

METHOD OF PROCESSING WORKPIECE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of processing a plate-shaped workpiece having rectangular face and reverse sides.

Description of the Related Art

Optical parts such as substrates for use as the screens of flat panel displays are manufactured by processing workpieces such as glass plates that are transparent in the visible light range. For processing such workpieces, for example, there are used a processing apparatus including a laser processing apparatus for generating and using a high-output laser beam and a cutting apparatus that has an annular cutting blade including abrasive grains and that is mounted on a spindle (see, for example, JP 2006-93333A).

These processing apparatuses generally extract a pattern of devices or the like existing on a workpiece from an image of the workpiece that is captured by a camera and confirm a position, i.e., a projected processing line, where the workpiece is to be processed. In a case where a workpiece free of such a pattern is to

be processed by a processing apparatus, the workpiece is placed in a predetermined position on a chuck table of the processing apparatus such that the workpiece can be processed at a given position, for example.

SUMMARY OF THE INVENTION

A delivery mechanism for delivering the workpiece in the processing apparatus is arranged to be able to load the workpiece highly accurately onto the chuck table. However, the actual position into which the workpiece is loaded often deviates from a target position on the chuck table by a distance of up to 5 mm. Therefore, the above process of placing the workpiece in the predetermined position on the chuck table is not effective enough to assist in processing the workpiece with sufficiently high accuracy.

For example, a workpiece having circular face and reverse sides can be processed highly accurately by determining a position corresponding to the center of the circular shape from the positions of three points on the outer circumferential edge of the circular shape. However, this process of processing a workpiece having circular face and reverse sides cannot directly be applied to the processing of workpieces having

rectangular face and reverse sides.

It is therefore an object of the present invention to provide a method of processing with high accuracy a plate-shaped workpiece having rectangular face and reverse sides.

In accordance with an aspect of the present invention, there is provided a method of processing a plate-shaped workpiece having a first rectangular surface having four sides and a second rectangular surface positioned opposite the first surface, with use of a chuck table having a holding surface and of a processing unit for processing the workpiece held on the chuck table. The method includes an acquiring step for, while the second surface of the workpiece is being held on the holding surface of the chuck table, acquiring an orientation of the four sides of the workpiece in an XY plane parallel to the holding surface and four sets of XY coordinates indicating positions of the four sides in the XY plane, from displacement information obtained by measuring a height of an area including the four sides of the workpiece, and a processing step for processing the workpiece on the basis of the orientation of the sides and the four sets of XY coordinates.

In the above aspect of the present invention, the

acquiring step may further include an orientation acquiring step for moving a measuring instrument for measuring a height and the chuck table relatively to each other to thereby measure a height of an area including a side of the workpiece on two straight lines that extend through different positions in Y directions and that are parallel to X directions, and calculating XY coordinates indicating two positions where the side and the two straight lines intersect with each other, from obtained displacement information, to acquire an orientation of the side, a first coordinate acquiring step for adjusting an orientation of the chuck table about a rotational axis perpendicular to the XY plane in order to make the orientation of the side acquired in the orientation acquiring step parallel to the Y directions, then moving the measuring instrument and the chuck table relatively to each other to thereby measure a height of an area including two opposite sides of the workpiece on a straight line parallel to the X directions, and acquiring two sets of XY coordinates indicating two positions where the two opposite sides and the straight line intersect with each other, from obtained displacement information, and a second coordinate acquiring step for adjusting the orientation of the chuck table about the rotational axis

in order to make the orientation of the side acquired in the orientation acquiring step perpendicular to the Y directions, then moving the measuring instrument and the chuck table relatively to each other to thereby measure a height of an area including other two opposite sides of the workpiece on a straight line parallel to the X directions, and acquiring two sets of XY coordinates indicating two positions where the other two opposite sides and the straight line intersect with each other, from obtained displacement information.

In the above aspect of the present invention, the acquiring step may further include a first coordinate acquiring step for moving a measuring instrument for measuring a height and the chuck table relatively to each other to thereby measure a height of an area including two opposite sides of the workpiece on two straight lines that extend through different positions in Y directions and that are parallel to X directions, and acquiring three or more sets of XY coordinates indicating three or more positions where the two opposite sides and the two straight lines intersect with each other, from obtained displacement information, a second coordinate acquiring step for, while an orientation of the chuck table about a rotational axis perpendicular to the XY plane is

perpendicular to an orientation of the chuck table in the first coordinate acquiring step, moving the measuring instrument and the chuck table relatively to each other to thereby measure a height of an area including other two opposite sides of the workpiece on a straight line parallel to the X directions, and acquiring two sets of XY coordinates indicating two positions where the other two opposite sides and the straight line intersect with each other, from obtained displacement information, an orientation acquiring step for acquiring an orientation of one of the two opposite sides from the two sets of XY coordinates that are acquired in the first coordinate acquiring step and that indicate two positions where one of the two opposite sides and the two straight lines intersect with each other, and a corrected coordinate acquiring step for correcting the two sets of XY coordinates that are acquired in the first coordinate acquiring step and that indicate two positions where the two opposite sides and one of the straight lines intersect each other and correcting the two sets of XY coordinates acquired in the second coordinate acquiring step, on the basis of the orientation of the side acquired in the orientation acquiring step, and acquiring corrected four sets of XY coordinates.

In accordance with another aspect of the present invention, there is provided a method of processing a plate-shaped workpiece having a first rectangular surface having four sides and a second rectangular surface positioned opposite the first surface, with use of a chuck table having a holding surface and of a processing unit for processing the workpiece held on the chuck table. The method includes an acquiring step for, while the second surface of the workpiece is being held on the holding surface of the chuck table, acquiring an orientation of a side of the workpiece in an XY plane parallel to the holding surface, from an image captured of an area including the side of the workpiece, and acquiring four sets of XY coordinates indicating positions of the four sides of the workpiece in the XY plane, from displacement information obtained by measuring a height of an area including the four sides of the workpiece, and a processing step for processing the workpiece on the basis of the orientation of the side and the four sets of XY coordinates.

In the methods of processing a workpiece according to the aspect and other aspect of the present invention, since the orientation of either side of the first surface of the workpiece and the four sets of XY coordinates

indicating positions on the four sides of the first surface are acquired, the workpiece can be processed highly accurately on the basis of the orientation and the four sets of XY coordinates.

