

POLISHING APPARATUS AND POLISHING METHOD

TECHNICAL FIELD

[0001] The present invention relates to a polishing apparatus and a polishing method.

BACKGROUND ART

[0002] A CMP (Chemical Mechanical Polishing) apparatus is widely known as an apparatus that polishes the surface of a substrate such as a semiconductor wafer. The CMP apparatus polishes, while supplying polishing liquid to a polishing pad on a rotating polishing table, the surface of the substrate by pressing the substrate against the polishing pad with a polishing head that is holding the wafer. In general, the CMP apparatus includes a thickness measurer that measures the film thickness of the substrate or a signal equivalent to the film thickness, controls a polishing load to the substrate based on a measurement value of the film thickness obtained from the thickness measurer, and determines a polishing end point. As the thickness measurer, an eddy current sensor or an optical sensor is generally used.

[0003] The thickness measurer in the CMP apparatus of the related art is disposed on the inside of the polishing table to face the substrate on the polishing pad. Therefore, every time the polishing table rotates, the thickness measurer measures the film thickness at a plurality of measurement points on the substrate while moving across the substrate. In the CMP apparatus of the related art, the thickness measurer is disposed to pass the center of the substrate. This is to measure the film thickness at the plurality of measurement points distributed in the radial direction of the substrate.

[0004] It is known that a plurality of sensors are provided in, for the purpose of acquiring accurate film thickness data, the entire surface including the center portion and the peripheral edge portion of the substrate in film thickness measurement for the substrate being polished (Japanese Patent No. 6470365). It is essential to improve polishing accuracy according to device refining. It is necessary to further improve measurement resolution for the improvement of the polishing accuracy. It is necessary to increase the number of sensor heads in order to improve the measurement resolution. A polishing apparatus is increased

in size if the number of signal processors that receive and process signals output by the sensor heads is increased according to the number of the sensor heads. This problem is more conspicuous when an optical sensor is used for the film thickness measurement than when an eddy current sensor is used. This is because a spectrometer, which is a signal processor of the optical sensor, is larger in size than a signal processor of the eddy current sensor. The larger size is a problem when an installation area of an apparatus is limited. There is also a problem in that productivity of a semiconductor in terms of a production amount per unit area of the apparatus is deteriorated.

[0005] An aspect of the present invention has been devised in order to solve such problems and an object of the aspect of the present invention is to provide a polishing apparatus, an increase in the size of which is further reduced than in the related art even if the number of sensor heads increases.

SUMMARY OF INVENTION

[0006] In order to solve the problems described above, a first aspect adopts a configuration of a polishing apparatus that polishes a substrate, the polishing apparatus including: a polishing table for holding a polishing pad; a polishing head configured to press a surface of the substrate against the polishing pad; a plurality of sensor heads configured to detect a signal concerning a film thickness of the substrate while moving across the substrate; one spectrometer configured to receive and process signals output by at least two sensor heads among the plurality of sensor heads; a switcher configured to selectively connect the at least two sensor heads to the spectrometer; and a controller, wherein the controller controls the switcher to switch, at timing when the at least two sensor heads simultaneously face the substrate, the connection to the spectrometer from one sensor head to another sensor head.

[0007] A second aspect adopts the configuration of the polishing apparatus described in the first aspect, wherein the polishing table is configured to rotate around an axis of the polishing table, and the plurality of sensor heads are disposed in a region of the polishing table facing a region including a center of the substrate.

[0008] A third aspect adopts the configuration of the polishing apparatus described in the

second aspect, wherein each two of a predetermined even number of the sensor heads among the plurality of sensor heads form a pair, the two sensor heads forming the pair are present substantially in positions on opposite sides to each other with respect to the axis, and the even number of the sensor heads are disposed such that lines connecting the two sensor heads forming each of the pairs are at a same angle interval around the axis.

[0009] A fourth aspect adopts the configuration of the polishing apparatus described in the second aspect, wherein, in predetermined four sensor heads among the plurality of sensor heads, the two sensor heads are present substantially in positions on opposite sides to each other with respect to the axis, the other two sensor heads are present substantially in positions on opposite sides to each other with respect to the axis, and an angle formed by a line connecting the two sensor heads and a line connecting the other two sensor heads is larger than 0 degrees and smaller than 180 degrees.

[0010] A fifth aspect adopts the configuration of the polishing apparatus described in any one of the first to fourth aspects, wherein the polishing apparatus includes, as the plurality of sensor heads, a first sensor head configured to detect a signal concerning a film thickness of the substrate in a region including a center of the substrate and a second sensor head configured to detect the signal concerning the film thickness of the substrate while moving along a peripheral edge portion of the substrate.

[0011] A sixth aspect adopts the configuration of the polishing apparatus described in the fifth aspects, wherein there are at least two first sensor heads as a plurality of the first sensor heads, there are at least two sensor heads as a plurality of the second sensor heads, the two first sensor heads are present substantially in positions on opposite sides to each other with respect to the axis, the axis is present on a line segment connecting the two second sensor heads, and an angle formed by a line connecting the two first sensor heads and the line segment connecting the second sensor heads is 0 degrees to 180 degrees.

[0012] A seventh aspects adopts the configuration of the polishing apparatus described in any one of the first to fifth aspects, wherein, in a predetermined number of the sensor heads among the plurality of sensor heads and the predetermined number of other sensor heads

among the plurality of sensor heads, each one of the predetermined number of other sensor heads is disposed on lines respectively connecting the predetermined number of sensor heads and the axis of the polishing table.

[0013] An eighth aspect adopts the configuration of the polishing apparatus described in any one of the first to fifth aspects, wherein, in predetermined two sensor heads among the plurality of sensor heads and other predetermined four sensor heads among the plurality of sensor heads, the predetermined two sensor heads are present substantially in positions on opposite sides to each other with respect to the axis, the axis is present on a first line segment connecting two sensor heads among the predetermined four sensor heads, the axis is present on a second line segment connecting other two sensor heads among the predetermined four sensor heads, and an angle formed by the first line segment and the second line segment is 0 degrees to 180 degrees.

[0014] A ninth aspect adopts the configuration of the polishing apparatus described in the eighth aspect, wherein the predetermined four sensor heads are disposed symmetrically with respect to a third line connecting the predetermined two sensor heads, and a minimum angle among angles formed by the third line and the first line segment is smaller than 90 degrees and a minimum angle among angles formed by the third line and the second line segment is smaller than 90 degrees.

[0015] A tenth aspect adopts a configuration of a polishing method for polishing a substrate, the polishing method including: a polishing table holding a polishing pad; a polishing head pressing a surface of the substrate against the polishing pad; a plurality of first sensor heads detecting a signal concerning a film thickness of the substrate in a region including a center of the substrate while moving across the substrate; one spectrometer receiving and processing signals output by the plurality of sensor heads; a switcher selectively connecting at least two of the sensor heads to the spectrometer; and a controller controlling the switcher to switch the connection to the spectrometer from one sensor head to another sensor head at a time when the at least two sensor heads simultaneously face the substrate.

[0016] An eleventh aspects adopt a configuration of a polishing apparatus that polishes a substrate, the polishing apparatus including: a polishing table for holding a polishing pad; a polishing head configured to press a surface of the substrate against the polishing pad; a plurality of sensors configured to detect a signal concerning a film thickness of the substrate while moving across the substrate; one signal processor configured to receive and process signals output by at least two sensors among the plurality of sensors; a switcher configured to selectively connect the at least two sensors to the signal processor; and a controller, wherein the controller controls the switcher to switch, at timing when the at least two sensors simultaneously face the substrate, the connection to the signal processor from one sensor to another sensor.

[0017] A twelfth aspect adopts a configuration of a polishing apparatus that polishes a substrate, the polishing apparatus including: a polishing table for holding a polishing pad; a polishing head configured to press a surface of the substrate against the polishing pad; a plurality of sensor heads configured to detect a signal concerning a film thickness of the substrate while moving across the substrate; one spectrometer configured to receive and process signals output by at least two sensor heads among the plurality of sensor heads; a switcher configured to selectively connect the at least two sensor heads to the spectrometer; and a controller, wherein the controller controls the switcher to start, at timing when one sensor head of the at least two sensor heads faces the substrate and another does not face the substrate, switching processing for switching the connection to the spectrometer from the one sensor head to the other sensor head or from the other sensor head to the one sensor head.

[0018] A thirteenth aspect adopts the configuration of the polishing apparatus described in the twelfth aspect, wherein the other sensor head passes an end of the substrate when moving from a position not facing the substrate to a position facing the substrate, and, when the switching processing is started, the other sensor head is located in a vicinity of the end.

[0019] A fourteenth aspect adopts the configuration of the polishing apparatus described in the twelfth aspect, wherein, before the one sensor head facing the substrate reaches a terminal end of a locus passing under the substrate, the switching processing from the one

sensor head to the other sensor head not facing the substrate is started.

[0020] A fifteenth aspect adopts the configuration of the polishing apparatus described in the twelfth aspect, wherein, after the one sensor head facing the substrate passes a start point of a locus passing under the substrate, the switching processing from the other sensor head not facing the substrate to the one sensor head is started.

[0021] A sixteenth aspect adopts the configuration of the polishing apparatus described in the twelfth aspect, wherein the polishing apparatus further includes a swinging device configured to swing the polishing head on the polishing pad during polishing, and the timing for starting the switching processing is controlled according to a swinging position of the polishing head.

[0022] A seventeenth aspect adopts a configuration of a polishing apparatus that polishes a substrate, the polishing apparatus including: a polishing table for holding a polishing pad; a polishing head configured to press a surface of the substrate against the polishing pad; a plurality of sensor heads configured to detect a signal concerning a film thickness of the substrate while moving across the substrate; one spectrometer configured to receive and process signals output by at least two sensor heads among the plurality of sensor heads; a switcher configured to selectively connect the at least two sensor heads to the spectrometer; and a controller, wherein the controller controls the switcher to start, at timing when one sensor head of the at least two sensor heads does not face the substrate, switching processing for switching the connection to the spectrometer from another sensor head to the one sensor head, and the switching processing is completed after the one sensor head passes a start point of a locus passing under the substrate.

[0023] An eighteenth aspect adopts the configuration of the polishing apparatus described in the seventeenth aspect, wherein the switching processing is started at timing when the other sensor head does not face the substrate.

[0024] A nineteenth aspect adopts the configuration of the polishing apparatus described in the seventeenth aspect, wherein the polishing apparatus further includes a swinging device configured to swing the polishing head on the polishing pad during polishing, and the timing

for starting the switching processing is controlled according to a swinging position of the polishing head.

[0025] A twentieth aspect adopts a configuration of a polishing method for polishing a substrate, the polishing method including: a polishing table holding a polishing pad; a polishing head pressing a surface of the substrate against the polishing pad; a plurality of sensor heads detecting a signal concerning a film thickness of the substrate while moving across the substrate; one spectrometer receiving and processing signals output by at least two sensor heads among the plurality of sensor heads; a switcher selectively connecting the at least two sensor heads to the spectrometer; and a controller controlling the switcher to start, at timing when one sensor head of the at least two sensor heads faces the substrate and another sensor head does not face the substrate, switching processing for switching the connection to the spectrometer from the one sensor head to the other sensor head or from the other sensor head to the one sensor head.

