

POLISHING APPARATUS

TECHNICAL FIELD

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

BACKGROUND ART

[0002] Conventionally, a polishing apparatus is used for polishing a to-be-polished object such as a semiconductor substrate or the like, for example. A polishing apparatus comprises a polishing table to which a polishing pad is attached, and a polishing head to which a substrate, which is an object of polishing, is attached. In the polishing apparatus, a substrate is polished by supplying a polishing liquid to the polishing pad, and rotating, in the state that the polishing pad and the substrate are in contact with each other, at least one of the polishing table and the polishing head.

[0003] The polishing table is provided with a film thickness sensor for monitoring the quantity of polishing with respect to a substrate or a film on a substrate. An eddy current sensor, which is able to measure the thickness of a conductive film on a substrate, may be used as a film thickness sensor (for example, refer to Patent Literature 1).

CITATION LIST

PATENT LITERATURE

[0004] PTL 1: Japanese Patent Application Public Disclosure No. 2011-023579

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] Generally, the degree of measurement sensitivity of an eddy current sensor changes according to the type of material, thickness, and so on of a film which is an object to be measured. It is desirable to use, depending on the type of material, thickness, and so on of a to-be-measured film, an eddy current sensor having a sensor characteristic(s) that is(are) most suitable therefor.

[0006] The present invention has been achieved in view of the above point; and an object of the invention is to provide a polishing apparatus which is able to efficiently monitor

film thickness of any of various kinds of to-be-polished objects.

SOLUTION TO PROBLEM

[0007] According to an embodiment, a polishing apparatus for polishing a to-be-polished object is provided: and the polishing apparatus comprises: a polishing head constructed to allow the to-be-polished object to be attached thereto, a polishing table which is arranged to face the to-be-polished object attached to the polishing head and constructed to be able to rotate, and a film thickness measuring system for measuring film thickness of a conductive film on the to-be-polished object which is polished by the polishing apparatus; the film thickness measuring system comprises multiple sensor heads installed in the polishing table, wherein each sensor head comprises an eddy current sensor, and a controller; and the controller comprises an oscillator which creates a common clock signal for driving the eddy current sensors, and multiple control circuits installed to correspond to the multiple sensor heads, respectively, wherein each control circuit is constructed to create, based on the clock signal from the oscillator, a driving signal supplied to an eddy current sensor in a corresponding sensor head and process a measurement signal received from the eddy current sensor in the corresponding sensor head.

[0008] In the above embodiment, each eddy current sensor in one or more sensor heads in the multiple sensor heads may have a sensor characteristic that is different from that of each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads.

[0009] In the above embodiment, each eddy current sensor in one or more sensor heads in the multiple sensor heads may be that corresponding to a film type that is different from a film type to that each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads corresponds.

[0010] In the above embodiment, each eddy current sensor in one or more sensor heads in the multiple sensor heads may be that corresponding to film thickness that is different from film thickness to that each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads corresponds.

[0011] In the above embodiment, each eddy current sensor in one or more sensor heads in the multiple sensor heads may be that having spatial resolution that is different from spatial resolution that each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads has.

[0012] In the above embodiments, the controller comprises a switch for performing switching of the sensor heads in accordance with a polishing recipe for making an eddy current sensor having an optimum sensor characteristic be used.

BRIEF DESCRIPTION OF DRAWINGS

[0013] Fig. 1 is a schematic drawing which shows a construction of a polishing apparatus according to an embodiment of the present invention.

Fig. 2 is a schematic drawing which shows a construction of a film thickness measuring system installed in a polishing apparatus according to an embodiment of the present invention.

Fig. 3 is a schematic drawing which shows a construction of a film thickness measuring system in a prior-art form.

Fig. 4A is a drawing which shows an example of a construction comprising multiple sensor heads in a film thickness measuring system according to an embodiment of the present invention.

Fig. 4B is a drawing which shows an example of a construction comprising multiple sensor heads in a film thickness measuring system according to an embodiment of the present invention.

Fig. 5 is a drawing which shows examples of arrangements of multiple sensor heads in polishing tables in film thickness measuring systems according to embodiments of the present invention.

DESCRIPTION OF EMBODIMENTS

[0014] In the following description, embodiments of the present invention will be explained with reference to the figures. In the figures that will be explained in the following description, a reference symbol assigned to one component is also assigned to the other

component if the other component is the same as or corresponds to the one component, and overlapping explanation of these components will be omitted.

