

CUTTING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a cutting apparatus including a cutting blade changing unit for automatically mounting and dismounting a cutting blade on and from a cutting unit.

Description of the Related Art

Chips containing semiconductor devices such as integrated circuits (ICs) or large scale integration (LSI) circuits are components indispensable in various electronic appliances including mobile phones, personal computers, etc. Such chips are generally manufactured by dividing a wafer where a number of devices are formed in respective areas on a face side thereof into individual pieces corresponding to the respective areas including the semiconductor devices.

A workpiece such as the wafer is divided by cutting the workpiece with the cutting apparatus, for example. Generally, such a cutting apparatus includes a chuck table for holding the workpiece thereon and a cutting unit with a cutting blade rotatably mounted thereon for cutting the workpiece held on the chuck

table. The cutting apparatus cuts the workpiece by bringing the outer circumferential edge of the cutting blade as it rotates into incising contact with the workpiece along the boundaries of areas of the workpiece that include respective semiconductor devices, thereby dividing the workpiece into individual chips.

Cutting blades wear away as they cut workpieces repeatedly. It is thus necessary for the cutting apparatus to replace cutting blades periodically after repeated usage. In view of such a requirement, there has been proposed a cutting apparatus including a cutting blade changing unit for automatically replacing cutting blades (see, for example, JP 2007-105829A).

Specifically, the cutting blade changing unit includes a cutting blade stocker, i.e., a blade rack, having a plurality of cutting blade storage units, i.e., blade storage means, for individually storing cutting blades, and a cutting blade delivery mechanism having guide means, a movable board, positioning means, a fastening nut mounting and dismounting mechanism, and a cutting blade mounting and dismounting mechanism, for delivering a cutting blade between the cutting blade stocker and a cutting unit. The cutting blade delivery mechanism automatically delivers a used cutting blade

from the cutting unit to the cutting blade stocker and delivers an unused cutting blade from the cutting blade stocker to the cutting unit.

SUMMARY OF THE INVENTION

On the cutting apparatus, it is the general practice for the operator to manually discard the used cutting blades stored on the respective cutting blade storage units and/or to manually replenish the emptied cutting blade storage units with unused cutting blades. The cutting apparatus is configured to detect such operator's manual operations to recognize the state of the cutting blade storage units storing used cutting blades and unused cutting blades therein.

However, if the operator has taken manual action to remove used cutting blades from cutting blade storage units and/or to supply unused cutting blades to cutting blade storage units during temporary shutdown of the cutting apparatus due to some error, then the cutting apparatus is likely to fail to accurately recognize the state of the cutting blade storage units storing cutting blades. The cutting apparatus that fails to accurately recognize the state of the cutting blade storage units storing cutting blades tends to cause various problems.

For example, the cutting blade delivery mechanism may possibly introduce a used cutting blade into a cutting blade storage unit that has already been storing an unused cutting blade. In this case, the cutting blades are liable to collide with each other in the cutting blade storage unit, causing damage to the cutting blade delivery mechanism or the unused cutting blade or leading to some other problems.

It is therefore an object of the present invention to provide a cutting apparatus including a cutting blade changing unit that is capable of preventing a cutting blade from being introduced into a cutting blade storage unit that has already been storing another cutting blade.

In accordance with an aspect of the present invention, there is provided a cutting apparatus including a chuck table for holding a workpiece thereon, a cutting unit having a cutting blade rotatably mounted for cutting the workpiece held on the chuck table, and a cutting blade changing unit for automatically mounting and dismounting the cutting blade on and from the cutting unit. The cutting blade changing unit includes a cutting blade stocker having a plurality of cutting blade storage units for individually storing the cutting blades and a

cutting blade delivery mechanism for delivering cutting blades between the cutting blade stocker and the cutting unit, the cutting blade stocker includes a storage determining unit for determining whether or not a cutting blade is stored on one of the cutting blade storage units, and the cutting blade delivery mechanism delivers a cutting blade to the one of the cutting blade storage units if the storage determining unit determines that a cutting blade is not stored on the one of the cutting blade storage units.

Preferably, the cutting apparatus further includes a control unit for controlling operation of the cutting blade delivery mechanism. The storage determining unit includes a lighting member for applying light to the one of the cutting blade storage units and an image capturing device for detecting light from the one of the cutting blade storage units to which the light is applied by the lighting member and converting the detected light into an electric signal. The control unit includes a brightness calculating section for calculating a brightness from an area included in an image captured by the storage determining unit and corresponding to the cutting blade delivered to the one of the cutting blade storage units, a threshold value storage section for

storing a threshold value used as a criterion for differentiating between the brightness of an area included in the captured image and corresponding to the cutting blade when the cutting blade is stored on the one of the cutting blade storage units and the brightness of an area included in the captured image and corresponding to the cutting blade when the cutting blade is not stored on the one of the cutting blade storage units and the cutting blade is placed in a position that is spaced a predetermined distance from the one of the cutting blade storage units, and a determining section for determining whether or not the cutting blade is stored on the one of the cutting blade storage units by comparing the brightness calculated by the brightness calculating section with the threshold value stored in the threshold value storage section.

Preferably, the cutting blade includes a recording portion where one or both of a type and characteristics of the cutting blade are recorded, and the determining section determines one or both of the type and characteristics of the cutting blade on the basis of an area included in the image captured by the storage determining unit and corresponding to the recording portion.

Preferably, the lighting member includes an oblique lighting member.

Preferably, each of the cutting blade storage units is disposed on a face side of a transparent support member, the storage determining unit is disposed on a reverse side of the support member, and the storage determining unit captures an image of the cutting blade through the support member.

According to the present invention, a cutting blade is delivered to a cutting blade storage unit that has been determined as not storing a cutting blade by a storage determining unit. A cutting blade is thus prevented from being delivered to a cutting blade storage unit that has already been storing another cutting blade.

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 schematically

illustrating by way of example a cutting apparatus according to an embodiment of the present invention;

FIG. 2 is an exploded perspective view schematically illustrating by way of example a cutting unit of the cutting apparatus;

FIG. 3A is a perspective view schematically illustrating a face side of a cutting blade of the cutting unit;

FIG. 3B is a perspective view schematically illustrating a reverse side of the cutting blade of the cutting unit;

FIG. 4 is a perspective view schematically illustrating by way of example a cutting blade changing unit of the cutting apparatus;

FIG. 5 is a perspective view schematically illustrating by way of example a cutting blade stocker of the cutting apparatus;

FIG. 6 is a perspective view schematically illustrating by way of example a mounting/dismounting unit of the cutting apparatus;

FIG. 7A is a fragmentary side elevational view schematically illustrating a cutting blade stocker where another cutting blade is stored on a cutting blade storage unit; and

FIG. 7B is a fragmentary side elevational view schematically illustrating a cutting blade stocker where another cutting blade is not stored on the cutting blade storage unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A cutting apparatus according to a preferred embodiment of the present invention will be described in detail below with reference to the accompanying drawings. FIG. 1 schematically illustrates in perspective the cutting apparatus, denoted by 2, according to the preferred embodiment. In FIG. 1, X-axis direction, also known as processing-feed direction, first horizontal direction, or forward and rearward direction, and Y-axis direction, also known as indexing-feed direction, second horizontal direction, or leftward and rightward direction, represent horizontal directions extending perpendicularly to each other in a horizontal plane. Further, Z-axis direction, also known as incising-feed direction, upward and downward direction, or heightwise direction, represent vertical direction extending perpendicularly to the X-axis direction and the Y-axis direction.

The cutting apparatus 2 illustrated in FIG. 1

includes a base 4 supporting or housing components of the cutting apparatus 2. The base 4 has a rectangular opening 4a defined in a corner of a front end portion thereof and being open upwardly at an upper surface thereof.

The base 4 also has another rectangular opening 4b defined therein on one side of the opening 4a and being open upwardly at an upper surface thereof. The rectangular opening 4b is of an elongate shape having a longitudinal axis extending along the X-axis direction. The opening 4a houses therein a cassette rest table 6 for placing a cassette 8 thereon. The cassette 8 includes a casing shaped as a rectangular parallelepiped for housing a plurality of workpieces 11 to be cut by the cutting apparatus 2.

A lifting/lowering unit, not illustrated, is coupled to the cassette rest table 6 for moving the cassette rest table 6 along the Z-axis direction, i.e., lifting and lowering the cassette rest table 6. The cassette 8 that houses the workpieces 11 therein is placed on an upper surface of the cassette rest table 6. In FIG. 1, the cassette 8 has only its contour illustrated by the two-dot-and-dash lines.

