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POINT OF USE DILUTION TOOL AND METHOD

Background of the Invention

The present invention relates in general to integrated circuits, and more particularly to preparing a solution through a filter for removing residue from an integrated circuit.

Semiconductor technology is producing integrated circuits that include more transistors with smaller dimensions and more detailed geometric features. The accurate reproduction of such devices requires a highly planar wafer surface with low levels of particles and other residue. Hence, where accurate geometries are needed, most manufacturing processes include surface planarization steps.

For example, a chemical-mechanical polishing (CMP) step is often used to polish away a blanket tungsten layer to the remaining tungsten plugs or to planarize an interlayer dielectric (ILD) material that isolates one interconnect layer from another. The wafer surface is mechanically polished using a slurry comprised of alumina particles suspended in an aqueous solution having a pH of 1.8-3.8. However, the low pH of the aqueous solution produces a zeta potential in the alumina particles opposite to that of the wafer, which creates an attraction force that causes many of the alumina particles to adhere to the wafer surface. Such particles produce photolithographic defects and wafer contamination which can result in a failure of the integrated circuit.

The particles are removed with a cleaning solution whose pH is set to about 12.0 to alter the polarity of the zeta potential and weaken the attraction force. Typically, an ammonium hydroxide solution having a 2% concentration by weight provides the correct pH for removing particles. Control over the concentration is important. Too low a concentration does not sufficiently raise the pH and therefore inhibits particle removal by

inadequately altering the zeta potential of the particles. Too high a concentration results in a more caustic solution which can corrode wafer materials such as tungsten plugs which are used to fill interlayer via openings.

Ammonium hydroxide is commercially available at a 30% concentration by weight. Prior art processes produce a 2% concentration by manually diluting 30% ammonium hydroxide with de-ionized (DI) water in a bulk storage tank, where it is hand-mixed and stored until needed. However, hand-mixing and hand-pouring such a strongly basic solution presents a safety hazard to people handling the chemical and those working in the area of the storage tank. Moreover, ammonia gas is highly volatile. When ammonia evaporates from the solution, not only does the safety hazard increase, but also the concentration of the NH_4OH in the cleaning solution drops significantly, lowering the pH of the diluted solution below acceptable levels.

Hence, there is a need for an apparatus and method of diluting ammonium hydroxide for removing residue from a semiconductor wafer which reduces evaporation and avoids the risk of exposing nearby persons to hazardous chemicals.

Brief Description of the Drawings

FIG. 1 is a flow diagram of an integrated circuit manufacturing apparatus; and

FIG. 2 is a diagram of an ammonium hydroxide dilution tool.

Detailed Description of the Drawings

Integrated circuit manufacturing processes include numerous steps in which substances are introduced in a wafer or on its surface, and other steps in which material is removed. For instance, a photolithographic step includes depositing a photoresist on the wafer surface, developing the photoresist and removing the undeveloped portion to form a pattern of geometric shapes for exposing portions of the wafer to further processing steps. When these steps are completed, the remaining photoresist is removed. Such photolithographic steps are examples where all of an originally deposited material is residue which must be removed to prevent the fabrication of a defective device. Similarly, a silicon dioxide layer such as an interlayer dielectric is deposited or grown on the wafer and a pattern is formed with a photoresist layer. The silicon dioxide is selectively etched in the exposed portions of the photoresist to provide openings for connecting between interconnect layers.

In each of the above examples, processing steps are included to remove unwanted material from the wafer to prevent an integrated circuit defect or failure. Such unwanted material is designated as residue, and includes unwanted material remaining from previous steps as well as material from the current step, such as particles or other impurities introduced by a non-deposition step such as a cleaning step.

Various solutions are used in integrated circuit manufacturing processes, including the removal of residue

from the wafers. Because of the high level of cleanliness required in fabricating semiconductor devices as well as the unique properties of some processing materials, it is often advantageous to form such solutions in the manufacturing plant by combining two or more fluids. In the present invention, a solution includes at least a homogeneous mixture of fluids which does not settle and whose proportions are not fixed, i.e., can be varied. For example, a solution can include true solutions, colloidal solutions, suspensions and the like.