[0015] Fig. 1 is a schematic drawing which shows a construction of a polishing apparatus 10 according to an embodiment of the present invention. As shown in the figure, the polishing apparatus 10 comprises a polishing table 30 for holding a polishing pad 31, and a top ring 40 (a polishing head) for holding a substrate (a wafer Wf), which is an object of polishing, in such a manner that the substrate faces the polishing pad 31, and pushing the substrate to a polishing surface of the polishing pad 31.

[0016] The polishing table 30 is connected, via a table shaft 32, to a table driving motor (which is not shown in the figure) positioned below the table shaft 32. The table driving motor is driven to rotate, and, accordingly, the polishing table 30 is able to rotate about an axis of the table shaft 32. The polishing pad 31 is attached to a top surface of the polishing table 30. A surface 311 of the polishing pad 31 comprises a polishing surface for polishing the wafer Wf. A polishing liquid supplying nozzle, which is not shown in the figure, is arranged in a position above the polishing table 30, and a polishing liquid is supplied from the polishing liquid supplying nozzle to the polishing pad 31 on the polishing table 30.

[0017] An eddy current sensor 80 is installed in the inside of the polishing table 30. The eddy current sensor 80 is installed in such a manner that the eddy current sensor 80 passes over the center of the wafer Wf when the polishing table 30 is rotated during a polishing process. The eddy current sensor 80 is connected to a controller 100 via a signal cable 81. The eddy current sensor 80 is constructed to induce eddy current in a conductive film on a surface of the wafer Wf. The eddy current sensor 80 is further constructed to output, in response to change in impedance due to a magnetic field created by the eddy current, a signal corresponding to the thickness of the conductive film on the surface of the wafer Wf. By using the output signal from the eddy current sensor 80, the thickness of the conductive film on the surface of the wafer Wf can be obtained. In this regard, although a single eddy current sensor 80 only is shown in Fig. 1, multiple eddy current sensors 80 may be installed in the inside of the polishing table 30 as shown in Fig. 2 or Fig. 5 which will be

explained below.

[0018] The top ring 40 is supported by an arm 50 via a top ring shaft 42. By using an up-and-down motion mechanism which is not shown in the figure, the top ring shaft 42 is able to move upward and downward in relation to the arm 50. Positioning of the top ring 40 relative to the arm 50 may be performed by moving the top ring 40 upward/downward by making the top ring shaft 42 move upward and downward. The top ring 40 is constructed to hold, on its bottom surface, the wafer Wf. Specifically, as shown in Fig. 1, the top ring 40 comprises a retainer ring 41A which holds an outer peripheral edge of the wafer Wf to prevent the wafer Wf from jumping out of the top ring 40, and a top-ring main body 41B which pushes the wafer Wf to the polishing surface 311.

[0019] A top ring driving motor 43 is fixed to the arm 50 which supports the top ring 40. Further, as shown in Fig. 1, the top ring shaft 42 is connected to a rotary cylinder 61; and a timing pulley 62 installed on an outer periphery of the rotary cylinder 61 is connected, via a timing belt 63, to a timing pulley 64 installed on the top ring driving motor 43. According to the above construction, as the top ring driving motor 43 rotates, the rotary cylinder 61 and the top ring shaft 42 integrally rotates via the timing pulley 64, the timing belt 63, and the timing pulley 62; and the top ring 40 rotates about the axis of the top ring shaft 42.

[0020] The arm 50 is connected to an arm driving motor 53 which is fixed to an arm shaft 52. The arm 50 and the top ring 40 supported by the arm 50 are able to rotate about the axis of the arm shaft 52 by driving the arm driving motor 53.

[0021] When the polishing apparatus 10 performs action, first, the top ring 40 receives, at a predetermined receiving position, the wafer Wf conveyed by a conveyance mechanism which is not shown in the figure, and holds the wafer Wf. The top ring 40, which has received the wafer Wf at the receiving position, is moved from the receiving position to a position above the polishing table 30 by rotational movement of the arm 50. Next, the top ring shaft 42 and the top ring 40 are moved downward, and, accordingly, the wafer Wf is pushed to the polishing surface 311 of the polishing pad 31. Thereafter, the table driving motor and the top ring driving motor 43 are driven to rotate them to thereby rotate the

polishing table 30 and the top ring 40, respectively; and, at the same time, a polishing liquid is supplied on the polishing pad 31 from the polishing liquid supplying nozzle installed in a position above the polishing table 30. According to the above construction, the wafer Wf is brought into contact, in a sliding contact manner, with the polishing surface 311 of the polishing pad 31, and the surface of the wafer Wf is polished accordingly. During polishing of the wafer Wf, polishing may be performed in such a manner that the top ring 40 is moved in a swinging manner relative to the polishing pad 31 (i.e., it is moved back and forth on the polishing pad 31) by making the arm 50 periodically rotate to the left and to the right by the arm driving motor 53.

