

DESCRIPTION

Title of Invention

INFORMATION PROCESSING DEVICE, INFERENCE DEVICE, MACHINE LEARNING DEVICE, INFORMATION PROCESSING METHOD, INFERENCE METHOD, AND MACHINE LEARNING METHOD

Technical Field

[0001]

The present invention relates to an information processing device, an inference device, a machine learning device, an information processing method, an inference method, and a machine learning method.

Background Art

[0002]

One type of substrate processing device that performs various processes on substrates such as semiconductor wafers is a substrate processing device that performs chemical mechanical polishing (CMP) processing. In a substrate processing device, for example, a polishing table having a polishing pad is rotated, a polishing liquid (slurry) is supplied to the polishing pad from a liquid supply nozzle, and a polishing head called a top ring presses the substrate against the polishing pad, thereby chemically and mechanically polishing the substrate. Then, in order to remove foreign substances such as polishing debris adhering to the polished substrate, a cleaning tool is brought into contact with the polished substrate while supplying a substrate cleaning fluid to the polished substrate to perform scrub cleaning. Then, the substrate is dried, completing the series of processes and moving on to the processing of the next substrate.

[0003]

In the series of processes described above, if the polishing is insufficient, the insulation of the electronic circuit formed on the completed wafer may be insufficient, leading to a risk of short circuits. In addition, if excessive polishing is performed, there is a problem that the resistance value increases due to a reduction in the cross-sectional area of the wiring, or the circuit itself may not be formed. Therefore, some recent polishing devices detect the endpoint of polishing by detecting changes in frictional

force, changes in motor current, or changes in the physical quantity of the wafer.

[Citation List]

[Patent Literature]

[0004]

PTL 1: JP 2021-028099 A

[Summary of Invention]

[Technical Problem]

[0005]

PTL 1 discloses a technology that has a trained model that uses machine learning to learn the waveforms of measurement data from the start of polishing to the end of polishing output from each of a plurality of types of endpoint detection sensors installed in one polishing unit during past polishing, and uses measurement data output from each of a plurality of types of endpoint detection sensors during new polishing from the start of polishing to the current time as input to estimate whether the current time is the timing of the endpoint indicating the end of polishing, thereby improving the accuracy of endpoint detection.

[0006]

However, conventional polishing devices equipped with endpoint detection technology lacked the capability to determine whether the endpoint detection results were reliable, leaving no choice but to use the detected results as they were.

[0007]

In view of the above problems, an object of the present invention is to provide an information processing device, an inference device, a machine learning device, an information processing method, an inference method, and a machine learning method that enable the appropriate prediction of reliability information for a polishing endpoint detection function, which indicates the reliability of the endpoint detection function for detecting that chemical mechanical polishing has reached its endpoint.

[Solution to Problem]

[0008]

In order to achieve the above object, an information processing device according to one aspect of the present invention includes: an information acquisition unit that

acquires reliability degradation factor state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including at least one of wear state information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing; and a state prediction unit that predicts reliability information of a polishing endpoint detection function for the reliability degradation factor state information by inputting the reliability degradation factor state information acquired by the information acquisition unit into a learning model that has been trained through machine learning to learn a correlation between the reliability degradation factor state information and reliability information of the polishing endpoint detection function that indicates reliability of an endpoint detection function that detects that the chemical mechanical polishing process has reached an endpoint.

[Advantageous Effects of the Invention]

[0009]

According to the information processing device according to one aspect of the present invention, the reliability degradation factor state information including at least one of wear state information indicating the wear state of components of the substrate processing device in the chemical mechanical polishing process and processing state information indicating the processing state during the polishing process is input to a learning model, and the reliability information of the polishing endpoint detection function for the reliability degradation factor state information is predicted. Thus, the reliability information of the polishing endpoint detection function indicating the reliability of the endpoint detection function that detects that the chemical mechanical polishing process has reached the endpoint can be appropriately predicted.

[0010]

Other objects, configurations, and effects will be clarified in the embodiments for implementing the invention described below.

[Brief Description of Drawings]

[0011]

[FIG. 1]

FIG. 1 is an overall configuration diagram showing an example of a substrate

processing system 1.

[FIG. 2]

FIG. 2 is a plan view showing an example of a substrate processing device 2.

[FIG. 3]

FIG. 3 is a perspective view showing an example of first to fourth polishing units 22A to 22D.

[FIG. 4]

FIG. 4 is a schematic cross-sectional view showing an example of a top ring 221.

[FIG. 5]

FIG. 5 is a block diagram showing an example of the substrate processing device 2.

[FIG. 6]

FIG. 6 is a hardware configuration diagram showing an example of a computer 900.

[FIG. 7]

FIG. 7 is a data structure diagram showing an example of production history information 30 managed by a database device 3.

[FIG. 8]

FIG. 8 is a data structure diagram showing an example of polishing test information 31 managed by the database device 3.

[FIG. 9]

FIG. 9 is a block diagram showing an example of a machine learning device 4 according to a first embodiment.

[FIG. 10]

FIG. 10 is a diagram showing an example of a first learning model 10A and first learning data 11A.

[FIG. 11]

FIG. 11 is a flowchart showing an example of a machine learning method by the machine learning device 4.

[FIG. 12]

FIG. 12 is a block diagram showing an example of an information processing device 5 according to the first embodiment.

[FIG. 13]

FIG. 13 is a functional explanatory diagram showing an example of the information processing device 5 according to the first embodiment.

[FIG. 14]

FIG. 14 is a flowchart showing an example of an information processing method by the information processing device 5.

[FIG. 15]

FIG. 15 is a schematic diagram for explaining an optical sensor 226 provided on a polishing table 220 according to a second embodiment.

[FIG. 16]

FIG. 16 is a block diagram showing an example of a machine learning device 4a according to the second embodiment.

[FIG. 17]

FIG. 17 is a diagram showing an example of a second learning model 10B and first learning data 11B.

[FIG. 18]

FIG. 18 is a block diagram showing an example of an information processing device 5a according to the second embodiment.

[FIG. 19]

FIG. 19 is a functional explanatory diagram showing an example of an information processing device 5a according to the second embodiment.

[Description of Embodiments]

[0012]

Hereinafter, embodiments for implementing the present invention will be described with reference to the drawings. The following provides a schematic illustration of the scope necessary for the explanation to achieve the objectives of the present invention. The description will primarily focus on the relevant portions of the invention, and any parts not explicitly explained will be assumed to be based on known technologies.

[0013]

(First Embodiment)

FIG. 1 is an overall configuration diagram showing an example of a substrate

processing system 1. The substrate processing system 1 according to this embodiment functions as a system for managing a series of substrate processing tasks including a chemical mechanical polishing process (hereinafter referred to as a "polishing process") for polishing the surface of a substrate (hereinafter referred to as a "wafer") W such as a semiconductor wafer to a flat surface, a cleaning process for cleaning the wafer W after the polishing, and the like.

[0014]

The substrate processing system 1 mainly includes a substrate processing device 2, a database device 3, a machine learning device 4, an information processing device 5, and a user terminal device 6. Each of the devices 2 to 6 is, for example, a general-purpose or dedicated computer (see FIG. 6 described later), and is connected to a wired or wireless network 7 so that various pieces of data can be exchanged between them (in FIG. 1, transmission and reception of some of the data are depicted using dashed arrows). The number of devices 2 to 6 and the connection configuration of the network 7 are not limited to the example in FIG. 1, and may be changed as appropriate.

[0015]

The substrate processing device 2 is a device that is configured of a plurality of units and performs each process, such as loading, polishing, cleaning, drying, film thickness measurement, and unloading, as a series of substrate processing tasks for one or a plurality of wafers W. In this case, the substrate processing device 2 controls the operation of each unit while referring to device setting information 265 consisting of a plurality of device parameters set for each unit, and substrate recipe information 266 that defines polishing process state information for the polishing process and cleaning process conditions for the cleaning process.

[0016]

The substrate processing device 2 transmits various reports R to the database device 3, the user terminal device 6, and the like, according to the operation of each unit. The various reports R include, for example, process information that identifies the wafer W to be processed when the substrate processing is performed, device state information that indicates the state of each unit when each processing is performed, event information detected by the substrate processing device 2, and operation information of a user (operator, production manager, maintenance manager, and the like) on the

substrate processing device 2.

[0017]

The database device 3 is a device that manages production history information 30 regarding the history of substrate processing performed on the wafer W for the current production, and polishing test information 31 regarding the history of tests for polishing process performed on a dummy wafer for testing (hereinafter referred to as "polishing tests"). In addition to the above, the database device 3 may also store device setting information 265 and substrate recipe information 266. In that case, the substrate processing device 2 may refer to these pieces of information.

[0018]

When the substrate processing device 2 performs substrate processing on the wafers W for the current production, the database device 3 receives various reports R from the substrate processing device 2 at any time and registers them in the production history information 30, so that the reports R related to the substrate processing are accumulated in the production history information 30.

[0019]

When the substrate processing device 2 performs a polishing test on a dummy wafer for testing, the database device 3 receives various reports R (including at least device state information) from the substrate processing device 2 at any time and registers them in the polishing test information 31. The test results of the polishing test are also registered in association with each other, so that the reports R and test results related to the polishing test are accumulated in the polishing test information 31.

[0020]

The dummy wafer is a jig that simulates a wafer W. A dummy wafer sensor, such as a pressure sensor or a temperature sensor, is provided on the surface or inside of the dummy wafer to measure the state of the wafer W when the polishing process is performed. The measurement value from the dummy wafer sensor is registered in the polishing test information 31 as a test result. The dummy wafer sensor may be provided at one or more locations on the substrate surface of the dummy wafer, or may be provided in a surface area. The polishing test may be performed in the substrate processing device 2 for the current production, or in a polishing test device (not shown) for testing that can reproduce a polishing process similar to that of the substrate

processing device 2.

[0021]

The machine learning device 4 operates as a subject of the learning phase of machine learning, and, for example, acquires a part of the polishing test information 31 from the database device 3 as first learning data 11A, and generates a first learning model 10A used in the information processing device 5 through machine learning. The trained first learning model 10A is provided to the information processing device 5 via the network 7, a recording medium, or the like.

