METHOD FOR POLISHING A WORKPIECE

Inventors: Tatsuya KOHAMA, Tokyo (JP); Itsuki Kobata, Tokyo (JP); Toshikazu Nomura, Tokyo (JP)

Correspondence Address:
WENDEROTH, LIND & PONACK, L.L.P.
1030 15th Street, N.W., Suite 400 East
Washington, DC 20005-1503 (US)

Appl. No.: 12/367,037
Filed: Feb. 6, 2009

Related U.S. Application Data
Division of application No. 11/086,420, filed on Mar. 23, 2005.

Foreign Application Priority Data
Nov. 18, 2004 (JP) ............................... 2004-334548

Publication Classification
Int. Cl.
B24B 49/04 (2006.01)
B24B 49/12 (2006.01)
B24B 49/10 (2006.01)
B24B 57/02 (2006.01)

U.S. Cl. ....................... 451/6; 451/8; 451/57; 451/60

ABSTRACT
A polishing apparatus can supply a polishing liquid uniformly and efficiently to a surface to be polished of a workpiece. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a semiconductor wafer and pressing the semiconductor wafer against the polishing surface. The polishing apparatus also includes a polishing liquid supply port for supplying a polishing liquid to the polishing surface, and a moving mechanism for moving the polishing liquid supply port to distribute the polishing liquid uniformly over an entire surface of the workpiece due to relative movement of the workpiece and the polishing surface.
FIG. 35
FIG. 36A

FIG. 36B
METHOD FOR POLISHING A WORKPIECE

[0001] This application is a divisional of application Ser. No. 11/086,420, filed Mar. 23, 2005.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] The present invention relates to a polishing apparatus and a polishing method, and more particularly to a polishing apparatus and a polishing method for polishing a workpiece such as a semiconductor wafer or the like to a flat finish.
[0004] The present invention also pertains to an interconnects forming method, and more particularly to an interconnects forming method for forming interconnects in the form of a conductive film on a substrate such as a semiconductor wafer or the like.

[0005] 2. Description of the Related Art
[0006] Recent rapid progress in semiconductor device integration demands smaller and smaller wiring patterns or interconnects and also narrower spaces between interconnects which connect active areas. One of the processes available for forming such interconnects is photolithography. Though a photolithographic process can form interconnects that are at most 0.5 µm wide, it requires that surfaces on which pattern images are to be focused by a stepper be as flat as possible because depth of focus of an optical system is relatively small. It is therefore necessary to make surfaces of semiconductor wafers flat for photolithography. One customary way of flattening surfaces of semiconductor wafers is to polish them with a polishing apparatus, and such a process is called Chemical Mechanical Polishing (CMP).

[0007] A chemical-mechanical polishing (CMP) apparatus has a polishing table with a polishing pad disposed on its upper surface and a top ring positioned above the polishing pad. A semiconductor wafer to be polished is supported by the top ring and placed between the polishing pad and the top ring. While a polishing liquid or slurry is being supplied to the surface of the polishing pad, the top ring presses the semiconductor wafer against the polishing pad and rotates the semiconductor wafer relatively to the polishing pad, thereby polishing a surface of the semiconductor wafer to a flat mirror finish.


SUMMARY OF THE INVENTION

[0009] It is a first object of the present invention to provide a polishing apparatus which is capable of supplying a polishing liquid uniformly and efficiently to a surface to be polished of a workpiece.
[0010] A second object of the present invention is to provide a polishing apparatus which is capable of stably supplying a polishing liquid between a polishing surface and a workpiece to be polished.
[0011] A third object of the present invention is to provide a polishing apparatus which is capable of forming a uniform polishing liquid film on a polishing surface by holding a suitable amount of polishing liquid on the polishing surface even under conditions in which polishing pressure on the polishing surface is low and relative speed between the polishing surface and a workpiece is high.

[0012] A fourth object of the present invention is to provide a polishing apparatus which is capable of increasing an amount of polishing liquid held on a polishing surface thereby to increase working efficiency of the polishing liquid.
[0013] A fifth object of the present invention is to provide a polishing apparatus and a polishing method which are capable of keeping a polishing surface clean at all times to stabilize polishing characteristics of a polishing surface.

[0014] A sixth object of the present invention is to provide a polishing method which is capable of effectively washing away and removing residues such as a polishing liquid attached to a surface to be polished of a workpiece after the workpiece has been polished in a main polishing process.

[0015] A seventh object of the present invention is to provide a polishing method which is capable of preventing a previous polishing step from posing an undue load on a subsequent polishing step in a multi-step polishing process.

[0016] An eighth object of the present invention is to provide interconnects forming method which is capable of forming interconnects without causing defects therein.

[0017] According to a first aspect of the present invention, there is provided a polishing apparatus which is capable of supplying a polishing liquid uniformly and efficiently to a surface to be polished of a workpiece. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface. The polishing apparatus also includes a polishing liquid supply port for supplying a polishing liquid to the polishing surface, and a moving mechanism for moving the polishing liquid supply port to distribute the polishing liquid uniformly over an entire surface of the workpiece due to relative movement of the workpiece and the polishing surface.

[0018] The polishing liquid can uniformly and efficiently be supplied to the surface to be polished of the workpiece by moving the polishing liquid supply port while the workpiece is being polished. Specifically, since the polishing liquid supplied to the surface to be polished of the workpiece is distributed uniformly, a polishing rate of the workpiece is improved, and in-plane uniformity of the polishing rate is increased. As the polishing liquid is efficiently supplied, an amount of the polishing liquid used is reduced, and any wasteful consumption of the polishing liquid is reduced, thereby lowering a polishing cost.

[0019] According to a second aspect of the present invention, there is provided a polishing apparatus which is capable of supplying a polishing liquid uniformly and efficiently to a surface to be polished of a workpiece. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface. The polishing apparatus also includes a plurality of polishing liquid supply ports for supplying a polishing liquid to the polishing surface, and a liquid rate control mechanism for controlling rates of the polishing liquid supplied from the polishing liquid supply ports to distribute the polishing liquid uniformly over an entire surface of the workpiece due to relative movement of the workpiece and the polishing surface.

[0020] The polishing liquid can uniformly and efficiently be supplied to the surface to be polished of the workpiece by
controlling the rates of the polishing liquid supplied from the polishing liquid supply ports. Specifically, since the polishing liquid supplied to the surface to be polished of the workpiece is distributed uniformly, a polishing rate of the workpiece is increased, and in-plane uniformity of the polishing rate is increased. As the polishing liquid is efficiently supplied, an amount of the polishing liquid used is reduced, and any wasteful consumption of the polishing liquid is reduced, thereby lowering a polishing cost.

(0021) According to a third aspect of the present invention, there is provided a polishing apparatus which is capable of supplying a polishing liquid uniformly and efficiently to a surface to be polished of a workpiece. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface. The polishing apparatus also includes a distributor for distributing and supplying a polishing liquid to the polishing surface, and a polishing liquid supply port for supplying the polishing liquid to the distributor.

(0022) Because the polishing liquid from the polishing liquid supply port is distributed and supplied to the polishing surface, the polishing liquid supplied to the surface to be polished of the workpiece is distributed uniformly. Therefore, a polishing rate of the workpiece is improved, and in-plane uniformity of the polishing rate is increased.

(0023) According to a fourth aspect of the present invention, there is provided a polishing apparatus which is capable of supplying a polishing liquid uniformly and efficiently to a surface to be polished of a workpiece. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface. The polishing apparatus also includes a polishing liquid supply port for supplying a polishing liquid to the polishing surface, and a distributor for distributing the polishing liquid supplied from the polishing liquid supply port and supplying this distributed polishing liquid between the workpiece and the polishing surface.

(0024) Inasmuch as the polishing liquid supplied from the polishing liquid supply port can be distributed by the distributor, the polishing liquid supplied to the surface to be polished of the workpiece is distributed uniformly. Therefore, a polishing rate of the workpiece is improved, and in-plane uniformity of the polishing rate is increased.

(0025) According to a fifth aspect of the present invention, there is provided a polishing apparatus which is capable of stably supplying a polishing liquid between a polishing surface and a workpiece to be polished. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface. The top ring has a retainer ring for holding an outer circumferential edge of the workpiece. The retainer ring, which comes into contact with the polishing surface, has a groove defined in a surface thereof, with the groove extending between outer and inner circumferential surfaces of the retainer ring. The groove has an opening ratio ranging from 10% to 50% at the outer circumferential surface of the retainer ring, the polishing liquid can effectively be supplied between the polishing surface and the workpiece, so that a stable polishing rate is achieved, and any inactive polishing liquid after it has reacted can be discharged effectively outside of the retainer ring through the groove.

(0027) According to a sixth aspect of the present invention, there is provided a polishing apparatus which is capable of forming a uniform polishing liquid film on a polishing surface by holding a suitable amount of polishing liquid on the polishing surface even under conditions in which polishing pressure on the polishing surface is low and relative speed between the polishing surface and a workpiece to be polished is high. The polishing apparatus includes a polishing table having a polishing surface, and a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface. The polishing apparatus also includes a polishing liquid supply port for supplying a polishing liquid to the polishing surface, and a top ring for moving the polishing surface and the workpiece relatively to each other at a relative speed of at least 2 m/s. The polishing surface has a groove having a cross-sectional area of at least 0.38 mm².

