

# **OPTICAL DETECTION METHOD**

## **TECHNICAL FIELD**

The present invention relates to the field of semiconductor technology and, in particular, to an optical detection method.

## **BACKGROUND**

In semiconductor manufacturing processes, an optomechanical system is often used to capture images of a substrate retained on a workpiece table by suction for use in a subsequent optical detection process, for example, for defect or alignment detection. Before this can be done, it may be necessary to move the workpiece table to a position where an intended portion of the substrate is aligned with a lens of the optomechanical system.

If an optical detection module of the optomechanical system is located in the center of the workpiece table, a detection area of the optical detection module, within a travel range of the workpiece table, could generally cover the whole substrate. However, the center of the initial position or other positions of the workpiece table are usually provided with some important optics, such as an illumination light source and a special large-aperture lens. Consequently, the optical detection module has to be horizontally offset from the center of the workpiece table, or the workpiece table has to be designed with an asymmetrical translation motion stroke. In either case, the detection area of the optical detection module may not cover the entire substrate. Although this can be addressed by extending the translation motion stroke of the workpiece table and increasing its accuracy of motion at distant positions of travel, or by modifying the frame structure and overall layout of the whole machine, this will ultimately increase the cost and footprint of the whole machine.

## **SUMMARY OF THE INVENTION**

It is an object of the present invention to provide an optical detection method, which overcomes the problem of the use of expensive, large-footprint optomechanical systems in conventional optical detection.

To this end, the present invention provides an optical detection method comprising:

- providing a substrate with a number of patterns to be detected;
- placing the substrate on a predetermined position of a workpiece table;
- providing an optical detection module for capturing the patterns to be detected, wherein some of the patterns to be detected are located outside of a detection area of the optical detection module, wherein the detection area is defined by a translation motion stroke of the workpiece table; and

- capturing at least some of the patterns to be detected within the detection area by the optical detection module, rotating the substrate through a predetermined angle by the workpiece table, and then capturing remaining patterns to be detected by the optical detection module.

Optionally, the optical detection module may, one by one, capture all the patterns to be detected within the detection area, and wherein after the substrate is rotated by the workpiece table through the predetermined angle, the optical detection module, one by one, captures the remaining patterns to be detected.

Optionally, the substrate may be divided into two equal regions including a first region located in the detection area and a second region, wherein the optical detection module, one by one, captures the patterns to be detected in the first region, and wherein after the substrate is rotated by the workpiece table through the predetermined angle, the optical detection modules, one by one, captures all the patterns to be detected in the

second region.

Optionally, the predetermined angle may be 180 degrees.

Optionally, the optical detection method may further comprise, after the substrate is placed on the predetermined position of the workpiece table:

acquiring a positional conversion relationship between the substrate and the workpiece table; and

for each pattern to be detected, obtaining a theoretical position of the workpiece table at which the pattern to be detected is aligned with the optical detection module according to a position of the pattern to be detected on the substrate and the positional conversion relationship.

Optionally, for each pattern to be detected, whether the pattern to be detected is located in the detection area is determined based on the theoretical position of the workpiece table corresponding to the pattern to be detected and on the translation motion stroke of the workpiece table.

Optionally, when the optical detection module, one by one, captures the at least some patterns to be detected in the detection area, the workpiece table is moved to the corresponding theoretical position,

wherein after the substrate is rotated by the workpiece table through the predetermined angle, a corrected theoretical position of the workpiece table is obtained based on the theoretical position of the workpiece table corresponding to the remaining patterns to be detected and the predetermined angle, and wherein when the optical detection module, one by one, captures the remaining patterns to be detected, the workpiece table is moved to the corresponding corrected theoretical position.

Optionally, wherein a first motion trajectory is planned for the workpiece table based on the theoretical positions of the workpiece table corresponding to the at least some patterns to be detected in the detection area, wherein when the optical detection

module, one by one, captures the at least some patterns to be detected in the detection area, the workpiece table moves according to the first motion trajectory, and

wherein after the substrate is rotated by the workpiece table through the predetermined angle, a second motion trajectory is planned for the workpiece table based on the corrected theoretical positions of the workpiece table corresponding to the remaining patterns to be detected, wherein when the optical detection module, one by one, captures the remaining patterns to be detected, the workpiece table moves according to the second motion trajectory.

