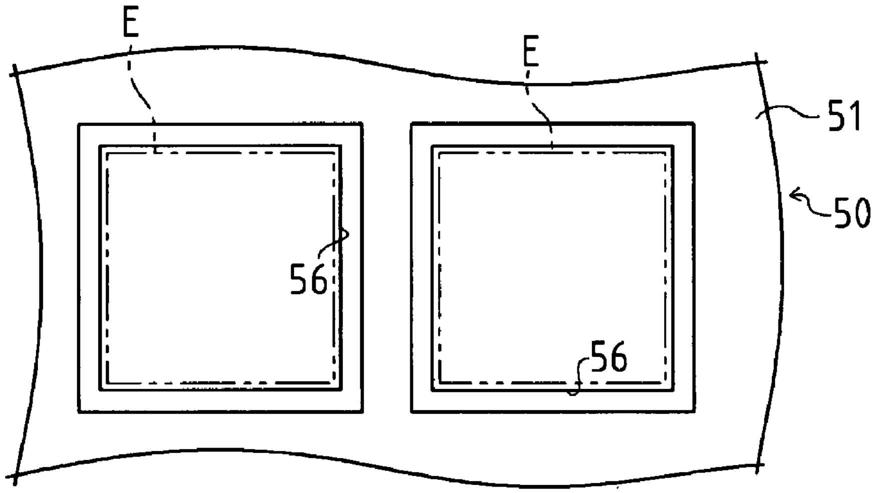
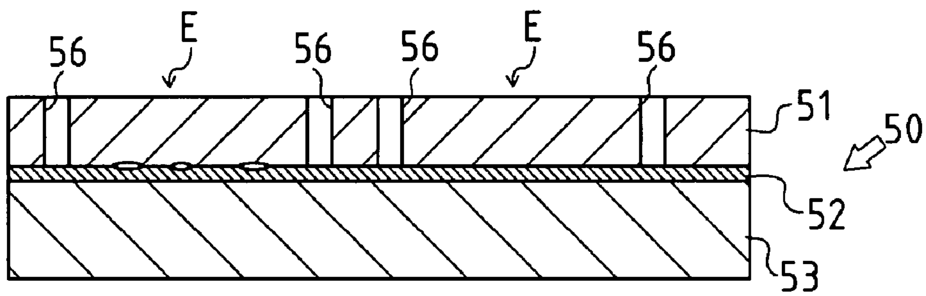


Fig. 11

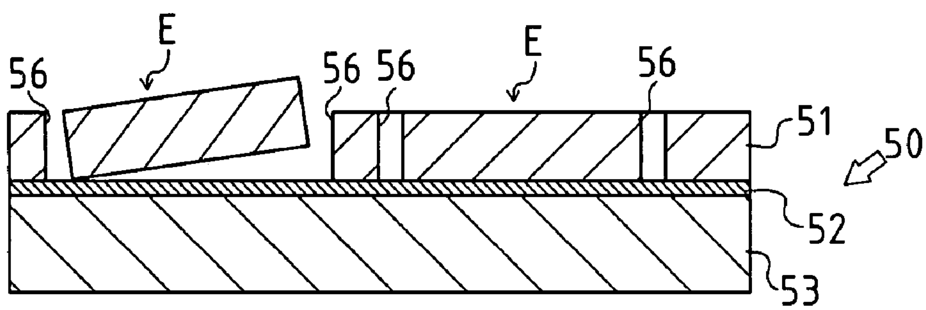
(a)



(b)



(c)



SEMICONDUCTOR SUBSTRATE, PRODUCTION METHOD THEREOF AND SEMICONDUCTOR DEVICE

THE TECHNICAL FIELD TO WHICH THE INVENTION BELONGS

[0001] The present invention relates to an art of a semiconductor substrate having trenches for separating elements, production method thereof, and a semiconductor device. Particularly, the present invention relates to an art for preventing an element formative layer (active layer) from peeling off from a buried insulating film (intermediate insulating layer), each of them constituting the semiconductor substrate.

DESCRIPTION OF THE PRIOR ART

[0002] Conventionally, there is well known trench structure as one of arts for separating elements of a semiconductor substrate. A so-called SOI wafer having a buried insulating film (intermediate insulating layer) is used as a substrate wafer, and trenches are formed between elements so as to reach the buried insulating film. Accordingly, the elements are separated from each other perfectly by insulator, whereby the elements are prevented from interfering with each other.