(0028) As the groove with this large cross-sectional area is defined in the polishing surface, a uniform polishing liquid film can be formed on the polishing surface by holding a suitable amount of polishing liquid on the polishing surface even under conditions in which the polishing pressure on the polishing surface is low and the relative speed between the polishing surface and the workpiece is high.

(0029) According to a seventh aspect of the present invention, there is provided a polishing apparatus which is capable of increasing an amount of polishing liquid held on a polishing surface thereby to increase a working efficiency of the polishing liquid. The polishing apparatus includes a polishing table having a polishing surface, a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface, and a polishing liquid supply port for supplying a polishing liquid to the polishing surface. The polishing surface has a plurality of holes defined therein and each having an opening area of at least 2.98 mm².

(0030) Since these plural holes each having a large opening area are defined in the polishing surface, an amount of polishing liquid held on the polishing surface is increased, and a working efficiency of the polishing liquid is increased. Therefore, an amount of the polishing liquid used is reduced, and a polishing cost is lowered.

(0031) According to an eighth aspect of the present invention, there is provided a polishing apparatus which is capable of supplying a polishing liquid uniformly to a surface to be polished of a workpiece. The polishing apparatus includes a polishing table having a polishing surface, and a plurality of polishing liquid supply ports for supplying a polishing liquid to the polishing surface. The polishing apparatus also includes a plurality of polishing liquid supply lines extending respectively from the polishing liquid supply ports and adapted to be connected directly to a polishing liquid circulation system which is disposed outside of the polishing apparatus.

(0032) With the above arrangement, the workpiece can uniformly be supplied with the polishing liquid. Therefore, a polishing rate of the workpiece is improved, and in-plane uniformity of the polishing rate is increased.
According to a ninth aspect of the present invention, there is provided a polishing apparatus which is capable of keeping a polishing surface clean at all times to stabilize polishing characteristics of the polishing surface. The polishing apparatus includes a polishing table having a polishing surface, a top ring for holding a workpiece to be polished and pressing the workpiece against the polishing surface, and a fluid ejecting mechanism for ejecting a mixed fluid of a cleaning liquid and a gas to the polishing surface. The polishing apparatus also includes a discharging mechanism for discharging the mixed fluid from the polishing surface, with the discharging mechanism being disposed downstream of the fluid ejecting mechanism with respect to a direction in which the polishing surface moves.

According to a tenth aspect of the present invention, there is provided a polishing method which is capable of keeping a polishing surface clean at all times to stabilize polishing characteristics of the polishing surface. According to the polishing method, a workpiece is pressed against a polishing surface of a polishing table and polished by moving the polishing surface and the workpiece relatively to each other. A mixed fluid of a cleaning liquid and a gas is ejected from a fluid ejecting mechanism to the polishing surface while the workpiece is being polished. The mixed fluid is discharged from the polishing surface with a discharging mechanism which is disposed downstream of the fluid ejecting mechanism with respect to a direction in which the polishing surface moves.

In the above polishing method, the discharging mechanism can immediately discharge the cleaning liquid supplied by the fluid ejecting mechanism, from the polishing surface, thereby keeping the polishing surface clean at all times. Therefore, the polishing characteristics of the polishing apparatus can be stabilized, making it possible for the fluid ejecting mechanism to perform in-situ atomizing while the workpiece is being polished.

According to an eleventh aspect of the present invention, there is provided a polishing method which is capable of effectively washing away and removing residues such as a polishing liquid attached to a surface to be polished of a workpiece after the workpiece has been polished in a main polishing process. According to the polishing method, the workpiece is polished under a low pressure of at most 13.79 kPa, and, thereafter, the workpiece is polished under a low pressure of at most 13.79 kPa at a relative speed of at least 2 m/s, between the workpiece and the polishing surface while a chemical solution is being supplied to the workpiece.

With the above polishing method, after the workpiece is polished under a low pressure, residues such as a polishing liquid attached to the surface to be polished of the workpiece can effectively be washed away and removed.

According to a twelfth aspect of the present invention, there is provided a polishing method which is capable of effectively washing away and removing residues such as a polishing liquid attached to a surface to be polished of a workpiece after the workpiece has been polished in a main polishing process. According to the polishing method, the workpiece is polished under a low pressure of at most 13.79 kPa, and, thereafter, the workpiece is polished under a low pressure of at most 13.79 kPa at a relative speed of at least 2 m/s, between the workpiece and the polishing surface while a chemical solution is being supplied to the workpiece.

According to a thirteenth aspect of the present invention, there is provided a polishing method which is capable of preventing a previous polishing step from posing an undue load on a subsequent polishing step in a multi-step polishing process, particularly a two-step polishing process. The polishing method includes polishing the workpiece to remove a substantial portion of a first film formed on the workpiece in a first-stage, and polishing the workpiece to remove a remaining portion of the first film until a second film on the workpiece is exposed in a second-stage, thereby leaving an interconnect area. The polishing method also includes presetting a film thickness distribution for the first film upon transition from the first-stage polishing to the second-stage polishing, measuring a thickness of the first film with an eddy-current sensor in the first-stage polishing to acquire a film thickness distribution of the first film, and adjusting polishing conditions in the second-stage polishing to equalize the acquired film thickness distribution of the first film to the preset film thickness distribution for the first film.

The above polishing method makes it possible to reliably achieve a finally desirable film thickness distribution while monitoring an actual film thickness distribution. Since the first-stage polishing can be switched to the second-stage polishing at a desired film thickness distribution at all times, the first-stage polishing is prevented from imposing an undue load on the second-stage polishing. Furthermore, the polishing method is capable of preventing dishing and erosion from occurring after the second-stage polishing, and of reducing a period of time spent by the second-stage polishing, resulting in an increase in productivity and a reduction in polishing cost.

According to a fourteenth aspect of the present invention, there is provided an interconnects forming method which is capable of forming interconnects without causing defects therein. The interconnects forming method includes forming a flat conductive thin film on a substrate, and removing the flat conductive thin film from the substrate by a chemical etching process.

After the flat conductive thin film is formed on the substrate, the conductive thin film is removed by the chemical etching process which is free of any mechanical action and does not require an electric connection. Therefore, interconnects can be formed on the substrate without causing defects.

According to the first through fourth aspects of the present invention, the polishing liquid can be supplied uniformly and efficiently to the surface to be polished of the workpiece.

According to the fifth aspect of the present invention, the uniform polishing liquid can stably be supplied between the polishing surface and the workpiece.

According to the sixth aspect of the present invention, the uniform polishing liquid film can be formed on the polishing surface by holding a suitable amount of polishing liquid on the polishing surface even under conditions in
which the polishing pressure on the polishing surface is low and the relative speed between the polishing surface and the workpiece is high.

According to the seventh aspect of the present invention, the amount of polishing liquid held on the polishing surface can be increased, thereby to increase a working efficiency of the polishing liquid.

According to the eighth aspect of the present invention, the polishing liquid can be supplied uniformly to the workpiece.

According to the ninth and tenth aspects of the present invention, the polishing surface is kept clean at all times to stabilize the polishing characteristics of the polishing surface.

According to the eleventh and twelfth aspects of the present invention, residues such as a polishing liquid attached to the surface to be polished of the workpiece after the workpiece has been polished in the main polishing process can effectively be washed away and removed.

According to the thirteenth aspect of the present invention, a previous polishing step is prevented from posing an undue load on a subsequent polishing step in a multi-step polishing process.

According to the fourteenth aspect of the present invention, interconnects can be formed without causing defects therein.

The above and other objects, features, and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a polishing apparatus according to an embodiment of the present invention;

FIG. 2 is a vertical cross-sectional view of a portion of a polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 3 is a bottom view of a retainer ring of a top ring shown in FIG. 2;

FIG. 4 is a bottom view of another retainer ring for use with the top ring shown in FIG. 2;

FIG. 5 is a bottom view of still another retainer ring for use with the top ring shown in FIG. 2;

FIG. 6 is a bottom view of still another retainer ring for use with the top ring shown in FIG. 2;

FIG. 7 is a schematic plan view of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 8 is a perspective view of a gas ejecting mechanism used in the polishing unit shown in FIG. 7;

FIG. 9 is a plan view of a modified polishing unit for use in the polishing apparatus shown in FIG. 1;

FIG. 10 is a perspective view of a polishing pad of the polishing unit shown in FIG. 7;

FIG. 11 is an enlarged vertical cross-sectional view of the polishing pad shown in FIG. 10;

FIG. 12 is an enlarged plan view of a modification of the polishing pad shown in FIG. 10;

FIG. 13 is a plan view of a modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 14 is a plan view of another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 15 is a plan view of still another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 16 is a plan view of still another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 17 is a plan view of still another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 18 is a plan view of still another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 19 is a plan view of still another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 20 is a plan view of still another modification of the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 21 is a perspective view of a modified polishing liquid supply nozzle for use in the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 22 is a vertical cross-sectional view of the polishing liquid supply nozzle shown in FIG. 21;

FIG. 23 is a perspective view of a modification of the polishing liquid supply nozzle shown in FIG. 21;

FIG. 24 is a perspective view of another modified polishing liquid supply nozzle for use in the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 25 is a perspective view of another modification of the polishing liquid supply nozzle shown in FIG. 21;

