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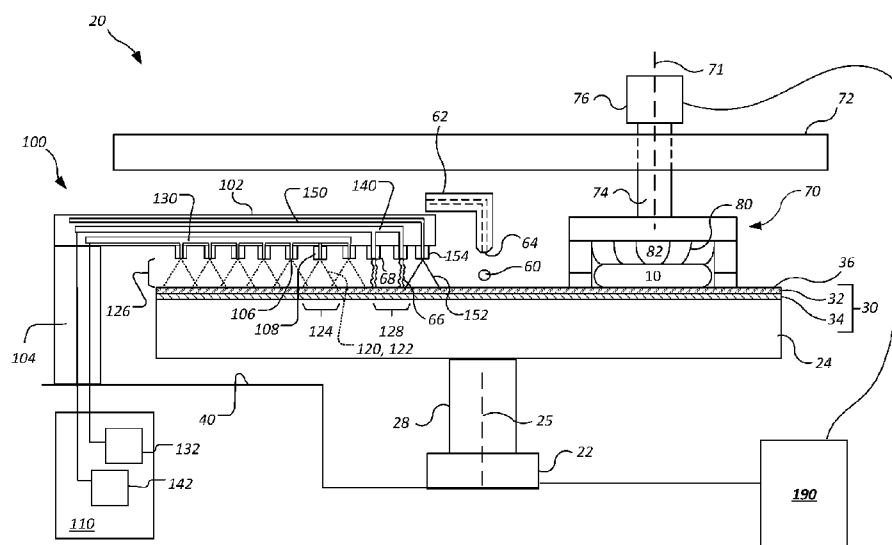


FIG. 1A

(57) **Abstract:** A chemical mechanical polishing apparatus includes a platen to hold a polishing pad, a carrier to hold a substrate against a polishing surface of the polishing pad during a polishing process, a polishing liquid dispenser having a polishing liquid port positioned over the platen to deliver polishing liquid onto the polishing pad, a temperature control system including coolant liquid fluid reservoirs for containing coolant fluids, a thermal controller configured to control the temperature of the coolant fluid within the coolant fluid reservoirs, and a first dispenser having openings in fluid connection with the coolant fluid reservoirs, the openings positioned configured to spray an aerosolized coolant liquid directly onto the polishing pad, and a second dispenser having a coolant port in fluid connection with the coolant fluid reservoirs, the coolant port positioned over the platen and configured to flow a stream of coolant liquid directly onto the polishing pad.



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COLD LIQUID POLISHING CONTROL

TECHNICAL FIELD

[0001] The present disclosure relates to chemical mechanical polishing, and more particularly to control of the polishing rate during the polishing process.

BACKGROUND

[0002] An integrated circuit is typically formed on a substrate by the sequential deposition of conductive, semiconductive, or insulative layers on a silicon wafer. One fabrication step involves depositing a filler layer over a non-planar surface and planarizing the filler layer. For certain applications, a conductive filler layer is planarized until the top surface of a patterned layer is exposed. For other applications, such as oxide polishing, the filler layer is planarized until a predetermined thickness is left over the non-planar surface. In addition, planarization of the substrate surface is usually required for photolithography.

[0003] Chemical mechanical polishing (CMP) is one accepted method of planarization. This planarization method typically requires that the substrate be mounted on a carrier or polishing head. The exposed surface of the substrate is typically placed against a rotating polishing pad. The carrier head provides a controllable load on the substrate to push it against the polishing pad. A polishing liquid, e.g., an abrasive slurry, is typically supplied to the surface of the polishing pad.

[0004] During some chemical mechanical polishing processes, it is desirable to perform different steps of the overall polishing process at different polishing rates. For example, it may be desirable to perform a bulk polishing step at a higher polishing rate than a clearing step. A conventional approach is to perform different steps, e.g., the bulk polishing and the clearing steps, at separate platens, e.g., with different slurries or different applied loads.

SUMMARY

[0005] In general, an aspect disclosed herein is a chemical mechanical polishing apparatus including a platen to hold a polishing pad; a carrier to hold a substrate against a polishing surface of the polishing pad during a polishing process; a polishing liquid dispenser having a polishing liquid port positioned over the platen to deliver polishing liquid onto the polishing pad; a temperature control system including one or more coolant liquid fluid reservoirs for containing one or more coolant fluids, a thermal controller configured to control the temperature of the one or more coolant fluid within the one or more coolant fluid reservoirs;

and a first dispenser having a plurality of openings in fluid connection with the one or more coolant fluid reservoirs, the plurality of openings positioned over the platen and configured to spray an aerosolized coolant liquid directly onto the polishing pad, a second dispenser having a coolant port in fluid connection with the one or more coolant fluid reservoirs, the coolant port positioned over the platen and configured to flow a stream of coolant liquid directly onto the polishing pad.

[0006] In general, an aspect disclosed herein is a chemical mechanical polishing system including two polishing stations, each station includes platen to hold a polishing pad, a carrier to hold a substrate against a polishing surface of the polishing pad during a polishing process, a polishing liquid dispenser having a polishing liquid port positioned over the platen to deliver polishing liquid onto the polishing pad, and a coolant dispenser having a coolant port positioned over the platen to deliver coolant liquid onto the polishing pad; and a temperature control system including a coolant fluid reservoir for containing coolant fluid and configured to deliver the coolant fluid to the respective coolant ports of the respective polishing stations, and a thermal controller configured to control the temperature of the coolant fluid within the coolant fluid reservoir.

[0007] In general, an aspect disclosed herein is a method for controlling a chemical mechanical polishing process, polishing a substrate on a surface of a polishing pad in a polishing process may include at least a bulk removal step and a clearing step; determining a desired temperature for the bulk removal step; during the bulk removal step, spraying the polishing pad with a cooling liquid to bring the polishing pad to the desired temperature; detecting a transition from the bulk removal step to the clearing step; and in response to detecting the transition from the bulk removal step to the clearing step dispensing, flowing the cooling liquid onto the surface to reduce a temperature of the polishing pad.

[0008] Examples may include one or more of the following features. The method where the cooling fluid is deionized water. The method may include controlling the temperature of the cooling fluid during the polishing process to be less than 5 °C.

[0009] Advantages may optionally include one or more of the following. The polishing rate can be lowered suddenly and precipitously without removing the substrate from the platen. Multiple sequential polishing steps, e.g., bulk polishing and clearing, can be performed on the same platen, thus increasing throughput and flexibility of use of other platens. Coolant fluid, e.g., deionized water (DI water), can be conserved, lowering consumable costs and reducing need for high-volume drainage around the platen.

[0010] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other aspects, features, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1A is a schematic cross-sectional view of a polishing system that includes a pad conditioner system for dispensing cold coolant fluid onto the pad from a rinse armature.

[0012] FIG. 1B is a schematic cross-sectional view of the polishing system that includes a pad conditioner system for dispensing cold coolant fluid onto the pad from a slurry armature.