[0022] Fig. 2 is a schematic drawing which shows a construction of a film thickness measuring system 20 installed in the polishing apparatus 10 according to an embodiment of the present invention. The film thickness measuring system 20 is a system for measuring the film thickness of a conductive film on a wafer Wf which is to be polished by the polishing apparatus 10, and comprises multiple sensor heads (eddy current sensors) 80 and a controller 100 for controlling the multiple sensor heads 80.

[0023] Each of the sensor heads 80 in the multiple sensor heads (eddy current sensors) 80 comprises a sensor coil 81 and an impedance matching resistor 82. Each sensor head (each eddy current sensor) 80 is installed in the inside of the polishing table 30 as explained above. The sensor coil 81 in each sensor head 80 makes eddy current be created in a conductive film on a surface of a wafer Wf by generating a magnetic field in response to a driving signal from the controller 100, and also creates a signal corresponding to the thickness of the conductive film on the surface of the wafer Wf in response to change in circuit impedance due to the eddy current.

[0024] The controller 100 comprises a driving circuit 100A and a detecting circuit 100B. The driving circuit 100A comprises an oscillator 110, a distributor 120, multiple multiplication circuits 130, multiple phase shifters 140, a switching circuit 150, multiple variable attenuators 160, multiple fixed gain amplifiers 170, and multiple impedance matching resistors 180. The detecting circuit 100B comprises multiple impedance matching

resistors 185, multiple AD (analog-digital) converters 190, and a signal processing circuit 195. The multiplication circuits 130, the phase shifters 140, the variable attenuators 160, the fixed gain amplifiers 170, the impedance matching resistors 180 and 185, and the AD converters 190 are installed to correspond to the multiple sensor heads 80, respectively.

[0025] Each of the components (the oscillator 110, the distributor 120, the multiplication circuits 130, and so on) of the driving circuit 100A may be housed in a single housing (for example, a metal housing). Similarly, each of the components (the signal processing circuit 195, the AD converters 190, and the impedance matching resistors 185) of the detecting circuit 100B may be housed in a single housing (for example, a metal housing). All components of the driving circuit 100A and the detecting circuit 100B may be housed in a single housing (for example, a metal housing).

[0026] The oscillator 110 creates a common clock signal (for example, a high frequency signal having a frequency of 1 MHz) for driving the multiple eddy current sensors 80. The distributor 120 distributes the clock signal from the oscillator 130 to the multiple multiplication circuits 130. Each multiplication circuit 130 in the multiple multiplication circuits 130 applies a multiplication process to the clock signal distributed by the distributor 120 to change its frequency to a frequency that falls within a frequency band used by an eddy current sensor 80 relating to the multiplication circuit 130. Each of the phase shifters 140 applies a phase shifting process, for synchronous detection, to a signal from a relating multiplication circuit 130.

[0027] The switching circuit 150 is a circuit for selecting and activating a driving signal(s) that is(are) to be supplied to an eddy current sensor(s) 80, which is(are) included in the multiple eddy current sensors 80 installed in the polishing table 30 and is(are) to be used actually. Specifically, the switching circuit 150 performs operation in such a manner that it supplies a signal(s) from a phase shifter(s) 140 to a variable attenuator(s) 160 relating to an eddy current sensor(s) 80 which is(are) to be used actually, and does not supply a signal(s) from the phase shifter(s) 140 to the variable attenuator(s) 160 relating to the eddy current sensor(s) 80 which is(are) not to be used. The number of driving signals that are to be

activated may be one or more than one. Selecting of a driving signal may be performed in accordance with a recipe created in advance, for example.

[0028] With respect to one or multiple driving signals which have been activated by the switching circuit 150, each driving signal is adjusted via a variable attenuator 160 and a fixed gain amplifier 170 to have predetermined signal strength, and supplied to a relating eddy current sensor 80. As a result, a magnetic field is generated by the sensor coil 81 in the eddy current sensor 80 and eddy current is created in a conductive film on the wafer Wf; and, in response thereto, a detection signal corresponding to the thickness of the conductive film is outputted from the eddy current sensor 80. The signal from the eddy current sensor 80 is inputted to the signal processing circuit 195 via the AD converter 190. The signal processing circuit 195 calculates the thickness of the conductive film on the surface of the wafer Wf by applying arithmetic processing to the detection signal from the eddy current sensor 80.

