

**SUBSTRATE POLISHING DEVICE, SUBSTRATE PROCESSING DEVICE,
METHOD, AND STORAGE MEDIUM**

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a substrate polishing device, a substrate processing device, a method, and a storage medium.

Description of the Related Art

[0002] As semiconductor devices become more highly integrated, circuit wiring becomes finer, and dimensions of integrated devices are also becoming finer. Thus, a process is needed in which a wafer having a surface on which a film such as metal is formed is polished and the surface of the wafer is planarized. One method of the planarization is polishing by a chemical mechanical polishing (CMP) device. The chemical mechanical polishing device includes a polishing member (such as polishing cloth or polishing pad), and a holding unit (such as top ring, polishing head, or chuck) that holds a polishing target object such as a wafer. A surface (surface to be polished) of the polishing target object is pressed against a surface of the polishing member and polished to be flat by supplying a polishing liquid (such as abrasive liquid, drug solution, slurry, or pure water) between the polishing member and the polishing target

object and relatively moving the polishing member and the polishing target object.

[0003] Foamed resin or non-woven fabric is typically used as the material of the polishing member used in such a chemical mechanical polishing device. Fine irregularities are formed on the surface of the polishing member and serve as chip pockets that are effective for preventing clogging and reducing polishing resistance. However, as polishing of the polishing target object is continued with the polishing member, the fine irregularities on the surface of the polishing member are crushed, causing decrease in the polishing rate of the polishing target object. Thus, the surface of the polishing member is dressed (sharpened) by a dresser on which a large number of abrasive particles such as diamond particles are electrodeposited, and accordingly, fine irregularities are re-formed on the surface of the polishing member.

[0004] In a method of dressing the polishing member, for example, while a rotating dresser is moved (reciprocated in an arc shape or a linear shape, or oscillated), the dressing surface is pressed against the rotating polishing member to dress the polishing member. During dressing of the polishing member, the surface of the polishing member is shaved even by a small amount. Thus, when dressing is not appropriately performed, inappropriate waviness occurs on the surface of the

polishing member, causing variation in the polishing rate of the polishing target object. Variation in the polishing rate may cause polishing defects, and thus a profile of the polishing member needs to be controlled by appropriately performing dressing so as not to cause inappropriate waviness on the surface of the polishing member. In other words, it is needed to avoid variation in a cut rate of the polishing member and to prevent inappropriate waviness from occurring by performing dressing at an appropriate moving speed of the dresser. [0005] However, in a case of a short dressing time, the moving speed of the dresser cannot be changed. Thus, when such a constraint exists, the profile of the polishing member cannot be suitably controlled, which is a problem.

SUMMARY

[1] A substrate polishing device according to an aspect of the present invention is a substrate polishing device that polishes a substrate by bringing the substrate into sliding contact with a polishing member, and includes:

a dresser configured to dress the polishing member by oscillating on the polishing member, the dresser being capable of adjusting a load and a rotational speed in a plurality of scan areas set on the polishing member in an oscillation direction;

a height detection unit configured to measure a surface height of the polishing member in a plurality of monitor areas preset on the polishing member in the oscillation direction of the dresser;

a dress model matrix production unit configured to produce a dress model matrix defined by the plurality of monitor areas, the plurality of scan areas, and a dress model;

an evaluation index production unit configured to calculate a height profile predicted value by using the dress model and an oscillation speed or a dwell time of the dresser in each scan area and to produce an evaluation index based on a difference from a target value of a height profile of the polishing member; and

a calculation unit configured to calculate the load and the rotational speed of the dresser in each scan area based on the evaluation index.

[0006] [2] In the substrate polishing device according to an aspect of the present invention in [1] described above,

 dressing of the polishing member is performed by simultaneously changing the load and the rotational speed of the dresser, which are calculated by the calculation unit.

[0007] [3] In the substrate polishing device according to an aspect of the present invention in [1] or [2] described above,

dressing of the polishing member is performed with the oscillation speed of the dresser being constant.

[0008] [4] In the substrate polishing device according to an aspect of the present invention in any of [1] to [3] described above,

 the evaluation index includes a first parameter corresponding to the load of the dresser, and a second parameter corresponding to the rotational speed of the dresser, and

 the evaluation index production unit produces the evaluation index such that a weight of the second parameter is larger than a weight of the first parameter.

[0009] [5] A substrate processing device according to an aspect of the present invention includes the substrate polishing device described above in any of [1] to [4].