Each of the workpieces 11 includes a disk-shaped

wafer made of a semiconductor such as silicon and has a face side and a reverse side that lie generally parallel to each other. The face side is illustrated as an upper surface facing upwardly in FIG. 1, whereas the reverse side faces downwardly as a lower surface, not illustrated, opposite the face side. The workpiece 11 has a plurality of rectangular areas demarcated on the face side by a grid of projected dicing lines or streets.

Semiconductor devices such as ICs or LSI circuits are formed respectively in the areas demarcated on the face side by the projected dicing lines. The cutting apparatus 2 will cut the workpiece 11 along the projected dicing lines, thereby dividing the workpiece 11 into individual chips having the respective semiconductor devices.

A circular tape, i.e., a dicing tape, 13 that is larger in diameter than the workpiece 11 is affixed to the reverse side of the workpiece 11. The tape 13 includes a circular film-like base member and an adhesive, i.e., a glue layer, disposed on the base member, for example.

The base member is made of a resin such as polyolefin, polyvinyl chloride, or polyethylene terephthalate, and the adhesive includes an epoxy

adhesive, an acrylic adhesive, a rubber adhesive, or the like. Alternatively, the adhesive may be made of an ultraviolet-curable resin that can be cured upon exposure to ultraviolet rays.

The tape 13 has an outer circumferential portion affixed to an annular frame 15 made of metal such as stainless steel (SUS). The frame 15 has a circular opening defined centrally therein that is larger in diameter than the workpiece 11.

The workpiece 11 is disposed within the opening of the frame 15, and the tape 13 has its central portion affixed to the reverse side of the workpiece 11 and its outer circumferential portion affixed to the frame 15, so that the workpiece 11 is supported by the frame 15 via the tape 13.

The workpiece 11 is not limited to any particular types, materials, shapes, structures, sizes, etc. The workpiece 11 may be a wafer made of any of semiconductors such as GaAs, InP, GaN, or SiC other than silicon, glass, ceramic, resin, metal, or the like. The devices formed on the workpiece 11 are not limited to any particular types, quantities, shapes, structures, sizes, layouts, or the like, and the workpiece 11 may be free of devices.

A chuck table moving mechanism 10 that includes a

ball screw mechanism is disposed in the opening 4b in the base 4. The chuck table moving mechanism 10 includes a moving table 10a shaped as a flat plate and can move the moving table 10a along the X-axis direction.

Dust-proof and drop-proof covers 12 in the form of bellows that cover the chuck table moving mechanism 10 in the opening 4b and can be expanded and contracted along the X-axis direction are disposed respectively on one and other sides, i.e., forwardly and rearwardly, of the moving table 10a in the X-axis direction.

A chuck table 14 for holding the workpiece 11 thereon is mounted on the moving table 10a. The chuck table 14 has an upper surface lying generally parallel to a horizontal plane, i.e., an XY plane, and acting as a circular holding surface 14a for holding the workpiece 11 thereon.

The holding surface 14a is connected to a suction source, not illustrated, such as an ejector, through a fluid channel, not illustrated, defined in the chuck table 14 and a valve, not illustrated. A plurality of clamps 16 for gripping and securing the frame 15 that supports the workpiece 11 on the holding surface 14a are disposed on an outer circumferential surface of the chuck table 14.

The chuck table moving mechanism 10 can move the chuck table 14 and the moving table 10a along the X-axis direction. The chuck table 14 is connected to a rotary actuator, not illustrated, such as an electric motor, for rotating the chuck table 14 about a rotational axis extending generally parallel the Z-axis direction through the center of the holding surface 14a.

A pair of guide rails 18 that extend along the Y-axis direction and are spaced apart from each other along the X-axis direction are disposed above a front end portion of the opening 4b. One of the guide rails 18 includes a bottom wall generally parallel to the horizontal plane and a side wall erected from the end of the bottom wall that is farther from the other guide rail 18. Similarly, the other guide rail 18 includes a bottom wall generally parallel to the horizontal plane and a side wall erected from the end of the bottom wall that is farther from the one of the guide rails 18.

The distance by which the guide rails 18 are spaced from each other along X-axis direction can be adjusted. For example, while the bottom walls of the guide rails 18 are supporting the lower surface of the frame 15, the distance by which the guide rails 18 are spaced from each other along X-axis direction can be

adjusted in order to bring the side walls of the guide rails 18 into contact with the outer circumferential edge of the frame 15, thereby positioning the workpiece 11 and the frame 15.

A first support structure 20 shaped as a portal frame is disposed on an upper surface of the base 4 across and over the opening 4b. The first support structure 20 has a front surface facing the guide rails 18 and supporting a rail 22 fixed thereto that extends along the Y-axis direction. A first delivery unit 26 is operatively coupled to a front surface of the rail 22 via a first delivery unit moving mechanism 24.

The first delivery unit moving mechanism 24 is slidable on the front surface of the rail 22, i.e., movable thereon along the Y-axis direction. The first delivery unit moving mechanism 24 includes a lifting and lowering unit such as an air cylinder that has a rod that can be lifted and lowered along the Z-axis direction.

The first delivery unit 26 is fixed to the lower end of the rod of the lifting and lowering unit. Therefore, the first delivery unit moving mechanism 24 can move the first delivery unit 26 along the Y-axis direction by sliding on the front surface of the rail 22 and/or can move the first delivery unit 26 along the Z-

axis direction by lifting and lowering the rod of the lifting and lowering unit.

Further, the first delivery unit 26 includes a plurality of suction pads for holding the frame 15. The suction pads have respective lower surfaces acting as holding surfaces for holding the upper surface of the frame 15 under suction. The holding surfaces of the suction pads are connected to a suction source, not illustrated, such as an ejector, through respective fluid channels, not illustrated, defined in the suction pads, pipes, not illustrated, held in fluid communication with the fluid channels, and valves, not illustrated, for controlling the flow of a gas through the pipes.

The first delivery unit 26 also includes a gripper 26a for gripping the frame 15 at an end thereof that is closer to the opening 4a, i.e., the cassette 8 on the cassette rest table 6. The first delivery unit moving mechanism 24 is movable, i.e., slidable on the front surface of the rail 22, along the Y-axis direction away from the cassette 8 to move the first delivery unit 26 away from the cassette 8 while the gripper 26a is gripping the frame 15 of one of the workpieces 11 housed in the cassette 8. When the first delivery unit moving mechanism 24 is thus moved, the workpiece 11 is delivered

together with the frame 15 out of the cassette 8 and placed on the guide rails 18.

Similarly, the first delivery unit moving mechanism 24 is movable, i.e., slidable on the front surface of the rail 22, along the Y-axis direction toward the cassette 8 to move the first delivery unit 26 toward the cassette 8 while the gripper 26a is gripping the frame 15 of a workpiece 11 on the guide rails 18. When the first delivery unit moving mechanism 24 is thus moved, the workpiece 11 is delivered together with the frame 15 into the cassette 8.

The front surface of the first support structure 20 also supports a rail 28 fixed thereto that extends along the Y-axis direction. A second delivery unit 32 is operatively coupled to a front surface of the rail 28 via a second delivery unit moving mechanism 30.

The second delivery unit moving mechanism 30 is slidable on the front surface of the rail 28, i.e., movable thereon along the Y-axis direction. The second delivery unit moving mechanism 30 includes a lifting and lowering unit such as an air cylinder that has a rod that can be lifted and lowered along the Z-axis direction.

The second delivery unit 32 is fixed to the lower end of the rod of the lifting and lowering unit.

Therefore, the second delivery unit moving mechanism 30 can move the second delivery unit 32 along the Y-axis direction by sliding on the front surface of the rail 28 and/or can move the second delivery unit 32 along the Z-axis direction by lifting and lowering the rod of the lifting and lowering unit.

Further, the second delivery unit 32 includes a plurality of suction pads for holding the frame 15. The suction pads have respective lower surfaces acting as holding surfaces for holding the upper surface of the frame 15 under suction. The holding surfaces of the suction pads are connected to a suction source, not illustrated, such as an ejector, through respective fluid channels, not illustrated, defined in the suction pads, pipes, not illustrated, held in fluid communication with the fluid channels, and valves, not illustrated, for controlling the flow of a gas through the pipes.

A second support structure 34 shaped as a portal frame is disposed on the upper surface of the base 4 across and over the opening 4b. The second support structure 34 has a front surface facing the first support structure 20 and supporting two cutting unit moving mechanisms 36a and 36b, each including a ball screw mechanism, disposed on respective opposite ends thereof

in the Y-axis direction.

