

METHOD FOR INSPECTING PHOTOMASK

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The present invention relates to a lithography process, and more particularly, to a method for inspecting photomask.

2. Description of Related Art

10 [0002] Along with rapid progress of the semiconductor process technique, dimensions of the semiconductor devices are scaled down and integrity thereof promoted continuously to further advance the operating speed and performance of the devices. Usually, as the semiconductor devices develop towards compact design, the lithography process is quite important in the whole fabrication. For the patterning of
15 each film or formation of doped regions, the pattern thereof is defined and the critical dimension (CD) is determined by the lithography process.

[0003] In the lithography process, firstly a photosensitive photoresist layer is formed on a wafer. Then, a photoresist exposure procedure is performed by using a photomask with a desired pattern, so as to transfer a latent pattern in the photoresist
20 layer on the wafer surface. After a development procedure is performed, a portion of the photoresist layer is removed to form a required photoresist pattern. As the devices are continuously miniaturized and integrated, the design of integrated circuit (IC) becomes increasingly complicated, such that the accuracy of transferring the photomask pattern to the wafer plays a crucial role. If the pattern on the photomask is not

accurate, e.g. with defects thereon, the pattern transfer is made to be further away from being accurate, which thus seriously impacts the subsequent process and product reliability. Accordingly, it is necessary to inspect the photomask to determine whether it is acceptable for utilization, so as to ensure the stability of the process.

5 [0004] Generally, in order to determine whether the photomask has the defects or not, a photomask inspecting tool is used for scanning the photomask. However, the photomask inspecting tool is usually very expensive, such that the fabrication cost is greatly increased. Furthermore, before using the photomask inspecting tool to scan the photomask, it is necessary to take out the photomask from the equipment to perform an
10 off-line photomask inspection. In this manner, it has to consume a long time in waiting for the result of the photomask inspection.

SUMMARY OF THE INVENTION

[0005] Accordingly, the present invention is directed to a method for inspecting a
15 photomask, which compares photoresist patterns of dies exposed by at least two different exposure conditions to determine whether the used photomask has defects or not.

[0006] A method for inspecting a photomask of the present invention is described as follows. A substrate is provided, and a first die is formed on the substrate by using the
20 photomask based on a first exposure condition. A second die is formed on the substrate by using the photomask based on a second exposure condition different from the first exposure condition. The first die and the second die are compared with each other by using a defect inspector.

[0007] According to an embodiment of the present invention, comparing the first

die and the second die includes performing an overlap comparison step to the first die and the second die. When the first die and the second die overlap incompletely, a part of the photomask has a defect. The defect is, for example, a haze or a particle.

5 [0008] According to an embodiment of the present invention, the first die is adjacent to the second die.

[0009] According to an embodiment of the present invention, the method further includes forming a third die on the substrate by using the photomask based on a third exposure condition, and comparing the second die and the third die by using the defect inspector. The third exposure condition is different from the first exposure condition
10 and the second exposure condition, for example, in at least one of focus and energy. Comparing the second die and the third die includes performing an overlap comparison step to the second die and the third die. When the second die and the third die overlap incompletely, a part of the photomask has a defect, e.g. a haze or a particle. The third die is adjacent to the second die, for example.

15 [0010] According to an embodiment of the present invention, the first exposure condition is different from the second exposure condition in at least one of focus and energy.

[0011] A method for inspecting a photomask of the present invention is also described as follows. A substrate is provided, and a pattern of the photomask is
20 transferred to the substrate based on at least two different exposure conditions, such that a plurality of shot regions is formed on the substrate. Two shot regions exposed by the different exposure conditions are compared by using a defect inspector.

[0012] According to an embodiment of the present invention, comparing the two shot regions exposed by the different exposure conditions includes performing an

overlap comparison step to the two shot regions. When the two shot regions exposed by the different exposure conditions overlap incompletely, a part of the photomask corresponding to the incompletely-overlapping shot regions has a defect. The defect is, for example, a haze or a particle.

5 [0013] According to an embodiment of the present invention, comparing the two shot regions exposed by different exposure conditions includes performing an overlap comparison step to two dies each of which is selected from the two shot regions exposed by the different exposure conditions respectively. The two selected dies are adjacent to each other.

10 [0014] According to an embodiment of the present invention, each of the shot regions includes only one die.

[0015] According to an embodiment of the present invention, the exposure conditions include at least one of focus and energy.

[0016] As mentioned above, the method for inspecting the photomask in the present
15 invention is implemented by exposing the dies based on at least two different exposure conditions, and then comparing two dies exposed by different conditions with use of the defect inspector. As the exposure condition changes, the tiny pattern profiles of the dies is changed as well. Accordingly, the defect of the photomask can be recognized by the differences between the two dies. Moreover, the method for inspecting the
20 photomask in the present invention can be further applied to the one shot-one die layout.