[0003] As a production method of a semiconductor substrate having the above-mentioned trench structure, for example, there is a method described in the Patent Literature 1.

[0004] FIG. **10** is a drawing explaining the flow of production of the conventional semiconductor substrate. FIG. **11** is a plan view of the conventional semiconductor substrate.

[0005] Firstly, with regard to a SOI wafer **50** comprising an element formative layer **51**, a buried insulating film **52** and a support substrate **53**, a trench mask **55** is formed in the element formative layer **51** while parts at which trenches are formed are not masked (FIG. **10***a*). Then, the parts of the element formative layer **51** not masked by the trench mask **55** are removed by etching so as to form the trenches **56** (FIG. **10***b*). The trench mask **55** is removed (FIG. **10***c*) and then the trenches **56** are oxidized thermally so as to form an oxide film **57** on the side wall of each of the trenches **56** (FIG. **10***d*). Subsequently, an insulator **58** such as polycrystalline silicon is accumulated on the trenches **56** by CVD or the like so as to fill the trenches **56** (FIG. **10***e*). Finally, the insulator **58** and the trench mask **55** on the upper layer are removed by etching, whereby the semiconductor substrate having the trench structure is completed (FIG. **10***f*).

[0006] However, if the trenches **56** are formed by the above-mentioned production method, the element formative layer **51** is divided into independent pieces. Normally, as shown in FIGS. **11***a* and **11***b*, each of the trenches **56** is formed in the element formative layer **51** along a perimeter of element formative area E in which the element is formed, whereby each of the pieces of the element formative layer **51** is independent. In this case, if a part exists which cohesive strength between the element formative layer **51** and the buried insulating film **52** is weak, the piece of the element formative layer **51** may be peeled off as shown in FIG. **11***c*. In addition, if void or dust exists between the element formative layer **51** and the buried insulating film **52**, the cohesive strength between the element formative layer **51** and the buried insulating film **52** becomes weak.

[0007] [Patent Literature 1] the Japanese Patent Laid Open Gazette Hei. 9-74132

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

[0008] The present invention provides an art for preventing an element formative layer (active layer) from peeling off from a buried insulating film (intermediate insulating layer) with regard to production method of a semiconductor substrate having trench construction.

Means for Solving the Problems

[0009] The above-mentioned problems are solved by the following means according to the present invention.

[0010] As specified in Claim **1**, production method of a semiconductor substrate, constructed by laminating a support substrate, a buried insulating film and an element formative layer in this order and having a trench in the element formative layer for separating an element, comprises a process forming one or plural trenches in the element formative layer along an outer perimeter of an element formative area so as to connect the element formative area of the element formative layer to an outer peripheral part thereof at a part thereof at least; a process oxidizing a part of the element formative layer connecting the element formative area to the outer peripheral part thereof; and a process filling up the trenches with an insulator.

[0011] As specified in Claim **2**, the trenches are enough deep to reach the buried insulating film, and are provided intermittently while a fixed distance exists between each two trenches adjacent to each other.

[0012] As specified in Claim **3**, the fixed distance between the trenches is not less than 0.1 μm and not more than 1 μm.

[0013] As specified in Claim **4**, the trenches are provided continuously along the outer perimeter of the element formative area while a fixed distance exists between the bottom surface of each of the trenches and the buried insulating film.

[0014] As specified in Claim **5**, the fixed distance between the bottom surface of each of the trenches and the buried insulating film is not less than 0.1 μm and not more than 0.5 μm.

[0015] As specified in Claim **6**, a semiconductor substrate, constructed by laminating a support substrate, a buried insulating film and an element formative layer in this order and having a trench in the element formative layer for separating an element, comprises one or plural trenches formed in the element formative layer so as to connect an element formative area of the element formative layer to an outer peripheral part thereof at a part thereof at least.

[0016] As specified in Claim **7**, the trenches are enough deep to reach the buried insulating film, and are provided intermittently while a fixed distance exists between each two trenches adjacent to each other.

[0017] As specified in Claim **8**, the fixed distance between the trenches is not less than 0.1 μm and not more than 1 μm.

[0018] As specified in Claim **9**, the trenches are provided continuously along the outer perimeter of the element formative area while a fixed distance exists between the bottom surface of each of the trenches and the buried insulating film.

[0019] As specified in Claim **10**, the fixed distance between the bottom surface of each of the trenches and the buried insulating film is not less than 0.1 μm and not more than 0.5 μm.

