

PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a processing apparatus for processing a reverse side of a workpiece while a face side of the workpiece with a predetermined pattern formed thereon is being held on a holding table.

Description of the Related Art

Semiconductor device chips for use in electric appliances such as mobile phones and personal computers are manufactured by processing disk-shaped wafers, referred to as workpieces, made of a semiconductor material such as silicon. The workpieces have a plurality of projected dicing lines established on their face sides with devices such as integrated circuits (ICs), large scale integration (LSI) circuits, or micro electro mechanical systems (MEMS) formed respectively in areas demarcated by the projected dicing lines. For fabricating device chips from a workpiece, a reverse side of the workpiece is ground to thin the workpiece to a predetermined thickness, and thereafter the workpiece is cut along the projected dicing lines to divide itself into device chips including respective devices.

In a cutting process, the workpiece is cut by a cutting apparatus including a cutting unit including a cutting blade mounted on an end of a spindle and a holding table for holding the workpiece under suction thereon. According to a normal cutting process, the workpiece is held under suction on the holding table with the reverse side held against the holding table and the face side facing upwardly. Thereafter, a camera disposed above the holding table captures an image of the face side of the workpiece, and an alignment process for positioning the workpiece and the cutting blade with respect to each other is carried out on the basis of the captured image. As the camera captures the image with visible light, the camera has an image capturing device such as a charge-coupled device (CCD) image sensor or a complementary metal-oxide-semiconductor (CMOS) image sensor. The alignment process, which may include a process of correcting the position of the workpiece with respect to the cutting unit, is carried out on the basis of the captured image of the face side of the workpiece that includes an alignment mark or the like. After the alignment process, the workpiece is cut along the projected dicing lines by the cutting blade.

In recent years, however, diversification of

devices has led to some workpieces that need to be cut from their reverse sides (see, for example, JP 2006-140341A). Such a workpiece is held on a holding table with a face side thereof held against the holding table. Therefore, a camera disposed above the holding table is unable to capture an image of the face side with an alignment mark or the like thereon as the camera captures an image of an upwardly facing reverse side of the workpiece. To circumvent the problem, there has been developed a cutting apparatus including a holding table made of a material that is transparent to visible light and a visible-light camera disposed below the holding table (see, for example, JP 2010-87141A). The cutting apparatus allows the camera to capture, from below the holding surface, a face side of a workpiece held on the holding table with the face side held against the holding table. Therefore, the cutting apparatus can perform an alignment process while the face side of the workpiece is being held on the holding table with the reverse side facing upwardly.

SUMMARY OF THE INVENTION

However, even with the cutting apparatus that includes the camera disposed below the holding table, the

operator may not be able to confirm whether or not cut grooves formed in the workpiece extend along projected dicing lines. Specifically, when cut grooves, i.e., half-cut grooves, are formed partly in the workpiece to a certain depth from the reverse side to the face side of the workpiece, the operator cannot confirm whether or not the cut grooves extend along projected dicing lines established on the face side of the workpiece.

It is therefore an object of the present invention to provide a processing apparatus that allows the operator to confirm whether or not cut grooves formed in a reverse side of a workpiece extend along projected dicing lines established on a face side of the workpiece.

In accordance with an aspect of the present invention, there is provided a processing apparatus including a plate-shaped holding table for holding a workpiece having a face side with a predetermined pattern formed thereon and a reverse side opposite the face side, the holding table including a surface and another surface positioned opposite the surface and having a predetermined region made of a transparent material from the surface to the other surface, a processing unit for processing the workpiece while the face side is being held on the surface of the holding table and the reverse

side is being exposed upwardly, a first image capturing unit disposed above the holding table in facing relation to the surface of the holding table, a second image capturing unit disposed below the holding table in facing relation to the other surface of the holding table, a display unit for displaying an image captured by at least either one of the first image capturing unit and the second image capturing unit, and a controller for displaying, on the display unit, the predetermined pattern included in a second region on the face side that corresponds to a first region on the reverse side of the workpiece in a thicknesswise direction thereof in overlapping relation to an image of the first region, the controller including a storage section for storing positional information of the predetermined pattern in an image of the face side of the workpiece that is captured by the second image capturing unit while the face side is being held on the surface of the holding table.

Preferably, the image of the first region displayed on the display unit includes a region representing processed grooves formed in the workpiece by the processing unit, and the controller displays the predetermined pattern in the second region over the image of the first region including the region representing the

processed grooves on the display unit.

Preferably, the image of the second region is displayed on the display unit, the image of the first region includes the region representing the processed grooves formed in the workpiece by the processing unit, and the controller displays a region representing at least the processed grooves in the image of the first region over the image of the second region on the display unit.

Preferably, the controller displays the image of the first region and the image of the second region overlappingly on the display unit while X-axis directions and Y-axis directions of the images of the first and second regions are of the same orientations as each other.

Preferably, the processing unit includes a cutting unit with a cutting blade mounted thereon for cutting the workpiece or a laser beam applying unit for applying a laser beam to the workpiece.

The holding table of the processing apparatus according to the aspect of the present invention has the predetermined region made of a transparent material from the surface to the other surface. The first image capturing unit is disposed above the holding table in

facing relation to the surface of the holding table, and the second image capturing unit is disposed below the holding table in facing relation to the other surface of the holding table. The controller includes the storage section for storing positional information of the predetermined pattern in an image of the face side that is captured by the second image capturing unit while the face side is being held on the surface of the holding table. The controller displays, on the display unit, the predetermined pattern included in the second region on the face side that corresponds to the first region on the reverse side of the workpiece in the thicknesswise direction thereof in overlapping relation to the image of the first region. Therefore, the operator of the processing apparatus can confirm whether or not grooves formed in the workpiece extend along the projected dicing lines.

