

LASER BEAM FOCAL POSITION DETECTING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a laser beam focal position detecting method for inspecting a focal position of a laser beam to be oscillated from laser beam oscillating means and next to be focused by focusing means in a laser processing apparatus.

Description of the Related Art

In a semiconductor device manufacturing process, a plurality of devices such as integrated circuits (ICs) and large scale integrations (LSIs) are formed on a front side of a substantially disk-shaped semiconductor wafer, in which the plural devices are respectively formed in a plurality of separate regions defined by a plurality of crossing division lines (streets). The semiconductor wafer is divided along these division lines by the following method to obtain the individual devices (device chips). For example, a pulsed laser beam having an absorption wavelength to the wafer is focused at a desired position by focusing means and applied along each division line to thereby form a laser processed groove as a break start point on the wafer along each division line.

Thereafter, an external force is applied to the wafer along each division line where the laser processed groove is formed as a break start point, thereby breaking the wafer along each division line (see Japanese Patent Laid-open No. 2006-294674, for example).

SUMMARY OF THE INVENTION

In the case of exchanging a chuck table for holding the semiconductor wafer or in the case in which a condition of an optical system is changed with the use of a laser processing apparatus, there is a possibility that the focal position of the laser beam may be changed. To cope with such a case, a pulsed laser beam is applied to a test wafer with the focal position changed, thereby forming a plurality of laser marks at different vertical positions. An operator makes visual inspection to determine the best one of the positions where the laser beams are formed, in which an edge of the laser mark formed at the best position is clear. Thus, the detection or correction for a just focus position are performed by the operator. Accordingly, the determination by the visual inspection of the operator is made from a personal point of view, causing troublesome work. That is, there is a problem in reliability and workability.

It is therefore an object of the present invention to provide a laser beam focal position detecting method which can detect a focal position of a laser beam easily and reliably.

In accordance with an aspect of the present invention, there is provided a focal position detecting method in a laser processing apparatus including holding means having a workpiece holding surface for holding a workpiece, laser beam applying means having focusing means applying a laser beam to an upper surface of the workpiece held on the workpiece holding surface of the holding means to thereby form a focal point, focal position adjusting means moving the focal point of the laser beam to be formed by the focusing means in a direction perpendicular to the workpiece holding surface of the holding means, feeding means relatively moving the holding means and the laser beam applying means in a feeding direction, imaging means imaging the upper surface of the workpiece held on the workpiece holding surface of the holding means, control means, and storage means. The focal position detecting method for detecting a focal position of the laser beam to be applied by the laser beam applying means, includes a test wafer mounting step of mounting a test wafer having a flat upper surface

and a flat lower surface on the workpiece holding surface of the holding means; a laser spot forming step of changing the focal position of the laser beam plural times in a predetermined range in a vertical direction with respect to the upper surface of the test wafer after performing the test wafer mounting step, and next continuously applying a pulsed laser beam having an absorption wavelength to the test wafer to thereby form a plurality of laser spots at different vertical positions in the predetermined range such that a spacing is defined between any adjacent ones of the laser spots in the feeding direction; and a just focus position deciding step including substeps of imaging the plurality of laser spots formed at the different vertical positions by using the imaging means after performing the laser spot forming step, next extracting a shape of each laser spot from an image obtained by the imaging means, next calculating a degree of similarity of the shape of each laser spot to an ideal laser spot shape previously stored in the storage means, and next deciding the focal position corresponding to a largest value for the degree of similarity as a just focus position, the substeps of extracting, calculating, and deciding being performed by the control means.

Preferably, the just focus position deciding step includes substeps of preparing an approximation curve for the degree of similarity of the shape of each laser spot and next deciding the focal position corresponding to a maximum value for the degree of similarity on the approximation curve as the just focus position.

According to the laser beam focal position detecting method of the present invention, the plural laser spots formed on the test wafer at the different vertical positions are imaged by the imaging means. Thereafter, the degree of similarity of the shape of each laser spot to the ideal laser spot shape is calculated to detect the just focus position according to the result of calculation. Accordingly, any special mechanism is not additionally required for the detection of the just focus position, and the inspection can be automatically performed simply and reliably.