[0013] FIG. 2 is a schematic cross-sectional view of the polishing system including a temperature control system for controlling the temperature of the coolant fluid.

[0014] FIG. 3 is a schematic cross-sectional view of the polishing system including another implementation of the temperature control system for controlling the temperature of the coolant fluid.

[0015] FIG. 4 is a schematic cross-sectional view of the polishing system including two platens with respective temperature control arms and associated temperature control systems.

[0016] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0017] As noted above, it is desirable to perform different steps of the overall polishing process at different polishing rates. For example, a bulk removal step in which the majority of a film thickness is removed can be performed at a relatively high polishing rate, and can be followed by a clearing step in which the remaining thickness is cleared at a relatively lower polishing rate to reveal underlying structures beneath the film. A problem with performing the different steps at different platens is reduced throughput, i.e., the time required to move the substrate to the new platen. On the other hand, a problem with performing the different steps sequentially at the same platen is that the high polishing rate at the end of the bulk removal step can transfer into the beginning of clearing steps. For example, simply reducing the pressure or changing the slurry applied to the substrate may not result in an immediate reduction of the polishing rate down to the lower rate expected for the lower pressure or new slurry. This effect can be termed ‘polishing rate momentum’, and without being limited to any particular theory may be related to the persistence of temperature and abrasive particles between the polishing steps. The polishing rate momentum from the bulk removal step can

make clearing the wafer difficult to control with in-situ metrology. During a clearing step, a high polishing rate can cause a wafer to clear unevenly and introduce undesirable dishing and erosion (hot spots) on pattern wafers most likely on the wafer edge.

[0018] Overall, to quickly change from a high polishing rate to a low polishing rate, e.g., to overcome the ‘polishing rate momentum’, can require altering the polishing rate through temperature changes of the process. One approach is the addition of a ‘quenching’ step between the bulk removal and clearing steps. In a typical quenching step, a large volume of room temperature DI water is dispensed at high pressure onto the polishing surface. This can both wash away the prior polishing liquid and reduce the polishing pad temperature. However, this type of quenching induces high process costs, as typically 10 L or more of DI water are dispensed in a single high-pressure rinse (HPR) quenching step.

[0019] A technique that can address these issues is to dispense cold liquid DI water to reduce the polishing rate. The cold liquid DI water can use low fluid volumes (e.g., 100 cc or 0.1 L) as compared to a high-pressure rinse step.

[0020] Current cooling methods may implement a fluid mist (e.g., deionized (DI) water) to cool the platen down gradually during the polishing process. However, mist does not reduce the rate momentum quickly enough to facilitate accurate control or high rates of change of the polishing rates during or between the bulk removal and clearing steps. Cold liquid DI water dispensed en masse directly onto the platen rapidly reduces the temperature of the surface of the polishing pad. Consequently, the polishing rate falls quickly.

[0021] A polishing processes using high polishing rate slurries can be stopped or paused at a smaller layer thickness prior to transitioning to the clearing step while still preventing film breakthrough due to ‘polishing rate momentum.’ Stated another way, a quenching step with cold liquid DI reduces the polishing rate rapidly, which facilitates the use of high polishing rate slurries, without significant increase in dishing or erosion. As more of the thickness can be removed during the bulk polishing step at a high rate, total process time can be reduced, and throughput can be increased.

[0022] Dispensing cold liquid DI can reduce the use of consumables and simplifies logistics in chemical mechanical polishing processes by obviating the need for changing to another slurry, for moving the substrate to another platen, or for using HPR rate quenching mid-process which can use large volumes of fluid, e.g., 10 L or more.

[0023] Dispensing cold coolant fluid can decrease the polishing rate for metal topography improvement by reducing metal loss on patterned wafers (PTWs) after polishing on the first platen of a polishing system. For example, dispensing the cold coolant fluid decreases the

polishing rate for copper (Cu) topography and reduces Cu loss on PTW. Lowering the polishing rate allows a longer clearing polish step for more controlled topography and facilitating low final thicknesses while reducing dishing and erosion, e.g., to the order of angstroms.

[0024] Dispensing cold coolant liquid provides a high rate of change in the polishing rate at high coolant liquid to slurry ratios. As an example, dispensing cold coolant liquid at a high ratio to slurry (e.g., 5:1 coolant:slurry, or 10:1 coolant:slurry) reduces the polishing rate in a short time. Alternatively, replacing the flow of slurry to the polishing pad with cold coolant liquid halts polishing as slurry is cleared from the pad. In one example, 100-200 cc of cold coolant liquid can displace the slurry from the pad and substantially reduce the polishing rate of the substrate. At other coolant liquid:slurry ratios, e.g., 1:1 coolant liquid:slurry, the polishing rate is reduced sufficiently to facilitate fine control of the final thickness, e.g., angstrom-level. The polishing rate reduction can vary depending on desired rate and consumable set.

[0025] As used herein, the term 'cold' will refer to temperatures in a range from 0 °C to 5 °C. Fluids in this range that remain liquid without freezing and have higher capacity for cooling than fluids at temperatures above this range. In implementations using water as the coolant fluid, water has a high heat capacity compared to other cooling fluids such that applying cold water to the surface of the polishing pad causes larger temperature changes.

[0026] FIG. 1A shows a polishing system 20 operable to polish a substrate 10. The polishing system 20 includes a rotatable platen 24, on which a polishing pad 30 is situated. The platen 24 is operable to rotate about an axis 25. For example, a motor 22 can turn a drive shaft 28 to rotate the platen 24. The polishing pad 30 can be a two-layer polishing pad with an outer polishing layer 34 having a polishing surface 36 and a softer backing layer 32.

[0027] The polishing system 20 includes a supply port 64, e.g., at the end of a slurry dispensing arm 62, to dispense a polishing liquid 60, such as an abrasive slurry, onto the polishing pad 30. The polishing system 20 can also include a polishing pad conditioner to abrade the polishing pad 30 to maintain the polishing pad 30 in a consistent abrasive state.

[0028] The polishing system 20 includes a carrier head 70 operable to hold the substrate 10 against the polishing pad 30 such as during a polishing process. The carrier head 70 can include a flexible membrane 80 having a substrate mounting surface to contact the back side of the substrate 10, and a plurality of pressurizable chambers 82 to apply different pressures to different zones, e.g., different radial zones, on the substrate 10. There could be one or two chambers, or four or more chambers, e.g., five chambers.

[0029] The carrier head 70 is suspended from a support structure 72, for example, a carousel or track, and is connected by a carrier drive shaft 74 to a carrier head rotation motor 76 so that the carrier head can rotate about an axis 71. In addition, the carrier head 70 can oscillate laterally across the polishing pad 30, e.g., by moving in a radial slot in the support structure 72 as driven by an actuator, by rotation of the carousel as driven by a motor, or movement back and forth along the track as driven by an actuator. In typical operation, the platen 24 is rotated about its central axis 25, and the carrier head 70 is rotated about its central axis 71 and translated laterally across the top surface of the polishing pad 30. A controller 190, such as a programmable computer, is connected to the motors 22, 76 to control the rotation rate of the platen 24 and carrier head 70.