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 embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a cutting apparatus as a processing apparatus according to a first embodiment of the present invention;

FIG. 2 is a perspective view of a workpiece unit including a workpiece to be processed by the cutting apparatus;

FIG. 3 is a perspective view of a holding table and other components of the cutting apparatus;

FIG. 4 is a side elevational view, partly in cross section, of the holding table and other components of the cutting apparatus;

FIG. 5 is an enlarged view of a section A illustrated in FIG. 4;

FIG. 6 is an enlarged perspective view of a Z-axis moving mechanism and other components of the cutting apparatus;

FIG. 7 is a view illustrating a cutting step performed by the cutting apparatus;

FIG. 8 is a view illustrating a reverse side displaying step performed by the cutting apparatus;

FIG. 9A is a view illustrating an example of an image of a first region;

FIG. 9B is a view illustrating an example of an image of a second region;

FIG. 10 is a view illustrating an example of an image displayed in the reverse side displaying step;

FIG. 11 is a view illustrating another example of an image displayed in the reverse side displaying step; and

FIG. 12 is a perspective view of a laser processing apparatus as a processing apparatus according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below with reference to the accompanying drawings. FIG. 1 illustrates in perspective a cutting apparatus 2 as a processing apparatus according to a first embodiment of the present invention. In FIG. 1, some components are illustrated in block form. X-axis directions, i.e., horizontal processing feed directions, including a + X direction and a - X direction, Y-axis directions, i.e., horizontal indexing feed directions, that including a + Y direction and a - Y direction, and Z-axis directions, i.e., vertical incising feed directions, including a + Z direction and a - Z direction

to be described below with reference to the drawings are perpendicular to each other. The cutting apparatus 2 has a base block 4 that supports thereon various components of the cutting apparatus 2. The base block 4 has an upwardly open opening 4a defined in a front corner thereof in the + Y direction with a cassette elevator, not depicted, movably disposed therein. The cassette elevator has an upper surface on which there is placed a cassette 6 housing a plurality of workpieces 11 (see FIG. 2) therein.

In FIG. 1, only the profile of the cassette 6 is depicted for illustrative purposes. According to the present embodiment, the workpiece 11 is in the form of a disk-shaped wafers made of a semiconductor material such as silicon. However, the workpiece 11 is not limited to any material, shape, structure, size, etc. The workpiece 11 may be, for example, a substrate made of another semiconductor material, ceramic, resin, metal, or the like. As illustrated in FIG. 2, the workpiece 11 has a face side 11a on a lower surface thereof having a plurality of areas demarcated by a plurality of projected dicing lines or streets 13. Devices 15 such as ICs, alignment marks 98 (see FIG. 9B) and the like are formed in the demarcated areas on the face side 11a. However,

the devices 15 are not limited to any kind, number, shape, structure, size, layout, etc. Furthermore, the workpiece 11 may be free of the devices 15.

A circular tape, i.e., a circular dicing tape, 17 that is larger in diameter than the workpiece 11 is affixed to the face side 11a of the workpiece 11. The tape 17 is made of a transparent material through which visible light can be transmitted. The tape 17 has is of a layered structure including a base layer and an adhesive layer or glue layer, for example. The base layer is made of polyolefin (PO) or the like, for example. The adhesive layer is made of an adhesive resin such as ultraviolet-curable acrylic resin, for example. The adhesive layer of the tape 17 is affixed to the face side 11a of the workpiece 11.

The tape 17 has an outer circumferential portion to which an annular frame 19 of metal is affixed. The workpiece 11 is thus supported on the frame 19 by the tape 17. The entire assembly including the workpiece 11, the tape 17, and the frame 19 is referred to as a workpiece unit 21. The workpiece unit 21 is stored in the cassette 6. FIG. 2 illustrates the workpiece unit 21 in perspective.

As illustrated in FIG. 1, the base block 4 has an

upwardly open opening 4b defined therein behind the opening 4a in the - Y direction. The opening 4b is elongate in the X-axis directions. A holding table or chuck table 10 is movably disposed in the opening 4b. The holding table 10 includes an annular frame suction plate, not depicted, disposed on an outer circumferential portion thereof and having a plurality of suction ports defined therein at circumferentially spaced intervals.

The holding table 10 and other components will hereinafter be described in detail with reference to FIGS. 3 through 5. FIG. 3 illustrates the holding table 10 and other components in perspective. FIG. 4 illustrates the holding table 10 and other components in side elevation, partly in cross section. In FIG. 4, hatching is omitted for convenience of description. FIG. 5 illustrates at an enlarged scale a section A illustrated in FIG. 4. In FIG. 5, a component is illustrated in block form. The holding table 10 has a holding member 12 constructed as a disk-shaped plate. The holding member 12 has a generally flat surface 12a and another surface 12b (see FIG. 5) positioned opposite the surface 12a. The holding member 12 is made of a transparent material through which visible light can be transmitted, such as soda glass, borosilicate glass, or

quartz glass.

The holding member 12 has a plurality of fluid channels defined therein. Specifically, the fluid channels include a straight first suction channel 12c₁ extending diametrically across the holding member 12 through the central axis of the disk shape thereof, as viewed along the Z-axis directions, and a straight second suction channel 12c₂ extending diametrically across the holding member 12 through the central axis of the disk shape thereof perpendicularly to the first suction channel 12c₁ in an XY plane defined by the X-axis directions and the Y-axis directions. The first suction channel 12c₁ and the second suction channel 12c₂ intersect with each other at a point 12c₃ positioned at the central axis of the disk shape of the holding member 12, and are connected to each other. The holding member 12 also has a plurality of openings 12d defined in an outer circumferential portion thereof at circumferentially spaced intervals. The openings 12d have upper ends open at the surface 12a and extend from the surface 12a to a predetermined depth in the holding member 12 where the openings 12d terminate short of the other surface 12b.