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 for carrying out a method of processing a workpiece according to an embodiment of the present invention;

FIG. 2 is a flowchart of the method of processing a workpiece according to the present embodiment;

FIG. 3 is a plan view illustrating an outline of an orientation acquiring step of the method;

FIG. 4 is a side elevational view, partly in cross section, illustrating the manner in which the height of the workpiece is measured;

FIG. 5 is a graph illustrating an example of displacement information;

FIG. 6 is a plan view illustrating an outline of a first coordinate acquiring step of the method;

FIG. 7 is a plan view illustrating an outline of a second coordinate acquiring step of the method;

FIG. 8 is a side elevational view, partly in cross section, illustrating an outline of a processing step;

FIG. 9 is a flowchart of a method of processing a workpiece according to a first modification;

FIG. 10 is a plan view illustrating an outline of a first coordinate acquiring step of the method according to the first modification; and

FIG. 11 is a plan view illustrating an outline of a second coordinate acquiring step of the method according to the first modification.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A method of processing a workpiece according to a preferred embodiment of the present invention will be described hereinbelow with reference to the accompanying drawings. FIG. 1 illustrates in perspective a laser processing apparatus, i.e., a processing apparatus, 2 for carrying out the method of processing a workpiece

according to the present embodiment. In FIG. 1, some of the components of the laser processing apparatus 2 are omitted from illustration. X directions, i.e., forward and rearward directions or processing feed directions, Y directions, i.e., leftward and rightward directions or indexing feed directions, and Z directions, i.e., vertical directions or incising feed directions, referred to in the description that follows extend perpendicularly to each other.

As illustrated in FIG. 1, the laser processing apparatus 2 includes a base 4 that supports thereon a plurality of components of the laser processing apparatus 2. The laser processing apparatus 2 also includes a column- or wall-shaped support structure 6 projecting upwardly at a rear end of the base 4. Further, the laser processing apparatus 2 includes a columnar housing 4a projecting upwardly at a front corner thereof.

The housing 4a has an opening defined in an upper end thereof and defines a space therein that is open outwardly through the opening in the upper end thereof. The housing 4a houses therein a cassette support table 8 having a generally flat upper surface and a lifting and lowering mechanism, not depicted, for lifting and lowering the cassette support table 8. The cassette

support table 8 has an upper surface exposed upwardly through the opening of the housing 4a. A cassette 10 that is capable of storing a plurality of workpieces 11 is placed on the upper surface of the cassette support table 8.

Each of the workpieces 11 is of a plate shape made of a glass material that is transparent in the visible light range, for example. The workpiece 11 has a first rectangular surface, i.e., a face side, 11a having four sides and a second rectangular surface, i.e., a reverse side, 11b (see FIG. 4, etc.) positioned opposite the first surface 11a. The first and second rectangular surfaces 11a and 11b of the workpiece 11 are free of structures such as devices.

A tape, i.e., a dicing tape, 13 that is larger in diameter than the workpiece 11 is affixed to the second rectangular surface 11b of the workpiece 11. The tape 13 has an outer circumferential portion fixed to an annular frame 15 that is disposed around the workpiece 11. In other words, the workpiece 11 as supported on the annular frame 15 by the tape 13 is stored in the cassette 10.

The workpieces 11 are not limited to any materials, shapes, structures, sizes, etc. For example, substrates made of materials including a semiconductor typified by

silicon, ceramic, resin, metal, and so on may be used as the workpieces 11. Similarly, devices such as integrated circuits (ICs) or light emitting diodes (LEDs) may be formed on the workpieces 11. Further alternatively, the workpieces 11 may not be supported on the annular frames 15 by the tapes 13.

A positioning unit 12 for roughly positioning one at a time of the annular frames 15 that support the workpieces 11 is disposed in a position adjacent to the housing 4a. The positioning unit 12 includes a pair of guide rails that are movable toward and away from each other while being kept parallel to the Y directions, for example. Each of the guide rails has a bottom surface supporting the frame 15 thereon and a side surface extending perpendicularly to the bottom surface.

For example, an annular frame 15 that supports a workpiece 11 is unloaded from the cassette 10 is placed on the guide rails of the positioning unit 12. Then, the guide rails are moved toward each other to grip the annular frame 15 therebetween, thereby positioning the annular frame 15 and hence the workpiece 11. A delivery unit 14 for delivering an annular frame 15 is disposed above the positioning unit 12.

The laser processing apparatus 2 further includes a

moving mechanism, i.e., a processing feed mechanism or an indexing feed mechanism, 16 disposed on the base 4 laterally of the positioning unit 12. The moving mechanism 16 includes a pair of Y-axis guide rails 18 that are fixedly mounted on an upper surface of the base 4 and that extend generally parallel to the Y directions. A Y-axis movable table 20 is slidably mounted on the Y-axis guide rails 18.

The Y-axis movable table 20 has a lower surface on which a nut, not depicted, is fixedly disposed. The nut is operatively threaded over a Y-axis ball screw 22 rotatable about its central axis, the Y-axis ball screw 22 extending generally parallel to the Y-axis guide rails 18. The Y-axis ball screw 22 has an end coupled to a Y-axis stepping motor 24. When the Y-axis stepping motor 24 is energized, it rotates the Y-axis ball screw 22 about its central axis, causing the nut to move the Y-axis movable table 20 in one of the Y-axis directions along the Y-axis guide rails 18.

The Y-axis movable table 20 has an upper surface on which there are fixedly mounted a pair of X-axis guide rails 26 extending generally parallel to the X directions. An X-axis movable table 28 is slidably mounted on the X-axis guide rails 26. The X-axis movable

table 28 has a lower surface on which a nut, not depicted, is fixedly disposed.

The nut is operatively threaded over an X-axis ball screw 30 rotatable about its central axis, the X-axis ball screw 30 extending generally parallel to the X-axis guide rails 26. The X-axis ball screw 30 has an end coupled to an X-axis stepping motor 32. When the X-axis stepping motor 32 is energized, it rotates the X-axis ball screw 30 about its central axis, causing the nut to move the X-axis movable table 28 in one of the X-axis directions along the X-axis guide rails 26.

The X-axis movable table 28 supports a θ table 34 on an upper surface thereof. The θ table 34 includes a table base 34a (see FIG. 4, etc.) rotatable about a vertical axis generally parallel to the Z directions and a rotary actuator, not depicted, such as an electric motor, coupled to the table base 34a. A chuck table 36 is fixedly mounted on an upper surface of the table base 34a. The chuck table 36 is thus rotatable in unison with the table base 34a.

The chuck table 36 includes a disk-shaped frame 38 (see FIG. 4, etc.) made of a metal typified by stainless steel, for example. The frame 38 has a recess 38a (see FIG. 4, etc.) defined in an upper surface thereof, the

recess 38a having a circular opening in an upper end thereof. A disk-shaped porous holding plate 40 (see FIG. 4, etc.) made of ceramic or the like is fixedly disposed in the recess 38a. The holding plate 40 has an upper surface lying generally parallel to the X directions and the Y directions and acting as a holding surface 40a for holding the second surface 11b of a workpiece 11 with the tape 13 interposed therebetween.