The above and other objects, features, and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a laser processing apparatus according to a preferred embodiment of the present invention;

FIG. 2 is a block diagram illustrating a configuration of laser beam applying means included in the laser processing apparatus illustrated in FIG. 1;

FIG. 3 is an enlarged plan view of an essential part of a wafer processed by a laser spot forming step;

FIG. 4 is an enlarged perspective view illustrating a plurality of laser spots formed at different vertical positions on a test wafer in a laser spot forming step of a focal position detecting method according to this preferred embodiment; and

FIG. 5 is a graph illustrating two modes of determination of the degree of similarity of image data of each laser spot to reference data.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

There will now be described a pulsed laser beam focal position detecting method according to a preferred embodiment of the present invention with reference to the attached drawings. FIG. 1 is a perspective view of a

laser processing apparatus 1 according to this preferred embodiment. The configuration of the laser processing apparatus 1 illustrated in FIG. 1 is merely illustrative. That is, any processing apparatus capable of processing a wafer as in this preferred embodiment may be used in the present invention.

As illustrated in FIG. 1, the laser processing apparatus 1 includes a base 2, a chuck table (holding means) 3 provided on the base 2, and laser beam applying means 4 provided above the chuck table 3. A disk-shaped wafer (workpiece) W held on the chuck table 3 is adapted to be processed by the laser beam applying means 4. A plurality of crossing streets ST are formed on a front side of the wafer W to define a plurality of separate regions where a plurality of devices D such as ICs and LSIs are respectively formed. The crossing streets ST are composed of a plurality of streets ST extending in a first direction and a plurality of streets ST extending in a second direction perpendicular to the first direction. A protective tape T formed from a synthetic resin sheet is attached to a back side of the wafer W. A ring frame F is attached to a peripheral portion of the protective tape T. Accordingly, the wafer W is supported through the protective tape T to the ring frame F. The

wafer W may be of any kind as far as a laser spot can be formed on the wafer W by a pulsed laser beam as described later. For example, the wafer W may be a semiconductor wafer including a semiconductor substrate formed of silicon or gallium arsenide, for example, and a plurality of semiconductor devices such as ICs and LSIs formed on the semiconductor substrate. Further, the wafer W may also be an optical device wafer including an inorganic material substrate formed of sapphire or silicon carbide, for example, and a plurality of optical devices such as light emitting diodes (LEDs) formed on the inorganic material substrate.

The chuck table 3 has an upper surface functioning as a holding surface (workpiece holding surface) 3a for holding the back side of the wafer W through the protective tape T under suction. The holding surface 3a is the upper surface of a suction member (vacuum chuck) formed of a porous ceramic material. The holding surface 3a is connected to a vacuum source (not illustrated) through a suction passage formed inside the chuck table 3. The chuck table 3 is a circular member, and it is rotatable about its axis (vertical axis) by rotating means (not illustrated). A pair of clamps 9 are supported through a pair of support arms to the outer circumference

of the chuck table 3 at diametrically opposite positions. Each clamp 9 is adapted to be driven by an air actuator. By operating the air actuator, each clamp 9 is driven to hold the ring frame F supporting the wafer W at two positions opposite to each other in the X direction indicated by a double-headed arrow X in FIG. 1.

A cover 11 is provided below the chuck table 3. The cover 11 is supported by a cylindrical member 10. The cylindrical member 10 is provided above indexing means 13 (Y moving means). The indexing means 13 includes a pair of parallel guide rails 14 extending in the Y direction indicated by a double-headed arrow Y in FIG. 1, a ball screw 15 extending parallel to the guide rails 14, and a Y table 16 slidably mounted on the guide rails 14. The back side (lower surface) of the Y table 16 is formed with a nut portion (not illustrated), and the ball screw 15 is threadedly engaged with this nut portion. A drive motor 17 is connected to one end of the ball screw 15. By operating the drive motor 17, the ball screw 15 is rotated to thereby move the Y table 16 along the guide rails 14 in an indexing direction (Y direction).

The indexing means 13 is provided on an X table 21 constituting feeding means 20 (X moving means). The feeding means 20 further includes a pair of parallel

guide rails 22 extending in the X direction and a ball screw 23 extending parallel to the guide rails 22. The X table 21 is slidably mounted on the guide rails 22. The back side (lower surface) of the X table 21 is formed with a nut portion (not illustrated), and the ball screw 23 is threadedly engaged with this nut portion. A drive motor 24 is connected to one end of the ball screw 23. By operating the drive motor 24, the ball screw 23 is rotated to thereby move the X table 21 along the guide rails 22 in a feeding direction (X direction).