[0029] Fig. 3 is a schematic drawing which shows a construction of a film thickness measuring system 21 in a prior-art form. The film thickness measuring system 21 comprises multiple sensor units 80'. Each sensor unit 80' comprises a distributor 120, a multiplication circuit 130, a phase shifter 140, a variable amplifier 170, a sensor coil 81, a buffer circuit 186, an AD converter 190, and a signal processing circuit 195. Further, one of the multiple sensor units 80' additionally comprises an oscillator 110. The respective components in the sensor unit 80' are similar to those in the film thickness measuring system 20 in Fig. 2 explained above.

[0030] In the film thickness measuring system 21 in Fig. 3, the components of each of the sensor units 80' are housed in a single housing (for example, a metal housing) which is separate from other respective housings for other respective sensor units. Accordingly, a signal cable 122 for transmitting a clock signal, that is distributed from the distributor 120, to the other sensor unit(s) 80' is installed outside the housings. Thus, in the part of the signal cable 122 installed outside the housings, there may be a risk that noise from external environment is mixed into the clock signal.

[0031] On the other hand, in the film thickness measuring system 20 which has the construction according to the embodiment of the present invention shown in Fig. 2, the signal cable used for transmitting the clock signal is prevented from exposure to noise from external environment. Accordingly, it is possible to avoid deterioration of the quality of the clock signal due to mixture of noise, and improve accuracy of measurement of film thickness in the film thickness measuring system 20 using the eddy current sensor(s) 80.

[0032] Further, with respect to the sensor head 80 in the film thickness measuring system 20 according to the embodiment of the present invention, the number of parts of the sensor head 80 is less than that of the sensor head 80' in the film thickness measuring system 21 in the prior-art form, and, accordingly, the size of the sensor head 80 is smaller than that of the sensor head 80'. Thus, in the polishing apparatus 10 in Fig. 1 in which the film thickness measuring system 20 according to the embodiment of the present invention is installed, more sensor heads (eddy current sensors) 80 can be installed in the polishing table 30.

[0033] Each of Figs. 4A and 4B is a drawing which shows an example of a construction comprising multiple sensor heads 80 in a film thickness measuring system 20 according to an embodiment of the present invention. In the example in Fig. 4A, a type-1 sensor head 80A, a type-2 sensor head 80B, type-3 sensor heads 80C, and a type-4 sensor head 80D are connected to the controller 100. The sensor heads (eddy current sensors) 80A, 80B, 80C, and 80D of the respective types have respective different sensor characteristics.

Specifically, the type-2 sensor head 80B has sensor characteristics that are appropriate for measuring a thick film of film-type 1 (for example, Cu (copper)). The type-3 sensor head 80C has sensor characteristics that are appropriate for measuring a thin film of the film-type 1. The type-1 sensor head 80A has sensor characteristics that are appropriate for measuring thickness of a type-1 film in a wide variety of film thickness ranging from a thin film to a thick film, and are excellent in performance to detect an edge part of a film since spatial resolution in measurement is high (i.e., the spot diameter of a magnetic field generated by the sensor coil 84 is small). The type-4 sensor head 80D has sensor characteristics that are appropriate for measuring thickness of a type-2 film (for example, W (tungsten)) in a wide

variety of film thickness ranging from a thin film to a thick film.

[0034] According to a construction comprising multiple sensor heads 80, specifically, the construction such as that shown in Fig. 4A, measurement of film thickness in various types of films can be performed flexibly by performing switching of sensor heads to select a sensor head(s) 80 which is(are) to be used, by using the switching circuit 150 and in accordance with a recipe that has been prepared in advance to correspond to the type of a to-be-polished wafer Wf.

[0035] In the example in Fig. 4B, three type-1 sensor heads 80A and two type-3 sensor heads 80C are connected to the controller 100. In this example, accuracy of calculation of film thickness can be improved, by using multiple sensor heads 80 of the same type simultaneously and calculating film thickness, based on signals from the multiple sensor heads 80, by the signal processing circuit 195.