The holding plate 40 has a lower surface connected to a suction source, not depicted, such as an ejector, through a fluid channel 38b defined in the frame 38 and a valve, not depicted, etc. When the tape 13 affixed to a workpiece 11 is held in contact with the holding surface 40a and then the valve is opened to allow a negative pressure from the suction source to act through the fluid channel 38b on the holding surface 40a, the workpiece 11 is drawn under suction to the chuck table 36 with the tape 13 interposed therebetween. Four clamps 42 are disposed around the chuck table 36 for securing the annular frame 15 that supports the workpiece 11, at four corresponding positions with respect to the chuck table 36.

A horizontal support arm 6a projects from a front vertical surface of the support structure 6. An

irradiating head, i.e., a processing unit, 44 is mounted on a distal end of the support arm 6a. The irradiating head 44 applies a pulsed laser beam 44a (see FIG. 8) emitted from a laser oscillator, i.e., the processing unit, not depicted, downwardly to an object to be processed by the laser processing apparatus 2, i.e., a workpiece 11, on the chuck table 36.

The laser beam 44a generated by the laser oscillator may be any desired wavelengths. According to the present embodiment, however, the laser oscillator generates a laser beam 44a having a wavelength transmittable through the workpieces 11, i.e., a transmissive laser beam 44a. The irradiating head 44 applies the transmissive laser beam 44a to a workpiece 11 while positioning a focused point thereof within the workpiece 11, thereby modifying portions in the workpiece 11, for example.

A camera, i.e., an image capturing unit, 46 is mounted on the distal end of the support arm 6a on one side of the irradiating head 44 in one of the X directions. The camera 46 includes a two-dimensional optical sensor such as a complementary metal oxide semiconductor (CMOS) image sensor or a charge coupled device (CCD) image sensor, the sensors having sensitivity

in the visible light range, and a focusing lens. The camera 46 captures an image of the upper surface, i.e., the first surface 11a, of a workpiece 11 held on the chuck table 36, i.e., generates an image including the workpiece 11.

An optical displacement measuring instrument, i.e., a measuring instrument, 48 for measuring the distance up to an object, i.e., a workpiece 11 on the chuck table 36, is mounted on the distal end of the support arm 6a on one side of the camera 46 in one of the X directions. The displacement measuring instrument 48 includes an emitting unit for applying a laser beam 48a (see FIG. 4) downwardly to the object and a detecting unit for detecting a laser beam 48a reflected upwardly from the object. The displacement measuring instrument 48 measures the height of the upper surface, i.e., the first surface 11a, of the workpiece 11 held on the chuck table 36, on the basis of the detected laser beam 48a, and generates information regarding a displacement, i.e., displacement information on the basis of the measured height.

Some of the components described above, i.e., the lifting and lowering mechanism, not depicted, for lifting and lowering the cassette support table 8, the positioning unit 12, the delivery unit 14, the Y-axis

stepping motor 24 and the X-axis stepping motor 32 of the moving mechanism 16, the rotary actuator for the θ table 34, the valve connected to the chuck table 36, the irradiating head 44, the laser oscillator, the camera 46, the displacement measuring instrument 48, etc. are connected to a control unit 50. The control unit 50 control the above components according to a sequence of steps required to process a workpiece 11.

The control unit 50 includes a computer including a processor 50a as a processing unit such as a central processing unit (CPU) and a storage unit 50b including a main storage device such as a dynamic random access memory (DRAM) and an auxiliary storage device such as a flash memory. The control unit 50 has its functions performed when the processor 50a executes software, i.e., programs, stored in the storage unit 50b. Alternatively, the functions of the control unit 50 may be implemented by only hardware.

For example, a workpiece 11, i.e., an annular frame 15, unloaded from the cassette 10 and positioned by the positioning unit 12 is loaded onto the chuck table 36 by the delivery unit 14 and has its second surface 11b held under suction on the holding surface 40a of the chuck table 36. At this time, the position of the workpiece 11

actually loaded on the chuck table 36 may often deviate from a target position on the chuck table 36 for the workpiece 11 on account of the accuracy of the position of the tape 13 affixed to the workpiece 11, the accuracy of the delivering operation of the delivery unit 14, and other factors.

According to the present embodiment, information regarding the orientation, the position, etc. of the workpiece 11 on the chuck table 36 is acquired and then the workpiece 11 is processed taking the acquired information into account in order to eliminate adverse effects of such a positional deviation. FIG. 2 is a flowchart of the method of processing a workpiece according to the present embodiment. As illustrated in FIG. 2, the method of processing a workpiece according to the present embodiment includes orientation acquiring step ST11 that is carried out to acquire the orientation of a side of the first rectangular surface 11a of the workpiece 11. FIG. 3 illustrates in plan an outline of orientation acquiring step ST11 of the method. In FIG. 3, some parts including the tape 13 are omitted from illustration.

In orientation acquiring step ST11, the height of an area including at least one side 11c of the workpiece

11 is measured, and XY coordinates representing the position of the side 11c are calculated from displacement information that is obtained. FIG. 4 illustrates in side elevation the manner in which the height of the workpiece 11 is measured. In FIG. 4, some parts are illustrated in cross section.

For example, the control unit 50 operates the displacement measuring instrument 48 to obtain the relation between the position in the X directions and the height of the workpiece 11 while moving the chuck table 36 that is holding the workpiece 11 in one of the X directions, as illustrated in FIG. 4. Specifically, the control unit 50 moves the displacement measuring instrument 48 and the chuck table 36 relatively to each other and measures the height of the area including the side 11c of the workpiece 11 on a straight line parallel to the X directions.

FIG. 5 is a graph illustrating an example of displacement information obtained by measuring the height of the area including the side 11c of the workpiece 11. As described above, when the control unit 50 moves the displacement measuring instrument 48 and the chuck table 36 relatively to each other and measures the height of the area including the side 11c of the workpiece 11 on

the straight line parallel to the X directions, the control unit 50 obtains displacement information representing a profile of the thickness of the workpiece 11. The control unit 50 stores the displacement information thus obtained in the storage unit 50b.

More specifically, the control unit 50 measures the height of the area including the side 11c of the workpiece 11 along a first straight line 21a illustrated in FIG. 3. At this time, there is a large difference, i.e., a large height difference, between the height of a position A where the first straight line 21a and the side 11c intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position A.

As illustrated in FIG. 5, the control unit 50 can calculate the X coordinate (X_1) of the position A by extracting, from the obtained displacement information, a position where there is a large height difference. The Y coordinates of any positions on the first straight line 21a parallel to the X directions are equal to each other. Therefore, the control unit 50 can calculate the Y coordinate (Y_1) of the position A from information, etc. representing the position of the Y-axis movable table 20, i.e., the chuck table 36, at the time the height of the

area including the side 11c of the workpiece 11 is measured.

Specifically, the processor 50a calculates the X coordinate (X_1) of the position A where the first straight line 21a and the side 11c intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_1) of the position A from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_1 , Y_1) of the position A in the storage unit 50b.