FIG. 1 is a diagram showing the flow of a semiconductor wafer through part of an integrated circuit manufacturing system which includes a chemical-mechanical polishing (CMP) tool 10, a wafer scrubber 20 and an ammonium hydroxide (NH_4OH) dilution tool 100.

CMP tool 10 receives an incoming semiconductor wafer at an input 11 and produces a polished, planarized wafer at an output 12. CMP tool is fully automated such that wafers are handled within CMP tool 10 by means of robot arms or similar devices controlled by a control unit within the tool. Typically, the incoming wafer is received after depositing an interconnect dielectric layer or after a metal such as tungsten has been applied as a blanket layer to plug the interlayer via openings in the dielectric layer.

In the case of planarization after a tungsten deposition, polishing is accomplished using a slurry comprised of metal particles and a buffer chemical such as ferric nitrate. For example, a typical slurry includes alumina particles mixed with de-ionized (DI) water with potassium iodate functioning as the buffer. The slurry is applied to a first spinning platen designated as the primary platen. The alumina particles produce a highly abrasive slurry which is applied at a rate that ensures that a specified amount of material is abraded from the wafer at a determinable rate. Once the primary platen is completely wetted by the alumina slurry, a wafer is held

face down against the surface of the rotating primary platen by a robot arm that activates polishing by rotating the wafer in the opposite direction as the platen.

The above polishing step leaves a residue of potassium iodate, tungsten and alumina particles on the wafer. Such materials are contaminants which can cause defects in the wafer that result in inaccurate geometric patterns being produced, structural defects in an integrated circuit component, or corrosion damage which can lead to an integrated circuit failure. In the case of alumina particles, their hardness leaves scratches on the surface of the wafer which can also damage an integrated circuit. Therefore, after the first polishing, the wafer is rinsed with DI water to remove the potassium iodate and some of the loose alumina particles. Other alumina particles remain attached to the wafer because their zeta potential is opposite in polarity to the zeta potential of the wafer surface, which produces an attraction force causing the particles to adhere to the wafer.

After rinsing, the wafer is transported to a secondary rotating platen in CMP 100 to receive a second polishing step to buff the scratches from the wafer surface. This step is similar to the first polishing step except that the slurry particles are comprised of softer silicon dioxide in a solution of NH_4OH or potassium hydroxide and DI water.

Potassium hydroxide is used to raise the pH of the slurry so that the zeta potential of the alumina has the same polarity as silicon dioxide on the wafer surface. The affinity of alumina to the wafer is thereby weakened to facilitate removal of the alumina particles. After buffing, the wafer again is rinsed with DI water and kept wet until further processing. Once a wafer dries, it is nearly impossible to remove the particles without damaging the wafer.

A batch of wet polished wafers are transported from CMP tool 10 to wafer scrubber 20. The wafers are loaded

in a cassette 24 and kept wet with DI water from spray heads 22. A wafer is scrubbed by passing between brushes 26, which are formed from a soft, spongy material such as polyvinyl acetate (PVA) and include small protrusions or stubs (not shown) around the circumference. Brushes 26 rotate as the wafer passes such that the protrusions conform to the wafer to gently rub off particles and other residue without damaging the surface. When hydrated, brushes 26 have a high water content, which provides self-lubrication to maintain contact without damaging the wafer.

A 2% NH_4OH solution is formed in dilution tool 100 and controlled by a valve 94 to drip onto brush 26 to scrub a wafer. The 2% NH_4OH solution has a pH of approximately 12.0, which further modifies the zeta potential of the remaining alumina particles on the wafer to facilitate their removal with brush 26. Control of the NH_4OH concentration is critical, because if the concentration is too low, the zeta potential is insufficiently modified and alumina particles retain their affinity to the wafer. If the concentration is too high, wafer materials such as tungsten plugs erode. In either case, damage to the wafer and device failure is likely. In one process, a concentration ranging from 1.5-2.5% by weight has been determined to be adequate for removing alumina particles and other residue without damage to the wafer. Other methods besides dripping could be used to apply NH_4OH solution to brush 26. For example, spraying could be used provided that the evaporation of ammonia (NH_3) from the finely divided spray particles is controlled to prevent a reduction in the concentration of the solution and a lowered pH.

