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Template, method for manufacturing template, and method for manufacturing semiconductor device

Abstract

According to one embodiment, a template includes a base material with a first surface at a first level. A first pattern on the template includes first protruding portions in a first region that protrude to a second level beyond the first level, a first recess portion between an adjacent pair of first protruding portions in a central portion of the first region, and a second recess portion between another adjacent pair of first protruding portions in an outer peripheral portion of the first region. A second pattern on the template includes a protrusion portion in a second region outside the first region. The protrusion portion protrudes to a third level. An optical layer is in the first recess portion and at least a portion of a bottom surface of the second recess portion is not covered by the optical layer.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION(S)

(1) This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2022-046028, filed on Mar. 22, 2022, the entire contents of which are incorporated herein by reference.

FIELD

(2) Embodiments described herein relate generally to a template, a method for manufacturing the template, and a method for manufacturing a semiconductor device related to imprint lithography techniques and the like.

BACKGROUND

(3) In a method for manufacturing a semiconductor device, a technique in which a micro pattern is formed using nanoimprint lithography (NIL) is known.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a schematic perspective view illustrating an example of a structure of a template.
(2) FIG. **2** is a schematic cross-sectional view illustrating an example of a structure of a template.
(3) FIG. **3** is a schematic top view illustrating an example of a layout of a surface MS.
(4) FIG. **4** is a schematic cross-sectional view illustrating an example of a template of a first embodiment.
(5) FIG. **5** is a schematic top view illustrating an example of a shape of an alignment mark pattern AM.
(6) FIG. **6** is a schematic top view illustrating an example of a shape of an alignment mark pattern AM.
(7) FIG. **7** is a schematic top view illustrating another example of a shape of an alignment mark pattern AM.
(8) FIGS. **8** to **21** are schematic cross-sectional views illustrating aspects of a method for manufacturing a template of a first embodiment.
(9) FIG. **22** is a schematic cross-sectional view illustrating a comparative example with a displaced optical layer in a peripheral region.
(10) FIG. **23** is a schematic cross-sectional view illustrating an embodiment example of with a displaced optical layer in a peripheral region.
(11) FIG. **24** is a schematic cross-sectional view illustrating an example of a template of a second embodiment.
(12) FIG. **25** is a schematic cross-sectional view illustrating another example of a template of a second embodiment.
(13) FIG. **26** is an enlarged view of a part of FIG. **24**.
(14) FIG. **27** is a schematic top view illustrating an example of a shape of an alignment mark pattern AM.
(15) FIGS. **28** to **45** are schematic cross-sectional views illustrating aspects of a method for manufacturing a template of a second embodiment.
(16) FIG. **46** is a schematic view illustrating a difference in a shape of an imprint material layer due to a difference in a shape of an optical layer.
(17) FIG. **47** is a schematic view illustrating a difference in a shape of an imprint material layer due to a difference in a shape of an optical layer.
(18) FIG. **48** is a schematic cross-sectional view illustrating an example of a template of a third embodiment.
(19) FIG. **49** is a schematic cross-sectional view illustrating an example portion of a template of a third embodiment.
(20) FIGS. **50** to **53** are schematic cross-sectional views illustrating aspects of a method for manufacturing a template of a third embodiment.
(21) FIGS. **54** to **57** are schematic cross-sectional views illustrating aspects of a method for manufacturing a semiconductor device using NIL.
DETAILED DESCRIPTION
(22) Embodiments provide a template capable of forming an alignment mark for high-precision alignment.
(23) In general, according to one embodiment, a template, includes a base material having a first surface at a first level. A first pattern is formed on the template and includes a plurality of first

protruding portions on the first surface in a first region. The first protruding portion protrudes to a second level beyond the first level. A first recess portion of the first pattern is between an adjacent pair of first protruding portions in a central portion of the first region, and a second recess portion is between another adjacent pair of first protruding portions in an outer peripheral portion of the first region. A second pattern is formed on the template and includes a protrusion portion on the first surface in a second region outside the first region. The protrusion portion protrudes to a third level. An optical layer is in the first recess portion, and least a portion of a bottom surface of the second recess portion is not covered by the optical layer.

(24) Hereinafter, certain example embodiments will be described with reference to drawings. In general, the depicted relationships between dimensions of each component in the drawings, the ratio in dimensions between components, and the number of components may be different from those of an actual product corresponding to the present disclosure. Furthermore, in the drawings, elements, components, and/or aspects that are substantially the same in different drawings are designated by the same reference numerals, and repeated description thereof may be omitted as appropriate.

First Embodiment

(25) (Example of Structure of Template)

(26) FIG. **1** is a schematic perspective view illustrating an example of a structure of a template. FIG. **2** is a schematic cross-sectional view illustrating the example of the structure of the template. FIGS. **1** and **2** illustrate an X-axis, a Y-axis orthogonal to the X-axis, and a Z-axis orthogonal to each of the X-axis and the Y-axis. FIG. **2** illustrates a part of a cross section along line A**1**-A**2** illustrated in FIG. **1**.

(27) As illustrated in FIGS. **1** and **2**, a template has a base material **1** including a surface MS (called a mesa) and a recess portion CO. FIG. **3** is a schematic top view illustrating an example of a layout on the surface MS, and illustrates a part of the X-Y plane of the base material **1**. The surface MS includes an alignment mark pattern AM and a device pattern DP. The alignment mark pattern AM is a pattern that forms an alignment mark used in a pattern forming method using NIL. The device pattern DP is a pattern that forms a device pattern to be transferred by the pattern forming method using NIL. The number, the position, and the shape of the alignment mark pattern AM and the device pattern DP are not particularly limited.