[0020] As specified in Claim **11**, a semiconductor device comprises the semiconductor substrate as set forth in one of claims **6** to **10**.

EFFECT OF THE INVENTION

[0021] The present invention constructed as the above brings the following effects.

[0022] Since the element formative areas of the element formative layer are connected to each other so as not to be independent, each element formative area of the element formative layer stuck to the buried insulating film are suppressed to peel off from the buried insulating film independently. Namely, even if any void or dust exists between the element formative layer and the buried insulating film, each element formative area E of the part of the element formative layer is prevented from peeling off from the buried insulating film independently. Therefore, in the producing step of the semiconductor substrate having the trench structure, the element formative layer (active layer) is prevented from peeling off from the buried insulating film (intermediate insulating layer).

THE BEST MODE OF EMBODIMENT OF THE INVENTION

[0023] A best embodiment of the present invention will be explained with reference to the accompanying drawings for understanding of the present invention.

[0024] FIG. **1** is a sectional side view of a SOI wafer concerning an embodiment of the present invention.

[0025] With regard to a production method of a semiconductor substrate concerning each embodiment of the present invention described below, as shown in FIG. **1**, a SOI wafer **50** is constructed by laminating a support substrate **53** comprising silicon, a buried insulating film **52** as an intermediate insulating layer comprising an oxide film, and an element formative layer **51** as an active layer comprising silicon in this order. By the SOI wafer **50**, a perfect dielectric separation type semiconductor substrate having trenches **56** on the element formative layer **51** is produced.

Embodiment 1

[0026] Explanation will be given on a production method of a semiconductor substrate concerning the Embodiment 1 of the present invention.

[0027] FIG. **2** is a flow chart of production of a semiconductor substrate concerning an embodiment of the present invention. FIG. **3** is a drawing explaining the flow of production of the semiconductor substrate according to the Embodiment 1. FIG. **4** is a plan view of trench pattern. FIG. **5** is a plan view of another trench pattern. FIG. **6** is a plan view of the semiconductor substrate.

[0028] Hereinafter, explanation will be given on a flow of production of a semiconductor substrate according to FIG. **2**.

[0029] Firstly, as shown in FIG. **3***a*, a trench mask **55** is formed in the element formative layer **51** of the SOI wafer **50** (trench mask formation step S**11**).

[0030] The trench mask **55** has a pattern so that parts of the element formative layer **51** in which the trenches **56** (grooves) are formed are exposed and parts thereof on which elements are formed are covered.

[0031] For example, as a method for forming the trench mask **55**, a photolithography method may be adopted so as to form the trench mask **55** comprising a photoresist film. Otherwise, the trench mask **55** may comprises a NSG (non-dope silica glass).

[0032] After forming the trench mask **55**, as shown in FIG. **3***b*, the parts of the element formative layer **51** not covered by the trench mask **55** are etched to the buried insulating film **52** so that the trenches **56** are formed in the element formative layer **51** (trench formation step S**12**).

[0033] As a method of etching, for example, reactive ion etching which is a kind of dry etching or wet etching may be adopted.

[0034] The areas in which independent elements of the element formative layer **51** are formed are referred to as element formative areas E. The outer peripheral part of each of the element formative areas E is the part of the element formative layer **51** outside the trenches **56**. As shown in FIG. **4**, the trenches **56** formed as mentioned above are formed along the outer perimeter of the element formative area E while connection parts **61** connecting the element formative area E with the outer peripheral part of the element formative area E are secured at a part thereof at least.

[0035] Namely, the trenches **56** are formed so that each of the element formative areas E of the part of the element formative layer **51** and the outer peripheral part thereof are connected to each other at a part thereof at least through the element formative layer **51** (the connection parts **61**).

[0036] By making each of the element formative areas E of the element formative layer **51** not independent, each of the element formative areas E of the element formative layer **51** stuck to the buried insulating film **52** are suppressed to peel off from the buried insulating film **52** independently. Accordingly, even if any void or dust exists between the element formative layer **51** and the buried insulating film **52**, each of the element formative areas E of the part of the element formative layer **51** is prevented from peeling off from the buried insulating film **52** independently. Therefore, in the producing step of the semiconductor substrate having the trench structure, the element formative layer **51** is prevented from peeling off from the buried insulating film **52**.

