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(54) **FIN STRUCTURE AND METHOD OF FORMING THE SAME**

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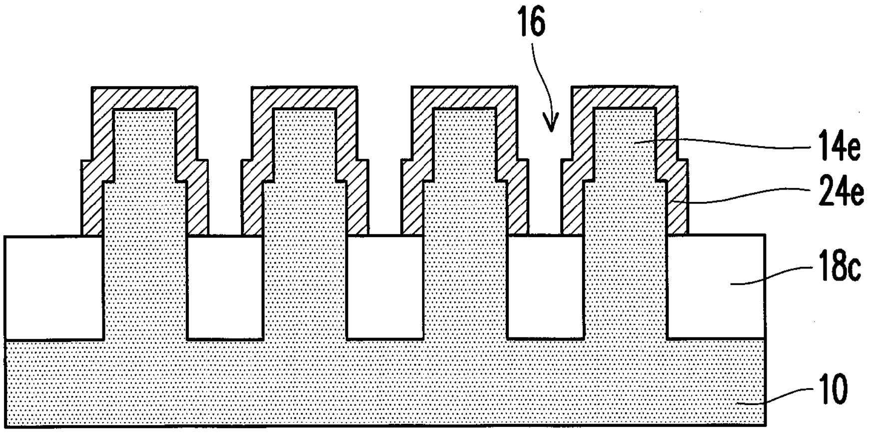
USPC **257/506**; 438/424; 257/E29.022; 257/E21.546

(57) **ABSTRACT**

A method of forming a fin structure is provided. The method includes forming a hard mask material layer on a substrate, and then patterning the hard mask material layer to form a first hard mask layer. Thereafter, a portion of the substrate is removed to form two trenches, wherein a remaining substrate forms a fin between the trenches. Afterwards, an insulating layer is formed in each trench, wherein the insulating layers expose an upper portion of the fin. Further, the upper portion of the fin is trimmed, so that the trimmed upper portion is narrower than a lower portion of the fin, and a fin structure having an inverse T shape is formed.



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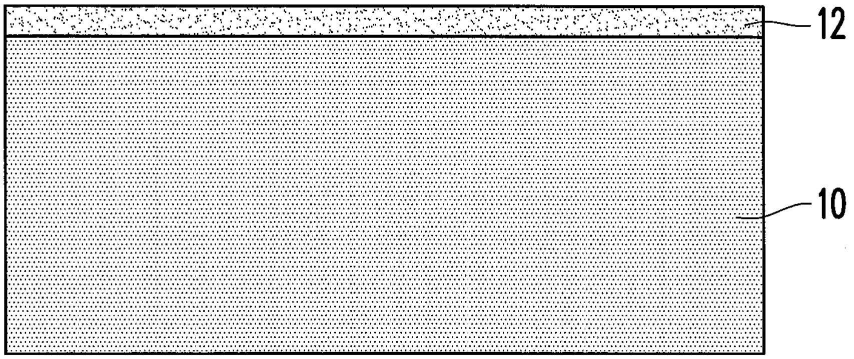