(28) FIG. **4** is a schematic cross-sectional view illustrating an example of a template of a first embodiment, and illustrates a part of the X-Z cross section of the template. As illustrated in FIG. **4**, the example of the template of the first embodiment is provided with the base material **1** and an optical layer **21**.

(29) The base material **1** comprises a first material having a first optical constant (complex refractive index) with respect to light from an optical detector. The first material is, for example, quartz. The light from the optical detector may penetrate the base material **1**.

(30) The base material **1** has a surface **1***a* and regions for the alignment mark pattern AM and the device pattern DP. For convenience, FIG. **4** schematically illustrates the alignment mark pattern AM and the device pattern DP to be directly adjacent to each other. However, the actual template is not limited to such a layout.

(31) In the pattern forming method using NIL, a mold (the template) is pressed onto an imprint material layer such as an ultraviolet curable resin provided on an object, light is irradiated to cure the layer containing the imprint material, and the device pattern DP is transferred to the imprint material layer from the mold. The object is, for example, an insulating layer formed above a semiconductor device or a silicon wafer.

(32) The alignment mark pattern AM includes at least one protrusion portion **11**, at least one recess portion **12***a*, and at least one recess portion **12***b* provided adjacent or proximate to the recess portion **12***a*. As an example, FIG. **4** illustrates the alignment mark pattern AM including a plurality of protrusion portions **11**, a plurality of recess portions **12***a*, and a plurality of recess portions **12***b*.

In this context, “recess portions” refer to the height difference formed relative to the upper surface **111** of the protrusion portions **11**. Here, the recess portions **12**_a_/**12**_b_ may be considered grooves, trenches, or the like formed in the upper surface **111**.

(33) The device pattern DP includes at least one protrusion portion **13**_a_ and at least one recess portion **14**. As an example, FIG. **4** illustrates a device pattern DP having a line-and-space pattern including a plurality of protrusion portions **13**_a_ and a plurality of recess portions **14**. In this context, “recess portions” refer to the height difference formed relative to the upper surface **130** of the protrusion portions **13**_a_.

(34) The protrusion portion **11** and the recess portion **12**_a_ are alternately provided, for example, in the X-axis direction. FIG. **4** illustrates an example in which the upper surface **130** is higher than the upper surface **111** with respect to the surface **1**_a_. However, the present disclosure is not limited thereto, and the upper surface **111** of the and the upper surface **130** may have the same height in other examples.

(35) The recess portion **12**_b_ is provided adjacent to the recess portion **12**_a_ when viewed in a top view of the base material **1**. The protrusion portion **11** and the recess portion **12**_b_ are alternately provided, for example, in the X-axis direction.

(36) FIG. **4** illustrates the example in which the depth of the recess portion **12**_a_ from the upper surface **111** is the same as the depth of the recess portion **12**_b_ from the upper surface **111**. However, the present disclosure is not limited thereto, and the depth of the recess portion **12**_a_ may be different from the depth of the recess portion **12**_b_.

(37) FIG. **4** illustrates the example in which the recessed depth of the recess portion **12**_a_ from the upper surface **111** is less than the recessed depth of the recess portion **14** from the upper surface **130**, though the bottoms of the recess portions **12** and **14** are depicted as being at the same level as one another. However, the present disclosure is not limited thereto, and the recessed depth of the recess portion **12**_a_ from the upper surface **111** may instead be the same as or greater than the depth of the recess portion **14** from the upper surface **130**.

(38) The optical layer **21** comprises a second material having a second optical constant (refractive index), which is different from the first optical constant (refractive index), with respect to light from an optical detector. The second material may be, for example, chromium. The present disclosure is not limited thereto, and the second material may, for example, comprise at least one material selected from a group consisting of titanium, tantalum, tungsten, chromium, copper, silicon carbide, and silicon fluoride. The optical layer **21** may form, for example, a light-shielding layer that reflects or blocks the light from an optical detector. Since imaging contrast may be improved between the recess portions **12**_a_ and other regions by providing the optical layer **21**, the alignment mark pattern AM may be more easily detected using an optical detector. Therefore, the precision of the alignment between the template and the object may be increased.

(39) The optical layer **21** is provided in the recess portion **12**_a_, but not provided in the recess portion **12**_b_. That is, while a bottom surface **121** of the recess portion **12**_a_ is in contact with (e.g., covered by) the optical layer **21**, the bottom surface **122** of the recess portion **12**_b_ is not covered by the optical layer **21**. The bottom surface **122** may be referred to as an exposed or uncovered surface. The thickness of the optical layer **21** may be smaller than the depth of the recess portion **12**_a_. The optical layer **21** may be in contact with only a part of the bottom surface **121** of some or all recess portions **12**_a_.

(40) FIGS. **5**, **6**, and **7** are schematic top views illustrating examples of a shape of the alignment mark pattern AM, and illustrate the protrusion portions **11**, the recess portions **12**_a_ (in which the optical layer **21** is formed), and the recess portions **12**_b_ (in which the optical layer **21** is not formed). The alignment mark pattern AM illustrated in FIG. **5** includes the protrusion portion **11** disposed in a stripe shape with recess portions **12**_a_ or recess portions **12**_b_ between each pair of protrusion portions **11**. The recess portions **12**_a_ are sandwiched between a pair of recess portions **12**_b_ disposed on the X-axis ends.