After scrubbing a number of wafers, particulate matter and other wafer residue accumulate in brushes 26, some of which can be re-introduced onto the wafer. Therefore, a second scrubbing step is performed using brushes 28, which are of similar composition as brushes 26

but are cleaner because much of the residue was previously removed by brushes 26. Valve 95 controls the flow rate for dripping 2% NH_4OH solution onto brushes 28 in a step similar to the step described for brushes 26. Brushes 26 and 28 are rinsed from time to time with the 2% NH_4OH to remove accumulated particles.

The wafer is moved to a spin drier comprising an infrared or equivalent heat source 30, a spray nozzle 31 and a spinner 32. The remaining residue is removed from the wafer by rinsing with DI water applied through nozzle 31 while the wafer spins on spinner 32. After rinsing, nozzle 31 is turned off and heat source 30 is switched on to spin dry the wafer. The dried wafer is loaded in a dry cassette 34 for removal from scrubber 20.

NH_4OH is typically obtained in high concentrations which, owing to its hazardous nature, reduces the number of containers that are transported and handled. A standard 30% concentration is widely available commercially and is typically used. Dilution tool 100 receives the 30% NH_4OH from a storage tank 91 and DI water from a storage tank 92. The 30% NH_4OH is diluted with DI water to produce a solution of NH_4OH with a 2% concentration which flows through tube 93 to valves 94-95 and to scrubber 20 as described above.

As noted above, the removal of alumina particles and other residue from a wafer after CMP processing requires a concentration ranging from 1.5-2.5%. In prior art NH_4OH dilution tools, the 30% solution is manually mixed with DI water and the dilute solution is poured into a storage tank. The storage tank is manually transported and plumbed into the cleaning tool and pressurized with nitrogen for delivering 2% NH_4OH when needed. Such systems have several drawbacks, including the safety hazard presented by hand-mixing and hand-pouring a highly caustic substance such as NH_4OH. Moreover, there is a high degree of variation in the concentration of the dilute solution due to the volatile nature of NH_3 gas;

which can evaporate from the solution during mixing, during storage, or whenever the solution is exposed to the atmosphere.

FIG. 2 is a schematic diagram of ammonium hydroxide dilution and delivery tool 100 including pressure regulators 112-114, a pressure relief valve 116, a storage ampule 118, a filter 130, a conductivity meter 166, pumps 141-142 and a motor 143. Bulk volumes of 30% NH_4OH solution are stored in a centralized chemical distribution module (CDM) for delivery to various processing stations in a wafer fabrication facility. In particular, 30% NH_4OH is delivered to dilution tool 100 through a tube 151. DI water is also pumped with a pressure in a range from 10,500-42,200 kilograms per square meter (Kg/M^2) gauge through tube 152. Pressure regulator 113 reduces the pressure going into ampule 118 and pump 142 to approximately 3,500 Kg/M^2 gauge.

If a problem arises in the CDM delivery system, the supply of 30% NH_4OH to dilution tool 100 could be interrupted. With some prior art systems in which the CDM delivers 2% NH_4OH directly to the wafer scrubber, such interruptions immediately result in inadequate wafer scrubbing. Moreover, when multiple processing stations require delivery at the same time, the delivery pressure can drop substantially, causing a failure where processing steps are timed or rely on a minimum pressure to function.

