

- 1 -

**SUBSTRATE BRUSH SCRUBBING AND PROXIMITY CLEANING-DRYING
SEQUENCE USING COMPATIBLE CHEMISTRIES, AND PROXIMITY
SUBSTRATE PREPARATION SEQUENCE, AND METHODS,
APPARATUS, AND SYSTEMS FOR
IMPLEMENTING THE SAME**

by Inventors:

*Michael Ravkin
John M. de Larios
Mikhail Korolik
Michael G. R. Smith, and
Carl Woods*

BACKGROUND

[0001] The present invention relates generally to substrate cleaning and drying and, more particularly, to systems, apparatuses, and methods for improving semiconductor substrate cleaning and/or drying by reducing contamination of substrate surfaces. The present invention further relates to systems, apparatus, and methods for improving semiconductor substrate preparation, cleaning, and/or drying by reducing preparation time and cost associated with substrate preparation operations.

2. Description of the Related Art

[0002] The fabrication of semiconductor devices involves numerous processing operations. These operations include, for example, dopant implants, gate oxide generation, inter-metal oxide depositions, metallization depositions, photolithography patterning, etching operations, chemical mechanical polishing (CMP), etc. As these operations generate particles and residues, substrate surfaces need to be cleaned so as to remove particulate contaminants adhered to the surfaces of the substrate.

[0003] Particulate contaminants generally consist of tiny bits of distinctly defined material having an affinity to adhere to the surfaces of the substrate. Examples of particulate contaminants can include organic and inorganic residues, such as silicon dust, silica, slurry residue, polymeric residue, metal flakes, atmospheric dust, plastic particles, and silicate particles, among others. Particulate contaminants should be removed from substrate surfaces as leaving behind such contaminants on substrate surface can have

detrimental effects on the performance of integrated circuit devices.

[0004] Cleaning the substrate front sides (i.e., the active side or top surface) has traditionally been given a higher priority in typical substrate cleaning systems and processes because deleterious defects may be caused in the processing of the substrates. However, as substrate sizes have increased and/or feature sizes have decreased, certain shortcomings have been associated with the failure to adequately and properly clean and process substrate backsides (i.e., non-active side).

[0005] One drawback of having contaminant particulates on substrate backsides is migration of particulate contaminants from the substrate backside to the substrate front side. For example, the migration may occur during a wet processing step and/or as the substrate is being moved or otherwise handled between the processing or metrology tools. Furthermore, the backside contaminants can undesirably migrate from one process tools or steps thus contaminating subsequent processes.

[0006] To eliminate such drawbacks, in certain substrate processing operations, first, the wafer backside is brush scrubbed using a roller type cleaning assembly followed by conditioning of the wafer front side. In the roller type cleaning assembly, a rotating brush is brought into contract with the wafer backside as fluid is supplied onto the cleaning interface. One of such exemplary fluids is SC1 defined as a mixture of ammonium hydroxide and hydrogen peroxide. When performing the brush scrubbing, however, undesirably, the cleaning fluid SC1 can in some cases be sprayed onto the wafer front side.

[0007] At this point, the wafer front side is conditioned in a cleaning module using a conditioning fluid such as a solution of hydrofluoric acid (HF) and DIW, which is not compatible with the SC1 brush scrubbing fluid. As a consequence of wafer front side cross contamination and incompatibility of SC1 and the HF solution, the quality of the cleaning operation may be reduced.

[0008] Aside from contaminating the wafer front side, cleaning wafer front side and backside using diverse and incompatible chemistries necessitates implementing an associate fluid handling arrangement and waste treatment unit for each of the implemented chemistries. By way of example, separate drainages and exhausts should be used to eliminate each chemistry from the cleaning chamber. As a direct result, not only

- 3 -

the footprint of the wafer processing system is unnecessarily increased but also the system chemical handling arrangements can become very complicated.

[0009] Such limitations can further be eliminated by cleaning the substrate front side and backside in a cleaning apparatus using chemicals. Thereafter, to produce a low defect level substrate, the substrate backside and front side are rinsed by, for example, De Ionized (DI) water. In this manner, the chemicals remaining on the substrate front side and backside are diluted and/or residual particulate contaminants thereon are displaced. Producing a substrate with low-defect level, however, can require that the substrate front side and backside be rinsed sufficiently. That is, the substrate front side and backside can be rinsed using a large amount of DI water for a specific period of time, which often, can be as long as the time spent to clean and/or process the substrate front side and backside. Of course, cleaning and/or processing the substrate surface may take an extended amount of time.

[0010] Additionally, in certain scenarios, certain conditions of the substrate front side (e.g., a portion of the device being expose, etc.) wherein rinsing the substrate front side may adversely affect the condition of the substrate surface. For instance, rinsing silicon substrate may result in re-growing of oxide on the exposed portions of the substrate surface while, in a copper substrate, rinsing the substrate front side and backside may result in corrosion.

[0011] In view of the foregoing, there is a need for a system, apparatus, and method for preparing substrates capable of implementing simplified fluid handling arrangements through improving substrate throughput by minimizing cross contamination resulting from using incompatible chemistries. There is also a need for a system, apparatus, and method for preparing substrate surfaces capable of substantially reducing the time and cost associated with processing the front side and backside of substrates.

SUMMARY OF THE INVENTION

[0012] Broadly speaking, the present invention fills these needs by providing a method, apparatus, and system for preparing substrate surfaces capable of simplifying fluid handling arrangements and improving substrate throughput by minimizing cross

contamination resulting from implementing incompatible chemistries. In one embodiment, a substrate is prepared by performing a brush scrubbing operation on a substrate backside using a brush scrubbing chemistry followed by proximity cleaning and/or drying the substrate front side and backside using chemistries compatible with the brush scrubbing chemistry. In another embodiment, the present invention provides a method, apparatus, and system for preparing substrate surfaces capable of substantially reducing time and cost associated with proximity preparing of substrate surfaces by eliminating the need to perform a rinse operation subsequent to a cleaning operation.

[0013] It should be appreciated that the present invention can be implemented in numerous ways, including as a process, an apparatus, a system, a device, or a method. Several inventive embodiments of the present invention are described below.

[0014] In one embodiment, a method for cleaning and drying a front and a back surface of a substrate is provided. The method includes brush scrubbing the back surface of the substrate using a brush scrubbing fluid chemistry. The method further includes forming a front meniscus with the front surface of the substrate and a back meniscus with the back surface of the substrate. Forming the front and the back meniscus is performed after the brush scrubbing of the back surface. The method further includes scanning the front surface of the substrate and the back surface of the substrate with the front and back meniscus. The front and back meniscus each includes a chemistry that is compatible with the brush scrubbing fluid chemistry.

[0015] In another embodiment, another method for cleaning and drying a front and a back surface of a substrate is provided. The method includes brush scrubbing the back surface of the substrate using a brush scrubbing fluid chemistry. The method further includes applying a front meniscus onto the front surface of the substrate upon completing the brush scrubbing of the back surface. The front meniscus includes a front cleaning chemistry that is chemically compatible with the brush scrubbing fluid chemistry.

[0016] In yet another embodiment, a substrate preparation system is provided. The system includes a brush, a front head, and a back head. The brush is configured to brush scrub a back surface of a substrate using a brush scrubbing chemistry. The front head is defined in close proximity to a front surface of the substrate while the back head is defined in close proximity to the back surface of the substrate. The back head is

positioned substantially opposite to the front head. The front head and the back head are applied as a pair to the substrate when the brush is apart from the substrate.

[0017] In one embodiment, a method for preparing a surface of a substrate is provided. The method includes scanning the surface of the substrate by a meniscus, preparing the surface of the substrate using the meniscus, and performing a next preparation operation on the surface of the substrate that was prepared without performing a rinsing operation.

[0018] In another embodiment, a method for preparing a surface of a substrate is provided. The method includes applying a first meniscus onto the surface of the substrate so as to prepare the surface of the substrate and applying a second meniscus onto the surface of the substrate that was prepared so as to prepare the surface of the substrate that was prepared for a second time. Applying the second meniscus is configured to substantially directly follow applying of the first meniscus without performing a rinse operation.

[0019] In still another embodiment, a method for preparing a front surface and a back surface of a substrate is provided. The method includes forming a front meniscus with the front surface of the substrate and a back meniscus with the back surface of the substrate. The method further includes scanning the front surface of the substrate and the back surface of the substrate with the front meniscus and the back meniscus, respectively. Scanning the front surface of the substrate and the back surface of the substrate is configured to substantially clean and dry the front surface of the substrate and the back surface of the substrate. The method also includes performing a next substrate preparation process on the front surface of the substrate and the back surface of the substrate after the operation of scanning the front surface of the substrate and the back surface of the substrate without performing a rinsing operation.

[0020] The advantages of the present invention are numerous. Most notably, in contrast to the prior art wherein incompatible chemistries such as SC1 and HF are used to clean wafer backside and front side, respectively, in the embodiments of the present invention, compatible chemistries are used to clean and/or dry the wafer front side and backside. Another advantage is that by using compatible chemistries to clean wafer front side and backside, fluid handling arrangements in the brush scrubbing and proximity

cleaning preparation system is simplified. Still another advantage of the present invention is that by implementing compatible chemistries to brush scrub and proximity clean and/or dry wafer surfaces, the scrubbing and proximity cleaning and/or drying chamber can be free of cross contamination. This is beneficial, as by not using incompatible chemistries, the footprint of the apparatus is also reduced. Yet another advantage is that the embodiments of the present invention simplify handling of the compatible chemistries within the apparatus thus reducing mechanical cost associated with using separate flow handling components and waste treatment units for each chemistry.

[0021] Still another advantage of the present invention is that in contrast to the prior art, some embodiments of the present invention have eliminated the need to rinse substrate front side and backside every time the wafer front side and backside are exposed to chemicals. In this manner, the process time and cost associated with processing each substrate can be reduced significantly. Another advantage of the present invention is that preparing the wafer surfaces using the proximity substrate preparation system wafer surfaces can be prepared so as that a state of wafer surfaces are remained substantially the same. For instance, wafer surfaces can remain clean for use in the next preparation stage without having to expose the wafer surfaces to water thus oxide re-growth on the semiconductor or wafer surfaces (e.g., metal surfaces) can be prevented.

[0022] Other aspects and advantages of the invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

Brief Description of the Drawings

[0023] The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, and like reference numerals designate like structural elements.

[0024] Figure 1A is a simplified cross-sectional view of an exemplary brush scrubbing and proximity cleaning and/or drying system, in accordance with one embodiment of the present invention.

- 7 -

[0025] Figure 1B is a simplified partial top view of an exemplary brush scrubbing and proximity cleaning and/or drying system illustrating supplying, delivery, and collecting of chemistries in the brush scrubbing proximity cleaning and/or drying system, in accordance with another embodiment of the present invention.

5 [0026] Figure 2A is a simplified cross-sectional view of a brush scrubbing and proximity cleaning and/or drying system, in accordance with yet another embodiment of the present invention.

[0027] Figure 2B is a simplified top view diagram illustrating brush scrubbing of the wafer backside using the brush, in accordance with still another embodiment of the present invention.

[0028] Figure 3A is a simplified cross sectional view illustrating proximity cleaning and/or drying of the wafer front and backsides employing a chemistry compatible with the brush scrubbing chemistry, in accordance with still another embodiment of the present invention.

15 [0029] Figure 3B is a simplified top view of the wafer front side illustrated in Figure 3A with the wafer surfaces being cleaned and/or dried by the front proximity head, in accordance with still another embodiment of the present invention.

[0030] Figure 4A is a simplified bottom view of an exemplary proximity head, in accordance with still another embodiment of the present invention.

20 [0031] Figure 4B a simplified bottom view of yet another exemplary proximity head, in accordance with still another embodiment of the present invention.

[0032] Figure 5A depicts a simplified cross sectional view of the wafer front side being cleaned and/or dried by the front proximity head, in accordance with still another embodiment of the present invention.

25 [0033] Figure 5B is a simplified magnification of a region shown in Figure 5A, in accordance with still another embodiment of the present invention.

[0034] Figure 5C is a simplified, partial, and enlarged cross sectional view of the wafer front surface including the plurality of metal lines having an oxide layer formed thereon after proximity cleaning and/or drying of the wafer front side, in accordance with still another embodiment of the present invention.

30

[0035] Figure 6A is a flowchart diagram depicting method operations performed in an exemplary brush scrubbing proximity cleaning and/or drying system, in accordance with still another embodiment of the present invention.

5 [0036] Figure 6B is a flowchart diagram depicting method operations performed while brush scrubbing the wafer backside, in accordance with one embodiment of the present invention.

[0037] Figure 6C is a flowchart diagram depicting method operations performed during proximity cleaning of wafer front and backsides, in accordance with still another embodiment of the present invention.

10 [0038] Figure 7A is a simplified cross-sectional view of an exemplary proximity substrate preparation system, in accordance with one embodiment of the present invention.

[0039] Figure 7B is a simplified top view depicting the beginning of proximity preparation of the wafer front side in the proximity substrate preparation system of Figure 15 7A, in accordance with another embodiment of the present invention.

[0040] Figure 7C is a simplified top view of the wafer front side shown in Figure 7B substantially at the conclusion of the cleaning/drying operation, in accordance with yet another embodiment of the present invention.

[0041] Figure 7D is a simplified cross-sectional view of the wafer front side 20 having been cleaned and/or dried by the front proximity head shown in Figure 7C, in accordance with yet another embodiment of the present invention.