Some of the openings 12d are defined respectively at both ends of the first suction channel 12c₁ and both

ends of the second suction channel 12c₂ and are connected thereto. The openings 12d are interconnected in circumferential directions of the holding member 12 by an outer circumferential suction channel 12e defined in an outer circumferential portion of the holding member 12 at the predetermined depth. The openings 12d are also connected to a suction channel 12f defined in the holding member 12 and extending radially outwardly. A suction source 14 (see FIG. 5) such as an ejector is connected to the suction channel 12f. When the suction source 14 is actuated, it generates a negative pressure that acts in the openings 12d through the suction channel 12f. Therefore, the surface 12a of the holding member 12 where the openings 12d are functions as a holding surface for holding the workpiece unit 21, i.e., the workpiece 11, under suction thereon.

The fluid channels in the holding member 12, which include the first suction channel 12c₁, the second suction channel 12c₂, the openings 12d, the outer circumferential suction channel 12e, and the suction channel 12f, disperse or reflect light that is applied to the holding member 12. Therefore, the fluid channels in the holding member 12, as they are viewed from the surface 12a or the other surface 12b, may not be completely transparent to

visible light, but may be transmissive of light or may be opaque to light. However, regions of the holding member 12 except these fluid channels are transparent from the surface 12a to the other surface 12b. Specifically, four regions of the holding member 12 that are divided by the first suction channel 12c₁ and the second suction channel 12c₂ and that are positioned radially inwardly of the outer circumferential suction channel 12e are transparent from the surface 12a to the other surface 12b.

A hollow cylindrical frame 16 made of a metal material such as stainless steel is disposed on an outer circumferential surface of the holding member 12. The frame 16 has an opening 16a (see FIG. 5) defined in an upper portion thereof. The holding member 12 is disposed on the frame 16 in covering relation to the opening 16a. As illustrated in FIGS. 3 and 4, the frame 16 is supported on an X-axis movable table 18. The X-axis movable table 18 includes a horizontal bottom plate 18a that is of a rectangular shape as viewed along the Z-axis directions. The X-axis movable table 18 also includes a vertical side plate 18b that is of a rectangular shape as viewed along the Y-axis directions and that has a lower end joined to a front end of the bottom plate 18a in the + Y direction, and a top plate 18c that is of a

rectangular shape as viewed along the Z-axis directions as with the bottom plate 18a and that has a front end joined to an upper end of the side plate 18b.

The bottom plate 18a and the top plate 18c jointly define a space 18d therebetween that is open at a rear end thereof in the - Y direction and also at both side ends thereof in the X-axis directions. The bottom plate 18a is slidable on and along a pair of X-axis guide rails 20 disposed below the bottom plate 18a in the - Z direction and extending generally parallel to each other in the X-axis directions. The X-axis guide rails 20 are fixedly mounted on an upper surface of a stationary base, not depicted.

An X-axis linear scale 20a for use in the detection of the position of the X-axis movable table 18 in the X-axis directions is disposed adjacent to and extends along one of the X-axis guide rails 20. A reading head, not depicted, is mounted on a lower surface of the X-axis movable table 18 in facing relation to the X-axis linear scale 20a. When the X-axis movable table 18 moves in one of the X-axis directions along the X-axis guide rails 20, the reading head reads graduations of the X-axis linear scale 20a for the calculation of the position or coordinate in the X-axis directions of the X-axis movable

table 18 and the distance that the X-axis movable table 18 has moved in the X-axis directions.

A nut, not depicted, is mounted on a lower surface of the bottom plate 18a of the X-axis movable table 18 and is operatively threaded over an X-axis ball screw 22 disposed between and extending generally parallel to the X-axis guide rails 20. The X-axis ball screw 22 has an end coupled to an X-axis stepping motor 24. When the X-axis stepping motor 24 is energized, it rotates the X-axis ball screw 22 about its central axis, causing the nut to move the X-axis movable table 18 in one of the X-axis directions along the X-axis guide rails 20. The X-axis guide rails 20, the X-axis ball screw 22, the X-axis stepping motor 24, etc., jointly make up an X-axis moving mechanism 26 for moving the X-axis movable table 18 along the X-axis guide rails 20.

The frame 16 is rotatably supported on an upper surface of the top plate 18c of the X-axis movable table 18 for rotation about a central axis generally parallel to the Z-axis directions. The frame 16 includes a pulley portion 16b defined by a cylindrical side surface thereof. The pulley portion 16b of the frame 16 that is supported on the X-axis movable table 18 is positioned above the top plate 18c thereof. A rotary actuator 30

such as an electric motor is mounted on the side plate 18b of the X-axis movable table 18. The rotary actuator 30 has a rotational shaft with a pulley 30a mounted thereon. An endless belt 28 is trained around the pulley 30a and the pulley portion 16b.

When the rotary actuator 30 is energized, it rotates its rotational shaft, rotating the pulley 30a to move the endless belt 28 to rotate the frame 16 and hence the holding table 10 about their central axis generally parallel to the Z-axis directions. By controlling the rotation of the pulley 30a, it is possible to turn the holding table 10 through a desired angle about the central axis. A Y-axis moving mechanism 32 is disposed on extension of the X-axis moving mechanism 26 in the X-axis directions. The Y-axis moving mechanism 32 includes a pair of Y-axis guide rails 34 extending generally parallel to each other in the Y-axis directions. The Y-axis guide rails 34 are fixedly mounted on the upper surface of the stationary base, not depicted.

