

DESCRIPTION

CUTTING APPARATUS AND CUTTING METHOD

[TECHNICAL FIELD]

[0001]

This invention relates to a cutting apparatus and a cutting method for use in cutting an article to be cut into separate pieces to provide a plurality of individual products.

[BACKGROUND ART]

[0002]

In the relevant technical field, there are substrates termed as “sealed substrate”. Specifically describing the sealed substrate, a substrate, including a printed board and a lead frame, is virtually divided into a plurality of grid-like regions to mount in each of these regions a chip-like device (for example, semiconductor chip), and the whole chip-mounted substrate is sealed in a resin material. The sealed substrate is cut by a cutting mechanism with a rotary blade attached thereto, and separate pieces in the respective regions thereby cut out from the sealed substrate will become individual products.

[0003]

In the cutting apparatuses conventionally used to cut the sealed substrate, the sealed substrate is cut by a rotary blade attached to a cutting mechanism by each of regions predefined thereon. To start with, the sealed substrate is mounted on and attached by suction to a cutting table. Then, the sealed substrate is aligned (positionally adjusted) to define positions of virtual cutting lines for division of the substrate into plural regions. Subsequently, the cutting mechanism and the cutting table with the sealed substrate attached by suction thereto are moved relative to each other. With

a cutting fluid being ejected onto sections-to-be-cut of the sealed substrate, the sealed substrate is cut into separate pieces along the cutting lines defined thereon by the cutting mechanism. Finally, the pieces cut out from the sealed substrate will become individual products.

[0004]

In the cutting mechanism, the rotary blade is connected to a driving mechanism through a rotating shaft. The cutting mechanism cuts the sealed substrate by way of high-speed rotation of the rotating shaft driven by the driving mechanism. The rotating shaft rotating at high speed generates heat and thermally expands, displacing in a direction along the center line of the rotating shaft (rotating-shaft direction). As the rotating shaft is displaced in the rotating-shaft direction, the rotary blade attached to an edge of the rotating shaft displaces in the same direction. In order to suppress the thermal expansion of the rotating shaft, cooling water is conventionally supplied to run around the rotating shaft. The degree of displacement of the rotating shaft is desirably reduced to a minimum extent. To this end, the cutting mechanism is supplied with a large quantity of cooling water against potential constant flow of rated current. Yet, electric current possibly affecting the cutting mechanism is mostly not as high as rated current, which is exemplified by electric current during idling. Under the circumstances, steady supply of a large quantity of cooling water to the cutting mechanism is considered a significant waste, unnecessarily increasing economic burden.

[0005]

In this context, the flow rate of cooling water supplied to the cutting mechanism would be desirably lowered. This is, however, fraught with the problem of a larger degree of displacement of the rotating shaft. Further disadvantageously, changes of the flow rate of cooling water during the operation of the cutting apparatus, in turn, invite changes of the positional displacement of the rotary blade attached to the edge of the

rotating shaft. Then, it follows that any change of the flow rate of cooling water makes it difficult to correct the positional displacement of the rotary blade associated with the displaced rotating shaft. Under the circumstances, there is currently no choice but to continue to wastefully supply the cutting mechanism with a large quantity of cooling water.

[0006]

So far has been disclosed a processing apparatus directed to economical use of fluids such as water and air. The processing apparatus “at least comprises: a spindle unit including; a rotary spindle ...; a spindle housing that rotatably supports the rotary spindle; and a fluid used or generated during cutting of an article to be cut, wherein a flow rate regulator is disposed in a fluid flow path to regulate the flow rate of the fluid, and the flow rate of the fluid is regulated in conjunction with activation / deactivation of the rotary spindle” (for example, [0110], Figs. 3 to 5 of the patent document 1).

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0007]

PATENT DOCUMENT 1 Japanese Laid-Open Patent Application No.
2001-259961

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0008]

The processing apparatus disclosed in the patent document 1 involves the problem described below. As illustrated in Fig. 4 of the patent document 1, in order to prevent generation of heat and resultant expansion of a rotary spindle 22 in a direction along Y axis (rotating-shaft direction) to avoid the risk of displacement of a dicing blade 18, cooling water is

continuously supplied to flow in a cooling water supply channel 30 while the rotary spindle 22 is rotating. During that time, the cooling water supplied by a cooling water generator 32 runs into the cooling water supply channel 30 by way of a first control valve 31 opened as instructed by a first controller 33. The cooling water is circulated inside a spindle housing 23 and then discharged through a drain.

[0009]

This processing apparatus provides for continuous supply of cooling water in a certain quantity while the rotary spindle 22 is rotating. The articles to be cut, however, differ in size, thickness, and used material and thus, depending on the articles to be cut, cutting load when cutting the articles to be cut differs. Increase of the cutting load requires higher load current to rotate the rotary blade 22, generating more heat. Further, adverse events, such as use-related wear of the dicing blade 18 and abrasive grains chipping off from the dicing blade 18, may undermine the cutting quality of the dicing blade 18, necessitating larger cutting load. When such events happen, the rotary spindle 22 even further thermally expands and displaces, demanding the supply of a large quantity of cooling water. Even with small load current whenever the cutting operation is inactive, a large quantity of cooling water is supplied as far as the rotary spindle 22 is rotating. Such an excess of cooling water wastefully supplied is a direct contributing factor to inability to cut down on operational costs of the cutting apparatus.

[0010]

To solve the problem of the prior art, the invention provides a cutting apparatus and a cutting method wherein the flow rate of cooling water supplied to the cutting mechanism may be controllable at all times while the rotating shaft is rotating.