[0030] The polishing system 20 includes a temperature control system 100 to control the temperature of the polishing pad 30 by dispensing cold liquid DI water onto the pad 30. The temperature control system 100 includes at least one temperature control arm 102 that extends over the platen 24 and polishing pad 30 from an edge of the polishing pad 30 to or at least near (e.g., less than 5% of the total radius of the polishing pad) the center of polishing pad 30.

[0031] The temperature control arm 102 can be supported by a base 104, and the base 104 can be supported on the same frame 40 as the platen 24. The base 104 can include one or more actuators, e.g., a linear actuator to raise or lower the temperature control arm 102, and/or a rotational actuator to swing the temperature control arm 102 laterally over the platen 24.

[0032] The temperature control arm 102 is positioned to avoid colliding with other hardware components such as the slurry dispensing arm 62, polishing head 70, and conditioner system. Along the direction of rotation of the platen 24, the temperature control arm 102 of the temperature control system 100 can be between the carrier head 70 and the slurry dispensing arm 62.

[0033] The temperature control system 100 has two dispensers that both deliver cold liquid: a “quenching” dispenser 140 that delivers cold liquid en masse, e.g., as a flowing fluid, onto the polishing pad 30 in order to quickly reduce the temperature and polishing rate, and a “process management” dispenser 130 that delivers cold liquid, e.g., as a spray, at a relatively lower flow rate in order to control the temperature of the polishing pad 30 in an ongoing polishing step at a lower rate of temperature change, e.g., to compensate for gradual build-up of heat during the polishing process.

[0034] The polishing system 20 can also include a rinsing liquid dispenser 150 that delivers a relatively larger volume of rinsing liquid 152 from a nozzle 154, e.g., in a high-pressure rinse, in order to flush the polishing liquid 60 from the polishing pad 30. The rinse liquid 152 can be at room temperature. In some examples, the rinsing liquid dispenser 150 delivers the volume of rinsing liquid 152 at a delivery rate in a range from 1 liter (L)/minute (min) to 10 L/min (e.g., 2 to 8 L/min, or 5 to 7 L/min).

[0035] The quenching dispenser 140 provides cooling during a polishing process to reduce the temperature of the surface 36 in a short time and at low cooling liquid volume. The quenching dispenser 140 controls the temperature of the surface 36 of the polishing pad 30 by quickly dispensing a temperature-controlled cooling liquid 66 from a source 142 onto the surface 36. The cooling liquid 66 is DI water cooled to at or below 5 °C (e.g., in a range from 0 °C to 5 °C) by a coolant management system 110 which controls the temperature of the source 142.

[0036] The quenching dispenser 140 can include one or more ports 68 on the arm 102 to dispense the coolant liquid 66 onto a zone 128 on the surface 36 of the pad 30. The ports 68 are connected to the coolant management system 110 via a channel, e.g., pipes, flexible tubing, or a passage through the arm 102, to the temperature-controlled source 142. Although FIG. 1A illustrates two ports 68, there could be just one port, or three or more ports 68.

[0037] When the controller 190 determines that a high polishing rate step has ended and a low polishing rate step begins, the controller 190 commands the temperature control system 100 to dispense the chilled coolant liquid 66 from the quenching dispenser 140 onto the pad 30 to reduce the polishing rate in a short time interval. In one example, the controller 190 causes the temperature control system 100 to begin dispensing of the chilled coolant liquid 66 within 5 second of the low polishing rate step beginning (e.g., within 3 seconds, within 1 second). In some implementations, the controller 190 causes the chilled coolant liquid 66 for a duration of up to 1-10 seconds, e.g., 3-8 seconds. In some implementations, the temperature control system 100 dispenses a preset amount of cold liquid 66 from the quenching dispenser 140.

[0038] The controller 190 determines a new temperature of the surface 36 after the preset amount of liquid 66 has been dispensed and, if further corrections are needed to achieve a target temperature, dispenses additional liquid 66. In some examples, the target temperature is achieved by the temperature control system 100 within 10 seconds (e.g., within 8 seconds, within 5 seconds). In some examples, the target polishing rate is achieved by the temperature control system 100 within 10 seconds (e.g., within 8 seconds, within 5 seconds). Achieving

the target polishing rate and/or target temperature within a short (e.g., less than 10 second) window beneficially increases the accuracy of the final layer thickness.

[0039] In another example, the controller 190 sends a target polishing rate to the temperature control system 100 which determines a quantity of the chilled coolant liquid 66 to dispense. The quantity of liquid 66 dispensed by the system 100 is sufficient to reduce the measured polishing rate at or below the target polishing rate. For example, the quantity of coolant liquid 66 dispensed can be in a range from 0.01 L to 0.1 L (e.g., 10 mL to 100 mL, 10 cc to 100 cc).

[0040] Without wishing to be bound by theory, the chilled coolant liquid 66 reduces the polishing rate both by displacing polishing liquid 60 from the surface 36 beneath the substrate 10 and by reducing the temperature of the polishing pad 30, and thus reducing the temperature at the interface between the substrate 10 and the polishing surface 36. This reduces the chemical kinetics of polishing chemistry present in the liquid 60.

[0041] The coolant management system 110 controls the temperature of the coolant liquid 66 in the source 142 such that the coolant liquid 66 is cold when dispensed from the ports 68. The coolant management system 110 includes at least one source 142 for containing a volume of the liquid 66 and a temperature controller and cooling elements for determining and controlling the temperature of the liquid 66 in the source 142 of the coolant management system 110. Some examples of the coolant management system 110 includes connections to sources of the coolant liquid 66 which provide the liquid 66 to the coolant management system 110 for temperature control and dispensing to the pad 30. Embodiments of the coolant management system 110 are shown further herein with reference to FIGS. 2, 3, and 4.

[0042] The process management dispenser 130 is configured to direct a spray of a cooling liquid 120, which can be the same composition as the cooling liquid 66, from one or more openings 106, e.g., in one or more nozzles 108. The nozzles can be formed in or suspended from the temperature control arm 102. In operation, the arm 102 is supported by the base 104 so that the nozzles 108 are separated from the polishing pad 30 by a gap 126. The gap 126 can be 1 to 10 cm.

[0043] The various openings 106 of the process management dispenser 130 direct jets 122 of the cooling liquid 120 that spray onto different radial zones 124 on the polishing pad 30. Adjacent radial zones can overlap. Optionally, some of the openings 106 can be oriented so that a central axis of the spray from that opening is at an oblique angle relative to the polishing surface 36. The jets can be directed from one or more of the openings 106 to have a

horizontal component in a direction opposite to the direction of motion of polishing pad 30 in the region of impingement as caused by rotation of the platen 24.

