

METHOD OF GRINDING WORKPIECE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of grinding a workpiece on a grinding apparatus.

Description of the Related Art

A process of manufacturing device chips makes use of a wafer having devices formed individually in a plurality of areas demarcated on the wafer by a plurality of intersecting streets, i.e., projected dicing lines. The wafer is divided along the streets into device chips including the respective devices. The device chips thus produced are incorporated in various electronic appliances such as mobile phones and personal computers.

Recent years have seen demands for thinner device chips for use in smaller electronic appliances. Before wafers are divided into individual device chips, it is customary to grind the wafers on a grinding apparatus, thereby thinning down the wafers. The grinding apparatus includes a chuck table having a holding surface for holding a workpiece, e.g., a wafer, and a grinding unit for grinding the workpiece. The grinding unit has a grinding wheel including grindstones. The grinding unit

grinds the workpiece by bringing the grindstones into abrasive contact with the workpiece while rotating the grinding wheel about its central axis.

For grinding a workpiece such as a wafer on the grinding apparatus, the positional relation between the chuck table and the grinding unit is adjusted such that the center of the workpiece held on the chuck table overlaps the path along which the grindstones move. When the grinding wheel is lowered toward the holding surface of the chuck table while the chuck table and the grinding wheel are rotated about their respective central axes, lower surfaces of the grindstones are brought into abrasive contact with an upper surface of the workpiece, thereby grinding the workpiece. Such a grinding step as described above is referred to as in-feed grinding.

There is another grinding step for grinding workpieces that is referred to as creep feed grinding. According to the creep feed grinding, the positional relation between the chuck table and the grinding unit is adjusted such that the grindstones are positioned outside of the workpiece and the lower surfaces of the grindstones are positioned below the upper surface of the workpiece. In the grinding step, in a state in which the chuck table is not rotated while the grinding wheel is

rotated, the chuck table is moved in a direction parallel to the holding surface, i.e., in a horizontal direction, bringing side surfaces and lower surfaces of the grindstones into abrasive contact with the upper surface of the workpiece. The workpiece is thus ground (see JP 2005-28550A).

SUMMARY OF THE INVENTION

The grindstones included in the grinding wheel are formed by securing abrasive grains made of diamond or the like together with a binder, i.e., a bonding material. The mechanism of the grindstones for grinding a workpiece is as follows: The abrasive grains that partly protrude from the binder collide with the workpiece, grinding the workpiece. When the grindstones continuously grind workpieces, the binder is worn, allowing the exposed abrasive grains to drop off and also allowing the embedded abrasive grains to be newly exposed out of the binder. The phenomenon is called self-dressing. The self-dressing of the grindstones maintains the grinding capability of the grindstones.

According to the creep feed grinding, the grindstones collide inwardly with a side surface of the workpiece to grind the workpiece. Therefore, the

grindstones are more liable to be worn on their side surfaces but are less liable to be worn on the lower surfaces thereof. As a consequence, the lower surfaces of the grindstones are not self-dressed as frequently as desired, resulting in a reduction in the grinding capability of the grindstones. Further, the swarf or ground debris produced by the grinding step collects on the lower surfaces of the grindstones, tending to make the abrasive grains insufficiently protrusive, i.e., to load the grindstones.

When the condition of the grindstones becomes worse in the creep feed grinding step, the grinding apparatus is more likely to cause a processing failure. According to one solution, a dressing step is carried out in the creep feed grinding step to hit the grindstones with a predetermined member, thereby causing the grindstones to wear intentionally. However, since the dressing of the grindstones interrupts the grinding step, the processing efficiency, i.e., the grinding efficiency, of the grinding apparatus tends to be lowered.

The present invention has been made in view of the above difficulties. It is an object of the present invention to provide a method of grinding a workpiece with grindstones in a manner to improve the condition of

grindstones while preventing the processing efficiency from being lowered.