[0042] Figure 7E is a simplified bottom view of an exemplary front proximity head, in accordance with yet another embodiment of the present invention.

[0043] Figure 8A is a simplified top view of a proximity head preparing the wafer 25 front side, in accordance with yet another embodiment of the present invention.

[0044] Figure 8B is a simplified cross-sectional view of the wafer front side being prepared as shown in Figure 8A, in accordance with still another embodiment of the present invention.

[0045] Figure 9A is a simplified cross sectional view of an exemplary sequential 30 proximity preparation system implementing a pair of parallel bar-type proximity heads, in accordance with still another embodiment of the present invention.

[0046] Figure 9B is a simplified top view of wafer front side being prepared by the two bar-type proximity heads shown in Figure 9A, in accordance with still another embodiment of the present invention.

5 [0047] Figure 9C is a simplified cross-sectional view of the wafer front side illustrated in Figure 9B as the wafer surface is being prepared by the two-bar proximity head, in accordance with still another embodiment of the present invention.

[0048] Figure 9D is a simplified top view of an exemplary proximity bar, in accordance with still another embodiment of the present invention.

10 [0049] Figure 10A is a simplified top view of a sequential proximity preparation system implementing a single bar-type proximity head, in accordance with still another embodiment of the present invention.

[0050] Figure 10B a simplified cross sectional view of the wafer front side being prepared by the single bar-type proximity head shown in Figure 10A, in accordance with still another embodiment of the present invention.

15 [0051] Figure 10C is a simplified bottom view of an exemplary single bar-type proximity head including two menisci, in accordance with still another embodiment of the present invention.

[0052] Figure 11 is a flowchart diagram depicting method operations performed in an exemplary proximity wafer preparation system, in accordance with still another embodiment of the present invention.

[0053] Figure 12 is a flowchart diagram depicting method operations performed in a sequential proximity preparation system using two bar-type proximity heads, in accordance with one embodiment of the present invention.

25 [0054] Figure 13 is a flowchart diagram depicting method operations performed in a sequential proximity preparation system implementing a single bar-type proximity head including two menisci, in accordance with still another embodiment of the present invention.

[0055] Figure 14 shows a wafer processing system in accordance with one embodiment of the present invention.

30 [0056] Figure 15A illustrates a proximity head performing a wafer processing operation in accordance with one embodiment of the present invention.

- 10 -

[0057] Figure 15B shows a top view of a portion of a proximity head in accordance with one embodiment of the present invention.

[0058] Figure 15C illustrates an inlets/outlets pattern of a proximity head in accordance with one embodiment of the present invention.

5 [0059] Figure 15D illustrates another inlets/outlets pattern of a proximity head in accordance with one embodiment of the present invention.

[0060] Figure 15E illustrates a further inlets/outlets pattern of a proximity head in accordance with one embodiment of the present invention.

10

DETAILED DESCRIPTION

[0061] An invention capable of simplifying fluid handling arrangements and improving substrate throughput by minimizing cross contamination resulting from implementing incompatible chemistries is provided. In one embodiment, a substrate is prepared by performing a brush scrubbing operation on a substrate backside using a brush chemistry followed by proximity cleaning and/or drying of the substrate front side and backside using chemistries compatible with the brush scrubbing chemistry. In one example, a front proximity head and a back proximity head are used to clean and/or dry substrate front side and backside substantially simultaneously, using a front and a back meniscus, respectively. In one embodiment, the proximity head 110 can apply isopropyl alcohol vapor in nitrogen gas IPA/N₂ may be applied to the wafer surface using source inlets, vacuum and a processing fluid. In one embodiment, fluid meniscus is generated as a result of the application of the IPA/N₂ and the processing fluid in addition to the application of the vacuum to remove the processing fluid and the IPA/N₂ from the wafer surface. According to one implementation, the fluid meniscus can be defined as a fluid layer defined between the proximity head and the wafer surface which can be moved across a wafer surface in a stable and controllable manner.

[0062] In one implementation, the brush scrubbing chemistry and front and back chemistries used to clean wafer front and backsides are solutions of hydrofluoric acid (HF) and de-ionized water (DIW). Depending on a desired application, a concentration of

30

- 11 -

HF in the brush scrubbing chemistry and front and back chemistries can be configured to be equal or different.

[0063] The present invention is further capable of substantially reducing cost and process time associated with preparing substrate surfaces by substantially eliminating a need to rinse substrate surfaces between substrate preparation operations is provided. In one embodiment, once the substrate surface is prepared by the proximity head using the meniscus that includes a chemistry, the next substrate preparation operation can be performed on the substrate surface without having to rinse the substrate surface. In one example, proximity preparation is cleaning and/or drying of the substrate surface, while in another embodiment, the proximity preparation is stripping of native oxide. According to yet another embodiment, the substrate surface can be proximity prepared by removing a layer formed over the substrate surface so as to intentionally generate precipitated residue using a first meniscus. Thereafter, the wafer substrate is proximity prepared using a second meniscus by causing a desired chemical reaction between a second chemistry of the second meniscus and the precipitated residue. Such subsequent substrate preparation operations are performed without having to rinse the substrate between the two proximity preparation operations. In one example, the first meniscus is utilized in one proximity head and the second meniscus is utilized in a second proximity head. In a different embodiment, the first meniscus and the second meniscus are utilized in a single proximity configured to traverse head traversing the entire wafer. In one implementation, the chemistry to prepare the wafer surface can be a solution of hydrofluoric acid (HF) and de-ionized water (DIW).

[0064] In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be understood, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present invention.

[0065] Figure 1 is a simplified cross-sectional view of an exemplary brush scrubbing-proximity cleaning and/or drying system 100, in accordance with one embodiment of the present invention. The brush scrubbing and proximity cleaning and/or

- 12 -

drying system 100 includes a chamber 104 disposed above a fluid handling system 106, front and back proximity heads 110a and 110b secured to an actuating component 114, and a system controller 116. Front and back proximity heads 110a and 110b are connected to the actuating component 114 by a front arm and a back arm 126a and 126b, respectively. In one embodiment, the actuating component 114 can be a motor, however, in a different embodiment, the actuating component 114 can be any component capable of moving front and back arms 126a and 126b. Furthermore, it must be appreciated by one of ordinary skill in the art that different mechanics and engineering can be implemented to move front and back arms 126a and 126b and thus front and back proximity heads 110a and 110b into and out of the chamber 104.

[0066] The chamber 104 includes a plurality of rollers 108 configured to engage and rotate a wafer 102. In one example, four rollers 108 are implemented two of which function as stabilizing members configured to engage the wafer 102. The remaining two rollers 108 are configured to cause the wafer 102 to rotate. The two stabilizing rollers 108 can be moved away so as to allow the wafer to be processed 102 to be inserted and then move back in so as to engage the wafer 102. A wafer front side 102a is shown to include contaminants 147 and liquid 146 while a wafer backside 102b is shown to include contaminants 145. In one example, wafer backside 102b may further include liquid 146'.

[0067] The chamber 104 also includes a brush 122 having a plurality of nodules 124. In the embodiment shown in Figure 1A, the brush 122 is disposed below the wafer backside 102b and in close proximity to a chamber bottom wall 104a, thus clearing the path for application of front and back proximity heads 110a and 110b. The chamber 104 further includes a drain/exhaust outlet 132 for eliminating waste and excess fluid from the chamber 104.

[0068] The fluid handling system 106 defined below the chamber 104 can be pulled out of a scrubbing and proximity cleaning and/or drying module 101 using for example, a slide mechanism. The fluid handling system 106 includes a drainage exhaust component 106a and a flow handling component 106b. The flow handling component 106b includes a plurality of flow controllers 118a, 118b, and 118c designed to contain raw chemistry to be used in cleaning the wafer 102. Each flow controller 118a-118c includes a source outlet 124a, 124b, and 124c, respectively.

[0069] In the same manner, the drainage/exhaust component 106a includes a waste treatment unit 120 designed to hold excess fluid, waste, residues, and contaminants being purged from the chamber 104. In the embodiment shown in Figure 1A, waste material enters the waste treatment unit 120 through three drain/exhaust inlets 128a, 128b, and 128c defined in the waste treatment unit 120. Additional information with respect to the flow handlers 118a-118c and waste treatment unit 120 as well as mixing and supplying of chemistries to the proximity heads 110a and 110b and the brush 122 are provided below with respect to Figure 1B.

[0070] Reference is made to Figure 1B illustrating supplying, delivery, and collecting of chemistries in the brush scrubbing proximity cleaning and/or drying system 100, in accordance with one embodiment of the present invention. A chemistry A contained within the flow controller 118a and a chemistry B contained within the flow controller 118b are shown to be mixed at a manifold 125 to a proper concentration. In one example, raw chemistry A is raw HF and chemistry B is DIW. That is, raw HF and DIW are pumped into the manifold 125 and are then mixed so as to make the front cleaning chemistry in the desired concentration.

[0071] In one example, computer software is used by the system controller 116 to monitor and maintain the desired concentration for each of the chemistries A and B. In one example, during the brush scrubbing operation, the mixture of the raw chemistry A and B (e.g., the solution of HF) can be supplied to the brush 122 through a supply tube 134. Thereafter, during proximity cleaning and/or drying, the same solution of HF can be supplied to the front proximity head 110a through supply tube 127 while DIW is supplied to the back proximity head 110b through supply tube 129. In the illustrated embodiment, chemistry A and DIW are directed to the manifold 125 through source outlets 124a and 124b so that HF can be mixed with DIW to an appropriate concentration. Thereafter, the solution of HF is supplied to the front proximity head 110a while DIW water is supplied to the back proximity head 110b through fluid inlet 126a and 126b defined in front and back proximity heads 110a and 110b, respectively.

[0072] In the same manner, chemistry C is shown to be supplied to the front and back proximity heads 110a and 110b using supply tubes 131 and 133, respectively. As shown, chemistry C is fed to the supply tube using the source outlet 124c, and then to

- 14 -

front and back proximity heads 110a and 110b through fluid inlets 126b and 126b'. In one example, chemistry C is Isopropyl alcohol (IPA) vapor, which uses N₂ as a carrier gas. As can be seen, valves 117 are used to control the flow of chemistries from flow controllers 118a-118c as well as the waste treatment unit 120. In one example, operation of valves
5 117 are controlled and monitored by the system controller 116.

[0073] As illustrated, waste materials such as chemistries, contaminants, and liquids vacuumed from over the wafer front side 102a and wafer backside 102b are drained from front and back proximity heads 110a and 110b through tubes 137 and 139, respectively. Vacuumed waste materials are fed into the tubes 137 and 139 through a
10 waste outlet 126c and a waste outlet 126c' defined in front and back proximity heads 110a and 110b. Thereafter, the waste materials are delivered to the waste treatment unit 120 through waste inlets 128a and 128b. In the same manner, chemistry supplied onto the wafer backside 102b during the brush scrubbing and proximity cleaning operation of wafer front and back sides 102a and 102b as well as the contaminants are purged from the
15 chamber 104 via a tube 130, and through the waste outlet 132 defined in the chamber bottom wall 104a, and then into the waste treatment unit 120 through a waste inlet 128c.

[0074] According to one embodiment, the chemistry A used to clean the wafer backside 102a during the brush scrubbing operation can be used as the chemistry for proximity cleaning and/or drying operation performed on the wafer front side 102a. In
20 this manner, the brush scrubbing proximity cleaning and/or drying system of the present invention can be smaller and have smaller foot print than brush scrubbing modules of the prior art. Furthermore, by using the same type of chemistry or compatible chemistries to brush scrub the wafer backside 102b and clean and/or dry the wafer front side 102a using the front proximity head 120a, the need to use separate waste components for each
25 chemistry is eliminated. In this manner, the same drainage and exhaust components can be used to eliminate waste fluids and contaminants from the chamber 104.

[0075] Proceeding to the simplified, cross sectional view shown in Figure 2A, brush scrubbing the wafer backside 102b using the brush 122 in the brush scrubbing proximity cleaning and/or drying system 100 of the present invention is provided, in
30 accordance with one embodiment of the present invention. Cleaning the wafer backside 102b is commenced by bringing the brush 122 into contact with the wafer backside 102b.

- 15 -

In one embodiment, the brush 122 originally defined in the vicinity of the chamber bottom wall 104a at a height H1 is moved to a height H2 in a direction 136. At this point, brush 122 and thus nodules 124 of the brush 138 are applied to the wafer backside 102b as the brush 122 rotates in a rotation direction 122 and is moved across the wafer backside 102b in an arc-like direction 142 as the wafer 102 is rotated in the rotation direction 140.

[0076] In the embodiment in Figure 2A, front and back arms 112a and 112b transport corresponding front and back proximity heads 110a and 110b into the chamber 104 before commencing the brush scrubbing operation. Front and back proximity heads 110a and 110b are transported into the chamber 104 until front and back proximity heads 110a and 110b are defined bordering above and below the roller 108, respectively, so as not to interfere with the brush scrubbing operation. In this manner, front and back proximity heads 110a and 110b can start proximity cleaning and drying wafer front side and backside 102a and 102b almost immediately after the conclusion of the brush scrubbing operation. Of course, one of ordinary skill in the art must appreciate that in a different embodiment, front and back proximity heads 110a and 110b may be transported into the chamber 104 at any appropriate time, before, during, and after the brush scrubbing operation. It must further be appreciated that in one implementation, the wafer front side and backside can be brush scrubbed using a brush scrubbing chemistry followed by proximity cleaning and/or drying wafer front side and backside.