FIG. 26 is a perspective view of still another modified polishing liquid supply nozzle for use in the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 27 is a plan view of still another modified polishing liquid supply nozzle for use in the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 28 is a schematic view of still another modified polishing liquid supply nozzle for use in the polishing unit of the polishing apparatus shown in FIG. 1;

FIG. 29 is a schematic view of a polishing liquid supply system of a conventional polishing apparatus;

FIG. 30 is a schematic view of a polishing liquid supply system according to the present invention;

FIGS. 31A and 31B are schematic views of fluid pressure valves for use in the polishing liquid supply system shown in FIG. 30;

FIG. 32 is a vertical cross-sectional view of a modification of the top ring shown in FIG. 2;

FIGS. 33A through 33C are cross-sectional views illustrative of a CMP process of planarizing copper damascene interconnects;

FIG. 34A is a cross-sectional view of an overpolished workpiece, and FIG. 34B is a cross-sectional view of an underpolished workpiece;

FIG. 35 is a plan view of a polishing apparatus for polishing a semiconductor wafer with a swingable polishing liquid supply nozzle; and

FIG. 36A is a graph showing a polishing rate of the semiconductor wafer which is polished by the polishing apparatus shown in FIG. 35 when the polishing liquid supply nozzle swings, while FIG. 36B is a graph showing a polishing rate of the semiconductor wafer which is polished by the polishing apparatus shown in FIG. 35 when the polishing liquid supply nozzle does not swing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A polishing apparatus according to an embodiment of the present invention will be described below with references to the drawings. In the drawings, like or corresponding parts are denoted by like or corresponding reference characters throughout views and will not be described repetitively.
FIG. 1 shows in plan a polishing apparatus according to an embodiment of the present invention. As shown in FIG. 1, the polishing apparatus has an array of three wafer cassettes 10 removable mounted on an end wall thereof for holding semiconductor wafers, and a traveling mechanism 12 disposed along the array of three wafer cassettes 10. A first transfer robot 14 is mounted on the traveling mechanism 12 and has two hands for selectively accessing the wafer cassettes 10. 

The polishing apparatus has an array of four polishing units 20 arranged in a longitudinal direction thereof. Each of the polishing units 20 includes a polishing table 22 having a polishing surface, a top ring 24 for holding and pressing a semiconductor wafer against the polishing surface of the polishing table 22 to polish the semiconductor wafer, a polishing liquid supply nozzle 26 for supplying a polishing liquid and a dressing liquid (e.g., water) to the polishing surface of the polishing table 22, a dresser 28 for dressing the polishing surface, and an atomizer 30 for atomizing a mixed fluid composed of a liquid (e.g., pure water) and a gas (e.g., nitrogen) and ejecting this atomized fluid from at least one nozzle to the polishing surface.

A linear transporter 32 and a second linear transporter 34 are disposed end to end alongside of the polishing units 20 for transporting semiconductor wafers in a longitudinal direction of the polishing apparatus along the array of polishing units 20. A reversing machine 36 for reversing a semiconductor wafer received from the first transfer robot 14 is disposed at an end of the first linear transporter 32 which is closer to the wafer cassettes 10. 

The polishing apparatus also has a second transfer robot 38, a reversing machine 40 for reversing a semiconductor wafer received from the second transfer robot 38, an array of four cleaning machines 42 for cleaning polished semiconductor wafers, and a transfer unit 44 for transferring semiconductor wafers between the reversing machine 40 and the cleaning machines 42. The second transfer robot 38, the reversing machine 40, and the cleaning machines 42 are arrayed linearly in the longitudinal direction of the polishing apparatus on one side thereof.

Semiconductor wafers housed in the wafer cassettes 10 are introduced into respective polishing units 20 through the reversing machine 36, the first linear transporter 32, and the second linear transporter 34. The semiconductor wafers are polished in each of polishing units 20. These polished semiconductor wafers are then introduced into the cleaning machines 42 through the second transfer robot 38 and the reversing machine 40, and cleaned by respective cleaning machines 42. These cleaned semiconductor wafers are then delivered by the first transfer robot 14 back into the wafer cassettes 10.

FIG. 2 shows in vertical cross section a portion of each of the polishing units 20. As shown in FIG. 2, the polishing table 22 of the polishing unit 20 is connected to a motor 50 disposed therebeneath for rotation about its own axis in a direction indicated by an arrow. A polishing pad (polishing cloth) 52 having an upper polishing surface is applied to an upper surface of the polishing table 22. The top ring 24 is coupled to a lower end of a vertical top ring shaft 54. A retainer ring 56 for holding an outer circumferential edge of a semiconductor wafer W is mounted on an outer circumferential surface of a lower portion of the top ring 24. The top ring shaft 54 is coupled at its upper end to a motor (not shown) and also to a lifting/lowering cylinder (not shown). The top ring 24 is therefore vertically movable and rotatable about its own axis as indicated by arrows for pressing the semiconductor wafer W against the polishing pad 52 under desired pressure and rotating the semiconductor wafer W with respect to the polishing pad 52.

In operation of the polishing unit 20, the semiconductor wafer W is held on a lower surface of the top ring 24, and pressed by the lifting/lowering cylinder against the polishing pad 52 on the polishing table 22 which is being rotated by the motor 50. A polishing liquid Q is supplied from a polishing liquid supply port 57 of the polishing liquid supply nozzle 26 onto the polishing pad 52. The semiconductor wafer W is now polished with the polishing liquid Q which is present between a lower surface, to be polished, of the semiconductor wafer W and the polishing pad 52.

As shown in FIG. 2, an eddy-current sensor 58 for measuring a film thickness of the semiconductor wafer W is embedded in the polishing table 22. A wire 60 extends from the eddy-current sensor 58 through the polishing table 22 and a support shaft 62 connected to a lower end thereof, and is connected to a controller 66 through a rotary connector (or a slip ring) 64 that is mounted on a lower end of the support shaft 62. While the eddy-current sensor 58 is moving beneath the semiconductor wafer W, the eddy-current sensor 58 detects the thickness of a conductive film, such as a copper film or the like, formed on the surface of the semiconductor wafer W continuously along a path of the eddy-current sensor 58 beneath the semiconductor wafer W.

To meet demands for higher-speed semiconductor devices, it has been studied to make an insulating film between interconnects in semiconductor devices of a material having a lower dielectric constant, e.g., a low-k material. Since a material having a lower dielectric constant, e.g., a low-k material, is porous and brittle mechanically, it is requested to minimize pressure (polishing pressure) applied to the semiconductor wafer being polished to a level of at most 13.79 kPa (2 psi), for example, in a polishing process of planarizing copper damascene interconnects of low-k material.

Generally, however, a polishing rate in a polishing process depends upon polishing pressure, and decreases as the polishing pressure is lowered. For polishing a copper film, therefore, a polishing liquid with a stronger chemical action may be used to compensate for a reduction in the polishing pressure. When such a polishing liquid with a stronger chemical action is used, uniform and stable polishing characteristics cannot be achieved unless a stabler chemical reaction occurs between the polishing liquid and the copper film. Consequently, it is desired in a polishing process using a polishing liquid with a stronger chemical action to stably supply an unreacted polishing liquid between the polishing pad and the semiconductor wafer.

According to this embodiment, the retainer ring 56 of the top ring 24 has grooves defined therein for more stably supplying the polishing liquid between the polishing pad 52 and the semiconductor wafer W. FIG. 3 is a bottom view of the retainer ring 56 shown in FIG. 2. As shown in FIG. 3, the retainer ring 56 has a plurality of grooves 74 defined in a bottom surface thereof at equal circumferential intervals and extending between an outer circumferential surface 70 and an inner circumferential surface 72 thereof. In FIG. 3, the top ring 24 rotates clockwise, and each of the grooves 74 has an outer circumferential opening 76 positioned ahead of an inner circumferential opening 78 thereof clockwise, i.e., in a direc-
tion in which the top ring 24 rotates. The grooves 74 thus defined in the retainer ring 56 are effective in efficiently and stably supplying polishing liquid between the semiconductor wafer W positioned inside of the retainer ring 56 and the polishing pad 52.

[0104] Outer circumferential openings 76 of the grooves 74 have an opening percentage ranging from about 10% to about 50% with respect to a surface area of the outer circumferential surface 70, depending on intensity of a chemical action of the polishing liquid. For example, when a certain polishing liquid is used, if the opening percentage of the outer circumferential openings 76 is 0%, then the polishing liquid cannot sufficiently be supplied between the polishing pad 52 and the semiconductor wafer W, thereby failing to achieve a sufficient polishing rate. If the opening percentage of the outer circumferential openings 76 is excessively high, e.g., exceeds 50%, on the other hand, then polishing liquid that has flowed through some grooves 74 radially inwardly of the retainer ring 56 tend to flow out through other grooves 74, and cannot effectively be retained between the polishing pad 52 and the semiconductor wafer W. If the opening percentage of the outer circumferential openings 76 is selected in the range from about 10% to about 50%, then the polishing liquid can effectively be supplied between the polishing pad 52 and the semiconductor wafer W for a stable polishing rate. The opening percentage of the outer circumferential openings 76, which is selected in the range from about 10% to about 50%, allows inactive polishing liquid after it has reacted to be discharged effectively outside of the retainer ring 56 through the grooves 74. Dimensions of the grooves 74 and a pitch between the grooves 74 are determined depending on the opening percentage of the outer circumferential openings 76.

