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(54) **POLISHING METHOD AND POLISHING APPARATUS**

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(57) **ABSTRACT**

A polishing method for polishing a workpiece using the chemical polishing process endpoint detecting technology is applicable to actual polishing processes and polishing apparatus. The polishing method including pressing the workpiece against a polishing surface of a polishing table, moving the workpiece and the polishing surface relatively to each other to polish the workpiece, and disposing a gas suction pipe having a gas inlet port, directly above the polishing surface, supplying an atmospheric gas from above the polishing surface through the gas inlet port to a gas detector via the gas suction pipe, and monitoring a particular gas contained in the atmospheric gas with the gas detector while the workpiece is being polished.

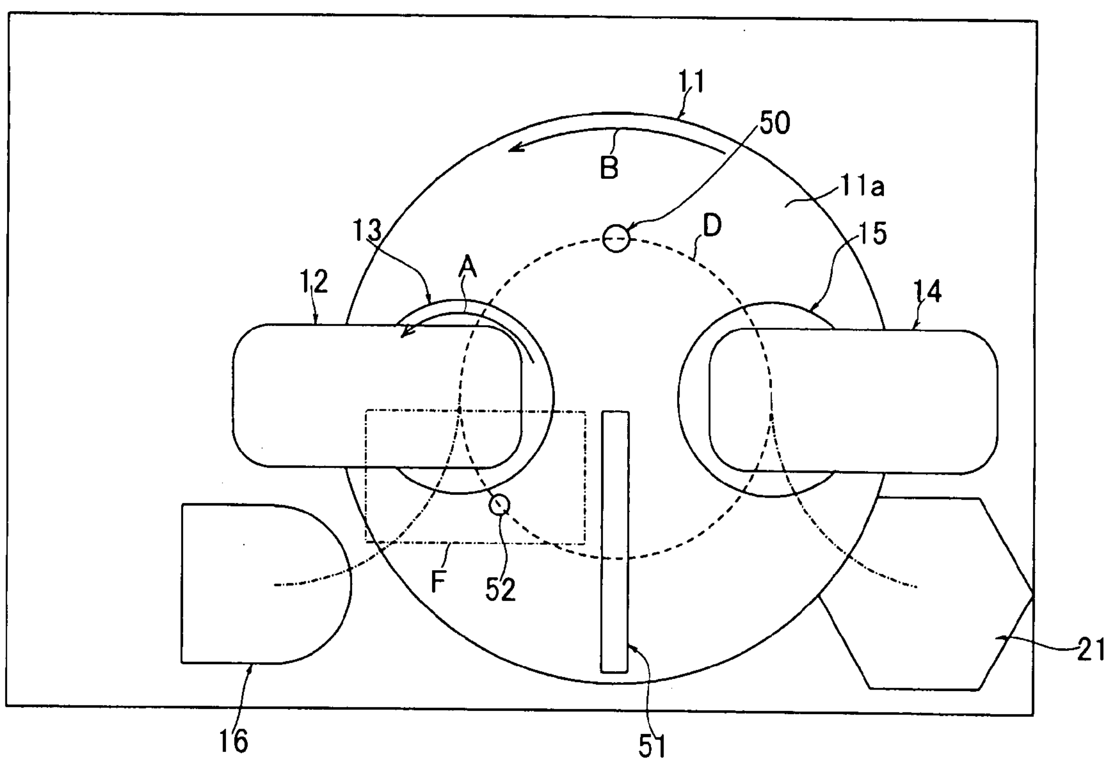
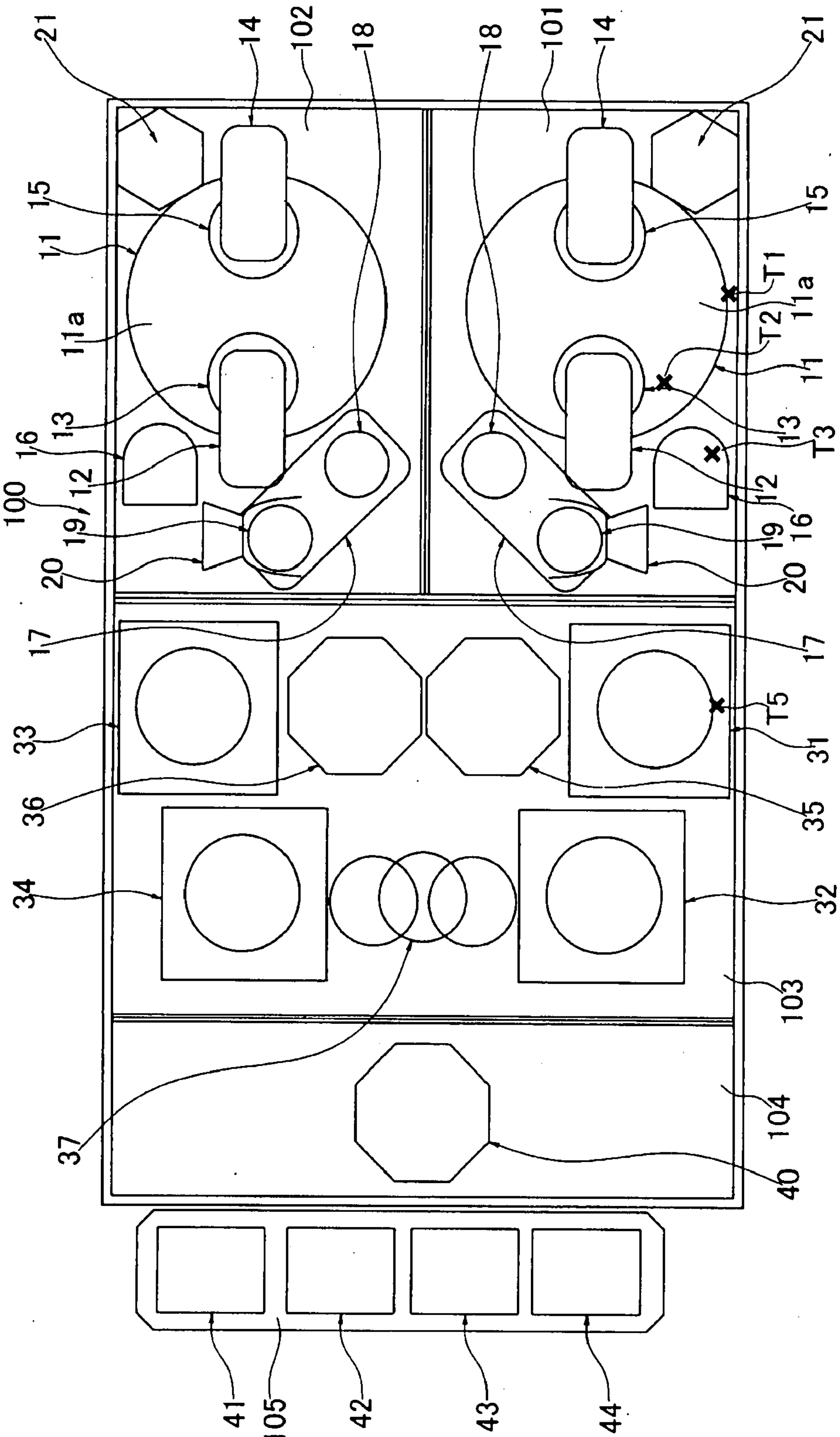


FIG. 1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14
102
18
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101
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11
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12
100
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T1
11a
T2
11
13
T3
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16
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T5
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103
37
104
40
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105
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43
44