[0026] A twenty-first aspect adopts a configuration of a polishing apparatus that polishes a substrate, the polishing apparatus including: a polishing table for holding a polishing pad; a polishing head configured to press a surface of the substrate against the polishing pad; a plurality of sensors configured to detect a signal concerning a film thickness of the substrate while moving across the substrate; one signal processor configured to receive and process signals output by at least two sensors among the plurality of sensors; a switcher configured to selectively connect the at least two sensors to the signal processor; and a controller, wherein the controller controls the switcher to start, at timing when one sensor of the at least two sensors faces the substrate and another sensor does not face the substrate, switching processing for switching the connection to the signal processor from the one sensor to the other sensor or from the other sensor to the one sensor.

[0027] A twenty-second aspect adopts a configuration of a polishing method for polishing a substrate, the polishing method including: a polishing table holding a polishing pad; a polishing head pressing a surface of the substrate against the polishing pad; a plurality of sensor heads detecting a signal concerning a film thickness of the substrate while moving

across the substrate; one spectrometer receiving and processing signals output by at least two sensor heads among the plurality of sensor heads; a switcher selectively connecting the at least two sensor heads to the spectrometer; and a controller controlling the switcher to start, at timing when one sensor head of the at least two sensor heads does not face the substrate, switching processing for switching the connection to the spectrometer from the other sensor head to the one sensor head and controlling the switcher such that the switching processing is completed after the one sensor head passes a start point of a locus passing under the substrate.

[0028] A twenty-third aspect adopts a configuration of a polishing apparatus that polishes a substrate, the polishing apparatus including: a polishing table for holding a polishing pad; a polishing head configured to press a surface of the substrate against the polishing pad; a plurality of sensors configured to detect a signal concerning a film thickness of the substrate while moving across the substrate; one signal processor configured to receive and process signals output by at least two sensors among the plurality of sensors; a switcher configured to selectively connect the at least two sensors to the signal processor; and a controller, wherein the controller controls the switcher to start, at timing when one sensor of the at least two sensors does not face the substrate, switching processing for switching the connection to the signal processor from another sensor to the one sensor and controls the switcher such that the switching processing is completed after the one sensor passes a start point of a locus passing under the substrate.

BRIEF DESCRIPTION OF DRAWINGS

[0029] Fig. 1A is a schematic diagram for explaining a principle of determining a film thickness based on a spectrum of reflected light from a substrate;

Fig. 1B is a plan view showing a positional relation between the substrate and a polishing table;

Fig. 2 is a graph showing a spectrum of reflected light obtained by performing a simulation concerning the substrate having structure shown in Fig. 1A based on a light interference theory;

Fig. 3 is a sectional view showing a configuration of a polishing apparatus according to an embodiment of the present invention;

Fig. 4 is a plan view showing disposition of a first optical head including a first light projector and a first light receiver and a second optical head including a second light projector and a second light receiver;

Fig. 5 is a diagram showing a locus on a surface of the substrate drawn by a distal end of the second optical head;

Fig. 6 is a plan view showing another example of the disposition of the first optical head and the second optical head;

Fig. 7 is a diagram showing a locus drawn by the distal end of the second optical head shown in Fig. 6;

Fig. 8 is a diagram showing an example including a spectrometer and a light source common to the first optical head and the second optical head;

Fig. 9 is a plan view showing still another example of the disposition of the first optical head and the second optical head;

Fig. 10 is a diagram showing a locus on the substrate drawn by the first optical head;

Fig. 11 is a diagram showing a locus on the substrate drawn by the first optical head;

Fig. 12 is a diagram showing disposition of first optical heads in a case in which the polishing apparatus includes four first optical heads;

Fig. 13 is a diagram showing a configuration of a thickness measurer;

Fig. 14 is a diagram showing disposition of optical heads in a case in which the polishing apparatus includes two first optical heads and two second optical heads;

Fig. 15 is a diagram showing disposition of the optical heads in the case in which the polishing apparatus includes the two first optical heads and the two second optical heads;

Fig. 16 is a diagram showing disposition of optical heads in a case in which the polishing apparatus includes three first optical heads and three second optical heads;

Fig. 17 is a diagram showing disposition of optical heads in a case in which the polishing apparatus includes two first optical heads and four second optical heads;

Fig. 18 is a diagram showing disposition of a third optical head and a fourth optical head;

Fig. 19 is a diagram showing disposition of the third optical head and the fourth optical head;

Fig. 20 is a diagram showing disposition of the third optical head and the fourth optical head; and

Fig. 21 is a diagram showing disposition of the third optical head and the fourth optical head.

DESCRIPTION OF EMBODIMENTS

[0030] Embodiments of the present invention are explained below with reference to the drawings. Note that, in the embodiments explained below, same or equivalent members are denoted by the same reference numerals and signs and redundant explanation of the members is sometimes omitted. Characteristics explained in the embodiments can be applied to other embodiments unless the characteristics contradict one another.

[0031] Embodiments of the present invention are explained below with reference to the drawings. Fig. 1A is a schematic diagram for explaining a principle of determining a film thickness based on a spectrum of reflected light from a substrate. Fig. 1B is a plan view showing a positional relation between the substrate and a polishing table. As shown in Fig. 1A, a substrate W to be polished includes a base layer (for example, a silicon layer) and a film (for example, an insulating film of SiO₂ or the like having light transmissivity) formed on the base layer. A surface of the substrate W is pressed against a polishing pad 22 on a rotating polishing table 20. The film of the substrate W is polished by sliding contact of the polishing pad 22.

[0032] A light projector 11 and a light receiver 12 are disposed to face the surface of the substrate W. The light projector 11 is connected to a light source 16 and irradiates the surface of the substrate W with light from the light source 16. The light projector

11 substantially perpendicularly projects light on the surface of the substrate W. The light receiver 12 receives reflected light from the substrate W. The light emitted by the light source 16 is multiwavelength light. As shown in Fig. 1B, the surface of the substrate W is irradiated with light every time the polishing table 20 rotates once. A spectrometer 14 is connected to the light receiver 12. The spectrometer 14 decomposes the reflected light according to wavelengths and measures the intensity of the reflected light for each of the wavelengths.

[0033] A processor 15 is connected to the spectrometer 14. The processor 15 reads measurement data acquired by the spectrometer 14 and generates an intensity distribution of the reflected light from measurement values of intensity. More specifically, the processor 15 generates a spectrum (a spectral profile) representing the intensity of light for each of wavelengths. The spectrum can be represented as a line graph showing a relation between the wavelength and the intensity of the reflected light. The processor 15 is further configured to determine a film thickness of the substrate W from the spectrum and further determine a polishing end point. As the processor 15, a general-purpose or dedicated computer can be used. The processor 15 executes a predetermined processing step according to a program (or computer software). The processor 15 includes a CPU, a memory, a recording medium, and software or the like recorded to the recording medium. The processor 15 may be an electronic circuit. The processor 15 (a controller) controls a switcher 40 to switch, at timing when at least two sensor heads simultaneously face a wafer, the connection to the spectrometer 14 from one sensor head to the other sensor head.

[0034] In this aspect, at the timing when the at least two sensor heads simultaneously face the substrate, the one spectrometer receives and processes the signals output by the at least two sensor heads among the plurality of sensor heads. Therefore, it is possible to provide the polishing apparatus in which an increase in the size of the polishing apparatus is further reduced than in the related art even if the number of the sensor heads increases.

[0035] Fig. 2 is a graph showing a spectrum of reflected light obtained by performing a simulation based on a light interference theory concerning the substrate having the structure

shown in Fig. 1A. In Fig. 2, a horizontal axis represents a wavelength of light and a vertical axis represents relative reflectance calculated from the intensity of the light. The relative reflectance is one indicator representing the intensity of the light and, specifically, is a ratio of the intensity of the reflected light and predetermined reference intensity. By dividing the intensity (measured intensity) of the reflected light by the predetermined reference intensity in this way, it is possible to obtain the intensity of the light from which a noise component is removed. The predetermined reference intensity can be set to, for example, the intensity of reflected light obtained when a silicon wafer, on which a film is not formed, is polished under presence of water. Note that the intensity itself of the reflected light may be used without using the relative reflectance.

[0036] The spectrum is an array of the intensities of lights arranged in the order of wavelengths and indicates the intensities of the lights at the wavelengths. The spectrum changes according to the film thickness of the substrate. This is a phenomenon due to interference of a wave of light. That is, light emitted to the substrate reflects on an interface between a medium and a film and an interface between the film and a layer present below the film. Waves of lights reflecting on the interfaces interfere with each other. A way of the interference of the waves of the lights changes according to the thickness of the film (that is, an optical wavelength). Therefore, a spectrum of reflected light returning from the substrate changes according to the thickness of the film as shown in Fig. 2.

[0037] The processor 15 is configured to determine a film thickness from an obtained spectrum. A publicly-known technique can be used for a method of determining a film thickness from a spectrum. For example, there is a method of comparing a spectrum (a measured spectrum) obtained during polishing and a reference spectrum prepared in advance to estimate a film thickness. In this method, spectra at points in time during polishing are compared with a plurality of reference spectra and a film thickness is determined from a reference spectrum having a shape closest to the shape of the spectra. The plurality of reference spectra are prepared in advance by polishing a sample substrate of the same type as a substrate to be polished. The reference spectra are correlated with film thicknesses at

which the reference spectra are acquired. Therefore, a present film thickness can be estimated from a reference spectrum having a shape closest to the spectrum obtained during the polishing.

[0038] The processor 15 is connected to a control unit 19 that determines a polishing condition such as a polishing load on the substrate. The spectrum generated by the processor 15 is transmitted to the control unit 19. The control unit 19 determines, based on the spectrum obtained during the polishing, an optimum polishing load for obtaining a target film thickness profile and controls the polishing load on the substrate as explained below.

[0039] Fig. 3 is a sectional view showing a configuration of a polishing apparatus 110 according to the embodiment of the present invention. The polishing apparatus 110 includes the polishing table 20 that supports the polishing pad 22, a polishing head 24 that holds the substrate W and presses the substrate W against the polishing pad 22, and a polishing liquid supply mechanism 25 that supplies polishing liquid (slurry) to the polishing pad 22. The polishing table 20 is coupled to a motor (not shown) disposed below the polishing table 20 and is configured to rotate around the axis of the polishing table 20. The polishing pad 22 is fixed to an upper surface of the polishing table 20.

[0040] An upper surface 22a of the polishing pad 22 configures a polishing surface that polishes the substrate W. The polishing head 24 is coupled to the motor and an elevation cylinder (not shown) via a polishing head shaft 28. Consequently, the polishing head 24 is capable of rising and falling and capable of rotating around the polishing head shaft 28. The substrate W is held on the lower surface of the polishing head 24 by vacuum attraction or the like.