[0077] Upon completion of the brush scrubbing operation, the wafer front side 102a and the wafer backside 102b are cleaned and/or dried using the same chemistry or a chemistry compatible with the brush scrubbing chemistry, substantially reducing the possibility of cross contamination of the wafer front side 102a by the brush scrubbing chemistry. Once front and back proximity heads 110a and 110b have concluded cleaning and/or drying wafer front side and backside 102a and 102b, front and back proximity heads 110a and 110b are transported out of the chamber 104 using front and back arms 112a and 112b, respectively.

[0078] In one exemplary embodiment, the brush 122 can be mounted on a brush core secured to a shaft. As shown, the outer surface of the brush 122 is covered with a plurality of nodules 124 that are brought into contact with the wafer backside 102b during

- 16 -

the brush scrubbing operation so as to remove the contaminants 145 from over the wafer backside 102b.

[0079] Figure 2B is a simplified top view diagram illustrating brush scrubbing of the wafer backside 102b using the brush 122, in accordance with one embodiment of the present invention. As shown, while front and back proximity heads 110a and 110b are defined within the chamber 104 and bordering an edge of the wafer 102, the back proximity head 110b borders the edge of the wafer 102 such that the back proximity head is defined outside the path of the brush 122 as the brush moved to be applied and being moved so as to be applied across the wafer backside 102b following the arc movement direction 142. The brush scrubbing chemistry is shown to have encroached on the wafer front side 102a forming drops 121' of brush scrubbing chemistry 121.

[0080] A brush core 123 is connected to a fluid inlet designed to supply brush scrubbing chemistry 121 into the brush cores 123 through a supply tube 134 disposed inside a shaft 143. In one example, the shaft 143 is used to apply the brush 122 onto the wafer backside 102b and move the brush 122 between heights H1 and H2. Although not shown, brush core 123 has a plurality of holes thereon, allowing brush scrubbing chemistry to exit the brush core 123 so as to flush the brush 122.

[0081] Once brush scrubbing the wafer backside 102b has concluded, the brush 122 is transported so as to assume the initial position, below the wafer 102 at height H1. In this manner, the brush 122 cannot obstruct the path of the front and back proximity heads 110a and 110b during proximity cleaning and/or drying.

[0082] Removing contaminants 145 from over the wafer backside 102b by scrubbing and rinsing the wafer backside 102b is achieved by supplying brush scrubbing chemistry 121 into the scrubbing interface through the brush (TTB), saturating the brush 122 with the brush scrubbing chemistry, and brush scrubbing the wafer backside 102b with brush scrubbing chemistry 121 for a desired time. Then, in one aspect, the wafer backside 102b can be rinsed TTB as the brush 122 is flushed and saturated with DI water so as to remove brush scrubbing chemistry 121 and any contaminants 145 remaining on wafer backside 102b. Of course, it must be noted that although in the illustrated embodiment the brush scrubbing chemistry 121 is introduced onto the wafer backside 102b TTB, in a different embodiment, the brush scrubbing chemistry 121 can be

- 17 -

introduced into the brush 122 and the wafer backside 102b in any suitable manner (e.g., dispense nozzles attached to the arm designed to dispense fluid at the contact interface, a dispense nozzle located outside the diameter of the wafer, etc.).

[0083] In one embodiment, the brush scrubbing chemistry 121 implemented to scrub the wafer backside 102b can be diluted so as to have a desired concentration. In this manner, once brush scrubbing the wafer backside 102b has been achieved, penetration of any brush scrubbing chemistry 121 onto the wafer front side 102a cannot result in cross contaminating the wafer front side 102a during subsequent cleaning operations, as the wafer front side 102a is cleaned using either the same chemistry as the back cleaning chemistry or any other chemistry being compatible with the brush scrubbing chemistry 121. Furthermore, depending on the application, different concentration of chemistries can be implemented.

[0084] According to one preferred embodiment, HF can be used as the brush scrubbing chemistry 121 to chemically assist removing contaminants 145 defined on the wafer backside 102b, in the same manner as the SC1 chemistry. In one example, the concentration of HF is about 100:1. In another embodiment, the concentration of HF is approximately about 1000:1. Of course, it must be noted that any other chemistry suitable to remove contaminants 145 from wafer backside 102b can be used so long as the chemistries implemented in the module are chemically compatible (e.g., buffered Oxide Etch (BOE), HF and citric acid, HF and oxidizer (H_2O_2), etc.).

[0085] In one embodiment, the brush 122 is configured to rotate between approximately about 50 and 400 RPMs, and a more preferred range of approximately about 200 and 400 RPMs and most preferably approximately about 200-250 RPMs during the brush scrubbing and rinsing operations. Furthermore, in one implementation, the flow rate of the rinse fluid can be between approximately about 0.5 and 2 liters/minute, and a more preferred range of approximately about 0.7 and 1.5 liter/minutes, and most preferably approximately about 1 liter/minute during the rinse operation. In another embodiment, the flow rate of brush scrubbing chemistry can be between approximately about 0.3 and 1.5 liters/minute, and a range of approximately about 0.5 and 1.0 liter/minutes, and most preferably approximately about 0.7 liter/minute during the brush scrubbing operation. Additionally, in one example, the wafer 102 can be configured to

rotate between approximately about one (1) rotation per minute (RPM) and 50 RPMs, and a more preferred range of approximately about 2 and 30 RPMs and most preferably approximately about 10 RPMs during the brush scrubbing and rinse operations.

[0086] In accordance with one embodiment of the present invention, the brush 122
5 can be made out of polyvinyl alcohol (PVA) foam. The PVA material can have any surface topography and in one embodiment, the surface can be smooth. In a different embodiment, however, the brush 122 can be made out of a material suitable for processing the wafer back side 102b (e.g., nylon, mohair, a mandrel wrapped with a polishing pad material, a polyurethane roller, high density PVA, Politex, polyurethane compounds (e.g.,
10 IC1000 (Rodel) polishing pads, etc.), etc.). Yet further, in another embodiment, the brush 122 can be configured to be a removable and disposable brush.

[0087] Proceeding to the simplified cross sectional view of the brush scrubbing proximity cleaning and/or drying system 100 illustrated in Figure 3A, proximity cleaning and/or drying the wafer front side 102a and wafer backside 102b employing a chemistry
15 compatible with the brush scrubbing chemistry can further be understood, in accordance with one embodiment of the present invention. Wafer front side and backside 102a and 102b are cleaned and/or dried by front and back proximity heads 110a and 110b while front and back proximity heads 110a and 110b move in a movement direction 144 along a radius of the wafer 102 using a front and a back menisci 150 and 152. As used herein, the
20 portion of fluids (e.g., front chemistry, rinse fluid, IPA vapor, etc.) defined in the region between the front proximity head 110a and the wafer front side 102a is defined as the front meniscus 150. In the same manner, the back meniscus 152 is generated using the back cleaning chemistry, if any, or DIW and IPA vapor.

[0088] Still referring to Figure 3A, front and back proximity heads 110a and 110b
25 are brought and held in close proximity to the corresponding wafer front side and backside 102a and 102b by the front and back arms 112a and 112b moving front and back proximity heads 110a and 110b in a vertical manner. Thus, when front and back proximity heads 110a and 110b are moved horizontally in the direction 144 to assume a position bordering the roller 108 so that brush scrubbing operation can be initiated,
30 proximity heads 110a and 110b are moved vertically to respective positions in close proximity to wafer front side and backside 102a and 102b. One must appreciate that close

- 19 -

proximity, as used herein, may be any suitable distance from wafer front side and backside 102a and 102b as long as corresponding front and back meniscus 150 and 152 can be maintained with respect to wafer front side and backside 102a and 102b. In one embodiment, proximity heads 110a and 110b may each be moved to between about 0.1 mm to about 10 mm from wafer front side and backside 102a and 102b to initiate wafer processing operations, and preferably, between about 0.5 mm to about 4.5 mm from the wafer front side and backside 102a and 102b.

[0089] In the embodiment shown in Figure 3A, front and back proximity heads 110a and 110b move horizontally in the direction 144 along the radius of the wafer 102. However, it should be appreciated that front and back proximity heads 110a and 110b can be moved in any suitable manner with respect to the wafer 102 so as to clean and/or dry the wafer 102, as desired. By way of example, front and back proximity heads 110a and 110b can be moved from the center of the wafer 102 to the edge of the wafer. Furthermore, it must be noted that front and back proximity heads 110a and 110b may have any suitable size or shape as shown by, for example, in Figures 4A and 4B. Yet further, one must appreciate that front and back proximity heads 110a and 110b can have numerous types of configurations capable of performing the processes described herein.

[0090] According to one embodiment, proximity cleaning and/or drying wafer front side and backside 102a and 102b by respective front proximity head 110a and back proximity head 110b results in creating a clean and/or dry area which may expand from the center region to the edge region of the wafer 102 in a spiral manner. However, it must be noted that any suitable cleaning and/or drying path may be generated by changing the configuration of the system 100, the orientation of proximity heads, or movement of proximity heads.

[0091] According to one implementation, the front meniscus 150 is formed between the front proximity head 110a and the wafer front side 102a and a back meniscus 152 is formed between the back proximity head 110b and the wafer backside 102b. Front and back meniscus 150 and 152 traverse wafer front and backsides 102a and 102b to clean and/or dry wafer surfaces by applying front and back cleaning chemistries correspondingly so as to remove contaminants and fluids from over wafer front and back sides 102a and 102b. In one embodiment, the rotation of the wafer 102 by rollers 108 serves to move a

wafer area that has not been processed into close proximity to front and back proximity heads 110a and 110b.

5 [0092] As can be appreciated, the rotation of rollers 108 causes the wafer 102 to rotate, thus allowing substantially entire surfaces of wafer front side and backside 102a and 102b be cleaned and/or dried. As will be described in more detail below, in operation, front and back proximity heads 110a and 110b remove contaminants and fluids from wafer front and backsides 102a and 102b by respectively applying and evacuating isopropyl alcohol (IPA), deionized water (DIW), and front cleaning chemistry to the wafer front side 102a, and IPA and DIW to the wafer backside 102b.

10 [0093] It should be appreciated, however, that in one example, different front and back chemistries could be applied to wafer front side and backside 102a and 102b, respectively, depending on the application desired. Depending on the application, front and back cleaning chemistries may be the same type of chemistry having the same or different concentrations, or front and back chemistries can be different compatible chemistries. It must further be appreciated that the wafer 102 may be engaged in any
15 suitable orientation as long as the orientation enables front and back proximity heads 110a and 110b to be in close proximity to a portion of corresponding wafer front side and backside 102a and 102b to be cleaned or dried.

[0094] With continued reference to Figure 3A, the portion of the wafer front side
20 102a defined ahead of the leading edge of the front proximity head 110a is partially covered by liquid 146, contaminants 147, drops 121' of the brush scrubbing chemistry 121 used to clean the wafer backside 102b. As illustrated, the portion of the wafer backside 102b defined ahead of the leading edge of the back proximity head 110b can be partially covered by brush scrubbing chemistry 121 and contaminants 145. The trailing edges of
25 front and back proximity heads 110a and 110b, however, are shown to be visually dry. As used herein, a leading edge of a proximity head is defined as the area between the proximity head and the wafer surface defined in front of the meniscus. In a like manner, the trailing edge of the proximity head is the area between the proximity head and the wafer surface defined at the back of the meniscus.

30 [0095] One of ordinary skill in the art must appreciate that the IPA inflow may be in any suitable form such as, for example, IPA vapor where IPA in vapor form is inputted

through use of a N₂ gas. In a like manner, although several embodiments of the present invention have been described as using DIW, in another embodiment, any other suitable fluid may be utilized that may enable or enhance the wafer processing such as, for example, water purified in other ways, cleaning fluids, etc.

5 **[0096]** In one example, proximity cleaning and/or drying wafer front and back side 102a and 102b can be described as follows: The front cleaning chemistry inflow and the IPA inflow are applied onto the wafer front side 102a, thus causing any liquid 146 and drops 121' of the brush scrubbing chemistry 121 defined on the wafer front surface 102a to be intermixed with the front cleaning chemistry inflow. At this time, front cleaning
10 chemistry and DIW inflows, as applied onto the wafer front side 102a, encounter the IPA inflow. As a result, the applied front cleaning chemistry and DIW inflows reside in the region between the front proximity head 110a and the wafer front side 102a along with the liquid 146 and brush chemistry liquid 121 defined on a portion of the wafer front side, forming the front meniscus 150. Therefore, front and back meniscus 150 and 152 are
15 constant flows of fluid being applied toward the corresponding wafer front side 102a and wafer backside 102b and can be removed along liquid 146 and brush scrubbing chemistry 121 on the wafer front side 102a at substantially the same time.

[0097] Accordingly, as the front proximity head 110a scans the wafer front side 102a, the front meniscus 150 moves along with the front proximity head 110a. In this
20 manner, the region of the wafer front side 102a previously occupied by the front meniscus 150 is cleaned and dried as a result of the movement of the front meniscus 150 as applying the meniscus and removal of fluid is achieved substantially simultaneously.