[0036] Fig. 5 is a drawing which shows examples of arrangement of multiple sensor heads 80 in polishing tables 30 in film thickness measuring systems 20 according to embodiments of the present invention. In arrangement example 1, a single type-1 sensor head 80A and a single type-2 sensor head 80B are installed in the polishing table 30. In arrangement example 2, two type-1 sensor heads 80A and a single type-3 sensor head 80C are installed in the polishing table 30. In arrangement example 3, three type-1 sensor heads 80A and a single type-2 sensor head 80B are installed in the polishing table 30. Further, in the arrangement example 3, a pressure sensor 85 may be installed in the polishing table 30. The pressure sensor 85 is that for detecting pressing force applied to the polishing table 30 by a wafer Wf held by the top ring 40. In addition to the pressure sensor 85 or in place of the pressure sensor 85, a temperature sensor for measuring temperature of a wafer Wf during polishing may be installed. In arrangement example 4, three type-1 sensor heads 80A, a single type-2 sensor head 80B, and three type-3 sensor heads 80C are installed in the polishing table 30. In arrangement example 5, four type-1 sensor heads 80A, four type-3 sensor head 80C, and four type-4 sensor heads 80D are installed in the polishing table 30. By installing the sensor heads 80 (80A, 80B, 80C, and 80D) of various types having different

sensor characteristics in the polishing table 30 as explained above, and appropriately selecting one or some of them by the switching circuit 150 (for example, in accordance with a recipe that has been prepared in advance to correspond to the type of a to-be-polished wafer Wf) and using it/them, measurement of thickness of a film on a wafer Wf in various types of wafers can be performed flexibly.

[0037] In the above description, embodiments of the present invention have been explained based on some examples; and, in this regard, the above explained embodiments of the present invention are those used for facilitating understanding of the present invention, and are not those used for limiting the present invention. It is obvious that the present invention can be changed or modified without departing from the scope of the gist thereof, and that the present invention includes equivalents thereof. Further, it is possible to arbitrarily combine components or omit a component(s) disclosed in the claims and the specification, within the scope that at least part of the above-stated problems can be solved or within the scope that at least part of advantageous effect can be obtained.

REFERENCE SIGNS LIST

- [0038]** 10 Polishing apparatus
20 Film thickness measuring system
30 Polishing table
31 Polishing pad
311 Polishing surface
32 Table shaft
40 Top ring
41A Retainer ring
41B Top-ring main body
42 Top ring shaft
43 Top ring driving motor
50 Arm
52 Arm shaft

- 53 Arm driving motor
- 61 Rotary cylinder
- 62 Timing pulley
- 63 Timing belt
- 64 Timing pulley
- 80 Eddy current sensor (Sensor head)
- 81 Sensor coil
- 82 Impedance matching resistor
- 100 Controller
- 100A Driving circuit
- 100B Detecting circuit
- 110 Oscillator
- 120 Distributor
- 130 Multiplication circuit
- 140 Phase shifter
- 150 Switching circuit
- 160 Variable attenuator
- 170 Fixed gain amplifier
- 180 Impedance matching resistor
- 185 Impedance matching resistor
- 190 AD converter
- 195 Signal processing circuit

WHAT IS CLAIMED IS:

1. A polishing apparatus for polishing a to-be-polished object comprising:
a polishing head constructed to allow the to-be-polished object to be attached thereto,
a polishing table which is arranged to face the to-be-polished object attached to the polishing head and constructed to be able to rotate, and
a film thickness measuring system for measuring film thickness of a conductive film on the to-be-polished object which is polished by the polishing apparatus;
wherein the film thickness measuring system comprises
multiple sensor heads installed in the polishing table, wherein each sensor head comprises an eddy current sensor, and
a controller;
wherein the controller comprises
an oscillator which creates a common clock signal for driving the eddy current sensors, and
multiple control circuits installed to correspond to the multiple sensor heads, respectively, wherein each control circuit is constructed to create, based on the clock signal from the oscillator, a driving signal supplied to an eddy current sensor in a corresponding sensor head and process a measurement signal received from the eddy current sensor in the corresponding sensor head.
2. The polishing apparatus as recited in Claim 1, wherein each eddy current sensor in one or more sensor heads in the multiple sensor heads has a sensor characteristic that is different from that of each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads.
3. The polishing apparatus as recited in Claim 2, wherein each eddy current sensor in one or more sensor heads in the multiple sensor heads is that corresponding to a film type that is different from a film type to that each eddy current sensor in one or more other eddy

current sensors in the multiple sensor heads corresponds.

4. The polishing apparatus as recited in Claim 2, wherein each eddy current sensor in one or more sensor heads in the multiple sensor heads is that corresponding to film thickness that is different from film thickness to that each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads corresponds.

5. The polishing apparatus as recited in Claim 2, wherein each eddy current sensor in one or more sensor heads in the multiple sensor heads is that having spatial resolution that is different from spatial resolution that each eddy current sensor in one or more other eddy current sensors in the multiple sensor heads has.

6. The polishing apparatus as recited in any one of Claims 2-5, wherein the controller comprises a switch for performing switching of the sensor heads in accordance with a polishing recipe for making an eddy current sensor having an optimum sensor characteristic be used.