[0017] In order to make the aforementioned and other features and advantages of the present invention more comprehensible, preferred embodiments accompanied with figures are described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] 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.

[0019] FIG. 1 is a flow chart illustrating a method for inspecting a photomask according to an embodiment of the present invention.

[0020] FIG. 2 schematically depicts, in a top view, a plurality of dies on a substrate according to an embodiment of the present invention.

[0021] FIG. 3 schematically depicts, in a top view, a plurality of dies on a substrate according to another embodiment of the present invention.

[0022] FIGs. 4A and 4B are images of photoresist patterns which are exposed by different exposure conditions according to two examples that are observed under a scanning electron microscope (SEM).

DESCRIPTION OF THE EMBODIMENTS

[0023] 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.

[0024] During the lithography process, a defect, such as a haze or a particle, is usually generated on the photomask. The haze or the particle may be residual products as the proceeding of the process. When the photomask with the defect is utilized in the pattern transferring, the defect on the photomask is generally transferred to a photoresist

layer on a processed wafer and thus the resultant pattern profile is out of desire, which not only affects the subsequent process but also impacts the process reliability. Especially, in the case of only one die transferred in each shot region, i.e. one shot-one die layout, the unwanted photoresist profiles of the dies due to the photomask defect are all located in the same position correspondingly, and thereby the photomask defect cannot be recognized by the resultant photoresist profiles in the one shot-one die layout. That is to say, even if the photomask has the defect formed thereon, the defect is transferred in all of the dies and the photoresist profiles thus exhibit no differences among them, which is so-called a repeating issue. The defect of the photomask cannot be detected by the photoresist profile of the one shot-one die layout unless the photomask is scanned by the photomask inspecting tool in the conventional method.

[0025] Therefore, in the present invention, the repeating issue of the photomask defect transferring in the one shot-one die layout is also taken into consideration. During the lithography process, die regions of the photoresist layer exposed by at least two different exposure conditions are compared with each other, so as to effectively inspect whether the defect is formed on the photomask or not. The implementation manner of the method for inspecting the photomask in the present invention is further described through a flow chart hereinafter. FIG. 1 is a flow chart illustrating a method for inspecting a photomask according to an embodiment of the present invention. FIG. 2 schematically depicts, in a top view, a plurality of dies on a substrate according to an embodiment of the present invention.

[0026] Referring to FIG. 1, in step S100, a substrate is provided. The substrate may be a semiconductor wafer, such as a silicon wafer. A photoresist layer is, for example, deposited on the substrate in advance, such that a pattern of a predetermined

photomask can be transferred to the photoresist layer on the substrate subsequently.

[0027] Afterwards, the pattern of the photomask is transferred to the substrate, e.g. to the photoresist layer, based on at least two different exposure conditions, so as to correspondingly form a plurality of photoresist patterns on the substrate. Each photoresist pattern can be utilized for defining the layout pattern within a die region. The method of transferring the pattern of the photomask to the photoresist layer can be carried out by performing a lithography process, such as an exposure step and a development step in sequence, which are well-known to those skilled in the art, and thus will not be described herein.

[0028] The pattern transferring from the photomask to the substrate based on at least two different exposure conditions is then illustrated in detail with reference to FIG. 2. It should be noted that the term "die" mentioned in the following disclosure may represent the correspondingly photoresist pattern within a single die region. In step S110, a first die 201 is formed on the substrate by using the photomask based on a first exposure condition. In step S120, a second die 202 is formed on the substrate by using the photomask based on a second exposure condition that is different from the first exposure condition. In an embodiment, a third die 203 can be further formed on the substrate by using the photomask based on a third exposure condition, wherein the third exposure condition is different from the first and the second exposure conditions (step S130). The foregoing exposure conditions are different in at least one of focus and energy. That is to say, after the first die 201 is exposed with certain exposure factors of focus and energy (i.e. the first exposure condition), the second die 202 may be exposed with the exposure factors by changing the focus or energy (i.e. the second exposure condition). Alternatively, when the second die 202 is conducted the exposure step, the

exposure focus and energy suitable for the first die 201 can both be altered as the second exposure condition. Likewise, the third exposure condition for the third die 203 is adjusted in a similar manner of changing the exposure focus and/or energy.