In accordance with an aspect of the present invention, there is provided a method of grinding a workpiece on a grinding apparatus including a chuck table that has a holding surface for holding the workpiece thereon and that is rotatable about a rotational axis extending along directions perpendicular to the holding surface, and a grinding unit with a grinding wheel mounted thereon, the grinding wheel including grindstones for grinding the workpiece. The method includes a first preparing step of adjusting a positional relation between the chuck table and the grinding unit such that the grindstones are positioned outside of the workpiece held on the chuck table and the grindstones have respective lower surfaces positioned a predetermined distance below an upper surface of the workpiece held on the chuck table, a first grinding step of, after the first preparing step is performed, relatively moving the chuck table and the grinding unit along directions parallel to the holding surface to grind the workpiece from one end to the other end thereof with the grindstones while the grinding wheel is rotated, a second preparing step of, after the first grinding step is performed, adjusting the

positional relation between the chuck table and the grinding unit such that the rotational axis of the chuck table and a path along which the grindstones move overlap, and a second grinding step of, after the second preparing step is performed, relatively moving the chuck table and the grinding unit along the directions perpendicular to the holding surface to grind the workpiece with the grindstones while the chuck table and the grinding wheel are rotated.

Preferably, in the method of grinding a workpiece, the first preparing step, the first grinding step, the second preparing step, and the second grinding step are each carried out twice or more times.

In the method of grinding a workpiece according to the aspect of the present invention, after the first grinding step of relatively moving the chuck table and the grinding unit along the directions parallel to the holding surface has been carried out, the second grinding step of relatively moving the chuck table and the grinding unit along the directions perpendicular to the holding surface is carried out. Therefore, wear on the lower surfaces of the grindstones is promoted, improving the condition of the grindstones. In the second grinding step, the lower surfaces of the grindstones are dressed

at the same time that they grind the workpiece. Consequently, as the workpiece is continuously ground while the lower surfaces of the grindstones are dressed, the processing efficiency, i.e., the grinding efficiency, of the grinding apparatus is increased.

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 sectional side elevational view of a grinding apparatus that carries out a method of grinding a workpiece according to an embodiment of the present invention;

FIG. 2 is a perspective view of a chuck table and a grinding unit of the grinding apparatus illustrated in FIG. 1;

FIG. 3A is a side elevational view of the chuck table and the grinding unit in a first preparing step of the method;

FIG. 3B is a side elevational view of the chuck table and the grinding unit in a first grinding step of the method;

FIG. 4A is a side elevational view of the chuck table and the grinding unit in a second preparing step of the method; and

FIG. 4B is a side elevational view of the chuck table and the grinding unit in a second grinding step of the method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described hereinbelow with reference to the accompanying drawings. First, a grinding apparatus that carries out a method of grinding a workpiece according to the present embodiment will be described below. FIG. 1 illustrates the grinding apparatus, which is generally denoted by 2, in sectional side elevation. Note that, in FIG. 1, X-axis directions (first processing feed directions, first horizontal directions, or forward and rearward directions) and Y-axis directions (second horizontal directions or leftward and rightward directions) extend perpendicularly to each other. In addition, Z-axis directions (second processing feed

directions, vertical directions, upward and downward directions, or heightwise directions) extend perpendicularly to the X-axis directions and the Y-axis directions.

The grinding apparatus 2 includes a base 4 supporting or housing various components of the grinding apparatus 2. The base 4 has an opening 4a in the shape of a rectangular parallelepiped defined in an upper surface side thereof. The opening 4a houses therein a chuck table (holding table) 6 for holding thereon a workpiece 11, which is typically a wafer, to be processed, i.e., ground, by the grinding apparatus 2. The chuck table 6 has an upper surface lying flatwise generally parallel to the X-axis directions and the Y-axis directions and acting as a holding surface 6a for holding the workpiece 11 thereon.