The laser beam applying means 4 is movable both in the Y direction and in the Z direction (vertical direction) indicated by a double-headed arrow Z in FIG. 1 above the chuck table 3 by a supporting mechanism (focal position adjusting means) 27. That is, the laser beam applying means 4 is supported by the supporting mechanism 27 so as to be movable both in the Y direction and in the Z direction. The supporting mechanism 27 includes a pair of parallel guide rails 28 provided on the base 2 so as to extend in the Y direction and a motor-driven Y table 29 slidably mounted on the guide rails 28. The Y table 29 is rectangular as viewed in plan and has a vertically extending side wall portion 30 formed at one end in the X direction.

The supporting mechanism 27 further includes a pair of parallel guide rails 32 (one of which being illustrated) provided on one side surface of the wall portion 30 so as to extend in the Z direction and a Z table 33 slidably mounted on the guide rails 32. The back side (lower surface) of the Y table 29 is formed with a nut portion (not illustrated), and a ball screw 34 is threadedly engaged with this nut portion. A drive motor 36 is connected to one end of the ball screw 34. By operating the drive motor 36, the ball screw 34 is rotated to thereby move the Y table 29 along the guide rails 28 in the Y direction. Similarly, the back side (side surface opposed to the wall portion 30) of the Z table 33 is formed with a nut portion (not illustrated), and a ball screw 35 is threadedly engaged with this nut portion. A drive motor 37 is connected to one end of the ball screw 35. By operating the drive motor 37, the ball screw 35 is rotated to thereby move the Z table 33 along the guide rails 32 in the Z direction. Accordingly, the laser beam applying means 4 supported to the supporting mechanism 27 is movable both in the Y direction and in the Z direction.

The laser beam applying means 4 includes a cylindrical casing 40 supported to the Z table 33 in a

cantilever fashion and focusing means 44 mounted at a front end of the casing 40. The configuration of the laser beam applying means 4 will now be described with reference to FIG. 2. FIG. 2 is a block diagram illustrating the configuration of the laser beam applying means 4. As illustrated in FIG. 2, the laser beam applying means 4 includes laser beam oscillating means 42 provided in the casing 40 illustrated in FIG. 1, an optical system 43 transmitting a pulsed laser beam oscillated by the laser beam oscillating means 42, focusing means 44 focusing the pulsed laser beam transmitted by the optical system 43 and applying the pulsed laser beam to the wafer W held on the chuck table 3 to form a focal point on the wafer W, and a wavelength converting mechanism 45 converting the wavelength of the pulsed laser beam oscillated by the laser beam oscillating means 42 to a short wavelength suitable for processing of the wafer W.

The laser beam oscillating means 42 is composed of a pulsed laser oscillator 421 oscillating a pulsed laser having a wavelength of 1064 nm, for example, and repetition frequency setting means 422 setting the repetition frequency of the pulsed laser beam to be oscillated by the pulsed laser oscillator 421. The

optical system 43 is interposed between the laser beam oscillating means 42 and the focusing means 44. The optical system 43 is composed of beam diameter adjusting means 431 adjusting the beam diameter of the pulsed laser beam oscillated by the laser beam oscillating means 42 and power adjusting means 432 adjusting the power of the pulsed laser beam oscillated by the laser beam oscillating means 42 to a predetermined power. The pulsed laser oscillator 421 and the repetition frequency setting means 422 of the laser beam oscillating means 42 and the beam diameter adjusting means 431 and the power adjusting means 432 of the optical system 43 are all controlled by control means 60 to be hereinafter described.

The focusing means 44 includes a direction changing mirror 441 and a focusing lens 442. The direction changing mirror 441 functions to change the traveling direction of the pulsed laser beam output from the wavelength converting mechanism 45 toward the chuck table 3. The focusing lens 442 functions to focus the pulsed laser beam reflected by the direction changing mirror 441 and apply the focused pulsed laser beam to the wafer W. The wavelength converting mechanism 45 is interposed between the optical system 43 and the focusing means 44. In the wavelength converting mechanism 45, the pulsed

laser beam having a wavelength of 1064 nm passed through the optical system 43 is converted into a pulsed laser beam having a wavelength of 532 or 266 nm, for example.