FIG. 2

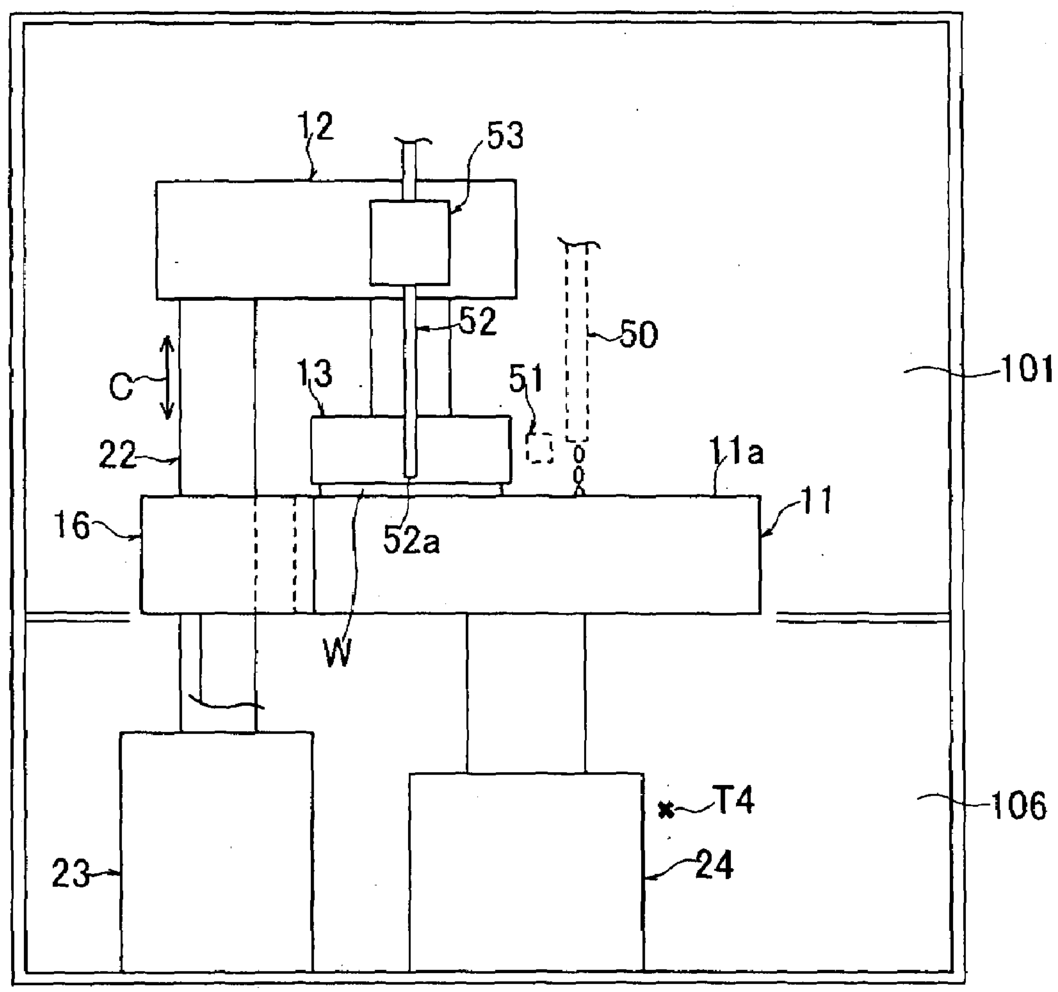


FIG. 3

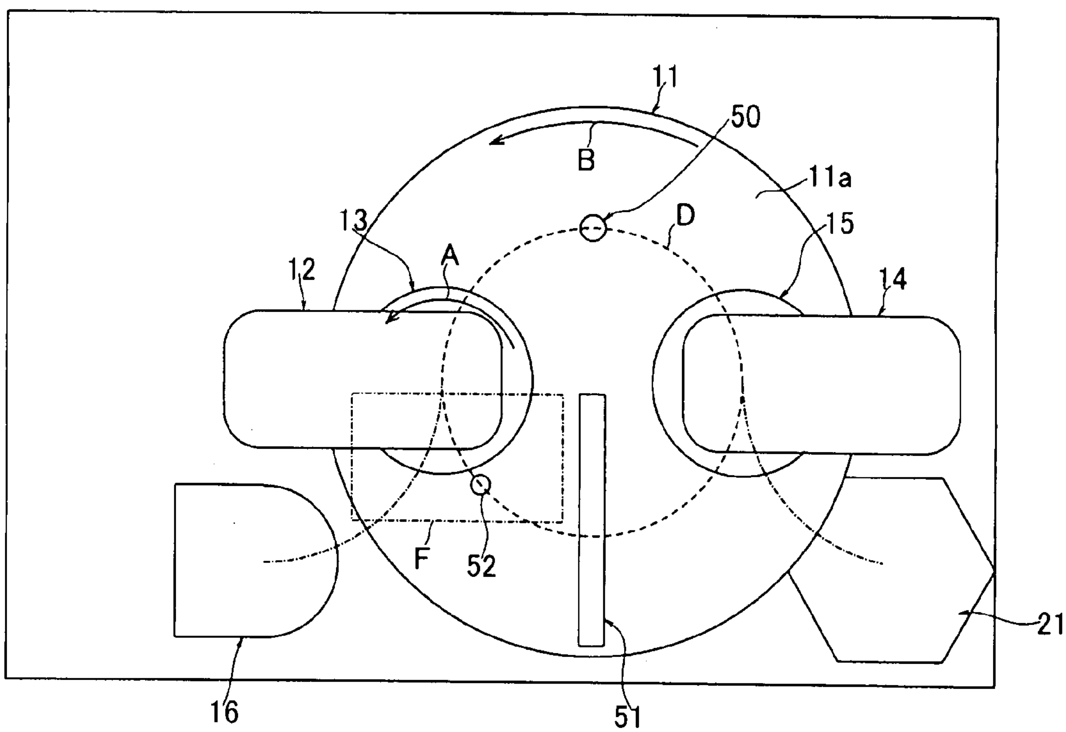


FIG. 4

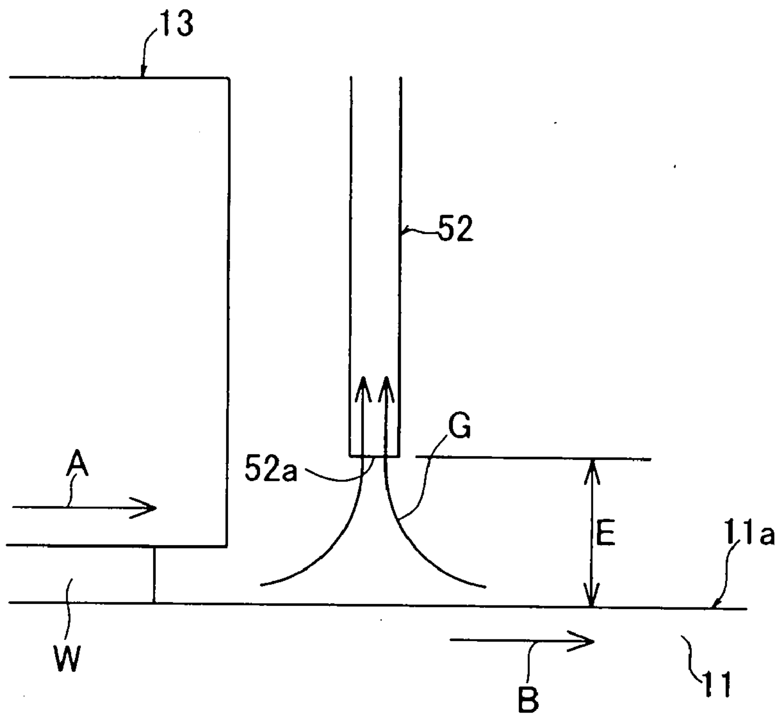


FIG. 5

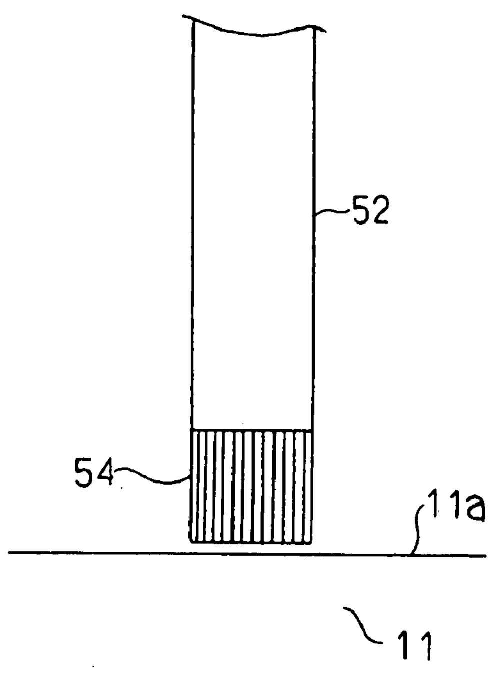


