METHODS OF PATTERNING PHOTORESIST

Coat photoresist  S200

align and expose the photoresist  S201

Perform first development process  S202

expose entire surface of the photoresist  S203

Perform second development process  S204

etch lower layer  S205

remove the photoresist  S206

ABSTRACT

Methods of patterning photoresist are disclosed. One example method includes forming photoresist on a substrate having a lower layer; performing a first exposure process to the photoresist in state of positioning a mask on the photoresist; performing a first development process to the photoresist; performing a second entire-surface exposure process to the photoresist; and performing a second development process to the photoresist.
FIG. 1
Related Art

[Diagram showing layers labeled 10, 11, 12, 12a, and 12b]
FIG. 2
Related Art

Coat photoresist \( \sim S100 \)

align and expose the photoresist \( \sim S101 \)

develop the photoresist \( \sim S102 \)

etch lower layer \( \sim S103 \)

remove the photoresist \( \sim S104 \)
FIG. 3

Coat photoresist \( \rightarrow \) S200

align and expose the photoresist \( \rightarrow \) S201

Perform first development process \( \rightarrow \) S202

expose entire surface of the photoresist \( \rightarrow \) S203

Perform second development process \( \rightarrow \) S204

etch lower layer \( \rightarrow \) S205

remove the photoresist \( \rightarrow \) S206
FIG. 4

threshold energy

photoresist thickness

FIG. 5

thickness of photoresist after development process

entire-surface exposure energy

thickness of photoresist before development process

thickness of photoresist by 90% of initial thickness of photoresist

threshold energy

exposure energy
METHODS OF PATTERNING PHOTORESIST

TECHNICAL FIELD

[0001] The present disclosure relates to semiconductor device fabrication, and more particularly, to methods of patterning photoresist.

BACKGROUND

[0002] With the recent development in information media such as computers, technology for manufacturing semiconductor devices has also developed rapidly. Accordingly, the semiconductor device has been researched and studied to obtain a high integration, a minute pattern, and a rapid operation speed. Thus, it is necessary to develop a minute pattern technology, such as a lithography process, for improving the integration of semiconductor device.

[0003] Lithography is a main technology for realizing minute patterns and high integration. Using photolithography technology a pattern of a mask is printed onto a substrate. Generally, the photolithography process is performed using consecutive steps of coating a photoresist, soft-baking the photoresist, and developing the photoresist.

[0004] The photoresist having the etching-resistant characteristics reacts to light when etching a lower layer, wherein the photoresist can be classified into a positive photoresist and a negative photoresist. In case of the positive photoresist, decomposition and chain scission generate on portions exposed to the light, whereby the solubility largely increases. Thus, the exposed portions of the positive photoresist are removed during the development process. That is, the positive photoresist has the etching-resistant characteristics and high solubility, so that the positive photoresist is generally used for the process of fabricating the high-integration semiconductor device. In the meantime, in case of the negative photoresist, bridge-construction generated on exposed portions of the negative photoresist, whereby the molecular weight largely increases. Thus, the exposed portions remain on the development process.

[0005] Through the development process, the photoresist changed by exposure is selectively removed, and a pattern of mask is printed onto a substrate. In this case, a wet etching is generally used, wherein the wet etching uses an alkali water solution as a developer, the chief ingredients of which are TetraMethyl Ammonium Hydroxide (hereinafter, referred to as TMAH).

[0006] To obtain the desired pattern, the development process is performed using, for example, a puddle method, a spray method, or a dipping method. In the puddle method, the developer is coated on the substrate, and then the photoresist is developed in a stationary state. In case of the spray method, the developer is continuously sprayed onto the substrate, so that it is helpful to the consecutive process. However, the spray method is disadvantageous in that it uses the large amount of developer. Also, in case of the dipping method, it is impossible to apply the consecutive process. In addition, the dipping method uses the large amount of developer. Thus, the dipping method is usually used for testing performed during the process of research and development.