After having measured the height of the area including the side 11c of the workpiece 11 along the first straight line 21a, the control unit 50 moves the chuck table 36, i.e., the Y-axis movable table 20, in one of the Y directions, and then makes similar measurements. Specifically, the processor 50a measures the height of an area including the side 11c of the workpiece 11 along a second straight line 21b that extends through a position different from the first straight line 21a in the Y directions and that is parallel to the X directions.

Then, the processor 50a calculates the X coordinate

(X_2) of a position B where the second straight line 21b and the side 11c intersect with each other, from the displacement information obtained by the measurements, and calculates the Y coordinate (Y_2) of the position B from information, etc. representing the position of the Y-axis movable table 20, i.e., the chuck table 36, at the time the height of the area including the side 11c of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_2 , Y_2) of the position B in the storage unit 50b.

According to the present embodiment, the coordinates of positions are calculated in relation to a coordinate system having its origin 0 located at a position where the axis about which the chuck table 36 is rotatable and an XY plane parallel to the holding surface 40a intersect with each other. However, the coordinates of positions may be calculated in relation to another coordinate system having its origin set to another position.

After having calculated the coordinates (X_1 , Y_1) of the position A and the coordinates (X_2 , Y_2) of the position B, the processor 50a acquires the orientation of the side 11c in the XY plane parallel to the holding surface 40a from the coordinates (X_1 , Y_1) of the position

A and the coordinates (X_2, Y_2) of the position B. For example, the processor 50a calculates an angle θ_1 formed between the side 11c and the Y directions by applying trigonometry to the coordinates (X_1, Y_1) of the position A and the coordinates (X_2, Y_2) of the position B. The processor 50a stores the calculated angle θ_1 in the storage unit 50b, as the orientation of the side 11c.

The processor 50a may alternatively calculate the angle between the side 11c and the X directions as the orientation of the side 11c. According to the present embodiment, the processor 50a acquires the orientation of the side 11c from the coordinates (X_1, Y_1) of the position A where the first straight line 21a and the side 11c intersect with each other and the coordinates (X_2, Y_2) of the position B where the second straight line B and the side 11c intersect with each other. However, the processor 50a may instead acquire the orientation of a side 11d opposite the side 11c, from the coordinates of two positions on the side 11d.

After orientation acquiring step ST11, the control unit 50 carries out first coordinate acquiring step ST12 (see FIG. 2) for acquiring two sets of coordinates representing positions on two opposite sides of the workpiece 11 in the XY plane parallel to the holding

surface 40a. FIG. 6 illustrates in plan an outline of first coordinate acquiring step ST12 of the method. In FIG. 6, some parts including the tape 13 are omitted from illustration.

In first coordinate acquiring step ST12, the control unit 50 adjusts the orientation of the chuck table 36 about its vertical axis perpendicular to the XY plane in order to make the orientation of the side 11c that has been acquired in orientation acquiring step ST11 parallel to the Y directions. Specifically, the control unit 50 turns the chuck table 36 about its axis from the angular position illustrated in FIG. 3 through the angle θ_1 , i.e., through the angle θ_1 clockwise as viewed in plan according to the present embodiment. The side 11c and the side 11d of the workpiece 11 that are opposite each other now extend parallel to the Y directions.

Thereafter, the control unit 50 moves the chuck table 36 that is holding the workpiece 11 thereon in one of the X directions and operates the displacement measuring instrument 48 to obtain the relation between the position in the X directions and the height of the workpiece 11. Specifically, the control unit 50 moves the displacement measuring instrument 48 and the chuck table 36 relatively to each other and measures the height of an

area including the side 11c and the side 11d of the workpiece 11 on a straight line parallel to the X directions. The control unit 50 stores the displacement information thus obtained in the storage unit 50b.

More specifically, the control unit 50 measures the height of the area including the side 11c and the side 11d of the workpiece 11 along a third straight line 21c illustrated in FIG. 6. At this time, there is a large difference, i.e., a large height difference, between the height of a position C1 where the third straight line 21c and the side 11c intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position C1. There is also a large difference, i.e., a large height difference, between the height of a position C2 where the third straight line 21c and the side 11d intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position C2.

The control unit 50 can calculate the X coordinate (X_{31}) of the position C1 and the X coordinate (X_{32}) of the position C2 by extracting, from the obtained displacement information, positions where there is a large height difference. The Y coordinates of any positions on the third straight line 21c parallel to the X directions are equal to each other. Therefore, the control unit 50 can

calculate the Y coordinate (Y_3) of the positions C1 and C2 from information, etc. representing the position of the Y-axis movable table 20, i.e., the chuck table 36, at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured.

Specifically, the processor 50a calculates the X coordinate (X_{31}) of the position C1 where the third straight line 21c and the side 11c intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_3) of the position C1 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{31} , Y_3) of the position C1 in the storage unit 50b.

In addition, the processor 50a calculates the X coordinate (X_{32}) of the position C2 where the third straight line 21c and the side 11d intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_3) of the position C2 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c and the side

11d of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{32} , Y_3) of the position C2 in the storage unit 50b.

After first coordinate acquiring step ST12, the control unit 50 carries out second coordinate acquiring step ST13 (see FIG. 2) for acquiring two sets of coordinates representing positions on other two opposite sides of the workpiece 11 in the XY plane parallel to the holding surface 40a. FIG. 7 illustrates in plan an outline of second coordinate acquiring step ST13 of the method. In FIG. 7, some parts including the tape 13 are omitted from illustration.

In second coordinate acquiring step ST13, the control unit 50 adjusts the orientation of the chuck table 36 about its vertical axis perpendicular to the XY plane in order to make the orientation of the side 11c that has been acquired in orientation acquiring step ST11 perpendicular to the Y directions. Specifically, the control unit 50 turns the chuck table 36 about its axis from the angular position illustrated in FIG. 6 through an angle of 90° , i.e., through the angle of 90° clockwise as viewed in plan according to the present embodiment. Two sides other than the sides 11c and 11d, i.e., sides 11e and 11f, of the workpiece 11 that are opposite each

other now extend parallel to the Y directions.

Thereafter, the control unit 50 moves the chuck table 36 that is holding the workpiece 11 thereon in one of the X directions and operates the displacement measuring instrument 48 to obtain the relation between the position in the X directions and the height of the workpiece 11. Specifically, the control unit 50 moves the displacement measuring instrument 48 and the chuck table 36 relatively to each other and measures the height of an area including the side 11e and the side 11f of the workpiece 11 on a straight line parallel to the X directions. The control unit 50 stores the displacement information thus obtained in the storage unit 50b.