FIG. 1A

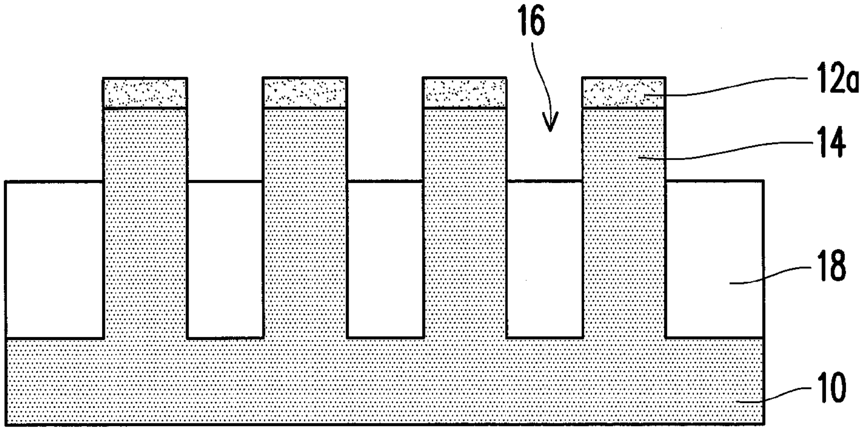

FIG. 1B

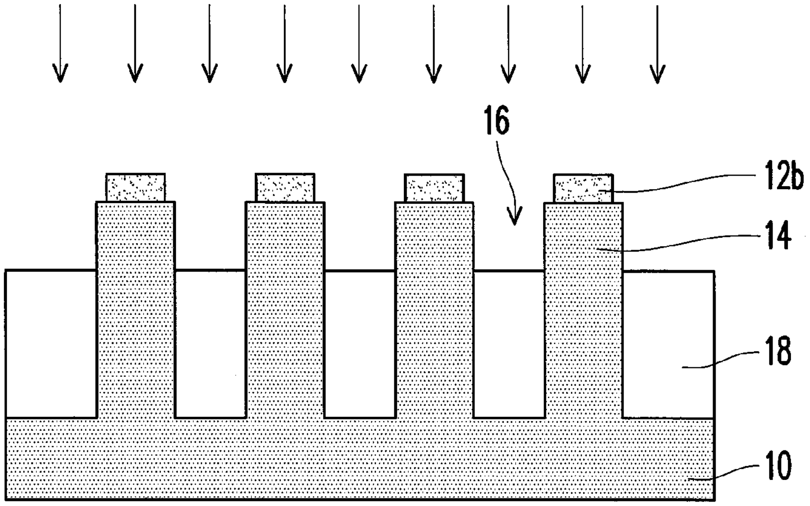

FIG. 1C

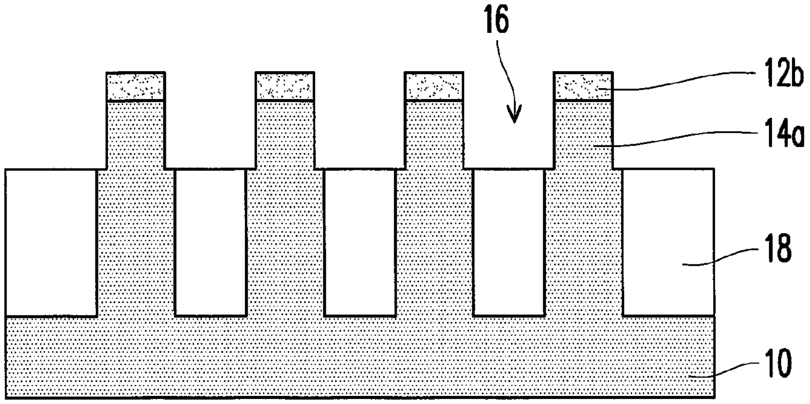

FIG. 1D

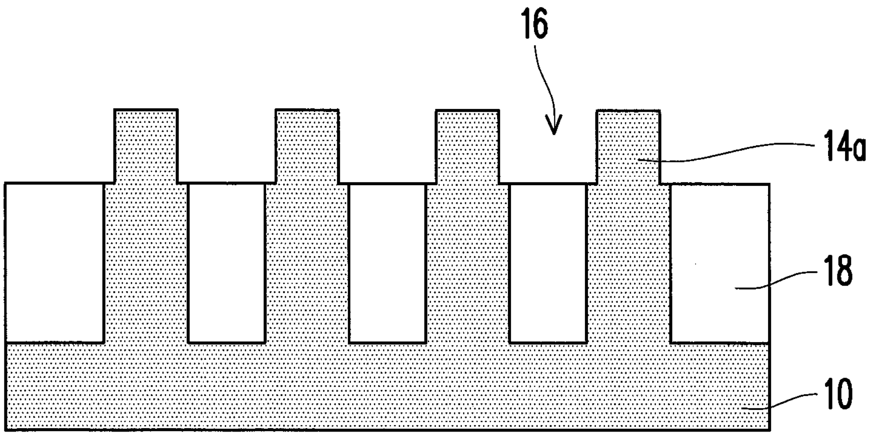

FIG. 1E

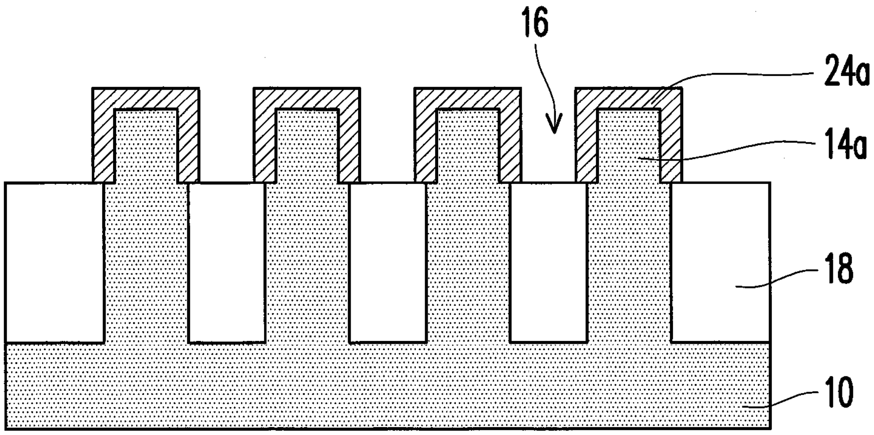

FIG. 1F

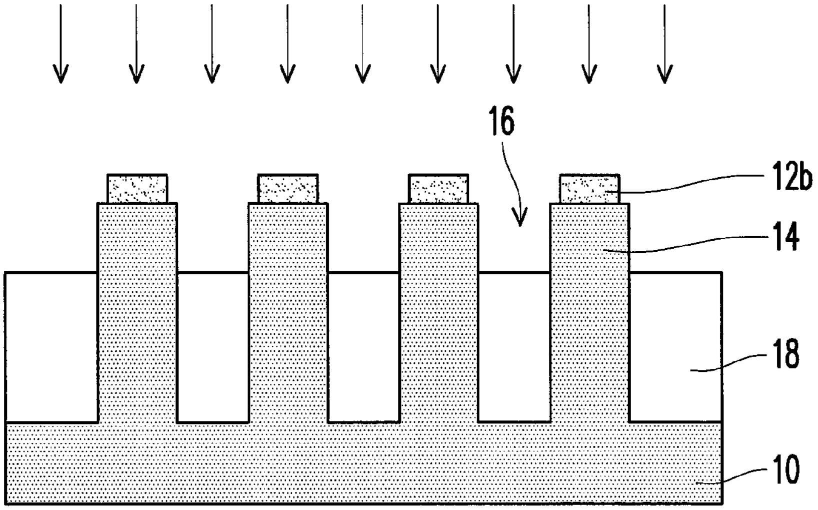

FIG. 2A

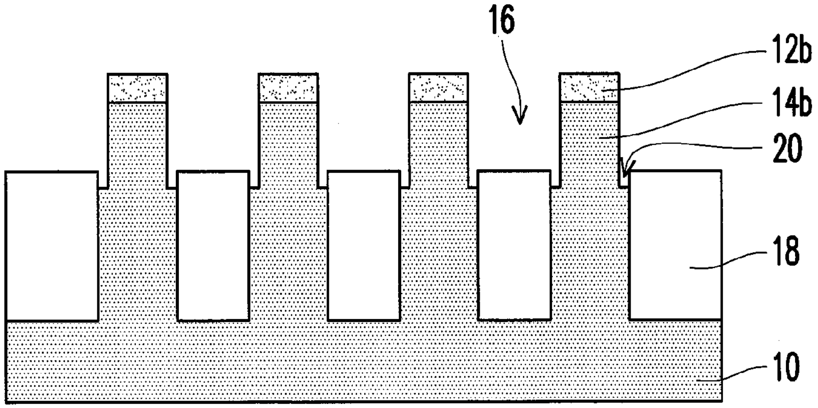

FIG. 2B

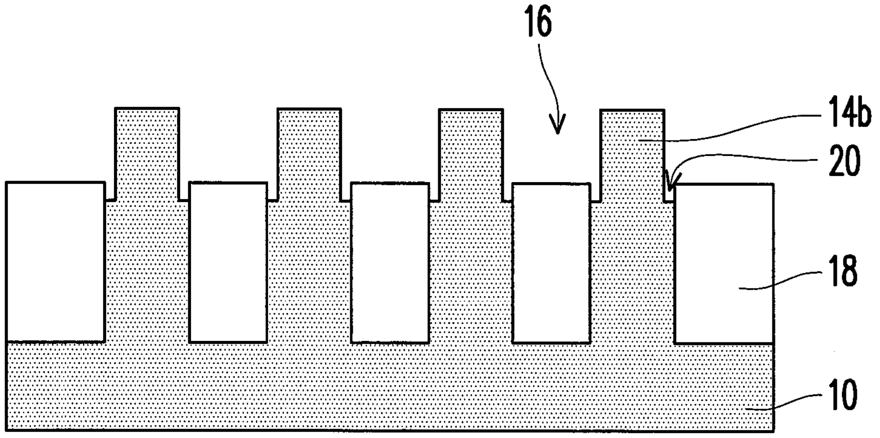

FIG. 2C

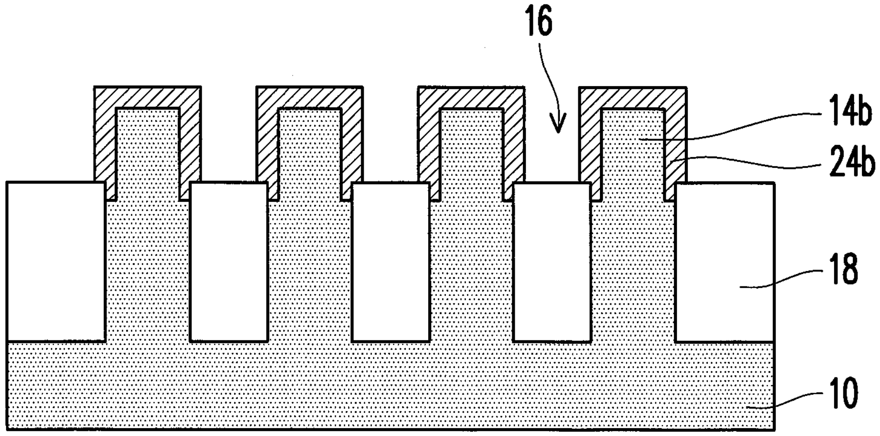

FIG. 2D

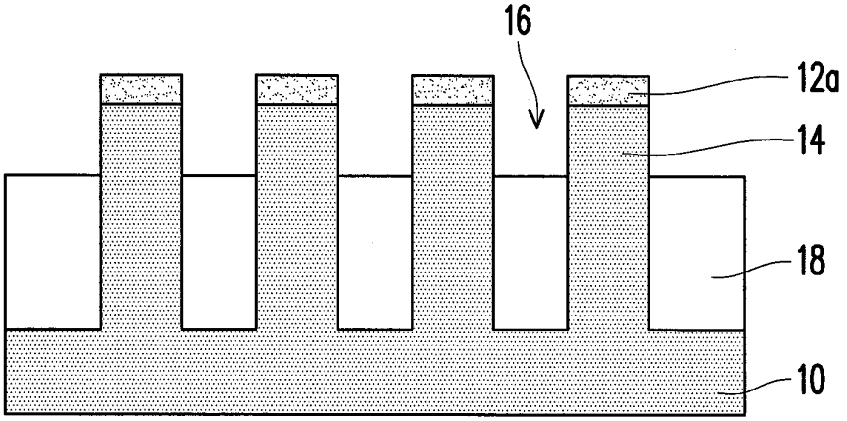

FIG. 3A

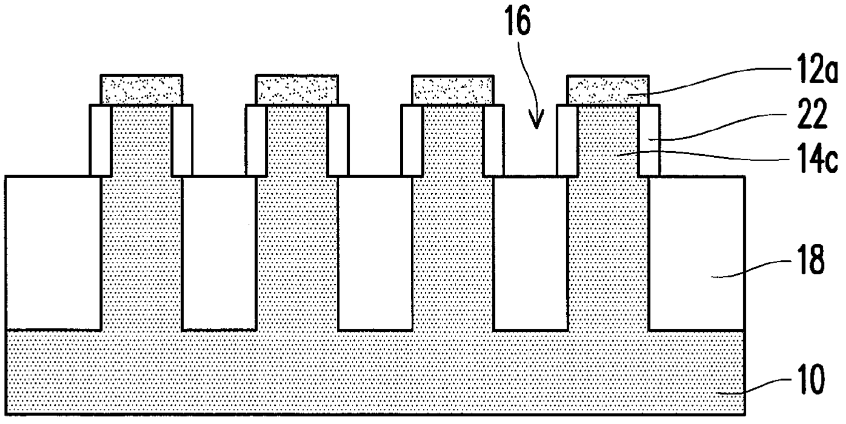

FIG. 3B

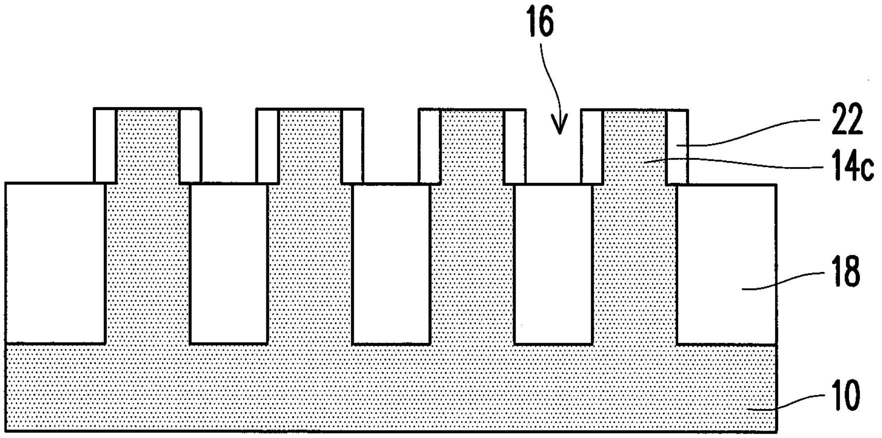

FIG. 3C

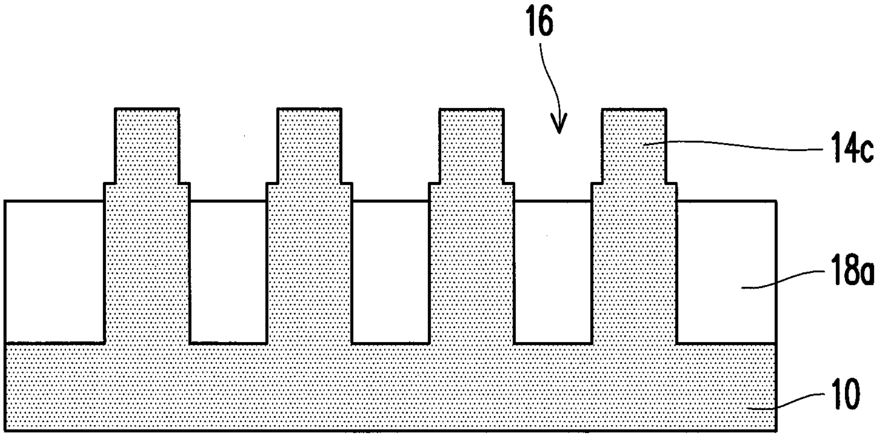

FIG. 3D

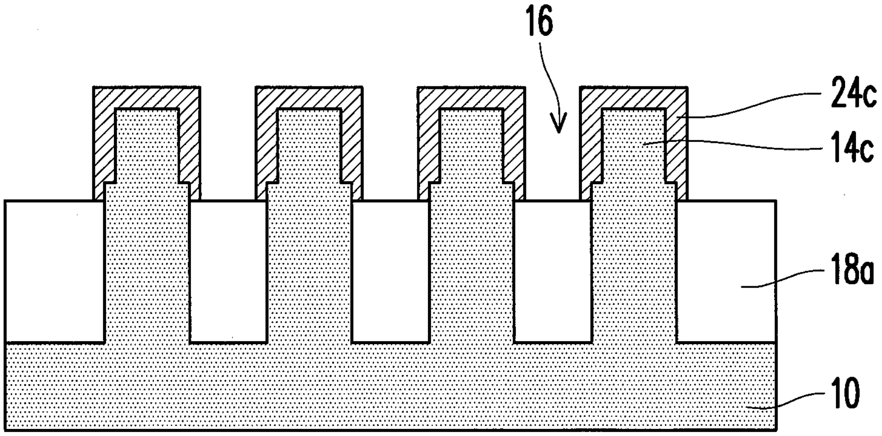

FIG. 3E

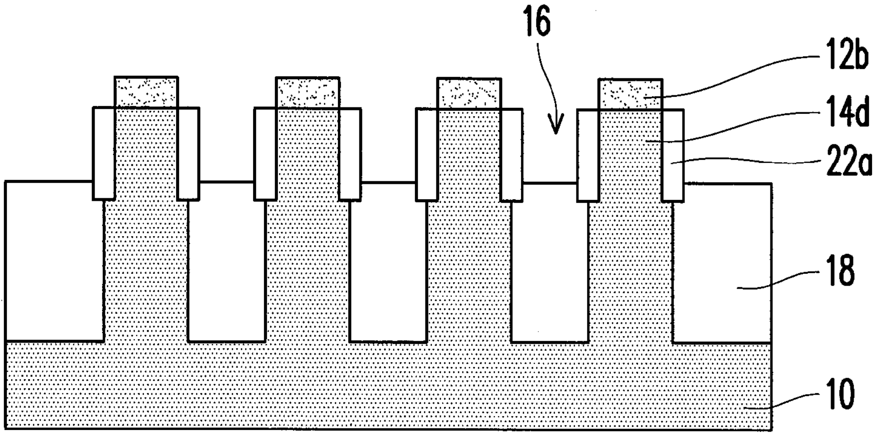

FIG. 4A

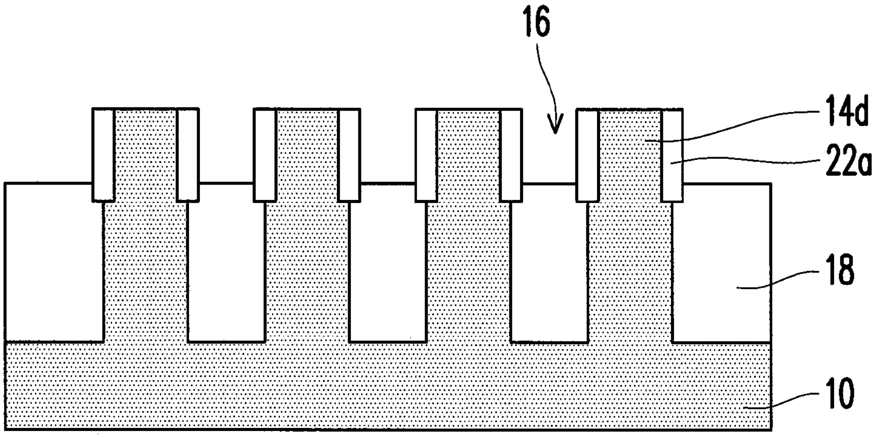

FIG. 4B

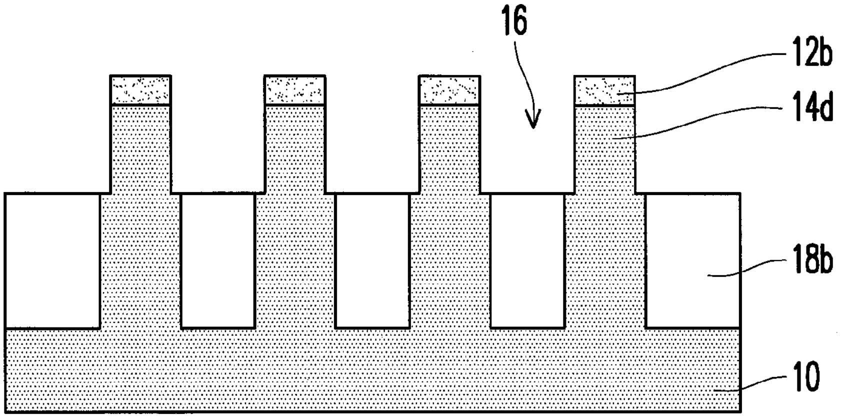

FIG. 4C

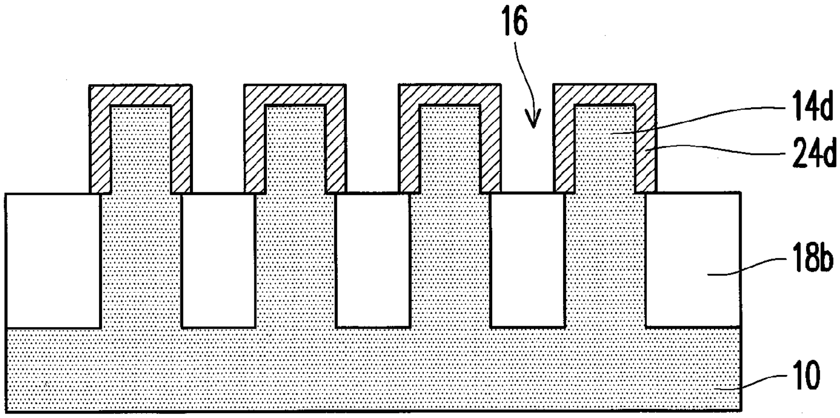

FIG. 4D

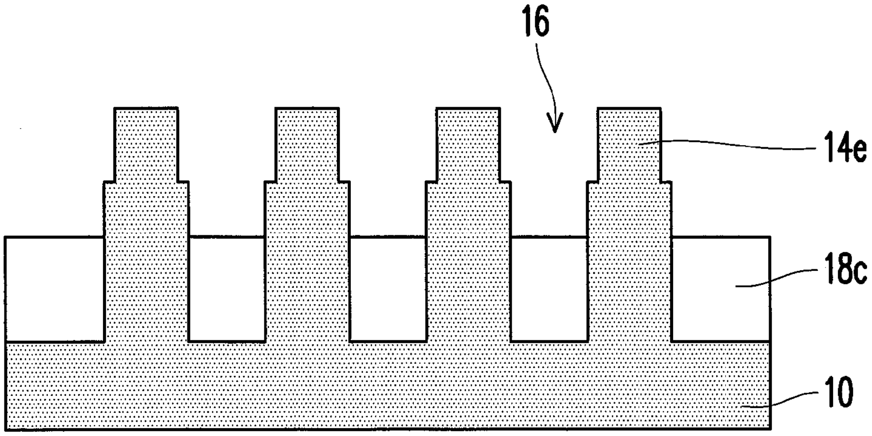

FIG. 5A

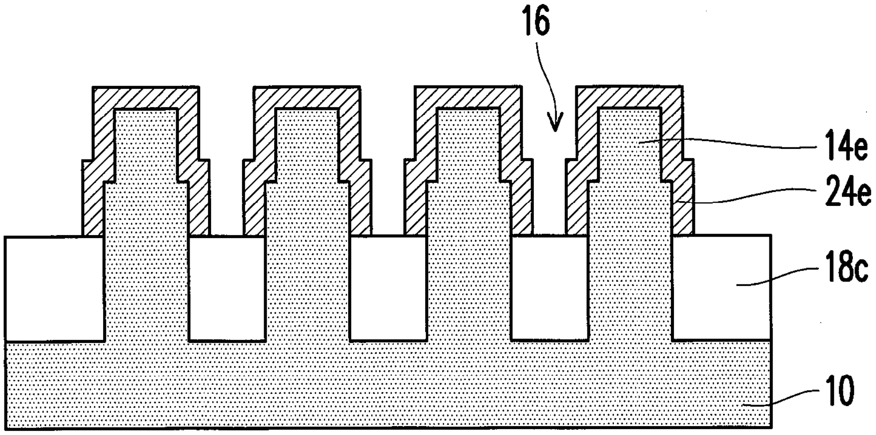

FIG. 5B

FIN STRUCTURE AND METHOD OF FORMING THE SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of Invention

[0002] The present invention relates to a semiconductor device and a method of forming the same, and more generally to a fin structure and a method of forming the same.

[0003] 2. Description of Related Art

[0004] Along with rapid progress in semiconductor technology, dimensions of integrated circuits (IC) are reduced and the degree of integration thereof is increased continuously to further enhance the speed and performance of the device. Generally speaking, with the design trend of scaling down the device size, the channel length of a transistor is accordingly shortened to facilitate the operation speed of the device. However, such design would cause the transistor to have problems such as serious leakage current, short channel effect, ‘on’ current decrease, etc.