[SOLUTIONS TO THE PROBLEM]

[0011]

A cutting apparatus according to the invention, includes:

a table to be mounted with the article to be cut;

a cutting mechanism that cuts the article to be cut; and

a moving mechanism that relatively moves the table and the cutting mechanism,

the cutting apparatus being for use in cutting the article to be cut along a cutting line into separate pieces to provide a plurality of individual products, the cutting apparatus further including:

a rotating shaft installed in the cutting mechanism;

a driving mechanism installed in the cutting mechanism to drive the rotating shaft to rotate;

a cooling water passage formed in the cutting mechanism around the rotating shaft;

a rotary blade attached to an edge of the rotating shaft;

a first fixture disposed on the edge at a position closer to the cutting mechanism;

a second fixture disposed at a position closer to the edge in view from the first fixture, the second fixture fixing the rotary blade being sandwiched between the first fixture and the second fixture;

an electric current supply mechanism that supplies the driving mechanism with electric current;

a measurement unit that measures a physical quantity associated with the cutting mechanism;

a flow rate regulating unit connected to the cooling water passage to regulate a flow rate of cooling water supplied to flow in the cooling water passage;

a cooling water delivery mechanism that delivers the cooling water to the flow rate regulating unit; and

a controller connected to at least the flow rate regulating unit,

wherein

the controller compares a measured value of the physical quantity measured by the measurement unit to a prestored value of the physical quantity, and

the flow rate of the cooling water supplied to flow in the cooling water passage is changed based on a result of the comparison.

[0012]

The cutting apparatus according to an aspect of the invention is further characterized in that the measurement unit is an electric current measurement unit connected to the driving mechanism to measure the electric current,

the physical quantity is the electric current,

the controller is connected to the electric current measurement unit, and

the controller detects variations of the electric current based on the result of the comparison, and increases or decreases the flow rate of the cooling water in accordance with a result of the detection.

[0013]

The cutting apparatus according to another aspect of the invention is further characterized in that the measurement unit is a distance measurement unit installed in the cutting mechanism to measure a distance between the cutting mechanism and the fixture,

the physical quantity is the distance,

the controller is connected to the distance measurement unit, and

the controller detects variations of the distance based on the result of the comparison, and increases or decreases the flow rate of the cooling water in accordance with a result of the detection.

[0014]

The cutting apparatus according to yet another aspect of the invention is further characterized in that the controller calculates a difference

between a measured value and a prestored value of the distance between the cutting mechanism and the fixture, and aligns a position of the rotary blade to a position of the cutting line based on the difference.

[0015]

The cutting apparatus according to yet another aspect of the invention is further characterized in that the distance measurement unit includes at least an eddy current displacement sensor or an optical displacement sensor.

[0016]

The cutting apparatus according to yet another aspect of the invention is further characterized in that the prestored value is a plurality of prestored values,

the plurality of prestored values are respectively associated with a plurality of flow rate values of the cooling water, and

the measured value is compared to the plurality of prestored values to regulate the flow rate of the cooling water supplied to flow in the cooling water passage to be any one of the plurality of flow rate values.

[0017]

The cutting apparatus according to yet another aspect of the invention is further characterized in that the article to be cut is a sealed substrate.

[0018]

The cutting apparatus according to yet another aspect of the invention is further characterized in that the article to be cut is a substrate embedded with functional elements in a plurality of regions respectively corresponding to the plurality of products.

[0019]

A cutting method according to the invention includes steps of:
mounting an article to be cut on a table;
relatively moving the table and a cutting mechanism;

cutting the article to be cut along a cutting line using the cutting mechanism by way of the relative movement between the table and the cutting mechanism;

supplying a driving mechanism installed in the cutting mechanism with electric current;

rotating, using the driving mechanism, a rotating shaft and a rotary blade fixedly sandwiched between a first fixture disposed on an edge of the rotating shaft at a position closer to the cutting mechanism and a second fixture disposed at a position closer to the edge in view from the first fixture;

delivering cooling water from a cooling water delivery mechanism to a flow rate regulating unit;

supplying a cooling water passage arranged around the rotating shaft with the cooling water from the flow rate regulating unit;

measuring a physical quantity associated with the cutting mechanism;

comparing a measured value of the physical quantity to a prestored value of the physical quantity; and

changing a flow rate of the cooling water supplied to flow in the cooling water passage based on a result of the comparison in the comparing step.

[0020]

The cutting method according to an aspect of the invention is further characterized in that the physical quantity is electric current, and

the step of changing the flow rate includes detecting variations of the electric current based on the result of the comparison and further includes increasing or decreasing the flow rate of the cooling water in accordance with a result of the detection.

[0021]

The cutting method according to another aspect of the invention is further characterized in that the physical quantity is a distance between the

cutting mechanism and the fixture, and

the step of changing the flow rate includes detecting variations of the distance based on the result of the comparison and further includes increasing or decreasing the flow rate of the cooling water in accordance with a result of the detection.

[0022]

The cutting method according to yet another aspect of the invention further includes steps of:

measuring the distance between the cutting mechanism and the fixture using a distance measurement unit installed in the cutting mechanism;

calculating a difference between a measured value and a prestored value of the distance; and

aligning a position of the rotary blade to a position of the cutting line based on the difference.

[0023]

The cutting method according to yet another aspect of the invention is further characterized in that the distance measurement unit includes at least an eddy current displacement sensor or an optical displacement sensor.

[0024]

The cutting method according to yet another aspect of the invention is further characterized in that the prestored value is a plurality of prestored values,

the plurality of prestored values are respectively associated with a plurality of flow rate values of the cooling water, and

the measured value is compared to the plurality of prestored values to regulate the flow rate of the cooling water supplied to flow in the cooling water passage to be any one of the plurality of flow rate values.

[0025]

The cutting method according to yet another aspect of the invention is further characterized in that the article to be cut is a sealed substrate.

[0026]

The cutting method according to yet another aspect of the invention is further characterized in that the article to be cut is a substrate embedded with functional elements in a plurality of regions respectively corresponding to the plurality of products.

EFFECTS OF THE INVENTION

[0027]

The invention provides the cutting apparatus with the following technical features. The cutting apparatus includes the table to be mounted with the article to be cut, the cutting mechanism to cut the article, and the moving mechanism to relatively move the table and the cutting mechanism to each other. The cutting mechanism includes the rotating shaft, the driving mechanism to rotate the rotating shaft, the cooling water passage arranged around the rotating shaft, and the rotary blade attached to an edge of the rotating shaft. The driving mechanism includes the electric current supply mechanism to supply the driving mechanism with electric current, the measurement unit to measure the physical quantity associated with the cutting mechanism, the cooling water delivery mechanism to deliver the cooling water, the flow rate regulating unit to regulate the cooling water flow rate, and the controller connected to the flow rate regulating unit. The controller compares the measured value of the physical quantity value measured by the measurement unit to the prestored value of the physical quantity, and changes the flow rate of the cooling water supplied to flow in the cooling water passage based on the comparison result. Changing the cooling water flow rate correspondingly to the measured physical value may advantageously economize the use of cooling water, consequently reducing

operational costs of the cutting apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1 is a block diagram schematically illustrating structural features of a spindle installed in a cutting apparatus according to a first example of the invention.