[0041] The substrate W held on the lower surface of the polishing head 24 is pressed against the polishing pad 22 on the rotating polishing table 20 by the polishing head 24 while being rotated by the polishing head 24. At this time, the polishing liquid is supplied from the polishing liquid supply mechanism 25 to the polishing surface 22a of the polishing pad 22 and the surface of the substrate W is polished in a state in which the polishing liquid is present between the surface of the substrate W and the polishing pad 22. A relative

movement mechanism for bringing the substrate W and the polishing pad 22 into sliding contact is configured by the polishing table 20 and the polishing head 24.

[0042] Holes 30A and 30B opened on the upper surface of the polishing table 20 are formed in the polishing table 20. In the polishing pad 22, through-holes 31A and 31B are formed in positions corresponding to the holes 30A and 30B. The hole 30A and the through-hole 31A communicate. The hole 30B and the through-hole 31B communicate. The through-holes 31A and 31B are opened on the polishing surface 22a. The holes 30A and 30B are coupled to a liquid supply source 35 via a liquid supply path 33 and a rotary joint 32. During polishing, water (preferably, pure water) is supplied to the holes 30A and 30B as transparent liquid from the liquid supply source 35. The water fills spaces formed by a lower surface of the substrate W and the through-holes 31A and 31B and is discharged through a liquid discharge path 34. The polishing liquid is discharged together with the water, whereby an optical path is secured. In the liquid supply path 33, a valve (not shown) that operates in synchronization with the rotation of the polishing table 20 is provided. The valve operates to stop a flow of the water or reduce a flow rate of the water when the substrate W is not located on the through-holes 31A and 31B. A form of sticking a polishing pad including a transparent window to a polishing table may be adopted instead of the method of supplying water into a through-hole and securing an optical path.

[0043] The polishing apparatus 110 includes the light source 16 that emits light. A first optical head 13A irradiates a region including a center 50 of the substrate W with the light from the light source 16 and receives reflected light from the substrate W while moving across the substrate W. A second optical head 13B irradiates a peripheral edge portion of the substrate W with the light from the light source 16 and receives reflected light from the substrate W while moving along the peripheral edge portion of the substrate W.

[0044] The polishing apparatus 110 includes an optical thickness measurer that measures a film thickness of the substrate according to the method explained above. The optical thickness measurer includes light sources 16a and 16b that emit lights, a first light projector 11a that irradiates the surface of the substrate W with the light emitted from the light source

16a, a first light receiver 12a that receives reflected light returning from the substrate W, a second light projector 11b that irradiates the surface of the substrate W with the light emitted from the light source 16b, a second light receiver 12b that receives reflected light returning from the substrate W, spectrometers 14a and 14b that decompose the reflected light from the substrate W according to wavelengths and measure the intensity of the reflected light over a predetermined wavelength range, and the processor 15 that generates a spectrum from measurement data acquired by the spectrometers 14a and 14b and determines a film thickness of the substrate W based on the spectrum. The spectrum indicates the intensity of light distributed over the predetermined wavelength range and indicates a relation between the intensity and a wavelength of the light.

[0045] The first light projector 11a, the first light receiver 12a, the second light projector 11b, and the second light receiver 12b are configured from optical fibers. The first light projector 11a and the first light receiver 12a configure the first optical head (a first sensor head) 13A. The second light projector 11b and the second light receiver 12b configure the second optical head (a second sensor head) 13B. The first light projector 11a is connected to the light source 16a. The second light projector 11b is connected to the light source 16b. The first light receiver 12a is connected to the spectrometer 14a. The second light receiver 12b is connected to the spectrometer 14b.

[0046] In Fig. 3, only one first optical head 13A and one second optical head 13B are shown. However, this depends on positions of a sectional view on a table. Details of the number and the disposition of the first optical heads 13A and the second optical heads 13B are explained below. In Fig. 3, the spectrometer 14a and the spectrometer 14b are shown as the spectrometer 14. This is to facilitate understanding while avoiding complexity of the figure. This does not mean that two spectrometers 14 are present. One spectrometer 14 is present in this embodiment. As explained below, the first optical head 13A and the second optical head 13B are connected to the one spectrometer 14.

[0047] As the light sources 16a and 16b, a light source that emits light having a plurality of wavelengths such as a light emitting diode (LED), a halogen lamp, and a xenon lamp can

be used. The first light projector 11a, the first light receiver 12a, the second light projector 11b, the second light receiver 12b, the light sources 16a and 16b, and the spectrometers 14a and 14b are disposed on the inside of the polishing table 20 and rotates together with the polishing table 20. The first light projector 11a and the first light receiver 12a are disposed in the hole 30A formed in the polishing table 20. The distal ends of the first light projector 11a and the first light receiver 12a are located in a vicinity of a surface to be polished of the substrate W. Similarly, the second light projector 11b and the second light receiver 12b are disposed in the hole 30B formed in the polishing table 20. The distal ends of the second light projector 11b and the second light receiver 12b are located in the vicinity of the surface to be polished of the substrate W.

[0048] The first light projector 11a and the first light receiver 12a are disposed perpendicularly to the surface of the substrate W. The first light projector 11a is configured to perpendicularly irradiate the surface of the substrate W with light. Similarly, the second light projector 11b and the second light receiver 12b are disposed perpendicularly to the surface of the substrate W. The second light projector 11b is configured to perpendicularly irradiate the surface of the substrate W with light.

[0049] The first light projector 11a and the first light receiver 12a are disposed to face the center of the substrate W held by the polishing head 24. Therefore, as shown in Fig. 1B, every time the polishing table 20 rotates, the distal ends of the first light projector 11a and the first light receiver 12a move across the substrate W and a region including the center of the substrate W is irradiated with light. This is because the first light projector 11a and the first light receiver 12a pass the center of the substrate W to measure the film thickness of the entire substrate W including the film thickness of the center of the substrate W. The processor 15 can generate a film thickness profile (a film thickness distribution) based on measured film thickness data.

[0050] On the other hand, the second light projector 11b and the second light receiver 12b are disposed to face a peripheral edge portion 68 of the substrate W held by the polishing head 24. The distal ends of the second light projector 11b and the second light receiver 12b

move along the peripheral edge portion 68 of the substrate W every time the polishing table 20 rotates. Therefore, the peripheral edge portion 68 of the substrate W is irradiated with light every time the polishing table 20 rotates.

[0051] During polishing of the substrate W, lights are emitted to the substrate W from the first light projector 11a and the second light projector 11b. The light from the first light projector 11a reflects on the surface of the substrate W and is received by the first light receiver 12a. The light from the second light projector 11b reflects on the surface of the substrate W and is received by the second light receiver 12b. While the substrate W is irradiated with the light, water is supplied to the hole 30A and the through-hole 31A, whereby spaces between the distal ends of the first light projector 11a and the first light receiver 12a and the surface of the substrate W are filled with the water. Similarly, while the substrate W is irradiated with light, the water is supplied to the hole 30B and the through-hole 31B, whereby spaces between the distal ends of the second light projector 11b and the second light receiver 12b and the surface of the substrate W are filled with the water.

[0052] The spectrometer 14 decomposes reflected light sent from the first light receiver 12a according to wavelengths and measures the intensity of the reflected light for each of the wavelengths. Similarly, the spectrometer 14 decomposes reflected light sent from the second light receiver 12b according to wavelengths and measures the intensity of the reflected light for each of the wavelengths. The processor 15 generates, from the intensity of the reflected light measured by the spectrometer 14, a spectrum indicating a relation between the intensity and the wavelength of the reflected light. Further, the processor 15 determines, from the obtained spectrum, a present film thickness of the substrate W using the publicly-known technique explained above.

[0053] Fig. 4 is a plan view showing disposition of the first optical head 13A including the first light projector 11a and the first light receiver 12a and the second optical head 13B including the second light projector 11b and the second light receiver 12b shown in Fig. 3. The other optical heads are not shown. As shown in Fig. 4, the center of the substrate W is located on a locus drawn by the first optical head 13A and the peripheral edge portion 68 of

the substrate W is located on a locus drawn by the second optical head 13B. As it is seen from Fig. 4, the second optical head 13B moves across only the peripheral edge portion 68 of the substrate W and a traveling direction of the second optical head 13B is generally a circumferential direction of the substrate W.

[0054] The first optical head 13A and the second optical head 13B are arrayed along a radial direction of the polishing table 20. Therefore, an angle formed by a line connecting the first optical head 13A and a center O of the polishing table 20 and a line connecting the second optical head 13B and the center O of the polishing table 20 is 0 degrees. The second optical head 13B is disposed on an outer side of the first optical head 13A with respect to the radial direction of the polishing table 20. That is, a distance between the second optical head 13B and the center O of the polishing table 20 is longer than a distance between the first optical head 13A and the center O of the polishing table 20.

[0055] Fig. 5 is a diagram showing a locus on the surface of the substrate W drawn by the distal end of the second optical head 13B. More specifically, Fig. 5 shows a locus drawn by the second optical head 13B when the polishing table 20 rotates twice. As it is seen from Fig. 5, the second optical head 13B moves along the peripheral edge portion 68 of the substrate W according to the rotation of the polishing table 20. As a result, the number of measurement points at the peripheral edge portion 68 of the substrate W is larger than the number of measurement points in a CMP apparatus that does not perform measurement at the peripheral edge portion 68. Therefore, it is possible to accurately determine a film thickness of the peripheral edge portion 68 of the substrate W from a larger number of measurement data.

[0056] Here, in this specification, as shown in Fig. 5, the peripheral edge portion 68 of the substrate is an annular part on the outermost side of the substrate. The width of the peripheral edge portion 68 is 10 mm to 20 mm. For example, in a case of a substrate having a diameter of 300 mm, the width of the peripheral edge portion 68 of the substrate is approximately 10 mm. The peripheral edge portion 68 of the substrate is a region where a device is formed. However, the width of the peripheral edge portion 68 is not limited to

10 mm to 20 mm. The peripheral edge portion 68 of the substrate is a region that is most easily affected by a polishing load and polishing liquid during polishing and is a region where a film thickness more easily greatly changes during the polishing compared with other regions of the substrate. Therefore, accurate film thickness monitoring is required during the polishing.

[0057] In in-situ measurement for measuring a film thickness of a substrate during polishing, the measurement of the film thickness is sometimes affected by the polishing liquid. In particular, in an optical thickness measurement device, in some case, light is blocked by the polishing liquid and accurate film thickness measurement is not performed. Therefore, in order to eliminate the influence of the film thickness measurement by the polishing liquid, the substrate may be polished (water-polished) while pure water being periodically supplied to the polishing pad 22 and the film thickness of the substrate may be measured during the supply of the pure water.

[0058] The processor 15 combines a film thickness value acquired using the first optical head 13A and a film thickness value acquired using the second optical head 13B to create a film thickness profile.