Optionally, a position of the optical detection module may be horizontally offset from a center of an initial position of the workpiece table; or the translation motion stroke of the workpiece table is horizontally asymmetrical.

Optionally, the pattern to be detected is a defect on a surface of the substrate, and the optical detection method is used for defect detection of the substrate; or wherein the pattern to be detected is an edge of the substrate, and the optical detection method is used for a coarse alignment of the substrate with the workpiece table.

In an optical detection method provided by the present invention, a substrate is placed on a predetermined position of a workpiece table, and firstly an optical detection module, one by one, captures at least some of the patterns to be detected located within a detection area. The substrate is then rotated through a predetermined angle by the workpiece table to move patterns to be detected that are outside of the detection area into the detection area, and the optical detection module then, one by one, captures remaining patterns to be detected. This dispenses with the need to extend a translation motion stroke of the workpiece table or increase its accuracy of motion at distant positions of travel, or to modify the frame structure and overall layout of the whole machine. This reduces the overall cost and footprint of the whole machine while improving process adaptability.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 shows a flowchart of an optical detection method according to a first embodiment of the present invention.

Fig. 2 is a schematic illustration of a substrate according to the first embodiment of the present invention.

Fig. 3 schematically illustrates a workpiece table and an optical detection module according to the first embodiment of the present invention.

Fig. 4 shows a schematic representation of a detection area of the optical detection module, which is located within a translation motion stroke of the workpiece table according to the first embodiment of the present invention.

Fig. 5 schematically illustrates the substrate according to the first embodiment of the present invention, which has been rotated through 180 degrees.

Fig. 6 shows a schematic representation of a detection area of an optical detection module, which is located within a translation motion stroke of a workpiece table according to a second embodiment of the present invention.

Fig. 7 schematically illustrates a substrate according to the second embodiment of the present invention, which has been rotated through 180 degrees.

### **List of Reference Numerals**

100-substrate; 101-patterns to be detected; 102-detection area; 200-workpiece table; 300-optical detection module; 110-first region; 120-second region.

## **DETAILED DESCRIPTION**

Specific embodiments of the present invention will be described in greater detail below with reference to the accompanying schematic drawings. From the following

description, advantages and features of the invention will become apparent. Note that the figures are provided in a very simplified form not necessarily drawn to exact scale for the only purpose of helping to explain the disclosed embodiments in a more convenient and clearer way.

### **Embodiment 1**

Fig. 1 shows a flowchart of an optical detection method according to a first embodiment of the present invention. As shown in Fig. 1, the optical detection method includes the steps of:

S100: providing a substrate with a number of patterns to be detected;

S200: placing the substrate at a predetermined position of a workpiece table;

S300: providing an optical detection module for capturing the patterns to be detected, wherein some of the patterns to be detected are located outside of a detection area of the optical detection module, wherein the detection area is defined by a translation motion stroke of the workpiece table; and

S400: capturing at least some of the patterns to be detected that are within the detection area by the optical detection module, rotating the substrate through a predetermined angle by the workpiece table, and then capturing the remaining patterns to be detected by the optical detection module.

Figs. 2 to 5 schematically illustrate steps in an optical detection method according to this embodiment. Next, the optical detection method according to this embodiment is described in detail with reference to Figs. 2 to 5.

Fig. 2 is a schematic illustration of a substrate 100 according to this embodiment. As shown in Fig. 2, in step S100, the substrate 100 is provided, which may be a substrate commonly known in the semiconductor field, such as a wafer or reticle. The substrate 100 may be, without limitation, circular or rectangular in shape.

There are a number of patterns to be detected 101 on the substrate 100. In this

embodiment, the patterns to be detected 101 are defects on the substrate 100, and the optical detection method is used to detect these defects on the substrate 100. In this embodiment, the positions of the patterns to be detected 101 on the substrate 100 are known, which are, for example, the centers of the defects on the substrate 100.