A cutting unit 38a for cutting workpieces 11 is fixedly mounted on a lower portion of the cutting unit moving mechanism 36a. A cutting unit 38b for cutting workpieces 11 is fixedly mounted on a lower portion of the cutting unit moving mechanism 36b.

The cutting unit moving mechanism 36a is capable of moving the cutting unit 38a along the Y-axis direction and/or the Z-axis direction. Further, the cutting unit moving mechanism 36b is capable of moving the cutting unit 38b along the Y-axis direction and/or the Z-axis direction.

FIG. 2 schematically illustrates the cutting unit 38a in exploded perspective. The cutting unit 38a includes a housing 40 shaped as a hollow cylinder. The housing 40 houses therein a spindle or rotational shaft 42 shaped as a hollow cylinder axially extending along the Y-axis direction.

The spindle 42 has a distal end portion exposed out of the housing 40. A mount 44 is fixed to the distal end portion of the spindle 42. The spindle 42 also has a proximal end portion, not illustrated, disposed opposite to the distal end portion and coupled to a rotary actuator, not illustrated, such as an electric motor for

rotating the spindle 42 about its central axis.

The mount 44 includes a disk-shaped flange 46 and a hollow cylindrical support shaft 48 protruding centrally from an end face 46a of the flange 46. The flange 46 includes an annular land 46b protruding from the end face 46a of the flange 46 on an outer circumferential portion thereof. The annular land 46b has a tip end face 46c lying generally parallel to the end face 46a.

The support shaft 48 has its outer circumferential surface 48a externally threaded. The support shaft 48 has a recess 48b defined centrally in its tip end face. An annular cutting blade 50 for cutting workpieces 11 is mounted on the support shaft 48.

FIG. 3A schematically illustrates a face side of the cutting blade 50 in perspective. FIG. 3B schematically illustrates a reverse side of the cutting blade 50 in perspective. As illustrated in FIGS. 3A and 3B, the cutting blade 50 includes an annular base 52 made of a metal such as aluminum (Al) and an annular cutting edge 54 mounted on and extending along an outer circumferential edge portion of the annular base 52.

The annular base 52 has a circular opening 52a defined centrally therein and extending thicknesswise

through the base 52. The support shaft 48 can be inserted through the opening 52a. The base 52 also has an annular land 52b extending around the opening 52a and protruding thicknesswise on a face side of the base 52.

A recording portion 52c where one or both of the type and characteristics of the cutting blade 50 are recorded is disposed on a reverse side of the base 52. The recording portion 52c includes, for example, a one-dimensional code, i.e., a bar code, or a two-dimensional code, i.e., a quick response (QR) code (registered trademark) or the like.

The cutting edge 54 is made of abrasive grains of diamond or the like that are bound together by a binder such as a nickel plating layer, for example. However, the cutting edge 54 is not limited to any particular abrasive grains and binders, and may be made of abrasive grains and a binder that are selected depending on the material of workpieces 11 to be cut thereby and the purpose for which workpieces 11 are to be cut thereby.

The remaining components of the cutting unit 38a will be described below with reference to FIG. 2. An annular nut 56 for securing the cutting blade 50 in position on the support shaft 48 is threaded over the externally threaded outer circumferential surface 48a of

the support shaft 48. The nut 56 has a circular opening 56a defined centrally therein that is commensurate in diameter with the support shaft 48.

The opening 56a is defined by an inner circumferential surface of the nut 56 that is internally threaded. The nut 56 has a plurality of through holes 56b defined therein that extend thicknesswise therethrough and are spaced at generally equal intervals in the circumferential direction of the nut 56.

The cutting blade 50 is mounted on the mount 44 such that the support shaft 48 is inserted in the opening 52a in the base 52. When the nut 56 is threaded and tightened over the externally threaded outer circumferential surface 48a of the support shaft 48, the annular base 52 of the cutting blade 50 is gripped between the tip end face 46c of the flange 46 and the nut 56, thereby securing the cutting blade 50 to the distal end portion of the spindle 42.

Though the cutting unit 38a has been described above, the cutting unit 38b is identical in structure to the cutting unit 38a. Therefore, the structural details of the cutting unit 38b will be omitted from description below. As illustrated in FIG. 1, the cutting blade 50 of the cutting unit 38a and the cutting blade 50 of the

cutting unit 38b are disposed in facing relation to each other and spaced from each other along the Y-axis direction.

As illustrated in FIG. 1, further, two cameras 60 for capturing images of a workpiece 11 held on the chuck table 14, etc., are disposed in respective positions adjacent to the respective cutting units 38a and 38b in the X-axis direction.

Each of the cameras 60 includes a visible light camera including an image capturing device for detecting and converting visible light into electric signals, or an infrared radiation camera including an image capturing device for detecting and converting infrared radiation into electric signals, or the like.

In the cutting apparatus 2, it is possible to position the workpiece 11 on the chuck table 14 with respect to the cutting units 38a and 38b on the basis of images captured by the cameras 60 of the workpiece 11 on the chuck table 14, for example.

A cleaning unit 62 is disposed on an upper surface of the base 4 at a position on one side of the opening 4b that is opposite the opening 4a. The cleaning unit 62 includes a spinner table 62a for holding a workpiece 11 in a tubular cleaning space defined in the

base 4.

The spinner table 62a is operatively connected to a rotary actuator, not illustrated, such as an electric motor for rotating the spinner table 62a about a rotational axis generally parallel to the Z-axis direction. The cleaning unit 62 also includes a nozzle 62b for ejecting a cleaning fluid, e.g., a mixture of water and air, toward the workpiece 11 held on the spinner table 62a. The nozzle 62b is disposed above the spinner table 62a.

The cleaning unit 62 operates as follows: While the spinner table 62a that is holding a workpiece 11 thereon is rotating about its rotational axis, the nozzle 62b ejects the cleaning fluid to the workpiece 11 on the spinner table 62a, thereby cleaning the workpiece 11.

The cutting apparatus 2 includes a cutting blade changing unit 64 for changing cutting blades 50 on the cutting units 38a and 38b. The cutting blade changing unit 64 is disposed behind the second support structure 34, i.e., rearwardly of the second support structure 34 in the X-axis direction. FIG. 4 schematically illustrates the cutting blade changing unit 64 in perspective. As illustrated in FIG. 4, the cutting blade changing unit 64 includes a pair of cutting blade

stockers 70a and 70b each for holding and stocking a plurality of cutting blades 50.

The cutting blade stockers 70a and 70b are disposed in facing relation to each other. The cutting blade stockers 70a and 70b stock used cutting blades 50 that have been used to cut workpieces 11 and replacement cutting blades 50, i.e., unused cutting blades 50.

Each of the cutting blade stockers 70a and 70b includes a columnar support structure 72 extending along the Z-axis direction. The support structure 72 is disposed rearwardly of the second support structure 34 (see FIG. 1), for example, and is fixed to an upper surface of the base 4. However, there is no limitation on the place where the support structure 72 is installed.

The support structure 72 of each of the cutting blade stockers 70a and 70b houses therein a hollow cylindrical spindle 74 extending along the Y-axis direction. The spindle 74 has an end portion, i.e., a distal end portion, exposed out of the support structure 72 and another end portion, i.e., a proximal end portion, operatively coupled to a rotary actuator, not illustrated, such as an electric motor.

A disk-shaped support member 76 is fixed to the distal end of the spindle 74. The support member 76 is

rotatable about a rotational axis generally parallel to the Y-axis direction by power transmitted from the rotary actuator through the spindle 74.

FIG. 5 schematically illustrates the cutting blade stocker 70a in perspective. The cutting blade stocker 70a will be described in detail below with reference to FIG. 5. The cutting blade stocker 70b is identical in structure to the cutting blade stocker 70a and will be omitted from description below.

As illustrated in FIG. 5, the support member 76 has a face side 76a and a reverse side 76b that lie generally parallel to each other. The distal end of the spindle 74 is fixed to the reverse side 76b of the support member 76. The support member 76 has on the face side 76a thereof a plurality of cutting blade storage units 78 for stocking respective cutting blades 50.

Specifically, the support member 76 has a plurality of circular openings 76c defined therein and extending thicknesswise through the support member 76 in the Y-axis direction. The openings 76c are disposed at generally equal intervals in the circumferential direction of the support member 76.