A Y-axis movable table 36 is slidable on and along the Y-axis guide rails 34. A nut, not depicted, is mounted on a lower surface of the Y-axis movable table 36 and is operatively threaded over a Y-axis ball screw 38 disposed between and extending generally parallel to the

Y-axis guide rails 34. The Y-axis ball screw 38 has an end coupled to a Y-axis stepping motor 40. When the Y-axis stepping motor 40 is energized, it rotates the Y-axis ball screw 38 about its central axis, causing the nut to move the Y-axis movable table 36 in one of the Y-axis directions along the Y-axis guide rails 34. The Y-axis guide rails 34, the Y-axis ball screw 38, the Y-axis stepping motor 40, etc., jointly make up the Y-axis moving mechanism 32 for moving the Y-axis movable table 36 along the Y-axis guide rails 34.

A Y-axis linear scale, not depicted, for use in the detection of the position of the Y-axis movable table 36 in the Y-axis directions is disposed adjacent to and extends along one of the Y-axis guide rails 34. A reading head, not depicted, is mounted on a lower surface of the Y-axis movable table 36 in facing relation to the Y-axis linear scale. When the Y-axis movable table 36 moves in one of the Y-axis directions along the Y-axis guide rails 34, the reading head reads graduations of the Y-axis linear scale for the calculation of the position or coordinate in the Y-axis directions of the Y-axis movable table 36 and the distance that the Y-axis movable table 36 has moved in the Y-axis directions.

A Z-axis moving mechanism 42 is disposed on an

upper surface of the Y-axis movable table 36. FIG. 6 illustrates the Z-axis moving mechanism 42 and other components in enlarged perspective. The Z-axis moving mechanism 42 has a support structure 42a fixed to the upper surface of the Y-axis movable table 36. A pair of Z-axis guide rails 44 that extend generally parallel to the Z-axis directions are fixed to a side surface of the support structure 42a that faces the X-axis movable table 18. A Z-axis moving plate 46 is slidable on and along the Z-axis guide rails 44.

A nut, not depicted, is mounted on a side surface of the Z-axis moving plate 46 that faces the support structure 42a and is operatively threaded over a Z-axis ball screw 48 disposed between and extending generally parallel to the Z-axis guide rails 44. The Z-axis ball screw 48 has an end coupled to a Z-axis stepping motor 50. When the Z-axis stepping motor 50 is energized, it rotates the Z-axis ball screw 48 about its central axis, causing the nut to move the Z-axis moving plate 46 in one of the Z-axis directions along the Z-axis guide rails 44. The support structure 42a, the Z-axis guide rails 44, the Z-axis ball screw 48, the Z-axis stepping motor 50, etc., jointly make up the Z-axis moving mechanism 42 for moving the Z-axis moving plate 46 along the Z-axis guide rails

44.

A Z-axis linear scale, not depicted, for use in the detection of the position of the Z-axis moving plate 46 in the Z-axis directions is disposed adjacent to and extends along one of the Z-axis guide rails 44. A reading head, not depicted, is mounted on a side surface of the Z-axis moving plate 46 in facing relation to the Z-axis linear scale. When the Z-axis moving plate 46 moves in one of the Z-axis directions along the Z-axis guide rails 44, the reading head reads graduations of the Z-axis linear scale for the calculation of the position or coordinate in the Z-axis directions of the Z-axis moving plate 46 and the distance that the Z-axis moving plate 46 has moved in the Z-axis directions.

A lower image capturing unit, i.e., a second image capturing unit, 54 is fixed to the Z-axis moving plate 46 by a support arm 52 that is elongate in the X-axis directions. The lower image capturing unit 54 is disposed in a position lower than the holding table 10, and includes a low-magnification camera 56 and a high-magnification camera 58 both having image capturing lenses, etc., disposed opposite the other surface 12b of the holding member 12. However, the lower image capturing unit 54 may not have two cameras, i.e., the low-

magnification camera 56 and the high-magnification camera 58, but may have a single camera having a predetermined magnification.

Each of the low-magnification camera 56 and the high-magnification camera 58 includes an optical system and an image capturing device such as a CCD image sensor or a CMOS image sensor. An illuminating apparatus 56a for applying visible light to a subject positioned above, e.g., the workpiece 11, is disposed alongside of the low-magnification camera 56. Similarly, an illuminating apparatus 58a for applying visible light to a subject positioned above, i.e., the workpiece 11, is disposed alongside of the high-magnification camera 58. For capturing an image of the subject with the lower image capturing unit 54, the X-axis movable table 18 is moved toward the Y-axis movable table 36 until the lower image capturing unit 54 is placed in the space 18d in the X-axis movable table 18. Then, the lower image capturing unit 54 can capture an image of the subject, i.e., the workpiece 11, placed on the surface 12a of the holding member 12 from below the holding member 12.

Other components of the cutting apparatus 2 will be described below with reference to FIG. 1. Bellows-shaped dust- and drip-resistant covers that are flexibly

extensible and contractible are disposed in the opening 4b in covering relation thereto on respective left and right sides of the top plate 18c of the X-axis movable table 18 in the + X direction and the - X direction. A portal-shaped support structure 4c is mounted on an upper surface of the base block 4 over and above the opening 4b. Two processing unit moving mechanisms 60, each including an indexing feed unit and an incising feed unit, are disposed on a side surface of the support structure 4c that faces an opening 4a side of the base block 4.