[0010] [6] A method according to an aspect of the present invention is a method of adjusting a load and a rotational speed of a dresser in a plurality of scan areas set on a polishing member in an oscillation direction, the dresser being configured to dress the polishing member by oscillating on the polishing member that polishes a substrate, the method including:

 measuring a surface height of the polishing member in a plurality of monitor areas preset on the polishing member in the oscillation direction of the dresser;

producing a dress model matrix defined by the plurality of monitor areas, the plurality of scan areas, and a dress model;

calculating a height profile predicted value by using the dress model and an oscillation speed or a dwell time of the dresser in each scan area, and producing an evaluation index based on a difference from a target value of a height profile of the polishing member; and

calculating the load and the rotational speed of the dresser in each scan area based on the evaluation index.

[0011] [7] A program according to an aspect of the present invention is a program for causing a computer to execute the method described above in [6].

[0012] [8] A storage medium according to an aspect of the present invention is a computer-readable storage medium storing the program described above in [7].

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic diagram illustrating a polishing device that polishes a substrate such as a wafer;

FIG. 2 is a plan view schematically illustrating a dresser and a polishing pad;

FIG. 3 is a diagram illustrating an example of scan areas set on the polishing pad;

FIG. 4 is an explanatory diagram illustrating a relation between the scan areas and monitor areas of the polishing pad;

FIG. 5 is a block diagram illustrating an exemplary configuration of a dresser monitoring device;

FIG. 6 is an explanatory diagram illustrating an example of profile transition of a polishing pad height in each scan area;

FIG. 7 is a flowchart illustrating an example of a procedure for adjusting parameters of the dresser; and

FIG. 8 is a diagram illustrating an example of comparison between a current profile and a target profile.

DETAILED DESCRIPTION OF THE INVENTION

[0014] An embodiment of the present invention will be described below with reference to the accompanying drawings. FIG. 1 is a schematic diagram illustrating a polishing device that polishes a substrate such as a wafer. The polishing device is provided in a substrate processing device capable of performing a series of processes of polishing, cleaning, and drying a wafer.

[0015] As illustrated in FIG. 1, the polishing device includes a polishing unit 10 for polishing a wafer W, a polishing table 12 holding a polishing pad (polishing member) 11, a polishing liquid supply nozzle 13 that supplies a polishing liquid onto the polishing pad 11,

and a dressing unit 14 that conditions (dresses) the polishing pad 11 used for polishing the wafer W. The polishing unit 10 and the dressing unit 14 are installed on a base 15.

[0016] The polishing unit 10 includes a top ring (substrate holding unit) 20 coupled to the lower end of a top ring shaft 21. The top ring 20 is configured to hold the wafer W on its lower surface by vacuum adsorption. The top ring shaft 21 rotates by driving of a non-illustrated motor, and the top ring 20 and the wafer W rotate by rotation of the top ring shaft 21. The top ring shaft 21 is configured to move up and down relative to the polishing pad 11 by a non-illustrated up-down mechanism (up-down mechanism constituted by, for example, a servomotor and a ball screw).

[0017] The polishing table 12 is coupled to a motor (not illustrated) disposed below the polishing table 12. The polishing table 12 is rotated about its axis by the motor. The polishing pad 11 is bonded to the upper surface of the polishing table 12, and the upper surface of the polishing pad 11 constitutes a polishing surface 11a that polishes the wafer W.

[0018] Polishing of the wafer W is performed as follows. The top ring 20 and the polishing table 12 are rotated, and the polishing liquid is supplied onto the polishing pad 11. In this state, the top ring 20 holding the wafer W is moved down, and the wafer W is pressed against the

polishing surface 11a of the polishing pad 11 by a pressurization mechanism (not illustrated) constituted by an air bag installed in the top ring 20. The wafer W and the polishing pad 11 are brought into sliding contact with each other in the presence of the polishing liquid, and accordingly, a surface of the wafer W is polished and planarized.

[0019] The dressing unit 14 includes a dresser 23 that contacts the polishing surface 11a of the polishing pad 11, a dresser shaft 24 coupled to the dresser 23, an air cylinder 25 provided at the upper end of the dresser shaft 24, and a dresser arm 26 that rotatably supports the dresser shaft 24. Abrasive particles such as diamond particles are fixed to the lower surface of the dresser 23. The lower surface of the dresser 23 constitutes a dressing surface that dresses the polishing pad 11.