[0098] In a like manner, the wafer backside 102b is cleaned and/or dried. In one embodiment, as will be explained in more detail below, a diluted HF inflow, DIW inflow,
25 and IPA vapor inflow are applied onto the wafer backside 102b forming the back meniscus 152. In such embodiment, a waste outlet may be utilized to apply vacuum to the region in close proximity to the wafer backside 102b so as to remove any fluid, contaminants, or vapor that may be located on or near the backside 102b.

[0099] In one embodiment, as illustrated in Figure 3A, it is believed that an
30 analysis of wafer front side or backside 102a and 102b may reveal the existence of precipitated residue (e.g., HF residue) on wafer front side and backside 102a and 102b.

- 22 -

Nonetheless, no liquid may be present. That is, it is believed that the portion of the wafer front side 102a and the portion of the wafer backside 102b previously occupied by front and back meniscus 150 and 152 may include precipitated residue. As will be described in more detail below, precipitated residue can be a residue generated as a result of removing fluid from front cleaning chemistry or back cleaning chemistry being used to clean and/or dry wafer front and backsides 102a and 102b. Thus, the embodiments of the present invention are designed to leave the wafer front side and backside 102a and 102b clean and dry subsequent to being cleaned and dried using the front or back cleaning chemistry inflows and IPA inflows without having to further rinse the wafer front side and backside 102a and 102b.

[00100] Figure 3B is a simplified top view of the wafer front side 102a being cleaned and/or dried by the front proximity head 110a illustrated in Figure 3A, in accordance with one embodiment of the present invention. The portion of the wafer front side 102a defined in front of the leading edge of the front proximity head 110a is shown to include drops 121' of brush scrubbing chemistry 121, contaminants 147, and liquid 146. It must be noted that liquid 146 can be any liquid that may have remained on the wafer front side 102a subsequent to any of the previous wafer processing operations (e.g., chemical mechanical planarization (CMP), etching, etc.).

[00101] According to one embodiment of the present invention, once the front proximity head 110a is moved in close proximity to the wafer front side 102a, front cleaning chemistry, and IPA inflows are introduced into the front proximity heads through fluid inlets 126a and 126b to generate the front meniscus 150 that is in contact with the wafer front side 102a. Almost simultaneously, liquid 146, drops 121' of the brush scrubbing chemistry 121, and contaminants 147 are vacuumed and removed from over the wafer front side 102a.

[00102] Figure 4A is a simplified top view of an exemplary front proximity head 110a, in accordance with one embodiment of the present invention. The front proximity head 110a is shown to have an oblong shape having a plurality of outlets design to introduce different types of fluid onto the wafer front side 102a as well as a plurality of vacuum inlets for almost simultaneously vacuuming fluid and contaminants from over the wafer front side 102a so as to clean and/or dry wafer front side 102a.

[00103] The plurality of front cleaning chemistry inlets 154 are defined substantially in the middle of the front proximity head 110a forming a substantially linear line designed to introduce liquid 146 onto the wafer front side 102a. Bordering the front cleaning chemistry inlets 154 is a plurality of vacuum outlets 158 designed to vacuum and eliminate contaminants and any type of fluid defined between the vacuum outlets 158 and the wafer front side 102a. As can further be seen, a plurality of isopropyl alcohol (IPA) inlets 156 are defined bordering the vacuum outlets 158, which in the embodiment shown in Figure 4A, define an elliptic path. In the illustrated embodiment, the front meniscus 150 is formed in an area confined within the elliptical path of the vacuum outlets 158.

[00104] Figure 4B depicts a simplified top view of an alternate front proximity head 110a, in accordance with another embodiment of the present invention. As can be seen, a plurality of vacuum outlets 158' is defined adjacent to the front cleaning chemistry inlets 154, a plurality of rinse inlets 160 is defined between the plurality of vacuum outlets 158' and the vacuum outlets 158. In one example, rinse inlets 160 are configured to introduce DIW inflow on to the wafer front side 102a so as to rinse the wafer surface 102a. According to the implementation shown in Figure 4B, the front meniscus 150 defined between the front proximity head 110a and the wafer front side 102a can be comprised of two concentric meniscus, an inner meniscus 150a and an outer meniscus 150b. In one example, the inner meniscus 150a is generated by the solution of the front cleaning chemistry and DIW while the outer meniscus 150b is formed by the DIW inflow 160.

[00105] It must be noted that although the illustrated embodiments of the present invention include a plurality of front cleaning chemistry inlets 154, vacuum outlets 158 and 158', DIW inlet 160, and IPA vapor inlet 156, in another embodiment, the embodiments of the present invention may implement at least one front cleaning chemistry inlet 154, at least one IPA vapor inlet 156, at least one DIW inlet 160, and at least one vacuum outlet 158.

[00106] With respect to the back proximity head 120b, the at least one IPA vapor inlet 156 can be defined adjacent to the at least one vacuum outlet 158, which in turn is defined adjacent to the at least one DIW inlet 160 so as to form an IPA-vacuum-DIW orientation. It must be noted by one of ordinary skill in the art that other types of

orientations such as IPA-DIW-vacuum, DIW-vacuum-IPA, vacuum-IPA-DIW, etc. may be utilized depending on the wafer processes desired and type of wafer cleaning and/or drying mechanism being enhanced. In one preferred embodiment, the IPA-vacuum-DIW orientation is used to intelligently and powerfully generate, control, and move the back meniscus 152 located between the back proximity heads 110b and the wafer backside 102b. In another embodiment, IPA-vacuum orientation can be used to clean and/or dry wafer front and back sides 102a and 102b.

[00107] Still further, it must be noted that DIW inlets 160, the IPA vapor inlets 156, the vacuum outlets 158, and front cleaning chemistry and back cleaning chemistry inlets may be arranged on the top surface of the front and back proximity heads 110a and 110b in any suitable manner so long as respective meniscus can be generated and controlled. For example, in addition to the front cleaning chemistry inlet, IPA vapor inlet, the vacuum outlet, and the DIW inlet, in an additional embodiment, there may be additional sets of IPA vapor outlets, DIW inlets and/or vacuum outlets depending on the configuration of the proximity head desired.

[00108] Yet further, it should be appreciated that front and back proximity heads 110a and 110b can have any number and type of inlets and outlets and that inlets and outlets may be oriented on front and back proximity heads in any appropriate orientation. Still further, front and back meniscus 150 and 152 can be managed in any suitable manner by controlling the amount of flow of fluids onto wafer front and back sides 102a and 102b and by controlling the vacuum applied. Yet further, it should be appreciated that the size as well as the locations of the inlets and outlets may be varied on front and back proximity heads 110a and 110b so long as front and back meniscus 150 and 152 are stable.

[00109] Still further, one of ordinary skill in the art must appreciate that it is believed that the brush scrubbing proximity cleaning and/or drying system of the present invention can be used to clean the wafer front side and backside 102a and 102b without having a need to rinse the wafer front and back sides 102a and 102b with a rinsing fluid.

[00110] Reference is made to simplified cross sectional views depicted in Figures 5A-5C, showing cleaning and/or drying of the wafer front side 102a using the front proximity head 110a after brush scrubbing the wafer backside 102b, in accordance with one embodiment of the present invention. By way of example, in the illustrated

- 25 -

embodiment, copper residue remaining over the wafer front side 102a is being removed after formation of copper metallization lines, using for instance, the mixture of HF and DIW. As the front proximity head 110a is traversing wafer front side 102a so as to clean and/or dry wafer front side 102a, copper residue as well as any liquid covering the wafer front side 102a is removed, leaving a visually clean and dry wafer front side 102a. According to one example, it is believed that precipitated HF residue may be detected upon close analysis of the wafer front side 102a. Thus, depending on the application and desired results, wafer front side 102a or wafer backside 102b may be rinsed off using DIW so as to remove any precipitated HF residue. It is believed that in most applications, the precipitated HF residue need not be rinsed. By way of example, in certain applications, having particulate residue between different layers formed over the substrate may not lead to any negative interactions, thus eliminating the need to rinse wafer front and backside 102a and 102b with DIW inflow.

[00111] Figure 5A depicts a cross sectional view of the wafer front side 102a being cleaned and dried by the front proximity head 110a, in accordance with one embodiment of the present invention. As shown, portion of the wafer front side 102a defined ahead of the leading edge of the front proximity head 110a partially includes liquid, drops 121' of brush scrubbing chemistry 121, and contaminants 147. The wafer front side 102a is shown to be cleaned and dried while the proximity head 110a and thus the front meniscus 150 is moved in the direction 144.

[00112] The portion of the wafer front side 102a defined at the trailing edge of the front proximity head 110a is shown to be visually dry. That is, after the portion of the wafer front side 102a is processed, all of the liquid 146, contaminants 147, and brush scrubbing chemistry 121 are intermixed with the front meniscus 150 and thus removed, leaving a visually clean and dry wafer front side 102a. In one embodiment, however, it is believed that the portion of the wafer front side 102a cleaned and/or dried previously, may include precipitated residue left over subsequent to drying of the wafer front side 102a. As the front cleaning chemistry, back cleaning chemistry, and the brush scrubbing chemistry are configured to be chemically compatible, negative effects resulting from wafer front side 102a cross contamination caused by penetration of SC1 associated with the prior art is significantly eliminated.

[00113] Figure 5B is a simplified, partial, and enlarged cross sectional view of the wafer front surface 102a having the plurality of metal lines 168 during cleaning and/or drying of the wafer front side 102a, according to one embodiment of the present invention. Contaminants 147, liquid 136, and drops 121' of brush scrubbing chemistry 121 partially covering the leading edge of the front proximity head 110a are shown to be removed by the movement of the front proximity head 110a. However, in one example, it is believed that precipitated residue may be detected at the trailing edge of the front proximity head 110a.

[00114] In one example, the front proximity head 110a cleanses and/or dries the wafer front side 102a using the mixture of HF and DIW inflow, IPA inflow, and vacuum to remove any type of liquid or contaminants remaining on the wafer front side 102a. According to one embodiment, while drying the wafer front side 102a, it is believed that precipitated residue of HF may be formed and remain on the portion of the wafer front side 102a being previously processed by the wafer front proximity head. Figure 5C is a simplified, partial, and enlarged cross sectional view of the wafer front surface 102a having the plurality of metal lines 168 and an oxide layer 103 formed thereon subsequent to proximity cleaning and/or drying of the wafer front side 102a, according to one embodiment of the present invention.

[00115] In accordance with one embodiment of the present invention, when using a front cleaning chemistry and a back cleaning chemistry, the front cleaning chemistry and back chemistries can be a solution of HF and DIW. Depending on the type of application, however, a concentration of HF in the front cleaning chemistry and back cleaning chemistry may be equivalent or vary. According to one implementation, the concentration of HF in the back cleaning chemistry can range between approximately 10:1 and 1500:1, and more preferably between approximately 20:1 and 1000:1, and most preferably approximately 50:1. Like wise, the concentration of HF in the front cleaning chemistry can range between approximately 50:1 and 10,000:1, and more preferably between approximately 100:1 and 1000:1.

[00116] Reference is made to a flowchart diagram 600 shown in Figure 6A depicting method operations performed in an exemplary brush scrubbing proximity cleaning and/or drying system, in accordance with one embodiment of the present

- 27 -

invention. The method begins in operation 602 in which the wafer backside is brush scrubbed using a brush scrubbing chemistry. In one example, the brush scrubbing chemistry is diluted HF having a concentration of approximately 100:1, and more preferably a concentration of approximately 1000:1. According to one implementation, the wafer front side and the wafer back side can be brush scrubbed almost simultaneously.

[00117] Next, in operation 604, the wafer front side and wafer backside are cleaned and/or dried using front and back meniscus formed between wafer front and backsides, correspondingly. A front cleaning chemistry is supplied to the front proximity head and a back cleaning chemistry is supplied to the back proximity head. The front and back chemistries are configured to be compatible with the brush scrubbing chemistry. In one embodiment, mixtures of HF and DIW are used to clean and/or dry the wafer front side and backside. Depending on the application and desired results, the concentration of HF in the front and back chemistries can be equivalent or may vary. In one example, the wafer front side can be cleaned and/or dried using the mixture of HF and DIW while the wafer backside is merely rinsed using DIW. Thereafter, the method continues to operation 606 in which the next wafer preparation operation is performed if such an operation exists.

[00118] Continuing to the flowchart diagram shown in Figure 6B, method operations performed while brush scrubbing the wafer backside can further be understood, according to one embodiment of the present invention. In operation 602a, a brush is provided, which in one example, can be a PVA brush. Next, in operation 602b, the brush is moved into close proximity of the wafer backside. In one instance, the brush which initially is defined below the wafer backside and close to the chamber bottom wall of the brush scrubbing proximity cleaning and/or drying module is moved so as to be defined in close proximity to the wafer backside. Thereafter, in operation 602c, brush scrubbing chemistry is introduced into the brush scrubbing interface. In one example, the brush scrubbing chemistry can be introduced through the brush.

[00119] Continuing to operation 602d, the brush is applied onto the wafer backside while brush scrubbing chemistry is being introduced. In one example, the brush is rotated and is moved in an arc direction so as to brush scrub the entire wafer backside. Next, applying the brush onto the wafer backside is discontinued in operation 602e. In this

manner, any contaminants and liquid remaining on the wafer backside subsequent to any of the other wafer preparation operations are mostly removed from wafer backside.