In some implementations, the patterns to be detected 101 may be one or more edges of the substrate 100, and in this case, the optical detection method may be used for edge detection of the substrate 100, so as to achieve a coarse alignment of the substrate 100 with the workpiece table. Moreover, in this case, the positions of the patterns to be detected 101 on the substrate 100 may correspond to positions of corners of the edges, or to a number of sampling points along the edge or edges, on the substrate 100.

It will be understood that, although the patterns to be detected 101 have been schematically illustrated as being circular in Fig. 2 for ease of understanding, they are not limited to being circular in practice, as any regular or irregular shape is possible. For example, they may even be points.

Fig. 3 schematically illustrates a workpiece table 200 and an optical detection module 300 according to this embodiment. As shown in Fig. 3, in steps S200 and S300, the substrate 100 may be picked up by a handler from a cassette and placed onto the workpiece table 200 at a predetermined position (typically at the center of the workpiece table 200). The optical detection module 300 is positioned above the workpiece table 200 and used to capture the patterns to be detected 101 on the substrate 100.

It will be understood that, if the position of the optical detection module 300 is horizontally offset from the center of the initial position of the workpiece table 200, or if the workpiece table 200 has an asymmetrical horizontal translation motion stroke, it may be highly likely that a detection area of the optical detection module 300 within the translation motion stroke of the workpiece table 200 does not encompass the entire

substrate 100. As shown in Fig. 3, the position of the optical detection module 300 is offset to the right (as viewed in the orientation of Fig. 3) in the X direction from the center of the initial position of the workpiece table 200, it may be highly likely that the detection area 102 of the optical detection module 300 within the translation motion stroke of the workpiece table 200 does not encompass a left edge portion of the substrate 100 (as viewed in the orientation of Fig. 3).

Since a deviation may occur during the loading by the handler, the position of the substrate 100 placed on the workpiece table 200 may be somewhat deviated from the predetermined position. When this happens, the workpiece table 200 may be moved to tune the optical detection module 300 into alignment with an alignment mark (not shown) on the substrate 100, and the optical detection module 300 may capture an image of the alignment mark on the substrate 100, referred to herein as an alignment image. The pixel positions of the alignment mark in the alignment image may be obtained by identifying the alignment image, and a positional conversion relationship between the substrate 100 and the workpiece table 200 may be derived from a positional conversion relationship between the optical detection module 300 and the workpiece table 200 and from the pixel positions of the alignment mark in the alignment image.

Since the position of each pattern to be detected 101 on the substrate 100 is known, using the positional conversion relationship between the substrate 100 and the workpiece table 200, positions of the patterns to be detected 101 on the substrate 100 may be converted to theoretical positions of the workpiece table 200. The theoretical positions of the workpiece table 200 are positions at which the workpiece table 200 is to be located when the respective patterns to be detected 101 are aligned with the optical detection module 300.

Next, based on the theoretical position of the workpiece table 200 corresponding to each pattern to be detected 101 and the translation motion stroke of the workpiece

table 200, it may be determined whether each pattern to be detected 101 is within the detection range. For example, assume that a coordinate system is established with its origin at the center of the workpiece table 200 and that the translation motion stroke of the workpiece table 200 is within the range of  $\pm 50$  in both the X and Y directions. If the X-coordinate of the theoretical position of the workpiece table 200 corresponding to a pattern to be detected 101 is greater than +50 or less than -50, or if the Y-coordinate of the theoretical position of the workpiece table 200 corresponding to a pattern to be detected 101 is greater than +50 or less than -50, it may be indicated that the pattern to be detected 101 is located outside of the detection range .

If all the patterns to be detected 101 are within the detection range, it is indicated that the optical detection module 300 is able to capture each pattern to be detected 101. In this case, the optical detection module 300 may be used to capture the patterns to be detected 101 one by one. If at least one of the patterns to be detected 101 is outside of the detection range, it is indicated that not all patterns to be detected 101 can be captured by the optical detection module 300.