A plurality of disk-shaped support bodies 80 that are made of a transparent material for supporting cutting

blades 50 thereon have respective portions fitted respectively in the openings 76c. The portions of the support bodies 80 that are fitted in the respective openings 86c are secured to the support member 76.

A hollow cylindrical boss, i.e., support shaft, 82 protrudes from a face side 80a of each of the support bodies 80 and is disposed centrally on the face side 80a of the support body 80. The boss 82 is made of the same transparent material as the support body 80, for example, and is fixed centrally to the support body 80.

The boss 82 is commensurate in diameter with the opening 52a (see FIG. 2) defined in the base 52 of the cutting blade 50. In other words, the boss 82 can be inserted into the opening 52a in the base 52.

When the boss 82 is inserted in the opening 52a in the base 52, the cutting blade 50 is supported by the face side 80a of the support body 80 and the boss 82. Each of the cutting blade storage units 78 is constructed of the face side 80a of the support body 80 and the boss 82.

An image capturing unit, i.e., a storage determining unit, 86 is fixed to a side surface of the support structure 72 behind the reverse side 76b of the support member 76. The image capturing unit 86 includes

an objective lens 86a, an annular lighting member 86b surrounding the objective lens 86a, and an image capturing device, not illustrated, for detecting and converting visible light or infrared radiation having passed through the objective lens 86a into electric signals while illuminating light is being emitted from the lighting member 86b.

The lighting member 86b includes an oblique lighting member for applying visible light or infrared radiation obliquely to the reverse side 76b of the support member 76 in order to concentrate the visible light or the infrared radiation on the reverse side 76b of the support member 76. The image capturing unit 86 is placed in a position overlapping the support member 76 along the Y-axis direction, for capturing an image of one of the cutting blade storage units 78 that is positioned in facing relation to the image capturing unit 86.

The cutting apparatus 2 determines whether or not a cutting blade 50 is stored on one of the cutting blade storage units 78 on the basis of an image captured by the image capturing unit 86. Details of the determining step will be described later.

When the support member 76 is rotated by the spindle 74 coupled to the rotary actuator, the cutting

blade storage units 78 move along the circumferential direction of the support member 76 and are successively brought into facing relation to the image capturing unit 86. In this manner, one of the cutting blade storage units 78 is selected as a target whose image is to be captured by the image capturing unit 86.

The transparent material of the support bodies 80 is selected depending on the kind of light that is used for the image capturing unit 86 to capture an image. For example, if the illuminating light emitted from the lighting member 86b is visible light, then the support bodies 80 are made of a material through which the visible light can be transmitted. For example, the support bodies 80 may be made of plastic or glass such as quartz glass or borosilicate glass. The bosses 82 may be made of the same material as the support bodies 80.

According to a modification, the support member 76 is free of the openings 76c and the support bodies 80, and is made of a transparent material such as plastic or glass. According to the modification, the bosses 82 protrude from the face side 76a of the support member 76, and the face side 76a of the support member 76 and the bosses 82 jointly make up the cutting blade storage units 78.

As illustrated in FIG. 4, the cutting blade stockers 70a and 70b are spaced from each other along the Y-axis direction such that the face side 76a of the support member 76 of the cutting blade stocker 70a and the face side 76a of the support member 76 of the cutting blade stocker 70b face each other along the Y-axis direction. A cutting blade delivery mechanism 88 for holding and delivering cutting blades 50 is disposed between the cutting blade stockers 70a and 70b as viewed in front elevation along the X-axis direction.

The cutting blade delivery mechanism 88 includes a mounting and dismounting unit moving mechanism 90 for moving a mounting and dismounting unit, i.e., a mounting and dismounting mechanism, 98 to be described later. The mounting and dismounting unit moving mechanism 90 includes a plate-shaped base 90a lying generally parallel to the X-axis direction and the Y-axis direction. The base 90a is disposed rearwardly of the second support structure 34 (see FIG. 1), for example.

A ball screw 92 extending along the X-axis direction is fixed to a lower surface of the base 90a. The ball screw 92 is threaded through a moving block 94 shaped as a rectangular parallelepiped. A support frame 96 that is channel-shaped or U-shaped as viewed in side

elevation is fixed to a lower surface of the moving block 94. The support frame 96 supports the mounting and dismounting unit 98 that mounts and dismounts cutting blades 50 and nuts 56 (see FIG. 2).

The ball screw 92 has an end coupled to a stepping motor, not illustrated. When the stepping motor rotates the ball screw 92 about its central axis, the mounting and dismounting unit 98 supported by the support frame 96 moves on and along the ball screw 92 in the X-axis direction, thereby controlling the position of the mounting and dismounting unit 98 along the X-axis direction.

The mounting and dismounting unit moving mechanism 90 includes a Y-axis moving mechanism, not illustrated, as a ball screw mechanism for moving the base 90a along the Y-axis direction. The Y-axis moving mechanism controls the position of the mounting and dismounting unit 98 along the Y-axis direction.

FIG. 6 schematically illustrates the mounting and dismounting unit 98 in perspective. The support frame 96 that supports the mounting and dismounting unit 98 includes a plate-shaped upper wall 96a fixed to the lower surface of the moving block 94, a columnar side wall 96b protruding downwardly from a rear end of the upper wall

96a, and a plate-shaped support panel 96c protruding forwardly from the lower end of the side wall 96b and lying generally parallel to the upper wall 96a.

The mounting and dismounting unit 98 is supported on the support panel 96c of the support frame 96. The mounting and dismounting unit 98 includes a blade mounting and dismounting unit 100 for mounting and dismounting cutting blades 50 and a nut mounting and dismounting unit 130 for mounting and dismounting nuts 56 (see FIG. 2) that secure the cutting blades 50.

The blade mounting and dismounting unit 100 and the nut mounting and dismounting unit 130 are fixed to the upper surface of the support panel 96c of the support frame 96. The blade mounting and dismounting unit 100 includes an electric motor 102 acting as a rotary actuator and a power transmitting mechanism 104 operatively coupled to the electric motor 102. The electric motor 102 and the power transmitting mechanism 104 are disposed adjacent to each other along the X-axis direction.

The electric motor 102 includes a casing 102a shaped as a hollow cube that houses motor components including a rotor, a stator, and so on therein and a spindle, not illustrated, connected to the rotor and

extending along the Z-axis direction. The spindle of the electric motor 102 has a distal end portion exposed from an upper surface of the casing 102a, and a disk-shaped pulley 102b is fixed to the exposed distal end portion of the spindle.

The power transmitting mechanism 104 includes a casing 104a shaped as a hollow cube and a spindle, not illustrated, housed in the casing 104a and extending along the Z-axis direction. The spindle of the power transmitting mechanism 104 has a distal end portion exposed from an upper surface of the casing 104a, and a disk-shaped pulley 104b is fixed to the exposed distal end portion of the spindle.

The casing 104a has a through hole 104c defined therein that extends through the casing 104a in leftward and rightward direction, i.e., in the Y-axis direction. A hollow cylindrical shaft 106 is inserted in the through hole 104c across and through the casing 104a and has opposite ends exposed from respective opposite outer side surfaces of the casing 104a.

The shaft 106 thus held in the casing 104a is rotatable about a rotational axis generally parallel to the Y-axis direction and is coupled to the spindle of the power transmitting mechanism 104 in the casing 104a.

Specifically, the casing 104a also houses therein a converting mechanism, not illustrated, for converting rotary power of the spindle of the power transmitting mechanism 104 that extends along the Z-axis direction into rotary power of the shaft 106 that extends along the Y-axis direction.

The converting mechanism includes bevel gears such as spiral bevel gears or straight bevel gears or hypoid gears. The electric motor 102 and the power transmitting mechanism 104 are operatively coupled to each other by an annular linking member 108 such as a belt or a chain.

Specifically, the linking member 108 is trained in an oblong shape as viewed in plan around the pulley 102b of the electric motor 102 and the pulley 104b of the power transmitting mechanism 104 while being kept in contact with a side surface of the pulley 102b and a side surface of the pulley 104b.

When the electric motor 102 is energized, the power of the electric motor 102 is transmitted through the pulley 102b, the linking member 108, and the pulley 104b to the rotational shaft, i.e., the spindle, of the power transmitting mechanism 104. The converting mechanism disposed in the casing 104a transmits the power

of the spindle of the power transmitting mechanism 104 to the shaft 106, rotating the shaft 106. The power of the electric motor 102 is thus transmitted to the shaft 106 by the power transmitting mechanism 104.

A blade holding unit 110a for holding a cutting blade 50 that is mounted on the cutting unit 38a (see FIG. 1) and a cutting blade 50 to be newly mounted on the cutting unit 38a is fixed to one of the ends of the shaft 106.