[0022]

The information processing device 5 operates as a subject of the inference phase of machine learning, and predicts the state of the wafer W when the polishing process is performed by the substrate processing device 2 on the wafer W for the current production, using the first learning model 10A generated by the machine learning device 4, and transmits the predicted result, that is, reliability information of the polishing endpoint detection function, to the database device 3, the user terminal device 6, and the like. The timing at which the information processing device 5 predicts the reliability information of the polishing endpoint detection function may be after the polishing process (post-prediction processing), during the polishing process (real-time prediction processing), or before the polishing process (pre-prediction processing).

[0023]

The user terminal device 6 is a terminal device used by a user, and may be a stationary device or a portable device. The user terminal device 6 accepts various input operations via a display screen of, for example, an application program, a web browser, or the like, and displays various pieces of information (for example, event notification, reliability information of the polishing endpoint detection function, production history information 30, polishing test information 31, and the like) via the display screen.

[0024]

(Substrate Processing Device 2)

FIG. 2 is a plan view showing an example of the substrate processing device 2. The substrate processing device 2 is configured with a load/unload unit 21, a polishing unit 22, a substrate transport unit 23, a cleaning unit 24, a film thickness measurement unit 25, and a control unit 26 housed within a housing 20 that is substantially

rectangular in plan view. The load/unload unit 21 is partitioned from the polishing unit 22, the substrate transport unit 23, and the cleaning unit 24 by a first partition wall 200A, and the substrate transport unit 23 and the cleaning unit 24 are partitioned by a second partition wall 200B.

[0025]

(Load/Unload Unit)

The load/unload unit 21 includes first to fourth front load units 210A to 210D on which wafer cassettes (FOUPs and the like) capable of storing a plurality of wafers W in the vertical direction are placed, a transport robot 211 that can move up and down along the storage direction (vertical direction) of the wafers W stored in the wafer cassettes, and a horizontal movement mechanism 212 that moves the transport robot 211 along the arrangement direction of the first to fourth front load units 210A to 210D (short side direction of the housing 20).

[0026]

The transport robot 211 is configured to be accessible to the wafer cassettes placed on the first to fourth front load units 210A to 210D, the substrate transport unit 23 (specifically, a lifter 232 described below), the cleaning unit 24 (specifically, a drying chamber 241 described below), and the film thickness measurement unit 25, and is equipped with two upper and lower hands (not shown) for delivering the wafer W between them. The lower hand is used to deliver the wafer W before processing, and the upper hand is used to deliver the wafer W after processing. When delivering the wafer W to the substrate transport unit 23 or the cleaning unit 24, a shutter (not shown) provided on the first partition wall 200A is opened and closed.

[0027]

(Polishing Unit)

The polishing unit 22 is equipped with first to fourth polishing units 22A to 22D that perform polishing (planarization) of the wafer W, respectively. The first to fourth polishing units 22A to 22D are arranged in a line along the longitudinal direction of the housing 20.

[0028]

FIG. 3 is a perspective view showing an example of the first to fourth polishing units 22A to 22D. The first to fourth polishing units 22A to 22D have the same basic

configuration and functions.

[0029]

Each of the first to fourth polishing units 22A to 22D includes a polishing table 220 on which a polishing pad 2200 having a polishing surface is attached, a top ring (polishing head) 221 for holding a wafer W and polishing the wafer W while pressing it against the polishing pad 2200 on the polishing table 220, a polishing fluid supply nozzle 222 as a polishing fluid supply unit for supplying a polishing fluid to the polishing pad 2200, a dresser 223 for dressing the polishing surface of the polishing pad 2200, an atomizer 224 for spraying a cleaning fluid onto the polishing pad 2200, and an environmental sensor 225 for measuring the state of the internal space of the housing 20 in which the polishing process is performed.

[0030]

The polishing table 220 is supported by a polishing table shaft 220a and includes a rotational movement mechanism 220b that rotates the polishing table 220 around its axis via a polishing table rotary connector 2201, and a polishing pad surface temperature control mechanism 220c that adjusts the surface temperature of the polishing pad 2200. The polishing pad surface temperature control mechanism 220c has a radiation thermometer 220c1 above the polishing table 220 to measure the surface temperature of the polishing pad 2200 or the surface temperature of the grindstone.

[0031]

The polishing table 220 of this embodiment also has a polishing table internal temperature control mechanism 220d that adjusts the temperature of the polishing table 220 by supplying and discharging temperature-controlled water to the inside of the polishing table 220. The polishing table internal temperature control mechanism 220d has a temperature-controlled water supply pipe 220d1 that supplies temperature-controlled water to the inside of the polishing table 220 and a temperature-controlled water discharge pipe 220d2 that discharges the temperature-controlled water. The polishing table internal temperature control mechanism 220d has a supply temperature-controlled water thermometer 220d3 in the temperature-controlled water supply pipe 220d1 to measure the temperature of the supplied temperature-controlled water, and a discharge temperature-controlled water thermometer 220d4 in the temperature-controlled water discharge pipe 220d2 to measure the temperature of the discharged

temperature-controlled water.

[0032]

The top ring 221 is supported by a top ring shaft 221a that can move in the vertical direction, and includes a top ring rotational movement mechanism 221c that rotates the top ring 221 around its axis, a top ring vertical movement mechanism 221d that moves the top ring 221 in the vertical direction, and a top ring swing movement mechanism 221e that turns (swings) the top ring 221 around the top ring swing support shaft 221b.

[0033]

The top ring swing movement mechanism 221e includes a top ring swing support shaft 221b, a top ring swing arm 221f that swingably connects the top ring shaft 221a to the top ring swing support shaft 221b, and a top ring swing shaft motor 221g that rotates the top ring swing support shaft 221b.

[0034]

The top ring swing movement mechanism 221e has a top ring swing torque sensor 221h that detects the top ring swing torque applied to the top ring swing arm 221f at the connection between the top ring swing arm 221f and the top ring swing shaft motor 221g. Specifically, the top ring swing torque sensor 221h may detect the torque applied to the top ring swing arm 221f from the current value of the top ring swing shaft motor 221g. The current value of the top ring swing shaft motor 221g is an amount that depends on the torque of the top ring swing arm 221f at the connection to the top ring swing shaft motor 221g. In this embodiment, the current value of the top ring swing shaft motor 221g may be the current value supplied to the top ring swing shaft motor 221g or a current command value generated in a driver (not shown). Note that the top ring swing torque may be detected by other methods.

[0035]

The top ring 221 may be fitted with an acceleration sensor 221j and/or an amplitude sensor (not shown) for measuring the vibration of the top ring 221 during the polishing process. A noise meter 221k for measuring the noise during the polishing process may be provided near the top ring 221.

[0036]

The polishing fluid supply nozzle 222 is supported by a support shaft 222a and

includes a swing movement mechanism 222b for swinging the polishing fluid supply nozzle 222 around the support shaft 222a, a polishing fluid flow rate regulator 222c for adjusting the flow rate of the polishing fluid, and a polishing fluid temperature control mechanism 222d for adjusting the temperature of the polishing fluid. The polishing fluid is a polishing liquid (slurry) or pure water, and may further include a chemical solution or may be a polishing liquid to which a dispersant has been added.

[0037]

The dresser 223 is supported by a dresser shaft 223a that can move in the vertical direction, and includes a dresser rotational movement mechanism 223c that rotates the dresser 223 around its axis, a dresser vertical movement mechanism 223d that moves the dresser 223 in the vertical direction, and a dresser swing movement mechanism 223e that swings the dresser 223 around the dresser swing support shaft 223b.

[0038]

The dresser swing movement mechanism 223e includes the dresser swing support shaft 223b, a dresser swing arm 223f that swingably connects the dresser shaft 223a to the dresser swing support shaft 223b, and a dresser swing shaft motor 223g that rotates the dresser swing support shaft 223b.

[0039]

The dresser swing movement mechanism 223e has a dresser swing torque sensor 223h that detects the dresser swing torque applied to the dresser swing arm 223f at the connection between the dresser swing arm 223f and the dresser swing shaft motor 223g. Specifically, the dresser swing torque sensor 223h may detect the torque applied to the dresser swing arm 223f from the current value of the dresser swing shaft motor 223g. The current value of the dresser swing shaft motor 223g is an amount that depends on the torque of the dresser swing arm 223f at the connection to the dresser swing shaft motor 223g. In this embodiment, the current value of the dresser swing shaft motor 223g may be the current value supplied to the dresser swing shaft motor 223g or a current command value generated in a driver (not shown). Note that the dresser swing torque may be detected by other methods.

[0040]

The atomizer 224 is supported by a support shaft 224a and includes an atomizer

swing movement mechanism 224b that swings the atomizer 224 around the support shaft 224a, and a cleaning fluid flow rate regulator 224c that regulates the flow rate of the cleaning fluid. The cleaning fluid is a mixed fluid of a liquid (for example, pure water) and a gas (for example, nitrogen gas) or a liquid (for example, pure water).
[0041]

The environmental sensor 225 is a sensor disposed in the internal space of the housing 20, and includes, for example, a temperature sensor 225a that measures the temperature of the internal space, a humidity sensor 225b that measures the humidity of the internal space, and an air pressure sensor 225c that measures the air pressure of the internal space. The environmental sensor 225 may include a camera (image sensor) that can capture images of the surface of the polishing pad 2200 and the like during or before/after the polishing process.

[0042]

In FIG. 3, the specific configurations of the rotational movement mechanisms 220b, 221c, 223c, the vertical movement mechanisms 221d, 223d, and the swing movement mechanisms 221e, 222b, 223e, 224b are omitted. However, for example, they are configured by appropriately combining modules such as motors and actuators for driving force generation, and mechanisms such as linear guides, ball screws, gears, belts, couplings, and bearings for driving force transmission, as well as sensors such as linear sensors, encoder sensors, limit sensors, and torque sensors.

[0043]

In FIG. 3, the specific configurations of the flow rate regulators 222c and 224c are omitted. However, for example, they are configured by appropriately combining modules such as pumps, valves, and regulators for fluid control, along with sensors such as flow rate sensors, pressure sensors, and liquid level sensors. Furthermore, in FIG. 3, the specific configurations of the polishing table surface temperature control mechanism 220c, the polishing table internal temperature control mechanism 220d, and the polishing fluid temperature control mechanism 222d are omitted. However, for example, they are configured by appropriately combining temperature control modules such as heaters and heat exchangers (conductive, radiative, or convective types) and sensors such as temperature sensors and current sensors.