The processing unit moving mechanisms 60 share a pair of Y-axis guide rails 62 fixedly mounted on the side surface of the support structure 4c and extending generally parallel to the Y-axis directions. The processing unit moving mechanisms 60 include two Y-axis moving plates 64 slidably on and along the Y-axis guide rails 62 independently of each other. Nuts, not depicted, are mounted on respective surfaces of the Y-axis moving plates 64 that face the support structure 4c and are operatively threaded over respective Y-axis ball screws 66 disposed between and generally parallel to the Y-axis guide rails 62. Specifically, the nut mounted on one of the Y-axis moving plates 64 that is positioned forward in

the + Y direction is operatively threaded over one of the Y-axis ball screws 66, whereas the nut mounted on the other Y-axis moving plate 64 that is positioned rearward in the - Y direction is operatively threaded over the other Y-axis ball screw 66.

The Y-axis ball screws 66 have respective ends coupled to respective Y-axis stepping motors 68 (one depicted). When the Y-axis stepping motors 68 are energized, they rotate the respective Y-axis ball screws 66 about their central axes, causing the nuts to move the Y-axis moving plates 64 in the Y-axis directions along the Y-axis guide rails 62. The Y-axis moving plates 64 support on their surfaces facing away from the support structure 4c respective pairs of Z-axis guide rails 72 extending generally parallel to the Z-axis directions. Z-axis moving plates 70 are slidable on and along the respective pairs of the Z-axis guide rails 72.

Nuts, not depicted, are mounted on respective surfaces of the Z-axis moving plates 70 that face the support structure 4c, i.e., the Y-axis moving plates 64, and are operatively threaded over respective Z-axis ball screws 74 disposed between and generally parallel to the pairs of the Z-axis guide rails 72. The Z-axis ball screws 74 have respective ends coupled to respective Z-

axis stepping motors 76. When the Z-axis stepping motors 76 are energized, they rotate the Z-axis ball screws 74 about their central axes, causing the nuts to move the Z-axis moving plates 70 in the Z-axis directions along the Z-axis guide rails 72.

Two cutting units, i.e., processing units, 78 are mounted on respective lower portions of the Z-axis moving plates 70. Each of the cutting units 78 includes a tubular spindle housing 80 in which a portion of a cylindrical spindle 82a (see FIG. 7) is rotatably housed. The spindle 82a has an end coupled to a rotating mechanism, not depicted, such as a servomotor for rotating the spindle 82a about its central axis. A cutting blade 82b having an annular cutting edge is mounted on the other end of the spindle 82a.

Upper image capturing units, i.e., first image capturing units, 84 are coupled to respective lower portions of the Z-axis moving plates 70 adjacent to the cutting units 78. The upper image capturing units 84 are positioned above the holding table 10 and have image capturing lenses, etc., disposed opposite the surface 12a of the holding member 12. The upper image capturing units 84 include respective optical systems and respective image capturing devices such as CCD or CMOS image sensors

for capturing an image of the workpiece 11 from above.

The base block 4 also has an upwardly open opening 4d defined therein that is positioned across the opening 4b from the opening 4a. The opening 4d houses therein a cleaning unit 86 for cleaning a workpiece 11, etc., after it has been cut. The cleaning unit 86 includes a cleaning table 88 for holding the workpiece 11 thereon and a nozzle 90 having an ejection nozzle facing the cleaning table 88.

The base block 4 supports thereon a casing, not depicted, having a front side surface on which there is disposed a touch panel or display panel 92 that functions as both an input apparatus and a display apparatus. The touch panel 92 displays images captured by the lower image capturing unit 54 and the upper image capturing unit 84, processing conditions, buttons of graphical user interface (GUI), etc. The cutting apparatus 2 includes a controller 94 for controlling the suction source 14, the X-axis moving mechanism 26, the rotary actuator 30, the Y-axis moving mechanism 32, the Z-axis moving mechanism 42, the lower image capturing unit 54, the processing unit moving mechanisms 60, the upper image capturing units 84, the cutting units 78, the touch panel 92, etc.

The controller 94 is arranged as a computer

including a processing apparatus such as a central processing unit (CPU), a main storage apparatus such as a dynamic random access memory (DRAM), and an auxiliary storage apparatus such as a flash memory or a hard disk drive. The functions of the controller 94 are performed by the processing apparatus, etc., as it operates according to software stored in the auxiliary storage apparatus. Part of the auxiliary storage apparatus functions as a storage section 96. The storage section 96 stores therein software for carrying out an image processing process such as a pattern matching process. For example, a predetermined pattern on the face side 11a of the workpiece 11 is extracted from an image of the face side 11a that is captured by the lower image capturing unit 54 according to the image processing software. The predetermined pattern represents the profiles of the projected dicing lines 13, the devices 15, the marks 98, and circuits 100 (see FIG. 9B), for example. The marks 98 may also be referred to as alignment marks, key patterns, target patterns, or the like.

A processing process for processing the workpiece 11 will be described below with reference to FIGS. 7 through 10. First, the workpiece unit 21 with the reverse

side 11b exposed upwardly is placed on the surface 12a of the holding table 10 in placing step S10. After placing step S10, the suction source 14 is actuated to hold the face side 11a of the workpiece 11 under suction on the surface 12a with the tape 17 interposed therebetween, and the frame 19 is held on a frame suction plate, not depicted, in holding step S20. After holding step S20, teaching step S30 is carried out.

In teaching step S30, while an image of the face side 11a that is captured by the lower image capturing unit 54 is being displayed on the touch panel 92, the operator searches for a mark 98 (see FIG. 9B, etc.) on the face side 11a. After the operator has found a mark 98, an image of the face side 11a that includes the mark 98 is captured by the lower image capturing unit 54. The shape, coordinates, etc., of the mark 98 are stored as a template for a pattern matching process in the storage section 96. Distances calculated between the mark 98 and the central lines of projected dicing lines 13, using the coordinates, etc., of the mark 98 and the projected dicing lines 13 are also stored in the storage section 96.