In addition, a blade holding unit 110b for holding a cutting blade 50 that is mounted on the cutting unit 38b (see FIG. 1) and a cutting blade 50 to be newly mounted on the cutting unit 38b is fixed to the other end of the shaft 106.

Each of the blade holding units 110a and 110b includes a plate-shaped support member 112 that is formed in an oblong shape as viewed in side elevation and fixed to the distal end of the shaft 106, and a pair of blade gripping units 114a and 114b mounted on a surface of the support member 112 that faces away from the power transmitting mechanism 104.

The blade gripping unit 114a is fixed to an end portion, i.e., a front end portion, of the support member 112, whereas the blade gripping unit 114b is fixed to

another end portion, i.e., a rear end portion, of the support member 112. Each of the blade gripping units 114a and 114b includes a hollow cylindrical gripper 116 fixed to the support member 112.

The gripper 116 has a surface 116a facing away from the power transmitting mechanism 104. The gripper 116 also has a positioning pin 118 protruding from the surface 116a. The positioning pin 118 has a distal end portion positionally alignable with and complementary in shape to the recess 48b (see FIG. 2) defined in the support shaft 48 of the mount 44, so that the distal end portion of the positioning pin 118 can be inserted into the recess 48b.

A plurality of gripping members 120 for gripping the land 52b (see FIG. 2) of the cutting blade 50 are disposed on an outer circumferential surface of the gripper 116 and angularly spaced at generally equal intervals in the circumferential direction of the gripper 116. Each of the gripping members 120 is of a columnar shape and has a proximal end portion, i.e., an end portion, joined to the outer circumferential surface of the gripper 116.

FIG. 6 illustrates by way of example four gripping members 120 for gripping the outer

circumferential surface of the land 52b of the cutting blade 50 at four angularly equally spaced locations thereon. Each of the gripping members 120 has a distal end portion, i.e., another end portion, protruding from the surface 116a of the gripper 116 and having a contact portion 120a for contacting the outer circumferential surface of the land 52b of the cutting blade 50.

The distal end portions of the respective gripping members 120 are movable radially with respect to the gripper 116 by a moving mechanism, not illustrated, housed in the gripper 116, for example. The moving mechanism selectively moves the distal end portions of the respective gripping members 120 between a state, i.e., a closed state, where the contact portions 120a contact the outer circumferential surface of the land 52b of the cutting blade 50, thereby gripping the cutting blade 50 and another state, i.e., an open state, where the contact portions 120a are positioned more radially outwardly of their positions in the closed state, thereby releasing the cutting blade 50.

For replacing the cutting blades 50 mounted respectively on the cutting units 38a and 38b with new cutting blades 50, the cutting blades 50 are dismounted and the new cutting blades 50 are mounted by the blade

holding units 110a and 110b. Specific details of operation of the blade holding units 110a and 110b for replacing the mounted cutting blades 50 with new cutting blades 50 will be described later.

A nut mounting and dismounting unit 130 is disposed on the support panel 96c forwardly of the blade mounting and dismounting unit 100. The nut mounting and dismounting unit 130 includes an electric motor 132 acting as a rotary actuator and a power transmitting mechanism 134 operatively coupled to the electric motor 132. The electric motor 132 and the power transmitting mechanism 134 are disposed adjacent to each other along the X-axis direction.

The electric motor 132 and the power transmitting mechanism 134 are structurally identical in structure to the electric motor 102 and the power transmitting mechanism 104, respectively, of the blade mounting and dismounting unit 100. Specifically, the electric motor 132 includes a casing 132a and a pulley 132b fixed to the distal end of a spindle of the motor 132. The power transmitting mechanism 134 includes a casing 134a and a pulley 134b fixed to the distal end of a spindle of the power transmitting mechanism 134.

The casing 134a has a through hole 134c defined

therein that extends through the casing 134a in leftward and rightward direction, i.e., in the Y-axis direction. A hollow cylindrical shaft 136 is inserted in the through hole 134c across and through the casing 134a and has opposite ends exposed from respective opposite outer side surfaces of the casing 134a.

The shaft 136 thus held in the casing 134a is rotatable about a rotational axis generally parallel to the Y-axis direction and is coupled to the spindle of the power transmitting mechanism 134 in the casing 134a. The electric motor 132 and the power transmitting mechanism 134 are operatively coupled to each other by an annular linking member 138 such as a belt or a chain.

Specifically, the linking member 138 is trained in an oblong shape as viewed in plan around the pulley 132b of the electric motor 132 and the pulley 134b of the power transmitting mechanism 134 while being kept in contact with a side surface of the pulley 132b and a side surface of the pulley 134b.

When the electric motor 132 is energized, the power of the electric motor 132 is transmitted through the pulley 132b, the linking member 138, and the pulley 134b to the rotational shaft, i.e., the spindle, of the power transmitting mechanism 134. A converting mechanism

disposed in the casing 134a transmits the power of the spindle of the power transmitting mechanism 134 to the shaft 136, rotating the shaft 136. The power of the electric motor 132 is thus transmitted to the shaft 136 by the power transmitting mechanism 134.

A nut holding unit 140a for holding and rotating the nut 56 (see FIG. 2) that is used to secure a cutting blade 50 to the spindle 42 of the cutting unit 38a is fixed to an end of the shaft 136. Further, another nut holding unit 140b for holding and rotating the nut 56 that is used to secure a cutting blade 50 to the spindle 42 of the cutting unit 38b is fixed to another end of the shaft 136.

Each of the nut holding units 140a and 140b includes a hollow cylindrical rotary member 142 connected to a distal end of the shaft 136. The rotary member 142 is normally biased by a spring or the like to move away from the power transmitting mechanism 134, and is movable along the Y-axis direction by an external force applied thereto.

The rotary member 142 has an annular surface 142a facing away from the power transmitting mechanism 134. The rotary member 142 includes four holding pins 144 protruding from the surface 142a in a direction away from

the power transmitting mechanism 134. The holding pins 144 are positionally alignable with and complementary in shape to the through holes 56b defined in the nut 56 (see FIG. 2), and can be inserted into the respective through holes 56b.

The number of the holding pins 144 is set to an appropriate value depending on the number of the through holes 56b. A plurality of gripping members 146 for gripping the nut 56 are disposed on an outer circumferential surface of the rotary member 142 and angularly spaced at generally equal intervals in the circumferential direction of the rotary member 142.

Each of the gripping members 146 is of a columnar shape and has a proximal end portion, i.e., an end portion, joined to the outer circumferential surface of the rotary member 142. FIG. 6 illustrates by way of example four gripping members 146 for gripping the outer circumferential surface of the nut 56 at four angularly equally spaced locations thereon.

Each of the gripping members 146 has a distal end portion, i.e., another end portion, protruding from the surface 142a of the rotary member 142 and having on a distal end thereof a hook 146a bent radially inwardly toward the center of the rotary member 142.

The gripping members 146 are normally biased by springs or the like to move radially outwardly with respect to the rotary member 142 to displace the hooks 146a in radially outward direction of the rotary member 142.

The rotary member 142 is radially surrounded by a hollow cylindrical cover 148. The rotary member 142 and the proximal end portions of the gripping members 146 that are closer to the power transmitting mechanism 134 are housed in the cover 148.

When the rotary member 142 is pressed to move axially into the cover 148, the rotary member 142 is pushed, together with the gripping members 146, axially into the cover 148, while compressing the spring that normally biases the rotary member 142 to move away from the power transmitting mechanism 134.

When the rotary member 142 is pushed axially into the cover 148 by an external force, the distal end portions, near the hooks 146a, of the gripping members 146 are pressed to move radially inwardly with respect to the rotary member 142 by contact with the inner wall surface of the cover 148, while compressing the springs that normally bias the gripping members 146 to move radially outwardly with respect to the rotary member 142.

The gripping members 146 are now positioned so as to extend lengthwise axially along the inner wall surface of the cover 148. At this time, the hooks 146a of the gripping members 146 are positioned radially inwardly of the outer circumferential edge of the rotary member 142 with respect to the rotary member 142. The gripping members 146 are now in a closed state.

On the other hand, when the rotary member 142 is released from the external force, the rotary member 142 moves axially out of the cover 148, releasing the distal end portions of the gripping members 146 out of pressed contact with the inner wall surface of the cover 148. The distal end portions of the gripping members 146 are moved radially outwardly with respect to the rotary member 142.