More specifically, the control unit 50 measures the height of the area including the side 11e and the side 11f of the workpiece 11 along a fourth straight line 21d illustrated in FIG. 7. At this time, there is a large difference, i.e., a large height difference, between the height of a position D1 where the fourth straight line 21d and the side 11e intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position D1. There is also a large difference, i.e., a large height difference, between the height of a position D2 where the fourth straight line 21d and the

side 11f intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position D2.

The control unit 50 can calculate the X coordinate (X_{41}) of the position D1 and the X coordinate (X_{42}) of the position D2 by extracting, from the obtained displacement information, positions where there is a large height difference. The Y coordinates of any positions on the fourth straight line 21d parallel to the X directions are equal to each other. Therefore, the control unit 50 can calculate the Y coordinate (Y_4) of the positions D1 and D2 from information, etc. representing the position of the Y-axis movable table 20, i.e., the chuck table 36, at the time the height of the area including the side 11e and the side 11f of the workpiece 11 is measured.

Specifically, the processor 50a calculates the X coordinate (X_{41}) of the position D1 where the fourth straight line 21d and the side 11e intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_4) of the position D1 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11e and the side 11f of the workpiece 11 is measured. The processor 50a

then stores the calculated coordinates (X_{41} , Y_4) of the position D1 in the storage unit 50b.

In addition, the processor 50a calculates the X coordinate (X_{42}) of the position D2 where the fourth straight line 21d and the side 11f intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_4) of the position D2 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11e and the side 11f of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{42} , Y_4) of the position D2 in the storage unit 50b.

As described above, after having measured the height of the workpiece 11 along the third straight line 21c, the control unit 50 turns the chuck table 36 through the angle of 90° for measuring the height of the workpiece 11 along the fourth straight line 21d. Therefore, the position of the workpiece 11 cannot appropriately be expressed by using the coordinates (X_{31} , Y_3) of the position C1 and the coordinates (X_{32} , Y_3) of the position C2, and the coordinates (X_{41} , Y_4) of the position D1 and the coordinates (X_{42} , Y_4) of the position D2 as they are.

Consequently, after second coordinate acquiring step ST13, the control unit 50 carries out corrected coordinate acquiring step ST14 (see FIG. 2) for acquiring corrected coordinates by correcting either the coordinates (X_{31} , Y_3) of the position C1 and the coordinates (X_{32} , Y_3) of the position C2 or the coordinates (X_{41} , Y_4) of the position D1 and the coordinates (X_{42} , Y_4) of the position D2.

Specifically, for example, the processor 50a carries out an arithmetic process for turning the coordinates (X_{41} , Y_4) of the position D1 and the coordinates (X_{42} , Y_4) of the position D2 through an angle of -90° , i.e., through the angle of 90° counterclockwise as viewed in plan according to the present embodiment, thereby acquiring coordinates of the position D1 that have been corrected, i.e., corrected coordinates of the position D1, and coordinates of the position D2 that have been corrected, i.e., corrected coordinates of the position D2. The processor 50a stores the corrected coordinates of the position D1 and the corrected coordinates of the position D2 that have been acquired in the storage unit 50b.

The control unit 50 of the laser processing apparatus 2 already knows the shape of the workpiece 11,

i.e., the shape of the first surface 11a. Therefore, the control unit 50 can appropriately grasp the position of the workpiece 11 from the corrected coordinates of the position D1 and the corrected coordinates of the position D2 as well as the coordinates (X_{31} , Y_3) of the position C1 and the coordinates (X_{32} , Y_3) of the position C2.

According to the present embodiment, the control unit 50 acquires the corrected coordinates of the position D1 and the corrected coordinates of the position D2. However, the control unit 50 may acquire corrected coordinates of the position C1 and corrected coordinates of the position C2. In the latter case, the processor 50a carries out an arithmetic process for turning the coordinates (X_{31} , Y_3) of the position C1 and the coordinates (X_{32} , Y_3) of the position C2 to match the coordinates (X_{41} , Y_4) of the position D1 and the coordinates (X_{42} , Y_4) of the position D2 through an angle of 90° , i.e., through the angle of 90° clockwise as viewed in plan according to the present embodiment.

After corrected coordinate acquiring step ST14, the control unit 50 carries out processing step ST15 (see FIG. 2) for processing the workpiece 11 with use of the information regarding the position and the orientation of the workpiece 11 that has been acquired in the above

acquiring steps including orientation acquiring step ST11, first coordinate acquiring step ST12, second coordinate acquiring step ST13, and corrected coordinate acquiring step ST14. Specifically, the workpiece 11 is processed on the basis of the orientation of the sides and the four sets of XY coordinates representing the positions of the sides. FIG. 8 illustrates an outline of processing step ST15 in side elevation, partly in cross section. In FIG. 8, some parts are omitted from illustration.

In processing step ST15 according to the present embodiment, internal portions of the workpiece 11 are modified along projected processing lines on the workpiece 11. Specifically, the control unit 50 adjusts the orientation of the chuck table 36 in view of the orientation of the sides described above, to make a target projected processing line parallel to the X directions. Next, the control unit 50 adjusts the orientation of the chuck table 36 in view of the four sets of XY coordinates described above, to positionally align the irradiating head 44 with a position above an extension of the target projected processing line.

Then, as illustrated in FIG. 8, while the irradiating head 44 is applying the laser beam 44a to the

workpiece 11, the chuck table 36 is moved in one of the X directions. In other words, the chuck table 36 and the irradiating head 44 are moved relatively to each other in a direction parallel to the projected processing line. The irradiating head 44 is adjusted to focus the laser beam 44a within the workpiece 11, for example.

Since the laser beam 44a whose wavelength is transmittable through the workpieces 11, i.e., the transmissive laser beam 44a, is focused in the workpiece 11, internal portions of the workpiece 11 are modified into modified layers 17. According to the present embodiment, as the laser beam 44a is applied to the projected processing line while the chuck table 36 and the irradiating head 44 are being moved relatively to each other, the modified layers 17 are formed in the workpiece 11 along the projected processing line. The above process is repeated until the workpiece 11 is processed along all the projected processing lines.

With the method of processing a workpiece according to the present embodiment, inasmuch as the orientation of the side, i.e., the side 11c, of the first surface 11a of the workpiece 11, and the four sets of the XY coordinates of the positions, i.e., the position C1, the position C2, the position D1, and the position D2, on the four sides,

i.e., the side 11c, the side 11d, the side 11e, and the side 11f, of the first surface 11a, are acquired, the workpiece 11 can be processed with high accuracy on the basis of the acquired orientation and four sets of the XY coordinates.

With the method of processing a workpiece according to the present embodiment, further, since the orientation of the side and the four sets of the XY coordinates are acquired using the displacement measuring instrument 48 that measures the distance up to an object, the position of the workpiece 11 can accurately be grasped even if the workpiece 11 is transparent or structures such as devices, i.e., a pattern, are not formed on the workpiece 11.