To reduce the occurrence of such supply interruptions or pressure variations, the 2% NH_4OH solution is produced locally near wafer scrubber 20. Ampule 118 provides local buffer storage to decouple dilution tool 100 from CDM delivery problems, operating as a local reservoir to ensure a continuous supply of 30% NH_4OH to dilution tool 100. Sensors 120-121 are capacitive sensors used to detect the fluid level in ampule 118. When ampule 118 is full, i.e., at the level of sensors 120, a signal is sent to the CDM to stop delivering NH_4OH. When the fluid level of ampule 118 is low, i.e., at the level of sensors 121, a

signal is sent to the CDM to resume delivery of NH_4OH. Sensors 120-121 are mounted on the outside of ampule 118 to avoid leaks and corrosion.

Continuity in the 30% NH_4OH supply is provided by setting sensors 121 to send a delivery command to the CDM before ampule 118 is empty, when an adequate amount of NH_4OH remains in ampule 118 to operate dilution tool 100 until the CDM has time to replenish the supply. For example, sensors 121 can be set to send a delivery signal to the CDM when a forty-five minute supply of NH_4OH remains in ampule 118. To further increase the reliability of dilution tool 100, sensors 120 and 121 are configured in duplicate to provide redundancy as shown. Each of the sensors 120 and 121 communicates with the CDM independently.

Clean, dry air is pressurized and coupled to ampule 118 through a pressure regulator 113, which maintains a constant positive pressure in ampule 118 to prevent effervescence and to keep pump 141 primed to avoid pump cavitation. In one embodiment, pressure regulator 113 is configured to maintain the pressure within ampule 118 between 3,500 and 5,625 Kg/M^2 gauge. To keep the fluids from deteriorating from stagnation, with the associated loss of NH_3 gas due to effervescence, dilution tool 100 maintains a trickle flow of 2% NH_4OH to wafer scrubber 20 even when wafers are not being scrubbed. This flow not only ensures the purity of the chemicals but also has the advantage of continuously cleaning particles from brush 26.

When ampule 118 is being refilled, the incoming NH_4OH increases the pressure in ampule 118 above 5,625 Kg/M^2 gauge. A pressure relief valve 116 is coupled to ampule 118 to bleed off the excess air/NH_3 mixture to maintain the pressure in tube 154 within the specified range of 3,500-5,625 Kg/M^2 gauge.

Pumps 141-142 are sealless metering pumps which are commercially available and have numerous advantages when

used in semiconductor manufacturing. The wetted components of pumps 141-142 are fabricated with fluoropolymers such as polytetrafluoroethylene (PTFE) and ceramics to allow pumping a wide variety of chemicals without corroding. For example, citric, oxalic and glacial acetic acids can be pumped without damage as well as NH_4OH and potessium hydroxide. In addition, the pump rotor does not contact the wall of the pump cavity, which reduces friction and wear and prevents contamination from particles abraded from the pump. As a result, semiconductor processing chemicals such as NH_4OH can be pumped while maintaining a high level of purity.

The flow rates through pumps 141-142 are easily and accurately controlled by an external adjustment that tilts the angle of the rotating piston within the pump cavity. Moreover, flow can be accurately regulated down to low levels by adjusting the motor speed (stroke rate). In one embodiment, pump 141 has a small pump head which produces a flow rate of NH_4OH of four microliters per revolution. Hence, when operating at a low speed of three revolutions per second, the flow rate is twelve microliters per second. Dial indicators 162-165 reveal the amount of tilt in each pump head in order to calibrate flow rates for pumps 141-142, which can be varies manually, mechanically, electronically, etc. Once set, the flow rates remain in a constant ratio even when the overall volume of fluid through pumps 141-142 varies. Alternatively, one dial indicator per pump head will indicate pump tilt.

Pump 142 receives DI water through an intake tube 152 at a pressure between 24,600 and 26,725 Kg/M^2 gauge. A pressure regulator 114 maintains pressure going into pump 142 between 3,500-5,625 Kg/M^2 gauge. Pump 142 is of similar construction as pump 141 but is substantially larger because fifteen times more water flows through pump 142 dilute the 30% NH_4OH solution down to a 2% concentration.