[00120] At this point, the brush is moved away from the wafer backside in operation 602f. In one example, the brush is moved back to the initial position of the brush, which in one embodiment, is in close proximity to the module bottom wall. In this manner, the brush mechanics cannot interfere with the operation of front and back proximity heads. Any encroachment of the brush scrubbing chemistry onto the wafer front side can have minimal negative effect on the wafer preparation operation as the possibility of having side effects resulting from incompatible chemistries associated with the prior art is substantially eliminated.

[00121] Reference is made to the flowchart diagram shown in Figure 6C, depicting method operations performed during front and back proximity cleaning of wafer front and back sides, in accordance with one embodiment of the present invention. In operation 604a, a front proximity head and a back proximity head are provided. Next, front cleaning chemistry is supplied to the front proximity head and back cleaning chemistry is supplied to the back proximity head along with respective IPA inflows so that front meniscus and back meniscus can be created, in operation 604b. Depending on the application, in one example, the front and back chemistries can be the same chemistry having the same concentration or diverse concentrations. In one example, front and back chemistries are solutions of HF and DIW having the same or different concentrations of HF. In a different embodiment, a back cleaning chemistry may not be implemented thus allowing the rinsing of the wafer backside with DIW inflow.

[00122] In operation 604d, the front meniscus is formed between the wafer front side and the front proximity head and the back meniscus is formed between the back proximity head and the wafer backside. Thereafter, in operation 604e, wafer front side and backside are scanned using front and back proximity heads respectively.

[00123] It must be noted that by using compatible brush scrubbing chemistry and front and back chemistries, negative effects associated with having cross-contamination within the module are also eliminated. Additionally, the same waste mechanism can be used to eliminate brush scrubbing chemistry and front and back chemistries, thus simplifying the system.

[00124] According to one embodiment of the present invention, the brush scrubbing and proximity cleaning and/or drying module of the present invention can be incorporated in a clustered wafer processing system. For instance, after a wafer front side and/or backside has been pre-processed in an etching chamber, a chemical vapor deposition system, a chemical mechanical polishing (CMP) system, etc., the wafer front side and back side can be cleaned and/or dried in the system of the present invention. Thereafter, the wafer backside and/or front side can be post-processed in an etching chamber, a chemical vapor deposition (CVD) system, physical vapor deposition (PVD) system, electrochemical deposition (ECD) system, an atomic layer deposition (ALD) system, a lithographic processing system (including coater and stepper) module, etc.

[00125] Of course, it must be noted that wafer pre-processing may be performed in any other apparatus, systems, and modules capable of providing other substrate preparation operations (e.g., spin, rinse, and dry module, proximity vapor process module, rapid thermal processing systems, etch systems, etc.).

[00126] Yet further, in one exemplary implementation, the brush scrubbing proximity cleaning and/or drying system of the present invention can be implemented in a clustered wafer cleaning apparatus that may be controlled in an automated way by a control station. For instance, the clustered cleaning apparatus may include a sender station, a brush scrubbing proximity cleaning and/or drying module, and a receiver station. Broadly stated, wafers initially placed in the sender station are delivered, one-at-a-time, to the brush scrubbing proximity cleaning and/or drying module. After being scrubbed and proximity cleaned and/or dried in the brush scrubbing proximity cleaning and/or drying module, dry wafers are then delivered to the receiver station for being stored temporarily. One of ordinary skill in the art must appreciate that in one embodiment, the clustered cleaning apparatus can be implemented to carry out a plurality of different substrate preparation operations (e.g., cleaning, etching, buffing, etc.).

[00127] Figure 7A is a simplified cross-sectional view of an exemplary proximity substrate preparation system 1000, in accordance with one embodiment of the present invention. The system 1000 includes a chamber 104, a plurality of rollers 108 defined therein, a fluid handling system 106, front and back proximity heads 110a and 110b, an actuating component 114, and a system controller 116. The chamber 104 is disposed over

- 30 -

the fluid handling system 106 while the front and back proximity heads 110a and 110b are secured to the actuating component 114 by a front arm and a back arm 112a and 112b, respectively. In one embodiment, the actuating component 114 can be a motor.

[00128] Rollers 108 are configured to engage and rotate a wafer 102 in a rotation direction 140. In the embodiment illustrated in Figure 7A, four rollers 108 are implemented two of which function as stabilizing members, and are configured to engage the wafer 102. The remaining two rollers 108 are configured to cause the wafer 102 to rotate in the rotation direction 140. When inserting the wafer, the two stabilizing rollers 108 are moved away and out of a path of the wafer 102, as the wafer to be processed 102 is delivered and inserted into the chamber 104. Thereafter, the stabilizing rollers 108 revert back so as to assume respective initial positions and to engage the wafer 102. Front and back proximity heads 110a and 110b are defined within the chamber 104 such that the Front and back proximity heads 110a and 110b border an edge of the wafer 102.

[00129] In the illustrated embodiment, chemistry implemented to clean the wafer backside 102b could encroach upon the wafer front side 102a. Contaminants 147 and 145 are shown to be disbursed over a wafer front side 102a and a wafer backside 102b, respectively. Liquid drops 146 and 146' are further disbursed over the wafer front side 102a and backside 102b, correspondingly. In one example, contaminants 147 and 145 and liquid drops 146 and 146' may have been generated during a preceding wafer preparation operation, which for instance, may be a brush scrubbing operation. Liquid drops 146, for instance, can be any liquid that may have remained on the wafer front side 102a subsequent to any of the previous wafer processing operations (e.g., chemical mechanical planarization (CMP), etching, etc.).

[00130] The fluid handling system 106 can be pulled out of the system 1000 using for example, a slide mechanism. In one embodiment, the fluid handling system 106 includes two components, a drainage exhaust component and a flow-handling component. The flow-handling component is configured to include a plurality of flow controllers designed to contain raw chemistry to be used in preparing (e.g., cleaning, etc.) the wafer 102. The drainage/exhaust component includes a waste treatment unit designed to hold excess fluid, waste, residues, and contaminants being purged from the chamber 104. In one example, chemistries contained within the flow controller can be mixed at a manifold

- 31 -

to a proper concentration. In one example, raw chemistry implemented to clean the wafer surfaces can be the mixture of raw HF and DIW. According to one embodiment, computer software can be used by the system controller 116 to monitor and maintain the desired concentration for each of the chemistries. During the proximity substrate preparation process, same or different chemistries can be supplied to the front proximity head 110a and the back proximity head 110b through corresponding supply tubes. In this manner, additional chemistry can further be supplied (e.g., Isopropyl alcohol (IPA) vapor using N₂ as a carrier gas, etc.). As used herein, the portion of fluids (e.g., chemistry, IPA vapor, etc.) defined in the region between the front proximity head 110a and the wafer front side 102a is defined as the front meniscus 150. In the same manner, a back meniscus 152 is generated using the back cleaning chemistry, IPA vapor, etc.

[00131] Waste materials such as chemistries, contaminants, and liquids vacuumed from over the wafer front side 102a and wafer backside 102b are configured to be drained from front and back proximity heads 110a and 110b through tubes connected to waste outlets defined in front and back proximity heads 110a and 110b. Thereafter, the waste materials are delivered to the waste unit (e.g., collection vacuum tank) and are then purged from the collection tank to the facilities drain. Once front and back proximity heads 110a and 110b have concluded preparing (i.e., cleaning and/or drying) wafer front side and backside 102a and 102b, front and back proximity heads 110a and 110b are transported out of the chamber 104 using front and back arms 112a and 112b, respectively.

[00132] One of ordinary skill in the art must appreciate that while in one embodiment the actuating component can be a motor, in a different embodiment, the actuating component 114 can be any component capable of moving front and back arms 112a and 112b. Furthermore, it must be appreciated by one of ordinary skill in the art that different mechanics and engineering can be implemented to move front and back arms 112a and 112b and thus front and back proximity heads 110a and 110b into and out of the chamber 104.

[00133] In one example, when front proximity head 110a and back proximity head 110b are moved horizontally in the direction 144 so as to assume respective positions substantially at a center of the wafer 102, for example, the front proximity head 110a is moved vertically to a position in close proximity to wafer front side 102a and the back

- 32 -

proximity head 110b is moved vertically to a position in close proximity to wafer backside 102b. One must appreciate that close proximity, as used herein, may be any suitable distance from wafer front side and backside 102a and 102b as long as corresponding front and back menisci 150 and 152 can be maintained with respect to wafer front side and backside 102a and 102b. In one embodiment, proximity heads 110a and 110b may each be moved to between about 0.1 mm to about 10 mm from wafer front side and backside 102a and 102b to initiate wafer processing operations, and preferably, between about 0.5 mm to about 4.5 mm from the wafer front side and backside 102a and 102b.

[00134] In the embodiment shown in Figure 7A, while preparing the wafer front side and backside 102a and 102b, front and back proximity heads 110a and 110b move horizontally in the direction 143 along a radius of the wafer 102. However, it should be appreciated that front and back proximity heads 110a and 110b can be moved in any suitable manner with respect to the wafer 102 so as to prepare the wafer front side 102a and wafer backside 102b, as desired. By way of example, front and back proximity heads 110a and 110b can be moved from an edge of the wafer 102 to the center of the wafer. Furthermore, it must be noted that front and back proximity heads 110a and 110b may have any suitable size or shape as shown by, for example, in Figures 7E, 9B, 9D, 10A, and 10C. Yet further, one must appreciate that front and back proximity heads 110a and 110b can have numerous types of configurations capable of performing the processes described herein.

[00135] According to one implementation, as shown in Figure 7A, front and back meniscus 150 and 152 traverse wafer front and backsides 102a and 102b so as to clean and/dry by exposing wafer surfaces to front and back chemistries. Thereafter, a next wafer preparation operation can be performed on wafer surfaces without having to rinse the wafer front side 102a or backside 102b with DI water. For instance, by applying front and back cleaning chemistries correspondingly to the wafer front side 102a and backside 102b, contaminants 147 and 145, 146, and 146' can be cleaned and removed from wafer front and back sides 102a and 102b, leaving substantially clean and/or dry wafer surfaces. In one embodiment, the rotation of the wafer 102 by rollers 108 serves to move a wafer area that has not been processed (e.g., cleaned and/or dried) into close proximity to front

and back proximity heads 110a and 110b, leaving the wafer area moved to be processed substantially clean and dry.

[00136] In one example, HF can be used to clean the wafer front side 102a with the HF having the concentration of about 100:1. In another embodiment, the concentration of
5 HF can be approximately about 1000:1. Of course, it must be noted that any chemistry suitable to remove contaminants 147 and 145, liquid drops 146 and 146' from wafer front side 102a and wafer backside 102b can be used so long as the chemistries selected for use in the module to prepare the wafer surfaces are selected such that the chemistries are chemically compatible (e.g., buffered Oxide Etch (BOE), HF and citric acid, HF and
10 oxidizer (H_2O_2), standard clean 1 (SC1), standard clean 2 (SC2), ammonia, surfactants, acidic acid, citric acid, combinations of the acidic acid and citric acid, combination of the acidic acid, citric acid, and surfactants, ammonium fluoride, mixed copper clean (MCC) 2500, MCC3000, a mixture of sulfuric acid and hydrogen peroxide, etc.).

[00137] In one example, the chemistries implemented can be any fluid having
15 surface preparation properties (e.g., semi-aqueous solvents having mostly low surface tension, etc.). Furthermore, it should be appreciated, that depending on the embodiment, different front and back chemistries could be applied to wafer front side and backside 102a and 102b, respectively, depending on the application desired. Depending on the application, front and back cleaning chemistries may be the same type of chemistry having
20 the same or different concentrations, or front and back chemistries can be different compatible chemistries.

[00138] One of ordinary skill in the art must appreciate that proximity preparation of wafer front side 102a and wafer back side 102b using the front and back proximity heads 110a and 110b can substantially be performed in the same manner. In the
25 illustrated embodiment, the wafer surfaces are being cleaned and/dried such that substantially no precipitated residue can be detected, thus eliminating the need to rinse the wafer surfaces prior to proceeding to the next wafer preparation operation.

[00139] Reference is made to Figure 7B depicting a simplified top view depicting the beginning of the wafer front side 102a being cleaned and/or dried in the proximity
30 substrate preparation system 1000 of the present invention, in accordance with one embodiment of the present invention. The front proximity head 110a has been brought

and held in close proximity to the wafer front side 102a by the front arm 112a and is being moved away from the center of the wafer front side in the direction 143 as the wafer 102 is being rotated in the rotation direction 140. The illustrated wafer front side 102a has contaminants 147 and liquid drops 146 spread thereon.

5 [00140] Figure 7C is a simplified top view of the wafer front side 102a shown in Figure 7B substantially at the conclusion of the cleaning and/or drying operation by the front proximity head 110a, in accordance with one embodiment of the present invention. As shown, while the front proximity head 110a moves in the direction 143, the wafer front side 102a is cleaned by the front proximity head 110a creating a clean and dry wafer front
10 side 102a expanding from the center of the wafer 102 to the edge of the wafer 102. Specifically, contaminants 147 have been cleaned and dried by the front proximity head 110a leaving a substantially dry wafer front side 102a. Thus, the proximity cleaning and/or drying of the wafer front side 102a and backside 102b using the proximity preparation system of the present invention results in clean and dry wafer front side 102a
15 and backside 102b such that the next preparation step can be performed on the wafer 102 surfaces without having to first rinse the wafer surfaces in a rinse operation.