Consequently, the method of processing a workpiece according to the present embodiment is highly effective in a case where the laser beam 44a is not to be applied to an outer circumferential edge of the workpiece 11 when the workpiece 11 is to be processed, for example. The method of processing a workpiece according to the present embodiment is also able to prevent the laser beam 44a from being applied in error to a region outside of the workpiece 11, for example.

The present invention is not limited to the above

embodiment, and various changes and modifications may be made therein. FIG. 9 is a flowchart of a method of processing a workpiece according to a first modification. As illustrated in FIG. 9, a sequence of acquiring steps for acquiring the orientation of a side of the workpiece 11 and the four sets of XY coordinates representing positions on the four sides of the workpiece 11 is different from the sequence of acquiring steps according to the above embodiment.

Specifically, the method of processing a workpiece according to the first modification includes first coordinate acquiring step ST21 for measuring the height of an area including two opposite sides of the workpiece 11 on two straight lines parallel to the X directions and for acquiring three or more sets of XY coordinates representing three or more positions where the two opposite sides and the two straight lines intersect with each other, from the displacement information that is obtained. FIG. 10 illustrates in plan an outline of first coordinate acquiring step ST21 of the method. In FIG. 10, some parts including the tape 13 are omitted from illustration.

In first coordinate acquiring step ST21 according to the first modification, the control unit 50 operates

the displacement measuring instrument 48 to obtain the relation between the position in the X directions and the height of the workpiece 11 while moving the chuck table 36 that is holding the workpiece 11 in one of the X directions. Specifically, the control unit 50 moves the displacement measuring instrument 48 and the chuck table 36 relatively to each other and measures the height of the area including two opposite sides of the workpiece 11 on a straight line parallel to the X directions. The control unit 50 stores the displacement information thus obtained in the storage unit 50b.

More specifically, the control unit 50 measures the height of the area including the opposite sides 11c and 11d of the workpiece 11 along a first straight line 31a illustrated in FIG. 10. At this time, there is a large difference, i.e., a large height difference, between the height of a position E1 where the first straight line 31a and the side 11c intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position E1. There is also a large difference, i.e., a large height difference, between the height of a position E2 where the first straight line 31a and the side 11d intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position E2.

The control unit 50 can calculate the X coordinate (X_{51}) of the position E1 and the X coordinate (X_{52}) of the position E2 by extracting, from the obtained displacement information, positions where there is a large height difference. The Y coordinates of any positions on the first straight line 31a parallel to the X directions are equal to each other. Therefore, the control unit 50 can calculate the Y coordinate (Y_5) of the positions E1 and E2 from information, etc. representing the position of the Y-axis movable table 20, i.e., the chuck table 36, at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured.

Specifically, the processor 50a calculates the X coordinate (X_{51}) of the position E1 where the first straight line 31a and the side 11c intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_5) of the position E1 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{51} , Y_5) of the position E1 in the storage unit 50b.

In addition, the processor 50a calculates the X

coordinate (X_{52}) of the position E2 where the first straight line 31a and the side 11d intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_5) of the position E2 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{52} , Y_5) of the position E2 in the storage unit 50b.

After having measured the height of the area including the opposite sides 11c and 11d of the workpiece 11 along the first straight line 31a, the control unit 50 moves the chuck table 36, i.e., the Y-axis movable table 20, in one of the Y directions, and then makes similar measurements. Specifically, the processor 50a measures the height of an area including the side 11c and the side 11d of the workpiece 11 along a second straight line 31b that extends through a position different from the first straight line 31a in the Y directions and that is parallel to the X directions.

Then, the processor 50a calculates the X coordinate (X_{61}) of a position F1 where the second straight line 31b and the side 11c intersect with each other, from the

displacement information obtained by the measurements, and also calculates the Y coordinate (Y_6) of the position F1 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{61} , Y_6) of the position F1 in the storage unit 50b.

In addition, the processor 50a calculates the X coordinate (X_{62}) of a position F2 where the second straight line 31b and the side 11d intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_6) of the position F2 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11c and the side 11d of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{62} , Y_6) of the position F2 in the storage unit 50b.

In first coordinate acquiring step ST21 according to the first modification, all of the four sets of XY coordinates representing the four positions where the first straight line 31a and the second straight line 31b, and the side 11c and the side 11d intersect with each

other are acquired. According to the present invention, however, it is sufficient if any three of those four sets of XY coordinates are acquired.

After first coordinate acquiring step ST21, the control unit 50 carries out second coordinate acquiring step ST22 (see FIG. 9) for measuring the height of an area including two other opposite sides of the workpiece 11 on a straight line parallel to the X directions and for acquiring two sets of XY coordinates representing two positions where the two other opposite sides and the straight line intersect with each other, from the displacement information that is obtained. FIG. 11 illustrates in plan an outline of second coordinate acquiring step ST22 according to the first modification. In FIG. 11, some parts including the tape 13 are omitted from illustration.

In second coordinate acquiring step ST22, the control unit 50 adjusts the orientation of the chuck table 36 about its vertical axis with respect to the orientation of the chuck table 36 in first coordinate acquiring step ST21 described above. Specifically, the control unit 50 turns the chuck table 36 about its axis from the angular position illustrated in FIG. 10 through an angle of 90° , i.e., through the angle of 90° clockwise

as viewed in plan according to the first modification.

Thereafter, the control unit 50 moves the chuck table 36 that is holding the workpiece 11 thereon in one of the X directions and operates the displacement measuring instrument 48 to obtain the relation between the position in the X directions and the height of the workpiece 11. Specifically, the control unit 50 moves the displacement measuring instrument 48 and the chuck table 36 relatively to each other and measures the height of the area including the two other opposite sides of the workpiece 11 on a straight line parallel to the X directions. The control unit 50 stores the displacement information thus obtained in the storage unit 50b.

More specifically, the control unit 50 measures the height of an area including the opposite sides 11e and 11f of the workpiece 11 along a third straight line 31c illustrated in FIG. 11. At this time, there is a large difference, i.e., a large height difference, between the height of a position G1 where the third straight line 31c and the side 11e intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position G1. There is also a large difference, i.e., a large height difference, between the height of a position G2 where the third straight line 31c and the side 11f

intersect with each other and the height of a position outside of the workpiece 11 adjacent to the position G2.

The control unit 50 can calculate the X coordinate (X_{71}) of the position G1 and the X coordinate (X_{72}) of the position G2 by extracting, from the obtained displacement information, positions where there is a large height difference. The Y coordinates of any positions on the third straight line 31c parallel to the X directions are equal to each other. Therefore, the control unit 50 can calculate the Y coordinate (Y_7) of the positions G1 and G2 from information, etc. representing the position of the Y-axis movable table 20, i.e., the chuck table 36, at the time the height of the area including the side 11e and the side 11f of the workpiece 11 is measured.