Referring back to FIG. 1, imaging means 50 is provided at a front end portion of the casing 40. The imaging means 50 includes a microscope for projecting a surface area of the wafer W with a predetermined magnification, and this surface area projected can be imaged. The imaging means 50 includes an imaging device (not illustrated) such as charge coupled device (CCD). The imaging device is composed of a plurality of pixels and can provide an electrical signal corresponding to the quantity of light received by each pixel. Accordingly, the imaging means 50 can image each street ST formed on the front side of the wafer W to thereby detect each street ST. According to the image obtained by the imaging means 50, alignment between the laser beam applying means 4 and the wafer W is performed.

The laser processing apparatus 1 further includes control means 60 centrally controlling all the components of this apparatus. The control means 60 is configured by a processor for executing various kinds of processing. A detection signal from the imaging means 50 and detection results from various detectors (not illustrated) are

input into the control means 60. Further, control signals are output from the control means 60 to the drive motors 17, 24, 36, and 37 and the laser beam oscillating means 42, for example.

The laser processing apparatus 1 further includes storage means 61 storing various parameters and a program, for example. The storage means 61 is configured by a memory. The memory includes one or more storage devices such as read only memory (ROM) and random access memory (RAM) according to uses. The storage means 61 previously stores data on the outline of the shape of an ideal laser spot LS (see FIG. 3) and a threshold value for the degree of similarity regarding this outline, which will be hereinafter described.

A wafer processing method using the laser processing apparatus 1 will now be described. In the wafer processing method according to this preferred embodiment, a plurality of laser spots LS (see FIG. 3) are formed at given intervals along each street ST on the wafer W.

In the wafer processing method according to this preferred embodiment, a wafer mounting step is first performed. In the wafer mounting step, the wafer W supported through the protective tape T to the ring frame

F is placed on the chuck table 3 illustrated in FIG. 1 by using transfer means (not illustrated) or the like.

Thereafter, suction means (not illustrated) is operated to hold the wafer W through the protective tape T on the chuck table 3 under suction. Further, the ring frame F is fixed by the clamps 9.

After performing the wafer mounting step, a laser spot forming step is performed. In the laser spot forming step, the feeding means 20 is operated to position the chuck table 3 directly below the imaging means 50. In this condition, alignment is performed by the imaging means 50 and the control means 60 to detect a target area of the wafer W to be processed. In this alignment, image processing such as pattern matching is performed by the control means 60 to each street ST of the wafer W imaged by the imaging means 50, in order to make the alignment between the focusing means 44 of the laser beam applying means 4 and the wafer W.

Thereafter, the movement and rotation of the chuck table 3 are controlled according to the result of calculation in the control means 60, thereby positioning the wafer W in such a manner that the streets ST extending in the first direction become parallel to the X direction. Thereafter, the focusing means 44 of the laser

beam applying means 4 is set directly above a predetermined one of the streets ST extending in the first direction parallel to the X direction. Further, the focal point of the pulsed laser beam to be applied from the focusing means 44 is set on the wafer W held on the chuck table 3. Thereafter, the pulsed laser beam having an absorption wavelength to the wafer W is applied from the focusing means 44 to the wafer W. At the same time, the feeding means 20 is operated to relatively move the chuck table 3 and the feeding means 44 in the X direction, or in the feeding direction.

Accordingly, a plurality of laser spots LS are formed at given intervals corresponding to the pulse pitch based on the wavelength of the pulsed laser beam, on the wafer W along the predetermined street ST as illustrated in FIG. 3. In other words, the plural laser spots LS are formed in such a manner that a spacing S is defined between any adjacent ones of the plural laser spots LS as illustrated in FIG. 3 by the continuous application of the pulsed laser beam. FIG. 3 is an enlarged plan view of an essential part of the wafer W processed by the laser spot forming step. As illustrated in FIG. 3, each laser spot LS has an oval shape like a racetrack with rounded corners or an oblong hole. However,

the shape of each laser spot LS is not limited, but various other shapes such as circular, elliptical, and rectangular shapes may be applied.