[0044] Although FIG. 1A illustrates the openings 106 and nozzles 108 of the process management dispenser 130 as spaced at even intervals, this is not required. The openings, e.g., the nozzles 108, could be distributed non-uniformly either radially, or angularly, or both. For example, openings 106 could be clustered more densely toward the outer edge of the polishing pad 30 (to compensate for the greater area being covered at the outer radius). In addition, although FIG. 1A illustrates seven openings 106, there could be a larger or smaller number of openings 106. The jets 122 of liquid spray can include temperature-controlled liquid 120 from the coolant management system 110 which is aerosolized by the nozzles 108 into a mist, e.g., an aerosolized spray of liquid. The coolant management system 110 includes a reservoir 132 for storing and controlling the temperature of a volume of the liquid 120. In other examples, the coolant management system 110 includes a single reservoir, e.g., source 142 or reservoir 132, from which a common coolant liquid 66 is supplied to both the process management dispenser 130 and the quenching dispenser 140.

[0045] The ports or openings of the process management dispenser 130, the quenching dispenser 140, and the rinsing liquid dispenser 150 are supported by the control arm 102. For example, the control arm 102 supports the nozzles 108, ports 68, and nozzles 154 related to the associated dispensers 130, 140, and 150. In other examples, the respective dispensers 130, 140, and 150 and associated nozzles 108, ports 68, and nozzles 154 can be supported on separate arms, or on a combination of arms.

[0046] Another configuration of the temperature control system 100 is shown in FIG. 1B in which the coolant liquid 66 is dispensed from an opening 69 on the slurry dispensing arm 62. The coolant liquid 66 can be dispensed at the same time the polishing liquid 60, e.g., concurrently, or partially overlapping with. The coolant liquid 66 can be dispensed in a desired ratio with the polishing liquid 60. In one example, the coolant liquid 66 is dispensed from the opening 69 on the slurry dispensing arm 62 concurrently with the polishing liquid 60 at the desired ratio. In an example, the coolant liquid 66 is dispensed to displace the polishing liquid 60 on the polishing pad 30 in a volume sufficient to cease the polishing process (e.g., a polishing rate of 20 angstrom/min or less, e.g., 10 angstrom/min). Such low rates are beneficial to control topography at near angstrom resolution.

[0047] Examples of coolant management system 110 include a single source 142 connected to heating elements, cooling elements, or both, to control the temperature of the coolant liquid 66 within the source 142. FIG. 2 shows a temperature control system 200 having a

coolant management system 210 in connection with a quenching dispenser 140. The coolant management system 210 includes a thermal controller 212 connected to temperature control elements 214a and 214b. The elements 214a and 214b are a heating element 214a and a cooling element 214b.

[0048] The controller 212 is electrically connected to a temperature sensor 205 arranged on the inside of a reservoir 204 which contains coolant liquid 66. The controller 212 receives temperature data from the sensor 205 and controls the elements 214a and/or 214b to heat or cool the coolant liquid 66 within the reservoir 204 to achieve a desired temperature value. In particular, the coolant liquid 66 can be cooled to 5 °C or below (e.g., in a range from 0 °C to 5 °C). The example temperature control system 200 and reservoir 204 can provide the coolant management system 110 and reservoirs 132 and 142 of FIG. 1A.

[0049] The controller 212 is in communication with a three-way diverting valve 202 and a three-way selecting valve 203. The input of the diverting valve 202 is connected to a coolant liquid source 266, such as a municipal water line, a filtration device, a distillation supply, or a deionizing water supply. One output of the diverting valve 202 is connected to an input of the three-way valve 203, and the other output of the diverting valve 202 is connected to the reservoir 204 such that the valve 202 can supply the coolant liquid 66 from the coolant liquid source 266 to either the valve 203 and ports 68 without temperature control, or to the reservoir 204 to be temperature controlled.

[0050] The selecting valve 203 has one input connected to the diverting valve 202 and another input connected to the reservoir 204. The output of the selecting valve 203 is connected to the ports 68 such that coolant liquid 66 received from the valve 202, which is direct from the coolant liquid source 266, or temperature-controlled coolant liquid 66, 120 from the reservoir 204, is directed to the ports 68. In some examples, though not shown in FIG. 2, one or more pump produces pressure in the temperature control system 200 to provide pressurized coolant liquid 66 from the ports 68.

[0051] In some examples, the coolant management system 110 includes multiple reservoirs for containing the polishing liquid 60 or the coolant liquids 66, 120 which are heated or cooled independently. FIG. 3 shows an example temperature control system 300 including a coolant management system 310 housing reservoirs for the polishing liquid 60 and the coolant liquid 66 to be dispensed by the quenching dispenser 140 supported by the control arm 102. The coolant management system 310 includes three separate reservoirs, referring to reservoir 304, 306, and 308. Reservoir 304 contains the polishing liquid 60, and reservoirs 306 and 308 contain the coolant liquid 66. Reservoir 304 is in fluid connection with the

supply port 64 supported by the arm 102 to dispense liquid 60 to the pad 30 during a polishing process.

[0052] In general, each of the reservoirs can be independently temperature controlled by a thermal controller 312 which operates a unique temperature control element (e.g., a heater or a cooler) in contact with associated reservoir. Reservoirs 306 and 308 are in contact with temperature control elements 314a and 314b, respectively, and the reservoir 304 is not temperature controlled in the example of FIG. 2. Temperature control element 314b is a cooling element and the coolant liquid 66 within the reservoir 308 is cooled. Temperature control element 314a is a heater and the coolant liquid 66 within reservoir 306 is heated.

[0053] Reservoirs 306 and 308 are in fluid connection with a three-way valve 302 which is connected to the thermal controller 312. The thermal controller 312 controls a gating state of the valve 302 such that the fluid received by the valve 302 from reservoir 306 or reservoir 308 is directed to the ports 68. An example of the valve 302 is a binary valve, e.g., either coolant liquid 66 from reservoir 306 or from reservoir 308 is directed to the ports 68. Another example of the valve 302 facilitates dispensing of the coolant liquid 66 from the reservoir 306 or reservoir 308 at specific ratios. In such an example, the valve 302 permits dispensing from the reservoir 306 and reservoir 308 concurrently in any ratio between all coolant liquid 66 from reservoir 306 (e.g., 100% heated coolant liquid 66) to all coolant liquid 66 from reservoir 308 (e.g., 100% chilled coolant liquid 66). The ratio between heated and chilled coolant liquid 66 can be controlled by the thermal controller 312 to achieve a desired temperature value at the outlet of the valve 302 or the ports 68.

[0054] The valve 302 can include a temperature sensor, or a temperature sensor can be mounted in-line with a downstream outlet of the valve 302 which generates temperature data and communicates the data to the thermal controller 312. The thermal controller 312 controls the valve 302, based on the downstream temperature data, to permit flow from reservoir 306, reservoir 308, or a combination of both such that a target temperature value of the coolant liquid 66 is achieved downstream of the valve 302 prior to dispensing by the ports 68 on the arm 102.