[0020] The dresser shaft 24 and the dresser 23 can be moved up and down relative to the dresser arm 26. The air cylinder 25 is a device that applies a dressing load on the polishing pad 11 onto the dresser 23. The dressing load can be adjusted by air pressure supplied to the air cylinder 25.

[0021] The dresser arm 26 is driven by a motor 30 and is configured to oscillate about a support shaft 31. The dresser shaft 24 is rotated by a non-illustrated motor installed in the dresser arm 26, and the dresser 23 is rotated about its axis by rotation of the dresser shaft

24. The air cylinder 25 presses the dresser 23 against the polishing surface 11a of the polishing pad 11 at a predetermined load through the dresser shaft 24.

[0022] Conditioning of the polishing surface 11a of the polishing pad 11 is performed as follows. The polishing table 12 and the polishing pad 11 are rotated by motors, and a dressing liquid (for example, pure water) is supplied from a non-illustrated dressing liquid supply nozzle to the polishing surface 11a of the polishing pad 11. In addition, the dresser 23 is rotated about its axis. The dresser 23 is pressed against the polishing surface 11a by the air cylinder 25 such that the lower surface (dressing surface) of the dresser 23 is brought into sliding contact with the polishing surface 11a. In this state, the dresser arm 26 is turned to oscillate the dresser 23 on the polishing pad 11 substantially in the radial direction of the polishing pad 11. The polishing pad 11 is shaved by the rotating dresser 23, and accordingly, conditioning of the polishing surface 11a is performed.

[0023] A pad height sensor (surface height measurement device) 32 that measures the height of the polishing surface 11a is fixed to the dresser arm 26. A sensor target 33 is fixed to the dresser shaft 24, facing the pad height sensor 32. The sensor target 33 moves up and down integrally with the dresser shaft 24 and the dresser 23, whereas the vertical position of the pad height

sensor 32 is fixed. The pad height sensor 32 is a displacement sensor and can indirectly measure the height of the polishing surface 11a (thickness of the polishing pad 11) by measuring displacement of the sensor target 33. Since the sensor target 33 is coupled to the dresser 23, the pad height sensor 32 can measure the height of the polishing surface 11a during conditioning of the polishing pad 11.

[0024] Measurement of the height of the polishing surface 11a by the pad height sensor 32 is performed in a plurality of predetermined regions (monitor areas) divided in the radial direction of the polishing pad. The pad height sensor 32 indirectly measures the polishing surface 11a from the vertical position of the dresser 23 in contact with the polishing surface 11a. Accordingly, the average of the height of the polishing surface 11a in a region (monitor area) in contact with the lower surface (dressing surface) of the dresser 23 is measured by the pad height sensor 32. A profile (sectional shape of the polishing surface 11a) of the polishing pad can be determined by measuring the height of the polishing pad in the plurality of monitor areas. Any type of sensor such as a linear scale sensor, a laser sensor, an ultrasonic sensor, or an eddy current sensor may be used as the pad height sensor 32.

[0025] The pad height sensor 32 is connected to a dressing monitoring device 35, and an output signal (that

is, measurement value of the height of the polishing surface 11a) from the pad height sensor 32 is sent to the dressing monitoring device 35. The dressing monitoring device 35 has a function for acquiring the profile of the polishing pad 11 from the measurement value of the height of the polishing surface 11a, and determining whether conditioning of the polishing pad 11 is correctly performed.

[0026] The polishing device includes a table rotary encoder 36 that measures rotation angles of the polishing table 12 and the polishing pad 11, and a dresser rotary encoder 37 that measures a turning angle of the dresser 23. The table rotary encoder 36 and the dresser rotary encoder 37 are absolute encoders that measure the absolute values of the angles. The rotary encoders 36 and 37 are connected to the dressing monitoring device 35, and the dressing monitoring device 35 can acquire the rotation angles of the polishing table 12 and the polishing pad 11 and the turning angle of the dresser 23 during measurement of the height of the polishing surface 11a by the pad height sensor 32.

[0027] The dresser 23 is coupled to the dresser shaft 24 through a universal joint 17. The dresser shaft 24 is coupled to a non-illustrated motor. The dresser shaft 24 is rotatably supported by the dresser arm 26, and the dresser 23 is configured to oscillate in the radial direction of the polishing pad 11 by the dresser arm 26

while contacting the polishing pad 11 as illustrated in FIG. 2. The universal joint 17 is configured to allow tilting of the dresser 23 while transmitting rotation of the dresser shaft 24 to the dresser 23. The dressing unit 14 is constituted by the dresser 23, the universal joint 17, the dresser shaft 24, the dresser arm 26, a non-illustrated rotary mechanism, and the like. The dressing monitoring device 35 that calculates a sliding distance and a sliding speed of the dresser 23 is electrically connected to the dressing unit 14. A dedicated or general-purpose computer may be used as the dressing monitoring device 35.