(41) The alignment mark pattern AM illustrated in FIG. **6** includes a protrusion portion **11** disposed in a grid shape with recess portions **12***a* and recess portions **12***b* being isolated between portions of the grid pattern. The recess portions **12***a* and **12***b* may be said to have "a dot shape" in this context. A plurality of dot-shaped recess portions **12***b* surround the plurality of dot-shaped recess portions **12***a*.
(42) The alignment mark pattern AM illustrated in FIG. **7** includes a plurality of protrusion portions **11** disposed in an array shape, a plurality of recess portions **12***a*, and a plurality of recess portions **12***b* provided around the plurality of recess portions **12***a*. On the upper surface of the base material **1**, the area of the recess portion **12***b* can be appropriately set according to the precision of the alignment of the mask during the forming (patterning) of the optical layer **21**.
(43) (Example of Method for Manufacturing Template)
(44) FIGS. **8** to **21** are schematic cross-sectional views illustrating an example of a method for manufacturing the template of the first embodiment, and illustrate a part of the X-Z cross section of the base material **1**. The example of the method for manufacturing the template will be described by schematically illustrating a region R**1** of the base material **1** in which the alignment mark pattern AM is ultimately formed and a region R**2** of the base material **1** in which the device pattern DP is ultimately formed. Each of the region R**1** and the region R**2** illustrated in FIGS. **8** to **21** can be considered a portion of the surface **1***a*.
(45) First, as illustrated in FIG. **8**, a hard mask layer **31** is formed on the surface **1***a*, and subsequently, as illustrated in FIG. **9**, a resist mask layer **32** is formed on the hard mask layer **31**.
(46) The hard mask layer **31** functions as a hard mask for processing the base material **1**. The hard mask layer **31** contains, for example, chromium. The hard mask layer **31** may be formed by using, for example, sputtering or an atomic layer deposition method (ALD).
(47) The resist mask layer **32** functions as a resist mask for processing the hard mask layer **31**. The resist mask layer **32** includes a protrusion portion **32***a* provided in the region R**1** and a protrusion portion **32***b* provided in the region R**2**. The protrusion portion **32***a* and the protrusion portion **32***b* cover portions where the hard mask layer **31** will be left. The protrusion portion **32***b* has a greater height above the surface **1***a* than the protrusion portion **32***a*. The resist mask layer **32** is formed, for example, by using a pattern forming method using NIL.
(48) Subsequently, a part of the resist mask layer **32** is removed in the thickness direction to expose a part of the hard mask layer **31**, and as illustrated in FIG. **10**, the exposed portion of the hard mask layer **31** is removed (etched). The resist mask layer **32** is processed such that each of the protrusion portion **32***a* and the protrusion portion **32***b* partially remains after this removal of the exposed hard mask layer. The resist mask layer **32** may be partially removed, for example, during reactive ion etching (RIE). The hard mask layer **31** may be selectively removed, for example, by dry etching. The dry etching that processes the hard mask layer **31** is, for example, inductively coupled plasma (ICP)-reactive ion etching (RIE) using a mixed gas of chlorine (Cl.sub.2) gas and oxygen (O.sub.2) gas.
(49) Subsequently, as illustrated in FIG. **11**, a part of the base material **1** is removed in the thickness direction by etching using the combination of the hard mask layer **31** and the resist mask layer **32** as a mask, and thus the protrusion portion **11**, the recess portion **12***a*, and the recess portion **12***b* are formed in the region R**1**, and the protrusion portion **13***a* and the recess portion **14** are formed in the region R**2**. The base material **1** is processed, for example, by being partially removed from the surface **1***a* side in the thickness direction, for example, by anisotropic etching such as dry etching. The dry etching that processes the base material **1** is, for example, inductively coupled plasma-reactive ion etching using trifluoromethane (CHF.sub.3) gas.
(50) Subsequently, as illustrated in FIG. **12**, a part of the resist mask layer **32** is removed to expose a part of the hard mask layer **31**. The resist mask layer **32** is processed such that the protrusion portion **32***a* is removed while the protrusion portion **32***b* still partially remains.
(51) Subsequently, as illustrated in FIG. **13**, the newly exposed portions of the hard mask layer **31**