[0105] If the top ring 24 rotates counterclockwise as viewed from its bottom surface, then the grooves 74 should be oriented in a direction opposite to the grooves 74 shown in FIG. 3, as shown in FIG. 4. Alternatively, as shown in FIG. 5, the grooves 74 may be disposed radially at equal circumferential spaced intervals so that the grooves 74 may be used irrespectively of which direction the top ring 24 may rotate. As shown in FIG. 6, the radial grooves 74 may have inner circumferential openings 78 greater than outer circumferential openings 76 thereof.

[0106] For making the grooves 74 of the retainer ring 56 more effective, a rotational speed of the top ring 24 should preferably be equal to or lower than a rotational speed of the polishing table 22, or more preferably be about 1/3 or even 1/5 of the rotational speed of the polishing table 22. The polishing table 22 and the top ring 24 may be rotated in one direction or in opposite directions. If the rotational speeds of the polishing table 22 and the top ring 24 are set to the above relative values, then the polishing apparatus can polish the semiconductor wafer W more uniformly.

[0107] Specifically, if the rotational speed of the top ring 24 is higher than the rotational speed of the polishing table 22, then the retainer ring 56 positioned on an outer circumferential surface of the top ring 24 tends to obstruct an inflow of polishing liquid between the polishing pad 52 and the semiconductor wafer W, thereby preventing the polishing liquid from being efficiently supplied. If the rotational speed of the top ring 24 is equal to or lower than the rotational speed of the polishing table 22, then the polishing liquid can efficiently be supplied through the grooves 74 between the polishing pad 52 and the semiconductor wafer W, thereby allowing the polishing apparatus to polish the semiconductor wafer W more uniformly.

[0108] FIG. 7 shows in schematic plan each of the polishing units 20 of the polishing apparatus shown in FIG. 1. As shown in FIG. 7, the atomizer 30 is disposed upstream of the top ring 24 with respect to a direction in which the polishing table 22 rotates. The atomizer 30 functions as a fluid ejecting mechanism for ejecting a mixed fluid composed of a cleaning liquid and a gas to the polishing pad 52. For example, a mixed fluid composed of a nitrogen gas and pure water or a chemical liquid is ejected from the atomizer 30 to the polishing pad 52. The mixed fluid is ejected as 1) fine liquid particles, 2) fine solidified liquid particles, or 3) liquid-evaporated gas particles (these phases may be referred to as a “nebulized or atomized” state) to the polishing pad 52.

[0109] When this nebulized or atomized mixed fluid is ejected to the polishing pad 52, any polishing liquid and swarf trapped in recesses in the polishing pad 52 are lifted therefrom by the gas contained in the mixed fluid, and are washed away by a cleaning liquid such as pure water, a chemical liquid, or the like. In this manner, any polishing liquid and swarf, which may be present on the polishing pad 52 and responsible for a scratch on the semiconductor wafer W, can effectively be removed.

[0110] After a semiconductor wafer is polished by a CMP process, polishing residues including remaining abrasive grains and swarf (copper complex if a copper film is polished) are generally present on a polished surface of a semiconductor wafer. If these polishing residues remain unremoved, they tend to damage the polished surface of the semiconductor wafer or suppress a chemical reaction of a polishing liquid in a subsequent polishing process to reduce a polishing rate. It is therefore desirable that no or little polishing residues be present on a surface being polished of a semiconductor wafer. According to a normal CMP process, in an interval between polishing cycles, dressing of the polishing surface is performed by a dresser, and an atomized mixed fluid composed of a cleaning liquid and a gas is applied from an atomizer to the polishing surface to remove polishing residues from the polishing surface. This process will be referred to as “atomizing process”.

[0111] As shown in FIG. 7, a draining mechanism 80 for draining mixed fluid ejected from the atomizer 30 off the polishing pad 52 is disposed downstream of the atomizer 30 with respect to the direction in which the polishing table 22 rotates. A cover 82 covering the atomizer 30 and the draining mechanism 80 is disposed above the atomizer 30 and the draining mechanism 80. The cover 82 should preferably be made of a water repelling material such as fluororesin or the like. The cover 82 may be open in a radial direction of the polishing table 22.

[0112] The draining mechanism 80 shown in FIG. 7 comprises a contact member 84 for being brought into contact with the polishing pad 52, and a holder (not shown) that holds the contact member 84. The contact member 84 should preferably be made of a material having a low coefficient of friction for smaller wear and also having a high liquid sealing capability. The draining mechanism 80 may include a pressure-adjustable pressing mechanism (not shown) for pressing the contact member 84 or the holder under controlled pressure, and the contact member 84 may be brought into contact with the polishing pad 52 under pressure from the pressing mechanism. The pressing mechanism may be a cylinder
mechanism for applying a fluid pressure such as a pneumatic or hydraulic pressure, or a ball screw mechanism.  

[0113] According to the conventional CMP process, it has been customary not to perform the atomizing process, i.e., to apply atomized fluid to the polishing surface, during polishing cycles because cleaning liquid supplied to the polishing surface changes the concentration of a polishing liquid, thereby changing a polishing capability of the polishing liquid. According to this embodiment, since the draining mechanism 80 can immediately drain the cleaning liquid supplied from the atomizer 30 off the polishing table 22, the polishing pad 52 can be kept clean at all times, thereby stabilizing polishing characteristics of the polishing apparatus. Therefore, the polishing apparatus according to this embodiment makes it possible for the atomizer 30 to perform the atomizing process (in-site atomizing process) during a polishing cycle.  

[0114] A dressing process performed by the dresser 28 in a polishing cycle (in-site dressing process) and the atomizing process performed by the atomizer 30 in the polishing cycle (in-site atomizing process) may be combined with each other for conditioning the polishing pad 52 in the polishing cycle. Accordingly, intervals between polishing cycles can be reduced for allowing the polishing apparatus to have an increased throughput.  

[0115] According to an example shown in FIG. 7, the contact member 84 extends in a radial direction of the polishing table 22. However, the contact member 84 may be inclined a certain angle ranging from 0° to 90° from a radial direction of the polishing table 22.  

[0116] The polishing unit 20 may have a gas ejecting mechanism having gas ejection ports for ejecting a gas to the polishing pad 52, instead of or in addition to the contact member 84. FIG. 8 shows in perspective such a gas ejecting mechanism 86. As shown in FIG. 8, the gas ejecting mechanism 86 has a plurality of gas ejection ports 88 for ejecting a gas, such as dry air or dry nitrogen, to the polishing pad 52, and a controller (not shown) for controlling an ejected amount of gas, pressure at which the gas is ejected, and a direction in which the gas is ejected. The cleaning liquid from the atomizer 30 is drained off the polishing pad 52 by the gas ejected from the gas ejection ports 88. The gas ejection ports 88 should preferably be shaped to eject the gas in a sectoral pattern like an air curtain. The gas ejection ports 88 may be in the form of slits for controlling the direction in which the gas is ejected.  

[0117] The draining mechanism 80, which is combined with the gas ejecting mechanism 86, is also capable of immediately draining the cleaning liquid supplied from the atomizer 30 off the polishing pad 52. Accordingly, the polishing pad 52 can be kept clean at all times so as to stabilize polishing characteristics of the polishing apparatus.  

[0118] Efforts are being made to produce higher-performance LSI circuits by employing finer interconnects to have them operate at higher speeds, allow them to be integrated more highly, and design them for lower power consumption. Technological development for finer interconnects has been performed essentially according to predictions based on the International Technology Roadmap for Semiconductors (ITRS). Developing finer interconnects has been parallelized by converting interconnect materials into copper having lower resistance and insulating materials into low-k materials having low dielectric constants. It is expected that there will be growing demands for a copper damascene planarizing process (copper CMP process).  

[0119] For achieving integration with low-k materials or porous low-k materials in the copper damascene planarizing process, it is necessary to improve planarizing characteristics with efforts to produce finer interconnects and also to take some countermeasures against material breakdown upon polishing due to low mechanical strength of these materials.  

[0120] To meet the above requirements, it may be proposed to lower pressure on a surface being processed, i.e., polishing pressure. According to an ordinary copper CMP process, after a copper complex is formed, the copper complex is mechanically removed to polish a copper film progressively. With a polishing liquid that is used by the ordinary CMP apparatus, however, mechanical strength of this formed copper complex is so high that reducing the polishing pressure tends to result in a reduction in a polishing rate.  

[0121] Recently, there has been developed a polishing liquid for forming a copper complex having such a low mechanical strength that the copper complex can mechanically be removed under a low polishing pressure. Because such a polishing liquid is of strong chemical reactivity, an amount and distribution of the polishing liquid supplied to a surface being polished of a semiconductor wafer greatly affects a polishing rate and in-plane uniformity of the polishing rate.  

[0122] With a conventional CMP apparatus, as polishing liquid is supplied from a fixed single polishing liquid supply port, the polishing liquid supplied therefrom to a surface being polished of a semiconductor wafer is liable to have a localized distribution, thereby impairing in-plane uniformity of a polishing rate. This problem manifests itself particularly when a relative speed between a polishing surface and the semiconductor wafer is high. In addition, an increased amount of polishing liquid is wasted, resulting in an increase in polishing cost. Accordingly, it is important that the surface being polished of the semiconductor wafer be uniformly and efficiently supplied with the polishing liquid.  