Fig. 2 is a flow chart of steps of regulating the flow rate of cooling water supplied to the spindle illustrated in Fig. 1 correspondingly to electric current values of a spindle motor.

Figs. 3 are schematic drawings of positional displacement of the spindle illustrated in Fig. 1, wherein (a) is a drawing of an initial state of a rotary blade, and (b) is a drawing of positional displacement of the rotary blade in a rotating-shaft direction.

Fig. 4 is a schematic top view of a cutting apparatus according to a second example of the invention.

EMBODIMENTS OF THE INVENTION

[0029]

As illustrated in Fig. 1, a cutting apparatus has a spindle 1 provided with a spindle motor 3, a rotating shaft 4 connected to the spindle motor 3 and a rotary blade 8 attached to an edge of the rotating shaft 4. The spindle 1 has a spindle body 2 which is furnished with a cooling water passage 7 for circulation of cooling water around the rotating shaft 4 and a positional displacement sensor 10 located at a position facing a flange 9. An electric current measurement unit 12 is connected to the spindle motor 3. The electric current measurement unit 12 measures electric current used to drive the rotating shaft 4. A flow rate regulating unit 13 is connected to the cooling water passage 7. The flow rate regulating unit 13 regulates the flow rate of cooling water to be circulated. A measured value $I(t)$ of the electric

current measured by the electric current measurement unit 12 is compared to a prestored value I_0 of the electric current. When the measured value $I(t)$ is greater than the prestored value I_0 , the cooling water is supplied from the flow rate regulating unit 13 to the spindle 1 at an initially set flow rate. When the measured value $I(t)$ is less than or equal to the prestored value I_0 , the cooling water is supplied from the flow rate regulating unit 13 to the spindle 1 at a flow rate lower than the initially set flow rate. Thus, the flow rate of the cooling water supplied to the spindle 1 may be regulated correspondingly to the magnitude of load current applied to the spindle motor 3. By virtue of this technical advantage, the cooling water may be supplied to the spindle 1 at an adequate flow rate corresponding to the cutting load when cutting a sealed substrate, in other words, the load current applied to the spindle motor 3.

[0030]

First Example

A first example of the cutting apparatus according to the invention is described in detail referring to Figs. 1 to 3. For clarity and readability of this description, any of the drawings that accompany the application documents of this application are schematically drawn with parts thereof suitably omitted or exaggerated. The same structural elements are identifiable by the same reference numerals. Descriptions of the same structural elements, therefore, may be omitted to the extent that is adequate.

[0031]

As illustrated in Fig. 1, a spindle 1 that works as a cutting mechanism has a spindle body 2, a spindle motor 3 as a driving mechanism, and a rotating shaft 4 connected to the spindle motor 3. The rotating shaft 4 is rotatably supported in the spindle body 2 in a non-contact manner with the air blown out from a radial air bearing 5 and an axial air bearing 6. To prevent generation of heat and resultant thermal expansion of the rotating shaft 4 rotating at high speed, a cooling water passage 7 for circulation of the

cooling water is arranged around the rotating shaft 4. The cooling water passage 7 preferably has a spiral shape in a manner that surrounds the rotating shaft 4. A rotary blade 8 used to cut a sealed substrate is attached to an edge of the rotating shaft 4. The rotary blade 8 sandwiched on its both sides by the paired flanges 9 is fixed to the rotating shaft 4. The rotary blade 8 is a detachable and replaceable component. The flanges 9 are made from an electrically conductive metal such as stainless steel or chromium steel.

[0032]

A positional displacement sensor 10 is attached to an edge of the spindle body 2 as a device to measure a distance between an edge of the spindle body 2 and the center line of the rotary blade 8. The positional displacement sensor 10 is attached to the spindle body 2 at a position facing a surface of the flange 9 closer to the spindle body 2. The positional displacement sensor 10 measures a distance between the flange 9 and an edge of the positional displacement sensor 10. Preferable examples of the positional displacement sensor 10 may include an eddy current displacement sensor that leverages variations of eddy current, and an optical displacement sensor that leverages laser reflections.

[0033]

To drive the spindle motor 3, a power feed mechanism 11 that feeds high frequency power is connected to the spindle motor 3. The spindle motor 3 is preferably a servo motor. In the case where the number of revolutions of the rotary blade 8 changes during the cutting operation, the servo motor is advantageous in that its servo driver can control drive current so that a certain number of revolutions is maintained. The electric current measurement unit 12 that measures electric current at the time of driving the spindle motor 3 is connected to the spindle motor 3.

[0034]

A flow rate regulating unit 13 is connected to a cooling water supply

port 14 arranged in the spindle body 2 to regulate the flow rate of the cooling water supplied to flow in the cooling water passage 7 of the spindle 1. A cooling water delivery mechanism 15 that delivers the cooling water in a predetermined quantity is connected to the flow rate regulating unit 13. In the spindle body 2, the cooling water supply port 14, the cooling water passage 7, and a cooling water discharge port 16 are communicating with one another. The cooling water is introduced into the cooling water passage 7 through the cooling water supply port 14 and discharged through the cooling water discharge port 16. The cooling water flowing around the rotating shaft 4 may effectively suppress thermal expansion of the rotating shaft 4. The cooling water discharge port 16 is connected to a cooling water circulation mechanism 17. The cooling water discharged through the cooling water discharge port 16 is delivered by the cooling water circulation mechanism 17 back to the cooling water delivery mechanism 15 for reuse.

[0035]

The distance obtained as a measure of positional displacement by the positional displacement sensor 10 is linearized into a proportional relationship between the distance and an output voltage by a converter 18, where a lateral axis represents the distance, and a vertical axis represents the output voltage in an orthogonal two-dimensional coordinate system. In this manner, the output voltage proportional to the distance may be obtained, and the distance between the flange 9 and the edge of the positional displacement sensor 10 may be calculated. By calculating the distance between the flange 9 and the edge of the positional displacement sensor 10, the degree of displacement of the rotating shaft 4 may be constantly measured with accuracy.