are removed by etching using the remaining resist mask layer **32** in region R**2** as a mask so that the still unexposed portions of the hard mask layer **31** in region R**2** remain.
(52) Subsequently, as illustrate in FIG. **14**, the remaining resist mask layer **32** is removed. Thereafter, as illustrated in FIG. **15**, the base material **1** is etched using the hard mask layer **31** as a mask. Therefore, since the protrusion portion **13***a* is protected, the protrusion portion **11**, the recess portion **12***a*, the recess portion **12***b*, and the recess portion **14** are removed (etched) in the thickness direction.
(53) Subsequently, as illustrated in FIG. **16**, the still remaining hard mask layer **31** is removed. Thereafter, as illustrated in FIG. **17**, an optical layer **21** that covers the surface **1***a*, the protrusion portion **11**, the recess portion **12***a*, the recess portion **12***b*, the protrusion portion **13***a*, and the recess portion **14** is formed. The optical layer **21** is formed by depositing a material that can be used as the optical layer **21** over the entire surface **1***a*, for example, by reactive sputtering.
(54) Subsequently, as illustrated in FIG. **18**, a resist mask layer **33** is formed on the optical layer **21**. The resist mask layer **33** functions as a resist mask for processing (patterning) the material for the optical layer **21**. The resist mask layer **33** includes a protrusion portion **33***a* provided above the recess portion **12***a*. The protrusion portion **33***a* is provided where the optical layer **21** will be left after processing. The resist mask layer **33** is formed, for example, by using a pattern forming method using NIL.
(55) Subsequently, as illustrated in FIG. **19**, a part of the resist mask layer **33** is removed in the thickness direction to expose a part of the optical layer **21** while leaving the resist mask layer **33** in the recess portion **12***a*. The resist mask layer **33** may be partially removed, for example, by reactive ion etching.
(56) Subsequently, as illustrated in FIG. **20**, the exposed portion of the optical layer **21** is removed by etching using the remaining resist mask layer **33** as a mask, with the recess portion **12***b*, the protrusion portion **13***a*, and the recess portion **14** left exposed (uncovered by resist mask layer **33**).
(57) Subsequently, as illustrated in FIG. **21**, the remaining resist mask layer **33** is removed. The above is the description of an example of a method for manufacturing the template of the first embodiment.
(58) In general, when the optical layer **21** is formed as described above, the alignment precision in the formation of the protrusion portion **33***a* with respect to the base material **1** is low. If the formation position of the optical layer **21** is displaced from an intended/desired position, then an optical pattern having a larger area than intended for the optical layer **21** formed in the recess portions **12***a* may be formed at the edge portion of the alignment mark pattern AM. In this case, when the alignment mark pattern AM is being detected using light from an optical detector, the unintended pattern portion spreading at the edge portion of the alignment mark pattern AM could cause stray light to shine brightly, which causes the alignment precision in the use of the template for subsequent pattern transfer processes to be deteriorated.
(59) FIGS. **22** and **23** are schematic cross-sectional views illustrating examples of formation of the optical layer **21** at the end portion of the alignment mark pattern AM. If the recess portion **12***b* is not formed (as illustrated in a comparative example in FIG. **22**), when the position of the pattern of the optical layer **21** is displaced from its intended position, for example, in an arrow A direction along the X-axis, as illustrated in FIG. **22**, an optical pattern portion **21***a* having a larger area than the optical layer **21** formed in the recess portion **12***a* can be formed at the edge portion of the alignment mark pattern AM.
(60) In contrast, in the template and the method of manufacturing the template of the first embodiment, the recess portion **12***b* in which the optical layer **21** is not intended to be formed is provided. In this case, as illustrated in FIG. **23**, even when the pattern of the optical layer **21** is displaced from its intended position and thus is optical layer **21** is formed outside of the recess portions **12***a*, the displaced portion of the optical pattern (optical layer **21**) will be formed in a recessed portion **12***b*. The recess portions **12***b* are similarly sized to the recess portions **12***a* in this

example, thus an optical pattern portion **21***a* or the like having a large area is prevented from being formed at the edge portion of the alignment mark pattern AM. Therefore, an alignment mark capable of high-precision alignment for subsequent pattern transfer processes using the template may be formed.
(61) The above embodiment may be appropriately combined with other described embodiments.
Second Embodiment
(62) (Example of Structure of Template)
(63) Similarly to the template of the first embodiment, a template of a second embodiment is provided with the base material **1** including the surface MS, and the recess portion CO. The surface MS includes the alignment mark pattern AM and the device pattern DP.
(64) FIG. **24** is a schematic cross-sectional view illustrating an example of the template of the second embodiment, and illustrates a part of the X-Z cross section of the template. Similarly to the first embodiment, the template of the second embodiment is provided with the base material **1** and the optical layer **21** thereon.
(65) The alignment mark pattern AM includes at least one protrusion portion **11** and at least one recess portion **12***c*. As an example, FIG. **24** illustrates the alignment mark pattern AM including a plurality of protrusion portions **11** and a plurality of recess portions **12***c*.
(66) The protrusion portion **11** and the recess portion **12***c* are alternately formed, for example, in the X-axis direction. For example, the layouts of the recess portion **12***a* illustrated in FIGS. **5**, **6**, and **7** may be taken as an upper surface layout of the recess portion **12***c*.
(67) The device pattern DP includes a protrusion portion **13***b*. The protrusion portion **13***b* includes a convex-shaped region **131**, and a convex-shaped region **132** protruding from the convex-shaped region **131**. FIG. **24** illustrates the device pattern DP including one protrusion portion **13***b* for forming a dual damascene structure as an example. In FIG. **24**, the height of the protrusion portion **11** from the surface **1***a* is equal to the height of the convex-shaped region **132** of the protrusion portion **13***b* from the surface **1***a*.
(68) A bottom surface **123** of the recess portion **12***c* is provided at a position deeper than the surface **1***a*.
(69) As illustrated in FIG. **25**, the alignment mark pattern AM may include at least one protrusion portion **112** between pluralities of recess portions **12***c*. FIG. **25** is a schematic cross-sectional view illustrating another example of the template of the second embodiment, and illustrates a part of the X-Z cross section of the template.
(70) The protrusion portion **112** is a light transmitting region that forms an alignment mark. The width of the protrusion portion **112** in the X-axis direction may be wider than the width of the protrusion portion **11** in the X-axis direction.
(71) The optical layer **21** is provided in the recess portions **12***c*. The bottom surface **123** of the recess portion **12***c* is in contact with the optical layer **21**. The thickness of the optical layer **21** may be less than the depth of the recess portion **12***c*.
(72) As illustrated in FIG. **26**, an upper surface **211** of the optical layer **21** may be substantially level with the level of surface **1***a*. FIG. **26** is an enlarged view of a part of FIG. **24**. In the present specification, the expression that the upper surface **211** and the surface **1***a* are substantially level with each other means that the difference in height between the upper surface **211** and the surface **1***a* is within ±5 nm.
(73) Similarly to the first embodiment, the optical layer **21** contains a second material having a second optical constant, which is different from the first optical constant, with respect to light from an optical detector.
(74) FIG. **27** is a schematic top view illustrating an example of a shape of the alignment mark pattern AM. The alignment mark pattern AM illustrated in FIG. **27** includes an alignment mark pattern region AR**1** and an alignment mark pattern region AR**2**. Each of the alignment mark pattern region AR**1** and the alignment mark pattern region AR**2** includes protrusion portions **112**