[0059] Fig. 6 is a plan view showing another example of the disposition of the first optical head 13A and the second optical head 13B and is a plan view showing a possible disposition example of the second optical head 13B disposed at the peripheral edge portion 68. The disposition of the first optical head 13A and the second optical head 13B shown in Fig. 6 is basically the same as the disposition shown in Fig. 4 but is different in that the second optical head 13B is disposed closer to the center O of the polishing table 20 than the first optical head 13A. That is, in the example shown in Fig. 6, the second optical head 13B is located further on the inner side than the first optical head 13A with respect to the radial direction of the polishing table 20. Therefore, the distance between the second optical head 13B and the center O of the polishing table 20 is shorter than the distance between the first optical head 13A and the center O of the polishing table 20. In Fig. 6, the other first optical head 13A and the like are not shown as in Fig. 4.

[0060] Fig. 7 is a diagram showing a locus drawn by the distal end of the second optical head 13B shown in Fig. 6 and shows a locus at the time when the polishing table 20 rotates twice. As it is seen from Fig. 7, the second optical head 13B moves along the peripheral edge portion 68 of the substrate W according to the rotation of the polishing table 20. Therefore, it is possible to measure the film thickness of the peripheral edge portion 68 of the substrate W at a larger number of measurement points. Further, it is seen from comparison of the locus shown in Fig. 5 and the locus shown in Fig. 7 that the locus of the second optical head 13B shown in Fig. 7 is longer than the locus of the second optical head 13B shown in Fig. 5. Therefore, in the disposition shown in Fig. 6, it is possible to measure the film thickness of the peripheral edge portion 68 of the substrate W at a larger number of measurement points.

[0061] In the disposition explained in the embodiment of the present application, one spectrometer can receive reflected light from the first optical head 13A and reflected light from the second optical head 13B in different times. That is, even if the one spectrometer receives reflected light from the center of the substrate W and reflected light from the peripheral edge portion 68 of the substrate W, the reflected lights are not superimposed in the spectrometer. A polishing apparatus including such a common spectrometer is explained with reference to Fig. 8.

[0062] As shown in Fig. 8, the first light receiver 12a and the second light receiver 12b are connected to the spectrometer 14 via an optical switch 40 (a switcher). The optical switch 40 selectively connects at least two sensor heads to the spectrometer 14. Here, the optical switch is a device that switches a light transmission path. A representative optical switch has a configuration including a mirror for changing a light traveling direction and is configured to reflect incident light with the mirror and switch the light transmission path. Other than the optical switch including the mirror, a waveguide type optical switch including a material, the refractive index of which is changed by input of heat, electricity, or the like, is sometimes used. As the optical switch 40, such a publicly-known optical switch can be used. In Fig. 8, one of two inputs is connected to the spectrometer 14. However, any one

of any number of inputs can be connected to the spectrometer 14 by the optical switch 40. Note that a shutter may be used instead of the optical switch.

[0063] In the configuration explained above, when the first optical head 13A moves across the substrate W, the spectrometer 14 is connected to the first light receiver 12a by the optical switch 40. On the other hand, when the second optical head 13B moves across the substrate W, the spectrometer 14 is connected to the second light receiver 12b by the optical switch 40. In this way, by using the optical switch 40, it is possible to alternately connect the spectrometer 14 to the first optical head 13A or the second optical head 13B. How to connect a plurality of optical heads and the optical switch 40 when a plurality of optical heads simultaneously move across the substrate W is explained below.

[0064] In the example shown in Fig. 1, the second optical head 13B is disposed further on the outer side than the first optical head 13A with respect to the radial direction of the polishing table 20. However, as shown in Fig. 9, the second optical head 13B may be disposed further on the inner side than the first optical head 13A with respect to the radial direction of the polishing table 20. That is, the distance between the second optical head 13B and the center O of the polishing table 20 may be set shorter than the distance between the first optical head 13A and the center O of the polishing table 20.

[0065] Here, the problems of the disposition of the optical head disclosed in Japanese Patent No. 6470365, which is the related art, are explained. In Fig. 9, only one first optical head 13A and one second optical head 13B are shown. A polishing apparatus including only the one first optical head 13A and the one second optical head 13B and disposed as shown in Fig. 9 is the polishing apparatus disclosed in Japanese Patent No. 6470365. Note that, in the embodiment of this application, at least two first optical heads 13A are disposed. A locus of the first optical head 13A shown in Fig. 9 is shown in Fig. 10.

[0066] Fig. 10 is a diagram showing a locus on the substrate W drawn by the first optical head 13A when the polishing table 20 and the polishing head 24 rotate under a certain condition. As shown in Fig. 10, under this condition, the locus of the first optical head 13A rotates 36 degrees every time the polishing table 20 rotates once. Therefore, a sensor locus

rotates by a half circumference on the substrate W every time the first optical head 13A scans the substrate W five times. The first optical head 13A scans the substrate W five times, whereby the first optical head 13A scans approximately 60% of the substrate W.

[0067] As it is seen from Figs. 5 and 7, concerning a locus of the second optical head 13B, only five times of 36 degrees (180 degrees), that is, approximately 60% of the peripheral edge portion 68 of the substrate W can be scanned. In order to scan the entire substrate W including the peripheral edge portion 68, when the polishing apparatus includes only the one first optical head 13A and the one second optical head 13B, the polishing table 20 needs to rotate ten times. A locus on the substrate W drawn by the first optical head 13A at the time when the polishing table 20 rotates ten times is shown in Fig. 11.

[0068] It is essential to improve polishing accuracy according to refining of a device. It is necessary to further improve measurement resolution in order to improve the polishing accuracy. It is necessary to increase the number of sensor heads in order to improve the measurement resolution. A polishing apparatus is increased in size if, according to the number of sensor heads, the number of signal processors that receive and process signals output by the sensor heads is increased. This problem is more conspicuous when an optical sensor is used for film thickness measurement than when an eddy current sensor is used. This is because a spectrometer, which is a signal processor, of the optical sensor is larger in size than a signal processor of the eddy current sensor. If the size is large, a problem occurs when an apparatus installation area is limited. There is also a problem in that productivity of a semiconductor in terms of a production amount per unit area of the apparatus is deteriorated.

[0069] In an embodiment of the present application, in order to solve this problem, a polishing apparatus explained below is provided to alternately measure a latter half (or a former half or a part) on a sensor locus of the surface of the substrate W using a plurality of sensors. A plurality of spectrometers 14 are not installed. Further, in this embodiment, it is possible to improve measurement resolution and grasp a film thickness profile in the surface of the substrate W in a short time.

[0070] Fig. 12 is a diagram showing disposition of the first optical head in a case in which the polishing apparatus includes four first optical heads. The polishing apparatus in this embodiment shown in Fig. 12 includes a plurality of first optical heads 131, 132, 133, and 134 that detect a signal (reflected light) concerning the film thickness of the substrate W in a region including the center 50 of the substrate W while moving across the substrate W and one spectrometer 14 (a signal processor) that receives and processes signals output by at least two (in this embodiment, four) first optical heads among the first optical heads 131, 132, 133, and 134. The spectrometer 14 outputs, for example, a spectrum of reflected light. The polishing table 20 is configured to rotate around the axis of the polishing table 20. The plurality of first optical heads 131, 132, 133, and 134 are disposed in a region of the polishing table 20 facing a region including the center of the substrate W.

[0071] The four first optical heads 131, 132, 133, and 134 rotate on a circular locus 52 around an axis O of the polishing table 20. While the plurality of first optical heads 131, 132, 133, and 134 are moving, there is timing (a time) when at least two (in this embodiment, two) first optical heads simultaneously face the substrate W. In the figure, the first optical heads 131 and 132 simultaneously face the substrate W. In the figure, the four first optical heads 131, 132, 133, and 134 are disposed at equal intervals of 90 degrees. Every time the polishing table 20 rotates 90 degrees, the first optical heads 131 and 132, the first optical heads 131 and 134, the first optical heads 134 and 133, and the first optical heads 133 and 132 simultaneously face the substrate W in this order. How many first optical heads simultaneously face the substrate W depends on the size of the radius of the substrate W and the positions of the first optical heads.

[0072] When the first optical heads simultaneously face the substrate W, (1) any one first optical head of at least two first optical heads is connected to the spectrometer 14 (the signal processor) or (2) the at least two first optical heads are connected to the spectrometer 14 in different times. In this embodiment, the connection method of (1) is possible. An embodiment in which the connection method of (2) is possible is explained below. In this embodiment, as a time in which one first optical head is connected to the spectrometer 14,

various times are possible. For example, (1) the first optical head 131 can be connected to the spectrometer 14 in a former half 54 of entirety 58 of the locus 52 in the time when the first optical head 131 faces the substrate W, (2) the first optical head 131 can be connected to the spectrometer 14 in a latter half 56 of the entirety 58 of the locus 52, (3) the first optical head 131 can be connected to the spectrometer 14 in the entirety 58 of the locus 52, and (4) the first optical head 131 can be connected to the spectrometer 14 in the middle of the entirety 58 of the locus 52.

[0073] When four first optical heads are connected to the spectrometer 14 in the former half 54 of the locus 52, a time for substantially equally scanning the entire surface of the substrate W is shorter than a time required for the polishing table 20 to rotate ten times. When the four first optical heads are connected to the spectrometer 14 in the latter half 56 of the locus 52, the entire surface of the substrate W can be substantially equally scanned in the same time as a time for scanning the entire surface of the substrate W when the four first optical heads are connected to the spectrometer 14 in the former half 54. When the four first optical heads are connected to the spectrometer 14 in the entirety 58 of the locus 52, substantially equally the entire surface of the substrate W can be scanned in a half time of the time for scanning the entire surface of the substrate W when the four first optical heads are connected to the spectrometer 14 in the former half 54. As a time in which the four first optical heads are connected, a half (a former half or a latter half) of a time required for the first optical heads to pass the entirety 58, a three quarter time, and the like are possible. A case in which the four first optical heads are connected to the spectrometer 14 in the middle of the locus 52 is, for example, a case in which the four first optical heads are connected in a section excluding an end of the entirety 58 when film thickness data of the peripheral edge portion 68 is not acquired. In this way, when there are two or more first optical heads, a time in which the entire surface of the substrate W is substantially equally scanned is an approximately half or less of the time of the related art.

[0074] When a case in which the four first optical heads are connected to the spectrometer 14 in the former half 54 of the locus 52 and a case in which the four first optical

heads are connected to the spectrometer 14 in the latter half 56 of the locus 52 are compared, the case in which the four first optical heads are connected in the latter half 56 is preferable because of the following reason. In this embodiment, it is conceived that the polishing table 20 and the substrate W are rotating counterclockwise. The first optical head 131 rotates and water is sprayed for measurement immediately before the first optical head 131 enters under the substrate W. When the latter half 56 and the former half 54 are compared, a state of the sprayed water is stable in the latter half 56. More accurate measurement can be performed when the measurement is performed in the latter half 56.