[00141] In one exemplary operation, front and back proximity heads 110a and 110b remove contaminants, fluids, and etch thin film from wafer front side and backside 102a and 102b using front and back menisci 150 and 152, respectively. Specifically, isopropyl
20 alcohol (IPA) and front cleaning chemistry are applied to and evacuated from wafer front side 102a, while IPA and back cleaning chemistry are applied to and evacuated from the wafer backside 102b. As can be appreciated, the rotation of rollers 108 causes the wafer 102 to rotate, thus allowing substantially entire wafer front side and backside 102a and 102b be cleaned and/or dried. In this manner, the process time as well as cost associated
25 with rinsing the wafer surfaces prior to proceeding to the next preparation stage is substantially eliminated.

[00142] Although in the embodiment shown in Figure 7C the front proximity head 110a moves in the direction 143, from the wafer center to the wafer edge, it must be noted that any suitable cleaning and drying path may be generated by changing the configuration
30 of the system 1000, the orientation of proximity heads, or movement of proximity heads. It must further be appreciated that the wafer 102 may be engaged in any suitable

- 35 -

orientation as long as the orientation enables front and back proximity heads 110a and 110b to be in close proximity to a portion of corresponding wafer front side and backside 102a and 102b to be cleaned or dried.

[00143] The wafer front side 102a having been cleaned and/or dried by the front proximity head 110a shown in Figure 7C is illustrated in the simplified cross-sectional view of Figure 7D, in accordance with one embodiment of the present invention. In the illustrated embodiment, the wafer front side 102a, which has been cleaned and/or dried by the front proximity head 110a, visibly, does not have any contaminants 147 and liquid drops 146 thereon. In one example, the portion of the wafer front side 102a defined ahead of the leading edge of the front proximity head 110a can be partially covered by contaminants 147 and liquid drops 146 prior to the cleaning and/or drying. However, as the proximity preparation continues, the trailing edges of front proximity head 110a are configured to leave behind clean and dry substrate surfaces. As used herein, a leading edge of a proximity head is defined as the area between the proximity head and the wafer surface defined in front of the meniscus. In a like manner, the trailing edge of the proximity head is the area between the proximity head and the wafer surface defined at the back of the meniscus.

[00144] In one exemplary embodiment, proximity cleaning and/or drying of the wafer front side 102a can be described as follows: A front cleaning chemistry inflow and the IPA inflow are applied onto the wafer front side 102a. In this manner, any fluid remaining on the wafer front side 102a is intermixed with the front cleaning chemistry inflow. At this time, front cleaning chemistry and DIW inflows, as applied onto the wafer front side 102a, encounter the IPA inflow. As a result, the applied front cleaning chemistry and DIW inflows reside in the region between the front proximity head 110a and the wafer front side 102a along with the liquid drops 146 (in certain embodiment, liquid film 146) and back chemistry droplets 146', forming the front meniscus 150. Therefore, front and back menisci 150 and 152 are configured to be constant flows of fluid being applied toward the corresponding wafer front side 102a and wafer backside 102b and can be removed along liquid drops 146 and back chemistry droplets 146' on the wafer front side 102a at substantially the same time. According to one embodiment of the present invention, once the front proximity head 110a is moved in close proximity to the

wafer front side 102a, front chemistry, and IPA inflows are introduced into the front proximity head 110a so as to generate the front meniscus 150 that is in contact with the wafer front side 102a. Almost simultaneously, liquid drops 146 and contaminants 147 are vacuumed and removed from over the wafer front side 102a.

5 [00145] Accordingly, as the front proximity head 110a scans the wafer front side 102a, the front meniscus 150 moves along with the front proximity head 110a. In this manner, the region of the wafer front side 102a previously occupied by the front meniscus 150 is cleaned and dried as a result of the movement of the front meniscus 150 as applying the meniscus and removal of fluid is achieved substantially simultaneously.

10 Thus, beneficially, the wafer front side 102a can be exposed to chemistry so as to be cleaned and/or be dried in the proximity cleaning and/or drying system of the present invention so as to produce a clean and/or dried wafer surface thus eliminating the need to the rinse the wafer front side 102a in a rinse operation.

[00146] In a like manner, although not shown, the wafer backside 102b can be
15 cleaned and dried in the proximity cleaning and drying system of the present invention without having to rinse the wafer backside 102b with DI water prior to performing the next preparation operation on the wafer backside 102b. In one embodiment, a diluted HF inflow, DIW inflow, and IPA vapor inflow can be applied onto the wafer backside 102b forming the back meniscus 152. In such embodiment, a waste outlet may be utilized to
20 apply vacuum to the region in close proximity to the wafer backside 102b so as to remove any fluid, contaminants, or vapor that may be located on or near the backside 102b.

[00147] According to one embodiment, as illustrated in Figure 7D, it is believed that an analysis of wafer front side or backside 102a and 102b may reveal the existence of precipitated residue (e.g., fluorine ions generated as a result of exposure to aqueous HF)
25 on wafer front side and backside 102a and 102b, if leaving the precipitated residue is intentional. That is, it is believed that the portion of the wafer front side 102a and the portion of the wafer backside 102b previously occupied by front and back meniscus 150 and 152 may include precipitated residue, if so selected. Nonetheless, substantially no liquid may be present. As will be described in more detail below, precipitated residue can
30 be generated as a result of removing contaminants and fluid from wafer front side 102a and wafer backside 102b, or if selected a layer formed over the wafer surface, entering

- 37 -

into a chemical reaction with the front cleaning chemistry or back cleaning chemistry being used to clean and/or dry wafer front and backsides 102a and 102b. Thus, the embodiments of the present invention are designed to leave the wafer front side and backside 102a and 102b clean and dry subsequent to being cleaned and dried using the front or back cleaning chemistry inflows and IPA inflows, if so selected, or precipitated residue can be intentionally generated so as to remain on the wafer front side and backside for use during the next preparation operation.

[00148] Figure 7E is a bottom view of an exemplary front proximity head 110a, in accordance with one embodiment of the present invention. The depicted front proximity head 110a has an oblong shape having a plurality of outlets and inlets. The plurality of outlets is designed to introduce different types of fluid onto the wafer front side 102a while a plurality of vacuum inlets are configured to be used to almost simultaneously vacuum fluid and contaminants from over the wafer front side 102a so as to clean and dry wafer front side 102a without rinsing the wafer front side with DI water. The plurality of chemistry inlets 154 are defined substantially in the middle of the front proximity head 110a forming a substantially linear line designed to introduce front chemistry inflow onto the wafer front side 102a. Bordering the front chemistry inlets 154 is a plurality of vacuum outlets 158 designed to vacuum and eliminate contaminants and any type of fluid defined between the vacuum inlets 158 and the wafer front side 102a. As can further be seen, a plurality of isopropyl alcohol (IPA) inlets 156 are defined bordering the vacuum outlets 158, which in the embodiment shown in Figure 7E, define an elliptic path. In the illustrated embodiment, the front meniscus 150 is formed in an area confined within the elliptical path of the vacuum inlets 158.

[00149] One of ordinary skill in the art must appreciate that the IPA inflow may be in any suitable form such as, for example, IPA vapor where IPA in vapor form is inputted through use of a N₂ gas. In a like manner, although several embodiments of the present invention have been described as using DIW, in another embodiment, any other suitable fluid may be utilized that may enable or enhance the wafer processing such as, for example, water purified in other ways, cleaning fluids, etc. Yet further, it should be appreciated that the size as well as the locations of the inlets and outlets may be varied on front and back proximity heads so long as front and back menisci are stable.

- [00150] In accordance with one embodiment of the present invention, when using a front cleaning chemistry and a back cleaning chemistry, the front cleaning chemistry and back chemistries can be a solution of HF and DIW. Depending on the type of application, however, a concentration of HF in the front chemistry and back chemistry may be equivalent or vary. According to one implementation, the concentration of HF in the back chemistry can range between approximately 10:1 and 1500:1, and more preferably between approximately 2:1 and 1000:1, and most preferably approximately 50:1. Likewise, the concentration of HF in the front chemistry can range between approximately 50:1 and 10,000:1, and more preferably between approximately 100:1 and 1000:1.
- 10 [00151] Reference is made to a simplified top view shown in Figure 8A depicting a proximity head 110 of the present invention preparing the wafer front side 102a for a subsequent operation, in accordance with one embodiment of the present invention. During the illustrated preparation operation, the proximity head 110 is being moved in the direction 143, from the center of the wafer 102 to the edge of the wafer 102, as the wafer 102 is being rotated in the direction 140. As shown, a native oxide layer 103 defined over the wafer front side 102a is being stripped as the meniscus 150' is being applied onto the native oxide layer 103. In one example, the native oxide layer 103 having a thickness of approximately 12 angstroms can be stripped by the proximity head 110 of the present invention by applying the meniscus 150' including HF having a concentration of approximately 6:1. In such an example, the meniscus 150' is applied onto the native oxide layer 103 such that the native oxide is removed as the HF defined substantially in the center of the meniscus 150' is being applied on the native oxide layer 103. Almost, at the same time, the native oxide layer 103, as stripped, as well as the HF are removed from over the wafer surface, by vacuum inlets defined in the proximity head 110, leaving the wafer front side 102a stripped of the native oxide layer 103 and substantially dry. In this manner, the native oxide layer 103 can be stripped from over wafer surfaces and be subsequently prepared using a different preparation operation, without having to rinse the wafer front side 102a in a rinse operation, thus eliminating the cost as well as process time associated with rinsing the wafer front side 102a.
- 30 [00152] By way of example, the wafer front side 102a, as stripped, can be substantially free of contaminants and excess liquid thus allowing the next preparation

- 39 -

operation (e.g., etch, storage, etc.) to be performed without having to first rinse the wafer surfaces. In a different embodiment, a layer (e.g., a monolayer) of protective film (e.g., BTA) can be left behind on the wafer surfaces so as to protect copper from possibly corroding in moist air. Accordingly, the embodiments of the present invention enable the use of very concentrated chemistry to remove, clean, and/or dry wafer surfaces without having a need to rinse the wafer surfaces thereafter before performing the next substrate preparation operation.

[00153] Stripping the native oxide layer 103 so as to create the stripped wafer front side 102a is shown in the simplified cross-sectional view of Figure 8B depicting the wafer front side 102a as shown in Figure 8A, in accordance with one embodiment of the present invention. As can be seen, the native oxide layer 103 as marked by the dotted line, has been removed as a result of the proximity head 110 and thus the meniscus 150' traversing from the center of the wafer front side 102a to the edge of the wafer front side 102b. In one embodiment, as the solution of HF strips the native oxide layer 103, all generated liquids and particulates are removed by the vacuum inlets defined in the proximity head 110. In this manner, the native oxide layer is stripped after being prepared by the proximity head using chemicals such that substantially all contaminants and liquids are removed from the wafer front side, leaving a stripped, cleaned, and/or dry wafer front side 102a. In this manner, the next wafer preparation operation can be performed without having to first rinse the wafer front side 102a.

[00154] According to yet another embodiment, a sequential proximity preparation system can be implemented to prepare the wafer surfaces such that wafer surfaces can exhibit a different property. Figure 9A is simplified cross sectional view of an exemplary sequential proximity preparation system 300 implementing two parallel bar-type proximity heads 210a and 210a' to sequentially prepare the wafer front side 102a, in accordance with one embodiment of the present invention. A first proximity head 210a is secured to a second proximity head 210' via a connection arm 113 while the second proximity head 210' is secured to the actuating component via the arm 112. In operation, the first proximity head 210 and the second proximity head 210', and thus the associated first and second menisci 250 and 250' are applied to the wafer front side 102a and are moved in the direction 144. In this embodiment, the wafer 102 is configured not to rotate

- 40 -

as the entire surfaces of the wafer 102 is being traversed, and thus processed. As is described in more detail below, in one embodiment, the sequential proximity preparation of the wafer front side 102a can be performed in the scale of an entire wafer front side, as shown in Figure 9B.

5 [00155] In one exemplary embodiment, the wafer front side 102a can be chemically processed in two sequential processes, as shown in the simplified top view in Figure 9B, in accordance with one embodiment of the present invention. As can be seen, almost three different sections can be visually depicted on the wafer front side 102a. The section 103a is the oxide layer 103 initially formed over the wafer front side 102a and defined
10 ahead of the leading edge of the first front proximity head 210, precipitated residue 111 generated as a result of exposing the oxide layer 103 to the first meniscus 250, and a desired layer 109 formed as a result of chemical reaction between the precipitated residue 111 and the second meniscus 250'. Of course, it must be noted that depending on a type of wafer preparation operation desired, the precipitated residue 111 can be configured to
15 cover the wafer front side 102a continuously, and thus be in the form of a film.

[00156] According to one embodiment of the present invention, sequentially preparing the wafer front side 102a using the two bar-type proximity heads 210 and 210' can be achieved as described below. Initially, the leading edge of the first proximity head 210 is brought in close proximity to the wafer front side 102a as the arm 112 is moved in
20 the direction 143'. At this point, the first meniscus 250 generated by the first chemistry and IPA inflow is brought into contact with the oxide layer 103 as defined at the edge of the wafer front side 102a. As a result of a desired chemical reaction between the oxide and the first meniscus 250, precipitated residue 111 is generated, almost covering the entire portion of the oxide layer 103 that has come into contact with the first meniscus
25 250. Substantially simultaneous with the formation of the precipitated residue 111, any liquid generated as a result of the chemical reaction or remaining on the wafer front side 102a from a previous wafer preparation process is vacuumed and removed from that specific portion of the wafer front side 102a.