surrounded by a plurality of recess portions **12***c*. In the alignment mark pattern region AR**1** and the alignment mark pattern region AR**2**, the extending direction of the recess portion **12***c* is different from each other. The recess portion **12***c* in the alignment mark pattern region AR**1** extends, for example, in the X-axis direction, and the recess portion **12***c* in the alignment mark pattern region AR**2** extends, for example, in the Y-axis direction.
(75) (Example of Method for Manufacturing Template)
(76) FIGS. **28** to **45** are schematic cross-sectional views illustrating an example of a method for manufacturing the template of the second embodiment, and illustrate a part of the X-Z cross section of the base material **1**. The example of the method for manufacturing the template will be described by schematically illustrating the region R**1** of the base material **1** in which the alignment mark pattern AM is formed and the region R**2** of the base material **1** in which the device pattern DP is formed. Each of the region R**1** and the region R**2** illustrated in FIGS. **28** to **45** can be considered a portion of the surface **1***a*.
(77) First, as illustrated in FIG. **28**, a hard mask layer **34** is formed on the surface **1***a*, and subsequently, as illustrated in FIG. **29**, a resist mask layer **35** is formed on the hard mask layer **34**.
(78) The hard mask layer **34** functions as a hard mask for processing the base material **1**. The hard mask layer **34** contains, for example, chromium. The hard mask layer **34** may be formed by using, for example, sputtering or an ALD.
(79) The resist mask layer **35** functions as a resist mask for processing the hard mask layer **34**. The resist mask layer **35** includes a protrusion portion **35***a* provided in the region R**1**, a recess portion **35***b* provided in the region R**1**, a protrusion portion **35***c* provided in the region R**2**, and a protrusion portion **35***d* provided in the region R**2**. The protrusion portion **35***a*, the protrusion portion **35***c*, and the protrusion portion **35***d* are provided in a positions where the hard mask layer **34** will be left. FIG. **29** illustrates an example in which the protrusion portion **35***d* is higher than the protrusion portion **35***c* from the surface **1***a*. The resist mask layer **35** is formed, for example, by using a pattern forming method using NIL.
(80) Subsequently, a part of the resist mask layer **35** is removed in the thickness direction to expose a part of the hard mask layer **34**, and as illustrated in FIG. **30**, the exposed portions of the hard mask layer **34** are removed. The resist mask layer **35** is processed such that the protrusion portion **35***a*, the protrusion portion **35***c*, and the protrusion portion **35***d* still partially remain at this time. The resist mask layer **35** may be partially removed, for example, by reactive ion etching. The hard mask layer **34** may be partially removed, for example, by dry etching. The dry etching that processes the hard mask layer **34** is, for example, inductively coupled plasma-reactive ion etching using a mixed gas of chlorine gas and oxygen gas.
(81) Subsequently, as illustrated in FIG. **31**, the base material **1** is partially removed by etching using the combination of the hard mask layer **34** and the resist mask layer **35** as a mask, and thus the protrusion portion **11** and the recess portion **12***c* are formed in the region R**1**, and the convex-shaped region **132** is formed in the region R**2**. The base material **1** is processed, for example, by being partially etched from the surface **1***a* in the thickness direction of the base material **1**, for example, by anisotropic etching such as dry etching. The dry etching that processes the base material **1** is, for example, inductively coupled plasma-reactive ion etching using trifluoromethane gas.
(82) Subsequently, as illustrated in FIG. **32**, a part of the resist mask layer **35** is removed in the thickness direction to remove the protrusion portion **35***c* and to expose a part of the hard mask layer **34**. The resist mask layer **35** is processed such that the protrusion portion **35***c* is removed but the protrusion portion **35***a* and the protrusion portion **35***d* still partially remain.
(83) Subsequently, as illustrated in FIG. **33**, the newly exposed portion of the hard mask layer **34** is removed by etching using the still remaining resist mask layer **35** as a mask.
(84) Subsequently, as illustrated in FIG. **34**, the resist mask layer **35** is completely removed. Thereafter, as illustrated in FIG. **35**, a resist mask layer **36** that covers the protrusion portion **11**, the