After forming the plural laser spots LS along the predetermined street ST, the application of the pulsed laser beam is stopped and the chuck table 3 and the focusing means 44 are next relatively moved (indexed) in the Y direction by the pitch of the streets ST. As a result, the focusing means 44 can be positioned directly above the next street ST adjacent to the above predetermined street ST. Thereafter, a plurality of laser spots LS are similarly formed along this next street ST. This operation is repeated to similarly form a plurality of laser spots LS along all the streets ST extending in the first direction parallel to the X direction. Thereafter, the chuck table 3 is rotated 90 degrees about its axis to make the other streets ST extending in the second direction parallel to the Y direction. Thereafter, a plurality of laser spots LS are similarly formed along the other streets ST extending in the second direction.

Each laser spot LS is formed on the wafer W such that the laser beam is focused at a predetermined position in the Z direction (vertical direction). In shipping the laser processing apparatus 1, the focal

position of the laser beam to be applied from the laser beam applying means 4 is previously set as a design value. In the case of exchanging the chuck table 3 or in the case in which the condition of the laser beam applying means 4 is changed with the use of the apparatus 1 (e.g., deformation or contamination of the lens and minute displacement of the optical system), there is a possibility that the focal position of the laser beam previously set may be deviated from the design value. Accordingly, it is necessary to detect the actual focal position of the laser beam before processing the wafer W.

In this preferred embodiment, the detection of the focal position of the laser beam is automatically performed by the control means 60. A detecting method for the focal position of the laser beam will now be described. This detecting method uses a test wafer in place of the wafer W. The test wafer is not limited as far as the laser spots LS can be formed as described above. For example, the test wafer may be the same as the wafer W for use in manufacturing the products or may be different in material (price) from the wafer W.

The laser beam focal position detecting method according to this preferred embodiment includes a wafer mounting step, a laser spot forming step, and a just

focus position deciding step, which are performed in this order.

In the laser beam focal position detecting method according to this preferred embodiment, the wafer W used in the wafer processing method mentioned above is changed to a test wafer, and the wafer mounting step and the laser spot forming step are similarly performed to the test wafer. Accordingly, the test wafer is denoted by reference symbol TS inside the parentheses attached to the reference symbol W of the wafer W in FIGS. 1 and 3, and the detailed description of the wafer mounting step will be omitted accordingly. As illustrated in FIG. 4, the test wafer TS has a flat front side (upper surface) and a flat back side (lower surface). In the condition where the test wafer TS is held on the chuck table 3 in the wafer mounting step, the upper surface U of the test wafer TS as viewed in FIG. 4 is horizontal. FIG. 4 is an enlarged perspective view illustrating an essential part of the test wafer TS. The outside shape of the test wafer TS is actually different from the shape illustrated in FIG. 4.

The laser spot forming step in the focal position detecting method is performed in a manner similar to that in the wafer processing method mentioned above to form a

plurality of laser spots LS on the test wafer TS at given intervals S in the X direction. In forming these laser spots LS, the focal position of the laser beam is changed plural times in a predetermined range in the Z direction (vertical direction) with respect to the upper surface U of the test wafer TS (i.e., the defocus amount is changed), so that the plural laser spots LS (LS1 to LS6) are formed at different vertical positions in the Z direction as illustrated in FIG. 4. In FIG. 4, the difference in focal position in the Z direction in forming the laser spots LS1 to LS6 is indicated by phantom line M. The number of laser spots to be formed in the laser spot forming step is arbitrary and the number of laser spots illustrated in FIG. 4 is merely illustrative.

After performing the laser spot forming step, the just focus position deciding step is performed. The just focus position deciding step includes an imaging step, extracting step, calculating step, and deciding step.

In the imaging step, the plural laser spots LS formed at different focal positions (with different defocus amounts) in the laser spot forming step are positioned directly below the imaging means 50 and then imaged by the imaging means 50 at plural positions in the

X direction as the feeding direction. Image data of these laser spots LS at the different focal positions as obtained by the imaging means 50 is input into the control means 60.