The distal end portions of the gripping members 146 are now positioned more radially outwardly than when they are in the closed state. At this time, the hooks 146a of the gripping members 146 are positioned radially outwardly of the outer circumferential edge of the rotary member 142 with respect to the rotary member 142. The gripping members 146 are now in an open state.

Each of the nut holding units 140a and 140b holds and rotates a nut 56. Specifically, the nut 56 is

brought into contact with the surface 142a of the rotary member 142 in order to insert the holding pins 144 of the rotary member 142 into the respective through holes 56b (see FIG. 2) in the nut 56.

Then, when the rotary member 142 is pressed to move axially into the cover 148, the gripping members 146 are brought into the closed state, causing the hooks 146a to contact an outer circumferential surface of the nut 56 thereby to grip the nut 56.

While the nut 56 is being held by the gripping members 146, the electric motor 132 is energized. The power of the electric motor 132 is transmitted through the power transmitting mechanism 134 to the shaft 136, rotating the shaft 136 about its rotational axis. The rotary member 142 is rotated thereby, rotating the nut 56 gripped by the gripping member 146.

By thus holding and rotating the nuts 56 with the respective the nut holding units 140a and 140b, the nuts 56 can automatically be tightened and loosened in changing the cutting blades 50 mounted on the respective cutting units 38a and 38b. A specific sequence of operation of the nut mounting and dismounting unit 130 for changing the cutting blades 50 will be described later.

Each of the components of the cutting apparatus 2, i.e., the chuck table moving mechanism 10, the chuck table 14, the clamps 16, the guide rails 18, the first delivery unit moving mechanism 24, the first delivery unit 26, the second delivery unit moving mechanism 30, the second delivery unit 32, the cutting unit moving mechanisms 36a and 36b, the cutting units 38a and 38b, the cameras 60, the cleaning unit 62, the cutting blade changing unit 64, etc., is electrically connected to a control unit 66 (see FIG. 1).

The control unit 66 generates control signals for controlling operation of the components of the cutting apparatus 2 and outputs the generated control signals. The control unit 66 includes a computer, for example, and includes a processing part for performing various processing sequences, i.e., arithmetic operations, etc., required to operate the components of the cutting apparatus 2, and a storage part for storing various pieces of information, i.e., data, programs, etc., used in the processing sequences performed by the processor.

The processing part includes a processor such as a central processing unit (CPU). The storage part includes various memories that provide a main storage device, an auxiliary storage device, etc.

The cutting apparatus 2 operates to process, i.e., cut, a workpiece 11. For processing the workpiece 11, the workpiece 11 to be processed is stored in the cassette 8, which is then placed on the upper surface of the cassette rest table 6.

The workpiece 11 stored in the cassette 8 on the cassette rest table 6 is unloaded from the cassette 8 by the first delivery unit 26. Specifically, while the gripper 26a of the first delivery unit 26 is gripping the frame 15, the first delivery unit 26 moves along the Y-axis direction away from the cassette 8.

The workpiece 11 is now pulled out of the cassette 8 and placed onto the guide rails 18. The workpiece 11 is then sandwiched by the guide rails 18 and positioned.

Then, the upper surface of the frame 15 is held by the first delivery unit 26, which delivers the workpiece 11 onto the chuck table 14. The workpiece 11 is placed on the chuck table 14 with the tape 13 interposed therebetween.

The frame 15 is secured in place by the clamps 16. Then, a negative pressure from the suction source is applied to the holding surface 14a, enabling the chuck table 14 to hold the workpiece 11 under suction with the

tape 13 interposed therebetween.

The cutting blades 50 mounted respectively on the cutting units 38a and 38b are rotated about their rotational axes and caused to incise the workpiece 11, cutting the workpiece 11. For example, the cutting blades 50 cut the workpiece 11 along the projected dicing lines, dividing the workpiece 11 into a plurality of device chips.

When the cutting step on the workpiece 11 is completed, the upper surface of the frame 15 is held by the second delivery unit 32, which delivers the workpiece 11 from the chuck table 14 to the cleaning unit 62. The cleaning unit 62 cleans the workpiece 11.

When the cleaning step on the workpiece 11 is completed, the upper surface of the frame 15 is held by the first delivery unit 26, which delivers the frame 15 and the workpiece 11 onto the guide rails 18. The frame 15 is then sandwiched by the guide rails 18 and positioned.

Thereafter, while the gripper 26a of the first delivery unit 26 is gripping the frame 15, the first delivery unit 26 moves along the Y-axis direction toward the cassette 8 and stores the workpiece 11 back into the cassette 8. The workpiece 11 has been processed, i.e.,

cut, by the cutting apparatus 2 as described above.

The storage part of the control unit 66 stores programs that are descriptive of the above sequence of operation of the cutting apparatus 2. When a signal instructing the cutting apparatus 2 to process the workpiece 11 is entered into the cutting apparatus 2, the processing part of the control unit 66 reads the programs from the storage part and successively generates control signals for controlling operation of the components of the cutting apparatus 2.

Since the cutting blades 50 mounted on the cutting units 38a and 38b tend to wear progressively as they cut more workpieces 11, they are periodically replaced or changed. The cutting blades 50 are automatically changed by the cutting blade changing unit 64.

A specific example of operation of the cutting blade changing unit 64 for changing cutting blades 50 will be described hereinbelow. Specifically, an operation of the cutting blade changing unit 64 for replacing a used cutting blade 50 mounted on the cutting unit 38a with an unused cutting blade 50, i.e., a replacement cutting blade 50, stocked on the cutting blade stocker 70a will be described below.

An operation of the cutting blade changing unit 64 for changing a used cutting blade 50 mounted on the cutting unit 38b to an unused cutting blade 50 stocked on the cutting blade stocker 70b is performed similarly to the operation of the cutting blade changing unit 64 to be described below and hence will not be described below.

First, the mounting and dismounting unit moving mechanism 90 moves the mounting and dismounting unit 98 along the X-axis direction to bring the blade gripping unit 114b (see FIG. 6) of the blade holding unit 110a into facing relation to the cutting blade stocker 70a (see FIG. 4).

At this time, if necessary, the spindle 74 of the cutting blade stocker 70a is rotated to cause the replacement cutting blade 50 held on one of the cutting blade storage units 78 of the cutting blade stocker 70a to confront the gripper 116 of the blade gripping unit 114b.

Then, the gripping members 120 disposed on the outer circumferential surface of the gripper 116 of the blade gripping unit 114b are moved into the open state by the moving mechanism housed in the gripper 116. Then, the Y-axis moving mechanism of the mounting and dismounting unit moving mechanism 90 moves the base 90a

along the Y-axis direction to bring the positioning pin 118 protruding from the surface 116a of the gripper 116 closely to the boss 82 (see FIG. 5) of the cutting blade storage unit 78.

Thereafter, the gripping members 120 disposed on the outer circumferential surface of the gripper 116 of the blade gripping unit 114b are moved into the closed state by the moving mechanism housed in the gripper 116. Therefore, the contact portions 120a of the distal end portions of the gripping members 120 contact the outer circumferential surface of the land 52b (see FIG. 2) of the cutting blade 50. In other words, the replacement cutting blade 50 is gripped by the gripping members 120.

Then, the base 90a is moved along the Y-axis direction by the Y-axis moving mechanism of the mounting and dismounting unit moving mechanism 90 to bring the positioning pin 118 away from the boss 82. Then, the mounting and dismounting unit moving mechanism 90 moves the mounting and dismounting unit 98 along the X-axis direction to bring the nut holding unit 140a (see FIG. 6) of the mounting and dismounting unit 98 into facing relation to the mount 44 of the cutting unit 38a.

Then, the cutting unit moving mechanism 36a moves the cutting unit 38a along the Y-axis direction to press

the nut 56 (see FIG. 2) that fastens the cutting blade 50 mounted on the cutting unit 38a against the surface 142a of the rotary member 142 of the nut holding unit 140a.

At this time, the holding pins 144 of the nut holding unit 140a are inserted into the respective through holes 56b in the nut 56. When the rotary member 142 is pressed by the nut 56, the rotary member 142 is pushed into the cover 148, bringing the gripping members 146 on the outer circumferential surface of the rotary member 142 into the closed state. Therefore, the nut 56 is gripped by the hooks 146a of the gripping members 146.

Then, the electric motor 132 (see FIG. 6) is energized to rotate the shaft 136 about its rotational axis, rotating the nut holding unit 140a in a direction to loosen the nut 56. Therefore, the nut 56 gripped by the nut holding unit 140a is detached from the support shaft 48 of the mount 44.