[0055] Some examples of the temperature control system 100 can control multiple polishing stations, each station including an independent temperature control arm 102, head 70, and platen 24 with polishing pad 30. FIG. 4 depicts a polishing system 421 with two polishing stations 401 and 407. Each polishing station 401 and 407 respectively includes platens 424, 424' supporting polishing pads 430, 430', temperature control arms 420, 420' supporting quenching dispensers 440, 440' having respective ports 467, 467' which dispense

the coolant liquid 460. Each of the polishing stations 401 and 407 are connected to respective coolant management systems 410 and 410' which include respective reservoirs 404 and 404'.

[0056] The reservoirs 404 and 404' contain coolant fluid, the temperature of which is controlled by the connected thermal controller 412. The thermal controller 412 controls the temperature control elements 414 and 414' to cool the coolant liquid 460 within the reservoir 404 or 404', respectively. The thermal controller 412 is connected to temperature sensors 405 and 405' which generate temperature data on the temperature of the coolant liquid 460 stored in the respective reservoirs 404 and 404' in which they are configured to generate temperature data from. The thermal controller 412 receives the temperature data and controls the temperature control elements 414 and 414' to achieve the desired temperature of the coolant liquid 460.

[0057] Each of the coolant management systems 410 and 410' have two three-way valves. coolant management system 410 includes three-way valves 402 and 403, and coolant management systems 410' includes three-way valves 402' and 403'. An inlet of the three-way valves 402 and 402' are in fluid connection with a coolant liquid source 466, such as the examples given for coolant liquid source 266.

[0058] The outlets of three-way valves 402 and 402' are in fluid connection with reservoirs 404 and 404', and inlets of three-way valves 403 and 403'. The valves 402 and 402' can each provide the coolant liquid 460 from the source 466 to either the reservoirs 404 or 404' for cooling, or directly to the valves 403 and 403' in situations in which the source 466 provides liquid 460 which is not cooled before being directed to the ports 467 and 467'.

[0059] In some examples, the system 421 has a common coolant management system to replace coolant management systems 410 and 410'. In such an example, the common coolant management system has one reservoir 404, one temperature sensor 405, and one temperature control element 414, connected to one thermal controller 412. The common coolant management system can have any number of three - way valves 403 to distribute the coolant liquid to the respective polishing stations 401 and 407.

[0060] A number of embodiments have been described. Nevertheless, it will be understood that various modifications may be made. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A chemical mechanical polishing apparatus comprising:
 - a platen to hold a polishing pad;
 - a carrier to hold a substrate against a polishing surface of the polishing pad during a polishing process;
 - a polishing liquid dispenser having a polishing liquid port positioned over the platen to deliver polishing liquid onto the polishing pad;
 - a temperature control system including
 - one or more coolant liquid fluid reservoirs for containing one or more coolant fluids,
 - a thermal controller configured to control the temperature of the one or more coolant fluid within the one or more coolant fluid reservoirs; and
 - a first dispenser having a plurality of openings in fluid connection with the one or more coolant fluid reservoirs, the plurality of openings positioned over the platen and configured to spray an aerosolized coolant liquid directly onto the polishing pad,
 - a second dispenser having a coolant port in fluid connection with the one or more coolant fluid reservoirs, the coolant port positioned over the platen and configured to flow a stream of coolant liquid directly onto the polishing pad.
2. The apparatus of claim 1, further comprising a temperature control arm extending over the platen, and wherein the one or more openings are formed in nozzles secured to the temperature control arm.
3. The apparatus of claim 2, wherein the coolant port is secured to the temperature control arm.
4. The apparatus of claim 2, wherein the coolant port is secured to a separate temperature control arm.

5. The apparatus of claim 4, comprising a polishing liquid arm extending over the platen, wherein the coolant port and the polishing liquid port are on the polishing liquid arm.
6. The apparatus of claim 1, wherein the thermal controller comprises a temperature sensor and a temperature control element and is configured to receive temperature value from the temperature sensor indicative of a temperature of the coolant fluid and, based on the received temperature value, control the temperature control element to cool the coolant fluid to below 5 °C.
7. The apparatus of claim 1, wherein one or more coolant fluid reservoirs include a first coolant fluid reservoir connected to the plurality of openings of the first dispenser and a second coolant fluid reservoir connected to the port of the second dispenser.
8. The apparatus of claim 7, wherein the second coolant fluid reservoir is configured to hold less coolant fluid than the first coolant fluid reservoir.
9. The apparatus of claim 7, wherein the first coolant fluid reservoir and the second coolant fluid reservoir hold a same composition of coolant liquid.
10. The apparatus of claim 9, wherein the coolant liquid is deionized water.
11. The apparatus of claim 7, wherein the temperature control system is configured to control both the first coolant fluid reservoir and the second coolant fluid reservoir to different temperature values, the temperature value of the second coolant fluid reservoir being lower than the temperature value of the first coolant fluid reservoir.
12. The apparatus of claim 1, wherein one or more coolant fluid reservoirs include a common coolant fluid reservoir connected to the plurality of openings of the first dispenser and to the port of the second dispenser.

13. The apparatus of claim 1, wherein the temperature control system is configured to dispense less than 1 L of fluid through the second dispenser to reduce a temperature of the polishing pad by at least 10 °C.

14. The apparatus of claim 1, further comprising a controller configured to cause the first dispenser to spray the aerosolized coolant liquid onto the polishing pad during a polishing step in which the substrate is polished on the polishing pad, and to cause the second dispenser to flow the stream of coolant fluid onto the polishing pad at a transition from a first polishing step to a second polishing step.

15. The apparatus of claim 14, wherein the controller is configured to receive a temperature measurement from a sensor during the polishing step and to control the first dispenser to spray the aerosolized coolant liquid so as to bring the measured temperature to a desired temperature.

16. The apparatus of claim 14, wherein the controller is configured to receive a signal indicating that less than a threshold amount of material remains to be polished, and to control the second dispenser to flow the stream of coolant fluid onto the polishing pad in response to the signal.

17. The apparatus of claim 1, further comprising a pad rinse system including a nozzle to direct a rinsing medium onto the polishing pad.

18. A chemical mechanical polishing system comprising:

two polishing stations, each station comprising

a platen to hold a polishing pad,

a carrier to hold a substrate against a polishing surface of the polishing pad during a polishing process,

a polishing liquid dispenser having a polishing liquid port positioned over the platen to deliver polishing liquid onto the polishing pad, and

a coolant dispenser having a coolant port positioned over the platen to deliver

coolant liquid onto the polishing pad; and

a temperature control system comprising

a coolant fluid reservoir for containing coolant fluid and configured to deliver the coolant fluid to the respective coolant ports of the respective polishing stations, and

a thermal controller configured to control the temperature of the coolant fluid within the coolant fluid reservoir.

19. A method for controlling a chemical mechanical polishing process, comprising:

polishing a substrate on a surface of a polishing pad in a polishing process comprising at least a bulk removal step and a clearing step;

determining a desired temperature for the bulk removal step;

during the bulk removal step, spraying the polishing pad with a cooling liquid to bring the polishing pad to the desired temperature;

detecting a transition from the bulk removal step to the clearing step; and

in response to detecting the transition from the bulk removal step to the clearing step dispensing, flowing the cooling liquid onto the surface to reduce a temperature of the polishing pad.