The opening 4a also houses therein a moving mechanism (moving unit) 8 that is operatively coupled to the chuck table 6 to move the chuck table 6 along the X-axis directions. Specifically, the moving mechanism 8 includes a ball screw 10 that extends along the X-axis directions and that is threaded through a nut (not illustrated) fixed to the chuck table 6, and a stepping motor 12 for rotating the ball screw 10 about its central

axis is connected to an end of the ball screw 10. When the stepping motor 12 is energized, it rotates the ball screw 10 about its central axis, causing the nut to move the chuck table 6 along one or the other of the X-axis directions.

A rotary actuator (not illustrated) such as an electric motor is coupled to the chuck table 6 to rotate the chuck table 6 about its central axis, i.e., a rotational axis generally parallel to the Z-axis directions, generally perpendicular to the holding surface 6a of the chuck table 6. The rotational axis of the chuck table 6 thus extends along directions perpendicular to the holding surface 6a.

A support structure (column) 14 in the shape of a rectangular parallelepiped is disposed on, i.e., erected from, a portion of the base 4 behind the chuck table 6 and the moving mechanism 8 (on a right side of the base 4 in FIG. 1) providing that a left side of the base 4 in FIG. 1 is assumed to be a front side of the grinding apparatus 2. A moving mechanism (moving unit) 16 is mounted on a surface, i.e., a front side, of the support structure 14. When the moving mechanism 16 is in operation, it relatively moves the chuck table 6 and a grinding unit 28, which is to be described later, on the

support structure 14 selectively toward and away from each other along directions, i.e., the Z-axis directions, perpendicular to the holding surface 6a of the chuck table 6.

Specifically, the moving mechanism 16 includes a pair of guide rails 18, one of which is illustrated in FIG. 1, fixedly mounted on the surface of the support structure 14. The guide rails 18 are spaced from each other in the Y-axis directions and extend vertically along the Z-axis directions. A flat movable plate 20 is slidably mounted on the guide rails 18 for sliding movement along the guide rails 18. A nut 22 is fixed to a reverse side, i.e., a rear surface, of the movable plate 20 and is operatively threaded over a ball screw 24 that is disposed between the guide rails 18 and that extends along the Z-axis directions. A stepping motor 26 for rotating the ball screw 24 about its central axis is coupled to the upper end of the ball screw 24. When the stepping motor 26 is energized, it rotates the ball screw 24 about its central axis, causing the nut 22 to move the movable plate 20 along the guide rails 18 in one or the other of the Z-axis directions, i.e., to lift or lower the movable plate 20 along the guide rails 18.

The grinding unit 28 that grinds the workpiece 11

on the chuck table 6 is mounted on a face side, i.e., a front surface, of the movable plate 20. The grinding unit 28 includes a hollow cylindrical support member 30 fixed to the face side of the movable plate 20. The support member 30 houses a cylindrical housing 32 therein. The housing 32 has a lower surface supported on the bottom of the support member 30 through a damper 34 of rubber or the like interposed therebetween.

A cylindrical spindle 36 extending along the Z-axis directions is rotatably housed in the housing 32. The spindle 36 has a distal end, i.e., a lower end, that is exposed out of the housing 32 and that protrudes downwardly from the support member 30 through an opening defined in the bottom of the support member 30. The spindle 36 has a proximal end, i.e., an upper end, to which there is coupled a rotary actuator (not illustrated) such as an electric motor for rotating the spindle 36 about its central axis. A disk-shaped mount 38 made of metal or the like is fixed to the distal end of the spindle 36. The mount 38 has a lower surface to which an annular grinding wheel 40 for grinding the workpiece 11 on the chuck table 6 is fixed by fastening members such as bolts, for example.

The grinding wheel 40 includes an annular base 42

that is made of metal such as aluminum or stainless steel and that has generally the same outside diameter as the diameter of the mount 38. The base 42 has an upper surface fixed to the lower surface of the mount 38 and a lower surface to which a plurality of grindstones 44 are secured. The grindstones 44 that are each shaped as a rectangular parallelepiped, for example, are spaced at generally equal angular intervals and arranged in an annular array along the circumferential directions of the base 42. Each of the grindstones 44 is made of abrasive grains of diamond or cubic boron nitride (cBN) bound by a binder (bonding material) such as metal bond, resin bond, or vitrified bond. However, the grindstones 44 are not limited to any material, shape, structure, size, and so on, and may be provided in any number.