Then, the cutting unit moving mechanism 36a moves the cutting unit 38a along the Y-axis direction to space the cutting unit 38a and the nut holding unit 140a from each other. The nut holding unit 140a is constructed to keep the rotary member 142 pushed in the cover 148, so that the nut 56 is held by the nut holding unit 140a even after it is detached from the support shaft 48.

Then, the mounting and dismounting unit moving mechanism 90 moves the mounting and dismounting unit 98 along the X-axis direction to bring the blade gripping unit 114b of the blade holding unit 110a into facing relation to the cutting blade 50 mounted on the cutting unit 38a.

Then, the moving mechanism housed in the gripper 116 of the blade gripping unit 114a brings the gripping members 120 disposed on the outer circumferential surface of the gripper 116 into the open state. Then, the cutting unit moving mechanism 36a moves the cutting unit 38a along the Y-axis direction to bring the support shaft 48 of the mount 44 closely to the positioning pins 118 protruding from the surface 116a of the gripper 116.

Then, the moving mechanism housed in the gripper 116 of the blade gripping unit 114a brings the gripping members 120 disposed on the outer circumferential surface of the gripper 116 into the closed state. Therefore, the contact portions 120a of the distal end portions of the gripping members 120 contact the outer circumferential surface of the land 52b of the cutting blade 50. In other words, the used cutting blade 50 is gripped by the gripping members 120.

Then, the cutting unit moving mechanism 36a moves

the cutting unit 38a along the Y-axis direction to space the cutting unit 38a and the nut holding unit 140a from each other. Therefore, the used cutting blade 50 is detached from the cutting unit 38a.

Then, the electric motor 102 (see FIG. 6) is energized to rotate the shaft 106 through 180° about its rotational axis. Thus, the support members 112 are rotated by the shaft 106, positionally switching around the blade gripping units 114a and the blade gripping units 114b. As a result, the blade gripping unit 114b that is holding the unused cutting blade 50 faces the mount 44 of the cutting unit 38a.

Then, the cutting unit moving mechanism 36a moves the cutting unit 38a along the Y-axis direction to bring the cutting unit 38a and the blade gripping unit 114b closely to each other. Therefore, the support shaft 48 of the mount 44 is inserted into the opening 52a in the unused cutting blade 50 gripped by the blade gripping unit 114b.

Then, the moving mechanism housed in the gripper 116 of the blade gripping unit 114a brings the gripping members 120 disposed on the outer circumferential surface of the gripper 116 into the open state. Therefore, the unused cutting blade 50 is mounted on the distal end

portion of the spindle 42.

Then, the cutting unit moving mechanism 36a moves the cutting unit 38a along the Y-axis direction to space the cutting unit 38a and the blade gripping unit 114b from each other. Then, the mounting and dismounting unit moving mechanism 90 moves the mounting and dismounting unit 98 to bring the nut holding unit 140a that is holding the nut 56 into facing relation to the mount 44.

Then, the cutting unit moving mechanism 36a moves the cutting unit 38a along the Y-axis direction to bring the cutting unit 38a and the nut holding unit 140a closely to each other. Thus, the nut 56 held by the nut holding unit 140a is positioned at the distal end portion of the support shaft 48 of the mount 44.

Then, the electric motor 132 is energized to rotate the shaft 136 about its rotational axis, rotating the nut holding unit 140a in a direction to tighten the nut 56. Therefore, the nut 56 is tightened over the externally threaded outer circumferential surface 48a of the support shaft 48 of the mount 44. As a consequence, the unused cutting blade 50 is sandwiched by the tip end face 46c of the land 46b of the mount 44 and the nut 56 and secured to the cutting unit 38a.

Then, the cutting unit moving mechanism 36a moves

the cutting unit 38a along the Y-axis direction to space the cutting unit 38a and the nut holding unit 140a from each other. At this time, the rotary member 142 moves out of the cover 148, bringing the gripping members 146 into the open state. Therefore, the gripping members 146 release the nut 56.

Then, the mounting and dismounting unit moving mechanism 90 moves the mounting and dismounting unit 98 along the X-axis direction to bring the blade gripping unit 114a where the gripping members 120 are gripping the used cutting blade 50 into facing relation to the cutting blade stocker 70a.

At this time, if necessary, the spindle 74 of the cutting blade stocker 70a is rotated to cause the gripper 116 of the blade gripping unit 114a and one of the cutting blade storage units 78 of the cutting blade stocker 70a to confront each other.

In the cutting blade changing unit 64, after it has been confirmed that another cutting blade is not stored on the cutting blade storage unit 78, using the image capturing unit, i.e., the storage determining unit, 86 (see FIG. 4) in the cutting blade stocker 70a, the used cutting blade 50 is stored on the cutting blade storage unit 78.

An operation of confirming whether or not another cutting blade is stored on the cutting blade storage unit 78 will be described below hereinbelow with reference to FIGS. 7A and 7B. FIG. 7A schematically illustrates in fragmentary side elevation the cutting blade stocker 70a where another cutting blade is stored on the cutting blade storage unit 78, and FIG. 7B schematically illustrates in fragmentary side elevation the cutting blade stocker 70a where another cutting blade is not stored on the cutting blade storage unit 78.

For confirming whether or not another cutting blade is stored on the cutting blade storage unit 78, first, a cutting blade 50 is placed in a position where the image capturing unit 86 disposed behind the reverse side 76b of the support member 76 is capable of capturing a clear image of the reverse side of the base 52, which is made of a metal such as aluminum (Al), of the cutting blade 50, the position being spaced a predetermined distance d from the face side 76a of the support member 76.

Specifically, the Y-axis moving mechanism of the mounting and dismounting unit moving mechanism 90 moves the base 90a along the Y-axis direction to enable the reverse side of the base 52 to reflect and apply the

illuminating light emitted from the lighting member 86b of the image capturing unit 86 to the objective lens 86a.

Stated otherwise, the lighting member 86b of the image capturing unit 86 has its light exit angle and position designed such that the image capturing unit 86 is capable of capturing a clear image of the reverse side of the base 52, i.e., the illuminating light emitted from the lighting member 86b can be reflected by the reverse side of the base 52 and applied to the objective lens 86a, when the cutting blade 50 is placed in a position that is spaced the distance d from the face side 76a of the support member 76.

Then, the image capturing unit 86 captures an image while the illuminating light is being emitted from the lighting member 86b. When another cutting blade 51 is stored on the cutting blade storage unit 78 as illustrated in FIG. 7A, the illuminating light emitted from the lighting member 86b does not reach the cutting blade 50, but is reflected by the reverse side of the base 52 of the cutting blade 51 and not applied to the objective lens 86a. Therefore, an image captured by the image capturing unit 86 includes a relatively dark annular area corresponding to the reverse side of the base 52 of the cutting blade 51.

On the other hand, when another cutting blade 51 is not stored on the cutting blade storage unit 78 as illustrated in FIG. 7B, the illuminating light emitted from the lighting member 86b is reflected by the reverse side of the base 52 of the cutting blade 50 and applied to the objective lens 86a. Consequently, an image captured by the image capturing unit 86 includes a relatively bright annular area corresponding to the reverse side of the base 52 of the cutting blade 50.

Then, the control unit 66 (see FIG. 1) determines whether or not a cutting blade 51 is stored on the cutting blade storage unit 78. The control unit 66 has a brightness calculating section 66a for calculating a brightness from an area included in the image captured by the image capturing unit 86 and corresponding to the cutting blade 51 or the cutting blade 50.

When a cutting blade 51 is stored on the cutting blade storage unit 78, the brightness calculating section 66a calculates a brightness from an area included in the image captured by the image capturing unit 86 and corresponding to the cutting blade 51. When a cutting blade 51 is not stored on the cutting blade storage unit 78, the brightness calculating section 66a calculates a brightness from an area included in the image captured by

the image capturing unit 86 and corresponding to the cutting blade 50.

In addition, the control unit 66 has a threshold value storage section 66b that stores a threshold value used as a criterion for differentiating between the brightness of an area included in the captured image and corresponding to the cutting blade 51 and the brightness of an area included in the captured image and corresponding to the cutting blade 50.

Further, the control unit 66 has a determining section 66c for determining whether or not a cutting blade 51 is stored on the cutting blade storage unit 78 by comparing the brightness calculated by the brightness calculating section 66a with the threshold value stored in the threshold value storage section 66b.