[0123] According to this embodiment, the polishing liquid supply port 57 (see FIG. 2) of the polishing liquid supply nozzle 26 is moved during a polishing process to supply the surface being polished of the semiconductor wafer with the polishing liquid uniformly and efficiently. Specifically, as shown in FIG. 1, the polishing liquid supply nozzle 26 of this embodiment can be pivoted about a shaft 27, and is pivoted about the shaft 27 by a pivoting mechanism (moving mechanism) during the polishing process.  

[0124] The polishing liquid is supplied from the polishing liquid supply nozzle 26 to the polishing pad 52. As the top ring 24 and the polishing table 22 move relatively to each other, the polishing liquid supplied to the polishing pad 52 is supplied to the surface being polished of the semiconductor wafer. When the polishing liquid supply nozzle 26 is pivoted about the shaft 27 to move the polishing liquid supply port 57 (see FIG. 2) mounted on its tip during the polishing process, the polishing liquid supplied to the polishing pad 52 is appropriately distributed over the polishing pad 52 so as to be supplied uniformly to an entire surface of the semiconductor wafer as the top ring 24 and the polishing table 22 move relatively to each other.  

[0125] As described above, the polishing liquid supply nozzle 26 according to this embodiment is capable of uniformly distributing the polishing liquid supplied to the surface being polished of the semiconductor wafer. Consequently, the polishing rate is improved, and the in-plane uniformity of the polishing is increased. As the polishing liquid is efficiently supplied, an amount of the polishing liquid used
is reduced, and any wasteful consumption of the polishing liquid is reduced, thereby lowering the polishing cost.

[0126] In this embodiment, the polishing liquid supply nozzle 26 is pivoted along an arcuate path. However, the polishing liquid supply nozzle 26 may be moved according to other patterns. For example, the polishing liquid supply nozzle 26 may be moved linearly, rotated, swung, or reciprocated. The polishing liquid supply nozzle 26 may be moved at a constant rate (e.g., 50 mm/s) or at a varying rate. The polishing liquid supply nozzle 26 may be combined with a liquid rate control mechanism for changing a rate of the polishing liquid that is supplied from the polishing liquid supply port 57 while the polishing liquid supply nozzle 26 is in motion. A range that is scanned by the polishing liquid supply port 57 should preferably be kept within a radius of the polishing table 22 and cover a diameter of the semiconductor wafer being polished.

[0127] In this embodiment shown in FIG. 1, the polishing liquid supply nozzle 26 extends in the radial direction of the polishing table 22. However, as shown in FIG. 9, the polishing liquid supply nozzle 26 may be inclined a certain angle ranging from 0° to 90° to the radial direction of the polishing table 22.

[0128] According to a CMP process, a semiconductor wafer is normally polished by chemical mechanical action of a polishing liquid that is retained on a polishing pad. Herefore, an ability of the polishing pad to retain the polishing liquid is so small that most of the polishing liquid supplied to the polishing pad is not consumed but discharged from the polishing pad. Since the polishing liquid is highly expensive and greatly affects polishing cost, it is necessary to increase a working efficiency of the polishing liquid for reducing the polishing cost.

[0129] In a polishing process where polishing pressure is low (at most 6.89 kPa (1 psi)) and a relative speed between a semiconductor wafer and a polishing surface is high (at least 2 m/s), when a film of a polishing liquid supplied to the polishing surface is of an increased thickness, slippage occurs between the semiconductor wafer and the polishing surface due to hydroplaning. Such a phenomenon manifests itself particularly if the polishing surface is supplied with the polishing liquid irregularly, for example, when the polishing surface has concentric grooves of small cross section defined therein or the polishing liquid is supplied to the polishing surface from a single point to a center of the polishing surface. When the hydroplaning phenomenon occurs, as no polishing pressure acts between the semiconductor wafer and the polishing surface, a polishing rate is lowered. If the polishing liquid is positively discharged from the polishing surface, on the other hand, then an amount of the polishing liquid retained on the polishing surface is reduced, resulting in a reduction in the polishing rate and working efficiency of the polishing liquid. Therefore, there has been a demand for retaining an appropriate amount of polishing liquid on the polishing surface to form a uniform film of polishing liquid on the polishing surface.

[0130] To meet such a demand, according to this embodiment, the polishing pad 52 has grooves defined in a surface thereof, with each of the grooves having a cross-sectional area of at least 0.38 mm². FIG. 10 shows the polishing pad 52 in perspective, and FIG. 11 shows the polishing pad 52 in an enlarged vertical cross section. As shown in FIG. 10, the polishing pad 52 has a plurality of concentric grooves 90 defined in an upper surface thereof and spaced at a pitch P₁ (see FIG. 11) of 2 mm, for example. According to an example shown in FIG. 11, each of the grooves 90 has a width W₁ of 0.5 mm, a depth D₁ of 0.76 mm, and a cross-sectional area of 0.38 mm². The depth of each of the grooves 90 may be greater than a depth of the conventional grooves, e.g., may be at least 1 mm.

[0131] As shown in FIG. 12, the polishing pad 52 may further have straight narrow slots 92 defined therein that interconnect adjacent ones of the concentric grooves 90. The narrow slots 92 are effective to make polishing liquid resistant to centrifugal forces. The narrow slots 92 should preferably be inclined at a certain angle α, e.g., 30°, relative to a circumferential direction of the polishing pad 52. Preferably, adjacent ones of the narrow slots 92 are spaced from each other by a pitch P₂ of 2 mm. Each of the narrow slots 92 should preferably have a width that is about 30% of the width of the grooves 90.

[0132] Though the polishing pad 52 has concentric grooves 90 in this embodiment, the polishing pad 52 may have grooves of other shapes. For example, the polishing pad 52 may have spiral grooves defined in the upper surface thereof and each having a cross-sectional area that is the same as the cross-sectional area of the concentric grooves 90. If the spiral grooves are inclined a certain angle, e.g., 45°, relative to a direction of a normal to the circumferential direction of the polishing pad 52, then polishing liquid can be discharged from the polishing pad 52 under certain centrifugal forces.

[0133] The polishing pad 52 may have a plurality of holes defined in the surface thereof, each having an opening area of at least 2.98 mm² and a diameter of at least 1.95 mm, instead of or in addition to the above-described grooves 90. The holes having such a large opening area, which are defined in the surface of the polishing pad 52, are effective to increase an amount of polishing liquid retained by the polishing surface and a working efficiency of the polishing liquid. The opening area of each of these holes should preferably be at least 3.14 mm² (a diameter of at least 2 mm), or more preferably be at least 19.63 mm² (a diameter of at least 5 mm). The holes may be circular or elliptical in shape, and may be arranged in a concentric, staggered, or grid pattern.

[0134] The CMP process mainly comprises (1) a main polishing process for pressing a semiconductor wafer against a polishing pad and polishing the semiconductor wafer while supplying a slurry to the polishing pad, and (2) a water polishing process for polishing (cleaning) the semiconductor wafer with water after the semiconductor wafer is polished by the slurry. In the main polishing process (1), an excessive film material on a surface of the semiconductor wafer is polished off. In the water polishing process (2), slurry deposits and debris produced in the main polishing process are washed off the surface of the semiconductor wafer.

[0135] As described above, as interconnects formed on semiconductor wafers become finer, insulating films of higher insulating ability are required. Porous low-k materials are known as candidates for materials of such insulating films of higher insulating ability. However, porous low-k materials are of very low mechanical strength. In view of this, polishing pressure applied in conventional CMP apparatus has been in the range from 13.79 to 344.47 kPa (2 to 5 psi). The polishing pressure will be required to be at most 13.79 kPa (2 psi), or at most 6.89 kPa (1 psi), in future.

[0136] Semiconductor wafers having low-k materials need to be polished under a low polishing pressure of 3.45 kPa (0.5 psi), for example. Both the main polishing process and the
water polishing process are required to be performed under a low polishing pressure. However, if the water polishing process is performed under a low polishing pressure, then deposits such as slurry cannot fully be removed from the semiconductor wafer, but may possibly remain unremoved on the semiconductor wafer.

[0137] According to this embodiment, the water polishing process is performed as follows: After the main polishing process has been performed on a semiconductor wafer under a low polishing pressure, the semiconductor wafer is pressed against the polishing pad 52 under a pressure which is equal to or lower than the polishing pressure exerted in the main polishing process, and the polishing table 22 is rotated at a linear velocity of at least 1.5 m/s, preferably at least 2 m/s, or more preferably at least 3 m/s. Pure water (DIW) is supplied at a flow rate of 1 l/min. to the polishing pad 52 to polish the semiconductor wafer with water. In this manner, a surface of the semiconductor wafer that has been polished under the low polishing pressure can be cleaned appropriately. Alternatively, the semiconductor wafer may be cleaned with a chemical solution such as a citric acid solution which is able to accelerate removal of slurry deposits and debris from the semiconductor wafer, rather than pure water (DIW). A period of time of a normal cleaning process may be prolonged from 10 sec. to 20 sec. to remove slurry deposits and debris from the semiconductor wafer. However, since such a prolonged cleaning process lowers throughput, the water polishing process or chemical solution cleaning process described above, performed on the semiconductor wafer while in high-speed rotation, is more preferable.