[0007] After completing the development process, the photoresist thinly remains between the patterns, thereby generating scum. Also, on the development process, because residue of photoresist remains, it also may cause the defects. Due to the scum and residue of photoresist, when etching a lower layer, the lower layer may be disturbed. Thus, a bridge is formed between lines, thereby generating a short circuit defect on the device.

[0008] FIG. 1 is a cross sectional view of a portion of a semiconductor device showing scum and residue after developing a photoresist. Referring to FIG. 1, a photoresist 12 is coated on a semiconductor substrate 10 having a lower layer 11, and then the photoresist 12 is developed after alignment and exposure process, thereby forming a photoresist pattern. If there are scum 12a and residue 12b, formed by the remaining photoresist 12, when etching the lower layer 11 by using the patterned photoresist 12 as a mask, the lower layer 11 corresponding to the scum 12a and the residue 12b is not etched, thereby generating the defect on a semiconductor device.

[0009] A pad open pattern process for etching a metal pad for bonding with an external circuit to be exposed, uses a relatively thick layer of photoresist and low exposure energy. Accordingly, defects such as scum are generated due to nonuniformity in thickness and exposure energy of the photoresist.

[0010] If the lower layer 11 is formed of a silicon oxide layer SiOx or a silicon nitride layer SiNx, the photoresist 12 is coated on the semiconductor substrate 10, and then a baking process is performed to the photoresist 12. Thus, PAG (Photo Acid Generator), one component of the photoresist 12, reacts on the silicon oxide layer SiOx or the silicon nitride layer SiNx so that a new material is produced. In this case, because the reactivity between the new material and the developer is low, the new material is not removed during the development process. That is, the new material remains as the scum. Also, the pad open pattern process may have more defects of scum because the lower layer is generally formed of a silicon nitride layer.

[0011] A lithography process including the photoresist pattern process according to the related art is described below with respect to FIG. 2, which is a flowchart of a photolithography process according to the related art.

[0012] First, a surface treatment is performed to a substrate, so that it is possible to enhance an adhesive strength to a photoresist. Then, the photoresist is coated on the substrate (S100). At this time, in order to enhance the adhesive strength to the photoresist, the substrate is treated with a material for improving the resistance to moisture by making the surface of substrate hydrophobic. The material may be, for example, HMDS (Hexa Methyl Disilazane) and a nitrogen gas that are together introduced to a tank and vapor-coated on the substrate.

[0013] Next, after performing a soft-baking process, a mask is aligned above the substrate, and then an exposure process is performed thereto (S101). In this case, the soft-baking process is performed to remove a solution from the photoresist, wherein it is necessary to preset a temperature condition that does not pyrolyze the components of photoresist.

[0014] After that, a Post-Exposure Baking (PEB) process is performed to cure the photoresist, and then a development process is performed thereto (S102). At this time, when light
interference generates at a corner of a light-shielding part in the mask, it is impossible to precisely define a desired pattern onto the substrate, thereby generating a standing wave. In order to solve this problem, the PEB process is performed to improve uniformity on width of line in the substrate.

Then, after obtaining the desired pattern by etching a lower layer (S103), the photoresist is removed (S104). However, the related art photoresist pattern process has the following disadvantages.

In case of patterning the photoresist by exposure and development, the defects such as scum and residue may generate. The scum and residue disturb the etching of lower layer, whereby the bridge generates between the lines, thereby causing the short defect on the device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view of a portion of a semiconductor device showing scum and residue of photoresist after performing a development process to the photoresist.

FIG. 2 is a flowchart of a photolithography process according to the related art.

FIG. 3 is a flowchart of one example disclosed photolithography process.

FIG. 4 is a graph showing a relation between a thickness of photoresist and threshold energy.

FIG. 5 is a graph of showing a relation between exposure energy and a thickness of photoresist after performing a development process to the photoresist.