FIG. 6

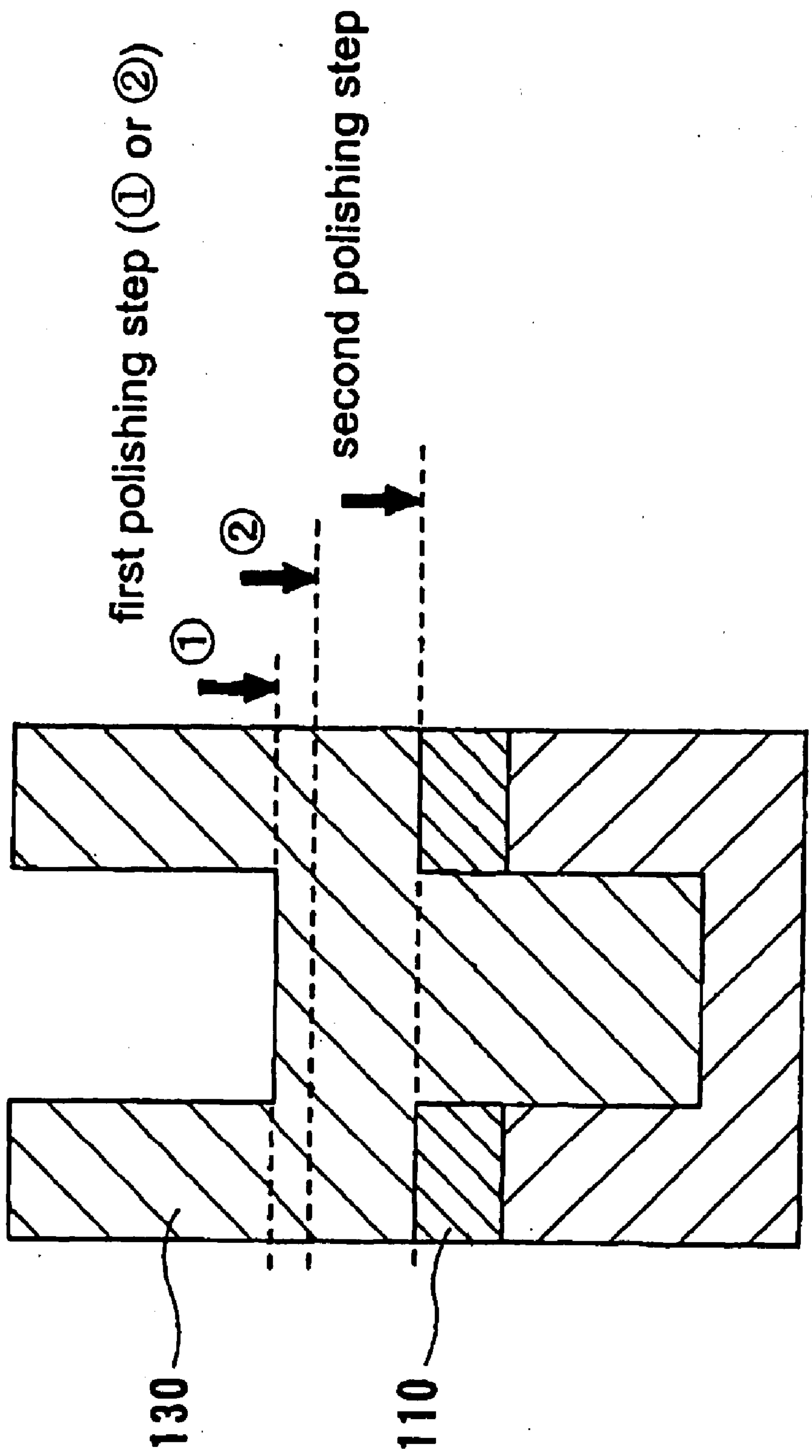


FIG. 7A

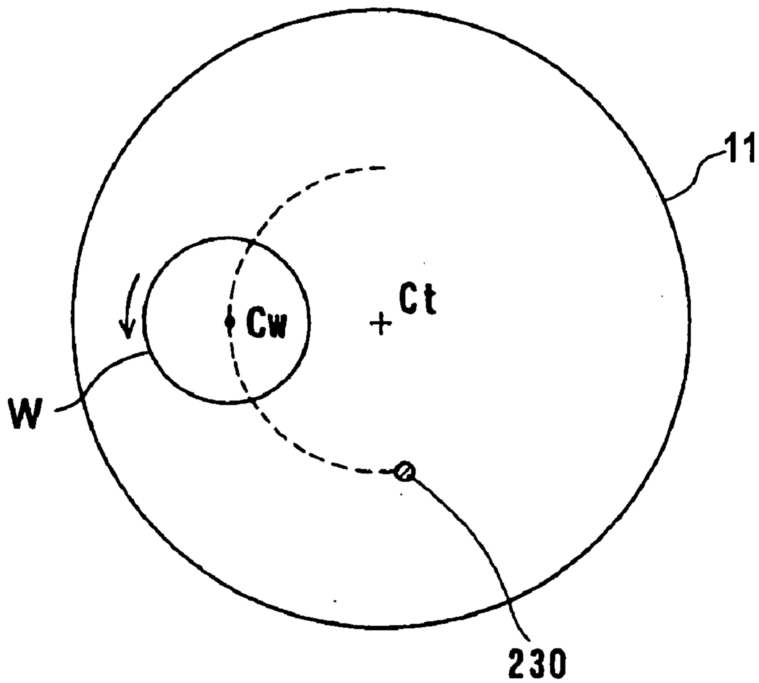


FIG. 7B

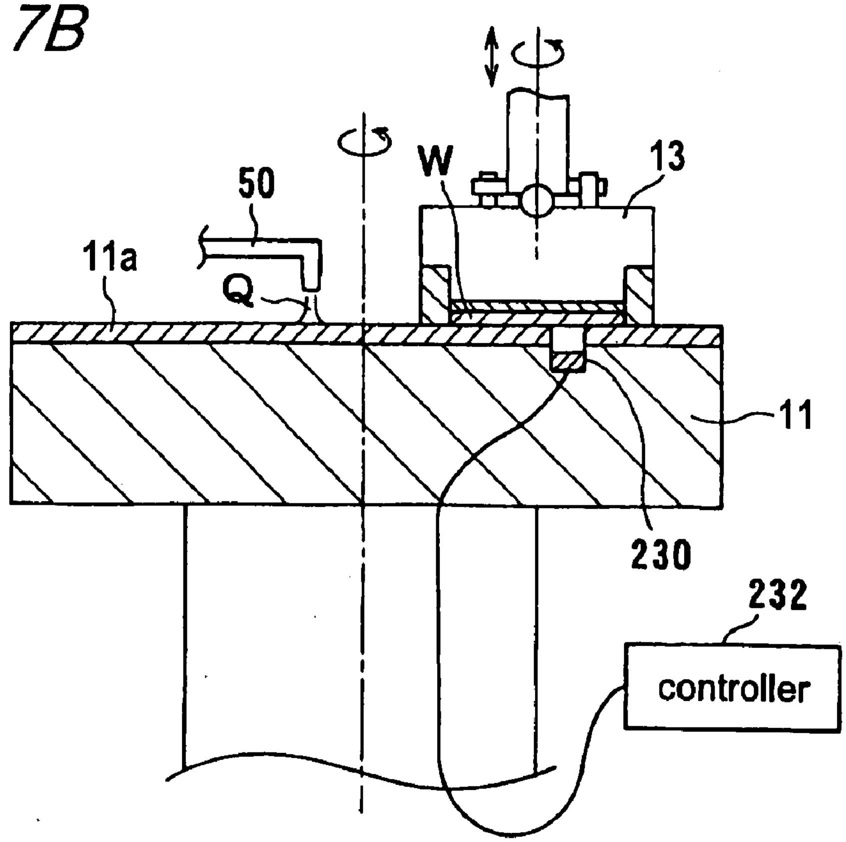
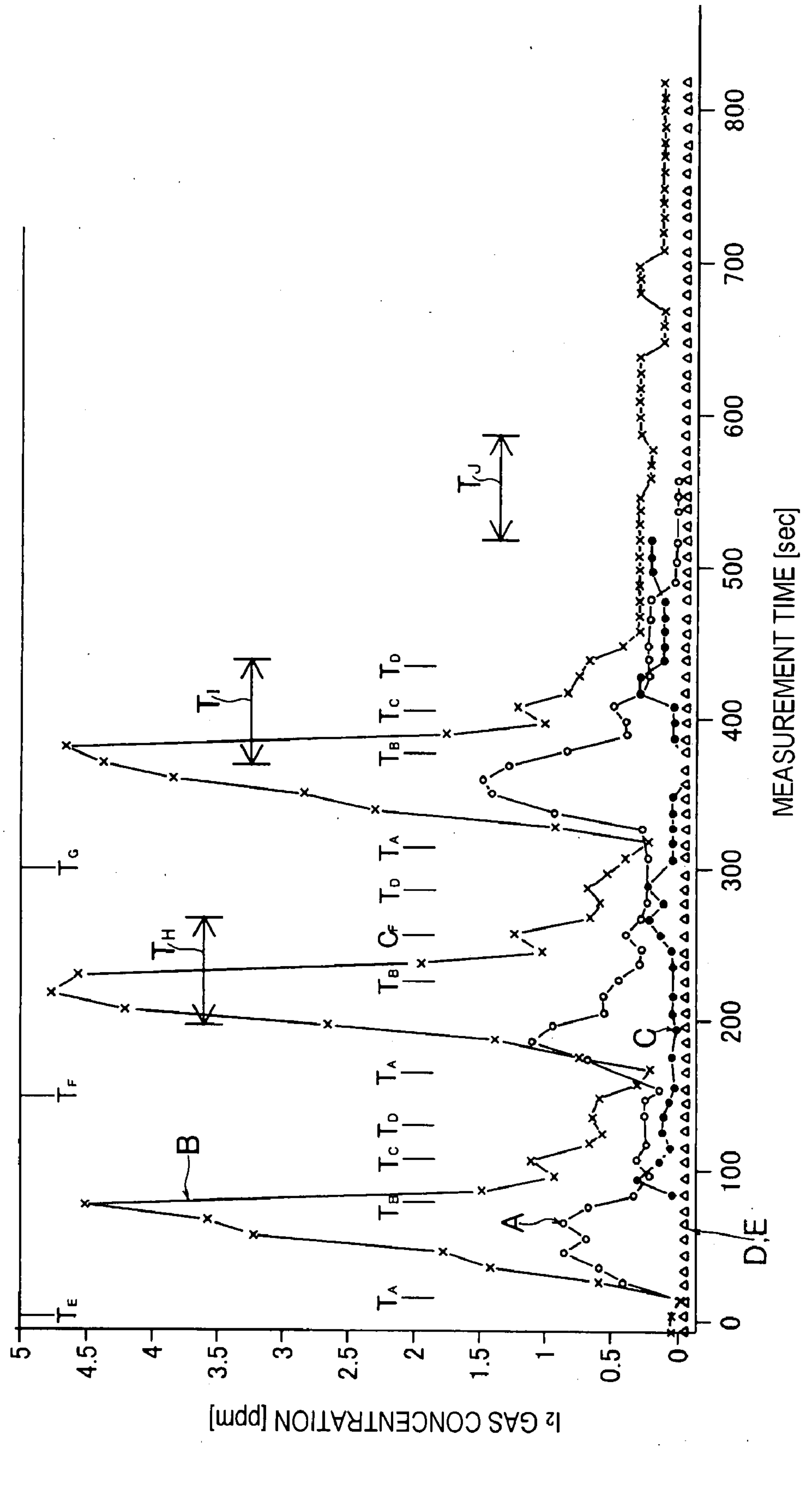