[0005] In recent years, a multi-gate structure is proposed to overcome the above-mentioned problems. A gate in the multi-gate structure surrounds the channel region, so that the entire channel region is subjected to the influence of the gate electric field. Ultimately, the ‘on’ current of the device is increased and the leakage current is reduced. A fin-type field effect transistor (FinFET) is a transistor having a multi-gate structure. However, the fin transistor has a three-dimensional structure, which is more complicated than the conventional structure and is more difficult in manufacturing. Moreover, the fin transistor is usually formed on a silicon-on-insulator (SOI) substrate, so that the manufacturing process thereof is difficult to compatible with the existing silicon substrate process. In addition, due to the special process of the fin transistor, certain problems occur when the fin transistor is integrated with the existing planar transistor. On the other hand, the fin structures for forming the fin transistor has a very small gap therebetween. Therefore, the epitaxial layers respectively around the neighboring fin structures are easy to connect to each other.

SUMMARY OF THE INVENTION

[0006] The present invention provides a method of forming a fin structure, and the method is integrated with the existing semiconductor process.

[0007] The present invention further provides a fin structure to prevent the epitaxial layers respectively around the neighboring fin structures from connecting to each other.

[0008] The present invention provides a method of forming a fin structure. The method includes forming a hard mask material layer on a substrate, and then patterning the hard mask material layer to form a first hard mask layer. Thereafter, a portion of the substrate is removed to form two trenches, wherein a remaining substrate forms a fin between the trenches. Afterwards, an insulating layer is formed in each trench, wherein the insulating layers expose an upper portion of the fin. Further, the upper portion of the fin is trimmed, so that the trimmed upper portion is narrower than a lower portion of the fin, and a fin structure having an inverse T shape is formed.

[0009] According to an embodiment of the present invention, a method of trimming the upper portion of the fin includes tuning the first hard mask layer to form a second hard mask layer, wherein the second hard mask layer exposes a portion of a surface of the fin; etching a portion of the fin by using the second hard mask layer as a mask; and removing the second hard mask layer.

[0010] According to an embodiment of the present invention, before the step of removing the second hard mask layer, the method further includes removing a portion of the fin between the insulating layers, so as to form a recess between the fin and each insulating layer.

[0011] According to an embodiment of the present invention, a method of trimming the upper portion of the fin includes performing an oxidation process that at least oxidizes a sidewall of the upper portion of the fin exposed by the first hard mask layer and the insulating layers to form an oxide; removing the first hard mask layer; and removing the oxides.

[0012] According to an embodiment of the present invention, the oxidation process further includes oxidizing a portion of the fin between the insulating layers, so that the oxide is formed to extend between the fin and each insulating layer.

[0013] According to an embodiment, the method further includes removing a portion of the insulating layers during the step pf removing the oxides, so that remaining insulating layers completely cover a sidewall of the lower portion of the fin. According to an embodiment of the present invention, after the step of removing the oxides, the method further includes removing a portion of the insulating layers, so as to expose a portion of a sidewall of the lower portion of the fin.

[0014] According to an embodiment, the method further includes removing a portion of the insulating layers during the step pf removing the oxides, so as to expose a portion of a sidewall of the lower portion of the fin. According to an embodiment of the present invention, a method of trimming the upper portion of the fin includes performing an oxidation process that at least oxidizes a sidewall of the upper portion of the fin exposed by the first hard mask layer and the insulating layers to form an oxide; removing the oxides; and removing the first hard mask layer.

[0015] According to an embodiment of the present invention, the oxidation process further includes oxidizing a portion of the fin between the insulating layers, so that the oxide is formed to extend between the fin and each insulating layer.