[0037] As an example of the construction that each of the element formative areas E of the part of the element formative layer **51** and the outer peripheral part thereof are connected to each other at a part thereof at least, as shown in FIG. **4**, each of the trenches **56** is short belt-shaped and the bottom thereof reaches the buried insulating film **52**, and the trenches **56** are arranged along the outer perimeter of the element formative area E intermittently while a fixed distance exists between each two trenches **56** adjacent to each other.

[0038] The part of the element formative layer **51** remaining between the two trenches **56** adjacent to each other is the connection part **61** which connects the element formative area E of the element formative layer **51** to the outer peripheral part of the element formative area E. In this case, the trenches **56** and the connection parts **61** are provided by turns along the outer perimeter of the element formative area E.

[0039] The distance between the two trenches **56** adjacent to each other, that is, the length W of the connection part **61** is preferably not less than 0.1 μm and not more than 1 μm (see FIG. **3***a* and **3***b*).

[0040] That is because too long treatment time is required for thermal oxidation of the connection part **61** in later-discussed thermal oxidation step if the distance between the two trenches **56** adjacent to each other is more than 1 μm.

[0041] If the distance between the two trenches **56** adjacent to each other is less than 0.1 μm, the etching treatment of the element formative layer **51** becomes difficult (the etching treatment becomes to require high accuracy), and the strength necessary to keep the element formative area E being connected to the element formative layer **51** cannot be obtained.

[0042] However, each of the element formative areas E of the element formative layer **51** is necessary only not to be independent. Accordingly, as shown in FIGS. **5***a* and **5***b*, it may alternatively constructed so that the trench **56** making nearly a round of the outer perimeter of the element formative area E is formed and at least one part of the trench **56** is divided by the connection part **61**.

[0043] After forming the trenches **56** in the element formative layer **51** as mentioned above, the trench mask **55** is removed as shown in FIG. **3***c* (trench mask removal step S**13**).

[0044] As an example of method for removing the trench mask **55**, for example, wet etching may be adopted.

[0045] Subsequently, as shown in FIG. **3***d*, thermal oxidation treatment is performed so as to oxidize the side wall of each trench **56** and each connection part **61** formed in the element formative layer **51** (thermal oxidation treatment step S**14**).

[0046] In this case, the side wall of each trench **56** is oxidized with the depth from 500 nm to 2 μm. Accordingly, silicon forming the connection part **61** between the trenches **56** is oxidized and becomes a thermal oxide film, whereby the connection part **61** functions as an insulating film (insulating layer). Namely, the connection part **61** functions both as an insulating film and as a member connecting the element formative area E to the outer peripheral part thereof.

[0047] Next, as shown in FIG. **3***e*, each of the trenches **56** is filled up with an insulator **58** (insulator filling step S**15**).

[0048] The insulator **58** may be polycrystalline silicon with which the trenches **56** is filled up by LPCVD, silicon oxide or silicon nitride with which the trenches **56** is filled up by plasma CVD, or NSG (non-dope silica glass) or PSG (phosphorus glass) with which the trenches **56** is filled up by atmospheric pressure CVD.

[0049] Finally, excessive insulator **58** on the outer layer is removed by etching (etch back step S**16**). Then, as shown in FIGS. **3***f* and **6**, the semiconductor substrate having the perfect dielectric separation type trench structure that each of the element formative areas E is insulated perfectly from each other is obtained.

[0050] Namely, in the semiconductor substrate, each of the element formative areas E of the element formative layer **51** is insulated perfectly from each other by an insulating layer comprising the insulator **58** with which the trenches **56** is filled up, the connection part **61** as the insulating film, and the buried insulating film **52**.

[0051] In addition, with regard to the semiconductor substrate constructed as mentioned above, elements such as transistors and diodes are formed in the element formative areas E of the element formative layer **51**, and wires and protective films are formed, whereby the semiconductor device is completed.

[0052] In addition, the semiconductor substrate may be installed into various semiconductor devices.

Embodiment 2

[0053] Explanation will be given on a production method of a semiconductor substrate concerning the Embodiment 2 of the present invention.

[0054] FIG. **2** is a flow chart of production of a semiconductor substrate concerning an embodiment of the present invention.

[0055] FIG. **7** is a drawing explaining the flow of production of the semiconductor substrate according to the Embodiment 2.

[0056] FIG. **8** is a plan view of the trench pattern.

[0057] FIG. **9** is a plan view of the semiconductor substrate.

[0058] Hereinafter, explanation will be given on a flow of production of a semiconductor substrate according to FIG. **2**.