Fig. 4 shows a schematic representation of the detection area 102 of the optical detection module 300 within the translation motion stroke of the workpiece table 200 according to this embodiment. As illustrated in Fig. 4, in this embodiment, there are 5 patterns to be detected 101 within the detection area 102 and 2 patterns to be detected 101 outside of the detection area 102. As would be appreciated, the relationship of the detection area 102 and the patterns to be detected 101 is shown in Fig. 4 only by example, and indeed, whether the pattern to be detected 101 is located in the detection range or not is to be determined based on practical situation.

With continued reference to Fig. 4, in step S400, a first motion trajectory is planned for the workpiece table 200 based on theoretical positions of the workpiece table 200 corresponding to the 5 patterns to be detected 101 in the detection area 102,

and the workpiece table 200 is moved along the first motion trajectory, and the optical detection module 300, one by one, captures the 5 patterns to be detected 101 in the detection area 102.

After that, the substrate 100 is rotated by the workpiece table 200 through a predetermined angle. In this embodiment, the predetermined angle may be 180 degrees. Fig. 5 schematically illustrates the substrate 100 according to this embodiment, which has been rotated through 180 degrees. As shown in Fig. 5, as a result of rotating the substrate 100 through 180 degrees by the workpiece table 200, the remaining two 2 patterns to be detected 101 that are outside of the detection area 102 are now moved into the detection area 102.

After the substrate 100 is rotated through 180 degrees, the position of the substrate 100 changes, and hence positions of the remaining 2 patterns to be detected 101 change as well. Accordingly, corrected theoretical positions of the workpiece table 200 may be obtained based on theoretical positions of the workpiece table 200 corresponding to the respective remaining 2 patterns to be detected 101 and the predetermined angle that the substrate 100 is rotated through. Thus, the corrected theoretical positions of the workpiece table 200 are positions at which the workpiece table 200 is located when the respective remaining 2 patterns to be detected 101 are aligned with the optical detection module 300.

Subsequently, a second motion trajectory is planned for the workpiece table 200 based on the corrected theoretical positions of the workpiece table 200 corresponding to the remaining 2 patterns to be detected 101, and the workpiece table 200 is moved along the second motion trajectory, and the optical detection module 300, one by one, captures the remaining 2 patterns to be detected 101. This dispenses with the need to extend the translation motion stroke of the workpiece table 200 or increase its accuracy of motion at distant positions of travel, or to modify the frame structure and overall

layout of the whole machine. This reduces the overall cost and footprint of the whole machine while improving process adaptability.

It will be understood that rotating the substrate 100 through 180 degrees ensures that all the patterns to be detected 101 that are outside of the detection area 102 are moved into the detection area 102 and allows for simpler subsequent processing. In alternative implementations, the predetermined angle may be other values than 180 degrees. In some implementations, the remaining patterns to be detected 101 can also be moved into the detection area 102 by rotating the substrate 100 by a different angle. Therefore, the predetermined angle may be indeed determined for the substrate 100 depending on considerations in practical applications.

## **Embodiment 2**

A second embodiment differs from the first embodiment in that the optical detection module 300, one by one, captures only some of the patterns to be detected 101 within the detection area 102 before the substrate 100 is rotated through the predetermined angle.

Fig. 6 shows a schematic representation of the detection area 102 of the optical detection module 300 located within the translation motion stroke of the workpiece table 200 according to this embodiment. As illustrated in Fig. 6, in this embodiment, there are 5 patterns to be detected 101 within the detection area 102 and 2 patterns to be detected 101 outside of the detection area 102. As would be appreciated, the detection area 102 and the patterns to be detected 101 are shown in Fig. 6 only by example, and indeed, whether the pattern to be detected 101 is located in the detection range or not is to be determined based on practical situation.

With continued reference to Fig. 6, in step S400, the substrate 100 is divided along the Y direction into two equal regions, referred to hereinafter respectively as a first region 110 and a second region 120. The first region 110 is entirely located in the

detection area 102, while a part of the second region 120 is located in the detection area 102, with its remaining being located outside the detection area 102. There are 3 patterns to be detected 101 in the first region 110 and 4 patterns to be detected 101 in the second region 120.