[0138] In the above-described embodiment, the polishing liquid is supplied from the polishing liquid supply port 57 at the distal end of the polishing liquid supply nozzle 26. Polishing liquid supply nozzles of other designs may be employed. For example, as shown in FIG. 13, a polishing liquid supply nozzle 26a may comprise a disk 100 having a polishing liquid supply port 57 and an arm 102 on which the disk 100 is mounted. The arm 102 may not be pivoted and only the disk 100 may be rotated while supplying the polishing liquid from the polishing liquid supply port 57, or the arm 102 may be pivoted and the disk 100 may be rotated while supplying the polishing liquid from the polishing liquid supply port 57. Alternatively, the arm 102 may be moved linearly. A moving speed of the polishing liquid supply port 57, i.e., a moving speed of the arm 102 and/or a rotational speed of the disk 100 may be varied while polishing liquid supply nozzle 26a is in operation. The polishing liquid supply nozzle 26a may be combined with a liquid rate control mechanism for changing a rate of polishing liquid that is supplied from the polishing liquid supply port 57 while the polishing liquid supply nozzle 26a is in motion.

[0139] In FIG. 14, a polishing liquid supply nozzle 26b may have a plurality of polishing liquid supply ports 57. The polishing liquid supply nozzle 26b may be pivoted, linearly moved, rotated, swung, or reciprocated. A moving speed of the polishing liquid supply nozzle 26b may be varied while the polishing liquid supply nozzle 26b is in motion. The polishing liquid supply nozzle 26b may be combined with a liquid rate control mechanism for individually controlling a rate of the polishing liquid that is supplied from each of the polishing liquid supply ports 57 while the polishing liquid supply nozzle 26b is in motion. The polishing liquid supply ports 57 may have different diameters. For example, the polishing liquid supply ports 57 may have progressively decreasing diameters in a radially inward direction of the polishing table 22. In FIG. 14, the polishing liquid supply nozzle 26b extends in a radial direction of the polishing table 22. However, as shown in FIG. 15, the polishing liquid supply nozzle 26b may be inclined a certain angle ranging from 0° to 45° relative to the radial direction of the polishing table 22.

[0140] Rather than moving the polishing liquid supply nozzle, the polishing liquid supply port may be moved in the polishing liquid supply nozzle. For example, as shown in FIG. 16, a polishing liquid supply nozzle 26c has a polishing liquid supply nozzle 57a movable linearly therein. Alternatively, the polishing liquid supply nozzle 57a may be pivoted, rotated, swung, or reciprocated. The polishing liquid supply nozzle 26c may not be pivoted and only the polishing liquid supply nozzle 57a may be moved while supplying polishing liquid. Alternatively, the polishing liquid supply nozzle 26c may be pivoted and the polishing liquid supply nozzle 57a may be moved while supplying the polishing liquid. A moving speed of the polishing liquid supply nozzle 57a may be varied while the polishing liquid supply nozzle 57a is in motion. The polishing liquid supply nozzle 26c may be combined with a liquid rate control mechanism for changing a rate of the polishing liquid that is supplied from the polishing liquid supply port 57a while the polishing liquid supply nozzle 26c is in motion. As shown in FIG. 17, a plurality of polishing liquid supply nozzles 26c, each shown in FIG. 16, may be combined with each other.

[0141] In FIG. 18, a polishing liquid supply nozzle 26d comprises a disk 100 having a plurality of polishing liquid supply ports 57 and an arm 102 on which the disk 100 is mounted. The arm 102 may not be pivoted and only the disk 100 may be rotated while supplying polishing liquid from the polishing liquid supply ports 57, or the arm 102 may be pivoted and the disk 100 may be rotated while supplying the polishing liquid from the polishing liquid supply port 57. Alternatively, the arm 102 may be moved linearly. A moving speed of the polishing liquid supply ports 57, i.e., a moving speed of the arm 102 and/or a rotational speed of the disk 100 may be varied while polishing liquid supply nozzle 26d is in operation. The polishing liquid supply nozzle 26d may be combined with a liquid rate control mechanism for individually controlling a rate of the polishing liquid that is supplied from each of the polishing liquid supply ports 57 while the polishing liquid supply nozzle 26d is in motion. The polishing liquid supply ports 57 may have different diameters. For example, the polishing liquid supply ports 57 may have progressively decreasing diameters in a radially inward direction of the polishing table 22. According to an example shown in FIG. 18, the polishing liquid supply ports 57 are positioned on one circle. However, the polishing liquid supply ports 57 may be positioned on a plurality of concentric circles or a single straight line or a plurality of straight lines.

[0142] In FIG. 19, a polishing liquid supply nozzle 26e comprises a hollow roll 104 having a plurality of polishing liquid supply ports 57 defined in its wall. The roll 104 is rotatable about an axis parallel to the surface of the polishing table 22. The polishing liquid supply ports 57 may be arranged in a linear pattern, a spiral pattern, or a random pattern. Polishing liquid may be supplied from the polishing liquid supply ports 57 while the roll 104 is being rotated or while the roll 104 is being pivoted and rotated. A moving speed of the polishing liquid supply ports 57, i.e., a rotational speed of the roll 104 and/or a pivoting speed of the roll 104, may be changed while the polishing liquid supply nozzle 26e.
is in operation. The polishing liquid supply nozzle 26e may be combined with a liquid rate control mechanism for individually controlling a rate of the polishing liquid that is supplied from each of the polishing liquid supply ports 57 while the polishing liquid supply nozzle 26g is in motion. The polishing liquid supply ports 57 may have different diameters. For example, the polishing liquid supply ports 57 may have progressively decreasing diameters in a radially inward direction of the polishing table 22. The roll 104 may be divided into a plurality of zones such that different polishing liquids are supplied therefrom depending on a longitudinal direction of the roll 104. According to an example shown in FIG. 19, the roll 104 of the polishing liquid supply nozzle 26e extends in a radial direction of the polishing table 22. However, the roll 104 may be inclined a certain angle ranging from 0° to 45° relative to the radial direction of the polishing table 22.

[0143] In FIG. 20, a polishing liquid supply nozzle 26f comprises a hollow roll 104 having a spiral slit 106 defined in its wall. Polishing liquid may be supplied from the spiral slit 106 while the roll 104 is being rotated or while the roll 104 is being pivoted and rotated. A rotational speed of the roll 104 and/or the pivoting speed of the roll 104 may be changed while the polishing liquid supply nozzle 26f is in operation. The polishing liquid supply nozzle 26f may be combined with a liquid rate control mechanism for controlling a rate of the polishing liquid that is supplied from the slit 106. An opening width of the slit 106 may be changed in location. For example, the opening width of the slit 106 may progressively decrease in a radially inward direction of the polishing table 22. The roll 104 may be divided into a plurality of zones such that different polishing liquids are supplied therefrom depending on a longitudinal direction of the roll 104. According to an example shown in FIG. 20, the roll 104 of the polishing liquid supply nozzle 26f extends in a radial direction of the polishing table 22. However, the roll 104 may be inclined a certain angle ranging from 0° to 45° relative to the radial direction of the polishing table 22.

[0144] According to the example shown in FIG. 20, the roll 104 has a spiral slit 106. However, the roll 104 may have a straight slit. FIG. 21 shows in perspective a polishing liquid supply nozzle 26g having a straight slit defined therein, and FIG. 22 shows the polishing liquid supply nozzle 26g in vertical cross section. As shown in FIG. 22, the polishing liquid supply nozzle 26g comprises a pressure holder 110 having a pressure chamber 108 defined therein, and a slit body 114 mounted in the pressure holder 110 and having a straight slit 112 defined therein which extends downwardly from the pressure holder 110. The pressure holder 110 controls pressure of a polishing liquid Q supplied to the pressure chamber 108 to adjust a flow rate of the polishing liquid Q that is discharged from the slit 112. The slit 112 is straight along the pressure holder 110, thereby allowing the polishing liquid Q to be discharged from the slit 112 uniformly therealong. As shown in FIG. 23, the pressure chamber 108 may be divided into a plurality of compartments, and the compartments may be supplied with the polishing liquid Q at different flow rates, so that the polishing liquid Q can be discharged from the slit 112 at different flow rates therealong. The polishing liquid supply nozzle 26g shown in FIGS. 21 and 22 may be disposed along a radial direction of the polishing table 22, or may be inclined a certain angle ranging from 0° to 45° relative to the radial direction of the polishing table 22.

[0145] A polishing liquid supply nozzle 26h shown in FIG. 24 may be employed to distribute polishing liquid supplied to the polishing pad 52. The polishing liquid supply nozzle 26h has a fan-shaped distribution plate (distribution skirt) 116 for distributing polishing liquid Q ejected from polishing liquid supply port 57. According to this polishing liquid supply nozzle 26h, while the polishing liquid Q ejected from the polishing liquid supply port 57 is flowing on the distribution skirt 116, the polishing liquid Q is distributed in different directions and supplied to the polishing pad 52. The distribution skirt 116 may have grooves or resistive members for limiting flow of the polishing liquid Q. The distribution skirt 116 may have a roughened surface to give resistance to the flow of the polishing liquid Q flowing thereon. The distribution skirt 116 should preferably be made of a chemical-resistant material such as fluororesin or the like. As shown in FIG. 25, the polishing liquid supply nozzle 26g shown in FIG. 21 may be combined with a distribution skirt 116.