[0036]

A control mechanism 19 is configured to set and control all of the operations and operating conditions associated with the cutting apparatus and the spindle 1. The control mechanism 19 has a memory to store therein

various collected data, a data processor to process and analyze the various data, and input/output units to transmit and receive signals to and from the structural elements of the cutting apparatus (none of these devices of the control mechanism 19 is illustrated in the drawings). All of the structural elements of the spindle 1, including the power feed mechanism 11, electric current measurement unit 12, flow rate regulating unit 13, cooling water delivery mechanism 15, and converter 18, are independently connected to the control mechanism 19. In the drawing of Fig. 1, all of the memory, data processor, and input/output units are included in the control mechanism 19, which is a non-limiting example. The memory and the data processor may be provided on the outside of the control mechanism 19.

[0037]

Referring to Figs. 1 and 2 is described an operation to regulate the flow rate of the cooling water supplied to the spindle 1. First, the cutting apparatus is set to be ready for operation. Next, the cooling water is delivered from the cooling water delivery mechanism 15 to the flow rate regulating unit 13. The cooling water delivery mechanism 15 receives up to 15 liters of cooling water per minute (15L/min.) from the water feeder of a factory (not illustrated in the drawings). During the normal operational status of the cutting apparatus, for instance, the flow rate, currently 15 liters per minute (15L/min.), of the cooling water supplied from the factory by the cooling water delivery mechanism 15 is changed to five liters per minute (5L/min.). The cooling water is then delivered by five liters per minute (5L/min.) from the cooling water delivery mechanism 15 to the flow rate regulating unit 13. The flow rate regulating unit 13 further regulates the flow rate of the cooling water supplied from the cooling water delivery mechanism 15 to a required flow rate. For example, the flow rate regulating unit 13 changes the flow rate, currently five liters per minute (5L/min.), of the cooling water supplied from the cooling water delivery mechanism 15 to three liters per minute (3L/min.). The cooling water is then supplied by

three liters per minute (3L/min.) from the flow rate regulating unit 13 to the spindle 1. The cooling water is introduced into the spindle 1 through the cooling water supply port 14 to flow in the cooling water passage 7 and cool the rotating shaft 4. This may effectively suppress the thermal expansion of the rotating shaft 4.

[0038]

The operation then proceeds to idling for run-in of the spindle 1. The power feed mechanism 11 feeds predetermined electric power to drive the spindle motor 3. By driving the spindle motor 3, the rotating shaft 4 and the rotary blade 8 rotate at high speed. During the idling, the rotating shaft 4 is rotated under the condition that the rotation speed thereof is set smaller than rotation speed preset for actual use or an actual rotation speed in a state used actually thereby to familiarize the rotating shaft 4 with the cooling water.

[0039]

Then, the electric current at the time of driving the spindle motor 3 is measured by the electric current measurement unit 12. The measured current value is referred to as a measured value $I(t)$, where (t) is a variable representing time. The measured value $I(t)$ obtained by the electric current measurement unit 12 is stored in the memory of the control mechanism 19. The data processor of the control mechanism 19 compares the measured value $I(t)$ to a prestored electric current value I_0 . The prestored value I_0 representing a predetermined threshold value is stored in the data processor. In the example described here, the prestored value (threshold value) is, for example, $I_0 = 5A$.

[0040]

The data processor compares the measured value $I(t)$ to the prestored value I_0 . When the measured value $I(t)$ is greater than the prestored value $I_0 = 5A$, the cooling water continues to be supplied from the flow rate regulating unit 13 by three liters per minute (3L/min.) to the spindle 1. When the measured value $I(t)$ is less than or equal to $I_0 = 5A$, the

flow rate of three liters per minute (3L/min.) is lowered to one liter per minute (1L/min.). Then, the cooling water is supplied to the spindle 1 at the lowered flow rate from the flow rate regulating unit 13. Thus, the flow rate of the cooling water supplied to the spindle 1 from the flow rate regulating unit 13 is adaptively regulated depending on the magnitude of load current applied to the spindle motor 3. With larger cutting load, meaning higher load current, the cooling water is supplied in a larger quantity to the spindle 1 to suppress thermal expansion of the rotating shaft 4. With smaller cutting load (lower load current), on the other hand, the cooling water is supplied at the reduced flow rate to the spindle 1 from the flow rate regulating unit 13. The flow rate of the cooling water is regulated correspondingly to the cutting load applied to the rotary blade 8 of the spindle 1, in other words, the load current applied to the spindle motor 3. Thus usage amount of the cooling water can be regulated and thereby reduced.

[0041]

During the operation of the cutting apparatus, the rotation of the rotating shaft 4 may be involved in various operational statuses, including cutting of the sealed substrate, idling, setting of cutting conditions and corrected values for the rotary blade 8, and dressing of the rotary blade 8. While the rotating shaft 4 is rotating, the electric current measurement unit 12 constantly measures, as the measured value $I(t)$, the electric current used to drive the spindle motor 3. The measured value $I(t)$ is then compared to the prestored value I_0 set as the threshold value to regulate the flow rate of the cooling water supplied to the spindle 1 from the flow rate regulating unit 13. The spindle 1 may be accordingly supplied with the cooling water at a flow rate adaptively regulated depending on the rotational state of the rotating shaft 4. Such a control of the flow rate of the cooling water during the operation of the cutting apparatus may advantageously economize the use of the cooling water, ultimately cutting down on operational costs of the cutting apparatus.

[0042]

Examples of the article to be cut by the cutting apparatus may include various kinds of objects including sealed substrates and semiconductor wafers. These cutting objects differ in, for example, structure, material, and dimension. Naturally, all of them differ in cutting load as well. According to this example, wherein the spindle 1 may be supplied with the cooling water at a flow rate correspondingly to the magnitude of the cutting load, the cooling water may be supplied at a flow rate flexibly adapted to any of such cutting objects.

[0043]

With more objects to be cut, use-related wear of the rotary blade 8 progressively advances. The rotary blade 8 may even lose some of its abrasive grains as the case may be, leading to larger cutting load as compared to its initial condition (new product). Notwithstanding such a situation, the spindle 1 may continue to be supplied with the cooling water at a flow rate suitably regulated for the cutting load at the time. Thus, the cooling water may be supplied at an adaptively-controlled flow rate regardless of the condition of the rotary blade 8.