[0044]

FIG. 4 is a cross-sectional view showing a schematic example of the top ring 221. The top ring 221 includes a top ring body 2210 attached to a top ring shaft 221a, a substantially disk-shaped carrier 2211 housed in the top ring body 2210, an elastic membrane 2212 arranged below the carrier 2211 and pressing the wafer W against the polishing pad 2200, a substantially annular retainer ring 2213 arranged on the outer periphery of the carrier 2211 and the elastic membrane 2212 and directly pressing the polishing pad 2200, and a retainer ring airbag 2214 as a retainer ring pressing mechanism arranged between the top ring body 2210 and the retainer ring 2213 and pressing the retainer ring 2213 against the polishing pad 2200.

[0045]

In this embodiment, the retainer ring airbag 2214 is used as the retainer ring pressing mechanism. However, the retainer ring pressing mechanism may be a fluid actuator using air, water, oil, or the like, an electric actuator using a ball screw or the like, an elastic member including a spring, a bag, or the like.

[0046]

The elastic membrane 2212 is formed of an elastic membrane and has a plurality of concentric partition walls 2212e therein, thereby providing first to fourth elastic membrane pressure chambers 2212a to 2212d arranged concentrically from the center of the top ring body 2210 toward the outer periphery. The elastic membrane 2212 also has a plurality of holes 2212f for adsorbing the wafer W on its lower surface, and functions as a substrate holding surface for holding the wafer W. The retainer ring airbag 2214 is formed of an elastic membrane and has a retainer ring pressure chamber 2214a therein. The configuration of the top ring 221 may be changed as appropriate, and may include a pressure chamber that presses the entire carrier 2211, the number and shape of the elastic membrane pressure chambers of the elastic membrane 2212 may be changed as appropriate, and the number and arrangement of the suction holes 2212f may be changed as appropriate. The elastic membrane 2212 may not have the suction holes 2212f.

[0047]

The first to fourth elastic membrane pressure chambers 2212a to 2212d are connected to first to fourth flow paths 2216A to 2216D, respectively, and the retainer

ring pressure chamber 2214a is connected to a fifth flow path 2216E. The first to fifth flow paths 2216A to 2216E are connected to the outside via a top ring rotary connector 2215 provided on the top ring shaft 221a, and are branched into first branch flow paths 2217A to 2217E and second branch flow paths 2218A to 2218E, respectively. Pressure sensors PA to PE are installed in the first to fifth flow paths 2216A to 2216E, respectively. The first branch flow paths 2217A to 2217E are connected to a gas supply source GS of pressurizing fluid (air, nitrogen, and the like) via valves V1A to V1E, flow rate sensors FA to FE, and pressure regulators RA to RE. The second branch flow paths 2218A to 2218E are connected to a vacuum source VS via valves V2A to V2E, respectively, and are configured to be able to communicate with the atmosphere via valves V3A to V3E.

[0048]

The wafer W is held by suction on the lower surface of the top ring 221 and moved to a predetermined polishing position on the polishing table 220, and then is polished by being pressed by the top ring 221 against the polishing surface of the polishing pad 2200 to which a polishing fluid is supplied from the polishing fluid supply nozzle 222. At this time, the top ring 221 independently controls the pressure regulators RA to RE to adjust the pressing force for pressing the wafer W against the polishing pad 2200 by the pressurizing fluid supplied to the first to fourth elastic membrane pressure chambers 2212a to 2212d for each region of the wafer W, and adjust the pressing force for pressing the retainer ring 2213 against the polishing pad 2200 by the pressurizing fluid supplied to the retainer ring pressure chamber 2214a. The pressures of the pressurizing fluids supplied to the first to fourth elastic membrane pressure chambers 2212a to 2212d and the retainer ring pressure chamber 2214a are measured by the pressure sensors PA to PE, respectively, and the flow rates of the pressurizing gases are measured by the flow rate sensors FA to FE, respectively.

[0049]

(Substrate Transport Unit)

As shown in FIG. 2, the substrate transport unit 23 includes first and second linear transporters 230A and 230B that are horizontally movable along the arrangement direction of the first to fourth polishing units 22A to 22D (the longitudinal direction of the housing 20), a swing transporter 231 disposed between the first and second linear

transporters 230A and 230B, a lifter 232 disposed on the load/unload unit 21 side, and a temporary storage stand 233 for the wafer W disposed on the cleaning unit 24 side.

[0050]

The first linear transporter 230A is a mechanism disposed adjacent to the first and second polishing units 22A and 22B to transport the wafer W between four transport positions (first to fourth transport positions TP1 to TP4, in order from the load/unload unit 21 side). The second transport position TP2 is a position for delivering the wafer W to the first polishing unit 22A, and the third transport position TP3 is a position for delivering the wafer W to the second polishing unit 22B.

[0051]

The second linear transporter 230B is a mechanism disposed adjacent to the third and fourth polishing units 22C and 22D and to transport the wafer W between three transport positions (fifth to seventh transport positions TP5 to TP7, in order from the load/unload unit 21 side). The sixth transport position TP6 is a position for delivering the wafer W to the third polishing unit 22C, and the seventh transport position TP7 is a position for delivering the wafer W to the fourth polishing unit 22D.

[0052]

The swing transporter 231 is disposed adjacent to the fourth and fifth transport positions TP4 and TP5, and has a hand that can move between the fourth and fifth transport positions TP4 and TP5. The swing transporter 231 is a mechanism that delivers the wafer W between the first and second linear transporters 230A and 230B, and temporarily places the wafer W on the temporary storage stand 233. The lifter 232 is a mechanism disposed adjacent to the first transport position TP1 to deliver the wafer W between the lifter 232 and the transport robot 211 of the load/unload unit 21. When delivering the wafer W, a shutter (not shown) provided on the first partition wall 200A is opened and closed.

[0053]

(Cleaning Unit)

As shown in FIG. 2, the cleaning unit 24 includes first and second cleaning chambers 240A and 240B for cleaning the wafer W using a cleaning tool, a drying chamber 241 for drying the wafer W, and first and second transport chambers 242A and 242B for transporting the wafer W. The chambers of the cleaning unit 24 are arranged

along the first and second linear transporters 230A and 230B in a partitioned state, for example, in the order of the first cleaning chamber 240A, the first transport chamber 242A, the second cleaning chamber 240B, the second transport chamber 242B, and the drying chamber 241 (in order of increasing distance from the load/unload unit 21). The number and arrangement of the cleaning chambers 240A and 240B, the drying chamber 241, and the transport chambers 242A and 242B are not limited to the example in FIG. 2, and may be changed as appropriate.

[0054]

(Thickness Measurement Unit)

The thickness measurement unit 25 is a measuring device that measures the thickness of the wafer W before or after the polishing process, and is composed of, for example, an optical thickness measurement device, an eddy current thickness measurement device, and the like. The wafer W is delivered to each thickness measurement module by the transport robot 211.

[0055]

(Control Unit)

FIG. 5 is a block diagram showing an example of the substrate processing device 2. The control unit 26 is electrically connected to each of the units 21 to 25 and controls each of the units 21 to 25 in an integrated manner. The following describes the control system (modules, sensors, sequencer) of the polishing unit 22 as an example, but the other units 21, 23 to 25 have the same basic configuration and functions, so their description will be omitted.

[0056]

The polishing unit 22 includes a plurality of modules 227_1 to 227_r that are to be controlled and are arranged in each subunit (for example, polishing table 220, top ring 221, polishing fluid supply nozzle 222, dresser 223, atomizer 224, and the like) of the polishing unit 22, a plurality of sensors 228_1 to 228_s that are arranged in each of the modules 227_1 to 227_r and detect data (detection values) required for controlling each of the modules 227_1 to 227_r , and a sequencer 229 that controls the operation of each of the modules 227_1 to 227_r based on the detection values from each of the sensors 228_1 to 228_s .

[0057]

The sensors 228₁ to 228_s of the polishing unit 22 include, for example, a sensor for detecting the flow rate of the polishing fluid, a sensor for detecting the pressing force of the retainer ring pressing mechanism, a sensor for detecting the rotational torque of the top ring 221, a sensor for detecting the rotational torque of the polishing table 220, a timer for measuring the time until the endpoint is detected, an optical sensor for detecting the endpoint, and the environmental sensor 225. In this embodiment, the rotational torque is the measurement of the sliding resistance between the top ring 221 or the dresser 223 that contacts the polishing surface and the polishing table 220.

[0058]

The control unit 26 includes a substrate processing control unit 260, a communication unit 261, an input unit 262, an output unit 263, and a storage unit 264. The control unit 26 is, for example, a general-purpose or dedicated computer (see FIG. 6 described later).

[0059]

The communication unit 261 is connected to the network 7 and functions as a communication interface for transmitting and receiving various pieces of data. The input unit 262 accepts various input operations, and the output unit 263 functions as a user interface by outputting various pieces of information via a display screen, a signal tower light, and a buzzer sound.

[0060]

The storage unit 264 stores various programs (operating system (OS), application programs, web browser, and the like) and data (device setting information 265, substrate recipe information 266, and the like) used in the operation of the substrate processing device 2. The device setting information 265 and substrate recipe information 266 are data that can be edited by the user via the display screen.

[0061]

The substrate processing control unit 260 obtains detection values from a plurality of sensors 218₁ to 218_q, 228₁ to 228_s, 238₁ to 238_u, 248₁ to 248_w, and 258₁ to 258_y (hereinafter referred to as a "sensor group") via a plurality of sequencers 219, 229, 239, 249, and 259 (hereinafter referred to as a "sequencer group"), and performs a series of substrate processing tasks such as loading, polishing, cleaning, drying, film thickness

measurement, and unloading by operating a plurality of modules 217₁ to 217_p, 227₁ to 227_r, 237₁ to 237_t, 247₁ to 247_v, and 257₁ to 257_x (hereinafter referred to as a "module group") in cooperation with each other.

[0062]

(Hardware Configuration of Each Device)

FIG. 6 is a hardware configuration diagram showing an example of a computer 900. Each of the control unit 26, the database device 3, the machine learning device 4, the information processing device 5, and the user terminal device 6 of the substrate processing device 2 is configured by a general-purpose or dedicated computer 900.

[0063]

As shown in FIG. 6, the computer 900 includes, as its main components, a bus 910, a processor 912, a memory 914, an input device 916, an output device 917, a display device 918, a storage device 920, a communication interface (I/F) unit 922, an external device I/F unit 924, an input/output (I/O) device I/F unit 926, and a media input/output unit 928. Note that the above components may be omitted as appropriate depending on the purpose for which the computer 900 is used.