[0146] A polishing liquid supply nozzle 26i shown in FIG. 26 may be employed to distribute polishing liquid supplied to the polishing pad 52. The polishing liquid supply nozzle 26i comprises a disk-shaped nozzle body 118 and a distribution plate 120 mounted on a lower surface of the nozzle body 118. The polishing liquid is supplied to the polishing pad 52 through central through holes (not shown) defined in the nozzle body 118 and the distribution plate 120. The distribution plate 120 has a lower surface made of a resistive material. According to this polishing liquid supply nozzle 26i, the polishing liquid supplied from the polishing liquid supply port 57 is distributed in many directions by a lower surface of the distribution plate 120 and applied to the polishing pad 52. The distribution plate 120 should preferably be made of a chemical-resistant material such as fluororesin or the like.

[0147] FIG. 27 shows a distribution plate (contact member) 122 disposed downstream of polishing liquid supply nozzle 26 with respect to a direction in which the polishing Table 22 rotates, and brought into contact with the polishing pad 52 for distributing polishing liquid Q supplied to the polishing pad 52. The distribution plate 122 distributes the polishing liquid Q supplied from the polishing liquid supply nozzle 26 in a radial direction of the polishing plate 22, thereby uniformizing distribution of the polishing liquid Q on the polishing pad 52. The distribution plate 122 should preferably be made of a wear-resistant elastic material such as fluororesin or the like. The distribution plate 122 may extend in a radial direction of the polishing plate 22 or may be inclined a certain angle ranging from 0° to 45° relative to the radial direction of the polishing plate 22. The distribution plate 122 may be held at rest, or may be pivoted, moved linearly, rotated, swung, or reciprocated. A moving speed of the distribution plate 122 may be varied while it is in motion. As shown in FIG. 28, the distribution plate 122 may have a plurality of slits 124 to distribute the polishing liquid Q supplied from the polishing liquid supply nozzle 26. Dimensions, e.g., width, height, and pitch, of the slits 124 should preferably be adjustable by a shutter or the like.

[0148] If polishing liquid supply devices shown in FIGS. 9 and 13 through 28 are employed, then the polishing pad 52 should preferably have a plurality of radially divided regions, such as the polishing pad with concentric grooves, as shown in FIG. 10. The polishing pad 52 with the radially divided regions allows polishing liquid to be efficiently supplied to a surface being polished of a semiconductor wafer while holding the polishing liquid in the radially divided regions, rather than mixing the polishing liquid on the polishing pad 52.
As shown in FIG. 29, a conventional CMP apparatus 500 with a plurality of polishing liquid supply ports is combined with a high-rate polishing liquid circulation system 502, which is disposed outside of the CMP apparatus 500, for circulating a polishing liquid at a high rate. A single polishing liquid supply line 504 is connected from the CMP apparatus 500 to the polishing liquid circulation system 502. In the CMP apparatus 500, the polishing liquid supply line 504 is branched into a plurality of lines 506 connected to respective polishing liquid supply ports. Depending on a shape of polishing liquid supply nozzles, polishing liquid tends to be supplied from the polishing liquid supply ports at different rates, and the polishing liquid supply nozzles need to be adjusted or combined with valves for supplying the polishing liquid uniformly to the polishing pad.

According to this embodiment, as shown in FIG. 30, a polishing apparatus 200 is combined with a high-rate polishing liquid circulation system 210 which comprises a polishing liquid tank 202, a pressure pump 204, a back-pressure valve 206, and a pipe 208. A plurality of polishing liquid supply lines 212 extend from respective polishing liquid supply ports 57, and are connected directly to the pipe 208 of the high-rate polishing liquid circulation system 210. The arrangement shown in FIG. 30 makes it possible to uniformly supply polishing liquid to a semiconductor wafer to be polished for thereby improving a polishing rate and greatly increasing in-plane uniformity of the polishing rate.

As shown in FIG. 30, the polishing liquid supply lines 212 have respective fluid pressure valves 214 as flow regulating valves for regulating flow rates of the polishing liquid supplied from the polishing liquid supply ports 57. As shown in FIGS. 31A and 31B, each of the fluid pressure valves 214 has a pipe compression section 216 for reducing a diameter of a flexible pipe 212b of one of the polishing liquid supply lines 212 under a fluid pressure. The pipe compression section 216 is disposed around the pipe 212b. As shown in FIG. 31B, when the pipe 212a is compressed by the pipe compression section 216 under the fluid pressure, a flow rate of the polishing liquid Q flowing through the pipe 212a is reduced. Since the pipe 212a is compressed by the pipe compression section 216 under the fluid pressure, the pipe 212a is prevented from being unduly worn.

The retainer ring of the top ring controls a polishing profile of a workpiece (semiconductor wafer) to be polished by (1) holding an outer circumferential edge of the workpiece and (2) pressing itself against a polishing surface (polishing pad). If a polishing liquid for forming a copper complex having a low mechanical strength is used under a low polishing surface pressure, as described above, then excessively pressing the retainer ring against the polishing surface tends to limit supply of the polishing liquid to a surface of the workpiece to be polished. Therefore, load applied to press the retainer ring against the polishing surface should be as small as possible. However, if the load applied to press the retainer ring against the polishing surface is too small, the workpiece held by the retainer ring is liable to be displaced from the retainer ring. Therefore, there has been a demand for preventing the workpiece from being displaced from the retainer ring even when the load applied to press the retainer ring against the polishing surface is small.

To meet such a demand, as shown in FIG. 32, a retainer ring 356, which comprises a presser 300 for pressing the polishing pad 52 to adjust a state of contact between the semiconductor wafer W and the polishing pad 52, and a ring-shaped guide 302 for preventing the semiconductor wafer W from being displaced from the top ring 24, may be employed. The guide 302 is positioned radially inwardly of the presser 300 closely to the semiconductor wafer W. According to this retainer ring 356, even if polishing pressure is low, the retainer ring 356 can control a polishing profile of the semiconductor wafer W while preventing the semiconductor wafer W from being displaced from the top ring 24.

The guide 302 is vertically positionally adjustable by a screw or an air cylinder to adjust a height between the surface of the polishing pad 52 and the guide 302. The guide 302 should preferably have a radial width of at most 6 mm, and should preferably be made of a material having a low level of hardness.

In a CMP process for planarizing copper damascene interconnects for semiconductor device fabrication, a copper film is fully removed up to a barrier metal, leaving copper interconnects. As shown in FIGS. 33A through 33C, a process of removing the copper film up to the barrier metal comprises a first step (bulk copper polishing process, see FIGS. 33A and 33B) of quickly removing most of an initial copper film 400 and reducing initial steps to leave a slight copper film 400a, and a second step (copper clearing process, see FIGS. 33B and 33C) of fully removing remaining copper film 400a to a barrier metal 402, leaving interconnects 400b.

In the bulk copper polishing process, an initial step is reduced (planarized) as much as possible and the copper film 400a is left uniformly in a film as thin as possible, for reducing resistive flux during the copper clearing process. For example, a thickness of the copper film 400a that remains after the bulk copper polishing process should be in a range from 100 to 150 nm, preferably at most 100 nm, or more preferably at most 50 nm. Generally, as shown in FIG. 34A, the copper clearing process is performed under a reduced polishing pressure in order to reduce dishing 410 and erosion 412 after removal of the copper film.

The conventional CMP apparatus has determined a timing for process switching based on information as to film thickness at a certain position in a wafer plane. According to such a method, since the timing for process switching is determined irrespective of a film thickness distribution during a polishing process, even if a polishing profile is changed, process switching is performed when the film thickness at a position being measured on a wafer reaches a predetermined value.

If a remaining copper film whose thickness is much larger than in the position being measured is present in another position on the wafer, then, as shown in FIG. 34B, remaining copper films 414 may possibly occur after a next copper clearing process is ended. Conversely, if a remaining copper film whose thickness is much smaller than in the position being measured is present in another position on the wafer, then dishing 410 and erosion 412 may possibly occur in such another position, as shown in FIG. 34A.

The above problem can be avoided by the following process: A film thickness distribution of a copper film upon transition from the bulk copper polishing process to the copper clearing process is preset and stored in a memory. During the bulk copper polishing process performed on a semiconductor wafer, a film thickness distribution of a copper film on the semiconductor wafer is acquired from the eddy-current sensor 58 (see FIG. 2). According to a simulation software program, the preset film thickness distribution and the acquired film thickness distribution are instantaneously com-
pared with each other, and polishing conditions required to achieve the preset film thickness distribution are simulated. Based on simulated polishing conditions, the top ring 24 controls a polishing profile to achieve the preset film thickness distribution. For example, the top ring 24 increases a polishing rate for an area where an amount of polishing is insufficient in the present film thickness distribution. This polishing profile control thus performed allows remaining copper film to have a uniform thickness or the preset film thickness distribution immediately prior to the copper clearing process. When an actual film thickness distribution agrees with the preset film thickness distribution, the bulk copper polishing process switches to the copper clearing process.

[0160] The above process makes it possible to achieve a finally desirable film thickness distribution securely while monitoring an actual polishing configuration (film thickness distribution). Since the bulk copper polishing process can switch to the copper clearing process at a desired film thickness distribution at all times, the copper clearing process can be started under constant conditions at all times without being affected by process variations of the bulk copper polishing process, i.e., variations of a polishing rate and polishing profile. Accordingly, any undue load on a next copper clearing process can be minimized. This process contributes to not only a reduction in the dishing 410 and the erosion 412 after the copper clearing process, but also a reduction in a period of time consumed by the copper clearing process, i.e., a reduction in excessive polishing time, an increase in productivity, and a reduction in polishing cost.

