

LASER PROCESSING METHOD FOR WORKPIECE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a laser processing method for a workpiece.

Description of the Related Art

As a method for forming chips by dividing a plate-shaped workpiece such as a semiconductor wafer, a method is known which forms a modified layer by condensing and applying a laser beam transmissible through the workpiece to the inside of the workpiece and divides the workpiece by applying an external force to the workpiece (see Japanese Patent No. 3408805, for example).

In such a processing method, when the modified layer is formed along a street formed on the workpiece, the workpiece slightly expands in a direction orthogonal to a direction in which the street extends. As a result, a cumulative positional displacement occurs in positional relation between the condensing point of the laser beam and the street. Thus, alignment work for correcting this positional displacement needs to be performed in the middle of processing. Productivity is thus decreased.

In order to solve this problem, a laser processing

method has been proposed which utilizes a phenomenon in which the workpiece expands toward a relatively small area when a modified layer or a laser-processed groove is formed along a street and which processes a central region having a largest area last (see Japanese Patent Laid-Open No. 2008-60164). With use of this method, correction (alignment work) for a positional displacement caused by the expansion of the workpiece can be reduced.

SUMMARY OF THE INVENTION

However, with recent miniaturization of chips, an effect of compressive stress on an unprocessed region which is applied from an already processed region has become significant. That is, when a method of performing processing from the outside toward the center of the workpiece as in Japanese Patent Laid-Open No. 2008-60164 is used, streets in the unprocessed region may be curved due to disturbance of symmetry between the already processed region and the unprocessed region, so that devices may be damaged during the processing. In addition, the compressive stress applied to the central region of the workpiece hinders formation of the modified layer, so that non-division tends to occur in the central region of the workpiece.

Accordingly, it is an object of the present invention to provide a laser processing method for a workpiece which can suppress damage to devices due to curving of streets and non-division of the workpiece.

In accordance with an aspect of the present invention, there is provided a laser processing method for a workpiece. In the laser processing method, laser processing is performed on a workpiece having a plurality of streets set on a top surface of the workpiece along the streets by using a laser processing apparatus. The laser processing apparatus includes a chuck table configured to hold the workpiece under suction, a laser beam irradiating unit including a condenser configured to irradiate the workpiece held on the chuck table with a laser beam, a processing feed unit configured to move the chuck table and the laser beam irradiating unit relative to each other in a processing feed direction, an indexing feed unit configured to move the chuck table and the laser beam irradiating unit relative to each other in an indexing feed direction, and a control unit configured to control each of the units. The laser processing method including a protective member affixing step, a suction holding step, a positioning step, a first laser processing step, and a second laser processing step. In

the protective member affixing step, a protective member is affixed to the top surface or an undersurface of the workpiece. In the suction holding step, the workpiece is held through the protective member under suction on the chuck table. In the positioning step, the workpiece is positioned such that a direction in which the streets extend is in parallel with the processing feed direction. In the first laser processing step, after the positioning step is performed, a condensing point of the laser beam is positioned at an unprocessed and outermost street among a plurality of streets set in one half region ranging from one edge to a center of the workpiece in the indexing feed direction, a processing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the processing feed direction and an indexing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the indexing feed direction orthogonal to the processing feed direction are sequentially repeated, and the laser processing is performed on a predetermined number of streets inward from the unprocessed and outermost street among the plurality of streets set in the one half region. In the second laser processing step, after the first laser processing step is performed, the

condensing point of the laser beam is positioned at an unprocessed and outermost street among a plurality of streets set in another half region ranging from another edge to the center of the workpiece in the indexing feed direction, the processing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the processing feed direction and the indexing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the indexing feed direction orthogonal to the processing feed direction are sequentially repeated, and the laser processing is performed on a predetermined number of streets inward from the unprocessed and outermost street among the plurality of streets set in the other half region. The laser processing is performed on all of the streets set on the workpiece by alternately repeating the first laser processing step and the second laser processing step.

Preferably, the laser processing method for a workpiece further includes a suction hold releasing step and a re-suction holding step. In the suction hold releasing step, compressive stress generated in the workpiece is released by releasing suction hold of the workpiece on the chuck table after the first laser

processing step and the second laser processing step are performed. In the re-suction holding step, the workpiece is held under suction on the chuck table again after the suction hold releasing step is performed.

The invention of the present application can suppress damage to devices due to curving of the streets and non-division of the workpiece.

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 some preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating an example of a configuration of a laser processing apparatus according to an embodiment;

FIG. 2 is a flowchart illustrating a flow of a laser processing method according to the embodiment;

FIG. 3 is a perspective view illustrating an example of a protective member affixing step illustrated in FIG. 2;

FIG. 4 is a side view illustrating one state in which a first laser processing step illustrated in FIG. 2 is performed;

FIG. 5 is a plan view of a workpiece in FIG. 4;

FIG. 6 is a side view illustrating a state in which the first laser processing step illustrated in FIG. 2 has been performed;

FIG. 7 is a plan view of the workpiece in FIG. 6;

FIG. 8 is a plan view of the workpiece in one state in which a second laser processing step illustrated in FIG. 2 is performed;

FIG. 9 is a plan view of the workpiece in a state in which the second laser processing step illustrated in FIG. 2 has been performed;

FIG. 10 is a diagram illustrating a distribution of compressive stress in a section of the workpiece that is yet to be subjected to a suction hold releasing step illustrated in FIG. 2;

FIG. 11 is a diagram illustrating a distribution of compressive stress in the section of the workpiece that has been subjected to the suction hold releasing step illustrated in FIG. 2;

FIG. 12 is a plan view of the workpiece in one state in which the first laser processing step is

performed after a re-suction holding step illustrated in FIG. 2;

FIG. 13 is a plan view of the workpiece in one state in which the second laser processing step is performed after the re-suction holding step illustrated in FIG. 2;