DETAILED DESCRIPTION

Hereinafter, methods for patterning a photoresist are described with reference to the accompanying drawings. The disclosed methods for patterning photoresist improve the precision of pattern formation and prevent defects such as scum.

FIG. 3 is a flowchart of an example disclosed photolithography process. According to one example of the disclosed process, a lower layer is first formed on a substrate, and then a surface treatment is performed to the lower layer of the substrate, to enhance an adhesive strength when forming a photoresist on the lower layer. Then, the photoresist is coated on the lower layer of the substrate (S200). At this time, a material for the lower layer is not limited. Also, according to one example, before coating the photoresist an oxygen plasma treatment is performed to the lower layer to improve the surface quality of the lower layer, so that it is possible to prevent defects such as scum. Especially, in case the lower layer is formed of a silicon oxide layer or a silicon nitride layer the surface quality of the lower layer is improved by the oxygen plasma treatment. During a pad open process of generating the defects such as scum, the silicon nitride layer generally remains on a metal layer for formation of pad. In this case, it is possible to remove the cause of generating the scum by performing the oxygen plasma treatment.

The oxygen plasma treatment changes the surface characteristics of the lower layer, whereby a Si—N bonding structure is changed to a Si—O bonding structure in the surface of the lower layer. Accordingly, the surface of the lower layer has the hydrophilic property, so that it is possible to prevent the reaction between the photoresist and the lower layer, thereby preventing the defects such as scum.

Next, an exposure process is performed after aligning a mask on the substrate (S201). Before aligning the mask and performing the exposure process, it is necessary to perform a soft-baking process. The soft-baking process is performed to remove a solvent from the photoresist. Also, the soft-baking process is set to an appropriate temperature level not to pyrolyze the photoresist. Accordingly to one example, after the soft-baking process, various steps are performed as follows: reading a position of alignment mark remaining on the substrate with an alignment sensor; measuring a position error by comparing the position of alignment mark remaining on the substrate with other alignment mark previously set in a job file; calculating translation, rotation and expansion data of the substrate with the position error; measuring an exposure position with the calculated data; and exposing the substrate.

The mask may be used as a general mask formed by sequentially depositing chrome and oxide chrome on a quartz substrate. In addition, the mask may be formed of a reflective mask or a phase shift mask. Also, an excimer laser light source may be used. For example, a KrF laser having a wavelength of 248 nanometers (nm) corresponding to a DUV (Deep Ultraviolet) region and ArF laser having a wavelength of 193 nm, as well as g-line of 436 nm, i-line of 365 nm, h-line of 405 nm and a broad band of 240 nm to 440 nm, emitted from a mercury or xenon (Xe) lamp may be used.

Next, a first development process is performed to the photoresist (S202). Before performing the first development process, according to an example, a PEB process is performed to improve uniformity in line width of the substrate. Also, a wet etching process of using an alkali water solution as a developer may be used. In one example, the chief ingredients of the wet etch process are TetraMethyl Ammonium Hydroxide (hereinafter, referred to as TMAH). In this case, it is possible to remove the considerable amount of scum and residue of the photoresist by performing an oxygen plasma treatment to the lower layer. However, after the completing the first development process, the scum and residue of photoresist may remain. Thus, a second development process is performed as follows, to completely remove the defects such as scum and residue.

After that, an entire-surface exposure process is performed (S203). When performing the entire-surface exposure process, it uses the same light source as that of the aforementioned exposure process (S201). Also, the step of aligning the mask on the substrate is not required in case of using low exposure energy suitable for selectively removing the scum and residue of photoresist without any influence to the photoresist pattern. That is, the exposure energy is set to an appropriate level not to perform the exposure process including the substrate alignment process.

As shown in FIG. 4, the exposure energy is controlled to an appropriate level not to perform the exposure process for removing the photoresist on the development process.