In the control unit 66, accordingly, the determining section 66c determines whether or not a cutting blade 51 is stored on the cutting blade storage unit 78 by comparing the brightness calculated by the brightness calculating section 66a from the area included in the image captured by the image capturing unit 86 and corresponding to the cutting blade 51 or the cutting blade 50 and the threshold value stored in the threshold value storage section 66b with each other.

Specifically, when the brightness is higher than the threshold value, the determining section 66c determines that a cutting blade 51 is not stored on the cutting blade storage unit 78. When the brightness is lower than the threshold value, the determining section 66c determines that a cutting blade 51 is stored on the cutting blade storage unit 78.

If the control unit 66 determines that a cutting blade 51 is not stored on the cutting blade storage unit 78, then the boss 82 of the cutting blade storage unit 78 is inserted into the opening 52a (see FIG. 2) of the cutting blade 50 held by the blade gripping unit 114a. Specifically, the Y-axis moving mechanism of the mounting and dismounting unit moving mechanism 90 moves the base 90a along the Y-axis direction to bring the cutting blade 50 into contact with the face side 76a of the support member 76.

Then, the moving mechanism housed in the gripper 116 of the blade gripping unit 114a brings the gripping members 120 disposed on the outer circumferential surface of the gripper 116 into the open state. Therefore, the contact portions 120a of the distal end portions of the gripping members 120 are spaced from the outer circumferential surface of the land 52b of the cutting

blade 50.

Then, the Y-axis moving mechanism of the mounting and dismounting unit moving mechanism 90 moves the base 90a along the Y-axis direction to space the positioning pins 118 protruding from the surface 116a of the gripper 116 from the boss 82. The used cutting blade 50 is thus delivered to the cutting blade storage unit 78.

On the other hand, if the control unit 66 determines that a cutting blade 51 is stored on the cutting blade storage unit 78, then the spindle 74 (see FIG. 5) of the cutting blade stocker 70a is rotated about its rotational axis to bring the gripper 116 of the blade gripping unit 114a and another cutting blade storage unit 78 into facing relation to each other. Then, an operation of confirming whether or not another cutting blade 51 is stored on the cutting blade storage unit 78 is performed again, as described above.

If the control unit 66 determines that cutting blades 51 are stored on all of the cutting blade storage units 78 of the cutting blade stocker 70a, then the control unit 66 sends an error message to the operator of the cutting apparatus 2 using a display, not illustrated, or a pilot lamp, not illustrated, of the cutting apparatus 2.

As described above, the cutting apparatus 2 delivers a cutting blade 50 to a cutting blade storage unit 78 that has been determined as not storing a cutting blade 51 using the image capturing unit, i.e., the storage determining unit, 86. Consequently, a cutting blade 50 is prevented from being delivered to a cutting blade storage unit 78 that has already stored another cutting blade 51.

Further, the recording portion 52c where one or both of the type and characteristics of the cutting blade 50 are recorded is disposed on the reverse side of the base 52 of the cutting blade 50 whose image is captured by the image capturing unit 86. Therefore, the determining section 66c of the control unit 66 can also determine one or both of the type and characteristics of the cutting blade 50 on the basis of the area included in the image captured by the image capturing unit 86 and corresponding to the cutting blade 51 or the cutting blade 50.

Specifically, the cutting apparatus 2 may perform two determining steps, i.e., the step of determining whether or not a cutting blade is stored on the cutting blade storage unit 78 and the step of determining one or both of the type and characteristics of the cutting blade

50, on the basis of the image captured by the single image capturing unit 86. In this case, the cutting apparatus 2 may be manufactured at a low cost as there is no need for a new mechanism for determining one or both of the type and characteristics of the cutting blade 50.

The cutting apparatus 2 represents merely an aspect of the present invention, and the cutting apparatus according to the present invention is not limited to the configuration of the cutting apparatus 2. For example, the present invention is applicable to any determining step insofar as it can determine whether or not another cutting blade 51 is stored on the cutting blade storage unit 78, and the determining step is not limited to the step described above.

Specifically, the image capturing unit 86 may be replaced with a light emitter for emitting visible light, infrared radiation, or the like and a sensor such as a photoelectric sensor for detecting light reflected from an object to be detected and generating an electric signal. According to the present invention, it may be determined whether or not another cutting blade 51 is stored on the cutting blade storage unit 78 on the basis of the electric signal generated by the sensor.

Further, a shutter movable between a closed

position where it covers the front side of the cutting blade storage unit 78 and an open position where it exposes the front side of the cutting blade storage unit 78 may be disposed over the front side of the cutting blade storage unit 78, i.e., the face side 76a of the support member 76.

The shutter has a surface that is spaced the distance d from the face side 76a of the support member 76 when the shutter is in the closed position. The surface of the shutter can reflect the illuminating light emitted from the lighting member 86b of the image capturing unit 86.

In this case, as with the determining step described above, it can be determined whether or not another cutting blade 51 is stored on the cutting blade storage unit 78 on the basis of an image captured by the image capturing unit 86 while the shutter is in the closed position.

Stated otherwise, it can be determined whether or not another cutting blade 51 is stored on the cutting blade storage unit 78 without the cutting blade 50 being placed in the position spaced the distance d from the face side 76a of the support member 76.

The lighting member 86b of the image capturing

unit 86 may not include an oblique lighting member, but may include a coaxial lighting member. If the lighting member 86b includes a coaxial lighting member, then an image captured by the image capturing unit 86 when another cutting blade 51 is stored on the cutting blade storage unit 78 includes a relatively bright annular area corresponding to the reverse side of the base 52 of the cutting blade 51.

On the other hand, an image captured by the image capturing unit 86 when another cutting blade 51 is not stored on the cutting blade storage unit 78 does not include such a relatively bright annular area.

Consequently, even if the lighting member 86b of the image capturing unit 86 is replaced with a coaxial lighting member, it is possible to determine whether or not a cutting blade 51 is stored on the cutting blade storage unit 78 according to the same step as the determining step described above.

The structures, processes, etc., according to the above embodiment and modifications may be changed and such changes may be reduced to practice without departing from the scope 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 cutting apparatus including a chuck table for holding a workpiece thereon, a cutting unit having a cutting blade rotatably mounted for cutting the workpiece held on the chuck table, and a cutting blade changing unit for automatically mounting and dismounting the cutting blade on and from the cutting unit, wherein

the cutting blade changing unit includes a cutting blade stocker having a plurality of cutting blade storage units for individually storing the cutting blades and a cutting blade delivery mechanism for delivering cutting blades between the cutting blade stocker and the cutting unit,

the cutting blade stocker includes a storage determining unit for determining whether or not a cutting blade is stored on one of the cutting blade storage units, and

the cutting blade delivery mechanism delivers a cutting blade to the one of the cutting blade storage units if the storage determining unit determines that a cutting blade is not stored on the one of the cutting blade storage units.

2. The cutting apparatus according to claim 1, further comprising:

a control unit for controlling operation of the cutting blade delivery mechanism, wherein

the storage determining unit includes a lighting member for applying light to the one of the cutting blade storage units and an image capturing device for detecting light from the one of the cutting blade storage units to which the light is applied by the lighting member and converting the detected light into an electric signal, and

the control unit includes

a brightness calculating section for calculating a brightness from an area included in an image captured by the storage determining unit and corresponding to the cutting blade delivered to the one of the cutting blade storage units,

a threshold value storage section for storing a threshold value used as a criterion for differentiating between the brightness of an area included in the captured image and corresponding to the cutting blade when the cutting blade is stored on the one of the cutting blade storage units and the brightness of an area included in the captured image and corresponding to the cutting blade when the cutting blade is not stored on the one of the cutting blade storage units and the

cutting blade is placed in a position that is spaced a predetermined distance from the one of the cutting blade storage units, and

a determining section for determining whether or not the cutting blade is stored on the one of the cutting blade storage units by comparing the brightness calculated by the brightness calculating section with the threshold value stored in the threshold value storage section.

3. The cutting apparatus according to claim 2, wherein

the cutting blade includes a recording portion where one or both of a type and characteristics of the cutting blade are recorded, and

the determining section determines one or both of the type and characteristics of the cutting blade on a basis of an area included in the image captured by the storage determining unit and corresponding to the recording portion.

4. The cutting apparatus according to claim 2 or 3, wherein

the lighting member includes an oblique lighting member.

5. The cutting apparatus according to any one of

claims 2 through 4, wherein

each of the cutting blade storage units is
disposed on a face side of a transparent support member,

the storage determining unit is disposed on a
reverse side of the support member, and

the storage determining unit captures an image of
the cutting blade through the support member.