The grinding wheel 40 is rotatable about its central axis that is generally perpendicular to the holding surface 6a of the chuck table 6, i.e., a rotational axis generally parallel to the Z-axis directions, by the power transmitted from the rotary actuator coupled to the proximal end of the spindle 36 through the spindle 36 and the mount 38. The rotational axis of the grinding wheel 40 thus extends along directions perpendicular to the holding surface 6a. When

the rotating grindstones 44 of the grinding wheel 40 are brought into abrasive contact with the upper surface of the workpiece 11 held on the chuck table 6, the grindstones 44 scrape off a layer from the upper surface of the workpiece 11. In this manner, the workpiece 11 is ground and thinned down.

The various components (chuck table 6, moving mechanism 8, moving mechanism 16, grinding unit 28, etc.) of the grinding apparatus 2 are electrically connected to a control unit (controller or control device) 46 that controls the grinding apparatus 2. The control unit 46 generates control signals for controlling operation of the components of the grinding apparatus 2, to control operation of the grinding apparatus 2. For example, the control unit 46 is a computer and includes a processing section for performing processing operations required to operate the grinding apparatus 2 and a storage section for storing various pieces of information (data, programs, etc.) used to operate the grinding apparatus 2. The processing section includes a processor such as a central processing unit (CPU). The storage section includes various memories functioning as a main storage device, an auxiliary storage device, etc.

The workpiece 11 is ground by the grinding unit 28

while being held on the chuck table 6. FIG. 2 illustrates the chuck table 6 and the grinding unit 28 in perspective. The chuck table 6 includes a cylindrical frame (main body) 48 made of metal such as stainless steel (SUS) or made of glass, ceramic, resin, or the like. The frame 48 has a cylindrical recess 48b defined centrally in an upper surface 48a of the frame 48. The recess 48b houses a disk-shaped holder 50 fitted therein that is made of a porous material such as porous ceramic. The holder 50 contains pores (fluid passages) therein that extend from upper to lower surfaces of the holder 50. The upper surface, which is denoted by 50a, of the holder 50 acts as a suction surface for attracting, under suction forces, the workpiece 11 that is held on the chuck table 6. The depth of the recess 48b and the thickness of the holder 50 are generally the same as each other. The upper surface 48a of the frame 48 lies substantially flush with the upper surface 50a of the holder 50. Further, the upper surface 48a of the frame 48 and the upper surface 50a of the holder 50 jointly make up the holding surface 6a of the chuck table 6. The holding surface 6a is held in fluid communication with a suction source (not illustrated) such as an ejector via the pores in the holder 50, a fluid channel (not

illustrated) defined in the frame 48, a valve (not illustrated), and so on.

For grinding and thinning down the workpiece 11 on the grinding apparatus 2, the workpiece 11 is placed on the holding surface 6a of the chuck table 6. The workpiece 11 is, for example, a disk-shaped wafer made of a semiconductor material such as silicon and includes a face side (first surface) 11a and the reverse side (second surface) 11b that lie generally parallel to each other. The workpiece 11 has a plurality of rectangular areas demarcated on the face side 11a by a grid of intersecting streets (projected dicing lines). Devices (not illustrated) such as integrated circuits (ICs), large-scale-integration (LSI) circuits, light-emitting diodes (LEDs), or micro-electro-mechanical systems (MEMS) devices are formed individually in the demarcated areas of the face side 11a of the workpiece 11.

The reverse side 11b of the workpiece 11 is ground by the grinding unit 28 of the grinding apparatus 2, thereby thinning down the workpiece 11. The thinned workpiece 11 is then divided along the streets into a plurality of device chips including the respective devices. Therefore, the device chips are of a thinned profile. Note that the workpiece 11 is not limited to any

kind, material, size, shape, structure, and so on. The workpiece 11 may be a disk-shaped wafer (board) made of a semiconductor material other than silicon, such as GaAs, InP, GaN, or Sic, or made of glass, ceramic, resin, metal, or the like, for example. Alternatively, the workpiece 11 may be a package board such as a chip-size-package (CSP) board or a quad-flat-non-leaded-package (QFN) board.