FIG. 8


I2 GAS CONCENTRATION [ppm]
MEASUREMENT TIME [sec]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
100
200
300
400
500
600
700
800
A
B
C
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TC
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POLISHING METHOD AND POLISHING APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a polishing method and a polishing apparatus incorporating a means for detecting a gas that is produced while a workpiece is being polished thereby, and more particularly to a polishing method and a polishing apparatus capable of detecting a particular gas that is produced while a workpiece, such as a semiconductor substrate or the like, is being polished, allowing an effective evasive action to be made quickly if the detected particular gas is a highly toxic gas, and detecting the endpoint of a process of polishing a surface film of the workpiece to planarize the same and also a process of chemical mechanical polishing the surface film based on the detection of the particular gas.

[0003] 2. Description of the Related Art

[0004] In the field of semiconductor devices, simultaneous efforts are being made to form circuit patterns in smaller dimensions and more layers in order to meet demands for higher device functionality. According to the fabrication technology for forming multi-level circuit patterns, it is necessary to planarize interlevel dielectric films and interconnect metal films for the purpose of producing highly reliable semiconductor devices. If those films are not planarized sufficiently, but contain surface irregularities, then the photolithographic process that is performed to form fine circuit patterns is liable to bring the light beam out of focus, making it difficult or impossible to form detailed circuit patterns. To solve such a problem, it has become widely practiced recently in the art to use the chemical mechanical polishing (CMP) process for chemically and mechanically polishing a film formed on a surface of a semiconductor substrate to a flat finish.

[0005] When a film is planarized by the CMP process, it is extremely important to stop the CMP process at the time a suitable thickness of the film has been removed, i.e., at the time the desired endpoint of the polishing process is reached. The CMP process has to be stopped when the endpoint is reached because if the film is removed too much, then the yield of semiconductor devices is reduced, and conversely, if the film is not removed sufficiently, then the film needs to be polished again, resulting in an increase in the cost. There have been developed various processes for detecting the endpoint of the polishing process at which the polishing process needs to be stopped after it has removed a desired thickness of the film.

[0006] The conventional endpoint detecting processes include (1) a polishing time management process for predicting a polishing process endpoint by simply managing the polishing time, (2) a process for detecting a polishing process endpoint based on a change in the electric current flowing through a motor which rotates a turntable or a top ring of a polishing apparatus, (3) a process for measuring a thickness of the film being polished by measuring an electrostatic capacitance, (4) an optical process for optically measuring a film thickness, and (5) an acoustic process for detecting a film thickness based on an acoustic change. These conventional endpoint detecting processes, however, are disadvantageous in that they fail to perform real-time supervision, cannot make measurements on site, and suffer insufficient sensitivity.

[0007] As circuit patterns are fabricated in smaller dimensions and more layers, planarization margins are becoming progressively smaller, resulting in a need for detecting a polishing process endpoint more strictly. It has been proposed to detect a polishing process endpoint by detecting an increase or reduction in the amount of a chemical substance involved in a polishing reaction, as disclosed in Japanese laid-open patent publication No. H6-318583, Japanese laid-open patent publication No. H8-64561, Japanese laid-open patent publication No. H9-63997, and Japanese laid-open patent publication No. H10-242089.

[0008] According to Japanese laid-open patent publication No. H6-318583, the waste slurry produced in the polishing process is analyzed from time to time while the polishing process is in progress, and the polishing process endpoint is detected as being reached when a certain component contained in the film being polished is dissolved into the waste slurry. There are known many processes for detecting the polishing process endpoint by analyzing the waste slurry as disclosed in Japanese laid-open patent publication No. H8-64561 and Japanese laid-open patent publication No. H9-63997. However, few processes are known for detecting a gas component produced by a polishing reaction. One of such gas detecting processes is revealed in Japanese laid-open patent publication No. H10-242089. According to the revealed polishing process endpoint detecting process in Japanese laid-open patent publication No. H10-242089, at least a polishing table is covered and a gas produced in the closed space is drawn and detected. It is therefore practically difficult to apply the disclosed polishing process endpoint detecting process to actual polishing apparatus.

[0009] In recent years, various polishing reactions are employed in polishing processes for polishing films on account of new materials introduced into semiconductor devices. Of those various polishing reactions, some produce a highly toxic gas during the polishing process. However, existing polishing apparatus are designed without concern for such a highly toxic gas, and hence do not necessarily take into account personnel safety control.

SUMMARY OF THE INVENTION

[0010] The present invention has been made in view of the above situation in the related art. It is therefore an object of the present invention to provide a polishing method and a polishing apparatus for polishing a workpiece using the chemical polishing process endpoint detecting technology that is applicable to actual polishing processes and polishing apparatus.

[0011] Another object of the present invention is to provide a polishing method and a polishing apparatus capable of quickly detecting a highly toxic gas that is produced while a workpiece is being polished, and allowing an effective evasive action to be made against possible danger.

[0012] According to the present invention, there is provided a method of polishing a workpiece, comprising pressing the workpiece against a polishing surface of a polishing table, moving the workpiece and the polishing surface relatively to each other to polish the workpiece, and disposing a gas suction pipe having a gas inlet port, directly above the polishing surface, supplying an atmospheric gas from above the polishing surface through the gas inlet port to a gas detector via the gas suction pipe, and monitoring a particular gas contained in the atmospheric gas with the gas detector while the workpiece is being polished.

[0013] In a preferred aspect of the present invention, the method further comprises detecting an endpoint of the polishing of the workpiece when the particular gas is produced or no longer produced.

[0014] The gas inlet port may be disposed at a height of 100 mm or smaller from the polishing surface.

[0015] The atmospheric gas is preferably drawn into the gas suction pipe at a rate ranging from 10 cc to 1 liter per minute.

[0016] The gas detector may have a lower detecting capability limit of 1 ppm or less, preferably 0.1 ppm or less.

[0017] In a preferred aspect of the present invention, the method further comprises supplying fresh air to a detecting element of the gas detector while the atmospheric gas is not being monitored by the gas detector.

[0018] According to the present invention, there is also provided an apparatus for polishing a workpiece, comprising a polishing table having a polishing surface, a mechanism for pressing the workpiece against the polishing table, and moving the workpiece and the polishing surface relatively to each other to polish the workpiece, a controller for controlling the polishing table and the mechanism, a gas suction pipe disposed directly above the polishing surface, and a gas detector, which is connected to the gas suction pipe, for detecting a particular gas, wherein the gas suction pipe has a gas inlet port for supplying an atmospheric gas from above the polishing surface through the gas inlet port to the gas detector via the gas suction pipe, so that the gas detector can detect a particular gas contained in the supplied atmospheric gas.

[0019] Preferably, the controller detects an endpoint of the polishing of the workpiece when the gas detector detects or no longer detects the particular gas.

[0020] The gas inlet port may be disposed at a height of 100 mm or smaller from the polishing surface.