[0028] Abrasive particles such as diamond particles are fixed to the lower surface of the dresser 23. A portion where the abrasive particles are fixed constitutes a dressing surface that dresses the polishing surface of the polishing pad 11. As aspects of the dressing surface, a circular dressing surface (dressing surface in which abrasive particles are fixed to the entire lower surface of the dresser 23), a ring-shaped dressing surface (dressing surface in which abrasive particles are fixed to a peripheral portion of the lower surface of the dresser 23), or a plurality of circular dressing surfaces (dressing surface in which abrasive particles are fixed to surfaces of a plurality of small-diameter pellets arranged at substantially equal intervals around the center of the dresser 23) may be applied. Note that a

circular dressing surface is provided in the dresser 23 in the present example.

[0029] When the polishing pad 11 is to be dressed, as illustrated in FIG. 1, the polishing pad 11 is rotated at a predetermined rotational speed in the direction of arrow, and the dresser 23 is rotated at a predetermined rotational speed in the direction of arrow by a non-illustrated rotary mechanism. Then, in this state, the dressing surface (surface on which the abrasive particles are disposed) of the dresser 23 is pressed against the polishing pad 11 at a predetermined dressing load to perform dressing of the polishing pad 11. In addition, the dresser 23 oscillates on the polishing pad 11 by the dresser arm 26, which enables dressing of a region used in polishing of the polishing pad 11 (polishing region, in other words, region in which a polishing target object such as a wafer is polish).

[0030] Since the dresser 23 is coupled to the dresser shaft 24 through the universal joint 17, the dressing surface of the dresser 23 is appropriately brought into contact with the polishing pad 11 even when the dresser shaft 24 is slightly tilted relative to a surface of the polishing pad 11. A pad roughness measurement device 38 that measures a surface roughness of the polishing pad 11 is disposed above the polishing pad 11. A well-known non-contact surface roughness measurement device such as an optical surface roughness measurement device may be

used as the pad roughness measurement device 38. The pad roughness measurement device 38 is connected to the dressing monitoring device 35 such that a measurement value of the surface roughness of the polishing pad 11 is sent to the dressing monitoring device 35.

[0031] A film thickness sensor (film thickness measurement device) 39 that measures a film thickness of the wafer W is disposed in the polishing table 12. The film thickness sensor 39 is disposed facing the surface of the wafer W held by the top ring 20. The film thickness sensor 39 is a film thickness measurement device that measures the film thickness of the wafer W while moving across the surface of the wafer W along with rotation of the polishing table 12. A non-contact sensor such as an eddy current sensor or an optical sensor may be used as the film thickness sensor 39. A measurement value of the film thickness is sent to the dressing monitoring device 35. The dressing monitoring device 35 is configured to generate a film thickness profile of the wafer W (film thickness distribution of the wafer W in the radial direction) from the measurement value of the film thickness.

[0032] Oscillation of the dresser 23 will be described below with reference to FIG. 2. The dresser arm 26 turns by a predetermined angle clockwise and anticlockwise around a point J. The position of the point J corresponds to the central position of the support shaft

31 illustrated in FIG. 1. By turning of the dresser arm 26, the rotation center of the dresser 23 oscillates in the radial direction of the polishing pad 11 in a range illustrated with an arc L.

[0033] FIG. 3 is an enlarged view of the polishing surface 11a of the polishing pad 11. As illustrated in FIG. 3, an oscillation range (oscillation width L) of the dresser 23 is divided into a plurality (seven in the example illustrated in FIG. 3) of scan areas (oscillation intervals) S1 to S7. The scan areas S1 to S7 are virtual intervals preset on the polishing surface 11a and are arranged in the oscillation direction of the dresser 23 (in other words, substantially the radial direction of the polishing pad 11). The dresser 23 dresses the polishing pad 11 while moving across the scan areas S1 to S7. The scan areas S1 to S7 may have the same length or different lengths.