A distance or street pitch calculated between two projected dicing lines 13 that are adjacent to each other

in the Y-axis directions, using the coordinates, etc., of marks 98, is also stored in the storage section 96. The stored coordinates, etc., represent XY coordinates in an XY coordinate system whose origin is represented by the point 12c₃. After teaching step S30, the alignment process for positioning the workpiece 11 is carried out in alignment step S40. In alignment step S40, images of the face side 11a are captured by the lower image capturing unit 54 at a plurality of locations that are spaced from each other on one of the projected dicing lines 13 along the X-axis directions.

Then, a pattern that is identical to the mark 98 stored as the template is detected in the images captured of the face side 11a at the plurality of locations according to a predetermined process such as a pattern matching process. An angular shift of the projected dicing line 13 in a θ direction about the central axis of the holding member 12 is specified on the basis of the pattern that is identical to the detected mark 98. Thereafter, the rotary actuator 30 is energized to move the belt 28 to turn the holding member 12 for thereby correcting the projected dicing line 13 out of the angular shift in the θ direction. In this manner, the projected dicing line 13 is oriented substantially

parallel to the X-axis directions. In alignment step S40, predetermined processes or operations other than the above process of correcting the projected dicing line 13 out of the angular shift in the θ direction may be carried out.

After alignment step S40, the lower image capturing unit 54 captures an image of the face side 11a, substantially in its entirety, of the workpiece 11 that is held on the holding table 10 in image acquiring step S50. In image acquiring step S50, an image of the face side 11a is captured while the relative positions of the holding table 10 and the lower image capturing unit 54 are being adjusted by the X-axis moving mechanism 26, the Y-axis moving mechanism 32, etc. In image acquiring step S50, however, an image of the face side 11a in its entirety may not necessarily be captured.

Specifically, the face side 11a includes a device region where the devices 15 are formed and an outer circumferential excess region surrounding the outer circumference of the device region. In image acquiring step S50, the lower image capturing unit 54 may capture only an image of the device region in its entirety or an image of a region including a mark 98 in the device region. Such a limited image acquiring region makes it

possible to reduce the time required to carry out image capturing step S50. After image acquiring step S50, the controller 94 performs an image processing process to detect edges of the acquired image. Next, the controller 94 calculates the degree of agreement between a geometrical shape defined by the edges and a pre-registered geometrical shape according to a predetermined process such as a pattern matching process, thereby extracting a predetermined pattern on the face side 11a.

The extracted predetermined pattern, positional information regarding the predetermined pattern, etc., are stored in the storage section 96 in storing step S60. For example, in a case where a mark 98 illustrated in FIG. 9B, etc., is used as a predetermined pattern, the shape of the mark 98 and the coordinates of corners B, C, D, etc., of the mark 98 that are positioned closely to the projected dicing lines 13 are stored in the storage section 96. At this time, the coordinates of at least any one of the projected dicing lines 13, the devices 15, and the circuits 100 whose relative positional relationship to the mark 98 have been determined in advance are also stored in the storage section 96.

The image of the face side 11a is stored in the storage section 96 in storing step S60 after its X- and

Y-axis directions have been made identical to the X- and Y-axis directions of the workpiece 11 as the reverse side 11b is viewed, i.e., as the workpiece 11 is viewed in plan, for example. The X- and Y-axis directions of the image of the face side 11a may be made identical to the X- and Y-axis directions of the image of the reverse side 11b by a predetermined coordinate transformation performed by the controller 94 on the image of the face side 11a, e.g., a mirror image conversion that inverts the image about the X-axis along the X-axis directions. The predetermined coordinate transformation is carried out according to predetermined software stored in the controller 94, for example.

Rather than performing the predetermined coordinate transformation, an image of the face side 11a may be captured via a mirror surface that is inclined 45 degrees to the X-axis in an XZ plane so that an image of the face side 11a that has been mirror-image-converted about the X-axis may be captured. According to the present embodiment in which the image capturing lenses of the lower image capturing unit 54 are disposed opposite the other surface 12b of the holding member 12, the mirror surface that is inclined 45 degrees to the X-axis in the XZ plane is disposed in a predetermined position between

the image capturing lenses of the lower image capturing unit 54 and the image capturing devices, not depicted, for example. Instead, the inclined mirror surface may be disposed between cover glass, not depicted, disposed opposite the other surface 12b and the image capturing lenses whose optical axes extend along the X-axis directions.

The mirror surface that is inclined 45 degrees to the X-axis in the XZ plane may alternatively be disposed outside of the lower image capturing unit 54 at a fixed position with respect to the lower image capturing unit 54. In this case, the optical axes of the image capturing lenses of the lower image capturing unit 54 extend along the X-axis directions so as to be directed toward the mirror surface. Any arbitrary XY coordinate positions on the face side 11a can be specified in the XY coordinate system whose origin is represented by the point $12c_3$, and any arbitrary XY coordinate positions on the reverse side 11b can also be specified in the XY coordinate system whose origin is represented by the point $12c_3$. Consequently, a second region on the face side 11a that corresponds to a first region on the reverse side 11b can be specified.