[0161] After a conductive film on a semiconductor wafer is polished in a process of forming interconnects, any defects that are present, e.g., residues 414 of the conductive film, scratches, and pits 416 (see FIGS. 34A and 34B) affect not only a sequential process of forming interconnects, but also electric characteristics of electric circuits that are finally formed on a semiconductor wafer. Consequently, it is desirable to eliminate these defects at an end of the polishing process.

[0162] According to the CMP process, the residues 414 of the conductive film may be eliminated by overpolishing the semiconductor wafer by a thickness greater than the thickness of the initial film. Generally, overpolishing the semiconductor wafer for a long period of time tends to cause dishing 410 and erosion 412 in interconnect areas of the semiconductor wafer, as shown in FIG. 34A. In addition, scratches and pits 416 are inevitable because of mechanical polishing action on the semiconductor wafer.

[0163] Generally, since remaining conductive films 414 cannot be removed by ordinary polishing, they need to be removed by overpolishing. However, overpolishing tends to cause dishing 410, erosion, scratches, and pits 416 on the semiconductor wafer, as described above. In order to eliminate these defects, the bulk copper polishing process is performed by CMP, and the subsequent copper clearing process by CMP is stopped when the remaining copper film reaches a thickness of at most 50 nm. Thereafter, the copper clearing process is performed by a chemical etching process to remove the copper film. The copper clearing process performed by a chemical etching process free of a mechanical polishing action can polish the copper film without causing defects.

[0164] An etchant used in the chemical etching process may be an acid such as sulfuric acid, nitric acid, hydrochloric acid (particularly, hydrofluoric acid or hydrochloric acid), an alkali such as ammonia water, or a mixture of an oxidizing agent such as hydrogen peroxide and an acid such as hydrogen fluoride or sulfuric acid. In the bulk copper polishing process, it is preferable to measure a thickness of a conductive thin film, and when this measured thickness reaches a predetermined thickness such as at most 100 nm, the bulk copper polishing process should preferably switch to the copper clearing process. The thickness of such a conductive thin film may be measured by at least one of an optical sensor for applying light to the conductive thin film to measure the film thickness, an eddy-current sensor for detecting an eddy current produced in the conductive thin film to measure the film thickness (see FIG. 2), a torque sensor for detecting a running torque of the polishing table 22 to measure the film thickness, and an ultrasonic sensor for applying ultrasonic energy to the conductive thin film to measure the film thickness.

[0165] The above chemical etching process is not limited to the bulk copper polishing process for forming a thin copper film with the CMP apparatus, but may be combined with other processes. Specifically, after various processes for forming a flat conductive thin film on a substrate, the conductive thin film may be removed by the chemical etching process.

[0166] For example, after a thin film is formed by an electrolytic polishing process, this formed thin film may be removed by the chemical etching process. The electrolytic polishing process is effective to reduce scratches and pits 416 because it does not involve a mechanical action. However, if a conductive film that fails to make an electric connection, e.g., a slight remaining conductive film on an insulating material, occurs, then the electrolytic polishing process is unable to remove such a remaining conductive film. However, a flat conductive thin film that is formed by the electrolytic polishing process can be removed by the chemical etching process which requires no electric connection, without causing defects. The electrolytic polishing process is not limited to any particular type. For example, an electrolytic polishing process using an ion exchanger or an electrolytic polishing process using no ion exchanger may be employed. The electrolytic polishing process should preferably be performed with use of ultrapure water, pure water, or a liquid or an electrolytic solution having an electric conductivity of not more than 500 μS/cm. For example, the electrolytic polishing process may be performed by an electrolytic processing apparatus as disclosed in Japanese laid-open patent publication No. 2003-145534, for example.

[0167] After a thin film is formed by a flat plating process, this formed thin film may be removed by the chemical etching process. Formation and removal of a copper film (Cu) has been described above. However, the present invention is applied to formation and removal of other films. For example, after a conductive thin film containing at least one of Ta, TaN, WN, TiN, and Ru is formed, this formed thin film may be removed by the chemical etching process.

Example

[0168] A polishing apparatus shown in FIG. 35 was used to polish a semiconductor wafer with a polishing liquid supply nozzle 26 being actually swung in a polishing process. FIG. 36A is a graph showing a polishing rate of the semiconductor wafer which was polished by the polishing apparatus shown in FIG. 35. FIG. 36B is a graph showing a polishing rate of a semiconductor wafer which was polished by the polishing apparatus shown in FIG. 35 with the polishing liquid supply nozzle 26 being not swung in the polishing process. A com-
Comparison between these graphs indicates that in-plane uniformity of a polishing rate of the semiconductor wafer was higher when the polishing liquid supply nozzle 26 was swung in the polishing process.

Although certain preferred embodiments of the present invention have been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.

170. (canceled)

71. A method for polishing a workpiece, the method comprising the steps of:
   polishing the workpiece to remove a substantial portion of a first film formed on the workpiece by pressing the workpiece against a polishing surface while supplying a polishing liquid to the polishing surface from a polishing liquid nozzle in a first-stage polishing;
   polishing the workpiece to remove a remaining portion of the first film until a second film on the workpiece is exposed in a second-stage polishing, leaving an interconnect area;
   presetting a film thickness distribution for the first film upon transition from said first-stage polishing to said second-stage polishing;
   measuring a thickness of said first film with a film thickness sensor in said first-stage polishing to acquire a film thickness distribution of said first film;
   and adjusting polishing conditions in said first-stage polishing to equalize the acquired film thickness distribution of said first film to the preset film thickness distribution for the first film.

72. A method according to claim 71, wherein said first-stage polishing is switched to said second-stage polishing when the acquired film thickness distribution of said first film is equalized to the preset film thickness distribution for the first film.

73. A method according to claim 71, wherein said adjusting polishing conditions in said first-stage polishing is carried out by adjusting polishing liquid supply conditions for supplying the polishing liquid to the polishing surface.

74. A method according to claim 71, wherein said film thickness sensor is an eddy current sensor.

75. A method according to claim 71, wherein said film thickness sensor is an optical sensor.

76. A method according to claim 73, wherein said adjusting polishing liquid supply condition is carried out by varying a moving speed of said polishing liquid supply nozzle while said polishing liquid supply nozzle is being moved.

77. A method according to claim 76, wherein said polishing liquid supply nozzle is moved such that said polishing liquid supply nozzle moves at least one of a pivoting motion, a reciprocating motion, a rotational motion, and a linear motion.

78. A method according to claim 76, wherein said polishing liquid supply nozzle has a plurality of polishing liquid supply ports.

79. A method according to claim 76, wherein said polishing liquid supply nozzle extends in a radial direction of said polishing surface.

80. A method according to claim 76, wherein said polishing liquid supply nozzle is inclined a predetermined angle to a radial direction of said polishing surface.

81. A method according to claim 73, wherein said adjusting polishing liquid supply condition is carried out by controlling a rate of the polishing liquid supplied from said polishing liquid supply nozzle to said polishing surface.

82. A method according to claim 79, wherein said polishing liquid supply nozzle has a plurality of polishing liquid supply ports and rates of the polishing liquid supplied from said polishing liquid supply ports to said polishing surface are individually controlled.

83. A method for polishing a workpiece, the method comprising:
   polishing the workpiece to remove a film formed on the workpiece by pressing the workpiece against a polishing surface while supplying a polishing liquid to the polishing surface from a polishing liquid nozzle;
   presetting a film thickness distribution for the film;
   measuring a thickness of the film with a film thickness sensor to acquire a film thickness distribution of the film during polishing of the film;
   simulating polishing conditions to achieve the preset film thickness distribution for the film by comparing the acquired film thickness distribution of the film and the preset film thickness distribution for the film with each other; and
   adjusting polishing condition of the film based on the simulated polishing conditions.

84. A method according to claim 83, wherein said adjusting polishing condition is carried out by adjusting polishing liquid supply conditions for supplying the polishing liquid to the polishing surface.

85. A method according to claim 83, wherein said film thickness sensor is an eddy current sensor.

86. A method according to claim 83, wherein said film thickness sensor is an optical sensor.

87. A method according to claim 84, wherein said adjusting polishing liquid supply condition is carried out by varying a moving speed of said polishing liquid supply nozzle while said polishing liquid supply nozzle is being moved.

88. A method according to claim 87, wherein said polishing liquid supply nozzle is moved such that said polishing liquid supply nozzle moves in at least one of a pivoting motion, a reciprocating motion, a rotational motion, and a linear motion.

89. A method according to claim 87, wherein said polishing liquid supply nozzle has a plurality of polishing liquid supply ports.

90. A method according to claim 87, wherein said polishing liquid supply nozzle extends in a radial direction of said polishing surface.

91. A method according to claim 87, wherein said polishing liquid supply nozzle is inclined a predetermined angle to a radial direction of said polishing surface.

92. A method according to claim 84, wherein said adjusting polishing liquid supply condition is carried out by controlling a rate of the polishing liquid supplied from said polishing liquid supply nozzle to said polishing surface.

93. A method according to claim 92, wherein said polishing liquid supply nozzle has a plurality of polishing liquid supply ports and rates of the polishing liquid supplied from said polishing liquid supply ports to said polishing surface are individually controlled.

* * * * *