[0034] FIG. 4 is an explanatory diagram illustrating a positional relation between the scan areas S1 to S7 and monitor areas M1 to M10 of the polishing pad 11, and the horizontal axis of the diagram represents the distance from the center of the polishing pad 11. In the present embodiment, an example in which the seven scan areas and the 10 monitor areas are set is described, and the numbers of these areas may be changed as appropriate. Furthermore, it is difficult to control the pad profile in regions having widths corresponding to the radius of

the dresser 23 from both ends of the scan areas, and thus monitor-excluded widths are provided on the inner side (regions R1 to R3 in FIG. 4) and the outer side (regions R4 to R2 in FIG. 4), but it is not necessarily needed to provide the excluded widths. In other words, the scan areas and the monitor areas may be identical.

[0035] A moving speed of the dresser 23 when oscillating on the polishing pad 11 is preset for each of the scan areas S1 to S7 and can be adjusted as appropriate if there is no constraint on a dressing time.

[0036] The moving speed of the dresser 23 is one of determinant factors of a pad height profile of the polishing pad 11. A cut rate of the polishing pad 11 indicates an amount (thickness) of the polishing pad 11 that is shaved by the dresser 23 per unit time. In a case where the dresser is moved at a constant speed, the thickness of the polishing pad 11 shaved in each scan area is normally different, and accordingly, the value of the cut rate is also different for each scan area.

However, it is normally preferable that the pad profile maintain an initial shape, and thus the moving speed is adjusted so that difference in the shaved amount among the scan areas decreases.

[0037] Increasing the moving speed of the dresser 23 means shortening a dwell time of the dresser 23 on the polishing pad 11, in other words, reducing the shaved amount of the polishing pad 11. On the other hand,

decreasing the moving speed of the dresser 23 means lengthening the dwell time of the dresser 23 on the polishing pad 11, in other words, increasing the shaved amount of the polishing pad 11. Thus, the shaved amount in a certain scan area can be reduced by increasing the moving speed of the dresser 23 in the scan area, and the shaved amount in a certain scan area can be increased by decreasing the moving speed of the dresser 23 in the scan area. Accordingly, the pad height profile of the entire polishing pad can be adjusted.

[0038] However, in a case where there is a constraint on the dressing time, it is difficult to change the moving speed of the dresser. Thus, in the present embodiment, the profile of the polishing pad 11 is controlled by adjusting a load and a rotational speed of the dresser in place of the moving speed of the dresser.

[0039] FIG. 8 is a diagram illustrating a relation between the pad radial position (radial position of the polishing member) and the pad height. As illustrated in FIG. 8, a difference occurs between the current profile of the polishing pad and a target profile. In the present embodiment, the load and the rotational speed of the dresser are prepared so that the difference decreases.

[0040] A functional configuration of the dressing monitoring device 35 according to the present embodiment will be described below.

[0041] As illustrated in FIG. 5, the dressing monitoring device 35 includes a dress model setting unit 41, a base profile calculation unit 42, a cut rate calculation unit 43, an evaluation index production unit 44, a parameter value calculation unit 45, a setting input unit 46, a memory 47, and a pad height detection unit 48. The dressing monitoring device 35 acquires the profile of the polishing pad 11 and sets the moving speed of the dresser 23 at a predetermined timing so that the moving speed is optimum in the scan areas.

[0042] The dress model setting unit 41 sets a dress model S for calculating an abrasion amount of the polishing pad 11 in the scan areas. The dress model S is a real number matrix of m rows and n columns, where the number of divisions of the monitor areas is m (in the present example, 10) and the number of divisions of the scan areas is n (in the present example, 7), and is determined by various parameters to be described later. Note that the dress model S is $S = [s_1, s_2, \dots, s_n]$ in a case where the scan areas and the monitor areas are identical.

[0043] The dwell time of the dresser (at the center) in each scan area is expressed by $T = W/V = [w_1/v_1, w_2/v_2, \dots, w_n/v_n]$, where a scanning speed of the dresser in each scan area set on the polishing pad 11 is $V = [v_1, v_2, \dots, v_n]$, and a width of each scan area is $W = [w_1, w_2, \dots, w_n]$. A pad abrasion amount U is calculated by performing matrix calculation of $U = ST$ by using the

dress model S and the dwell time T in each scan area described above, where a pad abrasion amount in each monitor area is $U = [u_1, u_2, \dots, u_m]$.