recess portion **12***c*, and the convex-shaped region **132** is formed. The resist mask layer **36** functions as a resist mask for processing the base material **1**. The resist mask layer **36** includes the recess portion **36***a* at a position overlapping the protrusion portions **11** and the recess portions **12***c*. The resist mask layer **36** is formed, for example, by using a pattern forming method using NIL.
(85) Subsequently, as illustrated in FIG. **36**, a part of the resist mask layer **36** is removed to expose a part of the hard mask layer **34** in the region R**1** on the protrusion portions **11**. The resist mask layer **36** may be partially removed, for example, by reactive ion etching.
(86) Subsequently, as illustrated in FIG. **37**, the base material **1** is partially removed in the thickness direction by etching using the combination of the hard mask layer **34** and the resist mask layer **36** as a mask. Therefore, while the protrusion portion **11** and the convex-shaped region **132** are protected, the recess portion **12***c* is processed to a position below the level of the surface **1***a*. That is, the recess portions **12***c* are etched deeper into the base material **1** such that the bottom of the recess portions **12***c* are deeper into the base material **1** than the level of the surface **1***a* in positions outside the recess portions **12***c*.
(87) Subsequently, as illustrate in FIG. **38**, the resist mask layer **36** is removed. Thereafter, as illustrated in FIG. **39**, the base material **1** is partially removed in the thickness direction by etching using the hard mask layer **34** as a mask. Therefore, while the protrusion portion **11** and a part of the convex-shaped region **132** are protected, the recess portion **12***c* is further processed into the thickness direction of the base material **1**, and another part of the convex-shaped region **132** is processed (etched), and thus, the convex-shaped region **131** is formed.
(88) Subsequently, as illustrate in FIG. **40**, the hard mask layer **34** is removed. Thereafter, as illustrated in FIG. **41**, an optical layer **21** that covers the entire surface **1***a* is formed. The optical layer **21** is formed by depositing a material on the surface **1***a*, for example, by reactive sputtering. The optical layer **21** is formed on each of the protrusion portions **11**, the recess portions **12***c*, the convex-shaped region **131**, and the convex-shaped region **132**.
(89) Subsequently, as illustrated in FIG. **42**, a resist mask layer **37** is formed on the optical layer **21**. The resist mask layer **37** function as a resist mask for processing the optical layer **21**. The resist mask layer **37** includes a protrusion portion **37***a* provided above the recess portions **12***c*. The protrusion portion **37***a* is provided in a portion where the optical layer **21** is to be left later. The resist mask layer **37** is formed, for example, by using a pattern forming method using NIL.
(90) Subsequently, as illustrated in FIG. **43**, a part of the resist mask layer **37** is removed in the thickness direction to expose some parts of the optical layer **21** while leaving the resist mask layer **37** in the recess portion **12***c*.
(91) Subsequently, as illustrated in FIG. **44**, the exposed portions of the optical layer **21** are removed by etching using the resist mask layer **37** as a mask, and the protrusion portion **11**, the convex-shaped region **131**, and the convex-shaped region **132** are exposed.
(92) Subsequently, as illustrated in FIG. **45**, the resist mask layer **37** is removed. The above is the description of an example of a method for manufacturing the template of the second embodiment.
(93) In the template of the second embodiment, by forming the upper surface **211** of the optical layer **21** to be substantially level with the surface **1***a*, a pattern can be transferred to the imprint material layer by NIL using the template including the alignment mark pattern AM, and it is possible to form an alignment mark capable of high-precision alignment without violating a design rule related to template feature height (depth) variations, limits, or the like when forming the alignment mark using a transferred or imprinted pattern.
(94) FIGS. **46** and **47** are schematic views illustrating a difference in a shape of an imprint material layer due to a difference in a shape of the optical layer **21**. When the upper surface **211** of the optical layer **21** is too high relative to the surface **1***a* level, as illustrated in FIG. **46** (note, template now faces downward), the height of a protrusion portion **102***a* of a layer **102**, which is an imprint material layer formed in the recess portion **12***c*, becomes lower. In this case, it is difficult to form the alignment mark formed using the transferred pattern including the protrusion portion **102***a* in a

