FIXTURE DRYING APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and benefit of U.S. Provisional Patent Application Serial No. 61/056,755, entitled "FIXTURE DRYING PROCEDURE AND APPARATUS", to Christopher Schneller et al., filed on May 28, 2008, and the specification thereof is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

[0002] Embodiments of the present invention relate to an apparatus and method for substantially drying and reducing the drying time after a manufacturing fixture has been washed, preferably a wafer carrier including but not limited to a front opening unified pod (FOUP) fixture. The invention may also be used on manufactured products, tooling fixtures or other elements requiring accelerated drying or removal of fluids.

BRIEF SUMMARY OF THE INVENTION

[0003] An embodiment of the present invention relates to an apparatus for washing and drying a carrier which includes a chamber capable of holding a carrier, the chamber having a carrier-exterior spray system and a carrier-interior spray system internal to the chamber, the carrier-exterior spray system having at least one slot which sprays a fluid onto an exterior surface of the carrier, and the interior spray system having at least one slot which sprays fluid into an interior of the carrier. The carrier can be a semi-conductor wafer carrier and/or a the lid of a semi-conductor wafer carrier. The fluid can be a liquid or a gas. The spray systems can move perpendicular to each other to prevent carrier movement. The carrier-exterior and/or carrier-exterior spray system can be at least partially rotatable.

[0004] In one embodiment, one or both of the spray systems oscillate in a sweeping motion. In addition, a motor can be provided for rotating the carrier. At least one heating system can also be provided and the heating system can include at least one heating pad. Optionally, the apparatus can be disposed within a mini clean environment. In one embodiment, a plurality of apparatuses can be disposed within a cabinet.

[0005] An embodiment of the present invention also relates to a method of washing and drying a carrier which method can include disposing a carrier into a chamber, spraying a liquid on an exterior of the carrier with an exterior spray system, spraying a liquid on an interior of the carrier with an interior spray system, spraying a gas on an exterior of the carrier with the exterior spray system, and spraying a gas on an interior of a carrier with the interior spray system. Optionally, the exterior

and interior of the carrier are sprayed in a perpendicular motion to one another. At least one of the spraying steps can include spraying in a sweeping motion.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0006] The accompanying drawings 1-39, illustrations and depictions which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating one or more preferred embodiments of the invention and are not to be construed as limiting the invention. In the drawings:

[0007] Fig. 1 is a front perspective view illustrating an embodiment of a washing and drying body chamber with a wafer carrier installed;

[0008] Fig. 2 is a front perspective view illustrating the Fig. 1 embodiment with door closed;

[0009] Fig. 3 is a perspective view illustrating the Fig. 1 embodiment with door removed;

[0010] Fig. 4 is a front view illustrating the Fig. 1 embodiment with the door closed;

[0011] Fig. 5 is a side view illustrating the Fig. 1 embodiment;

[0012] Fig. 6 is a back perspective view illustrating the Fig. 1 embodiment;

[0013] Fig. 7 is a rear view illustrating an embodiment of the present invention;

[0014] Fig. 8 is a perspective view illustrating an embodiment of a body chamber without side panel;

[0015] Fig. 9 is a front view illustrating a front face of a wafer carrier in an embodiment of the present invention;

[0016] Fig. 10 is a cross-sectional side view illustrating an interior spray system according to an embodiment of the present invention;

[0017] Fig. 11 is a top view illustrating an embodiment of the present invention;

[0018] Fig. 12 is an exploded view illustrating components of an embodiment of the present invention;

[0019] Fig.13 is an exploded perspective view illustrating components of an embodiment of the present invention;

[0020] Figs. 14A-G are drawings illustrating different views of a wafer carrier;

[0021] Fig. 15 is an underside view of a wafer carrier;

[0022] Fig. 16 is a top view illustrating a wafer carrier;

[0023] Figs. 17A and B are respectively front and exploded views of an air knife assembly;

[0024] Fig. 18 is a partially-exploded view of an air knife assembly;

[0025] Fig. 19 is a front view illustrating the Fig. 1 embodiment without the front door;

[0026] Fig. 20 is a view of a base frame;

[0027] Figs. 21A-B are views illustrating a butterfly valve;

[0028] Fig. 22 is a perspective front view of a lid chamber according to an embodiment of the present invention;

[0029] Fig. 23 is a perspective front view of the Fig. 22 embodiment with door closed;

[0030] Fig. 24 is a perspective view drawing illustrating the Fig. 22 embodiment with the door exploded from the chamber;

[0031] Fig. 25 is a front view illustrating the Fig. 22 embodiment with door closed.