It will be understood that the present invention is not limited to dividing the substrate 100 into two equal regions along the Y direction, as it may be divided in half otherwise as long as the resulting first region 110 is located in the detection area 102.

Next, a first motion trajectory is planned for the workpiece table 200 based on the theoretical positions of the workpiece table 200 corresponding to the 3 patterns to be detected 101 in the first region 110, and the workpiece table 200 is moved along the first motion trajectory, and the optical detection module 300 captures the patterns to be detected 101 in the detection area 102 one by one.

After that, the substrate 100 is rotated by the workpiece table 200 through 180 degrees. Fig. 7 schematically illustrates the substrate 100 according to this embodiment, which has been rotated through 180 degrees. As shown in Fig. 7, after the substrate 100 is rotated through 180 degrees by the workpiece table 200, the second region 120 that is partially outside of the detection area 102 is now located in the detection area 102. Accordingly, all the 4 patterns to be detected 101 in the second region 120 are moved into the detection area 102.

After the substrate 100 is rotated through 180 degrees, the position of the substrate changes, and hence positions of the patterns to be detected 101 in the second region 120 change. Accordingly, corrected theoretical positions of the workpiece table 200 may be obtained based on theoretical positions of the workpiece table 200 corresponding to the respective 4 patterns to be detected 101 in the second region 120 and the predetermined angle ( $180^\circ$ ) that the substrate 100 is rotated through. Thus, the corrected theoretical positions of the workpiece table 200 are positions at which the

workpiece table 200 is located when the respective 4 patterns to be detected 101 in the second region 120 are aligned with the optical detection module 300.

Afterwards, a second motion trajectory is planned for the workpiece table 200 based on the corrected theoretical positions of the workpiece table 200 corresponding to the 4 patterns to be detected 101 in the second region 120, and the workpiece table 200 is moved along the second motion trajectory, and the optical detection module 300, one by one, captures the 4 patterns to be detected 101 in the second region 120. This dispenses with the need to extend the translation motion stroke of the workpiece table 200 or increase its accuracy of motion at distant positions of travel, or to modify the frame structure and overall layout of the whole machine. This reduces the overall cost and footprint of the whole machine while improving process adaptability.

In summary, in an optical detection method provided by the disclosed embodiments, a substrate is placed onto a workpiece table at a predetermined position, and firstly an optical detection module, one by one, captures at least some of the patterns to be detected located within a detection area of the optical detection module. The substrate is then rotated through a predetermined angle by the workpiece table to move patterns to be detected that are outside of the detection range into the detection range, and the optical detection module then, one by one, captures the remaining patterns to be detected. This dispenses with the need to extend a translation motion stroke of the workpiece table or increase its accuracy of motion at distant positions of travel, or to modify the frame structure and overall layout of the whole machine. This reduces the overall cost and footprint of the whole machine while improving process adaptability.

It should be noted that the embodiments disclosed herein are described in a progressive manner, with the description of each embodiment focusing on its differences from others. Cross-reference is made between the embodiments for their common or similar features. Since the system embodiments correspond to the method

embodiments disclosed herein, they are described relatively briefly, and reference can be made to the description in connection with the method embodiments for more details.

It should also be noted that while the present invention has been described with reference to several preferred embodiments, the forgoing embodiments are not intended to limit the invention. In light of the teachings hereinabove, any person familiar with the art may make various possible variations and changes to the disclosed embodiments or modify them into equivalent alternatives, without departing from the scope thereof. Accordingly, any and all such simple variations, equivalent alternatives and modifications made to the foregoing embodiments without departing from the scope of the invention are intended to fall within the scope thereof.

Further, it should be understood that, as used herein, the terms “first”, “second”, “third” and the like are only meant to distinguish various components, elements, steps, etc. from each other and are not intended to indicate logical or sequential orderings thereof, unless otherwise indicated or specified.