[0016] According to an embodiment, the method further includes removing a portion of the insulating layers during the step pf removing the oxides, so that remaining insulating layers completely cover a sidewall of the lower portion of the fin.

[0017] According to an embodiment of the present invention, after the step of removing the oxides, the method further includes removing a portion of the insulating layers, so as to expose a portion of a sidewall of the lower portion of the fin.

[0018] According to an embodiment, the method further includes removing a portion of the insulating layers during the step pf removing the oxides, so that remaining insulating layers completely cover a sidewall of the lower portion of the fin.

[0019] According to an embodiment of the present invention, the method further includes forming an epitaxial layer to cover a surface of the fin exposed by the insulating layers.

[0020] The present invention further provides a fin structure including a fin and two insulating layers. The fin is disposed on a substrate, wherein an upper portion is narrower than a lower portion of the fin, and the fin has an inverse T shape. The insulating layers are disposed at two sides of the fin and at least expose the upper portion of the fin.

[0021] According to an embodiment of the present invention, the insulating layers cover a whole sidewall of the lower portion of the fin.

[0022] According to an embodiment of the present invention, the insulating layers expose a portion of a sidewall of the lower portion of the fin.

[0023] According to an embodiment of the present invention, a recess is disposed between the fin and each insulating layer.

[0024] According to an embodiment of the present invention, the fin structure further includes an epitaxial layer covering a surface of the fin exposed by the insulating layers and filling the recesses.

[0025] According to an embodiment of the present invention, the fin structure further includes an epitaxial layer covering a surface of the fin exposed by the insulating layers.

[0026] The method of forming the fin structure of the present invention can be integrated with the existing semiconductor process.

[0027] The fin structure of the present invention has a narrower upper portion and a wider lower portion, so as to prevent the epitaxial layers respectively around the neighboring fin structures from connecting to each other.

[0028] In order to make the aforementioned and other objects, features and advantages of the present invention comprehensible, a preferred embodiment accompanied with figures is described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0030] FIGS. **1**A to **1**F schematically illustrate cross-sectional views of a method of forming a fin structure according to a first embodiment of the present invention.

[0031] FIGS. **2**A to **2**D schematically illustrate cross-sectional views of a method of forming a fin structure according to a second embodiment of the present invention.

[0032] FIGS. **3**A to **3**E schematically illustrate cross-sectional views of a method of forming a fin structure according to a third embodiment of the present invention.

[0033] FIGS. **4**A to **4**D schematically illustrate cross-sectional views of a method of forming a fin structure according to a fourth embodiment of the present invention.

[0034] FIGS. **5**A to **5**B schematically illustrate cross-sectional views of a method of forming a fin structure according to a fifth embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0035] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0036] FIGS. **1**A to **1**F schematically illustrate cross-sectional views of a method of forming a fin structure according to a first embodiment of the present invention.

[0037] Referring to FIG. **1**A, a hard mask material layer **12** is formed on a substrate **10**. The substrate **10** includes a semiconductor material, such as silicon. The hard mask material layer **12** can be a single material layer or constituted by more than two material layers. In an embodiment, the hard mask material layer **12** is constituted by, from bottom to top, a silicon oxide layer and a silicon nitride layer, for example. The method of forming the silicon oxide layer and the silicon nitride layer includes performing a chemical vapour deposition (CVD) process.

[0038] Referring to FIG. **1**B, the hard mask material layer **12** is patterned by photolithography and etching processes, so as to form a hard mask layer **12***a*. Thereafter, a portion of the substrate **10** is etched away, so as to form trenches **16**. The remaining substrate **10** forms a fin **14** between the neighboring trenches **16**. In fact, the trenches **16** surrounds the fin **14** from topview. Below description will illustrate from cross-sectional view. Afterwards, an insulating layer **18** is formed in each trench **16** exposing an upper portion of each fin **14**. The method of forming the insulating layer **18** in each trench **16** includes the following steps. An insulating material layer is formed on the substrate **10**. Then, a planarization process is performed by using the hard mask layer **12***a* as a stop layer, so as to remove the insulating material layer obove the hard mask layer **12***a*. Afterwards, a portion of the insulating material layer in each trench **16** is removed, and the insulating material layer left on the bottom of each trench **16** is an insulating layer **18**. The insulating material layer includes silicon oxide, and the forming method thereof includes performing a CVD process. The planarization process is a chemical mechanical polishing (CMP) process, for example.

[0039] Referring to FIGS. **1**C and **1**D, the step of trimming the upper portion of each fin **14** is preformed, so that the trimmed upper portion is narrower than the lower portion of each fin **14***a*. Accordingly, each fin **14***a* is formed in the shape of an inverse T having a narrower upper portion and a wider lower portion. Each fin **14***a* is the fin structure of the present invention, as shown in FIG. **1**D.

[0040] Specifically, referring to FIG. **1**C, in this embodiment, the step of trimming the upper portion of each fin **14** includes tuning the hard mask layer **12***a* to form a hard mask layer **12***b*. The hard mask layer **12***b* has a smaller dimension than that of the hard mask layer **12***a*, and exposes a portion of the surface of each fin **14**.

[0041] Referring to FIG. **1**D, a portion of each fin **14** not covered by the hard mask layer **12***b* and the insulating layers **18** is etched by using the hard mask layer **12***b* as a mask. The etching method is, for example, an anisotropic etching process, and the etching depth can be controlled by a time mode. In this embodiment, with a time mode control, each fin **14***a* is a fin structure in the shape of an inverse T having a narrower upper portion and a wider lower portion. Two insulating layers **18** cover the whole sidewall of the lower portion of each fin **14***a* while exposing the sidewall and top of the upper portion of each fin **14***a* and exposing the top of the lower portion of each fin **14***a*.

[0042] Referring to FIG. **1**E, the hard mask layer **12***b* is removed. The method of removing the hard mask layer **12***b* includes performing an etching process, such as an anisotropic etching process.

[0043] Referring to FIG. **1**F, an epitaxial layer **24***a* is formed on the exposed surface of each fin **14***a*. The epitaxial layers **24***a* are for increasing the carrier mobility in the channels, and each of them can be a single-material layer, a two-material layer or a multi-material layer. Each epitaxial layer **24***a* includes a III-V semiconductor compound, a IV group element or a combination thereof. The IV group element is silicon, germanium, SiGe, SiC or graphene, for example. The III-V semiconductor compound is GaAs, for example. In a PMOS device, each epitaxial layer **24***a* can be a SiGe single layer, or constituted by a SiGe layer and a silicon layer. In an NMOS device, each epitaxial layer **24***a* can be a SiC single layer, or constituted by a SiC layer and a silicon layer. The method of forming the epitaxial layers **24***a* includes performing an selective epitaxial growth (SEG) process.