[0032] Fig. 26 is a side view illustrating the Fig. 22 embodiment;

[0033] Fig. 27 is a rear perspective view illustrating the Fig. 22 embodiment;

[0034] Fig. 28 is a back view illustrating the Fig. 22 embodiment;

[0035] Fig. 29 is a rear view illustrating an embodiment with the rear panel removed;

[0036] Fig. 30 is a perspective view illustrating an embodiment with the front door removed and showing a wafer carrier lid;

[0037] Fig. 31 is a front view illustrating an embodiment with the front door removed and showing a wafer carrier lid;

[0038] Fig. 32 is a cross section view illustrating an embodiment of a lid chamber assembly;

[0039] Fig. 33 is a top view illustrating an embodiment of a lid chamber assembly;

[0040] Fig. 34 is an exploded top view illustrating an embodiment of a lid chamber assembly;

[0041] Fig. 35 is an exploded view of the components of an embodiment of a lid chamber assembly;

[0042] Fig. 36 is a perspective view illustrating an embodiment of a mini-environment;

[0043] Fig. 37 is a perspective view illustrating an embodiment of a chamber cabinet of a mini-environment;

[0044] Fig. 38 is a cross-sectional view illustrating an embodiment of a chamber cabinet; and

[0045] Fig. 39 is a perspective view illustrating an embodiment of a chamber cabinet in a mini-environment with a robotic arm.

DETAILED DESCRIPTION OF THE INVENTION

[0046] As illustrated in Figs. 1-21, embodiments of the present invention comprise a fixture washing and drying body apparatus chamber, preferably for washing and drying a wafer carrier type manufacturing fixture. Figs. 22-35 illustrate lid chamber embodiments of the present invention. Figs. 36-39 illustrate embodiments of a mini-environment and chamber cabinets.

[0047] An embodiment of the present invention relates to an apparatus and method for washing and drying a fixture, especially useful for wafer carriers. Wafer carriers must be cleaned in a super clean environment. Embodiments of the present invention comprise a body chamber

assembly and a lid chamber assembly. The wafer carrier apparatus body chamber **10** (Fig. 1) is a chamber for washing and drying the body of a wafer carrier.

[0048] The term "chamber" as used throughout the specification and claims includes but is not limited to the meaning "an at least substantially enclosed space."

[0049] Embodiments of body chamber **10** (see Fig. 1) can be comprised of Polyvinyldiene fluoride (PVDF) sheets or a similar material, optionally about 25.5 inches deep by about 21 inches wide, and about 26 inches high, although dimensions can vary. In one embodiment, the present invention can be modular and scalable. As illustrated in Fig. 1, body chamber **10** preferably has door **12** and pulley driven drive **22** for movement of exterior spray bar **18** (see also Fig. 12). Body chamber **10** preferably comprises pulley drive **22** connected to spray bar manifold **20** by pulley belt **26**. Body chamber **10** also has interior spray bar **54** (Fig. 10) for washing and drying the interior of a wafer carrier that is preferably directly driven. Wafer carrier body **14** preferably sits on frame **16**. Corner supports are preferably provided and most preferably are slightly angled to prevent water collection and particle coagulation. All exposed sides of frame **16** can be chamfered at the top to prevent water collection and particle coagulation as well. Exterior spray bar **18** preferably contains holes and/or slots **19** that are positioned along the sides of the pipe facing wafer carrier body **14** and chamber **10** walls. Although slots **19** can be created through any manner know to those skilled in the art, slots **14** are most preferably created using a laser and act as water nozzles during the wash cycle and as fanning air nozzles during the air knife and dry cycles. Interior spray bar **54** preferably comprises holes and two fanning water nozzles that cover the interior of the wafer carrier **14** body. Body chamber **10**, exterior spray bar **18** and interior spray bar **54** preferably use water to work and sweep out particles with slots **19** and then purge and/or dry with air or compressed gas, which blow off droplets of water. Body chamber **10** preferably comprises panels **24** and butterfly valve **23**, although other valve types can of course be used in place of butterfly valve **23**. Body chamber **10** is preferably constructed with vent points to ensure a slight positive pressure during operation.

[0050] In the embodiment illustrated Fig. 2, pulley drive **22** connects to exterior spray bar manifold **20** which also contains the inlet connections for the air and water. This embodiment aids in the prevention of misalignment of the spray bar due to pressure changes and expansion and contraction of the piping material (which can be made of but is not limited to PVDF). Butterfly exhaust valve **23** preferably controls the pressure inside chamber **10**. During the wash cycle it is not as important to have a large pressure relief as it is during the air knife cycle due to the high pressure and volume of air. Butterfly valve **23** is optionally actuated via air to open then the pressure is released to close. As also illustrated in an embodiment in Figs. 21A-B, the design of the diaphragm allows for a minimal amount of exhaust to be pulled when closed. Embodiments of the present invention include in-line monitoring of particles to ensure cleanliness.