[0044] In derivation of the dress model matrix S , for example, elements 1) cut rate model, 2) dresser radius, and 3) scanning speed control are considered, and the elements can be combined as appropriate. As for the cut rate model, each element of the dress model matrix S is set on a premise that the element is proportional to a dwell time in a monitor area or proportional to a scratching distance (movement distance).

[0045] As for the dresser radius, each element of the dress model matrix S is set on a premise that the diameter of the dresser is considered (the polishing pad wears in accordance with the same cut rate over the entire effective area of the dresser) or the diameter of the dresser is not considered (the polishing pad wears in accordance with the cut rate only at the central position of the dresser). When the dresser radius is considered, an appropriate dress model can be defined even for a dresser in which, for example, diamond particles are applied in a ring shape. In addition, as for the scanning speed control, each element of the dress model matrix S is set in accordance with whether change in the moving speed of the dresser is step-shaped or slope-shaped. By combining these parameters as appropriate, a cut amount that matches an actual condition can be

calculated from the dress model S, and a correct profile predicted value can be obtained.

[0046] The pad height detection unit 48 detects the pad height in each monitor area by associating height data of the polishing pad, which is continuously measured by the pad height sensor 32, with measurement coordinate data on the polishing pad.

[0047] The base profile calculation unit 42 calculates a target profile (base profile) of the pad height at a time of convergence (refer to FIG. 6). The base profile is used for calculating a target cut amount used by the parameter value calculation unit 45 to be described later. The base profile may be calculated based on a height distribution ($\text{Diff}(j)$) of the polishing pad in a pad initial state and a measured pad height, or may be provided as a setting value. In a case where the base profile is not set, a target cut amount with which the shape of the polishing pad becomes flat may be calculated.

[0048] A base of the target cut amount is calculated by an expression below by using a pad height profile $H_p(j)$ [$j = 1, 2, \dots m$], which indicates pad heights in the respective monitor areas at a present time, and a convergence-time target wear amount A_{tg} that is separately set.

[0049] $\min\{H_p(j)\} - A_{tg}$

The target cut amount of each monitor area can be calculated by an expression below in consideration of the base profile described above.

$$[0050] \min\{H_p(j)\} - A_{tg} + \text{Diff}(j)$$

The cut rate calculation unit 43 calculates the cut rate of the dresser in each monitor area. For example, the cut rate may be calculated from the gradient of a change amount of the pad height in each monitor area (change amount of the pad height per unit time).

[0051] The evaluation index production unit 44 optimizes parameter values of the dresser in each scan area by using an evaluation index to be described later.

[0052] The evaluation index is an index including at least parameter values corresponding to 1) deviation from the target cut amount, 2) deviation from a load in a reference recipe, and 3) deviation from a rotational speed in the reference recipe. Then, each parameter value in each scan area is determined so that the evaluation index is minimized, and accordingly, the load and the rotational speed of the dresser are optimized.

[0053] 1) Deviation from target cut amount

When the target cut amount of the dresser is $U_0 = [U_{01}, U_{02}, \dots, U_{0m}]$, the deviation from the target cut amount is calculated by obtaining the square value ($|U - U_0|^2$) of a difference from the above-described pad abrasion amount U ($= ST$) in each monitor area. Note that a target profile for determining the target cut amount

can be determined at any timing after start of use of the polishing pad, or may be determined based on a manually set value.

[0054] 2) Deviation from load in reference recipe

The deviation from a load in the reference recipe can be calculated by obtaining the square value ($\Delta\text{DRP}^2 = |\text{DRP} - \text{DRP}_0|^2$) (first parameter) of a difference (ΔDRP) between a load (reference load (reference pressure DRP_0)) of the dresser based on the reference recipe set for each scan area and a load DRP of the dresser in each scan area. The reference load is a load with which a flat cut rate is expected to be obtained in each scan area, and is a value obtained by experiments or simulations in advance. In a case where the reference load is obtained by simulations, the reference load can be obtained, for example, on a premise that the load of the dresser and the cut amount of the polishing pad are proportional to each other. Note that the reference load may be updated as appropriate in accordance with the actual cut rate during use of the same polishing pad.

[0055] 3) Deviation from rotational speed in reference recipe

The deviation from a rotational speed in the reference recipe can be calculated by obtaining the square value ($\Delta\text{DRR}^2 = |\text{DRR} - \text{DRR}_0|^2$) (second parameter) of a difference (ΔDRR) between a rotational speed (reference rotational speed DRR_0) of the dresser set based on the

reference recipe for each scan area and a rotational speed DRR of the dresser in each scan area. The reference rotational speed is a rotational speed with which a flat cut rate is expected to be obtained in each scan area, and is a value obtained by experiments or simulations in advance. In a case where the reference rotational speed is calculated by simulations, the reference rotational speed can be obtained, for example, on a premise that the rotational speed of the dresser and the cut amount of the polishing pad are proportional to each other. Note that the reference rotational speed may be updated as appropriate in accordance with the actual cut rate during use of the same polishing pad.