desired shape, and thus, a design rule may be violated. Furthermore, when the upper surface **211** of the optical layer **21** is too low relative to the surface **1***a* level, as illustrated in FIG. **47**, the height of the protrusion portion **102***a* of the layer **102**, which is formed in the recess portion **12***c*, might also be low (the material of the layer **102** does not successfully fill the recess portion **12***c* in this example), and thus, a gap S may be left between the protrusion portion **102***a* and the upper surface **211** of the optical layer **21**. In this case, the gap S has an optical characteristic different from both the optical layer **21** and the layer **102**, and thus, the precision at the time of alignment may be deteriorated.
(95) The second embodiment may be appropriately combined with other described embodiments.
Third Embodiment
(96) (Example of Structure of Template)
(97) Similarly to the template of the second embodiment, a template of a third embodiment is provided with the base material **1** including the surface MS, and the recess portion CO. The surface MS includes the alignment mark pattern AM and the device pattern DP.
(98) FIG. **48** is a schematic cross-sectional view illustrating an example of the template of the third embodiment, and illustrates a part of the X-Z cross section of the template. Similarly to the second embodiment, the example of the template of the third embodiment is provided with the base material **1** and the optical layer **21**.
(99) Similarly to the second embodiment, the alignment mark pattern AM includes at least one protrusion portion **11** and at least one recess portion **12***c*, but additionally includes at least one recess portion **12***d*.
(100) The protrusion portion **11** and the recess portion **12***d* are alternately formed, for example, in the X-axis direction. For example, the layouts of the recess portion **12***b* illustrated in FIGS. **5**, **6**, and **7** may be applied as an upper surface layout of the recess portion **12***d*. A bottom surface **124** of the recess portion **12***d* is provided at a position deeper than the surface **1***a*.
(101) Similarly to the second embodiment, the device pattern DP includes the protrusion portion **13***b*.
(102) Similarly to the second embodiment, the alignment mark pattern AM may include the protrusion portion **112** illustrated in FIG. **25** between pluralities of recess portions **12***c*.
(103) The optical layer **21** is to be provided in the recess portion **12***c*, but not provided in the recess portion **12***d*. That is, while the bottom surface **121** of the recess portion **12***c* can be in contact with the optical layer **21**, the bottom surface **124** of the recess portion **12***d* is not in contact with the optical layer **21**, but is an exposed surface. The thickness of the optical layer **21** may be less than the depth of the recess portion **12***c*. The optical layer **21** may be in contact with a part of the bottom surface **123** of a plurality of recess portions **12***c*.
(104) As illustrated in FIG. **49**, the upper surface **211** of the optical layer **21** may be substantially level with the surface **1***a*. FIG. **49** is an enlarged view of a part of FIG. **48**.
(105) Similarly to the second embodiment, the optical layer **21** contains the second material having the second optical constant, which is different from the first optical constant, with respect to light from an optical detector.
(106) Similarly to the second embodiment, the alignment mark pattern of the third embodiment may have the example of the shape illustrated in FIG. **27**.
(107) (Example of Method for Manufacturing Template)
(108) FIGS. **50** to **53** are schematic cross-sectional views illustrating an example of a method for manufacturing the template of the third embodiment, and illustrate a part of the X-Z cross section of the base material **1**. The example of the method for manufacturing the template will be described by schematically illustrating the region R**1** of the base material **1** in which the alignment mark pattern AM is formed and the region R**2** of the base material **1** in which the device pattern DP is formed.
(109) Excepting that the recess portion **12***d* is formed by the same process as the recess portion

12*c*, similarly to the second embodiment, the protrusion portion **11**, the recess portion **12***c*, the protrusion portion **13***b*, and the optical layer **21** are formed through the processes from FIG. **28** to FIG. **41**. The description of the method of forming the recess portion **12***c* corresponds to the method of forming the recess portion **12***d*.

(110) As illustrated in FIG. **50**, the resist mask layer **37** is formed on the optical layer **21**. The resist mask layer **37** functions as a resist mask for processing the optical layer **21**. The resist mask layer **37** includes the protrusion portion **37***a* provided above the recess portions **12***c*. The protrusion portion **37***a* is provided in a portion where the optical layer **21** is to be left later. In FIG. **50**, the protrusion portion **37***a* is not overlapping the recess portion **12***d* in the Z-axis direction. The resist mask layer **37** is formed, for example, by using a pattern forming method using NIL.

(111) Subsequently, as illustrated in FIG. **51**, a part of the resist mask layer **37** is removed to expose parts of the optical layer **21** while leaving the resist mask layer **37** in the recess portions **12***c*.

(112) Subsequently, as illustrated in FIG. **52**, the exposed portion of the optical layer **21** is removed by etching using the remaining resist mask layer **37** as a mask, and the protrusion portion **11**, the convex-shaped region **131**, and the convex-shaped region **132** are exposed.

(113) Subsequently, as illustrated in FIG. **53**, the resist mask layer **37** is removed. The above is the description of an example of the method for manufacturing the template of the third embodiment.

(114) In the method of manufacturing the template of the third embodiment, the optical layer **21** is not intended to be formed in the recess portion **12***d*. However, even if the position of the optical layer **21** is displaced such that optical layer **21** is in fact formed in a recess portion **12***d* (e.g., due to manufacturing tolerances or alignment process limitations), the optical layer **21** may be prevented from entering the edge portion of the alignment mark pattern AM. Therefore, similarly to the first embodiment, an alignment mark capable of high-precision alignment may still be formed.

(115) Further, in the template and the method of manufacturing the template of the third embodiment, similarly to the second embodiment, by forming the upper surface **211** of the optical layer **21** to be substantially level with the surface **1***a*, a pattern is transferred to the imprint material layer by NIL using the template including the alignment mark pattern AM, and it is possible to form an alignment mark capable of high-precision alignment without violating a design rule when forming the alignment mark using the transferred pattern.

(116) The embodiment may be appropriately combined with other described embodiments.

Fourth Embodiment

(117) FIGS. **54** to **57** are schematic cross-sectional views illustrating an example of a method for manufacturing a semiconductor device using NIL.

(118) As illustrated in FIG. **54**, the position of the processing surface of an object **100** and the position of the pattern forming surface of a template **101** disposed to face the processing surface are aligned with each other. The positions may be aligned with each other, for example, by adjusting the position of the alignment mark pattern AM of the template **101** relative to the position of the alignment mark pattern provided in the object **100**.

(119) The object **100** is, for example, a stacked body formed by stacking a plurality of films on a semiconductor substrate. The configuration of the object **100** is not particularly limited.