After performing the imaging step, the extracting step is performed. In the extracting step, the control means 60 performs suitable processing for extracting the outline of each laser spot LS from the image data input from the imaging means 50. For example, the control means 60 performs image processing for linearly extracting the outline of each laser spot LS from the image data of each laser spot LS at each focal position by using a predetermined algorithm. This outline extraction processing in the extracting step is performed under the same conditions to the image data of all the laser spots LS at the different focal positions, in order to obtain a proper calculation result in the next calculating step.

In the extracting step, the outline extraction processing is performed to opposite end portions E enclosed by broken lines in FIG. 3, of each laser spot LS imaged in the imaging step. The opposite end portions E of each laser spot LS do not include a simple straight outline, but include a characteristic outline. Accordingly, the opposite end portions E are suitable for

edge detection, so that the outline extraction can be performed with high precision. Also in the case in which each laser spot LS has any shapes other the oval shape like a racetrack with rounded corners as illustrated in FIG. 3, it is preferable to select the longitudinally opposite end portions of each laser spot as a target for the outline extraction.

After performing the extracting step, the calculating step is performed. Prior to performing the calculating step, the storage means 61 previously stores reference data on an ideal outline as the ideal shape of each laser spot LS on the basis of the pulsed laser beam applying conditions or the like. This ideal shape may be set from the shape of a mask for controlling the pass of the laser beam for forming each laser spot LS.

In the calculating step, the control means 60 compares the image data of each laser spot LS (see FIG. 4) extracted in the extracting step (in particular, the image data on the outline of the opposite end portions E) with the reference data stored in the storage means 61 and then performs a predetermined image determination method such as pattern matching to calculate the degree of similarity of each image data to the reference data. The degree of similarity represents the amount of

deviation of each image data from the reference data. When the amount of deviation is large, the degree of similarity is low, whereas when the amount of deviation is small, the degree of similarity is high.

As illustrated in FIG. 4, the plural laser spots LS1 to LS6 formed by changing the focal position of the laser beam are different in position in the Z direction. Accordingly, the sharpness (the amount of blurring) of the outline of the laser spots LS1 to LS6 as imaged in the imaging step is different according to the different defocus amounts. According to this difference in the sharpness, the image data extracted from the laser spots LS1 to LS6 in the extracting step becomes different. As a result, in the calculating step, the degree of similarity of the image data of the laser spots LS1 to LS6 to the reference data becomes different. In other words, the difference in the degree of similarity calculated in the calculating step corresponds to the difference in the focal position of the laser beam, i.e., in the formed position of the laser spots LS1 to LS6.

After performing the calculating step, the deciding step is performed. In the deciding step, it is decided that the largest one of the degrees of similarity calculated in the calculating step for the image data of

the plural laser spots LS corresponds to the ideal outline of the laser spot and that the formed position of the laser spot LS corresponding to the largest degree of similarity is the just focus position.

FIG. 5 illustrates the concept of the determination of the degree of similarity for the plural laser spots LS (LS1 to LS6) formed at different vertical positions. In the graph of FIG. 5, the degree of similarity of the image data of the laser spot LS4 of all the laser spots LS1 to LS6 is largest. As a first mode of the deciding step, the formed position of the laser spot LS4 having the largest degree of similarity is directly decided as the just focus position.

As a second mode of the deciding step, an approximation curve AC (see FIG. 5) for the degree of similarity is prepared from the relation between the formed position (defocus amount) of each laser spot LS and the sharpness of the outline of the image data of each laser spot LS (the degree of similarity of the image data to the reference data). By using the approximation curve AC, the formed position LS-V corresponding to the maximum degree of similarity is decided as the just focus position. By preparing such an approximation curve, any formed position of the laser spot not imaged in the

imaging step can be set as the just focus position. That is, it is possible to realize higher-precision just focus determination.

After performing the deciding step, the control means 60 sets the focal position of the laser beam according to this just focus position decided above. Thereafter, this detecting method is completed. According to the focal position detected (corrected) above, the vertical position of the laser beam applying means 4 in the Z direction is controlled to perform the wafer processing method for laser-processing the wafer W.

As described above, the laser spot formed position as the just focus position can be decided by the control means 60 according to the result of imaging of the laser spots LS in the above detecting method according to this preferred embodiment. Accordingly, the visual inspection by an operator is not required. As a result, it is possible to prevent that the detection accuracy may become unstable according to a difference in skill of the operator. That is, the focal position of the laser beam can be detected accurately and stably. Further, the process time required for the determination can be reduced as compared with the case of the visual inspection by the operator, thereby making the detection

efficient.