FIG. 14 is a plan view of the workpiece in a state in which the second laser processing step has been performed after the re-suction holding step illustrated in FIG. 2;

FIG. 15 is a plan view of a dummy wafer for schematically illustrating a laser processing method according to a first comparative example;

FIG. 16 is a diagram illustrating a curved state of the dummy wafer illustrated in FIG. 15;

FIG. 17 is a plan view of a dummy wafer for schematically illustrating a laser processing method according to a second comparative example;

FIG. 18 is a diagram illustrating a curved state of the dummy wafer illustrated in FIG. 17;

FIG. 19 is a plan view of a dummy wafer for schematically illustrating the laser processing method according to the embodiment; and

FIG. 20 is a diagram illustrating a curved state of

the dummy wafer illustrated in FIG. 19.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will hereinafter be described in detail with reference to the drawings. The present invention is not limited by contents described in the following embodiment. In addition, constituent elements described in the following include constituent elements that are readily conceivable by those skilled in the art and that are essentially identical constituent elements. Further, configurations described in the following can be combined with each other as appropriate. In addition, various omissions, replacements, or modifications of configurations can be performed without departing from the spirit of the present invention.

A configuration of a laser processing apparatus 1 used in a laser processing method according to an embodiment of the present invention will first be described with reference to the drawings. FIG. 1 is a perspective view illustrating an example of the configuration of the laser processing apparatus 1 according to the embodiment. In the following description, X-axis directions extend in a horizontal

plane. Y-axis directions are orthogonal to the X-axis directions in the horizontal plane. Z-axis directions are orthogonal to the X-axis directions and the Y-axis directions. In the laser processing apparatus 1 according to the embodiment, processing feed directions are the X-axis directions, and indexing feed directions are the Y-axis directions.

As illustrated in FIG. 1, the laser processing apparatus 1 includes a chuck table 10, a laser beam irradiating unit 20, a processing feed unit 40, an indexing feed unit 50, a condensing point position adjusting unit 60, an imaging unit 70, a display unit 80, and a control unit 90. The laser processing apparatus 1 according to the embodiment is an apparatus that processes a workpiece 100 by irradiating the workpiece 100 held on the chuck table 10 with a laser beam 21 by the laser beam irradiating unit 20. The processing of the workpiece 100 by the laser processing apparatus 1 is, for example, modified layer formation processing of forming a modified layer within the workpiece 100 by stealth dicing.

The workpiece 100 is a wafer such as a semiconductor device wafer or an optical device wafer in a disk shape which has silicon (Si), sapphire (Al_2O_3),

gallium arsenide (GaAs), silicon carbide (SiC), or the like as a substrate 101 (see FIG. 3). It is to be noted that the workpiece 100 is not limited to the embodiment. The workpiece 100 in the present invention may not be in a disk shape. The workpiece 100 in the embodiment is held on the chuck table 10 in a state of being supported by a protective member 110 and an annular frame 111.

The chuck table 10 has a holding surface 11 and holds the workpiece 100 on the holding surface 11. The holding surface 11 has a disk shape and is formed of a porous ceramic or the like. The holding surface 11 in the embodiment is a flat surface parallel with a horizontal direction. The holding surface 11 is, for example, connected to a vacuum suction source via a vacuum suction path. The chuck table 10 holds, under suction, the workpiece 100 mounted on the holding surface 11. A plurality of clamp units 12 that sandwich the frame 111 supporting the workpiece 100 are arranged on the periphery of the chuck table 10.

A rotating unit 13 rotates the chuck table 10 about an axis parallel with the Z-axis directions. The rotating unit 13 is supported by an X-axis direction moving plate 14. The rotating unit 13 and the chuck table 10 are moved in the X-axis directions by the processing feed unit 40

via the X-axis direction moving plate 14. The rotating unit 13 and the chuck table 10 are moved in the Y-axis directions by the indexing feed unit 50 via the X-axis direction moving plate 14, the processing feed unit 40, and a Y-axis direction moving plate 15.

The laser beam irradiating unit 20 is a unit that irradiates the workpiece 100 held on the chuck table 10 with a pulsed laser beam 21. The laser beam irradiating unit 20 includes at least a condenser that condenses and applies the laser beam 21 to the workpiece 100 held on the chuck table 10.

The processing feed unit 40 is a unit that moves the chuck table 10 and the laser beam irradiating unit 20 relative to each other in the X-axis directions as the processing feed directions. The processing feed unit 40 in the embodiment moves the chuck table 10 in the X-axis directions. The processing feed unit 40 in the embodiment is installed on an apparatus main body 2 of the laser processing apparatus 1.

The processing feed unit 40 supports the X-axis direction moving plate 14 movably in the X-axis directions. The processing feed unit 40 includes a well-known ball screw 41, a well-known pulse motor 42, and well-known guide rails 43. The ball screw 41 is provided

so as to be rotatable about an axis. The pulse motor 42 rotates the ball screw 41 about the axis. The guide rails 43 support the X-axis direction moving plate 14 movably in the X-axis directions. The guide rails 43 are provided in a state of being fixed to the Y-axis direction moving plate 15.

The indexing feed unit 50 is a unit that moves the chuck table 10 and the laser beam irradiating unit 20 relative to each other in the Y-axis directions as the indexing feed directions. The indexing feed unit 50 in the embodiment moves the chuck table 10 in the Y-axis directions. The indexing feed unit 50 in the embodiment is installed on the apparatus main body 2 of the laser processing apparatus 1.

The indexing feed unit 50 supports the Y-axis direction moving plate 15 movably in the Y-axis directions. The indexing feed unit 50 includes a well-known ball screw 51, a well-known pulse motor 52, and well-known guide rails 53. The ball screw 51 is provided so as to be rotatable about an axis. The pulse motor 52 rotates the ball screw 51 about the axis. The guide rails 53 support the Y-axis direction moving plate 15 movably in the Y-axis directions. The guide rails 53 are provided in a state of being fixed to the apparatus main body 2.