[0064]

The processor 912 is configured of one or more arithmetic processing devices (central processing unit (CPU), micro-processing unit (MPU), digital signal processor (DSP), graphics processing unit (GPU), neural processing unit (NPU), and the like) and controls the entire computer 900. The memory 914 stores various pieces of data and programs 930 and is composed of, for example, a volatile memory (DRAM, SRAM, and the like) that functions as a main memory, a non-volatile memory (ROM), a flash memory, and the like.

[0065]

The input device 916 is composed of, for example, a keyboard, a mouse, a numeric keypad, an electronic pen, and the like, and functions as an input unit. The output device 917 is, for example, a sound (audio) output device, a vibration device, and the like, and functions as an output unit. The display device 918 is, for example, a liquid crystal display, an organic EL display, electronic paper, a projector, and the like, and functions as an output unit. The input device 916 and the display device 918 may be integrally configured, such as a touch panel display. The storage device 920 is, for

example, an HDD, an SSD (solid-state drive), and the like, and functions as a storage unit. The storage device 920 stores various pieces of data required for the execution of the operating system and the program 930.

[0066]

The communication I/F unit 922 is connected to a network 940 (which may be the same as the network 7 in FIG. 1) such as the Internet or an intranet via wired or wireless means, and functions as a communication unit that transmits and receives data to and from other computers according to a predetermined communication standard. The external device I/F unit 924 is connected to an external device 950 such as a camera, a printer, a scanner, a reader/writer, and the like, via wired or wireless means, and functions as a communication unit that transmits and receives data to and from the external device 950 according to a predetermined communication standard. The I/O device I/F unit 926 is connected to an I/O device 960 such as various sensors, actuators, and the like, and functions as a communication unit that transmits and receives various signals and data, such as detection signals from sensors and control signals to actuators, to and from the I/O device 960. The media input/output unit 928 is configured of a drive device such as a DVD drive, a CD drive, and the like, and reads and writes data from and to a medium (non-transitory storage medium) 970 such as a DVD or a CD.

[0067]

In the computer 900 having the above configuration, the processor 912 calls up the program 930 stored in the storage device 920 into the memory 914, executes it, and controls each part of the computer 900 via the bus 910. The program 930 may be stored in the memory 914 instead of the storage device 920. The program 930 may be recorded in the medium 970 in an installable file format or an executable file format, and provided to the computer 900 via the media input/output unit 928. The program 930 may be provided to the computer 900 by downloading it via the network 940 through the communication I/F unit 922. In addition, the computer 900 may realize various functions realized by the processor 912 executing the program 930, for example, with hardware such as an FPGA, an ASIC, or the like.

[0068]

The computer 900 is, for example, a stationary computer or a portable computer, and is an electronic device of any form. The computer 900 may be a client-type

computer, a server-type computer, or a cloud-type computer. The computer 900 may also be applied to devices other than the devices 2 to 6.

[0069]

(Production History Information 30)

FIG. 7 is a data structure diagram showing an example of the production history information 30 managed by the database device 3. The production history information 30 includes, for example, a wafer history table 300 for each wafer W and a polishing history table 301 for device state information in a polishing process, as tables in which the reports R obtained when the substrate processing is performed on the wafer W for the current production are classified and registered. In addition to the above, the production history information 30 includes a cleaning history table for device state information in a cleaning process, an event history table for event information, and an operation history table for operation information, but detailed explanations are omitted.

[0070]

Each record in the wafer history table 300 includes, for example, a wafer ID, a cassette number, a slot number, the start time and end time of each process, a used unit ID, and the like. In FIG. 7, the polishing process and the cleaning process are exemplified, but similar data is also registered for other processes.

[0071]

Each record in the polishing history table 301 is registered with, for example, a wafer ID, wear state information, processing state information, and the like.

[0072]

The wear state information is information indicating the wear state of each component of the substrate processing device 2 that can be obtained before the polishing process. The wear state information is, for example, information indicating the condition of the polishing pad 2200, information indicating the condition of the top ring rotary connector 2215, information indicating the condition of the polishing table rotary connector 2201, information indicating the condition of the dresser 223, and information indicating the condition of the substrate processing control unit 260. The information indicating each condition includes at least the usage time and the number of wafers processed of each component.

[0073]

The processing state information is information indicating the processing state of the substrate processing device 2 that can be obtained during the polishing process. The processing state information is, for example, the detection value from each sensor sampled at predetermined time intervals by a group of sensors such as a polishing fluid flow rate sensor, a pressing force sensor of the retainer ring pressing mechanism, a rotation torque sensor of the top ring 221, or a rotation torque sensor of the polishing table 220, which are included in the substrate processing device 2. Furthermore, the processing state information is, for example, a statistical value for the time until the endpoint is detected for each wafer W, and a statistical value of the time-series data of each sensor for each wafer W.

[0074]

By referring to the polishing history table 301, it is possible to extract the time-series data of each sensor as the device state of the substrate processing device 2 when the polishing process is performed on the wafer W identified by the wafer ID.

[0075]

(Polishing Test Information 31)

FIG. 8 is a data structure diagram showing an example of the polishing test information 31 managed by the database device 3. The polishing test information 31 includes a polishing test table 310 in which the report R and the test results obtained when the polishing test is performed are classified and registered.

[0076]

Each record in the polishing test table 310 is registered with, for example, a test ID, wear state information, processing state information, test result information, and the like. The wear state information and processing state information in the polishing test table 310 are information indicating the state of each part in the polishing test, and the data structure is the same as that in the polishing history table 301, so a detailed description is omitted.

[0077]

The test result information is information indicating the state of the polishing test device when the polishing process is performed in the polishing test. The test result information may be a measurement value measured by a polishing device measuring

device provided in the polishing test device. The test result information shown in FIG. 8 includes the number of wafers processed 1, 2, ..., m, ..., n and the usage time t1, t2, ..., tm, ..., tn after the start of the polishing process. Additionally, it includes the reliability of the endpoint detection at each time tm1, tm2, ..., tmm, ..., tmn included in the polishing process period for the m-th wafer, a sign of reliability degradation, a type of component that causes the reliability degradation, and a type of process TR1 to TR4 that causes the reliability degradation.

[0078]

By referring to the polishing test table 310, it is possible to extract the time-series data of each sensor indicating the state of the polishing unit 22 when the polishing process was performed in the polishing test identified by the test ID, and the reliability of the endpoint detection function at that time. For example, the sign of reliability degradation of the endpoint detection function can be obtained by using data from a first target period of the polishing process before the time tmm when the reliability of the endpoint detection function degraded, and the presence or absence of reliability degradation of the endpoint detection function can be obtained by using data from a second target period including the time tmm when the reliability of the endpoint detection function degraded.

[0079]

(Machine Learning Device 4)

FIG. 9 is a block diagram showing an example of the machine learning device 4 according to the first embodiment. The machine learning device 4 includes a machine learning control unit 40, a communication unit 41, a learning data storage unit 42, and a trained model storage unit 43.

[0080]

The machine learning control unit 40 functions as a learning data acquisition unit 400 and a machine learning unit 401. The communication unit 41 is connected to an external device (for example, the substrate processing device 2, the database device 3, the information processing device 5, the user terminal device 6, the polishing test device (not shown), and the like) via the network 7, and functions as a communication interface for transmitting and receiving various pieces of data.

[0081]

The learning data acquisition unit 400 is connected to an external device via the communication unit 41 and the network 7, and acquires first learning data 11A consisting of a set of reliability degradation factor state information as input data and reliability information of the polishing endpoint detection function as output data. The first learning data 11A is data used as teacher data (training data), verification data, and test data in supervised learning. In addition, the reliability information of the polishing endpoint detection function is data used as a correct answer label in supervised learning.

[0082]

The learning data storage unit 42 is a database that stores a plurality of sets of the first learning data 11A acquired by the learning data acquisition unit 400. The specific configuration of the database that constitutes the learning data storage unit 42 may be designed as appropriate.

[0083]

The machine learning unit 401 performs machine learning using a plurality of sets of the first learning data 11A stored in the learning data storage unit 42. That is, the machine learning unit 401 inputs a plurality of sets of the first learning data 11A to the first learning model 10A, and generates a trained first learning model 10A by causing the first learning model 10A to learn the correlation between the reliability degradation factor state information and the reliability information of the polishing endpoint detection function that are included in the first learning data 11A.

[0084]

The trained model storage unit 43 is a database that stores the trained first learning model 10A (specifically, the adjusted weight parameter group) generated by the machine learning unit 401. The trained first learning model 10A stored in the trained model storage unit 43 is provided to a real system (for example, the information processing device 5) via the network 7, a recording medium, or the like. In FIG. 9, the learning data storage unit 42 and the trained model storage unit 43 are shown as separate storage units, but they may be configured as a single storage unit.

[0085]

The number of first learning models 10A stored in the trained model storage unit 43 is not limited to one. For example, a plurality of learning models with different

conditions may be stored, such as machine learning methods, differences in the mechanisms and materials of the top ring 221, types of elastic membranes 2212, types of retainer rings 2213, types of polishing pads 2200, types of polishing fluids, types of data included in reliability degradation factor state information, and types of data included in reliability information of the polishing endpoint detection function. In that case, a plurality of types of learning data having data structures corresponding to a plurality of learning models with different conditions may be stored in the learning data storage unit 42.

[0086]

FIG. 10 is a diagram showing an example of the first learning model 10A and the first learning data 11A. The first learning data 11A used for the machine learning of the first learning model 10A includes reliability degradation factor state information and reliability information of the polishing endpoint detection function.

[0087]

The reliability degradation factor state information constituting the first learning data 11A includes wear state information indicating the wear state of the components of the substrate processing device 2, and polishing process state information indicating the processing state of the substrate processing device 2 that can be obtained during the polishing process.

[0088]

The wear state information included in the reliability degradation factor state information is information indicating the wear state of the components of the substrate processing device 2. The wear state information includes, for example, at least one of the condition of the polishing pad 2200, the condition of the top ring rotary connector 2215, the condition of the polishing table rotary connector 2201, the condition of the dresser 223, and the condition of the substrate processing control unit 260.