20. The method of claim 19, further comprising controlling the temperature of the cooling liquid during the polishing process to be less than 5 °C.

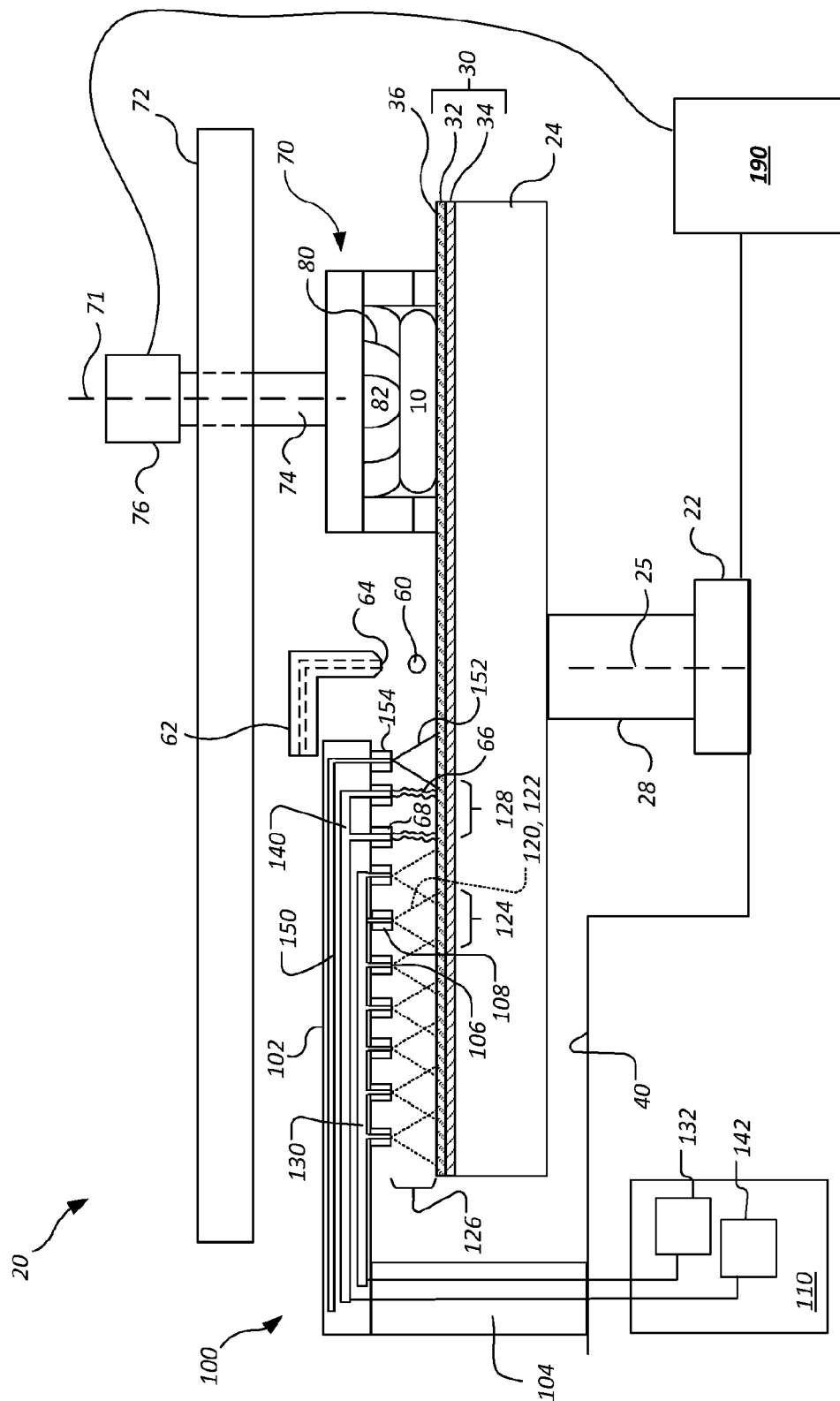


FIG. 1A

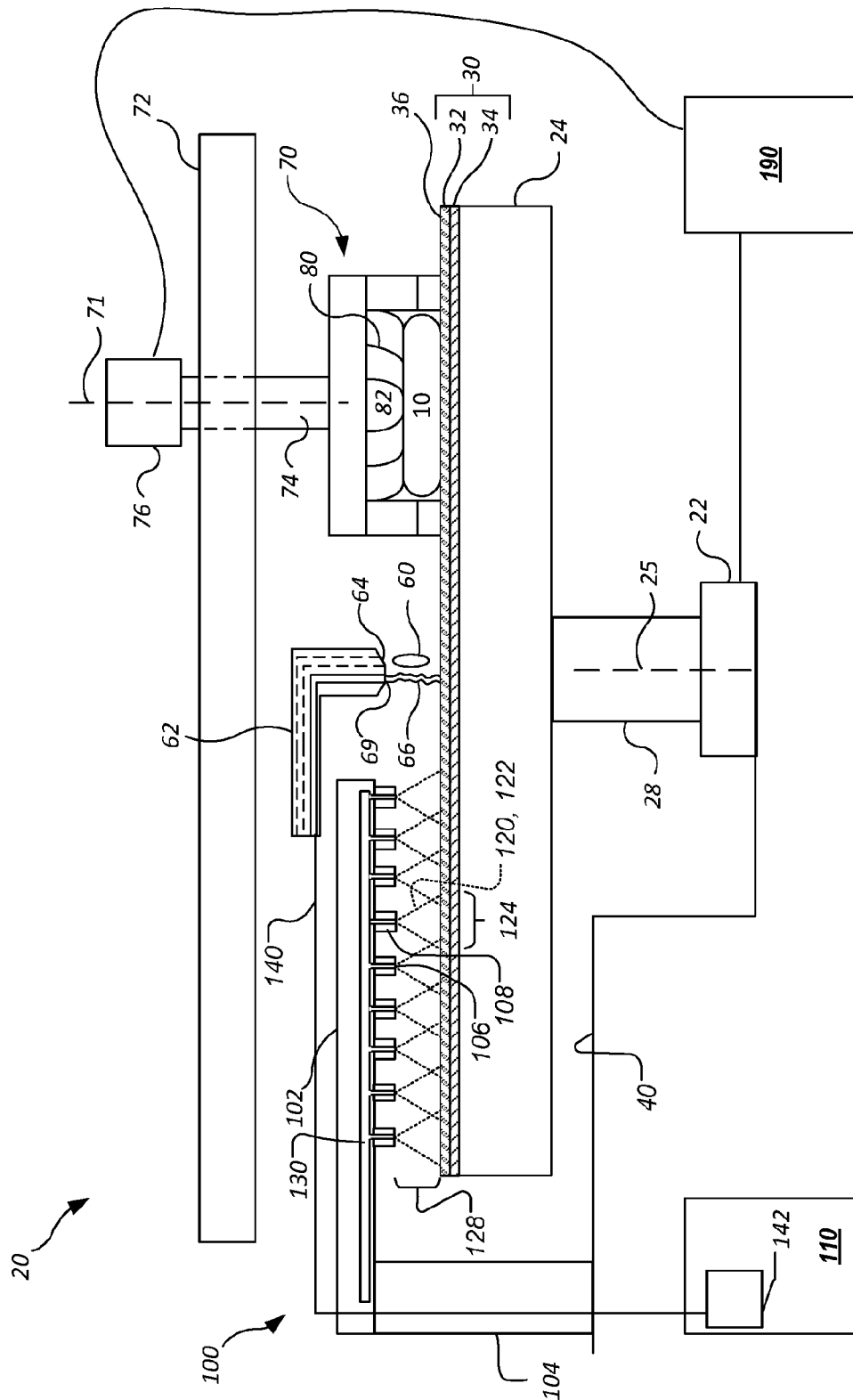


FIG. 1B

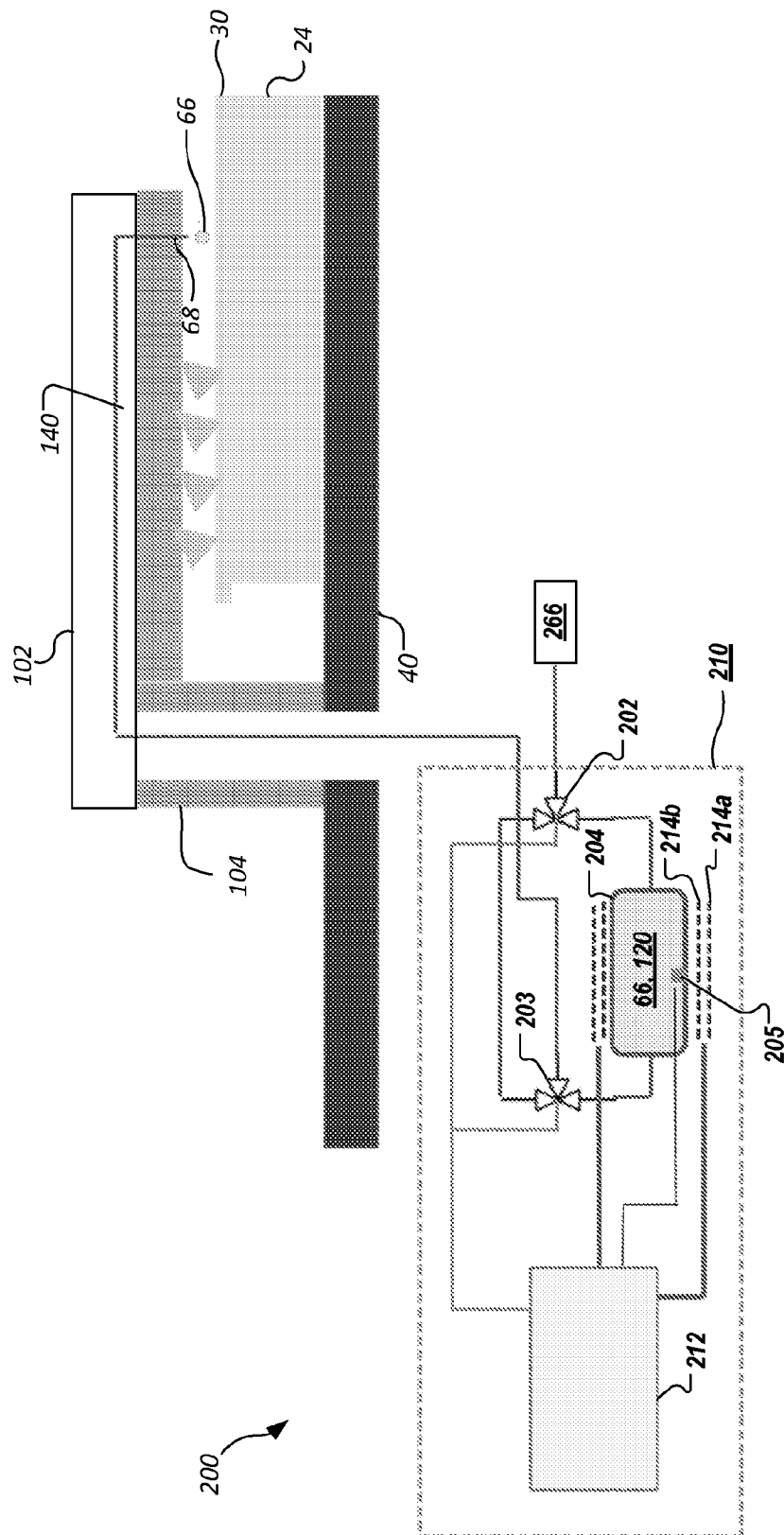


FIG. 2

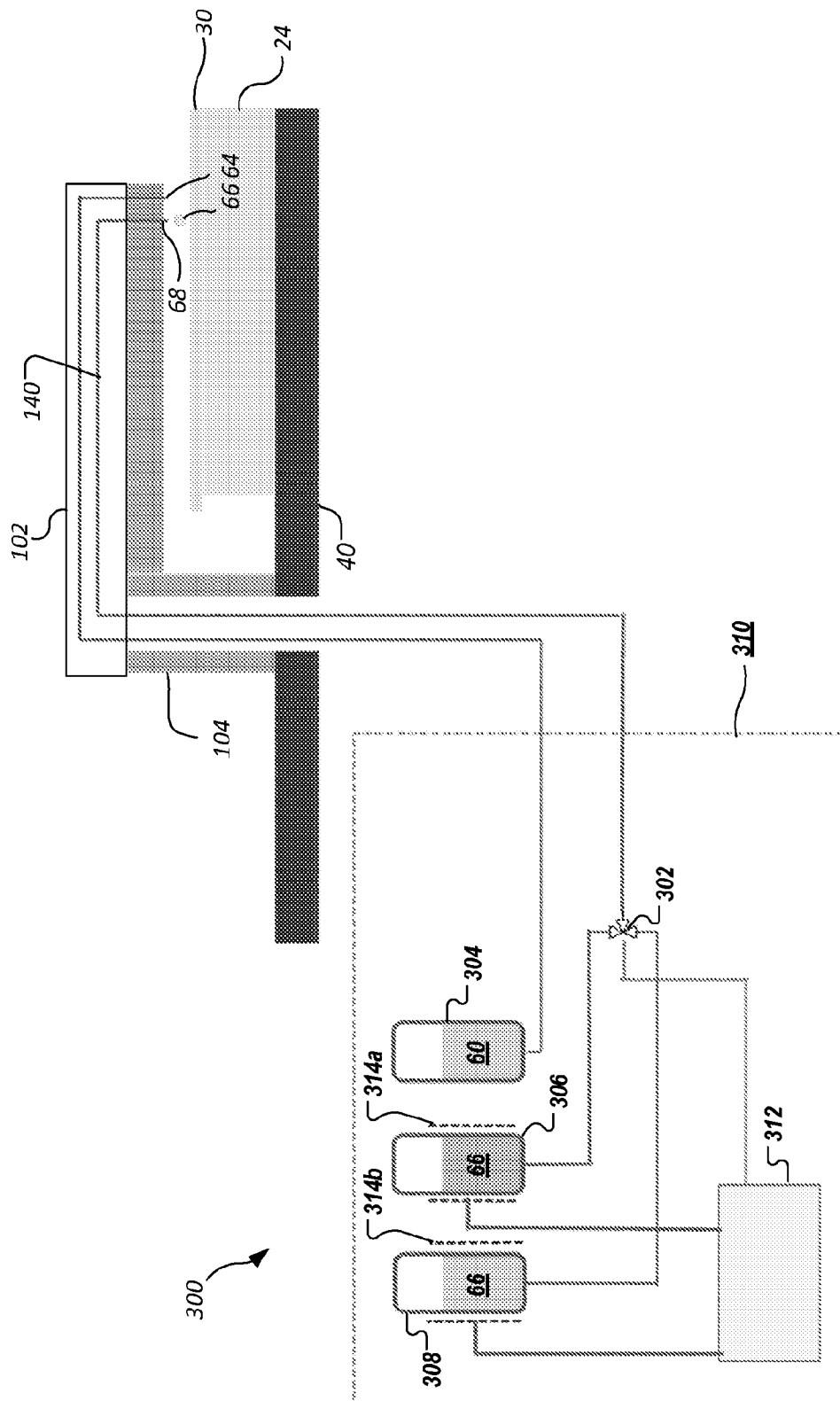


FIG. 3

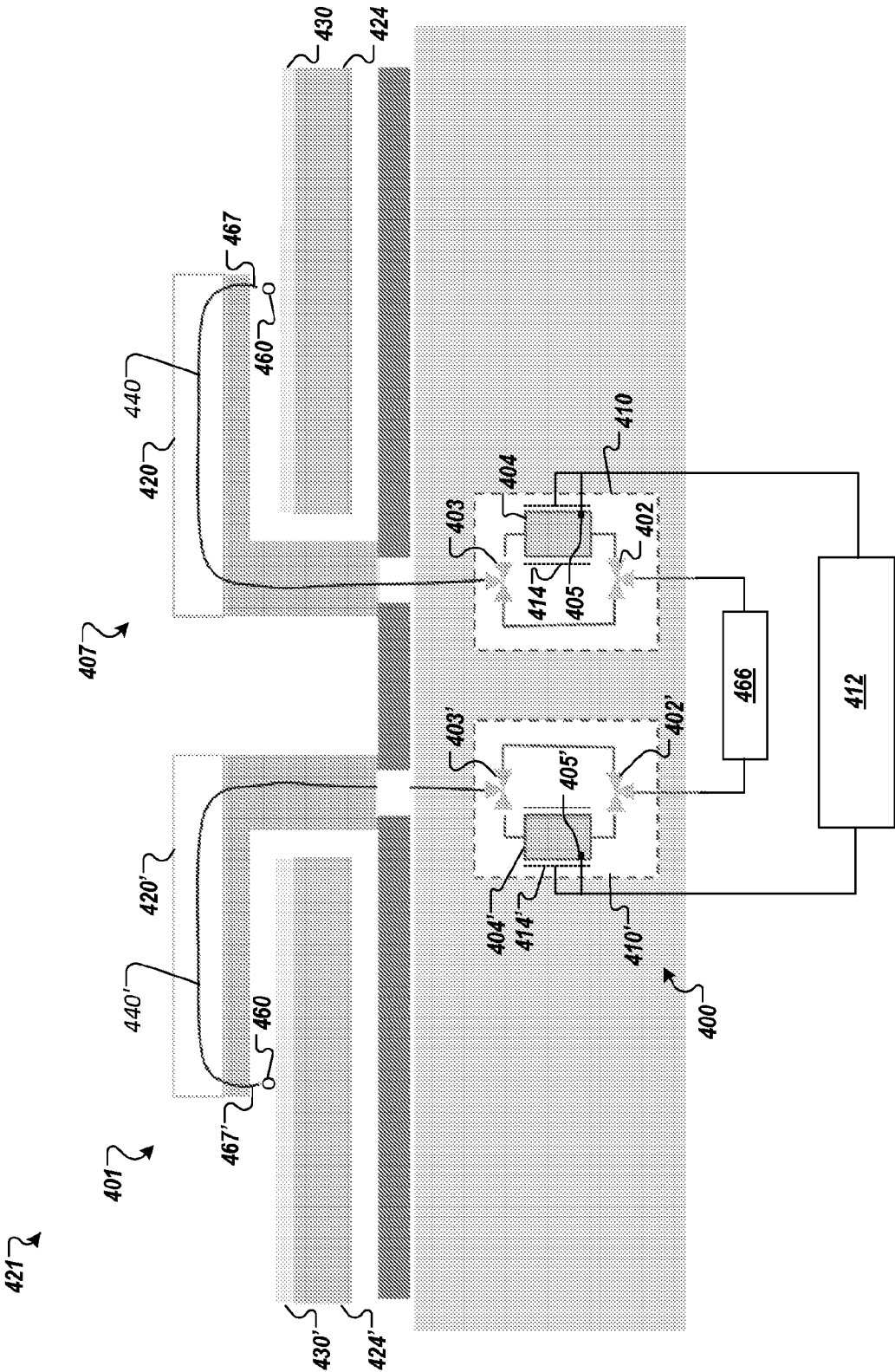


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/049468

A. CLASSIFICATION OF SUBJECT MATTER B24B 37/015 (2012.01)i; B24B 55/03 (2006.01)i; B24B 37/30 (2012.01)i; B24B 37/10 (2012.01)i; B24B 37/34 (2012.01)i; H01L 21/321 (2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B24B 37/015(2012.01); B24B 37/005(2012.01); B24B 37/013(2012.01); B24B 37/30(2012.01); C23F 1/08(2006.01); H01L 21/02(2006.01); H01L 21/304(2006.01); H01L 21/66(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: chemical mechanical polishing, substrate, carrier, platen, pad, temperature, cooling, polishing rate, control		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2022-0097198 A1 (APPLIED MATERIALS, INC.) 31 March 2022 (2022-03-31) abstract, paragraphs [0024]-[0050], and figures 2, 3A	1-12,17-20 13-16
Y	KR 10-1722555 B1 (KC TECH CO., LTD.) 03 April 2017 (2017-04-03) paragraphs [0063]-[0129], claims 1-4, and figures 4, 6	1-12,17-20
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A	KR 10-1739426 B1 (KC TECH CO., LTD.) 08 June 2017 (2017-06-08) claims 1-4 and figures 1-7	1-20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 09 January 2025		Date of mailing of the international search report 09 January 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Tae Wook Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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