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Motor 143 drives pumps 141-142 with a single shaft 144 to ensure that pumps 141-142 rotate at the same speed and therefore provide NH_4OH and DI water flow rates at a constant ratio. A fixed volume of fluid is pumped through each of the pumps 141-142 during each revolution or cycle of motor 143, so the flow rates can be varied together by adjusting the speed of motor 143. That is, to produce a larger volume of 2% NH_4OH solution, the speed of motor 143 is increased accordingly. As long as the fluid pressure going into pumps 141-142 is maintained within the specified range, the ratio of the flow rates of 30% NH_4OH to DI water remains constant at the higher speed. Such speed control can be provided by an operator or by using sensors (not shown) coupled to motor 143 through a feedback mechanism (not shown) from wafer scrubber 20.

Because pumps 141-142 are sealless, a clearance, e.g., of twenty millionths of a centimeter, is provided between the rotor and pump cavity wall to prevent friction from abrading particles from the pump. This clearance results in a predetermined portion of chemicals slipping past the pump rotor under pressure, which takes the pump out of calibration. For example, pumps 141-142 have approximately one percent pump slip, which means that one percent of the flow is due to input pressure rather than pump action. If the input pressure is too high, the percentage of pump slip increases and results in a deviation from the desired flow rate. Such a deviation can alter the concentration of the solution and result in inadequate or excessive scrubbing of the semiconductor wafer. To maintain the ratio of NH_4OH and DI water at a constant level, regulators 112-114 maintain the pressure of fluids going into pumps 141-142 within a range from 3,500-5,625 Kg/M^2 gauge.

A wetting line 154 runs from the DI water line to pump 141 to function as a wetting gland of pump 141. A continuous trickle of DI water to wet the rotor of pump 141 provides a wet seal to prevent volatile NH_3 from

evaporating from the 30% NH_4OH solution and escaping into the atmosphere as pump 141 rotates. Such wetting prevents NH_3 from escaping to create a hazard to the environment or to persons in the vicinity. The trickle flow has the additional advantage of preventing stagnation to ensure the purity of the DI water. Excess DI water is drained from pump 141 through tube 155.

Filter 130 provides a filtering function as well as a dissolving function as described below. The filtering function is achieved with a filter element 131 formed from PTFE which screens out particles larger than 0.2 micrometers in diameter. The alumina particles in the CMP slurry are larger than 0.2 micrometers in diameter, so effective cleaning requires a 2% NH_4OH solution having particles less than 0.2 micrometers in diameter.

Some prior art systems use a manifold to mix the constituent fluids. However, manifold mixing requires a high rate of flow to agitate the fluids sufficiently to prevent the formation of isolated layers in the manifold. Where the flow rates are relatively low, such as in dilution tool 100, there is insufficient agitation present to reliably form a solution. For example, the 30% NH_4OH and DI water have different densities and flow rates. When introduced into a manifold mixing system at low flow rates, the fluids tend to separate into layers, with the denser fluid settling to the bottom of the manifold.

Dilution tool 100 achieves the dissolving function at flow rates as low as 0.1 milliliters per second by combining a first fluid (30% NH_4OH) and a second fluid (DI water) through filter 130 to form the desired 2% NH_4OH solution to remove residue from a wafer. The heaviest fluid or the fluid with the highest flow rate is introduced in filter above the other fluid so as to fall through the other fluid to prevent the fluids from segregating into stratified layers. In particular, the 30% NH_4OH is introduced into filter 130 at input port 132 and DI water is introduced at input port 133, where port

133 is disposed in filter 130 above port 132. In one embodiment, port 133 is disposed at an elevation approximately three centimeters above that of port 132.

Operation of filter 130 is as follows. Recall that the DI water flows to filter 130 at fifteen times the flow rate of 30% NH_4OH and that the NH_4OH is introduced into filter 130 at a lower level. Hence, the larger volume of DI water falls through and turbulates the 30% NH_4OH, thereby breaking up the NH_4OH boundary layers or gradients to improve mixing in filter 130. The turbulence results in more intimate contact between the fluids in filter 130, which is prolonged and enhanced by the tortuous path through filter element 131 to complete the formation of dilute 2% NH_4OH solution in filter 130. The desired 2% NH_4OH solution flows out of filter 130 through tube 153 to wafer scrubber 20.