For example, the workpiece 11 is placed on the chuck table 6 such that the face side 11a faces the holding surface 6a and the reverse side 11b is exposed upwardly. When suction forces (negative pressure) from the suction source is applied to the holding surface 6a, the workpiece 11 is held under suction on the chuck table 6. Note that the face side 11a of the workpiece 11 may be covered with a protective sheet made of resin or the like for protecting the face side 11a, specifically the devices thereon, of the workpiece 11. In a case where the face side 11a is covered with a protective sheet, the workpiece 11 is held on the holding surface 6a of the chuck table 6 with the protective sheet interposed therebetween.

The workpiece 11 held on the chuck table 6 is ground and thinned by the grindstones 44 of the grinding

wheel 40. A grinding fluid supply passage (not illustrated) for supplying a fluid such as pure water, which is also referred to as a grinding fluid, is disposed in or near the grinding unit 28. For grinding the workpiece 11 with the grindstones 44 in a grinding step performed by the grinding apparatus 2, the grinding fluid supply passage supplies the grinding fluid to the workpiece 11 and the grindstones 44. The supplied grinding fluid cools the workpiece 11 and the grindstones 44 and washes away the swarf or ground debris produced by the grinding step.

According to the present embodiment, the grinding apparatus 2 grinds the workpiece 11 in a creep feed grinding step in which the chuck table 6 and the grinding wheel 40 are relatively moved along directions parallel to the holding surface 6a to grind the workpiece 11, and in an in-feed grinding step in which the chuck table 6 and the grinding wheel 40 are relatively moved along directions perpendicular to the holding surface 6a to grind the workpiece 11. A specific example of the method of grinding a workpiece according to the present embodiment on the grinding apparatus 2 that operates in the creep feed grinding step and the in-feed grinding step will be described hereinbelow.

First, the positional relation between the chuck table 6 and the grinding unit 28 is adjusted (first preparing step). FIG. 3A illustrates, in side elevation, the chuck table 6 and the grinding unit 28 in the first preparing step. In the first preparing step, the positional relation between the chuck table 6 and the grinding unit 28 is adjusted such that the grindstones 44 are positioned outside of the workpiece 11 held on the chuck table 6 and the lower surfaces of the grindstones 44 are positioned a predetermined distance below the upper surface, i.e., the reverse side 11b, of the workpiece 11 on the chuck table 6. Specifically, the position of the chuck table 6 along the X-axis directions is controlled by the moving mechanism 8 (see FIG. 1) to position the workpiece 11 forwardly of the grinding wheel 40, i.e., on the left side of the grinding wheel 40 in FIG. 3A, without overlapping the grinding wheel 40. Further, the position of the grinding unit 28 along the Z-axis directions is controlled by the moving mechanism 16 (see FIG. 1) to position the lower surfaces of the grindstones 44 below the reverse side 11b of the workpiece 11. The difference ΔH between the vertical position, i.e., the position along the Z-axis directions, of the reverse side 11b of the workpiece 11 and the

vertical position, i.e., the position along the Z-axis directions, of the lower surfaces of the grindstones 44 at this time represents a target value for the amount to be ground off the workpiece 11 in a next first grinding step, i.e., the difference between the thickness of the workpiece 11 before being ground and the thickness of the workpiece 11 after being ground.

Next, while the grinding wheel 40 is rotated about its central axis, the chuck table 6 and the grinding unit 28 are relatively moved along a direction parallel to the holding surface 6a to cause the grindstones 44 to grind the workpiece 11 diametrically from one end to the other end of the workpiece 11 (first grinding step). FIG. 3B illustrates, in side elevation, the chuck table 6 and the grinding unit 28 in the first grinding step.