[0059] In addition, later-discussed trench mask formation step S**11**, trench formation step S**12**, trench mask removal step S**13**, thermal oxidation treatment step S**14**, insulator filling step S**15** and etch back step S**16** are similar to the flow of production of the semiconductor substrate mentioned in the Embodiment 1, and so detailed explanation thereof is omitted.

[0060] Firstly, as shown in FIG. **7***a*, the trench mask **55** is formed on the element formative layer **51** of the SOI wafer **50** (trench mask formation step S**11**).

[0061] After forming the trench mask **55**, as shown in FIG. **7***b*, the parts of the element formative layer **51** not covered by the trench mask **55** are etched to the buried insulating film **52** so that the trenches **56** are formed in the element formative layer **51** (trench formation step S**12**).

[0062] In addition, as shown in FIGS. **7***b* and **8**, the trenches **56** are provided continuously along the outer perimeter of the element formative area E, and a fixed distance D exists between the bottom surface of each of the trenches **56** and the buried insulating film **52**. Namely, the bottom surface of each of the trenches **56** does not reach the buried insulating film **52**.

[0063] The element formative layer **51** remaining between the bottom surface of each of the trenches **56** and the buried insulating film **52** is the connection part which connects the element formative area E to the outer peripheral part of the element formative area E (the part of the element formative layer **51** outside the trenches **56**). By providing the connection part, each of the element formative area E of the element formative layer **51** is connected to the outer peripheral part of the element formative area E so as not to be independent.

[0064] In addition, the distance D between the bottom surface of each of the trenches **56** and the buried insulating film **52** is preferably not less than 0.1 μm and not more than 0.5 μm.

[0065] That is because too long treatment time is required for thermal oxidation of the connection part **61** in later-discussed thermal oxidation step if the distance D between the bottom surface of each of the trenches **56** and the buried insulating film **52** is more than 0.5 μm.

[0066] If the distance D between the bottom surface of each of the trenches **56** and the buried insulating film **52** is less than 0.1 μm, the etching treatment of the element formative layer **51** becomes difficult (the etching treatment becomes to require high accuracy), and the strength necessary to keep the element formative area E being connected to the element formative layer **51** cannot be obtained.

[0067] By connecting each of the element formative areas E of the element formative layer **51** by the element formative layer **51** remaining between the bottom surface of each of the trenches **56** and the buried insulating film **52**, each of the element formative areas E of the element formative layer **51** stuck to the buried insulating film **52** are suppressed to peel off from the buried insulating film **52** independently. Accordingly, even if any void or dust exists between the element formative layer **51** and the buried insulating film **52**, each of the element formative areas E of the part of the element formative layer **51** is prevented from peeling off from the buried insulating film **52** independently. Therefore, in the producing step of the semiconductor substrate having the trench structure, the element formative layer **51** is prevented from peeling off from the buried insulating film **52**.

[0068] After forming the trenches **56** in the element formative layer **51** as mentioned above, the trench mask **55** is removed as shown in FIG. **7***c* (trench mask removal step S**13**).

[0069] Subsequently, as shown in FIG. **7***d*, thermal oxidation treatment is performed so as to oxidize the side wall of each trench **56** and each connection part **61** formed in the element formative layer **51** (thermal oxidation treatment step S**14**).

[0070] In this case, the side wall and bottom surface of each of the trenches **56** are oxidized with the depth from 500 nm to 2 μm. Accordingly, silicon forming the connection part **61** between the bottom surface of each of the trenches **56** and the buried insulating film **52** is oxidized and becomes a thermal oxide film, whereby the connection part **61** functions as an insulating film (insulating layer).

[0071] Namely, the trenches **56** are formed between the element formative area E of the element formative layer **51** and the outer peripheral part thereof so that the element formative area E and the outer peripheral part thereof are connected to each other at a part thereof at least through the insulating layer. The element formative layer **51** between the bottom surface of each of the trenches **56** and the buried insulating film **52**, which is the connection part between the element formative area E and the outer peripheral part thereof, functions both as an insulating film and as a member connecting the element formative area E to the outer peripheral part thereof.

[0072] Next, as shown in FIG. **7***e*, each of the trenches **56** is filled up with an insulator **58** (insulator filling step S**15**).

[0073] Finally, excessive insulator **58** on the outer layer is removed by etching (etch back step S**16**). Then, as shown in FIGS. **7***f* and **9**, the semiconductor substrate having the perfect dielectric separation type trench structure that each of the element formative areas E is insulated perfectly from each other is obtained.