The condensing point position adjusting unit 60 is a unit that moves a condensing point 22 of the laser beam 21 condensed by the condenser of the laser beam irradiating unit 20, in an optical axis direction perpendicular to the holding surface 11 of the chuck table 10. More specifically, the condensing point position adjusting unit 60 moves the chuck table 10 and the laser beam irradiating unit 20 relative to each other in the Z-axis directions as condensing point position adjustment directions. The condensing point position adjusting unit 60 in the embodiment moves the condenser of the laser beam irradiating unit 20 in the Z-axis directions. The condensing point position adjusting unit 60 in the embodiment is installed on a column 3 erected from the apparatus main body 2 of the laser processing apparatus 1.

The condensing point position adjusting unit 60 supports at least the condenser of the laser beam irradiating unit 20 movably in the Z-axis directions. The condensing point position adjusting unit 60 includes a well-known ball screw 61, a well-known pulse motor 62, and well-known guide rails 63. The ball screw 61 is provided so as to be rotatable about an axis. The pulse motor 62 rotates the ball screw 61 about the axis. The

guide rails 63 support the laser beam irradiating unit 20 movably in the Z-axis directions. The guide rails 63 are provided in a state of being fixed to the column 3.

The imaging unit 70 is, for example, disposed so as to image a region below the condenser of the laser beam irradiating unit 20 from directly above the condenser. The imaging unit 70 includes a coaxial camera, a charge coupled device (CCD) camera, or an infrared camera.

The display unit 80 is a display unit including a liquid crystal display device or the like. The display unit 80 includes a display surface that displays an image captured by the imaging unit 70, a processing condition setting screen, the state of processing operation, and the like. In a case where the display surface includes a touch panel, the display unit 80 may include an input unit. The input unit can receive various kinds of operations such as a registration operation performed by an operator to register information regarding processing details. The input unit may be an external input device such as a keyboard. The information or the image displayed on the display surface of the display unit 80 is changed by an operation from the input unit or the like. The display unit 80 may include a notifying unit. The notifying unit notifies predetermined notification

information to the operator of the laser processing apparatus 1 by emitting at least either sound or light. The notifying unit may be an external notifying device such as a speaker or a light emitting device.

The control unit 90 makes the laser processing apparatus 1 perform processing operation on the workpiece 100 by controlling each of the above-described constituent elements of the laser processing apparatus 1. The control unit 90 controls the chuck table 10, the laser beam irradiating unit 20, the processing feed unit 40, the indexing feed unit 50, the condensing point position adjusting unit 60, the imaging unit 70, and the display unit 80.

The control unit 90 is a computer including an arithmetic processing device as arithmetic means, a storage device as storing means, and an input-output interface device as communicating means. The arithmetic processing device includes, for example, a microprocessor such as a central processing unit (CPU). The storage device has a memory such as a read only memory (ROM) or a random access memory (RAM). The arithmetic processing device performs various kinds of operation on the basis of a predetermined program stored in the storage device. The arithmetic processing device controls the laser

processing apparatus 1 by outputting various kinds of control signals to the above-described constituent elements via the input-output interface device according to a result of the operation.

A laser processing method for the workpiece 100 according to the embodiment will next be described. FIG. 2 is a flowchart illustrating a flow of the laser processing method according to the embodiment. The laser processing method for the workpiece 100 includes a protective member affixing step 201, a suction holding step 202, a positioning step 203, a first laser processing step 204, a second laser processing step 205, a suction hold releasing step 206, an end determining step 207, and a re-suction holding step 208.

(Protective Member Affixing Step 201)

FIG. 3 is a perspective view illustrating an example of the protective member affixing step 201 illustrated in FIG. 2. The protective member affixing step 201 is a step of affixing the protective member 110 to a top surface 102 or an undersurface 105 of the workpiece 100. In the protective member affixing step 201 of the embodiment, the protective member 110 is affixed to the undersurface 105 of the workpiece 100.

The workpiece 100 according to the embodiment will

first be described in more detail. As illustrated in FIG. 3, the workpiece 100 has streets 103 set in a lattice manner on the top surface 102 of the substrate 101 and devices 104 formed in regions demarcated by the streets 103. The device 104 is, for example, an integrated circuit such as an integrated circuit (IC) or a large scale integrated (LSI) circuit, or an image sensor such as a CCD image sensor or a complementary metal oxide semiconductor (CMOS) image sensor.

In the embodiment, a modified layer 120 (see FIG. 6) is formed along the street 103 of the workpiece 100. The workpiece 100 is divided into the individual devices 104 along modified layers 120 formed in the streets 103, and is thus separated into individual chips. Incidentally, the workpiece 100 according to the embodiment has an outside diameter of 8 inches and a thickness of 100 μm . In addition, while the chips in the embodiment have a square shape, the chips in the present invention may have a rectangular shape.

In the protective member affixing step 201, first, the protective member 110 is affixed to an undersurface of the frame 111. The frame 111 has an opening larger than the outside diameter of the workpiece 100. Next, the workpiece 100 is positioned at a predetermined position

in the opening of the frame 111, and the undersurface 105 is affixed to the protective member 110. The workpiece 100 is thus fixed to the protective member 110 and the frame 111.