[0089]

The condition of the polishing pad 2200 includes at least the usage time of the polishing pad 2200 and the number of wafers processed by the polishing pad 2200. The condition of the polishing pad 2200 may be set based on, for example, the cumulative number of rotations of the polishing table 220, the rotation speed of the polishing table 220, the rotation torque of the polishing table 220, whether or not the pad has been

dressed, whether or not it has been replaced, an image of the surface, the surface shape, flatness, cleanliness, wetness, and the like. The condition of the polishing pad 2200 may change over time during the polishing process, for example.

[0090]

The condition of the top ring rotary connector 2215 includes at least the usage time of the top ring 221 and the number of wafers processed by the top ring 221. The condition of the top ring rotary connector 2215 may also be set based on, for example, the cumulative number of rotations of the top ring 221, the rotation speed of the top ring 221, the rotation torque of the top ring 221, and the like. The condition of the top ring 221 may change over time during the polishing process, for example.

[0091]

The condition of the polishing table rotary connector 2201 includes at least the usage time of the polishing table 220 and the number of wafers processed by the polishing table 220. The condition of the polishing table rotary connector 2201 may be set based on, for example, the cumulative number of rotations of the polishing table 220, the rotation speed of the polishing table 220, the rotation torque of the polishing table 220, and the like. The condition of the polishing table 220 may change over time during the polishing process, for example.

[0092]

The condition of the dresser 223 includes at least the usage time of the dresser 223 and the number of wafers processed by the polishing table 220. The condition of the dresser 223 may be set based on, for example, the cumulative number of rotations of the dresser 223, the rotation speed of the dresser 223, the rotation torque of the dresser 223, whether or not the pad has been dressed, whether or not it has been replaced, an image of the surface, the surface shape, flatness, cleanliness, wetness, and the like. The condition of the dresser 223 may change over time during the polishing process.

[0093]

The condition of the substrate processing control unit 260 includes at least the usage time of the substrate processing control unit 260 and the number of wafers processed by the substrate processing control unit 260. The condition of the substrate processing control unit 260 may change over time during the polishing process.

[0094]

The processing state information included in the reliability degradation factor state information is information indicating the processing state of the substrate processing device 2 that can be obtained during the polishing process. The processing state information includes at least one of the following: flow rate of the polishing fluid, pressing force of the retainer ring pressing mechanism, rotation torque of the top ring 221, rotation torque of the polishing table 220, swing torque of the top ring 221, vibration of the top ring 221, swing torque of the dresser 223, noise during the polishing process, temperature of the polishing surface, temperature of the temperature-controlled water of the polishing table 220, statistical value of time until endpoint detection for each wafer, and statistical value of time-series data of each sensor for each wafer.

[0095]

The flow rate of the polishing fluid may be the flow rate of the polishing fluid supplied from the polishing fluid supply nozzle 222. In this embodiment, the pressing force of the retainer ring pressing mechanism may be the pressure in the retainer ring pressure chamber 2214a of the retainer ring airbag 2214, the flow rate of the pressurizing fluid supplied to the retainer ring pressure chamber 2214a, and the like. The rotation torque of the top ring 221 may be obtained from the motor current driving the top ring 221, and the like. The rotation torque of the polishing table 220 may be obtained from the motor current driving the polishing table 220, and the like.

[0096]

The swing torque of the top ring 221 may be the top ring swing torque applied to the top ring swing arm 221f detected by the top ring swing torque sensor 221h, and the like. The vibration of the top ring 221 may be the vibration of the top ring 221 during the polishing process measured by the acceleration sensor 221j attached to the top ring 221, and the like. The swing torque of the dresser 223 may be the dresser swing torque applied to the dresser swing arm 223f detected by the dresser swing torque sensor 223h, and the like. The noise during the polishing process may be the noise during the polishing process measured by the noise meter 221k provided near the top ring 221, and the like. The temperature of the polishing surface may be the surface temperature of the polishing pad 2200, the surface temperature of the grindstone, or the like measured by the radiation thermometer 220c1 installed above the polishing table 220. The

temperature of the temperature-controlled water of the polishing table 220 may be the temperature of the supplied temperature-controlled water or the like measured by the temperature-controlled water supply thermometer 220d3.

[0097]

The statistical value of the time until the endpoint detection for each wafer may be obtained from the measured time until the endpoint detection for each wafer. Alternatively, the measured time until the endpoint detection for each wafer may be divided into predetermined ranges and the statistical value may be obtained from the number of pieces of data for each range. The statistical value of the time-series data of each sensor for each wafer may be obtained from the time-series data measured by the sensors of the components such as the flow rate, pressing force, and rotation torque. Alternatively, the measured time until the endpoint detection for each piece of time-series data may be divided into predetermined ranges and the number of pieces of data for each range may be obtained.

[0098]

The statistical value obtained in this way may be used as it is, may be used after processing such as noise removal or the like that is easy for the measuring instrument to capture, or may be used as the result of statistical processing. In either case, it is necessary to determine the variation in the results.

[0099]

In this embodiment, since the retainer ring airbag 2214 is used as the retainer ring pressing mechanism, the top ring state information included in the polishing process state information includes the pressure in the retainer ring pressure chamber 2214a (retainer ring airbag pressure) and the flow rate of the pressurizing fluid supplied to the retainer ring pressure chamber 2214a (retainer ring airbag flow rate).

[0100]

When another pressing mechanism is used as the retainer ring pressing mechanism, the pressing force of the retainer ring pressing mechanism in the processing state information included in the reliability degradation factor state information may be the amount of an element that adjusts the pressing force of the retainer ring pressing mechanism, or the like. For example, when an electric actuator is used as the retainer ring pressing mechanism, the pressing force of the electric actuator may be the amount

of current that adjusts the pressing force of the electric actuator, or the like.

Furthermore, when an elastic member such as a spring, a bag, or the like is used as the retainer ring pressing mechanism, the pressing force of the retainer ring pressing mechanism may be the pressing force of the elastic member, the vertical position that adjusts the pressing force of the elastic member, and the like.

[0101]

The reliability information of the polishing endpoint detection function constituting the first learning data 11A is information indicating the reliability of the polishing endpoint detection function of the wafer W polished in a state indicated by the reliability degradation factor state information. In this embodiment, the reliability information of the polishing endpoint detection function is information on the current endpoint detection reliability, information on a sign of reliability degradation, information on the type of component that causes the reliability degradation, and information on the type of process that causes the reliability degradation.

[0102]

The learning data acquisition unit 400 acquires the first learning data 11A by referring to the polishing test information 31 and accepting an input operation of the user through the user terminal device 6 as necessary. For example, the learning data acquisition unit 400 acquires, as reliability degradation factor state information, wear state information indicating the wear state of the components of the substrate processing device 2 when the polishing test identified by the test ID was performed, and processing state information indicating the processing state of the substrate processing device 2 that can be acquired during the polishing process, by referring to the polishing test table 310 of the polishing test information 31.

[0103]

In the present embodiment, the reliability degradation factor state information is acquired as time-series data of the sensor group, but it may be appropriately changed according to the configuration of the polishing unit 22 (particularly the top ring 221 and the polishing table 220). As the reliability degradation factor state information, a command value to the module may be used, a parameter converted from the detection value of the sensor or the command value to the module may be used, or a parameter calculated based on the detection values of a plurality of sensors may be used.

Furthermore, the reliability degradation factor state information may be acquired as time-series data of the entire polishing process period, as time-series data of a target period that is a part of the polishing process period, or as time-point data at a specific target time, such as the time when the reliability of the polishing endpoint detection function is degraded. As described above, when changing the definition of the reliability degradation factor state information, the data structure of the input data in the first learning model 10A and the first learning data 11A may be appropriately changed.

[0104]

The learning data acquisition unit 400 also acquires test result information when a polishing test identified by the same test ID was performed as reliability information of the polishing endpoint detection function corresponding to the reliability degradation factor state information by referring to the polishing test table 310 of the polishing test information 31.

[0105]

In this embodiment, the reliability information of the polishing endpoint detection function is reliability information of the current endpoint detection, sign information of reliability degradation, type information of the component that causes the reliability degradation, and type information of the process that causes the reliability degradation, as shown in FIG. 10.

[0106]

The reliability information of the current endpoint detection is information on the percentage of reliability of the current endpoint detection. The reliability may be classified from 0 to 100%. For example, if the reliability of the current endpoint detection is 100%, it can be determined that the current endpoint detection is reliable, and if the reliability of the current endpoint detection is 0%, it can be determined that the current endpoint detection is unreliable.

[0107]

The sign information of reliability degradation is information on the time or the number of processed wafers until the reliability of endpoint detection is degraded or the endpoint is not detected. For example, if the reliability of endpoint detection is likely to be degraded in the polishing process several hours from now or several wafers from now, some kind of treatment can be taken on the substrate processing device 2 before

that happens.

[0108]

The type information of the component that causes reliability degradation is information on the type of component that causes the reliability of endpoint detection to be degraded among the provided components. For example, if the factor of the reliability of endpoint detection to be degraded is the top ring, some kind of treatment can be taken on the top ring.

[0109]

The type information of the process that causes reliability degradation is information on the type of process that causes the reliability of endpoint detection to be degraded among the pre-set processes. For example, if the factor of the reliability of endpoint detection to be degraded is the film formation process, some kind of treatment can be taken on the strength, film thickness, variation, and the like of the film in the film formation process.

[0110]

The first learning model 10A employs, for example, a neural network structure and includes an input layer 100, an intermediate layer 101, and an output layer 102. Synapses (not shown) that connect each neuron are laid between each layer, and each synapse is associated with a weight. A group of weight parameters consisting of the weights of each synapse is adjusted through machine learning.

[0111]

The input layer 100 has a number of neurons corresponding to the reliability degradation factor state information as input data, and each value of the reliability degradation factor state information is input to each neuron. The output layer 102 has a number of neurons corresponding to the reliability information of the polishing endpoint detection function as output data, and a prediction result (inference result) of the reliability information of the polishing endpoint detection function for the reliability degradation factor state information is output as output data.

[0112]

When the first learning model 10A is configured as a regression model, the reliability information of the polishing endpoint detection function is output as a numerical value normalized to a predetermined range (for example, 0 to 1). When the

first learning model 10A is configured as a classification model, the reliability information of the polishing endpoint detection function is output as a score (confidence level) for each class with a numerical value normalized to a predetermined range (for example, 0 to 1).