[00157] While the first proximity head 210 and thus the first meniscus 250 is being
30 applied onto the wafer front side 102a and is being moved in the direction 143', the second proximity head 210b and thus the second meniscus 250' trailing the first proximity

- 41 -

head 210 and first meniscus 250 is applied onto the wafer front side 102a, and more particularly, on that portion of the wafer surface 102a processed immediately before by the first proximity head 210 resulting in the formation of the precipitated residue 111. At this point, the second chemistry and IPA inflows of the second meniscus 250' chemically reacts with the precipitated residue 111 so as to generate the desired layer 109 over that portion of the wafer front side 102a previously prepared by both, the first proximity head 210 and the second proximity head 210'. In accordance with one embodiment, the first and second proximity heads 210 and 210' can be defined in close proximity to one another such that the desired layer 109 is formed substantially directly after the precipitated residue 111 is generated.

[00158] Chemically removing the oxide layer 103 so as to intentionally generate the desired precipitated residue 111 and subsequent chemical reactions so as to form the desired layer 109 can further be understood with respect to the simplified enlarged cross section view shown in Figure 9C, in accordance with one embodiment of the present invention. The portions of the oxide layer 103 being chemically treated by the first meniscus 250 of the first proximity head 210 is being modified such that precipitated residue 111 is formed. As can be seen, portions of the oxide layer 103a already treated by the first meniscus 250 have been chemically transformed, at least partially. However, the area directly beneath the first proximity head 250 not completely covered by the first meniscus 250 is being changed as the first front meniscus 250 is moved across the wafer front side 102a.

[00159] Analogously, the portions of the precipitated residue 111 previously treated by the second meniscus 250' is currently covered by the desired layer 109 whereas the portions of the precipitated residue 111 just being treated by the second meniscus 250' has not yet fully been transformed to the desired layer 109. Thus, beneficially, as the first proximity head 210 and second proximity head 210' are moved across the wafer front side 102a, a layer formed over the wafer front side 102a can be removed by chemically exposing the layer to a first chemistry. Thereafter, the layer removed can be replaced by a desired layer without the need to rinse the wafer front side with rinse chemistry after the removing of the formed layer and prior to forming the desired layer.

- 42 -

[00160] Figure 9D is a bottom view of an exemplary sequential substrate preparation system including a single meniscus, in accordance with one embodiment of the present invention. As can be seen, a plurality of vacuum outlets 158 is defined adjacent to the first chemistry inlets 254, while a plurality of IPA vapor inlet 156 is defined adjacent to the vacuum outlets 158. The outlets and inlets are substantially uniformly spread over the bottom surface of the first proximity head 210 so that the removal of the formed layer and formation of the desired layer can be achieved in a substantially uniform fashion. In this manner, the first proximity head 210 can be implemented to prepare the entire wafer front side 102a such that a substantially homogenous wafer front side 102a can be created. In one example, sequential proximity preparation processes can be removing an oxide layer followed by a passivation operation, a plating operation, re-growth of native oxide, etc. By way of example, the wafer front side can be passivated and an oxide layer formed over the wafer surface so as to store the wafer in storage. In such an example, rinsing the wafer front side 102a subsequent to being passivated is undesirable, as rinsing the passivated layer can nullify the passivation operation. In one exemplary embodiment, surfactants, polymers, benzene trizol (BTA) are chemistries that can be implemented to passivate a wafer front side layer. Yet another example is plating a wafer front side by removing of a layer formed over the wafer surfaces and forming a desired layer instead. For instance, an oxide layer is removed and thereafter the seed layer is applied through a type of chemical processing. In accordance with one embodiment, removal of the formed layer and replacement of the layer by a desired layer is configured to be performed in an inert atmosphere. In one example, such results can be achieved by using nitrogen and not exposing the wafer surfaces to oxygen by for instance, using a closed chamber.

[00161] This is achieved by using nitrogen as the inert gas between different strips of menisci. In one example, sequential removal and formation of layers on wafer front side can be achieved by using dilute chemicals to achieve the layer removal as well as the formation of the layer. Thereafter, the wafer front side can be processed in the next preparation stage, which in one example, can be deposition, etch, passivation, storage, etc.

[00162] Although in the embodiment shown in Figures 3A-3D first and second proximity heads have been implemented, in a different embodiment, multiple proximity

- 43 -

heads can be implemented so long as the operations of removing of a layer, generating precipitated residue, and forming of the desired layer can be achieved.

[00163] Proceeding to Figure 10A, removal of a layer, generation of precipitated residue, and formation of the desired layer using a two-menisci single bar-type proximity head is illustrated in accordance with one embodiment of the present invention. The leading edge of the proximity head 310 is brought in close proximity to the wafer front side 102a covered by the oxide layer 103 as the front arm 112 is moved in the direction 144. At this point, first, the front meniscus 250 generated by the first chemistry and IPA inflows and thereafter, the second meniscus 250' generated by the second front chemistry and IPA inflows are brought in contact with the oxide layer 103. As a result of the desired chemical reaction between the oxide 103 and the first front meniscus 250, precipitated residue 111 is generated, almost covering the portion of the wafer that was in contact with the first front meniscus 250. At this moment, any liquid generated as a result of the chemical reaction of the first meniscus 250 and the oxide layer 103 or remaining on the wafer front side 102a from a previous wafer preparation process is vacuumed and removed from over the wafer front side 102a. In one example, this is achieved almost concurrent with the formation of the precipitated residue 111.

[00164] However, as shown, the second meniscus 250' is trailing the first meniscus 250 and as such, is being applied onto the wafer front side 102a, and more particularly, onto the precipitated residue 111. At this point, the second chemistry and IPA inflows of the second meniscus 250' chemically react with the precipitated residue 111 so as to generate the desired layer 109 over the prepared portion of the wafer front side 102a. In accordance with one embodiment, the desired layer 109 can be formed substantially immediately after the precipitated residue 111 is generated.

[00165] Figure 10B is a simplified cross-sectional view of the wafer 102 being sequentially prepared in Figure 10A, in accordance with one embodiment of the present invention. As illustrated, the portions of the oxide layer 103 being chemically treated by the first meniscus 250 are being modified that the precipitated residue 111 can be generated. As can be seen, portions of the oxide layer being treated by the first front meniscus 250 has been chemically transformed, at least partially. However, the area

under the first proximity head 250 not covered by the first front meniscus 250 is to be changed as the first front meniscus 250 is moved across the wafer front side 102a.

5 [00166] Comparatively, the portions of the precipitated residue 111 previously treated by the second meniscus 250' is currently covered by the desired layer 109 whereas the portions of the precipitated residue 111 just being treated by the second meniscus 250' has not yet fully been transformed to the desired layer 109. Thus, beneficially, as the front proximity head 210 is traversing the wafer front side 102a, a layer formed over the wafer front side 102a can be removed and thereafter substantially instantaneously be replaced by a desired layer without first rinsing the wafer front side with a rinse chemistry.

10 [00167] Figure 10C is a bottom view of an exemplary double menisci bar-type proximity head 310, in accordance with one embodiment of the present invention. As can be seen, a plurality of vacuum outlets 158 is defined adjacent to the first chemistry inlets 254, while a plurality of IPA vapor inlet 156 is defined adjacent to the vacuum outlets 158. In the same manner, a plurality of vacuum outlets 158 is defined adjacent to the
15 second chemistry inlets 254', while a plurality of IPA vapor inlets 156 is defined adjacent to the vacuum outlets 158. The outlets and inlets are also substantially uniformly spread over the bottom surface of the proximity head 310 so that the removal of the formed layer and formation of the desired layer can be achieved in a substantially uniform fashion. In this manner, the proximity head 310 can be implemented to prepare the entire wafer front
20 side 102a such that a substantially homogenous wafer front side 102a can be created.

[00168] It must be noted that although in the illustrated embodiments the proximity heads of present invention include a plurality of front or back chemistry inlets 154, 154', 254, and 254', vacuum outlets 158 and 158', and IPA vapor inlet 156, in another embodiment, the embodiments of the present invention may implement at least one front
25 chemistry inlet, one back chemistry inlet, at least one IPA vapor inlet 156, and at least one vacuum outlet 158. It must be noted by one of ordinary skill in the art that other types of orientations such as IPA-DIW-vacuum, DIW-vacuum-IPA, vacuum-IPA-DIW, etc. may be utilized depending on the wafer preparation processes desired and type of wafer cleaning and/or drying mechanism being enhanced.

30 [00169] In one preferred embodiment, the IPA-vacuum-DIW orientation is used to intelligently and powerfully generate, control, and move the menisci located between the

proximity heads and the wafer surfaces. In another embodiment, IPA-vacuum orientation can be used to clean and/or dry wafer front and backsides 102a and 102b. For example, in addition to the front chemistry inlet, IPA vapor inlet, the vacuum outlet, and the DIW inlet, in an additional embodiment, there may be additional sets of IPA vapor outlets, DIW inlets and/or vacuum outlets depending on the configuration of the proximity head desired. Yet further, it should be appreciated that front and back proximity heads can have any number and type of inlets and outlets and that inlets and outlets may be oriented on front and back proximity heads in any appropriate orientation. Still further, front and back menisci can be managed in any suitable manner by controlling the amount of flow of fluids onto wafer front and backsides and by controlling the vacuum applied.

[00170] Reference is made to a flowchart diagram 1100 shown in Figure 11 depicting method operations performed in an exemplary proximity wafer preparation system, in accordance with one embodiment of the present invention. The method begins in operation 1102 in which a wafer surface is prepared using a proximity head utilizing a meniscus. In one example, the wafer preparation operation is configured to clean and/or dry the wafer surface. Thereafter, in operation 1104, the next wafer preparation operation is performed on the wafer surface without rinsing the wafer surface with rinse fluid. In this manner, for instance, DIW normally used to rinse wafer surface after the wafer surface has been exposed to chemicals is eliminated thus reducing the wafer process time as well as the cost associated with preparing the wafer surface.

[00171] Continuing to the flowchart diagram shown in Figure 12, method operations performed in a sequential two bar-type proximity head preparation system can further be understood, according to one embodiment of the present invention. In operation 1202, a layer formed over the wafer surface is removed by a first proximity head utilizing a first meniscus. In one example, the layer being removed is an oxide layer. Next, in operation 1204, precipitated residue is formed intentionally as a result of a desired chemical reaction between a first chemistry in the first meniscus and the layer being removed. Thereafter, in operation 1206, a desired layer is formed over the wafer surface using the second proximity head and second meniscus and the precipitated residue. In one example, a desired chemical reaction is achieved between a second chemistry of the second meniscus and the precipitated residue, forming the desired layer.

- 46 -

[00172] Reference is made to a flowchart diagram shown in Figure 13, depicting method operations performed during a sequential single bar-type proximity wafer preparation system including two menisci, in accordance with one embodiment of the present invention. In operation 1302, a layer formed over the wafer surface is removed using a first meniscus of the proximity head followed by generating precipitated residue in operation 1304. Precipitated residue is generated as a result of a desired chemical reaction between the formed layer and a first chemistry of the first meniscus. Next, in operation 1306, a desired layer is formed over the wafer surface using the proximity head utilizing a second meniscus of the proximity head and the precipitated residue. In one embodiment, the second meniscus trails the first meniscus, thus almost immediately covering an area of the wafer prepared by the first meniscus previously .

[00173] According to one embodiment of the present invention, the brush proximity wafer preparation system of the present invention can be incorporated in a clustered wafer processing system. For instance, after a wafer front side and/or backside has been pre-processed in an etching chamber, a chemical vapor deposition system, a chemical mechanical polishing (CMP) system, etc., the wafer front side and back side can be prepared in the system of the present invention. Thereafter, without having to rinse the wafer front side or backside, the wafer backside and/or front side can be post-processed in an etching chamber, a chemical vapor deposition (CVD) system, physical vapor deposition (PVD) system, electrochemical deposition (ECD) system, an atomic layer deposition (ALD) system, a lithographic processing system (including coater and stepper) module, etc. Of course, it must be noted that wafer pre-processing may be performed in any other apparatus, systems, and modules capable of providing other substrate preparation operations (e.g., spin, rinse, and dry module, proximity vapor process module, rapid thermal processing systems, etch systems, etc.).

[00174] The following figures describe an exemplary wafer processing system with an exemplary proximity head that can generate a fluid meniscus. It should be appreciated that any suitable type of system with any suitable type of proximity head that can generate a fluid meniscus can be used with the embodiments of the present invention described herein.