The protective member 110 includes, for example, a base material layer formed of a synthetic resin and a glue layer laminated to the base material layer and formed of an adhesive synthetic resin. The protective member 110 may have expandability. In this case, by expanding the protective member 110 in a surface direction after forming the modified layers 120 (see FIG. 6) along the streets 103 in the workpiece 100, it is possible to impart an external force to the workpiece 100 and divide the workpiece 100 into the individual chips. (Suction Holding Step 202)

The suction holding step 202 is a step of holding the workpiece 100 through the protective member 110 under suction on the chuck table 10. In the suction holding step 202 according to the embodiment, first, the undersurface 105 of the workpiece 100 is held on the holding surface 11 of the chuck table 10 of the laser processing apparatus 1 illustrated in FIG. 1 via the protective member 110. Next, the frame 111 supporting the workpiece 100 is sandwiched by the clamp units 12. Next,

the vacuum suction source connected to the holding surface 11 via the vacuum suction path activates a negative pressure to hold, under suction, the workpiece 100 mounted on the holding surface 11.

(Positioning Step 203)

The positioning step 203 is a step of performing positioning such that a direction in which a street 103 extends becomes parallel with the processing feed direction (X-axis direction). Here, the street 103 to be made parallel with the processing feed direction is a street 103 in which to form a modified layer 120 by the processing method according to the embodiment among the plurality of lattice-shaped streets 103 set on the top surface 102 of the workpiece 100. In the embodiment, alignment of the direction in which the street 103 extends is performed by rotating the chuck table 10 about an axis in a vertical direction by the rotating unit 13. When the positioning step 203 is completed, the processing proceeds to the first laser processing step 204.

(First Laser Processing Step 204)

FIG. 4 is a side view illustrating one state in which the first laser processing step 204 illustrated in FIG. 2 is performed. FIG. 5 is a plan view of the

workpiece 100 in FIG. 4. FIG. 6 is a side view illustrating a state in which the first laser processing step 204 illustrated in FIG. 2 has been performed. FIG. 7 is a plan view of the workpiece 100 in FIG. 6.

The first laser processing step 204 is performed after the positioning step 203 is performed. The first laser processing step 204 is a step of performing laser processing on a predetermined number of streets 103 parallel with the processing feed direction. This laser processing is performed toward one of the indexing feed directions. In the first laser processing step 204 according to the embodiment, modified layers 120 are formed in a predetermined number of streets 103 parallel with the processing feed direction, and this formation of the modified layers 120 is performed toward the one of the indexing feed directions.

The modified layer 120 refers to a region in which density, a refractive index, mechanical strength, or another physical property is different from that of surroundings. The modified layer 120 is, for example, a melted region, a crack region, a dielectric breakdown region, a refractive index changed region, a region in which these regions are mixed, and the like. The mechanical strength or the like of the modified layer 120

is lower than that of other parts of the workpiece 100.

In the first laser processing step 204, first, the streets 103 are detected by imaging the workpiece 100 by the imaging unit 70. After the streets 103 are detected, as illustrated in FIG. 5, alignment is carried out to position the condensing point 22 of the laser beam 21 at a street 103-1 of the workpiece 100. The street 103-1 is an unprocessed and outermost street 103-1 among a plurality of streets 103 set in one half region 106 of the workpiece 100. The one half region 106 ranges from one edge (upper end in FIG. 5) to a center of the workpiece 100 in the indexing feed direction (Y-axis direction).

In the first laser processing step 204, next, as illustrated in FIG. 6, the pulsed laser beam 21 is condensed and applied from the laser beam irradiating unit 20 to the inside of the workpiece 100. The laser beam 21 is a laser beam of a wavelength transmissible through the workpiece 100.

Next, a processing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the processing feed direction and an indexing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each

other in the indexing feed direction orthogonal to the processing feed direction are repeated sequentially. That is, the laser beam 21 is applied to a part corresponding to a predetermined number of streets 103-2 (see FIG. 7) inward (lower side in FIG. 5) from the street 103-1 of the workpiece 100 while the chuck table 10 is moved relative to the laser beam irradiating unit 20.

In such a manner, laser processing is performed on the predetermined number of streets 103-2 inward from the unprocessed and outermost street 103-1 among the plurality of streets 103 set in the one half region 106 ranging from the one edge to the center of the workpiece 100 in the indexing feed direction. As a result, as illustrated in FIG. 7, the modified layers 120 are formed. When the first laser processing step 204 is completed, the processing proceeds to the second laser processing step 205.

(Second Laser Processing Step 205)

FIG. 8 is a plan view of the workpiece 100 in one state in which the second laser processing step 205 illustrated in FIG. 2 is performed. FIG. 9 is a plan view of the workpiece 100 in a state in which the second laser processing step 205 illustrated in FIG. 2 has been performed.

The second laser processing step 205 is performed after the first laser processing step 204 is performed. The second laser processing step 205 is a step of performing laser processing on a predetermined number of streets 103 parallel with the processing feed direction. This laser processing is performed toward the other indexing feed direction. In the second laser processing step 205 according to the embodiment, modified layers 120 are formed in a predetermined number of streets 103 parallel with the processing feed direction, and this formation of the modified layers 120 is performed toward the other indexing feed direction.

In the second laser processing step 205, first, as illustrated in FIG. 8, alignment is carried out to position the condensing point 22 of the laser beam 21 at a street 103-3 of the workpiece 100. The street 103-3 is an unprocessed and outermost street 103-3 among a plurality of streets 103 set in another half region 107 of the workpiece 100. The other half region 107 ranges from another edge (lower end in FIG. 5) to the center of the workpiece 100 in the indexing feed direction (Y-axis direction).

In the second laser processing step 205, next, the pulsed laser beam 21 is condensed and applied from the

laser beam irradiating unit 20 to the inside of the workpiece 100 (see FIG. 6 and the like). Next, the processing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the processing feed direction and the indexing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the indexing feed direction orthogonal to the processing feed direction are repeated sequentially. That is, the laser beam 21 is applied to a part corresponding to a predetermined number of streets 103-4 (see FIG. 9) inward (upper side in FIG. 8) from the street 103-3 of the workpiece 100 while the chuck table 10 is moved relative to the laser beam irradiating unit 20.