[0021] The atmospheric gas is preferably drawn into the gas suction pipe at a rate ranging from 10 cc to 1 liter per minute.

[0022] The gas detector may have a lower detecting capability limit of 1 ppm or less, preferably 0.1 ppm or less.

[0023] In a preferred aspect of the present invention, the apparatus further comprises an air supply section for supplying fresh air to a detecting element of the gas detector while the atmospheric gas is not being detected by the gas detector.

[0024] For drawing in the atmospheric gas containing a high concentration of the particular gas to be detected, it is preferable that the gas inlet port be positioned closely to the workpiece, e.g., a substrate, and located in a direction opposite to the direction of a gas flow over the polishing surface, over a path along which the center of the workpiece moves on the polishing surface, so that the gas inlet port will not draw in a mist. If the atmospheric gas is supplied at all times to the gas detector, it may possibly lower the sensitivity of the gas detector. Therefore, the gas suction pipe may be movable such that, when no gas detection is required, the gas inlet port may be retracted away from the polishing surface to prevent the gas detector from being exposed to the atmospheric gas containing the particular gas to be detected.

[0025] If the atmospheric gas drawn in from the gas inlet port to the gas detector flows at a large rate, then the particular gas to be detected that is contained in the atmospheric gas is diluted to have its concentration lowered, and the gas detector tends to have its detecting sensitivity reduced. If the atmospheric gas flows at a low rate to the gas detector, then the atmospheric gas takes time to flow from the gas inlet port to the gas detector, and the gas detector tends to have its endpoint detecting accuracy reduced. Depending on the distance through the gas suction pipe from the gas inlet port to the gas detector, the atmospheric gas should be drawn into the gas suction pipe at a rate ranging from 10 cc to 1 liter per minute for preventing the detecting sensitivity from being lowered and achieving a higher endpoint detecting accuracy.

[0026] The gas suction pipe should preferably have an inside diameter of 10 mm or smaller, or more preferably 5 mm or smaller. The distance through the gas suction pipe from the gas inlet port to the gas detector should preferably be 2 m or smaller, or more preferably 50 cm or smaller.

[0027] Since the gas detector has a lower detecting capability limit of 1 ppm or less, the gas detector can detect the particular gas, which is produced according to a polishing reaction, with a high sensitivity.

[0028] The gas detector may be an electrochemical gas detector, a detection-tape gas detector, a thermally conductive gas detector, an optochemical gas detector, an infrared-absorption gas detector, or the like. An appropriate gas detector may be selected depending on the particular gas to be detected.

[0029] If the atmospheric gas is drawn into the gas suction pipe at a rate ranging from 10 cc to 1 liter per minute, then the gas detector has its detecting sensitivity prevented from being lowered and its endpoint detecting accuracy increased.

[0030] With the method according to the present invention, the atmospheric gas is supplied from the gas inlet port of the gas suction pipe disposed directly above the polishing surface of the polishing table to the gas detector, and the workpiece is polished while the particular gas to be detected, which is contained in the atmospheric gas, is being monitored by the gas detector. The gas detector can detect the particular gas highly accurately. If the workpiece comprises a substrate with a plurality of laminated films deposited thereon, then the type of a film that is being polished can be identified based on the detected particular gas. Since the gas detector can quickly detect the production of a highly toxic gas produced while the workpiece is being polished, an evasive action to avoid danger can quickly be taken.

[0031] The particular gas contained in the atmospheric gas may be produced from a chemical substance contained in a slurry, a component of the film to be polished, or both.

[0032] If the workpiece comprises a substrate with a plurality of laminated films deposited thereon, then when one of the films is completely polished away, the particular gas that is produced according to a chemical reaction between the film and a slurry is no longer produced. When the film directly beneath the film that has been polished away starts to be newly polished, then another particular gas starts being produced according to a chemical reaction between the new film and the slurry. By detecting when the previous particular gas is no longer detected or when the other particular gas starts being detected, the endpoint of the polishing process can accurately be detected.

[0033] Inasmuch as the gas inlet port is disposed at a height of 100 mm or smaller from the polishing surface, the gas inlet port can draw in the atmospheric gas containing a high concentration of the particular gas. The gas inlet port of the gas suction pipe needs to be positioned closely to the polishing surface in order to draw in the atmospheric gas containing as high a concentration as possible of the particular gas to be detected. If the gas inlet port is too close to the polishing surface, on the other hand, then it tends to draw in particles and a mist, thereby possibly clogging the gas suction pipe and lowering the sensitivity of the gas detector.

[0034] When the detecting element of the gas detector is supplied with fresh air when no gas detection is required, the detecting element of the gas detector is not exposed to the atmospheric gas containing a high concentration of the particular gas for a long time, and does not have its detecting sensitivity lowered. If a polishing process endpoint is detected based on the generation of the particular gas, then since the atmospheric gas is introduced from the gas inlet port to the gas detector, the highly concentrated gas remains in the gas suction pipe even after the polishing process endpoint has been detected. As a result, the detecting element of the gas detector remains exposed to the highly concentrated gas for a long time and is liable to suffer a reduction in its detecting sensitivity. If the detection of the generated gas is used for safety management, then the detecting element of the gas detector may possibly need to be exposed to the highly concentrated gas for a long time. In this case, a non-detecting period may be inserted into a detecting period, and the sample gas may be exchanged with fresh air in the non-detecting period thereby to prevent the gas detector from having its detecting sensitivity from being lowered.

[0035] With the apparatus according to the present invention, the gas inlet port of the gas suction pipe is disposed directly above the polishing surface of the polishing table, and the atmospheric gas is supplied from the gas inlet port to the gas detector via the gas suction pipe. The particular gas to be detected, which is contained in the atmospheric gas, is detected by the gas detector. As with the method of the present invention, the gas detector can detect the particular gas highly accurately. If the workpiece comprises a substrate with a plurality of laminated films deposited thereon, then the type of a film that is being polished can be identified based on the detected particular gas. Since the gas detector can quickly detect the production of a highly toxic gas produced while the workpiece is being polished, an evasive action to avoid danger can quickly be taken.

[0036] The controller is capable of detecting when the particular gas is detected or no longer detected, as endpoint of the polishing process. Therefore, as with the method of the present invention, the endpoint of the polishing process can accurately be detected by detecting when the particular gas is detected or no longer detected.

[0037] The gas inlet port is disposed at a height of 100 mm or smaller from the polishing surface. Therefore, as with the method of the present invention, the gas inlet port can draw in the atmospheric gas containing a high concentration of the particular gas and supply the atmospheric gas to the gas detector. The gas inlet port thus positioned is effective to prevent particles and a mist from being drawn in and clogging the gas suction pipe, and hence from lowering the sensitivity of the gas detector.

[0038] The apparatus may have the air supply section for supplying fresh air to the detecting element of the gas detector while the atmospheric gas is not being detected by the gas detector. Therefore, as with the method of the present invention, the detecting element of the gas detector is not exposed to the atmospheric gas containing the highly concentrated particular gas in the gas supply pipe for a long time, and does not have its detecting sensitivity lowered.

[0039] 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

[0040] FIG. **1** is a plan view of a polishing apparatus according to an embodiment of the present invention;

[0041] FIG. **2** is a side view of a right polishing chamber of the polishing apparatus of the present invention;

[0042] FIG. **3** is a plan view of the right polishing chamber of the polishing apparatus of the present invention;

[0043] FIG. **4** is a schematic view showing the layout of a polishing surface of a polishing table and a gas inlet port of a gas suction pipe of the polishing apparatus of the present invention;

[0044] FIG. **5** is a schematic view showing a modified lower end of the gas suction pipe of the polishing apparatus of the present invention;

[0045] FIG. **6** is a partial cross-sectional view of a substrate, showing a polishing procedure in which a fixed abrasive polishing process is applied to an STI forming process;

[0046] FIGS. **7**A and **7**B are views showing a polishing apparatus according to another embodiment of the present invention, FIG. **7**A being a plan view of a polishing table of the polishing apparatus and FIG. **7**B being a cross-sectional view of the polishing apparatus; and

[0047] FIG. **8** is a graph showing various concentrations of a particular gas which are detected at different atmospheric gas suction positions in the polishing apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0048] Preferred embodiments of the present invention will now be described with reference to the drawings. FIG. **1** shows in plan a polishing apparatus according to an embodiment of the present invention, and FIG. **2** shows in side view a right polishing chamber of the polishing apparatus. The polishing apparatus according to the present invention serves as a substrate polishing apparatus for polishing a semiconductor substrate having a plurality of laminated films on its surface. As shown in FIG. **1**, the polishing apparatus, generally denoted by **100**, has a right polishing chamber **101**, a left polishing chamber **102**, a cleaning chamber **103**, a transport chamber **104**, and a loading/unloading chamber **105**. The right polishing chamber **101** and the left polishing chamber **102** accommodate respective polishing tables **11** therein. The polishing apparatus **101** also has a lower chamber **106** (see FIG. **2**) disposed beneath the right polishing chamber **101** and the left polishing chamber **102** and housing therein two table drive motors **24** for rotating the polishing tables **11**, respectively. Each of the polishing tables **11** has an upper polishing surface **11***a*. Actually, the polishing surface **11***a* is provided by the upper surface of a polishing pad mounted on the upper surface of the polishing table **11**.