- 47 -

[00175] Figure 14 shows a wafer processing system 2000 in accordance with one embodiment of the present invention. It should be appreciated that any suitable manner of holding or moving the wafer can be used such as, for example, rollers, pins, platen, etc. The system 2000 may include rollers 2108a, 2108b, and 2108c which can hold and rotate
5 a wafer to enable wafer surfaces to be processed. The system 2000 may also include front and back proximity heads 110a and 110b that, in one embodiment, can be attached to a front arm 2112a and to a back arm 2112b respectively. The front arm 2112a and the back arm 2112b can be a part of a proximity head carrier assembly 2112 which enables substantially linear movement of the front and back proximity heads 110a and 110b along
10 a radius of the wafer 102. In one embodiment the proximity head carrier assembly 2112 may be configured to hold the front proximity head 110a above the wafer 102 and the back proximity head 110b below the wafer 102 in close proximity to the wafer 102. This may be accomplished by having the front arm 2112a and the back arm 2112b be movable in a vertical manner so once the front and back proximity heads are moved horizontally
15 into a location to start wafer processing, the front and back proximity heads 110a and 110b can be moved vertically to a position in close proximity to the wafer 102. In another embodiment, the fluid meniscus 150 and 152 may be formed between the front and back proximity heads 110a and 110b and moved onto the top and bottom surface of the wafer. The front arm 2112a and the back arm 2112b may be configured in any suitable way so
20 the front and back proximity heads 110a and 110b can be moved to enable wafer processing as described herein. It should also be appreciated that the system 2000 may be configured in any suitable manner as long as the proximity head(s) may be moved in close proximity to the wafer 102 so as to generate and control a meniscus on the wafer surface. In another exemplary embodiment, the proximity head 110 may be located at a first end of
25 an arm which rotates around an axis defined by a second end of the arm. Therefore, in such an embodiment, the proximity head 110 may be moved in an arc over the surface of the wafer 102. In yet another embodiment, the arm may be moved in a combination of a rotational movement and a linear movement. Although shown with a proximity head 110 for each side of the wafer, a single head can be used for a single side of a wafer. Other
30 surface preparation processes can be performed on sides where no proximity head 110 is used, such as a wafer scrub brush.

[00176] In another embodiment, the system 2000 may include a proximity head docking station that has a transition surface adjacent to the wafer. In such an embodiment, the fluid meniscus 150 may transition between a docking station and the surface of the wafer while in a controlled and managed state. Again, if only one side of the wafer 102 is desired to be processed, one arm with one proximity head 110 may be utilized.

[00177] Figure 15A illustrates a proximity head 110 performing a wafer processing operation in accordance with one embodiment of the present invention. The proximity head 110, in one embodiment, moves while in close proximity to the top surface 102a of the wafer 102 to conduct the wafer processing operation. It should be appreciated that depending on the type of fluid applied to the wafer 102, the fluid meniscus 150 generated by the proximity head 110 on the wafer surface 102a may be any suitable wafer processing operation such as, for example, cleaning, rinsing, drying, etching, plating, etc. It should be appreciated that the proximity head 110 may also be utilized to process the bottom surface 102b of the wafer 102. In one embodiment, the wafer 102 may be rotated so the proximity head 110 may be moved while fluid meniscus 150 processes the top surface 102a. In another embodiment, the wafer 102 may be held still while the proximity head 110 generates the fluid meniscus 150 on the wafer surface. Then the proximity head 110 may move or scan over the wafer surface and therefore move the fluid meniscus 150 along the surface of the wafer 102. In yet another embodiment, the proximity head 110 may be made large enough so the fluid meniscus 150 encompasses the surface area of the entire wafer 102. In such an embodiment, by applying the fluid meniscus 150 to the surface of the wafer 102 the entire surface of the wafer may be processed without movement of the proximity head 110.

[00178] In one embodiment, the proximity head 110 includes source inlets 2156 and 2154 and a source outlet 2158. In such an embodiment, isopropyl alcohol vapor in nitrogen gas IPA/N₂ 2155 may be applied to the wafer surface through a source inlet 2156, vacuum 2159 may be applied to the wafer surface through a source outlet 2158, and a processing fluid 2153 may be applied to the wafer surface through a source inlet 2154.

[00179] In one embodiment, the application of the IPA/N₂ 2155 and the processing fluid 2153 in addition to the application of the vacuum 2159 to remove the processing

fluid 2153 and the IPA/N₂ 2155 from the wafer surface 102a can generate the fluid meniscus 150. The fluid meniscus 150 may be a fluid layer defined between the proximity head 110 and the wafer surface that can be moved across a wafer surface 102a in a stable and controllable manner. In one embodiment, the fluid meniscus 150 may be defined by a constant application and removal of the processing fluid 2153. The fluid layer defining the fluid meniscus 150 may be any suitable shape and/or size depending on the size, number, shape, and/or pattern of the source inlets 2154, source outlets 2158 and source inlets 2156.

[00180] In addition, any suitable flow rates of the vacuum, IPA/N₂, vacuum, and the processing fluid may be used depending on the type of fluid meniscus desired to be generated. In yet another embodiment, depending on the distance between the proximity head 110 and the wafer surface, the IPA/N₂ may be omitted when generating and utilizing the fluid meniscus 150. In such an embodiment, the proximity head 110 may not include the source inlet 2159 and therefore only the application of the processing fluid 2153 by the source inlet 2154 and the removal of the processing fluid 2153 by the source outlet 2158 generates the fluid meniscus 150.

[00181] In other embodiments of the proximity head 110, the processing surface of the proximity head 110 (the region of the proximity head where the source inlets and source outlets are located) may have any suitable topography depending on the configuration of the fluid meniscus to be generated. In one embodiment, the processing surface of the proximity head may be either indented or may protrude from the surrounding surface.

[00182] Figure 15B shows a top view of a portion of a proximity head 110 in accordance with one embodiment of the present invention. It should be appreciated that the configuration of the proximity head 110 as described in reference to Figure 8B is exemplary in nature. Therefore, other configurations of proximity heads 110 may be utilized to generate the fluid meniscus 110 as long as the processing fluid can be applied to a wafer surface and removed from the wafer surface to generate a stable fluid meniscus on the wafer surface. In addition, as discussed above, other embodiments of the proximity head 110 do not have to have the source inlet 1316 when the proximity head 110 is configured to generate the fluid meniscus without usage of N₂/IPA.

[00183] In the top view of one embodiment, from left to right are a set of the source inlet 2156, a set of the source outlet 2158, a set of the source inlet 2154, a set of the source outlet 2158, and a set of the source inlet 2156. Therefore, as N₂/IPA and processing chemistry are inputted into the region between the proximity head 110 and the wafer 102, the vacuum removes the N₂/IPA and the processing chemistry along with any fluid film and/or contaminants that may reside on the wafer 102. The source inlets 2156, the source inlets 2154, and the source outlets 2158 described herein may also be any suitable type of geometry such as for example, circular opening, triangle opening, square opening, etc. In one embodiment, the source inlets 2156 and 2154 and the source outlets 2158 have circular openings. It should be appreciated that the proximity head 110 may be any suitable size, shape, and/or configuration depending on the size and shape of the fluid meniscus 110 desired to be generated. In one embodiment, the proximity head may extend less than a radius of the wafer. In another embodiment, the proximity head may extend more than the radius of the wafer. In another embodiment, the proximity head may extend greater than a diameter of the wafer. Therefore, the size of the fluid meniscus may be any suitable size depending on the size of a wafer surface area desired to be processed at any given time. In addition, it should be appreciated that the proximity head 110 may be positioned in any suitable orientation depending on the wafer processing operation such as, for example, horizontally, vertically, or any other suitable position in between. The proximity head 110 may also be incorporated into a wafer processing system where one or more types of wafer processing operations may be conducted.

[00184] Figure 15C illustrates an inlets/outlets pattern of a proximity head 110 in accordance with one embodiment of the present invention. In this embodiment, the proximity head 110 includes the source inlets 2156 and 2154 as well as source outlets 2158. In one embodiment, the source outlets 2158 may surround the source inlets 2154 and the source inlets 2156 may surround the source outlets 2158.

[00185] Figure 15D illustrates another inlets/outlets pattern of a proximity head 110 in accordance with one embodiment of the present invention. In this embodiment, the proximity head 110 includes the source inlets 2156 and 2154 as well as source outlets 2158. In one embodiment, the source outlets 2158 may surround the source inlets 2154 and the source inlets 2156 may at least partially surround the source outlets 2158.

[00186] Figure 15E illustrates a further inlets/outlets pattern of a proximity head 110 in accordance with one embodiment of the present invention. In this embodiment, the proximity head 110 includes the source inlets 2156 and 2154 as well as source outlets 2158. In one embodiment, the source outlets 2158 may surround the source inlets 2154. In one embodiment, the proximity head 110 does not include source inlets 2156 because, in one embodiment, the proximity head 110 is capable of generating a fluid meniscus without application of IPA/N₂. It should be appreciated that the above described inlets/outlets patterns are exemplary in nature and that any suitable type of inlets/outlets patterns may be used as long as a stable and controllable fluid meniscus can be generated.

[00187] Yet further, in one exemplary implementation, the proximity preparation system of the present invention can be implemented in a clustered wafer preparation apparatus that may be controlled in an automated way by a control station. For instance, the clustered preparation apparatus may include a sender station, a proximity wafer preparation module, and a receiver station. Broadly stated, wafers initially placed in the sender station are delivered, one-at-a-time, to the proximity wafer preparation module. After being proximity prepared, dry and clean wafers are then delivered to the receiver station for being stored temporarily. As appreciated, the wafer surfaces do not need to be rinsed by rinse water prior to storing the wafer to the receiver station. One of ordinary skill in the art must appreciate that in one embodiment, the clustered preparation apparatus can be implemented to carry out a plurality of different substrate preparation operations (e.g., cleaning, etching, buffing, etc.).

[00188] Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. For example, the embodiments of the present invention can be implemented to clean any substrate having varying sizes and shapes such as those employed in the manufacture of semiconductor devices, flat panel displays, hard drive discs, flat panel displays, and the like. Additionally, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

What is claimed is:

CLAIMS

1. A method for cleaning and drying a front and a back surface of a substrate, the method comprising:

5 brush scrubbing the back surface of the substrate using a brush scrubbing fluid chemistry; and

upon completing the brush scrubbing of the back surface, applying a front meniscus onto the front surface of the substrate, the front meniscus including a front cleaning chemistry, the front cleaning chemistry being chemically compatible with the
10 brush scrubbing fluid chemistry.

2. A method as recited in claim 1, the method further comprising:
scanning the front surface of the substrate.

15 3. A method as recited in claim 1, the method further comprising:
applying a back meniscus onto the back surface of the substrate, the back meniscus including a back cleaning chemistry, the back cleaning chemistry being chemically compatible with the brush scrubbing fluid chemistry.

20 4. A method as recited in claim 3, the method further comprising:
scanning the back surface of the substrate.

5. A method as recited in claim 1, wherein the front chemistry and the back chemistry of the front and back meniscus are configured to be compatible with the brush
25 scrubbing fluid chemistry so as to prevent chemical contamination of the front surface of the substrate.

6. A method as recited in claim 5, wherein chemical contamination causes particulate contaminants.

30

7. A substrate preparation system, the system comprising:

- 53 -

a brush configured to brush scrub a back surface of a substrate using a brush scrubbing chemistry;

a front head defined in close proximity to a front surface of the substrate; and

a back head defined in close proximity to the back surface of the substrate, the
5 back head being positioned substantially opposite to the front head,

wherein the front head and the back head are applied as a pair to the substrate when the brush is apart from the substrate.

8. A system as recited in claim 7, wherein the front head is configured to
10 scan the front surface of the substrate and the back head is configured to scan the back surface of the substrate substantially synchronously.

9. A system as recited in claim 7, the front head including a first front conduit, a second front conduit, and a third front conduit, wherein the first front conduit,
15 the second front conduit, and the third front conduit are configured to act substantially simultaneously when in operation, and the back head including a first back conduit, a second back conduit, and a third back conduit, wherein the first back conduit, the second back conduit, and the third back conduit are configured to act substantially
simultaneously when in operation.

20

10. A system as recited in claim 7, further comprising:

a front arm secured to the front head for moving the front head into close proximity of the front surface of the substrate; and

a back arm secured to the back head for moving the back head into close
25 proximity of the back surface of the substrate substantially at the same time as the front head.

11. A method for preparing a surface of a substrate, the method comprising:
scanning the surface of the substrate using a meniscus;
30 preparing the surface of the substrate using the meniscus; and

- 54 -

performing a next preparation operation on the surface of the substrate that was prepared without performing a rinsing operation.

12. A method as recited in claim 11, wherein the surface of the substrate
5 that was prepared is configured to be dry.

13. A method as recited in claim 11, wherein the meniscus includes a fluid having a substrate surface preparation property.

10 14. A method as recited in claim 11, wherein the operation of preparing the surface of the substrate includes one of a cleaning the surface of the substrate and stripping of a layer formed over the surface of the substrate, and further wherein the next preparation operation includes one of applying of a layer onto the surface of the substrate and storing the substrate.

15 15. A method for preparing a surface of a substrate, the method comprising:
applying a first meniscus onto the surface of the substrate so as to prepare the surface of the substrate; and
applying a second meniscus onto the surface of the substrate that was prepared
20 so as to prepare the surface of the substrate that was prepared for a second time, the applying of the second meniscus configured to substantially directly follow applying of the first meniscus without performing a rinse operation.

16. A method as recited in claim 15, wherein the operation of preparing the
25 surface of the substrate includes,
removing a layer formed over the substrate surface.

17. A method as recited in claim 15, wherein the operation of applying of the first meniscus onto the surface of the substrate is configured to leave the surface of
30 the substrate substantially dry.

- 55 -

18. A method as recited in claim 15, wherein the operation of applying of the first meniscus onto the surface of the substrate is configured to generate precipitated residue.

5 19. A method as recited in claim 15, wherein the operation of applying the second meniscus onto the surface of the substrate that was prepared includes, forming a layer of material over the surface of the substrate that was prepared.

10 20. A method as recited in claim 15, wherein the first meniscus includes a first chemistry and a second meniscus includes a second chemistry, and further wherein the layer of material formed over the surface of the substrate that was prepared is formed as a result of a chemical reaction between the second chemistry of the second meniscus and precipitated residue.

15