[0056] The evaluation index production unit 44 defines an evaluation index J represented by an expression below based on these three indexes.

$$[0057] J = |U - U_0|^2 + \lambda^2 |DRP - DRP_0|^2 + \gamma^2 |DRR - DRR_0|^2$$

The first, second, and third terms on the right hand side of the evaluation index J are indexes including at least parameter values corresponding to the deviation from the target cut amount, the deviation from a load in the reference recipe, and the deviation from a rotational speed in the reference recipe, respectively.

[0058] Then, the parameter value calculation unit 45 performs optimization calculation to minimize the value of the evaluation index J and calculates parameter values (load and rotational speed of the dresser) of the dresser

in each scan area. A quadratic programming method can be used as a method of the optimization calculation, but convergence calculation by simulations or PID control may be used.

[0059] In the above-described evaluation index J , λ and γ are predetermined weighting values (coefficients) and can be changed as appropriate during use of the same polishing pad. By changing these weighting values, an index to be prioritized can be adjusted as appropriate in accordance with characteristics of the polishing pad and the dresser and operating conditions of the device. For example, the weight γ of the parameter value ($\Delta DRR^2 = |DRR - DRR_0|^2$) related to the rotational speed of the dresser may be set to be larger than the weight λ of the parameter value ($\Delta DRP^2 = |DRP - DRP_0|^2$) related to the load of the dresser. Accordingly, plunging of the dresser into the polishing member can be suppressed.

[0060] In this manner, by optimizing the load (pressure) and the rotational speed of the dresser, the profile of the polishing member can be controlled even when there is a constraint that the moving speed of the dresser cannot be changed.

[0061] The setting input unit 46 is an input device such as a keyboard or a mouse, and inputs various parameters such as the values of the components of the dress model matrix S , setting of constraint conditions, a cut rate update cycle, and a parameter value update cycle. The

memory 47 stores data of programs for operating constituent components included in the dressing monitoring device 35, and various kinds of data such as the values of the components of the dress model matrix S , a target profile, the weighting values of the evaluation index J , and setting values of the moving speed, load, and rotational speed of the dresser.

[0062] FIG. 7 is a flowchart illustrating a processing procedure of controlling the parameter values of the dresser. When replacement of the polishing pad 11 is sensed (step S11), the dress model setting unit 41 derives the dress model matrix S in consideration of the cut rate model, the dresser radius, and parameters of the scanning speed control (step S12). Note that the dress model matrix may be continuously used in a case where pads of the same kind are used.

[0063] Subsequently, it is determined whether calculation of a reference value (reference load and/or reference rotational speed) of the dresser is to be performed (whether an input indicating that reference value calculation is to be performed has been made by the setting input unit 46) (step S13). In a case where the reference value calculation is to be performed, the parameter value calculation unit 45 sets the load and the rotational speed of the dresser in each scan area based on the target cut amount U_0 of the dresser and the pad abrasion amount U in each monitor area so that the next

evaluation index J is minimized (step S14). The calculated reference value may be set as an initial value.

$$[0064] J = |U - U_0|^2 + \lambda^2 |DRP - DRP_0|^2 + \gamma^2 |DRR - DRR_0|^2$$

Thereafter, as polishing processing of the wafer W is performed and dressing processing is performed on the polishing pad 11, the pad height sensor 32 measures the height (pad height) of the polishing surface 11a (step S15). Then, it is determined whether a condition for acquisition of the base profile (for example, polishing of a predetermined number of wafers W) is satisfied (step S16). In a case where the condition is satisfied, the base profile calculation unit 42 calculates a target profile (base profile) of the pad height at a time of convergence (step S17).

[0065] Thereafter, as polishing processing of the wafer W is performed and dressing processing is performed on the polishing pad 11, the pad height sensor 32 measures the height (pad height) of the polishing surface 11a (step S18). Then, it is determined whether a predetermined cut rate calculation cycle (for example, polishing of a predetermined number of wafers W) has been reached (step S19). In a case where the cycle has been reached, the cut rate calculation unit 43 calculates a cut rate of the dresser in each scan area (step S20).