[0029] Usually, during the lithography process, a stepper, for example, may be used to perform the exposure step by using the photomask repeatedly for a plurality of times at different positions of the substrate, such that a plurality of shot regions 210 is formed on the substrate. As shown in FIG. 2, the first die 201 is adjacent to the second die 202, and the second die 202 is adjacent to the third die 203, wherein these dies 201 to 203 are exposed by the different exposure conditions. In other words, since a single shot region 210 may be exposed based on a single exposure condition, the dies exposed by the different exposure conditions has to be formed in different shot regions 210, thereby each of the shot regions 210 including only one die in this embodiment.

[0030] Afterwards, in step S140, the first die 201 and the second die 202 are compared by using a defect inspector. The defect inspector can be a tool capable of conducting an overlap comparison step by measuring profiles of the resultant photoresist patterns and collecting the data. The overlap comparison step includes, for example, performing an overlap comparison to the first die 201 and the second die 202, so as to determine whether the profiles of two neighboring dies completely overlap each other or not.

[0031] It should be noticed that the photomask is usually fabricated by forming a chromic film with a desired pattern on a glass. If the photomask has the defect, e.g. haze or particle, thereon, the defect may be located at different depth of the photomask from the chromic pattern or, in the alternative, the defect is made of material different from chrome. Accordingly, the defect and the chromic pattern on the photomask each

have distinct capability of light absorption. In this case, when the exposure step is performed based on different exposure conditions, the tiny patterns exposed by the defect may exhibit different profiles in the different exposure conditions. Thus, in step S140, if the first die 201 and the second die 202 completely overlap each other in pairs, it can be indicated that no defect, i.e. haze or particle, is generated on the photomask. On the other hand, if the first die 201 and the second die 202 overlap incompletely, a defect signal can be reported due to the detection of different profiles exposed by the defect. In this manner, a corresponding part of the photomask may be found to have the defect by means of inspecting the mutual overlapping relation between the dies exposed by the different exposure conditions.

[0032] Optionally, in step S150, the second die 202 and the third die 203 can also be compared by using the defect inspector in a similar manner described above. Hence, the comparison result between the second die 202 and the third die 203 can facilitate the determination of the photomask defect owing to the dies exposed by the different exposure conditions. In an embodiment, the dies exposed based on 3 to 6 different exposure conditions can be compared, so as to further confirm the exhibition of the defect.

[0033] The foregoing inspection method merely demonstrates the concept for recognizing the repeating issue such as the haze or particle on the photomask by changing the exposure conditions, which enable one of ordinary skill in the art to practice the present invention but are not intended to limit the scope of this invention. It is noted that the above embodiment in which three neighboring dies are exposed by three different exposure conditions is provided for illustration purposes, and should not be construed as limiting the scope of the disclosure. The amount of the dies and the

variations in the exposure conditions are not specifically restricted in the present invention.

[0034] FIG. 3 schematically depicts, in a top view, a plurality of dies on a substrate according to another embodiment of the present invention. In an embodiment, the exposure conditions of each die 300 can be different from one another by altering both of the exposure focus F_1 to F_5 and energy E_1 to E_2 as a matrix shown in FIG. 3, so that any two neighboring dies 300 can be compared with each other to evaluate whether a defect is present on the photomask or not. Each offset of any two successive exposure focus F_1 to F_5 or energy E_1 to E_2 does not tend to be an extreme value, so as to prevent the complicated pattern even without defects from being misjudged. In practice, the offset values of the exposure focus F_1 to F_5 and energy E_1 to E_2 can be appropriately chosen in accordance with a previously-done focus exposure matrix (FEM) which mainly verifies effects of the focus depth and the exposure energy on the transferred layout pattern during exposure, particularly the effects on the profile of the layout pattern.

[0035] Furthermore, for illustration purposes, the above-mentioned disclosure is described in terms of only one die layout in each shot region as shown in FIGs. 2-3, which are illustrated only as exemplary examples, and should not be adopted for limiting the scope of the present invention. The layout in each shot region is not particularly limited by the present invention, whereas people skilled in the art should be able to embody the invention based on the illustration. In other words, each shot region can also include a plurality of dies. Thus, in an embodiment, the overlap comparison step by using the defect inspector can be performed to two dies each of which is selected from two shot regions exposed by different exposure conditions

respectively, so that the two dies exposed by the different exposure conditions can still be compared with each other. Alternatively, a shot region can be compared with another shot region exposed by a different exposure condition with the aid of the defect inspector in a similar manner illustrated above, so as to achieve defect recognition of the photomask owing to the difference in their profiles exposed by the different conditions.

[0036] The following example is provided to prove that the profiles of the photoresist patterns exhibit differences as the exposure conditions change, and the defect of the photomask can thus be recognized according to the present invention. This example is provided to illustrate effects upon the differences made by changing focus of the exposure conditions in the present invention, but is not intended to limit the scope of the present invention.