[0075] As shown in Fig. 13, the four first optical heads 131, 132, 133, and 134 are connected to the one spectrometer 14 via the optical switch 40. Fig. 13 is a diagram showing a configuration of the thickness measurer. Since only the one spectrometer 14 can process signals of a plurality of optical heads, an installation area may be small. The four first optical heads 131, 132, 133, and 134 are connected to one light source 16 via an optical switch 66.

[0076] The four first optical heads 131, 132, 133, and 134 shown in Fig. 12 are disposed as explained below as well. Each two of a predetermined even number of first optical heads among the plurality of first optical heads 131, 132, 133, and 134 form a pair. That is, two first optical heads 131 and 133 form a pair and two first optical heads 132 and 134 form a pair.

[0077] The four first optical heads 131, 132, 133, and 134 shown in Fig. 12 are disposed as explained below as well. In the case of the figure, the first optical head 131 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 132 exits the substrate W. The first optical head 134 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 131 exits the substrate W. The first optical head 133 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 134 exits the substrate W. The first optical head 132 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 133 exits the substrate W. This is possible in Figs. 13 to 16 referred to below

as well.

[0078] In the figure, a line 60 and a line 62 are orthogonal. However, when the substrate W is smaller than the substrate W shown in the figure, the line 60 and the line 62 are not orthogonal. That is, an angle 64 is larger than 90 degrees. At that time, the two first optical heads 131 and 132 can be disposed to be substantially simultaneously present at an end of the substrate W as shown in the figure and the two first optical heads 133 and 134 can be disposed to be substantially simultaneously present at the end of the substrate W as shown in the figure. At this time, the first optical head 131 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 132 exits the substrate W. The first optical head 133 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 134 exits the substrate W. In this case, an additional optical head may be disposed between the first optical head 132 and the first optical head 133 and/or between the first optical head 131 and the first optical head 134. This is possible in Figs. 13 to 16 referred to below as well.

[0079] The two first optical heads (for example, the first optical heads 131 and 133) forming the pair are present substantially in positions on opposite sides to each other with respect to the axis O. The even number of first optical heads are disposed such that lines 60 and 62 respectively connecting the first optical heads forming the pairs are at a same angle interval (in the figure, 90 degrees) around the axis O.

[0080] The four first optical heads 131, 132, 133, and 134 shown in Fig. 12 are considered to be disposed as explained below as well. In predetermined four first optical heads among the plurality of first optical heads, the two first optical heads 131 and 133 are present substantially in positions on opposite sides to each other with respect to the axis O and the other two first optical heads 132 and 134 are present substantially in positions on opposite sides to each other with respect to the axis. The angle 64 (in the figure, 90 degrees) formed by the line 60 connecting the two first optical heads and the line 62 connecting the other two first optical heads is larger than 0 degrees and smaller than 180 degrees. A connection method to the spectrometer 14 in a case in which the angle 64 is

close to 0 degrees or 180 degrees is explained below.

[0081] Next, another embodiment is explained with reference to Figs. 14 and 15. A polishing apparatus shown in the figures includes a plurality of second optical heads 141 and 142 that detect a signal concerning the film thickness of the substrate W while moving along the peripheral edge portion 68 of the substrate W. The spectrometer 14 receives and processes signals output by two (in the case of the figures, all of two) second optical heads 141 and 142 among the plurality of second optical heads 141 and 142.

[0082] There are at least two (in the figures, two) first optical heads 131 and 133 as the plurality of first optical heads 131 and 133. There are at least two (in the figures, two) second optical heads 141 and 142 as the plurality of second optical heads 141 and 142. The two first optical heads 131 and 133 are present substantially in positions on opposite sides to each other with respect to the axis O. The axis O is present on a line segment 70 connecting the two second optical heads 141 and 142. An angle 72 formed by the line 60 connecting the two first optical heads 131 and 133 and the line segment 70 connecting the second optical heads 141 and 142 is 0 degrees to 180 degrees.

[0083] While the plurality of first optical heads 131 and 133 and the plurality of second optical heads 141 and 142 are rotating and moving around the axis O, at least two (in the figures, two) optical heads among the plurality of first optical heads 131 and 133 and the plurality of second optical heads 141 and 142 sometimes simultaneously face the substrate W. When the two optical heads simultaneously face the substrate W, any one optical head 131, 133, 141, or 142 of the at least two (in the figures, two) first optical heads 131 and 133 or the plurality of second optical heads 141 and 142 is connected to the spectrometer 14. The at least two (in the figures, two) first optical heads 131 and 133 or second optical heads 141 and 142 are connected to the spectrometer 14 in different times.

[0084] (1) A case in which any one optical head 131 or 133 is connected to the spectrometer 14 and (2) a case in which the at least two (in the figures, two) first optical heads 131 and 133 or second optical heads 141 and 142 are connected to the spectrometer 14 in different times are explained below.

[0085] The case in which any one optical head is connected to the spectrometer 14 is, for example, a case in which a time in which the two first optical heads 131 and 132 simultaneously face the substrate W is a short time as shown in Fig. 12. In this case, an optical head facing the substrate W for a long time is connected to the spectrometer 14. The case in which at least two (in the figures, two) optical heads are connected to the spectrometer 14 in the different times is a time in which the two optical heads simultaneously face the substrate W for a time that is not a short time unlike the time shown in Fig. 12.

[0086] The case in which the two optical heads simultaneously face the substrate W for the time that is not a short time is, in Fig. 12, for example, a time when the angle 64 of an angle formed by the line 60 and the line 62 is smaller than 90 degrees and is, for example, a time when the angle 64 is close to 0 degrees or 180 degrees. The length of the time in which the two optical heads simultaneously face the substrate W for the time that is not a short time depends on the size of the substrate W, the distance between the axis O and the center 50, and the angle 64.

[0087] The case in which the two optical heads simultaneously face the substrate for the time that is not a short time is, in Figs. 14 and 15, for example, a time when the angle 72 of an angle formed by the line 60 and the line segment 70 is smaller than 90 degrees and is, for example, a time when the angle 72 is close to 0 degrees or 180 degrees. The length of the time in which the two optical heads simultaneously face the substrate for the time that is not a short time depends on the size of the substrate W, the distance between the axis O and the center 50, and the angle 72. In the case shown in Figs. 14 and 15, that is, when the angle 72 is 90 degrees, the two optical heads do not simultaneously face the substrate. However, when the angle 72 is near an angle far from 90 degrees, for example, close to 0 degrees or 180 degrees, the two optical heads surely simultaneously face the substrate for the time that is not a short time. This case is explained below.

[0088] When the two optical heads simultaneously face the substrate, as a time when the at least two (in the figures, two) optical heads are connected to the spectrometer 14 in different times, various times are possible. Although different from Fig. 15, it is conceived

that the first optical heads 131 and 133 and the second optical heads 141 and 142 are fixed to the polishing table 20 such that the angle 72 is 0 degrees or 180 degrees. That is, it is assumed that the second optical heads 141 and 142 are respectively fixed to a point 80 and a point 82 on a circle.

[0089] When the two optical heads simultaneously face the substrate, as a method of connecting the two optical heads to the spectrometer 14 in different times, methods explained below are possible. For example, (1) the first optical heads 131 and 133 are connected to the spectrometer 14 in the former half 54 of the entirety 58 of the locus 52 at the time when the first optical heads 131 and 133 face the substrate W and the second optical heads 141 and 142 are connected to the spectrometer 14 in a latter half 86 of entirety 76 of a locus 74 at the time when the second optical heads 141 and 142 face the substrate W. As another method, (2) the first optical heads 131 and 133 are connected to the spectrometer 14 in the latter half 56 of the entirety 58 of the locus 52 and the second optical heads 141 and 142 are connected to the spectrometer 14 in a former half 84 of the entirety 76 of the locus 74 at the time when the second optical heads 141 and 142 face the substrate W.

[0090] In the case of Figs. 14 and 15, the first optical head 131 passes ten loci shown in Fig. 11 in the order of numbers shown in the figure according to the rotation of the polishing table 20. The first optical head 133 present on the opposite side of the first optical head 131 passes the ten loci shown in Fig. 11 in the order of numbers 6, 7, 8, 9, 10, 1, 2, 3, 4, and 5 according to the rotation of the polishing table 20. When the first optical heads 131 and 133 are connected to the spectrometer 14 in the former half 54 of the entirety 58 of the locus 52 at the time when the first optical heads 131 and 133 face the substrate W, the first optical heads 131 and 133 are connected to the spectrometer 14 in a former half of the ten loci shown in Fig. 11 (a portion from a start point of the loci to the center 50). As a result, the entire surface of the substrate W can be substantially equally scanned at a point in time when the polishing table 20 rotates five times. That is, compared with the case of the related art shown in Fig. 9 in which only the one first optical head 131 is used (the polishing table 20 needs to rotate ten times), the entire surface of the substrate W can be substantially

equally scanned at a point in time when the polishing table 20 rotates five times. Compared with the related art shown in Fig. 9, a measurement time is reduced and a larger number of data of the peripheral edge portion 68 can be acquired. Note that a difference between Fig. 14 and Fig. 15 is that the second optical heads 141 and 142 are disposed closer to the center 50 in Fig. 15 compared with Fig. 14. As a result, in Fig. 15, compared with Fig. 14, a larger number of measurement data of the peripheral edge portion 68 can be acquired.

[0091] Next, another embodiment is explained with reference to Fig. 16. In a polishing apparatus shown in the figure, in a predetermined number of (in the figure, all of three first optical heads) first optical heads 131, 132, and 133 among a plurality of first optical heads 131, 132, and 133 and a predetermined number of (in the figure, all of three second optical heads) second optical heads 141, 142, and 143 among a plurality of second optical heads 141, 142, and 143, each one of the three second optical heads 141, 142, and 143 is disposed on lines 88, 90, and 92 respectively connecting the three first optical heads 131, 132, and 133 and the axis O of the polishing table 20.

[0092] In the disposition shown in the figure, in another expression, when the second optical heads 141, 142, and 143 enter the substrate W, each one of the three first optical heads 131, 132, and 133 is disposed on the lines 88, 90, and 92 connecting the axis O and the second optical heads 141, 142, and 143. Note that the three lines 88, 90, and 92 are disposed around the axis O at equal intervals, in the case of the figure, at intervals of 120 degrees. The three lines 88, 90, and 92 may not be disposed around the axis O at equal intervals.

[0093] In this embodiment, there is a time period in which two optical heads simultaneously face the substrate. As a method of connecting the two optical heads, for example, the first optical head 131 and the second optical head 141 to the spectrometer 14 in different times at this time, the following methods are possible. For example, (1) the first optical head 131 is connected to the spectrometer 14 in the former half 54 of the entirety 58 of the locus 52 when the first optical head 131 faces the substrate W and the second optical head 141 is connected to the spectrometer 14 in the latter half 86 of the entirety 76 of

the locus 74 at the time when the second optical head 141 faces the substrate W. As another method, (2) the first optical head 131 is connected to the spectrometer 14 in the latter half 56 of the entirety 58 of the locus 52 and the second optical head 141 is connected to the spectrometer 14 in the former half 84 of the entirety 76 of the locus 74 at the time when the second optical head 141 faces the substrate W.