[0044]

The flow rate of the cooling water supplied to the spindle 1 is regulated correspondingly to the measured value $I(t)$ measured by the electric current measurement unit 12. The varying flow rate of the cooling water causes the rotating shaft 4 to displace in different dimensions in the rotating-shaft direction. This degree of displacement of the rotating shaft 4 in the rotating-shaft direction, although affected by the cooling water flow rate, is constantly measured by the positional displacement sensor 10. This may provide for accurate correction of the degree of displacement of the rotating shaft 4, and proper alignment of the cutting position of the rotary blade 8 to each cutting line of the sealed substrate.

[0045]

Referring to Figs. 3 is described an operation to correct the degree of displacement of the rotating shaft 4 prior to the cutting operation. As for the spindle 1, a distance between the flange 9 and the edge of the positional displacement sensor 10 is measured by an eddy current displacement sensor or an optical displacement sensor which is an example of the positional displacement sensor 10. The measured distance is defined as $d(t)$, where (t) is a variable representing time. As illustrated in (a) of Figs. 3, at a point in time immediately before the sealed substrate starts to be cut, the measured distance between the flange 9 and the edge of the positional displacement sensor 10 is defined as $d(0)$, and a distance between the edge of the spindle body 2 and the center line of the rotary blade 8 is defined as $L(0)$, where “0” represents a point in time immediately before the sealed substrate starts to be cut. In an initial stage, $L(0) = d(0) + \alpha$, where “ α ” can be previously calculated from the dimension of the positional displacement sensor 10, thickness of the flange 9, and/or thickness of the rotary blade 8. The value of α is presented as a fixed value hardly affected by heat. In the case where the rotating shaft 4 is thermally expanded and thereby displaced in the rotating-shaft direction after the sealed substrate starts to be cut, the distance between the flange 9 and the edge of the positional displacement sensor 10 is measured. Based on the measured value of this distance, the distance between the edge of the spindle body 2 and the center line of the rotary blade 8 can be measured.

[0046]

The spindle motor 3 (see Fig. 1) is driven to rotate the rotary blade 8 at high speed, thereby cutting the sealed substrate. As the cutting of the sealed substrate advances, the rotating shaft 4 rotating at high speed starts to generate heat as illustrated in (b) of Figs. 3. The generated heat acts on the rotating shaft 4 to thermally expand and progressively displace in the rotating-shaft direction (+X direction in the drawing). As a result of the rotating shaft 4 displaced in the +X direction, the rotary blade 8 is

positionally displaced in the +X direction equally to the degree of displacement of the rotating shaft 4. Assuming that the distance between the flange 9 and the edge of the positional displacement sensor 10 is $d(X)$ at a point in time after the sealed substrate started to be cut, a distance $L(X)$ between the edge of the spindle body 2 and the center line of the rotary blade 8 is calculated as expressed by the formula, $L(X) = d(X) + \alpha$. The rotating shaft 4 thermally expanded is displaced in the X direction by $(d(X) - d(0))$. Prior to the cutting of the sealed substrate, the position of the rotary blade 8 is corrected by a difference between the distances associated with the degree of displacement of the rotating shaft 4, which is represented by the positional displacement, $(d(X) - d(0))$. To be specific, the center line of the rotary blade 8 is moved to a position shifted by $(d(X) - d(0))$ in -X direction. Then, the sealed substrate may be cut with the center line of the rotary blade 8 having being properly aligned to the cutting line of the sealed substrate.

[0047]

According to this example, the cutting apparatus is furnished with the spindle 1, spindle motor 3, rotating shaft 4 connected to the spindle motor 3, and rotary blade 8 attached to the edge of the rotating shaft 4. The spindle body 2 is furnished with the cooling water passage 7 to circulate the cooling water around the rotating shaft 4 and the positional displacement sensor 10 located at a position facing the flange 9. The electric current measurement unit 12 that measures the electric current used to drive the rotating shaft 4 is connected to the spindle motor 3. The flow rate regulating unit 13 that regulates the cooling water flow rate is connected to the cooling water passage 7 arranged in the spindle 1. The measured value $I(t)$ of the electric current measured by the electric current measurement unit 12 is compared to the prestored value I_0 set as the threshold value. When the measured value $I(t)$ is greater than the prestored value I_0 , the cooling water is supplied from the flow rate regulating unit 13 to the spindle 1 at the initially set flow rate; three liters per minute (3L/min.). When the measured

value $I(t)$ is less than or equal to the prestored value I_0 , the cooling water is supplied from the flow rate regulating unit 13 to the spindle 1 at the flow rate regulated to be lower than three liters per minute (3L/min.); one liter per minute (1L/min.). Thus, the flow rate of the cooling water supplied to the spindle 1 may be regulated correspondingly to the magnitude of the load current applied to the spindle motor 3. By virtue of this technical advantage, the cooling water may be supplied to the spindle 1 at a flow rate flexibly adapted to the cutting load when cutting a sealed substrate, in other words, the load current applied to the spindle motor 3.

[0048]

According to this example, the cooling water is supplied from the flow rate regulating unit 13 to the spindle 1 at an adequate flow rate correspondingly to the magnitude of the cutting load applied to the rotary blade 8 of the spindle 1, in other words, the magnitude of the load current applied to the spindle motor 3. The rotating shaft 4 may be rotated for cutting of the sealed substrate or dressing of the rotary blade, or while the apparatus is on standby with the rotating shaft 4 being rotated. This example may allow the spindle 1 to be supplied with the cooling water at different flow rates flexibly responding to all of such operational statuses of the apparatus. By supplying the spindle 1 with the cooling water at a flow rate adapted to any load imposed on the rotating shaft 4, operational costs of the cutting apparatus may be cut down.

[0049]

According to this example, the cooling water may be supplied from the flow rate regulating unit 13 to the spindle 1 at an adequate flow rate correspondingly to the magnitude of the cutting load applied to the rotary blade 8 of the spindle 1, in other words, the magnitude of the load current applied to the spindle motor 3. Thus the cooling water can be supplied at an adequate flow rate to the spindle 1 corresponding to cutting loads when cutting various kinds of articles to be cut, including sealed substrates and

semiconductor wafers.