[0044] FIGS. **2**A to **2**D schematically illustrate cross-sectional views of a method of forming a fin structure according to a second embodiment of the present invention.

[0045] According to the described method, the hard mask material layer **12** is patterned and a portion of the substrate **10** is removed, so as to form the hard mask layer **12***a*, trenches **16** and fins **14**. Thereafter, an insulating layer **18** is formed in each trench **16** exposing the upper portion of each fin **14**, as shown in FIG. **1**A.

[0046] Referring to FIGS. **2**A and **2**B, the step of trimming the upper portion of each fin **14** is preformed, so that the trimmed upper portion is narrower than the lower portion of each fin **14***b*. Accordingly, each fin **14***b* is formed in the shape of an inverse T having a narrower upper portion and a wider lower portion. Each fin **14***b* is the fin structure of the present invention, as shown in FIG. **2**B.

[0047] Specifically, referring to FIG. **2**A, in this embodiment, the step of trimming the upper portion of each fin **14** includes tuning the hard mask layer **12***a* to form a hard mask layer **12***b*. The hard mask layer **12***b* has a smaller dimension than that of the hard mask layer **12***a*, and exposes a portion of the surface of each fin **14**.

[0048] Referring to FIG. **2**B, a portion of each fin **14** exposed by the hard mask layer **12***a* and the neighboring insulating layers **18** is etched away by using the hard mask layer **12***b* as a mask, and the same etching step further etches downward to remove a portion of each fin **14** adjacent to the neighboring insulating layer **18**, and thus, a recess **20** is formed between each remaining fin **14***b* and the neighboring insulating layer **18**. The etching method is, for example, an anisotropic etching process, and the etching depth can be controlled by a time mode.

[0049] Referring to FIG. **2**C, the hard mask layer **12***b* is removed. The method of removing the hard mask layer **12***b* includes performing an etching process, such as an anisotropic etching process. Each remaining fin **14***b* is a fin structure in the shape of an inverse T having a narrower upper portion and a wider lower portion. It is noted that each fin **14***b* has an upper portion longer than that of each fin **14***a* (or fin structure) in FIG. **1**E. Two insulating layers **18** cover the whole sidewall of the lower portion of each fin **14***b* while exposing the sidewall and top of the upper portion of each fin **14***b* and exposing the top of the lower portion of each fin **14***b*. Further, a recess **20** is disposed between each fin **14***b* and the neighboring insulating layer **18**, so as to expose a portion of the sidewall of the insulating layer **18**.

[0050] Referring to FIG. **2**D, an epitaxial layer **24***b* is formed on the exposed surface of each fin **14***b*. The material and forming method of the epitaxial layers **24***b* are similar to those of the epitaxial layers **24***a* in the first embodiment, and the details are not iterated herein.

[0051] FIGS. **3**A to **3**E schematically illustrate cross-sectional views of a method of forming a fin structure according to a third embodiment of the present invention.

[0052] Referring to FIG. **3**A, according to the described methods in the first embodiment, the hard mask material layer **12** is patterned and a portion of the substrate **10** is removed, so as to form the hard mask layer **12***a*, trenches **16** and fins **14**. Thereafter, an insulating layer **18** is formed in each trench **16** exposing the upper portion of each fin **14**.

[0053] Referring to FIGS. **3**B and **3**D, the step of trimming the upper portion of each fin **14** is preformed, so that the trimmed upper portion is narrower than the lower portion of each fin **14***c*. Accordingly, each fin **14***c* is formed in the shape of an inverse T having a narrower upper portion and a wider lower portion. Each fin **14***c* is the fin structure of the present invention, as shown in FIG. **3**D.

[0054] Specifically, referring to FIG. **3**B, in this embodiment, the step of trimming the upper portion of each fin **14** includes performing an oxidation process that at least oxidizes the sidewall of the upper portion of each fin **14** exposed by the hard mask layer **12***a* and the neighboring two insulating layers **18** to form an oxide **22**. In an embodiment, each fin **14** includes silicon, and the oxidation process includes a thermal oxidation process.

[0055] Referring to FIG. **3**C, the hard mask layer **12***a* is removed, so as to expose the non-oxidized top of each fin **14***c*. The method of removing the hard mask layer **12***a* includes performing an etching process, such as an anisotropic etching process.

[0056] Referring to FIG. **3**D, the oxides **22** are moved, so as to expose a sidewall of the upper portion of each fin **14***c*. The method of removing the oxides **22** includes performing an etching process, such as an anisotropic etching process. In an embodiment, each insulating layer **18** is a silicon oxide layer, and a portion of the insulating layers **18** are removed during the step of removing the oxides **22**. Two remaining insulating layers **18***a* only cover a portion of the sidewall of the lower portion of each fin **14***c*, so as to expose the top and another portion of the lower portion of each fin **14***c*. Each remaining fin **14***c* is a fin structure in the shape of an inverse T having a narrower upper portion and a wider lower portion.

[0057] Referring to FIG. **3**E, an epitaxial layer **24***c* is formed on the exposed surface of each fin **14***c*. The material and forming method of the epitaxial layers **24***c* are similar to those of the epitaxial layers **24***a* in the first embodiment, and the details are not iterated herein.

[0058] FIGS. **4**A to **4**C schematically illustrate cross-sectional views of a method of forming a fin structure according to a fourth embodiment of the present invention.

[0059] In another embodiment, according to the described methods in the first embodiment, the hard mask material layer **12** is patterned and a portion of the substrate **10** is removed, so as to form the hard mask layer **12***a*, trenches **16** and fins **14**. Thereafter, an insulating layer **18** is formed in each trench **16** exposing the upper portion of each fin **14**.

[0060] Referring to FIGS. **4**A and **4**C, the step of trimming the upper portion of each fin **14** is preformed, so that the trimmed upper portion is narrower than the lower portion of each fin **14***d*. Accordingly, each fin **14***d* is formed in the shape of an inverse T having a narrower upper portion and a wider lower portion. Each fin **14***d* is the fin structure of the present invention, as shown in FIG. **4**C.

[0061] Specifically, referring to FIG. **4**A, in this embodiment, the step of trimming the upper portion of each fin **14** includes performing an oxidation process. However, in this embodiment, the oxidation process not only oxidizes the sidewall of the upper portion of each fin **14** exposed by the hard mask layer **12***a* and the neighboring two insulating layers **18**, but also oxidizes a portion of each fin **14** adjacent to the neighboring insulating layer **18**, and thus, an oxide **22***a* is formed between each fin **14***d* and the neighboring insulating layer **18**.