In such a manner, laser processing is performed on the predetermined number of streets 103-4 inward from the unprocessed and outermost street 103-3 among the plurality of streets 103 set in the other half region 107 ranging from the other edge to the center of the workpiece 100 in the indexing feed direction. As a result, as illustrated in FIG. 9, the modified layers 120 are formed. Incidentally, the number of streets 103 on which the laser processing is performed in the second laser processing step 205 is preferably the same as the

number of streets 103 on which the laser processing is performed in the first laser processing step 204. When the second laser processing step 205 is completed, the processing proceeds to the suction hold releasing step 206.

(Suction Hold Releasing Step 206)

FIG. 10 is a diagram illustrating a distribution of compressive stress in a section of the workpiece 100 that is yet to be subjected to the suction hold releasing step 206 illustrated in FIG. 2. FIG. 11 is a diagram illustrating a distribution of compressive stress in the section of the workpiece 100 that has been subjected to the suction hold releasing step 206 illustrated in FIG. 2. The suction hold releasing step 206 is performed after the first laser processing step 204 and the second laser processing step 205 are performed. The suction hold releasing step 206 is a step of releasing the suction hold of the workpiece 100 on the chuck table 10, and thereby releasing the compressive stress generated in the workpiece 100.

Since the modified layers 120 are formed in the streets 103-2 and 103-4 in the first laser processing step 204 and the second laser processing step 205, the workpiece 100 expands in the indexing feed directions (Y-

axis directions). Consequently, as illustrated in FIG. 10, the compressive stress is increased in a central region 101-1 of the substrate 101 in which no modified layers 120 are formed in the streets 103.

In the suction hold releasing step 206, the suction hold of the workpiece 100 mounted on the holding surface 11 is released by controlling the vacuum suction source connected to the holding surface 11 of the chuck table 10. As illustrated in FIG. 11, this releases the compressive stress generated in the central region 101-1 of the substrate 101 in which no modified layers 120 are formed in the streets 103. When the suction hold releasing step 206 is completed, the processing proceeds to the end determining step 207.

(End determining step 207)

The end determining step 207 is a step of determining whether or not to end the processing method according to the embodiment, which is illustrated in the flowchart of FIG. 2. Specifically, it is determined whether or not the modified layers 120 have been formed in all of the streets 103 in which to form the modified layers 120 by the processing method according to the embodiment. When the modified layers 120 are formed in all of the streets 103, the processing of the flowchart

illustrated in FIG. 2 is ended. When there still remain streets 103 in which the modified layers 120 are not formed in a central portion of the workpiece 100, the processing proceeds to the re-suction holding step 208. (Re-Suction Holding Step 208)

The re-suction holding step 208 is performed after the suction hold releasing step 206 if there still remain streets 103 in which the modified layers 120 are not formed in the central portion of the workpiece 100. The re-suction holding step 208 is a step of holding the workpiece 100 under suction on the chuck table 10 again.

In the re-suction holding step 208, the vacuum suction source connected to the holding surface 11 of the chuck table 10 via the vacuum suction path activates a negative pressure to hold, under suction, the workpiece 100 mounted on the holding surface 11 again. When the re-suction holding step 208 is completed, the method returns to the first laser processing step 204. Incidentally, although the clamp units 12 sandwich the frame 111 supporting the workpiece 100 in the embodiment, when the workpiece 100 is displaced in a horizontal direction with respect to the chuck table 10 in the suction hold releasing step 206, the processing returns to the positioning step 203, and positioning is performed again.

In a case where the vacuum suction path of the chuck table 10 is divided for each of a plurality of regions of the holding surface 11, for example, the holding surface 11 can be sucked in each region. Specifically, only in regions of the chuck table 10 which correspond to the regions in which the laser processing has been performed in the first laser processing step 204 and the second laser processing step 205, the suction hold may be released in the suction hold releasing step 206, and the suction hold may be performed again in the re-suction holding step 208. According to such a method, the suction hold of a region including unprocessed streets 103 is maintained, and the displacement in the horizontal direction is suppressed, so that an alignment operation for correcting the positional displacement can be omitted.

(First Laser Processing Step 204 after Re-Suction Holding Step 208)

FIG. 12 is a plan view of the workpiece 100 in one state in which the first laser processing step 204 is performed after the re-suction holding step 208 illustrated in FIG. 2.

In the first laser processing step 204 after the re-suction holding step 208, first, as illustrated in

FIG. 12, alignment is carried out to position the condensing point 22 of the laser beam 21 at a street 103-5 of the workpiece 100. The street 103-5 is an unprocessed and outermost street 103-5 among the plurality of streets 103 set in the one half region 106 of the workpiece 100. That is, the street 103-5 is a street 103-5 immediately inward of the streets 103-2 processed in the previous first laser processing step 204.

In the first laser processing step 204 after the re-suction holding step 208, next, as in the previous first laser processing step 204, the pulsed laser beam 21 is condensed and applied from the laser beam irradiating unit 20 to the inside of the workpiece 100. Next, the processing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the processing feed direction and the indexing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the indexing feed direction orthogonal to the processing feed direction are repeated sequentially. That is, the laser beam 21 is applied to a part corresponding to a predetermined number of streets 103-6 (see FIG. 13) inward (lower side in FIG. 12) from the street 103-5 of

the workpiece 100 while the chuck table 10 is moved relative to the laser beam irradiating unit 20.

In such a manner, laser processing is performed on the predetermined number of streets 103-6 inward from the unprocessed and outermost street 103-5 among the plurality of streets 103 set in the one half region 106. As a result, the modified layers 120 are formed (see FIG. 13). When the first laser processing step 204 is completed, the processing proceeds to the second laser processing step 205.