[0050]

According to this example wherein the cooling water is supplied from the flow rate regulating unit 13 to the spindle 1 at an adequate flow rate correspondingly to the magnitude of the cutting load applied to the rotary blade 8 of the spindle 1, in other words, the magnitude of the load current applied to the spindle motor 3. Thus, even though there is use-related wear or loss of abrasive grains with respect to the rotary blade 8, the cooling water may be supplied at an adequate flow rate to the spindle 1 in response to such states.

[0051]

According to this example, the cooling water flow rate is regulated correspondingly to the measured value $I(t)$ of the electric current measured by the electric current measurement unit 12. The flow rate thus regulated and changed invites changes of the degree of displacement of the rotating shaft 4 in the rotating-shaft direction. Yet, such different degrees of displacement of the rotating shaft 4 may be accurately measured by the positional displacement sensor 10. Thus even though the flow rate of the cooling water supplied to the spindle 1 is reduced, the amount of displacement of the rotating shaft 4 may be measured accurately. The positional displacement of the thermally expanded and thereby displaced rotating shaft 4 may be accordingly corrected so that the center line of the rotary blade 4 is properly aligned to each cutting line of the sealed substrate prior to the cutting operation. This avoids such an awkward situation that the sealed substrate is cut by the rotary blade 4 with its center line being misaligned to the cutting line of the sealed substrate. Therefore, improvements are expected in yield rate and product quality.

[0052]

Second Example

A second example of the cutting apparatus according to the

invention is hereinafter described in detail referring to Fig. 4. As illustrated in Fig. 4, a cutting apparatus 20 is for use in cutting an article to be cut into separate pieces which will become a plurality of products. The cutting apparatus 20 has structural elements including a substrate feeding unit A, a substrate cutting unit B, and an inspection unit C. These units (units A to C) are all structured to connect to and disconnect from the other units, and also replaceable with new ones.

[0053]

The substrate feeding unit A has a substrate feeding mechanism 21. A sealed substrate 22, which is an example of the article to be cut, is transported out of the substrate feeding mechanism 21 to the substrate cutting unit B by a transport mechanism (not illustrated in the drawings). The substrate feeding unit A further has a control mechanism 19 to control the operations of the cutting apparatus 20 and spindle 1 and the flow rate of cooling water.

[0054]

The cutting apparatus 20 illustrated in Fig. 4 is a cutting apparatus equipped with a single cutting table. The substrate cutting unit B, therefore, has one cutting table 23. The cutting table 23 is allowed to move in Y direction in the drawing by a moving mechanism 24 and to rotate in θ direction in the drawing by a rotary mechanism 25. The sealed substrate 22 is mounted on and attached by suction to the cutting table 23.

[0055]

The substrate cutting unit B has a spindle 1 that works as a cutting mechanism. The substrate cutting unit B is a single-spindle cutting apparatus equipped with just one spindle 1. The spindle 1 is allowed to move independently in X direction and Z direction and mounted with a rotary blade 8. A positional displacement sensor 10 is attached to the spindle 1 at a positing facing the flange 9 (see Fig. 1). The sealed substrate 22 is cut by way of relative movement between the cutting table 24 and the spindle 1.

The rotary blade 8 rotates in a plane including the Y and Z directions to cut the sealed substrate 22.

[0056]

The inspection unit C has an inspection table 26. On the inspection table 26 is mounted a cut substrate 27 including a plurality of products P which are separate pieces cut out from the sealed substrate 22. The products P are inspected by an inspection camera (not illustrated in the drawings) and classified into conforming products or inferior products. The conforming products are housed in a tray 28.

[0057]

This example described the cutting apparatus 20 with a single cutting table and a single spindle, which is, however, a non-limiting example. The spindle 1 according to the invention is applicable to cutting apparatuses with a single cutting table and twin spindles, or twin cutting tables and twin spindles.

[0058]

According to the first and second examples, the measured value $I(t)$ of the electric current measured by the electric current measurement unit 12 is compared to one prestored value I_0 of electric current to provide for two-phase regulation of the flow rate of the cooling water supplied from the flow rate regulating unit 13 to the spindle 1. Instead, the measured value $I(t)$ may be compared to a plurality of prestored values. This alternative option provides for multi-phase regulation of the cooling water flow rate correspondingly to the plural prestored values to supply the cooling water at a more adequate flow rate from the flow rate regulating unit 13 to the spindle 1. Thus, the flow rate of the cooling water supplied to the spindle 1 may be regulated in a more finely-tuned manner correspondingly to the magnitude of the cutting load that is the magnitude of the drive current.

[0059]

According to the first and second examples described so far, the flow

rate of the cooling water supplied from the flow rate regulating unit 13 to the spindle 1 is regulated based on the measured value $I(t)$ measured by the electric current measurement unit 12. Alternatively, the flow rate of the cooling water supplied from the flow rate regulating unit 13 to the spindle 1 may be regulated based on the degree of displacement measured by the positional displacement sensor 10 (rate of change of the distance between the flange 9 and the edge of the spindle body 2). In that case, the flow rate of the cooling water supplied from the flow rate regulating unit 13 is increased when a measured value of the rate of change increases, finally exceeding a prestored value (predetermined threshold value).

[0060]

The flow rate of the cooling water supplied from the flow rate regulating unit 13 to the spindle 1 may be regulated based on two values; measured value $I(t)$ of the electric current measured by the electric current measurement unit 12, and measured value of the positional displacement measured by the positional displacement sensor 10. In that case, a measured value of electric current is compared to a prestored value (threshold value) of electric current, and a measured value of positional displacement is compared to a prestored value (threshold value) of positional displacement. Then, the logical sum of these two comparison results is used to regulate the flow rate of the cooling water supplied from the flow rate regulating unit 13 to the spindle 1. To be specific, the cooling water flow rate is decreased when one of the measured values of electric current and positional displacement falls below its associated prestored value (threshold value).