[0049] The right polishing chamber **101** houses therein a top ring **13** rotatably supported on a top ring arm **12**, a dresser **15** rotatably supported on a dresser arm **14**, a buff table **16**, a linear transporter **17**, a pusher **18**, a lifter **19**, an inverting device **20**, and a dresser holding base **21**. Similarly, the left polishing chamber **102** houses therein a top ring **13** rotatably supported on a top ring arm **12**, a dresser **15** rotatably supported on a dresser arm **14**, a buff table **16**, a linear transporter **17**, a pusher **18**, a lifter **19**, an inverting device **20**, and a dresser holding base **21**. Each dresser holding base **21** may be a container containing a liquid, such as pure water or the like, for keeping the dresser **15** wet while the dresser **15** is being held therein prior to operation on the polishing table **11**.

[0050] In each of the right polishing chamber **101** and the left polishing chamber **102**, the top ring **13** is rotatably supported on a distal end of the top ring arm **12** and rotatable in the direction indicated by the arrow A (see FIG. **3**) by a motor, not shown, disposed in the top ring arm **12**. The top ring arm **12** is fixed to the upper end of a support rod **22** which is vertically movable in the directions indicated by the arrow C (see FIG. **2**) and angularly movable about its vertical axis by a lifting/lowering and turning mechanism **23** disposed in the lower chamber **106**. Therefore, the top ring **13** supported on the top ring arm **12** is also vertically movable and angularly movable about the vertical axis of the support rod **22**. When the top ring **13** is turned about the vertical axis of the support rod **22**, it can move between the pusher **18**, the polishing surface **11***a* of the polishing table **11**, and the buff table **16**.

[0051] In each of the right polishing chamber **101** and the left polishing chamber **102**, the dresser arm **14** is also is fixed to the upper end of a support rod, not shown, and is vertically movable and angularly movable about the vertical axis of the support rod by a lifting/lowering and turning mechanism, not shown. When the dresser arm **14** is turned about the vertical axis of the support rod, the dresser **15** can move between a position above the polishing surface **11***a* of the polishing table **11** and a position above the dresser holding base **21**. When the dresser arm **14** is vertically moved, the dresser **15** can move into and out of contact with the polishing surface **11***a* or can move into and away from the dresser holding base **21**.

[0052] As shown in FIG. **1**, the cleaning chamber **103** houses a first cleaning tank **31** and a second cleaning tank **32** in a right region thereof, and also houses a first cleaning tank **33** and a second cleaning tank **34** in a left region thereof. Transport devices **35**, **36**, such as robots or the like, are disposed between the first cleaning tank **31** in the right region and the first cleaning tank **33** in the left region. A temporary substrate holder **37** is positioned between the second cleaning tank **32** in the right region and the second cleaning tank **34** in the left region. The transport chamber **104** houses therein a transport device **40**, such as a robot or the like. The loading/unloading chamber **105** houses therein a plurality of substrate storage cassettes **41** through **44**.

[0053] Operation of the polishing apparatus **100** will be described below. The transport device **40** removes a substrate to be polished from one of the substrate storage cassettes **41** through **44**, and places the substrate on the temporary substrate holder **37**. The transport device **35** or **36** removes the substrate from the temporary substrate holder **37**, and transports the substrate to the inverting device **20** in the right polishing chamber **101** or the left polishing chamber **102**. The inverting device **20** inverts the substrate, i.e., turns the substrate upside down, and the lifter **19** receives the inverted substrate from the inverting device **20**. The lifter **19** then transfers the substrate to the linear transporter **17**. The linear transporter **17** moves the substrate horizontally and places it on the pusher **18**. At this time, the top ring arm **12** is turned to move the top ring **13** to a position over the pusher **18**.

[0054] The pusher **18** pushes the substrate upwardly to a predetermined height, whereupon the top ring **13** attracts the substrate under suction. While holding the substrate, the top ring **13** is angularly moved to a polishing position over the polishing surface **11***a* of the polishing table **11**. Then, the top ring **13**, while rotating about its own axis in the direction indicated by the arrow A, is lowered to bring the substrate, which is denoted by W in FIG. **2**, into contact with the polishing surface **11***a* while the polishing table **11** is rotating about its own axis in the direction indicated by the arrow B (see FIG. **3**). The top ring **13** presses the substrate W under a given pressure against the polishing surface **11***a*. An outermost film of the substrate W is now polished as the polishing surface **11***a* and the substrate W are moved relatively to each other. While being polished, the substrate W may be released from the top ring **13**. After having been polished, the substrate is transferred to the position over the pusher **18** and placed onto the pusher **18**. Alternatively, the polished substrate may first be buffed by the buff table **16** and then transferred to the position over the pusher **18** and placed onto the pusher **18**.

[0055] The substrate placed on the pusher **18** is then transferred by the linear transporter **17** to the inverting device **20** where the substrate is inverted. Thereafter, the substrate is transported by the transport device **35** or **36** to the first cleaning tank **31** in the right region of the cleaning chamber **103** or the first cleaning tank **33** in the left region of the cleaning chamber **103**. In the first cleaning tank **31** or **33**, both surfaces of the substrate are cleaned by sponge rolls, for example. After having been cleaned, the substrate is transported by the transport device **35** or **36** to the second cleaning tank **32** in the right region of the cleaning chamber **103** or the second cleaning tank **34** in the left region of the cleaning chamber **103**. In the second cleaning tank **32** or **34**, the substrate is cleaned and then dried. The dried substrate is returned to either one of the substrate storage cassettes **41** through **44** by the transport device **40**. After the substrate has been polished, the dresser arm **14** is angularly moved to move the dresser **15** to the position above the polishing surface **11***a* of the polishing table **11**. Then, the dresser **15** is lowered to come into contact with the polishing surface **11***a* and rotated to dress the polishing surface **11***a*. The above operation sequence of the polishing apparatus **100** is controlled by a controller, not shown.

[0056] As shown in FIGS. **2** and **3**, a slurry supply nozzle **50** for supplying a slurry and a liquid supply nozzle **51** for supplying a liquid, such as pure water or the like, or a mixture of a liquid and a gas are disposed above the polishing surface **11***a* of the polishing table **11** in the right polishing chamber **101**. A gas suction pipe **52** having a gas inlet port **52***a* in its lower end for drawing in an atmospheric gas is also disposed above the polishing surface **11***a*. The gas suction pipe **52** is positioned over a circular path D along which the center of the substrate W held by the top ring **13** moves on the polishing surface **11***a*, and is located adjacent to the outer circumferential edge of the top ring **13** downstream of the top ring **13** with respect to the direction indicated by the arrow B in which the polishing table **11**

rotates. The atmospheric gas drawn into the gas suction pipe **52** through the gas inlet port **52***a* is guided to a gas detector **53**. Although not shown, the left polishing chamber **102** also accommodates therein a slurry supply nozzle **50**, a liquid supply nozzle **51**, a gas suction pipe **52**, and a gas detector **53** which are positioned in the same manner as the counterparts in the right polishing chamber **101**.

[0057] While the polishing apparatus **100** is in operation, the slurry supply nozzle **50** supplies a slurry onto the polishing surface **11***a* of the polishing table **11**, and the top ring **13** presses the substrate W held thereby against the polishing surface **11***a* to polish the outermost film of the substrate W. At this time, the film and the slurry react with each other, producing a particular gas. The particular gas differs depending on the type of the film and the type of the slurry as described later. If the components of the slurry are known and also if the particular gas is contained in the atmospheric gas detected by the gas detector **53**, then a film of the substrate W, which is being polished, can be identified based on the particular gas. Stated otherwise, the gas detector **53** monitors whether the particular gas is contained in the atmospheric gas or not, and when the gas detector **53** detects the particular gas, the type of a film, which is being polished, can be identified. When the particular gas is no longer detected, it is recognized that a film being polished has been removed. When another particular gas is newly detected, it is recognized that the different film underneath the removed film has started to be polished. The controller of the polishing apparatus **100** performs the above monitoring and detecting process based on an output signal from the gas detector **53**, and controls various components of the polishing apparatus **100** depending on the monitoring and detecting process.