In the first grinding step, the grinding unit 28 grinds the workpiece 11 in the creep feed grinding step. Specifically, the spindle 36 is rotated to rotate the grinding wheel 40 about the rotational axis generally perpendicular to the holding surface 6a of the chuck table 6. For example, the grinding wheel 40 is rotated at a rotational speed in the range of 1000 to 3000 rpm. While the grinding wheel 40 is thus rotated, the chuck table 6 is moved by the moving mechanism 8 (see FIG. 1)

toward the grinding wheel 40 in one of the X-axis directions as indicated by an arrow in FIG. 3B without being rotated (first processing feed). The chuck table 6 and the grinding wheel 40 are now brought closely to each other along a direction parallel to the holding surface 6a of the chuck table 6. The chuck table 6 is moved at a speed, i.e., a processing feed speed, in the range of 1 to 20 mm/second, for example.

When the chuck table 6 is thus moved until one end of the workpiece 11 (the front end of the workpiece 11 in its moving direction, i.e., the right end thereof in FIG. 3B) reaches the path along which the grindstones 44 move, the grindstones 44 scrape a layer off the reverse side 11b of the workpiece 11 at the end of the workpiece 11. The chuck table 6 is continuously moved in the same X-axis direction indicated by the arrow in FIG. 3B until the other end of the workpiece 11 (the rear end of the workpiece 11 in its moving direction, i.e., the left end thereof in FIG. 3B) reaches a position underlying the path along which the grindstones 44 move. As a result, the reverse side 11b of the workpiece 11 is ground diametrically from the one end to the other end thereof, so that the workpiece 11 is thinned down in its entirety.

In the above creep feed grinding step, as the

grindstones 44 collide inwardly with the side surface of the workpiece 11 to grind the workpiece 11, the grindstones 44 are more liable to be worn on their side surfaces but are less liable to be worn on the lower surfaces thereof. In other words, during the grinding step, the position of the lower surfaces of the grindstones 44 does not tend to vary in the Z-axis directions. As a result, any error of the amount of material ground off the workpiece 11 is relatively small. Further, an arcuate flaw, which is also referred to as a ground mark or a saw mark, formed along the path along which the grindstones 44 move remains on the reverse side 11b of the workpiece 11 that has been ground. In the creep feed grinding step, since the workpiece 11 is ground while the chuck table 6 is not rotating, a plurality of generally parallel ground marks are formed on the reverse side 11b of the workpiece 11 that has been ground. As the ground marks are thus aligned in orientation, the anisotropy of the mechanical strength of the ground workpiece 11 can be controlled.

However, inasmuch as the grindstones 44 are less liable to be worn on the lower surfaces thereof in the creep feed grinding step, the lower surfaces of the grindstones 44 are not likely to be self-dressed.

Moreover, as the swarf or ground debris produced by the grinding step collects on the lower surfaces of the grindstones 44, the abrasive grains of the grindstones 44 are likely to be insufficiently protrusive, i.e., the swarf or ground debris are likely to load the grindstones 44. Consequently, when only the creep feed grinding step is performed over a long period of time, the grinding capability of the grindstones 44 may be lowered.

According to the present embodiment, in view of the above difficulties, the workpiece 11 is ground in the in-feed grinding step after it has been ground in the creep feed grinding step. When the workpiece 11 is ground in the in-feed grinding step, wear on the lower surfaces of the grindstones 44 is promoted, keeping the grindstones 44 in a good condition.

After the first grinding step has been carried out, the positional relation between the chuck table 6 and the grinding unit 28 is adjusted (second preparing step).