After storing step S60, the workpiece 11 is cut in

cutting step S70. FIG. 7 illustrates cutting step S70 carried out by the cutting units 78. Cutting step S70 as it is carried out by one of the cutting units 78 will be described below as the cutting units 78 operate in the same manner as each other. In cutting step S70, the cutting blade 82b that is rotating at a high speed is positioned on an extension of one of the projected dicing lines 13. At this time, the lower end of the cutting blade 82b is vertically positioned between the face side 11a and the reverse side 11b of the workpiece 11. Then, the X-axis moving mechanism 26 moves the holding table 10 and the cutting blade 82b relatively to each other along the X-axis directions. The workpiece 11 is now cut or processed, i.e., half-cut, by the cutting blade 82b to a depth, terminating short of the face side 11a, from the reverse side 11b in a thicknesswise direction of the workpiece 11, thereby forming a groove or processed groove 11c in the workpiece 11 progressively along the projected dicing line 13. In cutting step S70, the workpiece 11 may not necessarily be half-cut, but may be fully cut all the way from the reverse side 11b to the face side 11a.

After the workpiece 11 has been cut along the projected dicing line 13 parallel to the X-axis

directions, the cutting unit 78 is indexing-fed to position the cutting blade 82b on an extension of another projected dicing line 13 that is adjacent in the Y-axis directions to the projected dicing line 13 along which the groove 11c has been formed. Then, the workpiece 11 is cut along the projected dicing line 13 by the cutting blade 82b in the same manner as described above. After the workpiece 11 has been cut along a desired number of projected dicing lines 13, the operator acquires an image of the reverse side 11b in the first region from the upper image capturing unit 84 and displays the acquired image on the touch panel 92 in reverse side displaying step S80.

FIG. 8 illustrates reverse side displaying step S80. In FIG. 8, the controller 94 and the storage section 96 are illustrated in block form. In reverse side displaying step S80, the lower image capturing unit 54 is retracted out of the space 18d in the X-axis movable table 18. In reverse side displaying step S80 according to the present embodiment, the controller 94 displays a predetermined pattern including the marks 98, etc., in the second region on the face side 11a that corresponds to the first region on the reverse side 11b in the thicknesswise direction of the workpiece 11, in

overlapping relation to the image of the first region, on the touch panel 92.

FIG. 9A illustrates an example of the image of the reverse side 11b in the first region. In FIG. 9A, grooves 11c formed in the reverse side 11b in the first region are illustrated as solid black stripes. FIG. 9B illustrates an example of the image of the second region on the face side 11a that corresponds to the first region on the reverse side 11b. In FIG. 9B, the profiles of the devices 15, the projected dicing lines 13, the marks 98, and the circuits 100 are illustrated. The X- and Y-axis directions of the image of the second region on the face side 11a shown in FIG. 9B are of the same orientations as those of the X- and Y-axis directions of the image of the first region on the reverse side 11b, as described above.

The controller 94 reads the image of the second region on the face side 11a that corresponds to the first region on the reverse side 11b from the storage section 96, and displays an image 102 (see FIG. 10) where the predetermined pattern of the image of the second region is superposed on the image of the first region on the reverse side 11b on the touch panel 92. Therefore, the operator of the processing apparatus 2 can confirm whether or not the grooves 11c formed in the workpiece 11

extend along the projected dicing lines 13. According to the present embodiment, the image of the first region on the reverse side 11b that is displayed on the touch panel 92 is a real-time image acquired by the upper image capturing unit 84. However, the image of the first region on the reverse side 11b that is displayed on the touch panel 92 may be a still image of the first region on the reverse side 11b.

FIG. 10 illustrates an example of the image displayed in reverse side displaying step S80, as an image 102. In FIG. 10, the profiles of the devices 15, the projected dicing lines 13, the marks 98, and the circuits 100 are indicated by broken lines. Although all of the devices 15, the projected dicing lines 13, the marks 98, and the circuits 100 are displayed in overlapping relation to the image 102, only some of them, e.g., only the projected dicing lines 13, may selectively be displayed in overlapping relation to the image 102. Further, after the image of the second region on the face side 11a has been binarized, the profiles of the projected dicing lines 13, the marks 98, etc., may be processed into predetermined values of thickness, color, and brightness to make them stand out from the rest and then displayed over the image 102. In FIG. 10, only the

profiles of the projected dicing lines 13, the marks 98, etc., are displayed. However, the images of the projected dicing lines 13, the marks 98, etc., rather than the profiles thereof, may be displayed.

After reverse side displaying step S80, if the workpiece 11 has not been cut along all the projected dicing lines 13 parallel to the X-axis directions, control goes back to cutting step S70 to cut the workpiece 11. Cutting step S70 and reverse side displaying step S80 may be repeated a plurality of times. After the workpiece 11 has been cut along all the projected dicing lines 13 parallel to the X-axis directions, the rotary actuator 30 is energized to turn the holding table 10 by 90 degrees. Then, cutting step S70 is carried out again. At this time, cutting step S70 and reverse side displaying step S80 may be repeated a plurality of times.

In reverse side displaying step S80, an image where a region representing at least the grooves 11c of the image of the first region is superposed on the image including the predetermined pattern of the marks 98, etc., included in the second region may be displayed on the touch panel 92. FIG. 11 illustrates another example of the image displayed in reverse side displaying step

S80, as an image 102a. In FIG. 11, the profiles of the grooves 11c are indicated by broken lines. In the image including the region representing the grooves 11c, only the profiles of the grooves 11c may be displayed as illustrated in FIG. 11, or the captured image of the grooves 11c itself may be displayed. At any rate, at least the region representing the grooves 11c is used in the image of the first region. In a case where the image 102a is displayed on the touch panel 92, the operator is able to confirm whether or not the grooves 11c formed in the workpiece 11 extend along the projected dicing lines 13.