[0066] It is determined whether the parameter value update cycle (for example, polishing of a predetermined

number of wafers W) of the dresser has been reached (step S21). In a case where the cycle has been reached, the parameter value calculation unit 45 performs optimization of the parameter values (load and rotational speed of the dresser) in each scan area so that the evaluation index J is minimized (step S22). Then, the parameter values are updated to the optimized parameter values (step S23). Thereafter, the process returns to step S18, and the above-described processing is repeated until the polishing pad 11 is replaced.

[0067] In the above-described example, the load (pressure) and the rotational speed of the dresser are optimized by determining each parameter value in each scan area so that the evaluation index including at least parameter values corresponding to 1) deviation from the target cut amount, 2) deviation from a load in the reference recipe, and 3) deviation from a rotational speed in the reference recipe is minimized, but a monitoring target is not limited to the polishing pad height. The surface roughness of the polishing pad may be measured and the load (pressure) and the rotational speed of the dresser may be calculated so as to make the surface roughness uniform. In this case, an expression below may be used as the evaluation index.

$$J = |Ra - Ra_0|^2 + \lambda^2 |DRP - DRP_0|^2 + \gamma^2 |DRR - DRR_0|^2$$

In the expression, Ra_0 is an arithmetic average roughness of the dresser based on the reference recipe set in each

scan area, and Ra is an arithmetic average roughness of the dresser in each scan area.

The above-described embodiment is described for the purpose of enabling a person having ordinary knowledge in a technical field to which the present invention belongs to practice the present invention. Various modifications of the above-described embodiment can naturally be made by the skilled person in the art, and the technical idea of the present invention is applicable to other embodiments. The present invention is not limited to the described embodiment and is to be interpreted over the broadest range in accordance with the technical idea defined by the claims.

Other Embodiments

Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable

instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)[™]), a flash memory device, a memory card, and the like.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Applications No. 2024-229914, filed December 26, 2024,

which is hereby incorporated by reference herein in its entirety.

Claims

1. A substrate polishing device that polishes a substrate by bringing the substrate into sliding contact with a polishing member, the substrate polishing device comprising:

a dresser configured to dress the polishing member by oscillating on the polishing member, the dresser being capable of adjusting a load and a rotational speed in a plurality of scan areas set on the polishing member in an oscillation direction;

a height detection unit configured to measure a surface height of the polishing member in a plurality of monitor areas preset on the polishing member in the oscillation direction of the dresser;

a dress model matrix production unit configured to produce a dress model matrix defined by the plurality of monitor areas, the plurality of scan areas, and a dress model;

an evaluation index production unit configured to calculate a height profile predicted value by using the dress model and an oscillation speed or a dwell time of the dresser in each scan area and to produce an evaluation index based on a difference from a target value of a height profile of the polishing member; and

a calculation unit configured to calculate the load and the rotational speed of the dresser in each scan area based on the evaluation index.

2. The substrate polishing device according to claim 1, wherein dressing of the polishing member is performed by simultaneously changing the load and the rotational speed of the dresser, which are calculated by the calculation unit.

3. The substrate polishing device according to claim 1, wherein dressing of the polishing member is performed with the oscillation speed of the dresser being constant.

4. The substrate polishing device according to claim 1, wherein

the evaluation index includes a first parameter corresponding to the load of the dresser, and a second parameter corresponding to the rotational speed of the dresser, and

the evaluation index production unit produces the evaluation index such that a weight of the second parameter is larger than a weight of the first parameter.

5. A substrate processing device comprising the substrate polishing device according to claim 1.

6. A method of adjusting a load and a rotational speed of a dresser in a plurality of scan areas set on a polishing member in an oscillation direction, the dresser

being configured to dress the polishing member by oscillating on the polishing member that polishes a substrate, the method comprising:

measuring a surface height of the polishing member in a plurality of monitor areas preset on the polishing member in the oscillation direction of the dresser;

producing a dress model matrix defined by the plurality of monitor areas, the plurality of scan areas, and a dress model;

calculating a height profile predicted value by using the dress model and an oscillation speed or a dwell time of the dresser in each scan area, and producing an evaluation index based on a difference from a target value of a height profile of the polishing member; and

calculating the load and the rotational speed of the dresser in each scan area based on the evaluation index.

7. A non-transitory computer-readable medium storing a program for causing a computer to execute the method according to claim 6.