(120) The template **101** is a template manufactured by any of the manufacturing methods of the first to third embodiments. As an example, FIG. **54** illustrates the template **101** manufactured by the method for the second embodiment.

(121) The layer **102** is formed by applying the imprint material to the processing surface before or after the alignment between template **101** and object **100**. The imprint material contains, for example, a light curable resin. The imprint material is applied, for example, by droplet dispensing or spin-coating.

(122) Subsequently, as illustrated in FIG. **55**, the template **101** is pressed against the layer **102** to pattern the layer **102**, the formed layer **102** is cured while still in contact with the template **101**, and the device pattern DP and the alignment mark pattern AM are transferred to the layer **102**.

(123) Before curing the layer **102**, the object **100** and the template **101** can be precisely aligned while the template **101** is being pressed against the layer **102**. When the device pattern DP includes, for example, the convex-shaped region **131** and the convex-shaped region **132**, as illustrated in FIG. **55**, the cured layer **102** has a pattern for forming a dual damascene structure.
(124) When the layer **102** contains a light curable resin, the layer **102** is cured by being irradiated by light through the template **101**. The template **101** is separated from the layer **102** after the layer **102** is cured.
(125) Subsequently, as illustrated in FIG. **56**, an opening **100***a* is formed by processing a part of the object **100** using the layer **102** as mask. The object **100** is processed, for example, by partially removing the stacked layer that constitutes the object **100** by dry etching. The shape of the object **100** after the processing is determined in accordance with the shape of the device pattern DP.
(126) Subsequently, as illustrated in FIG. **57**, a film (processing target film) is formed on the object **100**, and the film is processed to form a layer **151** in the opening **100***a*. The layer **151** is, for example, a conductive layer containing a metal material. The layer **151** has a function as, for example, an embedded wiring.
(127) As described above, in a method of manufacturing the semiconductor device, a template manufactured by any of the manufacturing methods for the first to third embodiments can be used to form an applied layer on an object and to transfer a device pattern DP to the object. Therefore, for example, since a semiconductor device may be manufactured, for example, without forming an unnecessary metal layer, deterioration of the performance of the semiconductor device may be prevented.
(128) 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 disclosure. 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 disclosure. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the disclosure.

Claims

1. A template, comprising: a base material having a first surface at a first level; a first pattern including: a plurality of first protruding portions arranged in a fixed periodic manner on the first surface in a first region, each first protruding portion protruding to a second level beyond the first level, a first recess portion between an adjacent pair of first protruding portions in a central portion of the first region, and a second recess portion between another adjacent pair of first protruding portions in an outer peripheral portion of the first region; a second pattern including a protrusion portion on the first surface in a second region different from the first region, the protrusion portion protruding to a third level; and an optical layer in the first recess portion, wherein at least a portion of a bottom surface of the second recess portion is not covered by the optical layer.
2. The template according to claim 1, wherein the first pattern includes a plurality of first recess portions and a plurality of second recess portions.
3. The template according to claim 2, wherein the first recess portions form a periodic line-space pattern with the first protruding portions.
4. The template according to claim 2, wherein the first recess portions form a grid pattern with the first protruding portions.
5. The template according to claim 2, wherein the first region surrounds the second region.
6. The template according to claim 1, wherein the first pattern is a pattern of an alignment mark.
7. The template according to claim 1, wherein the bottom surface of the second recess portion is at the first level.

8. The template according to claim 1, wherein an upper surface of the optical layer is at the first level.
9. The template according to claim 8, wherein bottom surfaces of the first and second recess portions are at a fourth level further into the base material than the first level.
10. The template according to claim 1, wherein bottom surfaces of the first and second recess portions are at a fourth level further into the base material than the first level.
11. The template according to claim 1, wherein the optical layer is a metal layer.
12. The template according to claim 1, wherein the second level and the third level are at a same height above the first surface.
13. The template according to claim 1, wherein the base material is quartz.
14. The template according to claim 1, wherein the protrusion portion of the second pattern is a multi-level structure including an intermediate portion with an upper surface at a fourth level between the first and third levels.
15. The template according to claim 1, wherein an upper surface of the optical layer is at a fourth level between the first and second levels.
16. The template according to claim 1, wherein a portion of the bottom surface of the second recess is covered by the optical layer.
17. The template according to claim 1, wherein the distance between the adjacent pair of first protruding portions and the distance between the another adjacent pair of first protruding portions is the same.
18. A method for manufacturing a template, the method comprising: patterning a base material substrate having a first surface at a first level to have a first pattern including: a plurality of first protruding portions arranged in a periodic manner on the first surface in a first region, each first protruding portion protruding to a second level beyond the first level, a first recess portion between an adjacent pair of first protruding portions in a central portion of the first region, and a second recess portion between another adjacent pair of first protruding portions in an outer peripheral portion of the first region; and a second pattern including a protrusion portion on the first surface in a second region different from the first region, the protrusion portion protruding to a third level; forming an optical layer in the first and second recess portions; and removing at least a portion of the optical layer to expose at least a portion of a bottom surface of the second recess portion.
19. A method for manufacturing a semiconductor device, the method comprising: patterning a resin layer on a device substrate by pressing a template according to claim 1 against a resin material on the device substrate; curing the patterned resin layer; and transferring the second pattern to a process layer on the device substrate.
20. The method according to claim 19, wherein an upper surface of the optical layer is at the first level.