[0113]

An inference result corresponding to a numerical value is set in advance in the "predetermined range (0 to 1)". For example, in the case of the reliability information of the current endpoint detection, the inference result "predetermined range (0 to 1)" may be divided into a plurality of ranges, and the reliability of the current endpoint detection (0 to 100%) may be set for each divided range. In addition, in the case of the sign information of the reliability degradation, the inference result "predetermined range (0 to 1)" may be divided into a plurality of ranges, and the predictive time until the reliability degradation may be set for each divided range.

[0114]

In the case of the type information of the component that causes the reliability degradation, a predetermined threshold may be set within a "predetermined range (0 to 1)" that is the inference result of each component. If the output value is equal to or less than the threshold, the component may be set as "not a factor of reliability degradation", and if it exceeds the threshold, the component may be set as "a factor of reliability degradation". Note that each component may be prepared in advance, and a threshold may be set for each component.

[0115]

In the case of the type information of the process that causes reliability degradation, a predetermined threshold is set within a "predetermined range (0 to 1)" that is the inference result of each process. If the output value is equal to or less than the threshold, the process is set as "not a factor of reliability degradation", and if it exceeds the threshold, it is set as "a factor of reliability degradation". Note that each process may be prepared in advance, and a threshold may be set for each process.

[0116]

(Machine Learning Method)

FIG. 11 is a flowchart showing an example of a machine learning method by the machine learning device 4.

[0117]

First, in step S100, the learning data acquisition unit 400 acquires a desired number of pieces of first learning data 11A from the polishing test information 31 and the like, as a preparation for starting machine learning, and stores the acquired first learning data 11A in the learning data storage unit 42. The number of pieces of first learning data 11A to be prepared here may be set in consideration of the inference accuracy required for the first learning model 10A to be finally obtained.

[0118]

Next, in step S110, the machine learning unit 401 prepares the first learning model 10A before learning in order to start machine learning. The first learning model 10A before learning prepared here is configured with the neural network model exemplified in FIG. 10, and the weights of each synapse are set to an initial value.

[0119]

Next, in step S120, the machine learning unit 401 acquires, for example, one set of first learning data 11A randomly from a plurality of sets of first learning data 11A stored in the learning data storage unit 42.

[0120]

Next, in step S130, the machine learning unit 401 inputs polishing process state information (input data) included in the set of first learning data 11A to the input layer 100 of the prepared first learning model 10A before learning (or during learning). As a result, the output layer 102 of the first learning model 10A outputs the reliability information (output data) of the polishing endpoint detection function as an inference result, but the output data is generated by the first learning model 10A before learning (or during learning). Therefore, in the state before learning (or during learning), the output data output as an inference result indicates information different from the reliability information (correct answer label) of the polishing endpoint detection function included in the first learning data 11A.

[0121]

Next, in step S140, the machine learning unit 401 compares the reliability information (correct answer label) of the polishing endpoint detection function included in the set of first learning data 11A acquired in step S120 with the reliability information (output data) of the polishing endpoint detection function output as an

inference result from the output layer in step S130, and performs a process (backpropagation) of adjusting the weight of each synapse, thereby performing machine learning. As a result, the machine learning unit 401 causes the first learning model 10A to learn the correlation between the reliability degradation factor state information and the reliability information of the polishing endpoint detection function.

[0122]

Next, in step S150, the machine learning unit 401 determines whether a predetermined learning end condition is satisfied based on, for example, an evaluation value of an error function based on the reliability information (correct answer label) of the polishing endpoint detection function included in the first learning data 11A and the reliability information (output data) of the polishing endpoint detection function output as an inference result, or the remaining number of pieces of untrained first learning data 11A stored in the learning data storage unit 42.

[0123]

In step S150, if the machine learning unit 401 determines that the learning end condition is not satisfied and machine learning is to be continued (No in step S150), the process returns to step S120, and the process of steps S120 to S140 is performed a plurality of times on the first learning model 10A being trained using the untrained first learning data 11A. On the other hand, in step S150, if the machine learning unit 401 determines that the learning end condition is satisfied and machine learning is to be ended (Yes in step S150), the process proceeds to step S160.

[0124]

Then, in step S160, the machine learning unit 401 stores the trained first learning model 10A (adjusted weight parameter group) generated by adjusting the weights associated with each synapse in the trained model storage unit 43, and ends the series of machine learning methods shown in FIG. 11. In the machine learning method, step S100 corresponds to a learning data storage process, steps S110 to S150 correspond to a machine learning process, and step S160 corresponds to a trained model storage process.

[0125]

As described above, according to the machine learning device 4 and the machine learning method of this embodiment, it is possible to provide the first learning model 10A that can predict (infer) reliability information of the polishing endpoint detection

function indicating the state of the wafer W from reliability degradation factor state information including wear state information and processing state information.

[0126]

(Information Processing Device 5)

FIG. 12 is a block diagram showing an example of the information processing device 5 according to the first embodiment. FIG. 13 is a functional explanatory diagram showing an example of the information processing device 5 according to the first embodiment. The information processing device 5 includes an information processing control unit 50, a communication unit 51, and a trained model storage unit 52.

[0127]

The information processing control unit 50 functions as an information acquisition unit 500, a state prediction unit 501, and an output processing unit 502. The communication unit 51 is connected to an external device (for example, the substrate processing device 2, the database device 3, the machine learning device 4, the user terminal device 6, and the like) via the network 7, and functions as a communication interface for transmitting and receiving various pieces of data.

[0128]

The information acquisition unit 500 is connected to an external device via the communication unit 51 and the network 7, and acquires reliability degradation factor state information including wear state information and processing state information.

[0129]

For example, when performing a "real-time prediction process" of the reliability information of the polishing endpoint detection function for a wafer W during the polishing process, the information acquisition unit 500 receives a report R on reliability degradation factor state information from the substrate processing device 2 performing the polishing process at any time. In this way, the information acquisition unit 500 acquires wear state information and processing state information as reliability degradation factor state information at any time during the polishing process of the wafer W.

[0130]

The state prediction unit 501 predicts the reliability information of the polishing endpoint detection function for the wafer W undergoing the polishing process indicated

in the reliability degradation factor state information by inputting the reliability degradation factor state information acquired by the information acquisition unit 500 as input data to the first learning model 10A as described above.

[0131]

The trained model storage unit 52 is a database that stores the trained first learning model 10A used by the state prediction unit 501. Note that the number of first learning models 10A stored in the trained model storage unit 52 is not limited to one. For example, a plurality of learning models with different conditions may be stored and may be selectively used, such as machine learning methods, differences in the mechanisms and materials of the top ring 221, types of elastic membranes 2212, types of retainer rings 2213, types of polishing pads 2200, types of polishing fluids, types of data included in reliability degradation factor state information, and types of data included in reliability information of the polishing endpoint detection function. The trained model storage unit 52 may be replaced by a storage unit of an external computer (for example, a server-type computer or a cloud-type computer). In that case, the state prediction unit 501 may access the external computer.

[0132]

The output processing unit 502 performs output processing for outputting the reliability information of the polishing endpoint detection function generated by the state prediction unit 501. For example, the output processing unit 502 may transmit the reliability information of the polishing endpoint detection function to the user terminal device 6 such that a display screen based on the reliability information of the polishing endpoint detection function is displayed on the user terminal device 6. Alternatively, the output processing unit 502 may transmit the reliability information of the polishing endpoint detection function to the database device 3 such that the reliability information of the polishing endpoint detection function is registered in the production history information 30.

[0133]

(Information Processing Method)

FIG. 14 is a flowchart showing an example of an information processing method by the information processing device 5. In the following, an example of an operation in which a user operates the user terminal device 6 to perform "prediction processing" of

the reliability information of the polishing endpoint detection function for a specific wafer W will be described.

[0134]

First, in step S200, when the user performs an input operation to input a wafer ID for identifying a wafer W to be predicted to the user terminal device 6, the user terminal device 6 transmits the wafer ID to the information processing device 5.

[0135]

Next, in step S210, the information acquisition unit 500 of the information processing device 5 receives the wafer ID transmitted in step S200. In step S211, the information acquisition unit 500 acquires reliability degradation factor state information when a polishing process is performed on the wafer W identified by the wafer ID by referring to the polishing history table 301 of the production history information 30 using the wafer ID received in step S210.

[0136]

Next, in step S220, the state prediction unit 501 inputs the reliability degradation factor state information acquired in step S211 as input data to the first learning model 10A, thereby generating reliability information of the polishing endpoint detection function for the reliability degradation factor state information as output data, and predicts the state of the wafer W.

[0137]

Next, in step S230, the output processing unit 502 transmits the reliability information of the polishing endpoint detection function generated in step S220 to the user terminal device 6 as an output process for outputting the reliability information of the polishing endpoint detection function. The destination of the reliability information of the polishing endpoint detection function may be the database device 3 in addition to or instead of the user terminal device 6.

[0138]

Next, in step S240, when the user terminal device 6 receives the reliability information of the polishing endpoint detection function transmitted in step S230 as a response to the transmission process of step S200, the user terminal device 6 displays a display screen based on the reliability information of the polishing endpoint detection function, so that the state of the wafer W is visually recognized by the user. In the

above information processing method, steps S210 and S211 correspond to an information acquisition process, step S220 corresponds to a state prediction process, and step S230 corresponds to an output processing process.

[0139]

As described above, according to the information processing device 5 and the information processing method of the present embodiment, the reliability degradation factor information in the polishing process is input to the first learning model 10A, and the reliability information of the polishing endpoint detection function for the reliability degradation factor state information is predicted. Therefore, the reliability information of the polishing endpoint detection function indicating the reliability of the endpoint detection function that detects that the chemical mechanical polishing process has reached the endpoint can be appropriately predicted.

[0140]

(Second Embodiment)

The second embodiment differs from the first embodiment in that an optical sensor is used as the polishing endpoint detection function. The following describes the machine learning device 4a and the information processing device 5a according to the second embodiment, focusing on the differences from the first embodiment.

[0141]

FIG. 15 is a schematic diagram for explaining the optical sensor 226 provided on the polishing table 220 according to the second embodiment.

[0142]

As shown in FIG. 15, an optical sensor 226 that detects the state of the film on the wafer W is embedded inside the polishing table 220. The optical sensor 226 irradiates the wafer W with light and detects the state of the film (film thickness and the like) of the wafer W from the intensity of the reflected light from the wafer W (reflection intensity or reflectance).