It is also recognized that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention. It must be noted that, as used herein and in the appended claims, the singular forms “a” and “an” include the plural reference unless the context clearly dictates otherwise. Thus, for example, a reference to “a step” or “a device” is a reference to one or more steps or devices and may include sub-steps and sub-devices. All conjunctions used are to be understood in the most inclusive sense possible. Thus, the term “or” should be understood as having the definition of a logical “or” rather than that of a logical “exclusive or” unless the context clearly necessitates otherwise. Further, implementation of the method and/or device according to the embodiments of the present invention may involve performing selected tasks manually, automatically, or a combination thereof.

## CLAIMS

1. An optical detection method, comprising:
  - providing a substrate with a number of patterns to be detected;
  - placing the substrate on a predetermined position of a workpiece table;
  - providing an optical detection module for capturing the patterns to be detected,wherein some of the patterns to be detected are located outside of a detection area of the optical detection module, wherein the detection area is defined by a translation motion stroke of the workpiece table; and
  - capturing at least some of the patterns to be detected within the detection area by the optical detection module, rotating the substrate through a predetermined angle by the workpiece table, and then capturing remaining patterns to be detected by the optical detection module.
2. The optical detection method of claim 1, wherein the optical detection module, one by one, captures all the patterns to be detected within the detection area, and wherein after the substrate is rotated by the workpiece table through the predetermined angle, the optical detection module, one by one, captures the remaining patterns to be detected.
3. The optical detection method of claim 1, wherein the substrate is divided into two equal regions including a first region located in the detection area and a second region, wherein the optical detection module, one by one, captures the patterns to be detected in the first region, and wherein after the substrate is rotated by the workpiece table through the predetermined angle, the optical detection modules, one by one, captures all the patterns to be detected in the second region.
4. The optical detection method of claim 3, wherein the predetermined angle is 180 degrees.
5. The optical detection method of any one of claims 1 to 4, further comprising,

after the substrate is placed on the predetermined position of the workpiece table:

acquiring a positional conversion relationship between the substrate and the workpiece table; and

for each pattern to be detected, obtaining a theoretical position of the workpiece table at which the pattern to be detected is aligned with the optical detection module according to a position of the pattern to be detected on the substrate and the positional conversion relationship.

6. The optical detection method of claim 5, wherein, whether the pattern to be detected is located in the detection area is determined based on the theoretical position of the workpiece table corresponding to the pattern to be detected and on the translation motion stroke of the workpiece table.

7. The optical detection method of claim 5, wherein when the optical detection module, one by one, captures the at least some patterns to be detected in the detection area, the workpiece table is moved to the corresponding theoretical position, and

after the substrate is rotated by the workpiece table through the predetermined angle, a corrected theoretical position of the workpiece table is obtained based on the theoretical position of the workpiece table corresponding to the remaining patterns to be detected and the predetermined angle, and wherein when the optical detection module, one by one, captures the remaining patterns to be detected, the workpiece table is moved to the corresponding corrected theoretical position.

8. The optical detection method of claim 7, wherein a first motion trajectory is planned for the workpiece table based on the theoretical positions of the workpiece table corresponding to the at least some patterns to be detected in the detection area, wherein when the optical detection module, one by one, captures the at least some patterns to be detected in the detection area, the workpiece table moves according to the first motion trajectory, and

wherein after the substrate is rotated by the workpiece table through the predetermined angle, a second motion trajectory is planned for the workpiece table based on the corrected theoretical positions of the workpiece table corresponding to the remaining patterns to be detected, wherein when the optical detection module, one by one, captures the remaining patterns to be detected, the workpiece table moves according to the second motion trajectory.

9. The optical detection method of claim 1, wherein a position of the optical detection module is horizontally offset from a center of an initial position of the workpiece table; or the translation motion stroke of the workpiece table is horizontally asymmetrical.

10. The optical detection method of claim 1, wherein the pattern to be detected is a defect on a surface of the substrate, and the optical detection method is used for defect detection of the substrate; or wherein the pattern to be detected is an edge of the substrate, and the optical detection method is used for a coarse alignment of the substrate with the workpiece table.