[0062] Referring to FIG. **4**B, the hard mask layer **12***a* is removed, so as to expose the non-oxidized top of each fin **14***d*. The method of removing the hard mask layer **12***a* includes performing an etching process, such as an anisotropic etching process.

[0063] Referring to FIG. **4**C, the oxides **22***a* are removed, so as to expose a sidewall of the upper portion of each fin **14***d*. The method of removing the oxides **22***a* includes performing an etching process, such as an anisotropic etching process. In an embodiment, each insulating layer **18** is a silicon oxide layer, and a portion of the insulating layers **18** are removed during the step of removing the oxides **22***a*. Therefore, by appropriately controlling the depth of the formed oxides **22** and the process time of the removing step, two remaining insulating layers **18***b* completely cover the sidewall of the lower portion of each fin **14***d*, so as to expose the top of the lower portion of each fin **14***d*. Each remaining fin **14***d* is a fin structure in the shape of an inverse T having a narrower upper portion and a wider lower portion. It is noted that each fin **14***d* has an upper portion longer than that of each fin **14***c* (or fin structure) in FIG. **3**D.

[0064] Referring to FIG. **4**D, an epitaxial layer **24***d* is formed on the exposed surface of each fin **14***d*. The material and forming method of the epitaxial layers **24***d* are similar to those of the epitaxial layers **24***a* in the first embodiment, and the details are not iterated herein.

[0065] FIGS. **5**A to **5**B schematically illustrate cross-sectional views of a method of forming a fin structure according to a fourth embodiment of the present invention.

[0066] Referring to FIG. **5**A, after the fin **14***d* of the fourth embodiment as shown in FIG. **4**C is formed, a portion of each insulating layer **18***b* is further removed to reduce the thickness of each insulating layer **18***b*. Therefore, two remaining insulating layers **18***c* only cover a portion of the sidewall of the lower portion of each fin **14***e*, so as to expose another portion of the sidewall of the lower portion of each fin **14***e*. The method of removing the portion of each insulating layer **18** includes performing an etching back process, and the removing thickness can be controlled by a time mode.

[0067] Each fin **14***e* in this embodiment is a fin structure in the shape of an inverse T having a narrower upper portion and a wider lower portion. It is noted that each fin **14***e* has an upper portion longer than that of each fin **14***c* (or fin structure) in FIG. **3**D.

[0068] Referring to FIG. **5**B, an epitaxial layer **24***e* is formed on the exposed surface of each fin **14***e*. The material and forming method of the epitaxial layers **24***e* are similar to those of the epitaxial layers **24***a* in the first embodiment, and the details are not iterated herein.

[0069] In the third to fifth embodiments, the hard mask layer **12***a* is removed before the oxides **22** or **22***a* are removed. However, the present invention is not limited thereto. In another embodiment, the hard mask layer **12***a* can be removed after the oxides **22** or **22***a* are removed.

[0070] The fin structure of the present invention has a narrower upper portion and a wider lower portion, so as to prevent the epitaxial layers respectively around the upper portions of the neighboring fin structures from connecting to each other. Therefore, the fin structure of the present invention is suitable for manufacturing a multi-gate field transistor.

[0071] The method of forming the fin structure of the present invention can be integrated with the existing semiconductor process.

[0072] The present invention has been disclosed above in the preferred embodiments, but is not limited to those. It is known to persons skilled in the art that some modifications and innovations may be made without departing from the spirit and scope of the present invention. Therefore, the scope of the present invention should be defined by the following claims.

1. A method of forming a fin structure, comprising:
- forming a hard mask material layer on a substrate;
- patterning the hard mask material layer to form a first hard mask layer;
- removing a portion of the substrate to form two trenches, wherein a remaining substrate forms a fin between the trenches;
- forming an insulating layer in each trench, wherein the insulating layers expose an upper portion of the fin;
- after the insulating layer formed in each trench, tuning the first hard mask layer to form a second hard mask layer, wherein the second hard mask layer exposes a portion of a surface of the fin;
- trimming the upper portion of the fin by etching a portion of the fin using the second hard mask layer as a mask, so that the trimmed upper portion is narrower than a lower portion of the fin, and a fin structure having an inverse T shape is formed; and
- removing the second hard mask layer.

2. (canceled)

3. The method of claim **1**, further comprising, before the step of removing the second hard mask layer, removing a portion of the fin between the insulating layers, so as to form a recess between the fin and each insulating layer.

4. The method of claim **1**, wherein a method of trimming the upper portion of the fin comprises:
- performing an oxidation process that at least oxidizes a sidewall of the upper portion of the fin exposed by the first hard mask layer and the insulating layers to form an oxide;
- removing the first hard mask layer; and
- removing the oxides.

5. The method of claim **4**, wherein the oxidation process further comprises oxidizing a portion of the fin between the insulating layers, so that the oxide is formed to extend between the fin and each insulating layer.

6. The method of claim **5**, further comprising removing a portion of the insulating layers during the step of removing the oxides, so that remaining insulating layers completely cover a sidewall of the lower portion of the fin.

7. The method of claim **5**, further comprising, after the step of removing the oxides, removing a portion of the insulating layers, so as to expose a portion of a sidewall of the lower portion of the fin.

8. The method of claim **4**, further comprising removing a portion of the insulating layers during the step of removing the oxides, so as to expose a portion of a sidewall of the lower portion of the fin.

9. The method of claim **1**, wherein a method of trimming the upper portion of the fin comprises:
- performing an oxidation process that at least oxidizes a sidewall of the upper portion of the fin exposed by the first hard mask layer and the insulating layers to form an oxide;

removing the oxides; and

removing the first hard mask layer.

10. The method of claim **9**, wherein the oxidation process further comprises oxidizing a portion of the fin between the insulating layers, so that the oxide is formed to extend between the fin and each insulating layer.

11. The method of claim **10**, further comprising removing a portion of the insulating layers during the step of removing the oxides, so that remaining insulating layers completely cover a sidewall of the lower portion of the fin.

12. The method of claim **11**, further comprising, after the step of removing the oxides, removing a portion of the insulating layers, so as to expose a portion of a sidewall of the lower portion of the fin.

13. The method of claim **9**, further comprising removing a portion of the insulating layers during the step of removing the oxides, so as to expose a portion of a sidewall of the lower portion of the fin.

14. The method of claim **1**, further comprising forming an epitaxial layer to cover a surface of the fin exposed by the insulating layers.

15-20. (canceled)

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