Examples

[0037] FIGs. 4A and 4B are images of photoresist patterns which are exposed by different exposure conditions according to two examples that are observed under a scanning electron microscope (SEM).

[0038] As shown in FIG. 4A, the three images illustrate photoresist profiles exposed by using the same photomask based on three different exposure condition, i.e. different exposure focus, respectively. By changing the exposure focus from $-0.05\text{ }\mu\text{m}$ to $+0.05\text{ }\mu\text{m}$ wherein $0\text{ }\mu\text{m}$ is considered as a normal process condition, it is observed that these patterns under different exposure conditions vary with the exposure focus, thereby exhibiting differences as designated by arrows on each image. Accordingly, the indicated differences owing to the variant exposure conditions can facilitate the recognition of the defect formed on the photomask. Likewise, the images shown in FIG. 4B illustrate other photoresist profiles exposed by using the same photomask based

on three different exposure focus, respectively. It is also observed that the patterns shown in FIG. 4B exhibit differences as the exposure focus changes where arrows designate. Hence, the defect of the photomask, such as haze or particle, can still be advantageously recognized with the aid of changing the exposure conditions as
5 proposed in the present invention, even though the repeating issue is encountered.

[0039] In view of the above, the method for inspecting the photomask according to the present invention is carried out by using the defect inspector to compare the dies which are exposed by at least two different exposure conditions. Since the defect and the chromic pattern on the photomask have distinct capability of light absorption, the
10 pattern profiles exhibit differences under the different exposure conditions. Therefore, a corresponding part of the photomask may be found to have the defect by detecting the differences between the pattern profiles.

[0040] Moreover, even if there is only one die layout in each shot region, the repeating issue still can be reported due to the profile variation with the different
15 exposure conditions. Hence, the one shot-one die layout can benefit greatly by the method for inspecting the photomask according to the present invention.

[0041] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the
20 present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

WHAT IS CLAIMED IS:

1. A method for inspecting a photomask, comprising:
providing a substrate;
forming a first die on the substrate by using the photomask based on a first
5 exposure condition;
forming a second die on the substrate by using the photomask based on a
second exposure condition different from the first exposure condition; and
comparing the first die and the second die by using a defect inspector.
2. The method according to claim 1, wherein comparing the first die and the
10 second die comprises performing an overlap comparison step to the first die and the
second die, and when the first die and the second die overlap incompletely, a part of the
photomask has a defect.
3. The method according to claim 2, wherein the defect comprises a haze or
a particle.
- 15 4. The method according to claim 1, wherein the first die is adjacent to the
second die.
5. The method according to claim 1, further comprising:
forming a third die on the substrate by using the photomask based on a third
exposure condition, wherein the third exposure condition is different from the first
20 exposure condition and the second exposure condition; and
comparing the second die and the third die by using the defect inspector.
6. The method according to claim 5, wherein comparing the second die and
the third die comprises performing an overlap comparison step to the second die and the
third die, and when the second die and the third die overlap incompletely, a part of the

photomask has a defect.

7. The method according to claim 6, wherein the defect comprises a haze or a particle.

8. The method according to claim 5, wherein the third die is adjacent to the
5 second die.

9. The method according to claim 5, wherein the third exposure condition is different from the first exposure condition and the second exposure condition in at least one of focus and energy.

10. The method according to claim 1, wherein the first exposure condition is
10 different from the second exposure condition in at least one of focus and energy.

11. A method for inspecting a photomask, comprising:

providing a substrate;

transferring a pattern of the photomask to the substrate based on at least two
different exposure conditions, such that a plurality of shot regions is formed on the
15 substrate; and

comparing two shot regions exposed by the different exposure conditions by
using a defect inspector.

12. The method according to claim 11, wherein comparing the two shot
regions exposed by the different exposure conditions comprises performing an overlap
20 comparison step to the two shot regions, and when the two shot regions exposed by the
different exposure conditions overlap incompletely, a part of the photomask
corresponding to the incompletely-overlapping shot regions has a defect.

13. The method according to claim 12, wherein the defect comprises a haze or
a particle.

14. The method according to claim 11, wherein comparing the two shot regions exposed by different exposure conditions comprises performing an overlap comparison step to two dies each selected from the two shot regions exposed by the different exposure conditions respectively.

5 15. The method according to claim 14, wherein the two dies are adjacent to each other.

16. The method according to claim 11, wherein each of the shot regions comprises only one die.

17. The method according to claim 11, wherein the exposure conditions
10 comprise at least one of focus and energy.