Further, the laser spots LS can be detected by using the imaging means 50 for use in alignment for the wafer W. Accordingly, no additional sensor or imaging equipment for the detection of the laser spots LS is required, so that the configuration of the apparatus 1 can be simplified.

As a modification, a threshold value may be set for the determination of the degree of similarity to the reference data in the deciding step. In the case in which for all the image data of the plural laser spots LS obtained in the imaging step and the extracting step, the degree of similarity of each image data to the reference data as calculated in the calculating step is lower than the threshold value (i.e., the degree of similarity is too low), there is a possibility that any error has occurred in the laser application by the laser beam applying means 4 or in the holding condition of the test wafer TS, causing improper formation of the laser spots. In this case, the control means 60 may suspend the decision of the just focus position in the deciding step and may notify the operator of such an error condition by using any alarm means (not illustrated) such as display and sound.

Further, the present invention is not limited to the above preferred embodiment and modification mentioned above, but various other modifications, replacements, and changes may be made within the scope of the present invention. Further, if the technical idea of the present invention can be realized by any other methods using any technical progress or derivative techniques, the present invention may be embodied by using these methods. Accordingly, the present invention claimed herein is intended to cover all embodiments that may fall within the scope of the present invention.

In the above preferred embodiment, the degree of similarity of the shape of each laser spot LS to the ideal shape of the laser spot is calculated by using pattern matching in the calculating step. However, the calculating method for the degree of similarity in shape between two laser spots is not especially limited, but various other methods may be adopted as far as the degree of correlation between two laser spots can be calculated.

Further, while the imaging means 50 is used in common for the detection of the laser spots LS and the alignment for the wafer W in the above preferred embodiment, imaging means dedicated to the detection of the laser spots LS and imaging means dedicated to the

alignment for the wafer W may be separately provided.

As described above, the present invention has an effect that the focal position of the laser beam can be determined easily and reliably. In particular, the present invention is useful in applying a laser beam to a workpiece to form laser spots and thereby process the workpiece.

The present invention is not limited to the details of the above described preferred embodiment. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the equivalence of the scope of the claims are therefore to be embraced by the invention.

WHAT IS CLAIMED IS:

1. A focal position detecting method in a laser processing apparatus including holding means having a workpiece holding surface for holding a workpiece, laser beam applying means having focusing means applying a laser beam to an upper surface of the workpiece held on the workpiece holding surface of the holding means to thereby form a focal point, focal position adjusting means moving the focal point of the laser beam to be formed by the focusing means in a direction perpendicular to the workpiece holding surface of the holding means, feeding means relatively moving the holding means and the laser beam applying means in a feeding direction, imaging means imaging the upper surface of the workpiece held on the workpiece holding surface of the holding means, control means, and storage means,

the focal position detecting method for detecting a focal position of the laser beam to be applied by the laser beam applying means, comprising:

a test wafer mounting step of mounting a test wafer having a flat upper surface and a flat lower surface on the workpiece holding surface of the holding means;

a laser spot forming step of changing the focal position of the laser beam plural times in a

predetermined range in a vertical direction with respect to the upper surface of the test wafer after performing the test wafer mounting step, and next continuously applying a pulsed laser beam having an absorption wavelength to the test wafer to thereby form a plurality of laser spots at different vertical positions in the predetermined range such that a spacing is defined between any adjacent ones of the laser spots in the feeding direction; and

a just focus position deciding step including substeps of imaging the plurality of laser spots formed at the different vertical positions by using the imaging means after performing the laser spot forming step, next extracting a shape of each laser spot from an image obtained by the imaging means, next calculating a degree of similarity of the shape of each laser spot to an ideal laser spot shape previously stored in the storage means, and next deciding the focal position corresponding to a largest value for the degree of similarity as a just focus position, the substeps of extracting, calculating, and deciding being performed by the control means.

2. The focal position detecting method according to claim 1, wherein the just focus position deciding step includes substeps of preparing an approximation curve for

the degree of similarity of the shape of each laser spot and next deciding the focal position corresponding to a maximum value for the degree of similarity on the approximation curve as the just focus position.