[0094] Next, another embodiment is explained below with reference to Fig. 17. In a polishing apparatus shown in the figure, in predetermined two first optical heads (in the figure, two first optical heads 131 and 132) among a plurality of first optical heads 131 and 132 and predetermined four second optical heads (in the figure, all of four second optical heads) among a plurality of second optical heads 141, 142, 143, and 144, the two first optical heads 131 and 132 are located substantially on opposite sides to each other with respect to the axis O. The axis O is present on a first line segment 94 connecting two second optical heads 141 and 142. The axis O is present on a second line segment 96 connecting the other two second optical heads 143 and 144. An angle of an angle 104 formed by the first line segment 94 and the second line segment 96 is 0 degrees to 180 degrees. In the figure, the angle of the angle 104 is smaller than 90 degrees.

[0095] The predetermined four second optical heads 141, 142, 143, and 144 are symmetrically disposed with respect to a third line 98 connecting the predetermined two first optical heads 131 and 133. A minimum angle (in the case of the figure, an angle of an angle 100) among angles formed by the third line 98 and the first line segment 94 is smaller than 90 degrees. A minimum angle (in the case of the figure, an angle of an angle 102) among angles formed by the first line segment 94 and the second line segment 96 is smaller than 90 degrees.

[0096] In the case of the figure, the first optical head 131 enters the substrate W immediately after (or substantially simultaneously when) the second optical head 143 exits the substrate W. The first optical head 131 passes the former half 54 and the second optical head 141 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 131 passes the former half 54. The second optical head 144 enters the

substrate W immediately after (or substantially simultaneously when) the second optical head 141 exits the substrate W. The first optical head 133 enters the substrate W immediately after (or substantially simultaneously when) the second optical head 144 exits the substrate W. The first optical head 133 passes the former half 54 and the second optical head 142 enters the substrate W immediately after (or substantially simultaneously when) the first optical head 133 passes the former half 54. Thereafter, the above is repeated.

Consequently, a large number of data can be efficiently acquired.

[0097] Note that the examples in which the two first optical heads or second optical heads face the substrate are explained with reference to Figs. 12 to 17. However, three or more first optical heads or second optical heads can also face the substrate. This is possible by further reducing a time for one optical head connected to the spectrometer 14 than in the case of two optical heads. As shown in Fig. 4, the second optical head may be present on the outer side of the first optical head when viewed from the axis. When a plurality of optical heads are connected to the one spectrometer 14 but the number of optical heads is large, not all of the optical heads may be connected to the one spectrometer 14 and a second spectrometer 14 may be provided. Note that, in the embodiment explained above, the first optical head detects the signal concerning the film thickness of the substrate in the region including the center of the substrate. However, the first optical head may detect the signal concerning the film thickness of the substrate in a region not including the center of the substrate. The second optical head detects the signal concerning the film thickness of the substrate while moving along the peripheral edge portion of the substrate. However, the second optical head may detect the signal concerning the film thickness of the substrate while moving in a portion other than the peripheral edge portion of the substrate.

[0098] In a polishing method for polishing the substrate W, which is an embodiment of the present invention, the polishing table 20 holds the polishing pad 22. The polishing head 24 presses the surface of the substrate W against the polishing pad 22. The plurality of first optical heads 131, 132, 133, and 134 detect a signal concerning the film thickness of the substrate W while moving across the substrate W. One signal processor 14 receives and

processes signals output by the plurality of first optical heads 131, 132, 133, and 134. The switcher 40 selectively connects at least two optical heads to the spectrometer 14. The controller 15 controls the switcher 40 to switch the connection to the spectrometer 14 from one optical head to the other optical head when the at least optical heads simultaneously face the substrate W.

[0099] In the examples explained above, the optical heads are provided. However, the present invention is not limited to the optical thickness measurement device and can also be applied to other thickness measurement devices such as an eddy current sensor. For example, according to the example shown in Fig. 14 explained above, a first eddy current sensor, which is a film thickness sensor, may be disposed to face the center of a substrate and a second eddy current sensor may be disposed to face the peripheral edge portion of the substrate. At this time, a switcher (an electric switch) selectively connects at least two sensors to a signal processor (an electronic circuit). One signal processor receives and processes signals output by at least two eddy current sensors among a plurality of eddy current sensors. A control device (an electronic circuit) controls the switcher to switch, at timing when the at least two eddy current sensors simultaneously face the substrate, the connection to the signal processor from one eddy current sensor to the other eddy current sensor.

[0100] In the examples explained above, the control device 15 controls the switcher 40 to switch, at timing when at least two optical heads simultaneously face the substrate, the connection to the spectrometer from one optical head to the other optical head.

[0101] Incidentally, when a response delay (a communication delay, operation delays of portions, and the like), fluctuation in an operation due to a temperature change, and the like are considered, in a method of switching the connection to the spectrometer from one optical head to the other optical head after the optical heads move from a position not facing the substrate to a position facing the substrate, the switching is sometimes delayed. That is, data acquisition at an end of the substrate is insufficient.

[0102] Therefore, the processor 15 sometimes preferably controls the switcher 40 to

start, at timing when one optical head of the at least two optical heads does not face the substrate, that is, a third optical head (one optical head) of the at least two optical heads faces the substrate and a fourth optical head (the other optical head) of the at least two optical heads does not face the substrate, switching processing for switching the connection to the spectrometer 14 from a third optical head 231 facing the substrate W to a fourth optical head 232 not facing the substrate W. Note that "face the substrate" means that "a film structure that should be measured is present in at least a part of a spot area of light output by an optical head and the optical head is present in a position where film thickness information can be obtained in the spot area". This embodiment is explained with reference to Fig. 18.

[0103] Geometrical disposition of optical heads (sensor heads) in the figure is the same as the geometrical disposition shown in Fig. 16. That is, concerning the geometrical disposition, the third optical head 231 (a third sensor head) corresponds to the first optical head 131, the fourth optical head 232 (a fourth sensor head) corresponds to the first optical head 132, and a fifth optical head 233 corresponds to the first optical head 133. Sixth optical heads 241, 242, and 243 are respectively present in positions corresponding to the second optical heads 141, 142, and 143.

[0104] However, a control method for optical heads is different. In the figure, the third optical head 231, the fourth optical head 232, and the fifth optical head 233 are connected to the spectrometer 14 via the switcher 40. The sixth optical heads 241, 242, and 243 are connected to a spectrometer (not shown) different from the spectrometer 14 via the switcher 40. That is, the third optical heads 231, the fourth optical head 232, and the fifth optical head 233 passing the center of the substrate W are not switched to and from the sixth optical heads 241, 242, and 243 passing the end of the substrate W.

[0105] Fig. 18 shows the positions of the third optical head 231 and the fourth optical head 232 at the time when the connection to the spectrometer 14 is switched from the third optical head 231 facing the substrate W to the fourth optical head 232 not facing the substrate W. Timing for the switching is explained. The optical heads 231, 232, and 233 move on a locus 156. A moving direction (that is, a rotating direction of the polishing table 20) is

indicated by an arrow 154. When the processor 15 starts switching processing for switching the third optical head 231 to the fourth optical head 232, the fourth optical head 232 is present in a position 158 on the locus 156. At this time, the third optical head 231 is located at a first end 150 of the substrate W. The switching to the fourth optical head 232 is completed at the time when the fourth optical head 232 reaches a second end 152 of the substrate W.

[0106] Here, "the switching is completed" means that the fourth optical head 232 becomes capable of acquiring a signal corresponding to the film thickness of the substrate W. Note that it is not essential that the switching is completed when the fourth optical head 232 reaches the end 152. For example, the switching is completed before the end 152 and acquisition of data is started. Since light from the fourth optical head 232 does not shine on the substrate W, the data is not used for end point detection and the like. The switching may be completed when the third optical head 231 is located further on the inner side of the substrate W than the end 150.

[0107] That is, the problems of the related art, that is, "the switching is delayed" or "data acquisition at the end of the substrate W is insufficient" because "the switching is delayed" can be solved by the embodiment shown in Fig. 18. However, when the switching is completed is determined according to necessity. When the rotating speed of the polishing table 20 is high and, in particular, the number of sensors on the locus 156 is large, to perform measurement in a desired region where data is desired to be acquired, it is necessary to perform switching considering a response delay of switching processing to the following optical head when the preceding optical head on the locus 156 is present under the substrate W.

[0108] In the case of the figure, the fourth optical head 232 moves from the position 158 to the second end 152 during the switching. To which time timing of a switching start is set, that is, how long before the second end 152 the switching should be started depends on factors described below. That is, the switching start is earlier as the rotating speed of the polishing table 20 is higher and the response delay is larger. The switching start being

earlier means that, in another expression, the distance between the position 158 where the switching is started and the second end 152 is longer.

[0109] In the figure, the third optical head 231 is located at the first end 150 at the switching start time. However, the switching is sometimes started when the third optical head 231 is present between the first end 150 and the second end 152. This case is shown in Fig. 19. In Fig. 19, the switching is started when the third optical head 231 is located in a position 161 and the fourth optical head 232 is located in a position 162. That is, the position of the third optical head 231 at the switching start time is closer to the second end 152 as the rotating speed of the polishing table 20 is higher, the magnitude of the response delay is larger, and the number of optical heads disposed on the locus 156 is larger. For example, it could occur that it is necessary to start the switching processing when the third optical head 231 has not yet advanced halfway across the substrate, that is, when the third optical head 231 is located between the center 50 of the substrate W and the second end 152.

[0110] In Fig. 19, considering the above, before the third optical head 231 (one sensor head) facing the substrate W reaches the terminal end 150 of a locus passing under the substrate W, in the position 161, the switching processing from the third optical head 231 to the fourth optical head 232 (the other sensor head) not facing the substrate W is started. The third optical head 231 starts the switching while leaving a measurable region between the position 161 and the terminal end 150. When the switching processing is completed, the fourth optical head 232 is located in a position 170. Switching is performed from the sensor head facing the substrate to the sensor head not facing the substrate.

[0111] In Figs. 18 and 19 and Figs. 20 and 21 referred to below, the fourth optical head 232 is located in the vicinity of the second end 152 when the switching processing is started. The fourth optical head 232 passes the second end 152 of the substrate W when moving from a vicinity position not facing the substrate W to a position facing the substrate W. The third optical head 231 passes the first end 150 of the substrate W when moving from a position facing the substrate W to a position not facing the substrate W. The fourth optical head 232 is located in the vicinity of the second end 152 when the switching processing from the

third optical head 231 to the fourth optical head 232 is started.