[0061]

The first and second examples presented at least one of the electric current measured value and the positional displacement measured value as the physical quantity based on which the cooling water flow rate is decreased. This is, however, a non-limiting example. A second prestored value (second

threshold value) may be set and stored in preparation for even greater values of the measured physical quantity, wherein the cooling water flow rate may be increased for a better cooling effect whenever one of the electric current measured value and the positional displacement measured value exceeds the second prestored value. The cooling water flow rate in normal condition is, for example, five liters per minute (5L/min.). Then, the cooling water flow rate may be increased from five liters per minute (5L/min.) to a cooling-enhancing flow rate; seven liters per minute (7L/min.) when at least one of the electric current measured value and the positional displacement measured value is greater than the second prestored value. This more effectively cools the spindle 1, thereby reducing the electric current or the positional displacement.

[0062]

The electric current measurement unit 12 that measures the electric current and the positional displacement sensor 10 that measures the positional displacement are devices functioning to measure the physical quantity. Based on values of the physical quantity measured by the electric current measurement unit 12 and the positional displacement sensor 10, the control mechanism 19 may display the electric current value and the positional displacement value respectively measured. In this context, the combination of the electric current measurement unit 12 with the control mechanism 19 and the combination of the positional displacement sensor 10 with the control mechanism 19 correspond to a measurement unit in a broad sense, respectively.

[0063]

Optionally, a third prestored value (third threshold value) against potential abnormal circumstances may be further preset for each value of the physical quantity (electric current, positional displacement). In that case, when one of the electric current measured value and the positional displacement measured value is greater than the third prestored value, the

cooling water may be supplied at an increased flow rate as compared to the cooling-enhancing flow rate. The cooling-enhancing flow rate of the cooling water is, for example, seven liters per minute (7L/min.). Then, 10 liters per minute (10L/min.) is set as an abnormality flow rate of the cooling water. This advantageously prevents, in the case of, for example, an abnormal operation of the spindle motor 3, breakage including fire damage of the spindle motor 3. In such an event, it is preferable, in addition to the setting of the abnormality flow rate, the cutting apparatus is preferably further configured to move the spindle 1 to a standby position, deactivate the spindle motor 3, turn on a warning light, and/or generate a warning sound. The control mechanism 16 is in charge of comparing the measured value of the physical quantity to the prestored value, setting the flow rate of the cooling water delivered from the cooling water delivery mechanism 15, and setting the flow rate of the cooling water supplied to the spindle 1 from the flow rate regulating unit 13.

[0064]

The physical quantity; electric current or positional displacement, used as a criterion for deciding the cooling water flow rate may be in the form of an absolute value or a rate of change. As for a measured value $L(t)$ of the distance between the edge of the spindle body 2 and the center line of the rotary blade 8, for example, $D\mu\text{m}$ per minute ($D\mu\text{m}/\text{min.}$) is set as a rate-of-change prestored value (threshold value). When the rate of change of the continuously measured distance value $L(t)$ is greater than $D\mu\text{m}$ per minute ($D\mu\text{m}/\text{min.}$), the normal flow rate of the cooling water may be changed to the cooling-enhancing flow rate (or abnormality flow rate).

[0065]

The spindle body 2 has the positional displacement sensor 10 at a position facing the flange 9. However, the positional displacement sensor 10 may be located at other various positions by the use of a suitably-shaped (for example, L-shaped) mounting plate. A part of the mounting plate

corresponding to the vertical line of its shape is attached to an end surface of the spindle body 2 (right-side surface in Fig. 1), and the positional displacement sensor 10 is attached to a part of the mounting plate corresponding to the horizontal line of its shape. The positional displacement sensor 10, including an eddy current positional displacement sensor, measures changes in eddy current by targeting a ridge part of the flange 9 (lower-left corner in Fig. 1). Then, a distance between the right end of the spindle body 2 and the ridge part of the flange 9 may be measured by the positional displacement sensor 10. The positional displacement sensor 10 may be located at such a position that allows for measurement of changes in eddy current targeted for a ridge (lower-right corner in Fig. 1) of the right-side flange (may be a fastening member such as nut, no reference symbol in Fig. 1). The positional displacement sensor 10 may be located at a position facing a top surface (right-side surface in Fig. 1) of the right-side flange by the use of a suitably-shaped mounting plate.

[0066]

In the examples described so far, the rotary blade 8 may be, for example, a washer-type rotary blade having a doughnut-like shape (toroidal shape). This non-limiting example may be replaced with a hub-like rotary blade in which a blade edge part is attached to a base.

[0067]

The article to be cut in the examples described so far is the sealed substrate 22 including chip-like devices. This invention may be applicable to, as well as cutting of the sealed substrate 22, cutting of articles exemplified below into separate pieces; semiconductor wafers including silicon or compound semiconductors and embedded with functional elements such as circuit elements and MEMS (Micro Electro Mechanical Systems); and ceramic substrates embedded with functional elements such as resistors, capacitors, sensors, and surface acoustic wave devices to provide such products as chip resistors, chip capacitors, chip-like sensors, and surface

acoustic wave devices. In these examples, semiconductor wafers and ceramic substrates are substrates-to-be-cut which are embedded with functional elements in a plurality of regions. Other possible articles to be cut may include: resin molds from which optical products are obtained, such as lenses, optical modules, and light-guiding plates; and resin molds from which conventional molded forms are obtained. The description given thus far may be applied to various cases including these four examples.

[0068]

Thus far described are a few non-limiting examples of the invention in all aspects. The invention may be carried out in many other forms without departing its technical concept or principal technical features. Any modifications within the scope of this invention may be optionally combined or selected, if necessary.

DESCRIPTION OF REFERENCE NUMERALS

[0069]

- | | |
|----|--|
| 1 | spindle (cutting mechanism) |
| 2 | spindle body |
| 3 | spindle motor (driving mechanism) |
| 4 | rotating shaft |
| 5 | radial air bearing |
| 6 | axial air bearing |
| 7 | cooling water passage |
| 8 | rotary blade |
| 9 | flange (first fixture, second fixture) |
| 10 | positional displacement sensor (measurement unit, distance measurement unit) |
| 11 | electric current supply mechanism (power feed mechanism) |
| 12 | electric current measurement unit (measurement unit) |
| 13 | flow rate regulating unit |