Specifically, the processor 50a calculates the X coordinate (X_{71}) of the position G1 where the third straight line 31c and the side 11e intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_7) of the position G1 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11e and the side 11f of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{71} , Y_7) of the

position G1 in the storage unit 50b.

In addition, the processor 50a calculates the X coordinate (X_{72}) of the position G2 where the third straight line 31c and the side 11f intersect with each other, from the displacement information obtained by the measurements, and also calculates the Y coordinate (Y_7) of the position G2 from information, etc. representing the position of the Y-axis movable table 20 at the time the height of the area including the side 11e and the side 11f of the workpiece 11 is measured. The processor 50a then stores the calculated coordinates (X_{72} , Y_7) of the position G2 in the storage unit 50b.

After second coordinate acquiring step ST22, the control unit 50 carries out orientation acquiring step ST23 (see FIG. 9) for acquiring the orientation of one of two opposite sides of the workpiece 11, from the two sets of XY coordinates that are acquired in first coordinate acquiring step ST21 and that represent the two positions where one of the two opposite sides and the two straight lines intersect with each other.

For example, the processor 50a calculates an angle θ_2 formed between the side 11c and the Y directions, by applying trigonometry to the coordinates (X_{51} , Y_5) of the position E1 where the side 11c and the first straight

line 31a intersect with each other and the coordinates (X_{61}, Y_6) of the position F1 where the side 11c and the second straight line 31b intersect with each other. The processor 50a stores the calculated angle θ_2 in the storage unit 50b, as the orientation of the side 11c.

The processor 50a may alternatively calculate the angle between the side 11c and the X directions as the orientation of the side 11c. The processor 50a may further alternatively calculate the angle between the side 11d and the Y directions or the X directions by applying trigonometry to the coordinates (X_{52}, Y_5) of the position E2 where the side 11d and the first straight line 31a intersect with each other and the coordinates (X_{62}, Y_6) of the position F2 where the side 11d and the second straight line 31b intersect with each other.

After orientation acquiring step ST23, the control unit 50 carries out corrected coordinate acquiring step ST24 for acquiring corrected coordinates by correcting either the two sets of XY coordinates acquired in first coordinate acquiring step ST21 and the two sets of XY coordinates acquired in second coordinate acquiring step ST22, on the basis of the orientation of the side acquired in orientation acquiring step ST23.

Specifically, for example, the processor 50a

carries out an arithmetic process for turning the coordinates (X_{51}, Y_5) of the position E1 where the side 11c and the first straight line 31a intersect with each other and the coordinates (X_{52}, Y_5) of the position E2 where the side 11d and the first straight line 31a intersect with each other through an angle of θ_2 , i.e., through the angle of θ_2 clockwise as viewed in plan according to the present modification, thereby acquiring coordinates of the position E1 that have been corrected and coordinates of the position E2 that have been corrected, i.e., corrected coordinates of the position E1 and corrected coordinates of the position E2. The processor 50a stores the corrected coordinates of the position E1 and the corrected coordinates of the position E2 that have been acquired in the storage unit 50b.

The processor 50a may alternatively carry out an arithmetic process for turning the coordinates (X_{61}, Y_6) of the position F1 where the side 11c and the second straight line 31b intersect with each other and the coordinates (X_{62}, Y_6) of the position F2 where the side 11d and the second straight line 31b intersect with each other through the angle of θ_2 , i.e., through the angle of θ_2 clockwise as viewed in plan according to the present modification, thereby acquiring corrected coordinates of

the position F1 and corrected coordinates of the position F2.

Further, the processor 50a carries out an arithmetic process for turning the coordinates (X_{71} , Y_7) of the position G1 where the side 11e and the third straight line 31c intersect with each other and the coordinates (X_{72} , Y_7) of the position G2 where the side 11f and the third straight line 31c intersect with each other through an angle of $\theta_2 - 90^\circ$, i.e., through the angle of $\theta_2 - 90^\circ$ clockwise as viewed in plan according to the present modification, thereby acquiring corrected coordinates of the position G1 and corrected coordinates of the position G2. The processor 50a stores the corrected coordinates of the position G1 and the corrected coordinates of the position G2 that have been acquired in the storage unit 50b.

The corrected coordinates thus acquired indicate the position E1, the position E2, the position G1, and the position G2 with the orientation of the side 11c being adjusted parallel to the Y directions. Using the coordinates thus corrected, the workpiece 11 can be processed accurately. The control unit 50 may acquire corrected coordinates indicating the positions with the orientation of the side 11c being adjusted

perpendicularly to the Y directions, according to a similar process.

After corrected coordinate acquiring step ST24, the control unit 50 carries out processing step ST25 for processing the workpiece 11 with use of using the information regarding the position and the orientation of the workpiece 11 that has been acquired in the above sequence of acquiring steps including first coordinate acquiring step ST21, second coordinate acquiring step ST22, orientation acquiring step ST23, and corrected coordinate acquiring step ST24. Specifically, the workpiece 11 is processed on the basis of the orientation of the sides and the four sets of XY coordinates representing the positions of the sides. Specific details of processing step ST25 may be the same as those of processing step ST15 according to the above embodiment.

With the method of processing a workpiece according to the first modification, inasmuch as the orientation of the side, i.e., the side 11c, of the first surface 11a of the workpiece 11, and the four sets of the XY coordinates of the positions, i.e., the position E1, the position E2, the position G1, and the position G2, on the four sides, i.e., the side 11c, the side 11d, the side 11e, and the side 11f, of the first surface 11a, are acquired, the

workpiece 11 can be processed with high accuracy on the basis of the acquired orientation and four sets of the XY coordinates.

With the method of processing a workpiece according to the first modification, further, since the orientation of the side and the four sets of the XY coordinates are acquired using the displacement measuring instrument 48 that measures the distance up to an object, the position of the workpiece 11 can accurately be grasped even if the workpiece 11 is transparent or structures such as devices, i.e., a pattern, are not formed on the workpiece 11.

Consequently, the method of processing a workpiece according to the first modification is highly effective in a case where the laser beam 44a is not to be applied to an outer circumferential edge of the workpiece 11 when the workpiece 11 is to be processed, for example. The method of processing a workpiece according to the first modification is also able to prevent the laser beam 44a from being applied in error to a region outside of the workpiece 11, for example.

According to the embodiment described above, the control unit 50 acquires the orientation of the sides of the first surface 11a of the workpiece 11 by obtaining

displacement information with use of the displacement measuring instrument 48. However, the control unit 50 may acquire the orientation of a side of the first surface 11a, according to a second modification in which the camera 46 is used to capture an image of the workpiece 11, for example.

According to the second modification, specifically, a method of processing a workpiece includes an orientation acquiring step in which the processor 50a acquires the orientation of a side of the workpiece 11 by calculating the coordinates of two positions on the side, from an image captured by the camera 46 of an area including the side of the workpiece 11. The method of processing a workpiece according to the second modification includes other steps that may be the same as those of the method of processing a workpiece according to the embodiment described above.