[0143]

The polishing pad 2200 is also provided with a light-transmitting portion 2200a for transmitting the light from the optical sensor 226. The light-transmitting portion 2200a is made of a material with high transmittance, such as quartz glass, glass material, or pure water (a transparent fluid supply unit and a flow path not shown are provided).

Alternatively, the light-transmitting portion 2200a may be formed by providing a through-hole in the polishing pad 2200 and a transparent fluid such as pure water is supplied from the transparent fluid supply unit underneath the wafer W that blocks the through-hole. The light-transmitting portion 2200a is disposed at a position passing through the center of the wafer W held by the top ring 221.

[0144]

As shown in FIG. 15, the optical sensor 226B includes a light source 226a, an optical fiber 226b as a light-emitting portion that irradiates the light from the light source 226a onto the polished surface of the wafer W, an optical fiber 226c as a light-receiving portion that receives the reflected light from the polished surface, a spectrometer unit 226d that includes a spectrometer that disperses the light received by the optical fiber 226c and a plurality of light-receiving elements that store the light dispersed by the spectrometer as electrical information, an operation control unit 226e that controls the turning on and off of the light source 226a and the timing of starting reading the light-receiving elements in the spectrometer unit 226d, and a power source 226f that supplies power to the operation control unit 226e. Note that power is supplied to the light source 226a and the spectrometer unit 226d via the operation control unit 226e.

[0145]

The light-emitting end of the light-emitting optical fiber 226b and the light-receiving end of the light-receiving optical fiber 226c are configured to be approximately perpendicular to the polished surface of the wafer W. For example, a 128-element photodiode array can be used as the light-receiving element in the spectrometer unit 226d. The spectrometer unit 226d is connected to the operation control unit 226e. Information from the light-receiving element in the spectrometer unit 226d is sent to the operation control unit 226e, and spectral data of the reflected light is generated based on this information. That is, the operation control unit 226e reads the electrical information stored in the light-receiving element to generate the spectral data of the reflected light. This spectral data indicates the intensity of the reflected light resolved according to the wavelength, and changes depending on the film thickness.

[0146]

The operation control unit 226e is connected to an optical sensor control unit

226g. In this manner, the spectral data generated by the operation control unit 226e is transmitted to the optical sensor control unit 226g. The optical sensor control unit 226g calculates a characteristic value associated with the film thickness of the wafer W based on the spectral data received from the operation control unit 226e, and uses the calculated characteristic value as a monitoring signal to perform endpoint detection. The optical sensor control unit 226g may be included in the substrate processing control unit 260.

[0147]

FIG. 16 is a block diagram showing an example of a machine learning device 4a according to the second embodiment. FIG. 17 is a diagram showing an example of a second learning model 10B and second learning data 11B. The second learning data 11B is used for machine learning of the second learning model 10B.

[0148]

The reliability degradation factor state information constituting the second learning data 11B includes the condition of the optical sensor 226 and the condition of the transparent liquid supply unit as wear state information, and the light reflection intensity information of the optical sensor 226 and the transparent liquid flow rate information as processing state information. Note that other reliability degradation factor state information constituting the second learning data 11B is the same as that in the first embodiment, so a description thereof will be omitted.

[0149]

The condition of the optical sensor 226 includes at least the usage time of the optical sensor 226 and the number of wafers processed by the optical sensor 226. The condition of the optical sensor 226 may be set based on, for example, the usage time of the light source 226a such as a lamp of the optical sensor 226, the temperature of the optical sensor 226, and the like. The condition of the optical sensor 226 may change over time during the polishing process, for example.

[0150]

The condition of the pure water transparent liquid supply unit includes at least the usage time of the pure water supply unit and the number of wafers processed by the polishing unit 22. The condition of the transparent liquid supply unit may be set based on, for example, the cumulative supply flow rate of the transparent liquid supply unit or

the like. The condition of the transparent liquid supply unit may change over time during the polishing process.

[0151]

The light reflection intensity information of the optical sensor 226 may be the intensity of the reflected light of the light emitted by the optical sensor 226 and reflected by the wafer W. The transparent liquid information may be the flow rate of the transparent liquid such as pure water supplied from the transparent liquid supply unit.

[0152]

The learning data acquisition unit 400 acquires the second learning data 11B by referring to the polishing test information 31 and accepting user input operations from the user terminal device 6 as necessary. For example, the learning data acquisition unit 400 refers to the polishing test table 310 of the polishing test information 31 to acquire the wear state information and processing state information (time-series data of each sensor of each component) when the polishing test identified by the test ID was performed as the reliability degradation factor state information.

[0153]

FIG. 18 is a block diagram showing an example of the information processing device 5a that functions as the information processing device 5a according to the second embodiment. FIG. 19 is a functional explanatory diagram showing an example of the information processing device 5a according to the second embodiment.

[0154]

The information acquisition unit 500 acquires the reliability degradation factor state information including the wear state information and processing state information, as in the first embodiment.

[0155]

When performing the "post-prediction process" of the reliability information of the polishing endpoint detection function for the wafer W after the polishing process has already been performed, the information acquisition unit 500 may acquire the wear state information and processing state information when the polishing process was performed for the wafer W as the reliability degradation factor state information by referring to the polishing history table 301 of the production history information 30.

[0156]

As described above, the state prediction unit 501 inputs the reliability degradation factor state information acquired by the information acquisition unit 500 as input data to the second learning model 10B, thereby predicting reliability information of the polishing endpoint detection function for the wafer W undergoing the polishing process indicated in the reliability degradation factor state information.

[0157]

As described above, according to the information processing device 5a and the information processing method of the present embodiment, the reliability degradation factor state information including the wear state information and the processing state information in the polishing process is input to the second learning model 10B, and the reliability of the polishing endpoint detection function for the reliability degradation factor state information is predicted. Thus, the reliability of the polishing endpoint detection function of the wafer W in the polishing process can be appropriately predicted.

[0158]

Note that, in the second embodiment, the optical sensor 226 is used to detect the polishing endpoint of the wafer W, but other polishing endpoint detection functions may be used. For example, an eddy current sensor may be used as another example of the polishing endpoint detection function.

[0159]

The eddy current sensor has an excitation coil, and when the magnetic lines of force generated from the excitation coil connected to a high-frequency AC power source pass through a conductive film, eddy currents are generated on the surface of the wafer W. The magnitude of this eddy current changes depending on the resistance of the metal film, that is, the thickness of the metal film. On the other hand, when an eddy current flows, magnetic lines of force are generated from the eddy current in the opposite direction to the magnetic lines of force generated from the excitation coil. The change in the thickness of the metal film can be measured by measuring the strength of the magnetic lines of force generated in the opposite direction with a detection coil.

[0160]

The eddy current sensor is installed below the polishing table 220 shown in FIG.

3, and magnetic lines of force are generated in a direction penetrating the polishing table 220. When the polishing table 220 rotates, the eddy current sensor rotates together with the polishing table 220 and passes below the wafer W held by the top ring 221. At this time, if a conductive film exists on the surface of the wafer W, the magnetic lines of force pass through the conductive film, so that the thickness of the conductive film can be measured.

[0161]

As the polishing of the wafer W progresses, the metal film on the surface of the wafer W decreases, and the resistance value of the metal film increases accordingly. Then, the eddy current generated by the magnetic lines of force generated from the coil of the eddy current sensor decrease, and the strength of the magnetic lines of force generated by the eddy current also decreases. The eddy current sensor converts the change in the magnetic lines of force generated by the eddy current into a voltage corresponding to the change in the film thickness by the circuit and software in the sensor.

[0162]

In this way, the eddy current sensor can detect the polishing endpoint by measuring and storing in advance the detected voltage for the wafer W in a state where polishing has been completed, and comparing the stored voltage value with the voltage value during the polishing process of the wafer W. Note that the analog processing part of the eddy current sensor may be replaced with digital processing. By using digital processing, the performance and stability of the eddy current sensor are improved.

[0163]

When an eddy current sensor is used, the condition of the eddy current sensor can be used as wear state information, and the magnetic field strength information of the eddy current sensor can be used as processing state information.

[0164]

The condition of the eddy current sensor includes at least the usage time of the eddy current sensor and the number of wafers processed by the eddy current sensor. The condition of the eddy current sensor may be set based on, for example, the usage time of the excitation coil. The condition of the eddy current sensor may change over time during the polishing process.

[0165]

The magnetic field strength information of the eddy current sensor may be the magnetic field strength generated in the reverse direction detected by the eddy current sensor.

[0166]

In addition, a rotation torque method may be used as another example of the polishing endpoint detection function. The rotation torque method may detect at least one of the rotation torque of the polishing table rotation motor of the rotational movement mechanism 220b that rotates the polishing table 220, or the rotation torque of the top ring rotation motor of the top ring rotational movement mechanism 221c that rotates the top ring 221.

[0167]

When the wafer W is planarized, the polishing resistance decreases rapidly, so that it is possible to detect when the polishing of the wafer W is completed.

[0168]

The endpoint of the polishing of the wafer W may be detected by any one of an optical sensor, an eddy current sensor, and a torque method, or by a combination of all of them.

[0169]

(Other Embodiments)

The present invention is not limited to the above-mentioned embodiment, and various modifications can be made without departing from the spirit of the present invention. All of these modifications are included in the technical concept of the present invention.

[0170]

In the above embodiment, the database device 3, the machine learning device 4, and the information processing device 5 are described as being configured as separate devices, but the three devices may be configured as a single device, or any two of the three devices may be configured as a single device. In addition, at least one of the machine learning device 4 and the information processing device 5 may be incorporated in the control unit 26 or the user terminal device 6 of the substrate processing device 2.

[0171]

In the above embodiment, the substrate processing device 2 is described as including each of the units 21 to 25, but the substrate processing device 2 may include at least the polishing unit 22, and other units may be omitted.

[0172]

In the above embodiment, a neural network is used as a learning model for realizing machine learning by the machine learning unit 401, but other machine learning models may be used. Examples of other machine learning models include tree-based models such as decision trees and regression trees, ensemble learning methods such as bagging and boosting, recurrent neural networks, convolutional neural networks, neural network models such as Long Short-Term Memory (LSTM) (including deep learning), hierarchical clustering, non-hierarchical clustering, k-nearest neighbors, k-means clustering, multivariate analyses such as principal component analysis, factor analysis, and logistic regression, and support vector machines.