[0058] The gas inlet port **52***a* of the gas suction pipe **52** needs to be positioned closely to the polishing surface **11***a* in order to draw in the atmospheric gas containing as high a concentration as possible of the gas component to be detected. However, if the gas inlet port **52***a* is too close to the polishing surface **11***a*, then it tends to draw in particles and a mist, thereby possibly clogging the gas suction pipe **52** and lowering the sensitivity of the gas detector **53**. To avoid these shortcomings, as shown in FIG. **4**, the distance E between the gas inlet port **52***a* and the polishing surface **11***a* is selected to be less than 100 mm. The distance E thus selected allows the gas suction pipe **52** to draw in the atmospheric gas, denoted by G in FIG. **4**, containing a high concentration of the gas component to be detected, and also prevents particles and a mist from being drawn in and clogging the gas suction pipe **52**, and hence from lowering the sensitivity of the gas detector **53**.

[0059] As shown in FIG. **5**, a brush of synthetic resin, such as nylon or the like, or a gas introduction member **54** of flexible synthetic resin material may be mounted on the lower end of the gas suction pipe **52**. The brush or gas introduction member **54** may be positioned as closely to the polishing surface **11***a* as possible or may be placed in contact with the polishing surface **11***a* for reliably introducing the atmospheric gas directly above the polishing surface **11***a* into the gas suction pipe **52**.

[0060] For drawing in the atmospheric gas G containing a high concentration of the gas component to be detected, it is preferable that the gas inlet port **52***a* be positioned closely to the substrate W to be polished and located in a direction opposite to the direction of a gas flow over the polishing surface **11***a*, i.e., downstream of the substrate W with respect to the direction indicated by the arrow B in which the polishing table **11** rotates, over the path D along which the center of the substrate W held by the top ring **13** moves on the polishing surface **11***a*, so that the gas inlet port **52***a* will not draw in a mist. If the atmospheric gas is supplied at all times to a detecting element of the gas detector **53**, it may possibly lower the sensitivity of the gas detector **53** as described later. Therefore, when no gas detection is required, the gas inlet port **52***a* may be retracted away from the polishing surface **11***a* so as to be able to draw in fresh air, and immediately before a polishing process endpoint is reached, the gas inlet port **52***a* may be moved to a position (within an area F in FIG. **3**) over the polishing surface **11***a* in which the gas inlet port **52***a* can draw in the atmospheric gas G.

[0061] Specifically, the gas suction pipe **52** is secured to the top ring arm **53** such that the gas suction pipe **52** is located in the area F while the substrate W is being polished. Consequently, the gas suction pipe **52** stays in the area F over the polishing table **11** during the polishing process, and is retracted away from the polishing table **11** to draw in fresh air when no polishing process is carried out, i.e., when no gas detection is required, because the top ring **13** is moved to the pusher **18** after the substrate W has been polished. In order to switch freely between the suction of the gas and the suction of fresh air, the gas suction pipe may incorporate a three-way solenoid-operated valve near its distal end, and the three-way solenoid-operated valve may have a port connected to the gas inlet port facing the polishing table and another port connected to an N_2 gas supply pipe or a pipe extending out of the polishing chamber. The three-way solenoid-operated valve may be switched depending on whether the atmospheric gas needs to be detected or not, the need for the recovery of a gas suction sensor, or whether any gas remaining in the gas suction pipe or the gas detector needs to be purged out.

[0062] If the atmospheric gas G drawn in from the gas inlet port **52***a* to the gas detector **53** flows at a large rate, then the particular gas to be detected, which is contained in the atmospheric gas G, is diluted to have its concentration lowered, and the gas detector **53** tends to have its detecting sensitivity reduced. If the atmospheric gas G flows at a low rate to the gas detector **53**, then the atmospheric gas takes time to flow from the gas inlet port **52***a* to the gas detector **53**, and the gas detector **53** tends to have its detecting accuracy reduced. According to the present invention, the atmospheric gas G should be drawn into the gas suction pipe **52** at a rate ranging from 10 cc to 1 liter per minute. More preferably, depending on the distance through the gas suction pipe **52** from the gas inlet port **52***a* to the gas detector **53**, the atmospheric gas G should be drawn into the gas suction pipe **52** at a rate ranging from 10 cc to 100 cc per minute for preventing the detecting sensitivity from being lowered and achieving a higher endpoint detecting accuracy.

[0063] The gas suction pipe **52** should preferably have an inside diameter of 10 mm or smaller, or more preferably 5 mm or smaller. The distance through the gas suction pipe **52** from the gas inlet port **52***a* to the gas detector **53** should preferably be 2 m or smaller, or more preferably 50 cm or smaller.

EXAMPLE 1

[0064] When a substrate to be polished with a tungsten film formed thereon is polished by a silica abrasive grain while being oxidized with an iodate acidic slurry, an iodine gas is produced according to the following reaction:

$$5W+6KIO_3+3H_2O \rightarrow 5WO_3+3I_2+6KOH$$

[0065] Since the tungsten film is polished at a polishing rate of about 100 nm per minute, if the substrate W has a diameter of 300 mm, the iodine gas is produced at a range of 2.22 milliliters per minute. Under these polishing conditions, a Teflon (registered trademark) tube having an inside diameter of 4 mm and a length of 1 m was used as the gas suction pipe **52**, and the gas inlet port **52***a* thereof was placed 5 mm above the polishing surface **11***a* of the polishing table **11** over the path D along which the center of the substrate W moves. The atmospheric gas G was introduced through the gas suction pipe **52** at a rate of 0.8 liter per minute to the gas detector **53** (see FIGS. **3** and **4**), which monitored the production of an iodine gas. A constant-potential electrolytic gas detector (SC-90 manufactured by Riken Keiki Company, Ltd.) was used as the gas detector **53**.

[0066] When the gas detector **53** is exposed to a highly concentrated iodine gas for a long time, it tends to suffer a delay in returning to the zero point. For example, when the gas detector **53** is supplied with fresh air after having been exposed to an iodine gas of 2 ppm for two minutes, the indicated value is reduced to one-half after 10 seconds. However, after the gas detector **53** is supplied with fresh air after having been exposed for about 10 seconds, the indicated value immediately returns to the zero point. In this example, the gas detector started to be supplied with the atmospheric gas 10 seconds prior to the polishing process endpoint predicted from the polishing rate.

[0067] When the atmospheric gas G started to be drawn in the gas suction pipe **52** from the gas inlet port **52***a* 10 seconds prior to the polishing process endpoint predicted from the polishing rate, as described above, the indicated value of the gas detector **53**, which represents the detected iodine gas, immediately increased to 4.5 ppm, and sharply dropped at the polishing process endpoint predicted from the polishing rate. Therefore, using the time at which the indicated value sharply drops as the endpoint of the polishing process, the polishing process can accurately be stopped. In this example, if appropriate detecting conditions are selected, then the production of an iodine gas at a rate of 0.05 milliliter per minute can be detected providing the gas detector **53** has a detecting accuracy of about 0.1 ppm.

EXAMPLE 2

[0068] One of the processes, in which CMP is employed, is a process of forming an STI (Shallow Trench Isolation), as shown in FIG. **6**. The purpose for polishing an STI forming substrate is to remove a silicon oxide film **130** covering a silicon nitride film **110** to expose the silicon nitride film **110** (first and second polishing steps). In the process of STI forming process, a silicon nitride film **110** is generally used as a CMP stopping film. Specifically, the deposited silicon oxide film **130** with surface irregularities is planarized by CMP in a first polishing step (planarizing step), and is thereafter continuously polished to reduce a thickness of the silicon oxide film **130** in a second polishing step (film thickness reducing step) until the silicon nitride film **110** is exposed, whereupon the polishing process is stopped. Since the deposited silicon oxide film **130** needs to be highly planarized and the exposed silicon nitride film **110** should not be excessively polished away, the polishing process employs a polishing compound which comprises a mixture of a slurry of cerium oxide (ceria) and an additive, such as a surface active agent.

[0069] In order to highly planarize the silicon oxide film **130** in the first polishing step, the polishing pressure is set to a low pressure level of 300 hPa or lower, and the additive is added in a large quantity, i.e., the additive is added to a slurry having a ceria concentration ranging from 0.1 to 1.0 wt %. The endpoint of the first polishing step is detected based on a change in the electric current of a table drive motor for the polishing table or by an optical endpoint monitor. The optical endpoint process is comprised of applying light to the substrate and detecting the intensity of reflected light to read a change in the film thickness of the silicon oxide film **130**.

[0070] Depending on the characteristic of the slurry used, only the polishing pressure and the table rotational speed may be changed under same slurry element for the first polishing step and the second polishing step.

[0071] FIGS. **7**A and **7**B are views showing a polishing apparatus according to another embodiment of the present invention, FIG. **7**A being a plan view of a polishing table of the polishing apparatus and FIG. **7**B being a cross-sectional view of the polishing apparatus.