[0074] Namely, in the semiconductor substrate, each of the element formative areas E of the element formative layer **51** is insulated perfectly from each other by an insulating layer comprising the insulator **58** with which the trenches **56** is filled up, the connection part **61** as the insulating film, and the buried insulating film **52**.

[0075] With regard to the semiconductor substrate constructed as mentioned above, elements such as transistors and diodes are formed in the element formative areas E of the element formative layer **51**, and wires and protective films are formed, whereby the semiconductor device is completed.

[0076] In addition, the semiconductor substrate may be installed into various semiconductor devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0077] [FIG. **1**] It is a sectional side view of a SOI wafer concerning an embodiment of the present invention.

[0078] [FIG. **2**] It is a flow chart of production of a semiconductor substrate concerning an embodiment of the present invention.

[0079] [FIG. **3**] It is a drawing explaining the flow of production of the semiconductor substrate according to the Embodiment 1.

[0080] [FIG. **4**] It is a plan view of trench pattern.

[0081] [FIG. **5**] It is a plan view of another trench pattern.

[0082] [FIG. **6**] It is a plan view of the semiconductor substrate.

[0083] [FIG. **7**] It is a drawing explaining the flow of production of the semiconductor substrate according to the Embodiment 2.

[0084] [FIG. **8**] It is a plan view of the trench pattern.

[0085] [FIG. **9**] It is a plan view of the semiconductor substrate.

[0086] [FIG. **10**] It is a drawing explaining the flow of production of the conventional semiconductor substrate.

[0087] [FIG. **11**] It is a plan view of the conventional semiconductor substrate.

DESCRIPTION OF NOTATIONS

[0088] **50** a SOI wafer

[0089] **51** an element formative layer

[0090] **52** a buried insulating film

[0091] **53** a support substrate

[0092] **55** a trench mask

[0093] **56** trenches

[0094] **57** an oxide film

[0095] **58** an insulator

1. Production method of a semiconductor substrate constructed by laminating a support substrate, a buried insulating film and an element formative layer in this order and having a trench in the element formative layer for separating an element, comprising:

a process forming one or plural trenches in the element formative layer along an outer perimeter of an element formative area so as to connect the element formative area of the element formative layer to an outer peripheral part thereof at a part thereof at least;

a process oxidizing a part of the element formative layer connecting the element formative area to the outer peripheral part thereof; and

a process filling up the trenches with an insulator.

2. The production method of a semiconductor substrate as set forth in claim **1**, wherein the trenches are enough deep to reach the buried insulating film, and are provided intermittently while a fixed distance exists between each two trenches adjacent to each other.

3. The production method of a semiconductor substrate as set forth in claim **2**, wherein the fixed distance between the trenches is not less than 0.1 μm and not more than 1 μm.

4. The production method of a semiconductor substrate as set forth in claim **1**, wherein the trenches are provided continuously along the outer perimeter of the element formative area while a fixed distance exists between the bottom surface of each of the trenches and the buried insulating film.

5. The production method of a semiconductor substrate as set forth in claim **4**, wherein the fixed distance between the bottom surface of each of the trenches and the buried insulating film is not less than 0.1 μm and not more than 0.5 μm.

6. A semiconductor substrate constructed by laminating a support substrate, a buried insulating film and an element formative layer in this order and having a trench in the element formative layer for separating an element, comprising:

one or plural trenches formed in the element formative layer so as to connect an element formative area of the element formative layer to an outer peripheral part thereof at a part thereof at least.

7. The semiconductor substrate as set forth in claim **6**, wherein the trenches are enough deep to reach the buried insulating film, and are provided intermittently while a fixed distance exists between each two trenches adjacent to each other.

8. The semiconductor substrate as set forth in claim **7**, wherein the fixed distance between the trenches is not less than 0.1 μm and not more than 1 μm.

9. The semiconductor substrate as set forth in claim **6**, wherein the trenches are provided continuously along the outer perimeter of the element formative area while a fixed distance exists between the bottom surface of each of the trenches and the buried insulating film.

10. The semiconductor substrate as set forth in claim **9**, wherein the fixed distance between the bottom surface of each of the trenches and the buried insulating film is not less than 0.1 μm and not more than 0.5 μm.

11. A semiconductor device comprising the semiconductor substrate as set forth in one of claims **6** to **10**.

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