A processing apparatus according to a second embodiment of the present invention will be described below. The processing apparatus according to the second embodiment is in the form of a laser processing apparatus 104 for cutting the workpiece 11. Placing step S10 through reverse side displaying step S80 described above in the first embodiment are also carried out in the same manner in the second embodiment. FIG. 12 illustrates in perspective the laser processing apparatus 104 according to the second embodiment. Those parts of the laser processing apparatus 104 which are identical to those of the cutting apparatus 2 according to the first embodiment

are denoted by identical reference characters. Only those components of the laser processing apparatus 104 which are different from those of the cutting apparatus 2 will mainly be described below. In the laser processing apparatus 104, the lower image capturing unit 54 is fixedly mounted on a stationary base 106. The X-axis movable table 18 is disposed in a 90°-turned orientation in the XY plane so that the lower image capturing unit 54 can enter the space 18d in the X-axis movable table 18 from a position remote from the side plate 18b thereof.

The laser processing apparatus 104 has a Y-axis movable table 108 on which the pair of X-axis guide rails 20 are fixedly mounted. The Y-axis movable table 108 is slidable on and along a pair of Y-axis guide rails 110 fixed to an upper surface of the stationary base 106. A Y-axis linear scale 110a for use in the detection of the position of the Y-axis movable table 108 in the Y-axis directions is disposed adjacent to and extends along one of the Y-axis guide rails 110. A nut, not depicted, is mounted on a lower surface of the Y-axis movable table 108 and is operatively threaded over an Y-axis ball screw 112 disposed between and extending generally parallel to the Y-axis guide rails 110.

The Y-axis ball screw 112 has an end coupled to a

Y-axis stepping motor 114. When the Y-axis stepping motor 114 is energized, it rotates the Y-axis ball screw 112 about its central axis, causing the nut to move the Y-axis movable table 108 in one of the Y-axis directions along the Y-axis guide rails 110. The Y-axis guide rails 110, the Y-axis ball screw 112, the Y-axis stepping motor 114, etc., jointly make up a Y-axis moving mechanism 116 for moving the Y-axis movable table 108 along the Y-axis guide rails 110. A vertical column 118 that projects upwardly from the upper surface of the stationary base 106 is disposed at a position adjacent to the lower image capturing unit 54. An elongate casing 120 is attached to the column 118 and has a longitudinal axis extending substantially parallel to the X-axis directions.

The casing 120 houses therein at least a portion of a laser beam applying unit 122. The laser beam applying unit 122 includes a laser oscillator, not depicted, for generating a laser beam having a wavelength absorbed by the workpiece 11 or a wavelength transmittable through the workpiece 11. The laser beam applying unit 122 includes, on a distal end thereof in the + X direction, an emitting head 124 including a beam condenser. The laser beam having a predetermined wavelength generated by the laser beam applying unit 122 travels through an

optical system, not depicted, thereof and is emitted downwardly from the emitting head 124. The upper image capturing unit 84 is mounted on a distal end of the casing 120 at a position adjacent to the emitting head 124.

In reverse side displaying step S80 according to the second embodiment, the predetermined pattern including the marks 98, etc., acquired in image acquiring step S50 can be displayed in overlapping relation to the image of the first region on the reverse side 11b on the touch panel 92. Therefore, the operator can confirm whether or not the grooves 11c formed in the workpiece 11 extend along the projected dicing lines 13. The structure, process, etc., according to the second embodiment may be changed or modified in various ways insofar without departing from the scope of the present invention. For example, in the second embodiment, a Y-axis moving mechanism for moving the Z-axis moving mechanism 42 in the Y-axis directions may be added to the laser processing apparatus 104, as with the first embodiment.

The present invention is not limited to the details of the above described preferred embodiments. 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 processing apparatus comprising:

a plate-shaped holding table for holding a workpiece having a face side with a predetermined pattern formed thereon and a reverse side opposite the face side, the holding table including a surface and another surface positioned opposite the surface and having a predetermined region made of a transparent material from the surface to the other surface;

a processing unit for processing the workpiece while the face side is being held on the surface of the holding table and the reverse side is being exposed upwardly;

a first image capturing unit disposed above the holding table in facing relation to the surface of the holding table;

a second image capturing unit disposed below the holding table in facing relation to the other surface of the holding table;

a display unit for displaying an image captured by at least either one of the first image capturing unit and the second image capturing unit; and

a controller for displaying, on the display unit, the predetermined pattern included in a second region on

the face side that corresponds to a first region on the reverse side of the workpiece in a thicknesswise direction thereof in overlapping relation to an image of the first region, the controller including a storage section for storing positional information of the predetermined pattern in an image of the face side of the workpiece that is captured by the second image capturing unit while the face side is being held on the surface of the holding table.

2. The processing apparatus according to claim 1, wherein

the image of the first region displayed on the display unit includes a region representing processed grooves formed in the workpiece by the processing unit, and

the controller displays the predetermined pattern in the second region over the image of the first region including the region representing the processed grooves on the display unit.

3. The processing apparatus according to claim 1, wherein

the image of the second region is displayed on the display unit,

the image of the first region includes the region

representing the processed grooves formed in the workpiece by the processing unit, and

the controller displays a region representing at least the processed grooves in the image of the first region over the image of the second region on the display unit.

4. The processing apparatus according to claim 1, wherein the controller displays the image of the first region and the image of the second region overlappingly on the display unit while X-axis directions and Y-axis directions of the images of the first and second regions are of the same orientations as each other.

5. The processing apparatus according to claim 1, wherein the processing unit includes a cutting unit with a cutting blade mounted thereon for cutting the workpiece or a laser beam applying unit for applying a laser beam to the workpiece.