[0072] As shown in FIGS. **7**A and **7**B, the polishing apparatus according to the present embodiment has an optical sensor **230** disposed in the polishing table **11**. As shown in FIG. **7**B, the optical sensor **230** comprises a light-emitting element and a light-detecting element. The light-emitting element applies light to the surface, being polished, of the substrate W, and the light-detecting element detects light reflected from the surface being polished. The light emitted from the light-emitting element comprises either a laser beam or an LED light beam or white-light beam. When the silicon oxide film **130** or the silicon nitride film **110** is polished to a predetermined film thickness, part of the light applied from the light-emitting element to the surface, being polished, of the substrate passes through the film, and is reflected from a film beneath the film being polished. Therefore, there are two types of light reflected from the substrate, i.e., the light reflected from the film beneath the film being polished, and the light reflected from the surface of the film being polished. The light-detecting element detects the two types of reflected light, and outputs a signal to a controller **232**. The controller **232** processes the supplied signal to accurately detect the film thickness of the remaining silicon oxide film **130**.

[0073] In the second polishing step, the concentration of the additive is selected to be lower than in the first polishing step such that the silicon oxide film **130** is polished at a high polishing rate for flat film surface after planalized and the polishing rate for the silicon nitride film **110** is as low as possible with respect to the polishing rate for the silicon oxide film **130**, i.e., such that the selective ratio is large. The first polishing step and the second polishing step may be performed successively on one polishing table, or may be performed separately on different polishing tables.

[0074] When a substrate to be polished with a silicon oxide film formed on a silicon nitride film as a stopping film is polished using a ceria slurry, the instant the polishing of the silicon oxide film is finished and the ceria slurry is brought into contact with the silicon nitride film, ammonia is produced according to the following reaction:

$$Si_3N_4+6H_2O \rightarrow 4NH_3+3SiO_2$$

[0075] If the slurry is a strong acidic slurry, then ammonium ions are dissolved in the slurry according to the following reaction:

$$NH_3+H^+ \rightarrow NH_4^+$$

[0076] If the slurry is a normal week acidic slurry or alkaline slurry, the above reaction does not occur, and an ammonia gas is emitted from the slurry due to an increase in the surface temperature of the polishing table during the polishing process. A mixture of HS8005TPB and HS7303TPB, for example, both manufactured by Hitachi Chemical Co., Ltd. may be used as the slurry in the present invention. If the temperature of the polishing table is low during the polishing process due to polishing conditions, then temperature regulating water, not shown, may be passed through the polishing table during the polishing process to adjust the temperature of the polishing table to a temperature of 30° C. or higher at which an ammonia gas can easily be produced. Accordingly, the endpoint of the process of polishing the silicon oxide film can be detected by detecting when the ammonia gas is produced.

[0077] If the silicon nitride film is polished using the ceria slurry at a polishing rate of about 10 nm per minute and the area of the silicon nitride film has a proportion of 20% in the entire substrate surface, then the ammonia gas is produced from the substrate W having a diameter of 300 mm at a rate of 0.3 milliliter per minute. It can be seen from the results of Example 1 that the endpoint of this polishing process can be detected if the gas detector **53** has a detecting sensitivity of 0.6 ppm. Though it is difficult for an electrochemical gas detector, such as a constant-potential electrolytic gas detector, to detect ammonia at such a concentration level, a detection-tape gas detector is capable of detecting ammonia at such a concentration level in a few seconds.

[0078] A Teflon (registered trademark) tube having an inside diameter of 4 mm and a length of 1 m, which was the same as the Teflon tube used in Example 1, was used as the gas suction pipe **52**, and the gas inlet port **52***a* thereof was placed 5 mm above the polishing surface **11***a* of the polishing table **11** over the path D along which the center of the substrate W moves. A detection-type ammonia gas detector (EAM-100C manufactured by Ebara Corporation) was used as the gas detector **53**. The atmospheric gas G was introduced through the gas suction pipe **52** at a rate of 0.5 liter per minute to the gas detector **53**. The gas detector **53** detected the production of an ammonia gas at the time when a polishing torque sharply changed as detected by the conventional detecting process.

[0079] FIG. **8** shows various detected concentrations of a particular gas (I_2 gas) contained in the atmospheric gas at different positions where the gas inlet port **52***a* of the gas suction pipe **52** is located, i.e., different atmospheric gas suction positions, in the above-described substrate polishing apparatus **100**. In FIG. **8**, T_A represents a start point for starting a main polishing process (using slurry), T_B a start point for starting a water polishing process, T_C a start point for starting a process of dressing the polishing surface **11***a* of the polishing table **11**, and T_D an endpoint for ending the process of dressing the polishing surface **11***a* of the polishing table **11**. T_E represents a time at which a first substrate W is brought into contact with the polishing surface **11***a*, T_F a time at which a second substrate W is brought into contact with the polishing surface **11***a*, and T_G a time at which a third substrate W is brought into contact with the polishing surface **11***a*. T_H represents a period during which the first substrate W is present in the first cleaning tank **31**, T_I represents a period during which the second substrate W is present in the first cleaning tank **31**, and T_J represents a period during which the third substrate W is present in the first cleaning tank **31**.

[0080] In FIG. **8**, the polygonal-line curve A represents the concentration of the particular gas, to be detected, detected at a measurement point T**1** (see FIG. **1**) near the outer circumferential edge of the polishing table **11** in the right polishing chamber **101**, the polygonal-line curve B represents the concentration of the particular gas, to be detected, detected at a measurement point T**2** (see FIG. **1**) over the polishing table **11** in the right polishing chamber **101** near the top ring **15** downstream thereof with respect to the direction in which the polishing table **11** rotates, the polygonal-line curve C represents the concentration of the particular gas, to be detected, detected at a measurement point T**3** (see FIG. **1**) over the buff table **16** in the right polishing chamber **101**, the polygonal-line curve D represents the concentration of the particular gas, to be detected, detected at a measurement point T**4** (see FIG. **2**) in the lower chamber **106** beneath the right polishing chamber **101** and the left polishing chamber **102**, and the polygonal-line curve E represents the concentration of the particular gas, to be detected, detected at a measurement point T**5** (see FIG. **1**) in the first cleaning tank **31** in the right region of the cleaning chamber **103**. The vertical axis of the graph shown in FIG. **8** represents the I_2 gas concentration [ppm] and the horizontal axis thereof the measurement time [sec].

[0081] As indicated by the polygonal-line curve B in FIG. **8**, the concentration of the particular gas detected at the measurement point T**2** over the polishing table **11** in the right polishing chamber **101** near the top ring **15** downstream thereof with respect to the direction in which the polishing table **11** rotates, has a concentration peak within **50** seconds after the start point T_A for starting the main polishing process. At the measurement point T**2**, therefore, the particular gas can be detected with higher sensitivity than at the other measurement points T**1**, T**3**, T**4**, and T**5**.

[0082] Although certain preferred embodiments of the present invention has 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.

What is claimed is:

1. A method of polishing a workpiece, comprising:

pressing the workpiece against a polishing surface of a polishing table;

moving the workpiece and the polishing surface relatively to each other to polish the workpiece;

disposing a gas suction pipe having a gas inlet port, directly above the polishing surface;

supplying an atmospheric gas from above the polishing surface through the gas inlet port to a gas detector via the gas suction pipe; and

monitoring a particular gas contained in the atmospheric gas with the gas detector while the workpiece is being polished.

2. A method according to claim **1**, further comprising:
detecting an endpoint of the polishing of the workpiece when the particular gas is produced or no longer produced.

3. A method according to claim **1**, wherein the gas inlet port is disposed at a height of 100 mm or smaller from the polishing surface.

4. A method according to claim **1**, further comprising:
supplying fresh air to a detecting element of the gas detector while the atmospheric gas is not being monitored by the gas detector.

5. An apparatus for polishing a workpiece, comprising:
a polishing table having a polishing surface;
a mechanism for pressing the workpiece against the polishing table, and moving the workpiece and the polishing surface relatively to each other to polish the workpiece;
a controller for controlling the polishing table and the mechanism;
a gas suction pipe disposed directly above the polishing surface; and
a gas detector, which is connected to the gas suction pipe, for detecting a particular gas;
wherein the gas suction pipe has a gas inlet port for supplying an atmospheric gas from above the polishing surface through the gas inlet port to the gas detector via the gas suction pipe, so that the gas detector can detect a particular gas contained in the supplied atmospheric gas.

6. An apparatus according to claim **5**, wherein the controller detects an endpoint of the polishing of the workpiece when the gas detector detects or no longer detects the particular gas.

7. An apparatus according to claim **5**, wherein the gas inlet port is disposed at a height of 100 mm or smaller from the polishing surface.

8. An apparatus according to claim **5**, further comprising:
an air supply section for supplying fresh air to a detecting element of the gas detector while the atmospheric gas is not being detected by the gas detector.

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