[0173]

In the above embodiment, the test result information is information indicating the state when the polishing process is performed in the polishing test using a dummy wafer in the test device. However, it may be continuously acquired as information indicating the state of an actual wafer when the polishing process is performed using an actual polishing unit 22 equipped with a sensor that detects the state of each component. The continuously acquired test result information is continuously trained by the machine learning device 4.

[0174]

In addition, the test result information may be continuously acquired in the polishing unit 22 without sensors, where an operator determines reliability degradation of the polishing endpoint detection function and labels the data.

[0175]

Furthermore, the information continuously acquired using the actual polishing unit 22 may be uploaded to the cloud, and after machine learning is performed in the cloud, the trained model may be deployed to the substrate processing device 2. In addition, the processing method may be trained within the substrate processing device 2 without uploading to the cloud.

[0176]

(Machine Learning Program and Information Processing Program)

The present invention may also be provided in the form of a program (machine learning program) that causes the computer 900 to function as each part of the machine learning device 4, or a program (machine learning program) that causes the computer 900 to execute each step of the machine learning method. The present invention can also be provided in the form of a program (information processing program) for causing the computer 900 to function as each unit of the information processing device 5, or a program (information processing program) for causing the computer 900 to execute each step of the information processing method according to the above embodiment.

[0177]

(Inference Device, Inference Method, and Inference Program)

The present invention can also be provided in the form of an inference device (inference method or inference program) used to infer reliability information of the polishing endpoint detection function, in addition to the information processing device 5 (information processing method or information processing program) according to the above embodiment. In that case, the inference device (inference method or inference program) can include a memory and a processor, and the processor executes a series of processes. The series of processes includes an information acquisition process (information acquisition step) for acquiring reliability degradation factor state information, and an inference process (inference step) for inferring reliability information of the polishing endpoint detection function indicating the reliability of the polishing endpoint detection function of the substrate subjected to the polishing process based on the reliability degradation factor state information when the reliability degradation factor state information is acquired in the information acquisition process.

[0178]

By providing it in the form of an inference device (inference method or inference program), it can be easily applied to various devices compared to implementing an information processing device. It can be naturally understood by those skilled in the art that when the inference device (inference method or inference program) infers reliability information of the polishing endpoint detection function, the inference method implemented by the state prediction unit can be applied using a trained learning

model generated by the machine learning device and machine learning method according to the above embodiment.

[Reference Signs List]

[0179]

- 1 Substrate processing system,
- 2 Substrate processing device,
- 3 Database device,
- 4, 4a Machine learning device,
- 5, 5a Information processing device,
- 6 User terminal device,
- 7 Network,
- 10 Learning model,
- 10A First learning model,
- 10B Second learning model,
- 11A First learning data,
- 11B Second learning data,
- 20 Housing,
- 21 Load/unload unit,
- 22 Polishing unit,
- 22A to 22D Polishing unit,
- 23 Substrate transport unit,
- 24 Cleaning unit,
- 25 Film thickness measurement unit,
- 26 Control unit,
- 30 Production history information,
- 31 Polishing test information,
- 40 Machine learning control unit,
- 41 Communication unit,
- 42 Learning data storage unit,

43 Trained model storage unit,
 50 Information processing control unit,
 51 Communication unit,
 52 Trained model storage unit,
 220 Polishing table,
 221 Top ring,
 222 Polishing fluid supply nozzle,
 223 Dresser,
 224 Atomizer,
 225 Environmental sensor
 260 Substrate processing control unit,
 21 Communication unit,
 262 Input unit,
 263 Output unit,
 264 Storage unit,
 300 Wafer history table,
 301 Polishing history table,
 310 Polishing test table,
 400 Learning data acquisition unit,
 401 Machine learning unit,
 500 Information acquisition unit,
 501 State prediction unit,
 502 Output processing unit,
 900 Computer
 2200 Polishing pad,
 2210 Top ring body,
 2211 Carrier,
 2212 Elastic membrane,
 2212a to 2212d Elastic membrane pressure chamber,
 2213 Retainer ring,

- 2214 Retainer ring airbag (retainer ring pressing mechanism),
- 2214a Retainer ring pressure chamber,
- 226 Optical sensor

CLAIMS

[Claim 1]

An information processing device comprising:

an information acquisition unit that acquires reliability degradation factor state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including at least one of wear state information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing; and

a state prediction unit that predicts reliability information of a polishing endpoint detection function for the reliability degradation factor state information by inputting the reliability degradation factor state information acquired by the information acquisition unit into a learning model that has been trained through machine learning to learn a correlation between the reliability degradation factor state information and reliability information of the polishing endpoint detection function that indicates reliability of an endpoint detection function that detects that the chemical mechanical polishing process has reached an endpoint.

[Claim 2]

The information processing device according to claim 1, wherein the substrate processing device further includes:

a polishing table that rotatably supports a polishing pad;

a top ring that presses a substrate against the polishing pad;

a dresser that rotatably supports a dresser disk and brings the dresser disk into contact with the polishing pad to dress the polishing pad; and

a substrate processing control unit that controls the entire substrate processing device, and

the wear state information includes at least one of:

a condition of the polishing pad;

a condition of a rotary connector that rotatably installs the top ring and the polishing table;

a condition of the dresser; and

a condition of the substrate processing control unit.

[Claim 3]

The information processing device according to claim 2, wherein
the substrate processing device further includes:

a transparent liquid supply unit that supplies a transparent liquid to the polishing
pad; and

an optical sensor that measures a reflection intensity of light from a lamp that
emits light to detect that the chemical mechanical polishing process has reached an
endpoint, and

the wear state information includes at least one of:

a condition of the optical sensor; and

a condition of the transparent liquid supply unit.

[Claim 4]

The information processing device according to claim 2 or 3, wherein
the substrate processing device includes:

a polishing table that rotatably supports a polishing pad;

a top ring that presses a substrate against the polishing pad; and

a polishing fluid supply unit that supplies a polishing fluid to the polishing pad,
the top ring includes:

a top ring body that is moved by a rotational movement mechanism, a vertical
movement mechanism, and a swing movement mechanism;

an elastic membrane that is housed in the top ring body and presses the substrate
against the polishing pad in response to pressurizing fluid supplied to an elastic
membrane pressure chamber;

a retainer ring that is disposed on an outer periphery of the elastic membrane and
presses the polishing pad; and

a retainer ring pressing mechanism that adjusts a pressing force of the retainer
ring, and

wherein the processing state information includes at least one of:

a flow rate of the polishing fluid;

a pressing force of the retainer ring pressing mechanism;

a rotational torque of the top ring and the polishing table;

a swing torque of the top ring;

- a vibration of the top ring;
- a swing torque of the dresser;
- noise of the top ring during polishing;
- a temperature of the polishing surface of the top ring during polishing;
- a temperature of a temperature-controlled water of the polishing table;
- a statistical value of the time until the endpoint is detected for each substrate;

and

- a statistical value of time-series data of each sensor for each substrate.

[Claim 5]

The information processing device according to claim 4, wherein the substrate processing device further includes:

- a transparent liquid supply unit that supplies a transparent liquid to the polishing pad; and
- an optical sensor that detects that the chemical mechanical polishing process has reached an endpoint, and

the processing state information includes at least one of:

- a light reflection intensity of the optical sensor; and
- a flow rate of the transparent liquid.

[Claim 6]

The information processing device according to claim 1, wherein the reliability information of the polishing endpoint detection function includes at least one of:

- current endpoint detection reliability information;
- sign information of reliability degradation;
- type information of the components of the substrate processing device that cause reliability degradation; and

type information of the substrate processing process that causes reliability degradation.

[Claim 7]

An inference device comprising a memory and a processor, wherein the processor executes:

- an information acquisition process of acquiring reliability degradation factor

state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including at least one of wear state information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing; and

an inference process of, upon acquiring the reliability degradation factor state information in the information acquisition process, inferring reliability information of a polishing endpoint detection function that indicates reliability for the polishing process state information, of an endpoint detection function that detects that the chemical mechanical polishing process has reached an endpoint.

[Claim 8]

A machine learning device comprising:

a learning data storage unit that stores a plurality of sets of learning data consisting of reliability degradation factor state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including at least one of wear state information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing, and reliability information of a polishing endpoint detection function that indicates reliability of an endpoint detection function that detects that the chemical mechanical polishing process has reached an endpoint;

a machine learning unit that causes a learning model to learn a correlation between the reliability degradation factor state information and the reliability information of the polishing endpoint detection function by inputting the plurality of sets of learning data to the learning model; and

a trained model storage unit that stores the learning model trained with the correlation by the machine learning unit.

[Claim 9]

An information processing method comprising:

an information acquisition step of acquiring reliability degradation factor state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including

at least one of wear state information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing; and

a state prediction step of predicting reliability information of a polishing endpoint detection function for the polishing process state information by inputting the polishing process state information acquired by the information acquisition step into a learning model that has been trained through machine learning to learn a correlation between the reliability degradation factor state information and reliability information of the polishing endpoint detection function that indicates reliability of an endpoint detection function that detects that the chemical mechanical polishing process has reached an endpoint.

[Claim 10]

An inference method executed by an inference device having a memory and a processor, wherein

the processor executes:

an information acquisition step of acquiring reliability degradation factor state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including at least one of wear state information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing; and

an inference step of, upon acquiring the reliability degradation factor state information in the information acquisition step, inferring reliability information of a polishing endpoint detection function that indicates reliability for the polishing process state information, of an endpoint detection function that detects the chemical mechanical polishing process has reached an endpoint.

[Claim 11]

A machine learning method comprising:

a learning data storage step of storing a plurality of sets of learning data consisting of reliability degradation factor state information in a chemical mechanical polishing process of a substrate performed by a substrate processing device, the reliability degradation factor state information including at least one of wear state

information indicating a wear state of components of the substrate processing device and processing state information indicating a processing state during polishing, and reliability information of a polishing endpoint detection function that indicates reliability of an endpoint detection function that detects that the chemical mechanical polishing process has reached an endpoint;

a machine learning step of causing a learning model to learn a correlation between the reliability degradation factor state information and the reliability information of the polishing endpoint detection function by inputting the plurality of sets of learning data to the learning model; and

a learning data storage step of storing a plurality of sets of the learning models trained to learn the correlation in the machine learning step in a learning data storage unit.