Referring to FIG. 4, there is a threshold energy value, which is a minimum value for removing the photo-
resist on the development process. Generally, there is the exposure energy, which can selectively remove the scum and residue of photosresist without any influence to the photosresist pattern since it has a higher value as the photosresist becomes thicker, and it has a lower value as the photosresist becomes thinner. Accordingly, as shown in FIG. 5, if the exposure energy is applied to the entire surface of the substrate at a level for developing the thickness of photosresist between 5% and 20%, advantageously, approx. 10%, it is possible to selectively remove the scum and residue of photosresist.

Accordingly, as the entire-surface exposure process is performed, it is possible to improve the precision in forming the pattern, and to prevent the scum and residue of photosresist, without the increase of the fabrication cost and time.

However, if the exposure process doesn’t cause a bottle neck in the entire fabrication process, it is possible to obtain the more precise pattern by aligning the mask for patterning the photosresist and performing the exposure process.

To remove the scum and residue of photosresist by performing the entire-surface exposure process, a positive photosresist may be used in which a portion exposed to the light is removed. For example, the positive photosresist may be formed of a novolak type composition, a chemical amplification composition, or a chain scission composition.

Next, the scum and residue of photosresist are removed by performing a second development process (S204). In one example, the second development process uses the same developer as that in the first development process.

Then, after etching the lower layer (S205), the photosresist is removed (S206). In case of the pad open process, a metal pad for bonding with an external circuit is exposed by etching the lower layer.

The example disclosed methods for patterning the photosresist by photolithography makes it possible to improve the precision in forming the pattern, and to prevent the scum and residue of photosresist, with the small fabrication cost and time.

The foregoing discloses example methods of patterning a photosresist that substantially obviate one or more problems due to limitations and disadvantages of the related art. In particular, the disclosed example methods improve precision in pattern and prevent defects such as scum, by additionally performing an entire-surface exposure process and a development process after firstly performing an exposure and development process to a photosresist coated on a substrate.

As disclosed above, according to one example, a method for patterning a photosresist pattern includes forming a photosresist on a substrate having a lower layer; performing a first exposure process to the photosresist in state of positioning a mask on the photosresist; performing a first development process to the photosresist; performing a second entire-surface exposure process to the photosresist; and performing a second development process to the photosresist.

What is claimed is:

1. A method of patterning a photosresist pattern comprising:
   - forming a photosresist on a substrate having a lower layer;
   - performing a first exposure process to the photosresist in state of positioning a mask on the photosresist;
   - performing a first development process to the photosresist;
   - performing a second entire-surface exposure process to the photosresist; and
   - performing a second development process to the photosresist.

2. The method of claim 1, further comprising, performing an oxygen plasma treatment to the lower layer, before forming the photosresist.

3. The method of claim 1, further comprising, performing a soft-baking process to the photosresist, to remove a solvent from the photosresist, before performing the first exposure process.

4. The method of claim 1, wherein the soft-baking process is performed at a temperature level not to pyrolyze components of the photosresist.

5. The method of claim 1, further comprising, baking the exposed photosresist, before performing the first development process.

6. The method of claim 1, wherein the lower layer is formed of a silicon nitride layer or a silicon oxide layer.

7. The method of claim 1, wherein an exposure-energy level of the exposure process is appropriate for decreasing a thickness of the photosresist at 5% to 20%.

8. The method of claim 1, wherein the first and second exposure processes use the same light source.

9. The method of claim 1, wherein the first and second exposure processes use the light source of g-line of 436 nm, i-line of 365 nm, h-line of 405 nm, and a broad band of 240 nm to 440 nm, emitted from a mercury or xenon Xe lamp.

10. The method of claim 1, wherein the first and second exposure processes use the light source of KrF laser having a wavelength of 248 nm corresponding to a DUV (Deep Ultraviolet) region and ArF laser having a wavelength of 193 nm.

11. The method of claim 1, wherein the second exposure process is performed with the same mask used during the first exposure process.