In the above embodiment and modifications, second coordinate acquiring step ST13 and second coordinate acquiring step ST22 are carried out after first coordinate acquiring step ST12 and first coordinate acquiring step ST21. However, these steps may be switched around. According to the first modification, furthermore, orientation acquiring step ST23 is carried out after

second coordinate acquiring step ST22. However, orientation acquiring step ST23 may be carried out after first coordinate acquiring step ST21 and before second coordinate acquiring step ST22.

In the above embodiment and modifications, moreover, the modified layers 17 are formed in the workpiece 11 in processing step S15 and processing step S25. According to the present invention, the workpiece 11 may be ablated by a laser beam in the processing step. In this case, a laser processing apparatus having a laser oscillator for generating a laser beam having a wavelength absorbable by the workpiece 11, i.e., an absorbable laser beam is used to process the workpiece 11.

According to the present invention, the workpiece 11 can be processed by an annular cutting blade made of abrasive grains bound by a binder, i.e., a processing unit, such that the annular cutting blade is caused to cut into the workpiece 11 while in rotation. In this case, a cutting apparatus having a spindle with an annular cutting blade mounted thereon, i.e., a processing apparatus having a processing unit, instead of the irradiating head 44 or the laser oscillator, is used to process the workpiece 11.

In the above embodiment and modifications, the optical displacement measuring instrument 48 is used to measure the distance up to an object with the laser beam 48a. However, a back-pressure sensor, an ultrasonic sensor, or the like can be used as a displacement measuring instrument, i.e., a measuring instrument, instead of the optical displacement measuring instrument 48.

In the methods of processing a workpiece according to the embodiment and modifications described above, the X directions and the Y directions may be switched around insofar as no contradictory results are achieved. For example, according to the above embodiment and modifications, the height of an area including any desired side is measured by moving the chuck table 36 and the displacement measuring instrument 48 relatively to each other in the X directions. However, the height of an area including any desired side can be measured by moving the chuck table 36 and the displacement measuring instrument 48 relatively to each other in the Y directions.

Further, the coordinates of a desired position on the workpiece, e.g., the coordinates of the center of gravity of the workpiece 11, may be acquired on the basis

of the orientation of the sides and the four sets of XY coordinates that are acquired according to the above embodiment and modifications, and may be used in subsequently processing the workpiece 11.

The structures, methods, etc. according to the above embodiment and modifications may be changed or modified within the scope of the object of the present invention.

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 method of processing a plate-shaped workpiece having a first rectangular surface having four sides and a second rectangular surface positioned opposite the first surface, with use of a chuck table having a holding surface and of a processing unit for processing the workpiece held on the chuck table, the method comprising:

an acquiring step for, while the second surface of the workpiece is being held on the holding surface of the chuck table, acquiring an orientation of the four sides of the workpiece in an XY plane parallel to the holding surface and four sets of XY coordinates indicating positions of the four sides in the XY plane, from displacement information obtained by measuring a height of an area including the four sides of the workpiece; and

a processing step for processing the workpiece on a basis of the orientation of the sides and the four sets of XY coordinates.

2. The method of processing a workpiece according to claim 1, wherein

the acquiring step further includes

an orientation acquiring step for moving a measuring instrument for measuring a height and the chuck table relatively to each other to thereby measure a

height of an area including a side of the workpiece on two straight lines that extend through different positions in Y directions and that are parallel to X directions, and calculating XY coordinates indicating two positions where the side and the two straight lines intersect with each other, from obtained displacement information, to acquire an orientation of the side,

a first coordinate acquiring step for adjusting an orientation of the chuck table about a rotational axis perpendicular to the XY plane in order to make the orientation of the side acquired in the orientation acquiring step parallel to the Y directions, then moving the measuring instrument and the chuck table relatively to each other to thereby measure a height of an area including two opposite sides of the workpiece on a straight line parallel to the X directions, and acquiring two sets of XY coordinates indicating two positions where the two opposite sides and the straight line intersect with each other, from obtained displacement information, and

a second coordinate acquiring step for adjusting the orientation of the chuck table about the rotational axis in order to make the orientation of the side acquired in the orientation acquiring step

perpendicular to the Y directions, then moving the measuring instrument and the chuck table relatively to each other to thereby measure a height of an area including other two opposite sides of the workpiece on a straight line parallel to the X directions, and acquiring two sets of XY coordinates indicating two positions where the other two opposite sides and the straight line intersect with each other, from obtained displacement information.

3. The method of processing a workpiece according to claim 1, wherein

the acquiring step further includes

a first coordinate acquiring step for moving a measuring instrument for measuring a height and the chuck table relatively to each other to thereby measure a height of an area including two opposite sides of the workpiece on two straight lines that extend through different positions in Y directions and that are parallel to X directions, and acquiring three or more sets of XY coordinates indicating three or more positions where the two opposite sides and the two straight lines intersect with each other, from obtained displacement information,

a second coordinate acquiring step for, while an orientation of the chuck table about a

rotational axis perpendicular to the XY plane is perpendicular to an orientation of the chuck table in the first coordinate acquiring step, moving the measuring instrument and the chuck table relatively to each other to thereby measure a height of an area including other two opposite sides of the workpiece on a straight line parallel to the X directions, and acquiring two sets of XY coordinates indicating two positions where the other two opposite sides and the straight line intersect with each other, from obtained displacement information,

an orientation acquiring step for acquiring an orientation of one of the two opposite sides from the two sets of XY coordinates that are acquired in the first coordinate acquiring step and that indicate two positions where one of the two opposite sides and the two straight lines intersect with each other, and

a corrected coordinate acquiring step for correcting the two sets of XY coordinates that are acquired in the first coordinate acquiring step and that indicate two positions where the two opposite sides and one of the straight lines intersect each other and correcting the two sets of XY coordinates acquired in the second coordinate acquiring step, on a basis of the orientation of the side acquired in the orientation

acquiring step, and acquiring corrected four sets of XY coordinates.

4. A method of processing a plate-shaped workpiece having a first rectangular surface having four sides and a second rectangular surface positioned opposite the first surface, with use of a chuck table having a holding surface and of a processing unit for processing the workpiece held on the chuck table, the method comprising:

an acquiring step for, while the second surface of the workpiece is being held on the holding surface of the chuck table, acquiring an orientation of a side of the workpiece in an XY plane parallel to the holding surface, from an image captured of an area including the side of the workpiece, and acquiring four sets of XY coordinates indicating positions of the four sides of the workpiece in the XY plane, from displacement information obtained by measuring a height of an area including the four sides of the workpiece; and

a processing step for processing the workpiece on a basis of the orientation of the side and the four sets of XY coordinates.