(Second Laser Processing Step 205 after Re-Suction Holding Step 208)

FIG. 13 is a plan view of the workpiece 100 in one state in which the second laser processing step 205 is performed after the re-suction holding step 208 illustrated in FIG. 2. FIG. 14 is a plan view of the workpiece 100 in a state in which the second laser processing step 205 has been performed after the re-suction holding step 208 illustrated in FIG. 2.

In the second laser processing step 205 after the re-suction holding step 208, first, as illustrated in FIG. 13, alignment is carried out to position the condensing point 22 of the laser beam 21 at a street 103-7 of the workpiece 100. The street 103-7 is an

unprocessed and outermost street 103-7 among the plurality of streets 103 set in the other half region 107 of the workpiece 100. That is, the street 103-7 is a street 103-7 immediately inward of the streets 103-4 processed in the previous second laser processing step 205.

In the second laser processing step 205 after the re-suction holding step 208, next, as in the previous second laser processing step 205, the pulsed laser beam 21 is condensed and applied from the laser beam irradiating unit 20 to the inside of the workpiece 100. Next, the processing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the processing feed direction and the indexing feed that moves the workpiece 100 and the condensing point 22 of the laser beam 21 relative to each other in the indexing feed direction orthogonal to the processing feed direction are repeated sequentially. That is, the laser beam 21 is applied to a part corresponding to a predetermined number of streets 103-8 inward (upper side in FIG. 13) from the street 103-7 of the workpiece 100 while the chuck table 10 is moved relative to the laser beam irradiating unit 20.

In such a manner, laser processing is performed on

the predetermined number of streets 103-8 inward from the unprocessed and outermost street 103-7 among the plurality of streets 103 set in the other half region 107. As a result, as illustrated in FIG. 14, the modified layers 120 are formed. When the second laser processing step 205 is completed, the processing proceeds to the suction hold releasing step 206 again.

Thus, in the method of processing the workpiece 100 according to the embodiment, the laser processing is performed on all of the streets 103 set on the workpiece 100, by alternately repeating the first laser processing step 204 and the second laser processing step 205. When it is determined in the end determining step 207 that the laser processing has been performed on all of the streets 103, the processing of the flowchart illustrated in FIG. 2 is ended.

As described above, in the laser processing method for the workpiece 100 according to the embodiment, processing from one end portion of the workpiece 100 (first laser processing step 204) and processing from the other end portion of the workpiece 100 (second laser processing step 205) are alternately performed. A balance (symmetry) of compressive stress generated from already processed streets 103 is thus maintained. Thus, curving

of the street 103 can be suppressed, and consequently, damage to the devices 104 can be suppressed. In addition, displacement of streets 103 in an unprocessed region in one direction can be suppressed. An effect is thus produced in that alignment work for correcting the positional displacement can be omitted or that the frequency of the alignment work can be reduced.

In addition, the compressive stress applied to the central region 101-1 of the workpiece 100 may be released by releasing the suction hold of the workpiece 100 on the chuck table 10 after a predetermined number of streets 103 of the workpiece 100 are processed. This can remove the compressive stress that hinders the formation of the modified layers 120. Thus, the chips can be prevented from being undivided when the chips are to be divided.

Conventionally, work that assists in dividing the workpiece is performed by pressing an undivided region by a squeegee or the like in order to divide the undivided region. However, this work can be omitted by suppressing the non-division. Thus, a reduction in the number of man-hours and space saving can be realized, and the occurrence of particles when the pressing is performed by the squeegee can also be suppressed.

Effects of the embodiment will next be examined.

FIG. 15 is a plan view of a dummy wafer 300 for schematically illustrating a laser processing method according to a first comparative example. FIG. 16 is a diagram illustrating a curved state of the dummy wafer 300 illustrated in FIG. 15. FIG. 17 is a plan view of a dummy wafer 300 for schematically illustrating a laser processing method according to a second comparative example. FIG. 18 is a diagram illustrating a curved state of the dummy wafer 300 illustrated in FIG. 17. FIG. 19 is a plan view of a dummy wafer 300 for schematically illustrating the laser processing method according to the embodiment. FIG. 20 is a diagram illustrating a curved state of the dummy wafer 300 illustrated in FIG. 19.

The inventors of the present invention performed laser processing on the dummy wafers 300 of the first comparative example, the second comparative example, and the present invention illustrated in FIG. 15, FIG. 17, and FIG. 19, and checked effects of the laser processing method according to the embodiment. The dummy wafer 300 is a wafer that does not have any devices (for example, the devices 104 of the workpiece 100 illustrated in FIG. 3) formed thereon, that is, a wafer that is formed by only a substrate 301. In an experiment, a dummy wafer 300 having an outside diameter of 8 inches and a thickness of

100 μm was used.

In addition, in the experiment, positions in the processing feed direction (X-axis direction) at a first position 400 and a second position 500 on a top surface of the dummy wafer 300 were each measured with respect to the Y-axis direction, and a curved state of the dummy wafer 300 was checked. The first position 400 is set within one half region 306 ranging from one edge (upper end in FIG. 15 and the like) toward a center of the dummy wafer 300 in the indexing feed direction (Y-axis direction) and is at 50 mm from the one edge toward the center of the dummy wafer 300 in the indexing feed direction. The first position 400 is indicated by a solid line in the figures. The second position 500 is set within another half region 307 ranging from another edge (lower end in FIG. 15 and the like) to the center of the dummy wafer 300 in the indexing feed direction (Y-axis direction) and is at 50 mm from the other edge toward the center of the dummy wafer 300 in the indexing feed direction. The second position 500 is indicated by alternate long and short dashed line in the figures.

In addition, in the graphs illustrated in FIG. 16, FIG. 18, and FIG. 20, an axis of abscissas indicates positions in the processing feed direction (X-axis

direction), and an axis of ordinates indicates positions in the Y-axis direction on the top surface of the dummy wafer 300. In addition, on the axis of ordinates, a position in the Y-axis direction on the top surface of the dummy wafer 300 that is yet to be subjected to laser processing is set to zero, and positions on the upper side of the position in which the laser processing is yet to be performed are indicated by positive numbers while positions on the lower side of the position are indicated by negative numbers.