It should be noted that other solutions can be formed through a filter besides dilute NH_4OH. For example, citric acid and DI water can be introduced into filter 130 to form dilute citric acid, which is a solution used for removing iron precipitates from the surface of a semiconductor wafer after metal polish.

To monitor the concentration of the 2% NH_4OH solution, prior art systems use chemical methods which sample the solution from the bulk storage tank. In a typical prior art system the concentration is determined by removing a sample of solution from the tank and measuring one of its physical or chemical properties, such as specific gravity. However, many wafers can be processed with the solution during the time needed to evaluate the sample, so substantial damage can occur before discovering that the concentration has fallen outside of the specified range. A further disadvantage of such systems is the need to open the system to the atmosphere to take the sample, increasing the risk of contamination and exposing persons in the vicinity to hazardous chemicals. Moreover, prior art systems are

susceptible to samples not being representative of the bulk solutions because of the loss of volatile chemicals at sample taking, sample transport, sample storage, and sample assay, e.g., titration.

The present invention uses a conductivity meter 166 disposed in tube 153 to measure the conductivity or resistivity of the solution, which is a function of the concentration. Conductivity meter 166 remains disposed in tube 153 such that a reading can be taken at any time, or even continuously, to determine conductivity. Such a determination is made in significantly less time than the sample evaluation which characterizes prior art systems. Hence, appropriate steps can be taken to reduce damage to wafers when a defective solution is detected. Conductivity meter 166 has the further advantage that concentration can be determined without opening the system, which reduces contamination and avoids the risk of exposing nearby persons to hazardous chemicals.

In an alternative embodiment, the sealless pumps could be driven by separate motors which can be controlled independently to adjust the solution at the filter output. The conductivity meter can measure the conductivity of the solution to provide a control signal to adjust the speed of each motor or the output stroke volume of each pump head to vary the concentration of the solution. The motor adjustment is provided by a feedback path from the conductivity meter to the motors which includes electrical or mechanical devices. Such an embodiment would have the benefit of adjusting the concentration of the output solution, e.g., 2% NH_4OH, when the concentration of the input fluids, e.g., 30% NH_4OH, varies.

In summary, the present invention provides a novel dilution tool and a method of manufacturing an integrated circuit that includes preparing a solution of two fluids for removing residue from a semiconductor wafer. The fluids are combined in a filter to form the desired solution. Sealless pumps driven by a common motor pump

the fluids while maintaining a constant ratio of flow rates as the flow rate of the solution varies. The concentration of the solution is determined by measuring the conductivity with a conductivity meter.

A dilute NH_4OH solution is formed in the amount needed at any point in time, avoiding the need to prepare and store bulk quantities of a solution whose concentration varies with the evaporation of NH_3 gas. The tool operates in a sealed enclosure to reduce safety and environmental hazards and the need to handle caustic chemicals.

CLAIMS

What is claimed is:

1. A method of manufacturing an integrated circuit, comprising a step of combining first and second fluids through a filter to form a solution to remove residue from the integrated circuit.

2. The method of claim 1, further comprising the steps of:

introducing the first fluid into the filter at a first location of the filter; and

introducing the second fluid into the filter at a second location of the filter above the first location.

3. The method of claim 2, wherein the step of combining includes the steps of:

pumping the first fluid through the filter at a first flow rate; and

pumping the second fluid through the filter at a second flow rate higher than the first flow rate.

4. The method of claim 1, wherein the first fluid includes ammonium hydroxide and the second fluid includes water.

5. The method of claim 3, wherein the step of pumping the first fluid includes pumping ammonium hydroxide into the filter, and the step of pumping the second fluid includes pumping water into the filter at the second flow rate.