FIG. 4A illustrates, in side elevation, the chuck table 6 and the grinding unit 28 in the second preparing step. In the second preparing step, the positional relation between the chuck table 6 and the grinding unit 28 is adjusted such that the rotational axis of the chuck table 6 and the path along which the grindstones 44 move

overlap. Note that the path along which the grindstones 44 move refers to an annular route, i.e., a travel route or rotational route, along which each of the grindstones 44 passes when the grinding wheel 40 is rotated. Specifically, the moving mechanism 16 (see FIG. 1) lifts the grinding unit 28 to space the grindstones 44 away from the workpiece 11 on the chuck table 6. Then, the position of the chuck table 6 along the X-axis directions is controlled by the moving mechanism 8 (see FIG. 1) such that the rotational axis of the chuck table 6 overlaps the path along which the grindstones 44 move. For example, the position of the chuck table 6 is adjusted such that the center of the holding surface 6a and the center of the workpiece 11 overlap one of the grindstones 44 that is disposed on the front end of the grinding wheel 40, i.e., the left end thereof in FIG. 4A.

Then, while the chuck table 6 and the grinding unit 28 are rotated, the chuck table 6 and the grinding unit 28 are relatively moved toward each other along directions perpendicular to the holding surface 6a, i.e., the Z-axis directions, causing the grindstones 44 to grind the workpiece 11 (second grinding step). FIG. 4B illustrates, in side elevation, the chuck table 6 and the grinding unit 28 in the second grinding step.

In the second grinding step, the workpiece 11 is ground in the in-feed grinding step. Specifically, while the chuck table 6 and the grinding wheel 40 are rotated, the grinding unit 28 is lowered by the moving mechanism 16 (see FIG. 1) in one of the Z-axis directions as indicated by an arrow in FIG. 4B (second processing feed). The chuck table 6 and the grinding wheel 40 are now brought closely to each other along a direction perpendicular to the holding surface 6a of the chuck table 6. When the lower surfaces of the grindstones 44 are brought into abrasive contact with the upper surface, i.e., the reverse side 11b, of the workpiece 11, the grindstones 44 scrape a layer off the reverse side 11b of the workpiece 11, thereby thinning down the workpiece 11. The workpiece 11 is continuously ground until the workpiece 11 is thinned down to a predetermined thickness.

In the second grinding step, the lower surfaces of the grindstones 44 that are held in abrasive contact with the workpiece 11 are worn and self-dressed, preventing themselves from being loaded with the swarf. Therefore, the lower surfaces of the grindstones 44 are dressed at the same time that the workpiece 11 is ground. As a consequence, the condition of the grindstones 44 is

improved, and the grinding capability of the grindstones 44 is recovered.

Processing conditions for the workpiece 11 in the second grinding step are established to allow the lower surfaces of the grindstones 44 to be dressed appropriately. For example, the amount of material to be ground off the workpiece 11 is set to a value in the range of 10 to 100 μm , preferably of 20 to 40 μm . The rotational speed of the chuck table 6 is set to a value in the range of 100 to 300 rpm. The speed of descent of the grinding unit 28, i.e., the processing feed speed, is set to a value in the range of 0.2 to 1 $\mu\text{m}/\text{second}$. In the second grinding step, the rotational speed of the grinding wheel 40 should preferably be lower than that used when workpieces are ground in an ordinary in-feed grinding step mainly for the purpose of thinning down the workpieces. Wear on the lower surfaces of the grindstones 44 is thus promoted, and the condition of the grindstones 44 is improved in a short period of time. Specifically, the rotational speed of the grinding wheel 40 should preferably be in the range of 2000 to 3000 rpm, for example.

Thereafter, a third preparing step whose details are the same as those of the first preparing step (see

FIG. 3A) and a third grinding step whose details are the same as those of the first grinding step (see FIG. 3B) are successively carried out, thus resuming the creep feed grinding step. In the third grinding step, the workpiece 11 is ground by the grindstones 44 whose condition has been improved in the second grinding step. The quality of the processed workpiece 11 is thus increased, and processing failures are prevented from being caused. The grinding of the workpiece 11 is completed when the workpiece 11 is thinned down until the thickness of the workpiece 11 reaches a predetermined target value, i.e., a finished thickness.