FIG. 15 illustrates the laser processing method according to the first comparative example, and FIG. 16 illustrates the curved state of the dummy wafer 300 in the first comparative example. In the first comparative example, laser processing was performed, with index feeding set to 0.2 mm, from the other edge of the other half region 307 toward the one edge of the one half region 306 until the above-described first position 400.

FIG. 17 illustrates the laser processing method according to the second comparative example, and FIG. 18 illustrates the curved state of the dummy wafer 300 in the second comparative example. In the second comparative example, laser processing was performed, with index feeding set to 0.2 mm, from the one edge of the one half

region 306 to the above-described first position 400, and thereafter, laser processing was performed, with index feeding set to 0.2 mm, from the other edge of the other half region 107 to the center of the dummy wafer 300.

FIG. 19 illustrates the laser processing method according to the embodiment, and FIG. 20 illustrates the curved state of the dummy wafer 300 in the embodiment. In the example of the embodiment, the first laser processing step 204 in which laser processing was performed, with index feeding set to 0.2 mm, from the one edge of the one half region 306 toward the center of the dummy wafer 300 and the second laser processing step 205 in which laser processing was performed, with index feeding set to 0.2 mm, from the other edge of the other half region 307 toward the center of the dummy wafer 300 were alternately repeated, and each step was performed five times. Thus, the laser processing of the laser processing method illustrated in the embodiment was performed to the first position 400 and the second position 500 described earlier.

In the first comparative example, regarding the curved state of the dummy wafer 300, as illustrated in FIG. 16, a maximum amount of curvature 401 at the first position 400 was approximately 12 μm , and a maximum

amount of curvature 501 at the second position 500 was approximately 4.5 μm . In the second comparative example, regarding the curved state of the dummy wafer 300, as illustrated in FIG. 18, a maximum amount of curvature 402 at the first position 400 was approximately 6 μm , and a maximum amount of curvature 502 at the second position 500 was approximately 3 μm .

In contrast to the first comparative example and the second comparative example, in the example of the embodiment, regarding the curved state of the dummy wafer 300, as illustrated in FIG. 20, a maximum amount of curvature 403 at the first position 400 was approximately 3 μm , and a maximum amount of curvature 503 at the second position 500 was approximately 3 μm .

Hence, as illustrated in FIG. 16, FIG. 18, and FIG. 20, an experiment result is obtained which indicates that the dummy wafer 300 processed by the processing method according to the embodiment has a smaller curve after the processing than the dummy wafers 300 processed by the processing methods according to the respective comparative examples. That is, it has become clear that curving of the streets 103 can be suppressed by alternately performing the processing from one end portion side of the workpiece 100 (first laser processing

step 204) and the processing from the other end portion side (second laser processing step 205), and that, as a result, damage to the devices 104 can be suppressed.

It is to be noted that the present invention is not limited to the foregoing embodiment. That is, the present invention can be modified and carried out in various manners without departing from the gist of the present invention. For example, the suction hold releasing step 206 and the re-suction holding step 208 may not necessarily be included. In addition, while the devices 104 of the workpiece 100, that is, the divided chips, have a square shape in drawings used in the description of the embodiment, the chips in the present invention may have a rectangular shape.

For example, the processing method according to the present invention may not be used for streets 103 for which an index amount in the indexing feed direction is large, but the processing method according to the present invention may be used for streets 103 for which an index amount in the indexing feed direction is small. For example, in a case where a chip size is $0.223 \text{ mm} \times 10 \text{ mm}$, the laser processing apparatus 1 may process the side of the chip having a large index of 10 mm without using the processing method according to the present invention on a

first channel, and process the side of the chip having a small index of 0.223 mm by using the processing method according to the present invention on a second channel.

In this case, when the first laser processing step 204 and the second laser processing step 205 in each of which the processing is performed at 12.5 mm, for example, from the end portion of the workpiece 100 and the suction hold releasing step 206 are repeatedly performed on the second channel, division into individual chips can be made by only expansion.

Incidentally, a division ratio is approximately 50% in a case where streets are subjected to processing from the one edge in the indexing feed direction toward the center until a predetermined position that is set on one edge side from the center and where remaining streets are then subjected to processing from the other edge toward the one edge. In addition, the division ratio is approximately 70% in a case where the first laser processing step 204 and the second laser processing step 205 in each of which the processing is performed at 50 mm and the suction hold releasing step 206 are repeatedly performed. In addition, the division ratio is approximately 75% in a case where the first laser processing step 204 and the second laser processing step

205 in each of which the processing is performed at 25 mm and the suction hold releasing step 206 are repeatedly performed.

In addition, the laser processing apparatus 1 may automatically determine, by the control unit 90, millimeters at which processing is performed in each of the first laser processing step 204 and the second laser processing step 205, that is, a timing of switching processing directions. The control unit 90 may, for example, obtain the position of a target set at the center of the workpiece 100 from the imaging unit 70 or the like, and perform control to switch the processing directions when the target is displaced by a predetermined amount (for example, 2 μm) or more.

The target set at the center of the workpiece 100 may be, for example, an element included in the pattern surface of the top surface 102 of the workpiece 100, or may be a grinding trace present on the undersurface 105, an element included in the top surface of the protective member 110, or the like. In a case where the target is facing the chuck table 10, the target is observed by using a visible light camera from below the workpiece 100. In a case where the surface opposite to the surface on which the target is set is facing the chuck table 10,

the target is observed by using an infrared (IR) camera from below the workpiece 100.