[0112] The vicinity of the second end 152 is, for example, as explained below. The vicinity of the second end 152 is a peripheral region of the second end 152 where the fourth optical head 232 can be present and is a presence range of the fourth optical head 232 in which the fourth optical head 232 can reach the second end 152, the inside of the substrate W, or the outside of the substrate W from when the processor 15 starts the switching until when the switching is completed in the switcher 40. In the case of Fig. 18, the vicinity includes at least the locus 156 from the position 158 to the second end 152. In the case of Fig. 18, the switching is started in the position of the fourth optical head 232 shown in the figure. The switching is completed in the switcher 40 when the fourth optical head 232 reaches the position of the second end 152 shown in the figure. "The switching is completed" means that film thickness measurement by the fourth optical head 232 is possible. The switching may be completed before the second end 152 in good time. The range of the vicinity is, for example, a range of one eighth of the total length of the locus 156 on each of both sides of the second end 152 on the locus 156, a range of quarter of the total length in total. When the vicinity is indicated by an angle, one eighth of 360 degrees is 45 degrees and an angle 160 shown in the figure is 45 degrees. A range of 45 degrees on each of both sides from the second end 152 is an example of the vicinity. Since the fourth optical head 232 is present in the position 158, the fourth optical head 232 is within a range of 45 degrees on the locus 156. Note that the position 158 where the switching is started may not be present in the vicinity of the second end 152. This is because, for example, when the response delay is large, the position 158 is sometimes absent in the vicinity of the second end 152.

[0113] A specific example of a switching method is as explained below. For example, when the processor 15 checks the position or the angle of the fourth optical head 232 and confirms that the fourth optical head 232 has approached the second end 152 up to a predetermined distance or angle (in Fig 18, to the position 158), the processor 15 starts the switching. The predetermined position or angle can be determined by, for example,

measuring a response delay using test polishing before actual polishing. The predetermined position or angle is preferably as close as possible to the second end 152. This is because a polishing state can be measured up to as close as possible to the end of the substrate W by the third optical head 231. A method of checking the position or the angle of the fourth optical head 232 is performed by, for example, detecting a rotation angle of the polishing table 20.

[0114] For the detection of the rotation angle, an angle sensor (not shown) can be used. That is, a dog (not shown) is attached to the polishing table 20 to make it possible to detect the position of the polishing table 20 when the polishing table 20 rotates. The angle sensor detects the dog. In every rotation, the processor 15 starts the switching processing after a predetermined time elapses from the detection of the dog. Alternatively, a rotation phase may always be grasped by an encoder that detects an angle of a rotary motor of the polishing table 20.

[0115] In the embodiment shown in Figs. 18, 19, and 20, while one optical head is still present under the substrate W, the processor 15 switches the one optical head to an optical head that enters under the substrate W next. This is because, if the one optical head is switched to the next optical head after the one optical head exits under the substrate W, the switching is sometimes late because of a response delay or the like.

[0116] In the polishing method for polishing the substrate W, which is the embodiment shown in Figs. 18, 19, and 20, the polishing table 20 holds the polishing pad 22. The polishing head 24 presses the surface of the substrate W against the polishing pad 22. The third optical head 231, the fourth optical head 232, and the fifth optical head 233 detect a signal concerning the film thickness of the substrate W while moving across the substrate W. The one signal processor 14 receives and processes signals output by the third optical head 231, the fourth optical head 232, and the fifth optical head 233. The switcher 40 selectively connects the third optical head 231, the fourth optical head 232, and the fifth optical head 233 to the spectrometer 14. The controller 15 controls the switcher 40 to start, at timing when the third optical head faces the substrate and the fourth optical head does not face the substrate, the switching processing for switching connection to the spectrometer 14 from the

third optical head facing the substrate to the fourth optical head not facing the substrate.

[0117] In Figs. 18, 19, and 20, the optical heads are provided. However, the present invention is not limited to the optical thickness measurement device and can also be applied to other thickness measurement devices such as an eddy current sensor. For example, the eddy current sensor, which is a film thickness sensor, may be disposed according to the example shown in Figs. 18, 19, and 20. At this time, a switcher (an electric switch) selectively connects at least two sensors to a signal processor (an electronic circuit). One signal processor receives and processes signals output by at least two eddy current sensors among a plurality of eddy current sensors. A control device (an electronic circuit) controls the switcher to start, at timing when a third sensor of at least two sensors face a substrate and a fourth sensor of the at least two sensors does not face the substrate, switching processing for switching the connection to the signal processor from the third sensor facing the substrate to the fourth sensor not facing the substrate.

[0118] Usually, a bevel portion (a chamfered and cut portion present in the outer circumference of the substrate W; the chamfered portion is a curved surface or a flat surface) is present at the end of the substrate W. A non-device region where a device is not formed is present in the bevel portion. The end in this specification can be interpreted as the outermost edge of the substrate W and can also be interpreted as an interface between the non-device region and a device region.

[0119] As an embodiment of the present invention, in some case, the switcher is sometimes controlled to start, at timing when one sensor head of the at least two sensor heads faces the substrate and the other does not face the substrate, the switching processing for switching the connection to the spectrometer from the other sensor head to one sensor head. For example, when the fourth optical head 232 only advances less than half on the substrate W, that is, the fourth optical head 232 is located between the center 50 of the substrate W and the second end 152, it could occur that it is necessary to start the switching processing from the third optical head 231 to the fourth optical head 232. That is, after the fourth optical head 232 (one sensor head) facing the substrate W passes a start point 152 of a locus passing

under the substrate W, the switching processing from the third optical head 231 (the other sensor head) not facing the substrate W to the fourth optical head 232 is started. Switching is performed from the sensor head not facing the substrate to the sensor head facing the substrate.

[0120] An example of the positions of the third optical head 231 and the fourth optical head 232 at this time are shown in Fig. 20. In Fig. 20, the fourth optical head 232 is located in a position 164 and the third optical head 231 is located in a position 166. At this time, the switching processing from the third optical head 231 to the fourth optical head 232 is started. The switching processing is completed and measurement of a film thickness is started when the fourth optical head 232 reaches a position 168. The fourth optical head 232 passes a measurable region on the substrate W while moving from the start point 152 of the locus to the position 168.

[0121] One of a form shown in Figs. 18 and 19 and a form shown in Fig. 20 can be selected as appropriate according to, for example, the quality of data acquired from a sensor head. This is because the quality of film thickness data obtained in the former half portion of the substrate W and the quality of film thickness data obtained in the latter half portion of the substrate W are sometimes different. Figs. 18 and 19 show a form in which measurement from an end in the former half portion is prioritized over measurement in the latter half portion among measurement points on the locus 156 of the substrate W. On the other hand, Fig. 20 shows a form in which measurement to the end in the latter half portion is prioritized over measurement in the former half portion.

[0122] The polishing apparatus 110 further includes, as shown in Fig. 19, a swinging device 172 that swings the polishing head 24 on the polishing pad 22 during polishing. When swinging the polishing head 24, the polishing apparatus 110 controls, according to a swinging position of the polishing head 24, timing for starting the switching processing. The swinging device 172 includes a shaft 174 coupled to a polishing head shaft 28 and a motor 178 that swings the shaft 174 around a swinging center 176.

[0123] At the timing for starting the switching processing, for example, the form shown

in Fig. 19 and a form shown in Fig. 21 explained below are switched according to a swinging position. This is because, even if a response delay in the switching processing is the same, a positional relation between a sensor head and a substrate changes according to a swinging position of a polishing head. When the polishing head 24 is swung, if the switching processing is started from the same position on the polishing table 20, the fourth optical head 232 can or cannot reach the end of the substrate W before measurement is started. That is, optimum switching timing is likely to change according to a swinging position.

[0124] Next, an embodiment shown in Fig. 21 is explained. In this embodiment, after the third optical head 231 passes under the substrate W and exits to the outside of the substrate W, switching processing to the fourth optical head 232 present on the outside of the substrate W is started. Switching from a sensor facing the substrate to a sensor not facing the substrate is performed. Completion of the switching to the fourth optical head 232, that is, a measurement start is performed after the fourth optical head 232 enters the inner side of the substrate W. Measurement from the end 152 to a measurement start point 180 is not performed. This is because quality of data is sometimes low because, for example, a measurement value is unstable in measurement of the former half in measurement from the position 152 (the start point of the locus) to the position 150 (the end point of the locus). Measurement accuracy is improved by not performing measurement in a portion where data is disarranged.

[0125] In Fig. 21, a switcher is controlled to start, at timing when the fourth optical head 232 (one sensor head) of at least two sensor heads does not face the substrate (is in the position 158), switching processing for switching connection to a spectrometer from the third optical head 231 (the other sensor head) to the fourth optical head 232 of the at least two sensor heads. The switching processing is completed after the fourth optical head 232 passes a start point of a locus passing under the substrate W. The switching processing is started at timing when the third optical head 231 does not face the substrate W.

[0126] In the figure, the switching from the sensor head not facing the substrate to the sensor head not facing the substrate is performed. The position 180 is the position of the

fourth optical head 232 at the time when the switching is completed. The measurement is started after the fourth optical head 232 passes a start portion of a measurable region.

[0127] In the embodiment shown in Fig. 21 as well, the polishing apparatus 110 may further include a swinging device that swings a polishing head on a polishing pad during polishing and control timing for starting switching processing according to a swinging position of the polishing head.

[0128] In a polishing method for polishing the substrate W, which is the embodiment shown in Fig. 21, the polishing table 20 holds the polishing pad 22. The polishing head 24 presses the surface of the substrate W against the polishing pad 22. The third optical head 231 and the fourth optical head 232 detect a signal concerning the film thickness of the substrate W while moving across the substrate W. The one signal processor 14 receives and processes signals output by the third optical head 231 and the fourth optical head 232. The switcher 40 selectively connects the third optical head 231 and the fourth optical head 232 to the spectrometer 14. The controller 15 controls the switcher 40 to start, at timing when the fourth optical head 232 does not face the substrate, switching processing for switching the connection to the signal processor 14 from the third optical head 231 to the fourth optical head 232. The controller 15 controls the switcher 40 such that the switching processing is completed after the fourth optical head 232 passes the start point 152 of the locus passing under the substrate.

[0129] In Fig. 21, the optical heads are provided. However, the present invention is not limited to the optical thickness measurement device and can also be applied to other thickness measurement devices such as an eddy current sensor. For example, the eddy current sensor, which is a film thickness sensor, may be disposed according to the example shown in Fig. 21. At this time, a switcher (an electric switch) selectively connects at least two sensors to a signal processor (an electronic circuit). One signal processor receives and processes signals output by at least two eddy current sensors among a plurality of eddy current sensors. A control device (an electronic circuit) controls the switcher to start, at timing when one sensor of at least two sensors does not face a substrate, switching processing

for switching the connection to the signal processor from the other sensor to one sensor.

The control device controls the switcher such that the switching processing is completed after one sensor passes a start point of a locus passing under the substrate.

[0130] The examples of the embodiments of the present invention are explained above. However, the embodiments of the invention explained above are for facilitating understanding of the present invention and is not for limiting the present invention. It goes without saying that the present invention can be changed and improved without departing from the gist of the present invention and the present invention includes equivalents of the present invention. Any combination or omission of the constituent elements described in the claims and the specification is possible in a range in which at least a part of the problems described above can be solved or a range in which at least a part of the effects described above can be achieved.