The grinding apparatus 2 grinds the workpiece 11 as described above when the control unit 46 (see FIG. 1) controls operation of the components of the grinding apparatus 2. Specifically, the storage section of the control unit 46 stores programs descriptive of a series of operations of the components of the grinding apparatus 2 that are required to carry out the first preparing step, the first grinding step, the second preparing step, the second grinding step, the third preparing step, and the third grinding step. For grinding the workpiece 11, the processing section of the control unit 46 reads the programs from the storage section and output control

signals to the components of the grinding apparatus 2 according to the programs. Operation of the grinding apparatus 2 is now controlled to automatically carry out the method of grinding a workpiece according to the present embodiment.

With the method of grinding a workpiece according to the present embodiment, as described above, after the first grinding step, i.e., the creep feed grinding step, has been carried out to relatively move the chuck table 6 and the grinding unit 28 along the directions parallel to the holding surface 6a, the second grinding step, i.e., the in-feed grinding step, is carried out to relatively move the chuck table 6 and the grinding unit 28 along the directions perpendicular to the holding surface 6a. Therefore, wear on the lower surfaces of the grindstones 44 is promoted, improving the condition of the grindstones 44. Further, in the second grinding step, i.e., the in-feed grinding step, the lower surfaces of the grindstones 44 are dressed at the same time that they grind the workpiece 11. Consequently, as the workpiece 11 is continuously ground while the lower surfaces of the grindstones 44 are dressed, the processing efficiency, i.e., the grinding efficiency, of the grinding apparatus 2 is increased.

Note that, in the method of grinding a workpiece according to the present embodiment, the number of times that the creep feed grinding step, i.e., the first preparing step and the first grinding step, is carried out, and the number of times that the in-feed grinding step, i.e., the second preparing step and the second grinding step, is carried out, may be set to appropriate values depending on the material of the workpiece 11, the amount of material to be ground off the workpiece 11, and other factors. Specifically, the first preparing step, the first grinding step, the second preparing step, and the second grinding step may each be carried out twice or more times. For example, after the creep feed grinding step, i.e., the first preparing step and the first grinding step, has been carried out once or twice, the in-feed grinding step, i.e., the second preparing step and the second grinding step, is carried out once, improving the condition of the grindstones 44. Thereafter, the creep feed grinding step and the in-feed grinding step are successively repeated to thin down the workpiece 11 in a similar manner. In this way, the grindstones 44 can thin down the workpiece 11 to a desired thickness while the grindstones 44 are maintained in a good condition. However, the last grinding step to

be performed on the workpiece 11 should preferably be the creep feed grinding step (third grinding step). The workpiece 11 thus ground has thickness variations reduced, and the anisotropy of the mechanical strength of the ground workpiece 11 is controlled.

The structural details, steps, and other features according to the above embodiment may be changed or modified appropriately 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 method of grinding a workpiece on a grinding apparatus,

the grinding apparatus including

a chuck table that has a holding surface for holding the workpiece thereon and that is rotatable about a rotational axis extending along directions perpendicular to the holding surface, and

a grinding unit with a grinding wheel mounted thereon, the grinding wheel including grindstones for grinding the workpiece,

the method comprising:

a first preparing step of adjusting a positional relation between the chuck table and the grinding unit such that the grindstones are positioned outside of the workpiece held on the chuck table and the grindstones have respective lower surfaces positioned a predetermined distance below an upper surface of the workpiece held on the chuck table;

a first grinding step of, after the first preparing step is performed, relatively moving the chuck table and the grinding unit along directions parallel to the holding surface to grind the workpiece from one end to another end of the workpiece with the grindstones while

the grinding wheel is rotated;

a second preparing step of, after the first grinding step is performed, adjusting the positional relation between the chuck table and the grinding unit such that the rotational axis of the chuck table and a path along which the grindstones move overlap; and

a second grinding step of, after the second preparing step is performed, relatively moving the chuck table and the grinding unit along the directions perpendicular to the holding surface to grind the workpiece with the grindstones while the chuck table and the grinding wheel are rotated.

2. The method of grinding a workpiece according to claim 1, wherein the first preparing step, the first grinding step, the second preparing step, and the second grinding step are each carried out twice or more times.