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6. The method of claim 3, wherein the step of combining includes a step of forming dilute ammonium hydroxide solution at a third flow rate, further comprising the step of maintaining a ratio of the second flow rate to the first flow rate substantially constant as the third flow rate varies.

7. The method of claim 6, wherein the ratio of the second flow rate to the first flow rate is approximately fifteen and the step of combining includes forming the solution having a concentration of approximately two percent ammonium hydroxide.

8. The method of claim 1, further comprising a step of measuring a conductivity of the solution to determine the concentration of the solution.

9. An apparatus for manufacturing an integrated circuit, comprising a filter having first and second inputs for receiving first and second fluids, respectively, and an output for providing a solution for removing residue from the integrated circuit.

10. The apparatus of claim 9, wherein the second fluid flows to the filter at a higher flow rate than the first fluid and the second input is disposed above the first input.

11. The apparatus of claim 10, further comprising:

a first pump having an output for delivering the first fluid to the first input of the filter; and

a second pump having an output for delivering the second fluid to the second input of the filter.

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12. The apparatus of claim 11, further comprising a motor coupled to the first and second pumps for delivering a first volume of the first fluid while delivering a second volume of the second fluid to produce a third volume of the solution.

13. The apparatus of claim 12, wherein the motor has a shaft for driving the first and second pumps such that a ratio of the second volume to the first volume is held constant as the third volume varies.

14. The apparatus of claim 9, wherein the first fluid includes ammonium hydroxide, the second fluid includes de-ionized water, and the residue includes alumina.

15. The apparatus of claim 14, wherein the ratio of the second volume to the first volume is approximately fifteen and the solution has a concentration of approximately two percent ammonium hydroxide.

16. The apparatus of claim 9, further comprising a conductivity meter coupled to the output of the filter for determining a concentration of the solution.

17. An integrated circuit manufactured by the process of combining first and second fluids through a filter to form a solution to remove residue from the integrated circuit.

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18. The integrated circuit of claim 17, wherein the second fluid has a flow rate higher than the flow rate of the first fluid, the process further comprising the steps of:

introducing the first fluid into the filter at a first location; and

introducing the second fluid into the filter at a second location above the first location.

19. The integrated circuit of claim 18, wherein the process further comprises the steps of:

pumping the first fluid to the filter at a first flow rate; and

pumping the second fluid to the filter at the second flow rate.

20. The integrated circuit of claim 18, wherein the step of combining includes a step of forming the solution at a third flow rate, further comprising the step of maintaining a concentration of the solution substantially constant as the third flow rate varies.

21. The integrated circuit of claim 17, wherein the process further comprises a step of measuring a conductivity of the solution to control a concentration of the solution.

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22. An apparatus for removing residue from an integrated circuit, comprising:

a first pump for pumping a first fluid;

a second pump for pumping the second fluid;

a combining device having first and second inputs for receiving the first and second fluids from the first and second pumps, respectively, and an output for providing a cleaning solution; and

a measurement device coupled to the output of the combining device for measuring a conductivity of the cleaning solution.

23. The apparatus of claim 22, further comprising a motor for driving the first and second pumps to deliver the first fluid at a first flow rate and the second fluid at a second flow rate to produce the cleaning solution at a third rate, where a ratio of the first and second rates is constant as the third rate varies.

24. The apparatus of claim 22, wherein the combining device comprises a filter.

25. The apparatus of claim 24, wherein the first flow rate is lower than the second flow rate, and the first input of the combining device is disposed below the second input.

26. A method of combining first and second fluids, comprising a step of introducing the first and second fluids into a filter to form a solution.

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27. The method of claim 26, wherein the first fluid has a lower density than the second fluid, and the step of introducing includes the steps of:

introducing the first fluid into the filter at a first input; and

introducing the second fluid into the filter at a second input higher than the first input.

28. The method of claim 27, further comprising the steps of:

delivering the first fluid to the filter at a first flow rate; and

delivering the second fluid to the filter at a second flow rate greater than the first flow rate.

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