Incidentally, in the case where the surface opposite to the surface on which the target is set is facing the chuck table 10, the target may be imaged by using a visible light camera from above the workpiece 100. Imaging the target from above the workpiece 100 eliminates a need to add an imaging unit to image the target from below the workpiece 100, and can thus contribute to a reduction in cost.

On the other hand, imaging the target from below the workpiece 100 makes it possible to monitor for displacement of the target at all times while processing is performed, and thus obviates a need for a time to check for the displacement and contributes to an improvement in yield.

By automatically controlling the switching of the processing direction as described above, it is possible to determine a positional displacement of the workpiece 100 quantitatively, and switch the processing directions in an appropriate timing. Displacement of streets 103 in an unprocessed region in one direction can thus be suppressed. Thus, alignment work for correcting the positional displacement can be omitted, or the frequency

of the alignment work can be reduced.

In addition, a minimum correction distance in the Y-axis direction at which positional displacement can be suppressed can be calculated by the automatic control of the switching of the processing direction. It is thus possible to suppress a decrease in throughput due to an increase in movement processing in the Y-axis direction with switching of the processing direction.

Further, in a case where a plurality of workpieces 100 as wafers having the same thickness and the same chip size are processed one after another in a mass production process, an appropriate timing for switching the processing directions can be estimated to be substantially similar. Hence, data regarding a switching timing calculated at a time of processing of a first workpiece 100 may be applied to processing of a second and subsequent workpieces 100. This further contributes to shortening of a processing time.

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 laser processing method for a workpiece to perform laser processing on a workpiece having a plurality of streets set on a top surface of the workpiece along the streets by using a laser processing apparatus,

the laser processing apparatus including

a chuck table configured to hold the workpiece under suction,

a laser beam irradiating unit including a condenser configured to irradiate the workpiece held on the chuck table with a laser beam,

a processing feed unit configured to move the chuck table and the laser beam irradiating unit relative to each other in a processing feed direction,

an indexing feed unit configured to move the chuck table and the laser beam irradiating unit relative to each other in an indexing feed direction, and

a control unit configured to control each of the units,

the laser processing method comprising:

a protective member affixing step of affixing a protective member to the top surface or an undersurface of the workpiece;

a suction holding step of holding the workpiece through the protective member under suction on the chuck table;

a positioning step of positioning the workpiece such that a direction in which the streets extend is in parallel with the processing feed direction;

a first laser processing step of positioning, after the positioning step is performed, a condensing point of the laser beam at an unprocessed and outermost street among a plurality of streets set in one half region ranging from one edge to a center of the workpiece in the indexing feed direction,

sequentially repeating a processing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the processing feed direction and an indexing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the indexing feed direction orthogonal to the processing feed direction, and

performing the laser processing on a predetermined number of streets inward from the unprocessed and outermost street among the plurality of streets set in the one half region; and

a second laser processing step of

positioning, after the first laser processing step is performed, the condensing point of the laser beam at an unprocessed and outermost street among a plurality of streets set in another half region ranging from another edge to the center of the workpiece in the indexing feed direction,

sequentially repeating the processing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the processing feed direction and the indexing feed that moves the workpiece and the condensing point of the laser beam relative to each other in the indexing feed direction orthogonal to the processing feed direction, and

performing the laser processing on a predetermined number of streets inward from the unprocessed and outermost street among the plurality of streets set in the other half region,

a suction hold releasing step of releasing compressive stress generated in the workpiece, by releasing suction hold of the workpiece on the chuck table after the first laser processing step and the second laser processing step are performed;

a re-suction holding step of holding the workpiece under suction on the chuck table again after the suction

hold releasing step is performed; and

returning to the first laser processing step, when the re-suction holding step is completed, wherein

the laser processing is performed on all of the streets set on the workpiece by alternately repeating the first laser processing step, the second laser processing step, the suction hold releasing step, and the re-suction holding step.

2. The laser processing method for a workpiece according to claim 1, further comprising:

an end determining step, after the suction holding releasing step, of determining whether or not to end the laser processing.

3. The laser processing method for a workpiece according to claim 2, wherein

in the end determining step,

when determined that modified layers are formed in all of the streets, the laser processing ends; and

when there still remain streets in which the modified layers are not formed in a central portion of the workpiece, the re-suction holding step is performed after the suction hold releasing step.

4. The laser processing method for a workpiece

according to claim 1, wherein

the number of streets on which the laser processing is performed in the second laser processing step is the same as the number of streets on which the laser processing is performed in the first laser processing step.

5. The laser processing method for a workpiece according to claim 1, wherein

after the re-suction holding step, when the workpiece is displaced in a horizontal direction with respect to the chuck table in the suction hold releasing step, the positioning step is performed again.

6. The laser processing method for a workpiece according to any one of the preceding claims, wherein

a vacuum suction path of the chuck table is divided for each of a plurality of regions of a holding surface of the chuck table.

7. The laser processing method for a workpiece according to claim 6, wherein

only in the regions of the chuck table which correspond to regions in which the laser processing has been performed in the first laser processing step and the second laser processing step, the suction hold is released in the suction hold releasing step, and

the suction hold is performed again in the re-suction holding step.

8. The laser processing method for a workpiece according to any one of the preceding claims, wherein

the laser processing apparatus is configured to automatically determine, by the control unit, millimeters at which the processing is performed in each of the first laser processing step and the second laser processing step, that is, a timing of switching processing directions.

9. The laser processing method for a workpiece according to claim 8, wherein

the control unit is configured to obtain the position of a target set at the center of the workpiece from an imaging unit, and perform control to switch the processing directions when the target is displaced by a predetermined amount.

10. The laser processing method for a workpiece according to claim 9, wherein

the target set at the center of the workpiece comprises

an element included in a pattern surface of the top surface of the workpiece, or

a grinding trace present on the undersurface of the

workpiece, or

an element included in a top surface of the
protective member.