[0131] This application claims priority under the Paris Convention to Japanese Patent Application No. 2022-208670 filed on December 26, 2022 and Japanese Patent Application No. 2023-189873 filed on November 7, 2023. The entire disclosure of Japanese Patent No. 6470365 including specification, claims, drawings and summary is incorporated herein by reference in its entirety.

REFERENCE SIGNS LIST

[0132]	O	axis
	11	light projector
	12	light receiver
	14	spectrometer
	15	processor
	16	light source
	20	polishing table
	22	polishing pad
	24	polishing head

40	optical switch
50	center
52	locus
66	optical switch
68	peripheral edge portion
110	polishing apparatus
131 to 134	first sensor head
141 to 144	second sensor head
231	third sensor head
232	fourth sensor head

WHAT IS CLAIMED IS:

1. A polishing apparatus that polishes a substrate, the polishing apparatus comprising:
 - a polishing table for holding a polishing pad;
 - a polishing head configured to press a surface of the substrate against the polishing pad;
 - a plurality of sensor heads configured to detect a signal concerning a film thickness of the substrate while moving across the substrate;
 - one spectrometer configured to receive and process signals output by at least two sensor heads among the plurality of sensor heads;
 - a switcher configured to selectively connect the at least two sensor heads to the spectrometer; and
 - a controller, wherein
 - the controller controls the switcher to switch, at timing when the at least two sensor heads simultaneously face the substrate, the connection to the spectrometer from one sensor head to another sensor head.
2. The polishing apparatus according to claim 1, wherein the polishing table is configured to rotate around an axis of the polishing table, and the plurality of sensor heads are disposed in a region of the polishing table facing a region including a center of the substrate.
3. The polishing apparatus according to claim 2, wherein
 - each two of a predetermined even number of the sensor heads among the plurality of sensor heads form a pair,
 - the two sensor heads forming the pair are present substantially in positions on opposite sides to each other with respect to the axis, and
 - the even number of the sensor heads are disposed such that lines connecting the two sensor heads forming each of the pairs are at a same angle interval around the axis.

4. The polishing apparatus according to claim 2, wherein
in predetermined four sensor heads among the plurality of sensor heads,
two sensor heads are present substantially in positions on opposite sides to each
other with respect to the axis, and other two sensor heads are present substantially in
positions on opposite sides to each other with respect to the axis, and

an angle formed by a line connecting the two sensor heads and a line connecting
the other two sensor heads is larger than 0 degrees and smaller than 180 degrees.

5. The polishing apparatus according to any one of claims 1 to 4, wherein the
polishing apparatus includes, as the plurality of sensor heads, a first sensor head configured
to detect the signal concerning the film thickness of the substrate in a region including a
center of the substrate and a second sensor head configured to detect the signal concerning
the film thickness of the substrate while moving along a peripheral edge portion of the
substrate.

6. The polishing apparatus according to claim 5, wherein
there are at least two first sensor heads as a plurality of the first sensor heads, and
there are at least two sensor heads as a plurality of the second sensor heads,

the two first sensor heads are present substantially in positions on opposite sides
to each other with respect to the axis,

the axis is present on a line segment connecting the two second sensor heads, and
an angle formed by a line connecting the two first sensor heads and the line
segment connecting the second sensor heads is 0 degrees to 180 degrees.

7. The polishing apparatus according to any one of claims 1 to 4, wherein, in a
predetermined number of the sensor heads among the plurality of sensor heads and a
predetermined number of other sensor heads among the plurality of sensor heads,

each one of the predetermined number of other sensor heads is disposed on lines
respectively connecting the predetermined number of sensor heads and the axis of the
polishing table.

8. The polishing apparatus according to any one of claims 1 to 4, wherein

in predetermined two sensor heads among the plurality of sensor heads and other predetermined four sensor heads among the plurality of sensor heads,

the predetermined two sensor heads are present substantially in positions on opposite sides to each other with respect to the axis,

the axis is present on a first line segment connecting two sensor heads among the predetermined four sensor heads,

the axis is present on a second line segment connecting other two sensor heads among the predetermined four sensor heads, and

an angle formed by the first line segment and the second line segment is 0 degrees to 180 degrees.

9. The polishing apparatus according to claim 8, wherein

the predetermined four sensor heads are disposed symmetrically with respect to a third line connecting the predetermined two sensor heads, and

a minimum angle among angles formed by the third line and the first line segment is smaller than 90 degrees and a minimum angle among angles formed by the third line and the second line segment is smaller than 90 degrees.

10. A polishing method for polishing a substrate, the polishing method comprising:

a polishing table holding a polishing pad;

a polishing head pressing a surface of the substrate against the polishing pad;

a plurality of sensor heads detecting a signal concerning a film thickness of the substrate in a region including a center of the substrate while moving across the substrate;

one spectrometer receiving and processing signals output by the plurality of sensor heads;

a switcher selectively connecting at least two of the sensor heads to the spectrometer; and

a controller controlling the switcher to switch the connection to the spectrometer from one sensor head to another sensor head at a time when the at least two sensor heads simultaneously face the substrate.

11. A polishing apparatus that polishes a substrate, the polishing apparatus comprising:

a polishing table for holding a polishing pad;

a polishing head configured to press a surface of the substrate against the polishing pad;

a plurality of sensors configured to detect a signal concerning a film thickness of the substrate while moving across the substrate;

one signal processor configured to receive and process signals output by at least two sensors among the plurality of sensors;

a switcher configured to selectively connect the at least two sensors to the signal processor; and

a controller, wherein

the controller controls the switcher to switch, at timing when the at least two sensors simultaneously face the substrate, the connection to the signal processor from one sensor to another sensor.

12. A polishing apparatus that polishes a substrate, the polishing apparatus comprising:

a polishing table for holding a polishing pad;

a polishing head configured to press a surface of the substrate against the polishing pad;

a plurality of sensor heads configured to detect a signal concerning a film thickness of the substrate while moving across the substrate;

one spectrometer configured to receive and process signals output by at least two sensor heads among the plurality of sensor heads;

a switcher configured to selectively connect the at least two sensor heads to the spectrometer; and

a controller, wherein

the controller controls the switcher to start, at timing when one sensor head of the

at least two sensor heads faces the substrate and another does not face the substrate, switching processing for switching the connection to the spectrometer from the one sensor head to the other sensor head or from the other sensor head to the one sensor head.

13. The polishing apparatus according to claim 12, wherein
the other sensor head passes an end of the substrate when moving from a position not facing the substrate to a position facing the substrate, and
when the switching processing is started, the other sensor head is located in a vicinity of the end.

14. The polishing apparatus according to claim 12, wherein, before the one sensor head facing the substrate reaches a terminal end of a locus passing under the substrate, the switching processing from the one sensor head to the other sensor head not facing the substrate is started.

15. The polishing apparatus according to claim 12, wherein, after the one sensor head facing the substrate passes a start point of a locus passing under the substrate, the switching processing from the other sensor head not facing the substrate to the one sensor head is started.

16. The polishing apparatus according to claim 12, further comprising a swinging device configured to swing the polishing head on the polishing pad during polishing, wherein
the timing for starting the switching processing is controlled according to a swinging position of the polishing head.

17. A polishing apparatus that polishes a substrate, the polishing apparatus comprising:

a polishing table for holding a polishing pad;

a polishing head configured to press a surface of the substrate against the polishing pad;

a plurality of sensor heads configured to detect a signal concerning a film thickness of the substrate while moving across the substrate;

one spectrometer configured to receive and process signals output by at least two

sensor heads among the plurality of sensor heads;

a switcher configured to selectively connect the at least two sensor heads to the spectrometer; and

a controller, wherein

the controller controls the switcher to start, at timing when one sensor head of the at least two sensor heads does not face the substrate, switching processing for switching the connection to the spectrometer from another sensor head to the one sensor head, and the switching processing is completed after the one sensor head passes a start point of a locus passing under the substrate.

18. The polishing apparatus according to claim 17, wherein the switching processing is started at timing when the other sensor head does not face the substrate.

19. The polishing apparatus according to claim 17, further comprising a swinging device configured to swing the polishing head on the polishing pad during polishing, wherein the timing for starting the switching processing is controlled according to a swinging position of the polishing head.

20. A polishing method for polishing a substrate, the polishing method comprising:
a polishing table holding a polishing pad;
a polishing head pressing a surface of the substrate against the polishing pad;
a plurality of sensor heads detecting a signal concerning a film thickness of the substrate while moving across the substrate;

one spectrometer receiving and processing signals output by at least two sensor heads among the plurality of sensor heads;

a switcher selectively connecting the at least two sensor heads to the spectrometer; and

a controller controlling the switcher to start, at timing when one sensor head of the at least two sensor heads faces the substrate and another sensor head does not face the substrate, switching processing for switching the connection to the spectrometer from the one sensor head to the other sensor head or from the other sensor head to the one sensor head.

21. A polishing apparatus that polishes a substrate, the polishing apparatus comprising:

a polishing table for holding a polishing pad;

a polishing head configured to press a surface of the substrate against the polishing pad;

a plurality of sensors configured to detect a signal concerning a film thickness of the substrate while moving across the substrate;

one signal processor configured to receive and process signals output by at least two sensors among the plurality of sensors;

a switcher configured to selectively connect the at least two sensors to the signal processor; and

a controller, wherein

the controller controls the switcher to start, at timing when one sensor of the at least two sensors faces the substrate and another sensor does not face the substrate, switching processing for switching the connection to the signal processor from the one sensor to the other sensor or from the other sensor to the one sensor.

22. A polishing method for polishing a substrate, the polishing method comprising:

a polishing table holding a polishing pad;

a polishing head pressing a surface of the substrate against the polishing pad;

a plurality of sensor heads detecting a signal concerning a film thickness of the substrate while moving across the substrate;

one spectrometer receiving and processing signals output by at least two sensor heads among the plurality of sensor heads;

a switcher selectively connecting the at least two sensor heads to the spectrometer; and

a controller controlling the switcher to start, at timing when one sensor head of the at least two sensor heads does not face the substrate, switching processing for switching the connection to the spectrometer from another sensor head to the one sensor head and

controlling the switcher such that the switching processing is completed after the one sensor head passes a start point of a locus passing under the substrate.

23. A polishing apparatus that polishes a substrate, the polishing apparatus comprising:

- a polishing table for holding a polishing pad;

- a polishing head configured to press a surface of the substrate against the polishing pad;

- a plurality of sensors configured to detect a signal concerning a film thickness of the substrate while moving across the substrate;

- one signal processor configured to receive and process signals output by at least two sensors among the plurality of sensors;

- a switcher configured to selectively connect the at least two sensors to the signal processor; and

- a controller, wherein

- the controller controls the switcher to start, at timing when one sensor of the at least two sensors does not face the substrate, switching processing for switching the connection to the signal processor from another sensor to the one sensor and controls the switcher such that the switching processing is completed after the one sensor passes a start point of a locus passing under the substrate.