14	cooling water supply port
15	cooling water delivery mechanism
16	cooling water discharge port
17	cooling water circulation mechanism
18	converter
19	control mechanism
20	cutting apparatus
21	substrate feeding mechanism
22	sealed substrate (article to be cut)
23	cutting table (table)
24	moving mechanism
25	rotary mechanism
26	inspection table
27	cut substrate
28	tray
I(t)	measured value of electric current
I ₀	prestored value of electric current
d(t)	measured value of distance between edge of positional displacement sensor and flange
L(t)	distance between edge of spindle body and center line of rotary blade
α	fixed value
A	substrate feeding unit
B	substrate cutting unit
C	inspection unit
P	product

CLAIMS

1. A cutting apparatus, comprising:
 - a table to be mounted with the article to be cut;
 - a cutting mechanism that cuts the article to be cut; and
 - a moving mechanism that relatively moves the table and the cutting mechanism,

the cutting apparatus being for use in cutting the article to be cut along a cutting line into separate pieces to provide a plurality of individual products, the cutting apparatus further comprising:

 - a rotating shaft installed in the cutting mechanism;
 - a driving mechanism installed in the cutting mechanism to drive the rotating shaft to rotate;
 - a cooling water passage formed in the cutting mechanism around the rotating shaft;
 - a rotary blade attached to an edge of the rotating shaft;
 - a first fixture disposed on the edge at a position closer to the cutting mechanism;
 - a second fixture disposed at a position closer to the edge in view from the first fixture, the second fixture fixing the rotary blade being sandwiched between the first fixture and the second fixture;
 - an electric current supply mechanism that supplies the driving mechanism with electric current;
 - a measurement unit that measures a physical quantity associated with the cutting mechanism;
 - a flow rate regulating unit connected to the cooling water passage to regulate a flow rate of cooling water supplied to flow in the cooling water passage;
 - a cooling water delivery mechanism that delivers the cooling water to the flow rate regulating unit; and
 - a controller connected to at least the flow rate regulating unit,

wherein

the controller compares a measured value of the physical quantity measured by the measurement unit to a prestored value of the physical quantity, and

the flow rate of the cooling water supplied to flow in the cooling water passage is changed based on a result of the comparison.

2. The cutting apparatus as claimed in claim 1, wherein the measurement unit is an electric current measurement unit connected to the driving mechanism to measure the electric current,

the physical quantity is the electric current,

the controller is connected to the electric current measurement unit, and

the controller detects variations of the electric current based on the result of the comparison, and increases or decreases the flow rate of the cooling water in accordance with a result of the detection.

3. The cutting apparatus as claimed in claim 1 or 2, wherein

the measurement unit is a distance measurement unit installed in the cutting mechanism to measure a distance between the cutting mechanism and the fixture,

the physical quantity is the distance,

the controller is connected to the distance measurement unit, and

the controller detects variations of the distance based on the result of the comparison, and increases or decreases the flow rate of the cooling water in accordance with a result of the detection.

4. The cutting apparatus as claimed in claim 3, wherein

the controller calculates a difference between a measured value and a prestored value of the distance between the cutting mechanism and the fixture, and aligns a position of the rotary blade to a position of the cutting line based on the difference.

5. The cutting apparatus as claimed in claim 3, wherein

the distance measurement unit includes at least an eddy current displacement sensor or an optical displacement sensor.

6. The cutting apparatus as claimed in claim 1 or 2, wherein
the prestored value is a plurality of prestored values,
the plurality of prestored values are respectively associated with a plurality of flow rate values of the cooling water, and

the measured value is compared to the plurality of prestored values to regulate the flow rate of the cooling water supplied to flow in the cooling water passage to be any one of the plurality of flow rate values.

7. The cutting apparatus as claimed in claim 1 or 2, wherein
the article to be cut is a sealed substrate.

8. The cutting apparatus as claimed in claim 1 or 2, wherein
the article to be cut is a substrate embedded with functional elements in a plurality of regions respectively corresponding to the plurality of products.

9. A cutting method, comprising steps of:
mounting an article to be cut on a table;
relatively moving the table and a cutting mechanism;
cutting the article to be cut along a cutting line using the cutting mechanism by way of the relative movement between the table and the cutting mechanism;
supplying a driving mechanism installed in the cutting mechanism with electric current;
rotating, using the driving mechanism, a rotating shaft and a rotary blade fixedly sandwiched between a first fixture disposed on an edge of the rotating shaft at a position closer to the cutting mechanism and a second fixture disposed at a position closer to the edge in view from the first fixture;
delivering cooling water from a cooling water delivery mechanism to a flow rate regulating unit;
supplying a cooling water passage arranged around the rotating

shaft with the cooling water from the flow rate regulating unit;

measuring a physical quantity associated with the cutting mechanism;

comparing a measured value of the physical quantity to a prestored value of the physical quantity; and

changing a flow rate of the cooling water supplied to flow in the cooling water passage based on a result of the comparison in the comparing step.

10. The cutting method as claimed in claim 9, wherein

the physical quantity is the electric current, and

the step of changing the flow rate includes detecting variations of the electric current based on the result of the comparison and further includes increasing or decreasing the flow rate of the cooling water in accordance with a result of the detection.

11. The cutting method as claimed in claim 9 or 10, wherein

the physical quantity is a distance between the cutting mechanism and the fixture, and

the step of changing the flow rate includes detecting variations of the distance based on the result of the comparison and further includes increasing or decreasing the flow rate of the cooling water in accordance with a result of the detection.

12. The cutting method as claimed in claim 11, further comprising steps of:

measuring the distance between the cutting mechanism and the fixture using a distance measurement unit installed in the cutting mechanism;

calculating a difference between a measured value and a prestored value of the distance; and

aligning a position of the rotary blade to a position of the cutting line based on the difference.

13. The cutting method as claimed in claim 11, wherein
the distance measurement unit includes at least an eddy current
displacement sensor or an optical displacement sensor.
14. The cutting method as claimed in claim 9 or 10, wherein
the prestored value is a plurality of prestored values,
the plurality of prestored values are respectively associated with a
plurality of flow rate values of the cooling water, and
the measured value is compared to the plurality of prestored
values to regulate the flow rate of the cooling water supplied to flow in the
cooling water passage to be any one of the plurality of flow rate values.
15. The cutting method as claimed in claim 9 or 10, wherein
the article to be cut is a sealed substrate.
16. The cutting method as claimed in claim 9 or 10, wherein
the article to be cut is a substrate embedded with functional
elements in a plurality of regions respectively corresponding to the plurality
of products.