[0051] Fig. 2 illustrates an embodiment of body chamber **10** with front door **12** closed. Pulley drive **22** is connected by belt **26** to exterior spray bar manifold **20**. Door **12** has hinge **28** and chamber pressure lock **30**. Panels **24** are most preferably used to form top, bottom and sides of chamber **10**.

[0052] Fig. 3 illustrates a partially exploded view of body chamber **10**. Exterior spray bar 18 preferably comprises numerous parts all preferably made of PVDF and/or Teflon and the like. Body chamber **10** comprises door **12**. Door **12** preferably has a plurality of components including but not limited to door assembly **34**, and Fig. 3 also shows door lock assembly **36**. Fluid spray, which in one embodiment is preferably water, is preferably heated to between approximately 130°F to approximately 150°F coming out of the spray slots **19** (see Fig. 1) and cools slightly upon spraying. Fluid is passed through a rotary joint and is most preferably super clean and purified by filtering. O rings and rotary joint are preferably designed and constructed with materials which will not contaminate fluid.

[0053] Figs. 4-7 illustrate different perspectives of an embodiment of the present invention. In one embodiment, body chamber **10** preferably comprises: door **12**; panels **24**; water inlet piping **38**; door lock **36**; door assembly **34**; air inlet piping **42**; and butterfly valve **23**. Water piping **38** optionally has a pea trap to prevent the backflow of contaminants. Fig. 8 illustrates an embodiment without a side panel. Manifold **40** preferably connects pulley drive **22**, water and air inlets 38 and 42, and spray bar **18** together. Three large holes **122** (see Figs. 17A and B) preferably allow for air and water to flow into exterior spray bar **18** without creating pressure from the rotation. Holding brackets 124 are preferably welded or otherwise fixedly secured to the pipe and prevent interference of the slots so that there is full contact of air and water to carrier body **14**. The driving side of pulley drive **22** preferably utilizes limit switches **44** (and also **80**, Fig. 12) to prevent exterior spray bar **18** from over rotating and damaging the pipe. Exterior spray bar **18** preferably rotates approximately 270° from back to front and front to back in a sweeping motion. Alternatively, exterior spray bar **19** may be stationary or oscillate.

[0054] Fig. 8 illustrates a perspective view of body chamber **10**. Manifold drive **40** and switching manifold **46** preferably assist in controlling the flow of fluid to the system. Body chamber **10** also comprises chamber frame **50**.

[0055] Fig. 9 illustrates chamber **10** with wafer carrier **14** inside. Fig. 10 illustrates a cross section, side view where body chamber **10** comprises carrier **56**, interior panel **58**, interior spray bar **54**, air inlet **62** and water piping **60**.

[0056] Figs. 11 and 12 illustrate a top view of an embodiment of a body chamber. Air inlet **64** (Fig. 11) and exploded view with stabilizer **66**, piping connector **68** and piping **70**, drive **72**, plate **74**, switch **80**, piston **84**, pulley belt **88**, and exterior spray bar **78**.

[0057] Fig. 13 illustrates an exploded view of body chamber **10** and back portion **98** separated. Fig. 13 also illustrates heating blankets **108**. Heating blankets **108** preferably heat the walls of the chamber. Embodiments of the present invention optionally can use one and/or a plurality of heating blankets to heat PVDF panels **24** of chamber **10**. Panels **24** absorb and radiate heat into chamber **10**. Alternative embodiments include but are not limited to use of other heat transmitting materials for panels and/or for sandwiching heating elements within walls and or any combination thereof. Heating blankets **108** are optionally used for target heating and/or surrounding chamber or any combination thereof. Chamber **10** is preferably not cooled between washing and drying cycle to increase efficiency of cleaning process.

[0058] Figs. 14A-G and 15 illustrate a wafer carrier which can be used in conjuction with embodiments of the present invention. Industry standards dictate the size of wafer carrier **14** but depending on the manufacturer there are differences in the design and intricacy. Many wafer carriers are single, injection molded containers comprised of a poly-carbonate that have additions welded onto the interior and exterior (see Figs. 14A-G). There are at least three distinct additions/characteristics of a wafer carrier: the robotic flange (Fig. 14G), the wafer combs, and the kinematic flange (Fig. 14E). The robotic flange (Fig. 14G) is what the robotic transportation and tools can use to maneuver the wafer carriers from place to place. Wafer combs space the wafers in the container to prevent damage during transportation, a typical wafer carrier can house 25 wafers. A kinematic flange (Fig. 14E and Fig. 15) is used as a base to stabilize the wafer carrier. A kinematic flange holds the information pertaining to a wafer carrier's capabilities and manufacturing as well as locking manifold **118** (Fig. 14G).

[0059] Figs. 17B and 18 illustrate exploded views of exterior spray bar **126** that is also used as an air knife during a drying process. Manifold **128** preferably connects pulley drive **130**, **132**, **134**, and **136**. Three large holes **122** preferably allow for air flow and brackets 124 prevent interference of slots for full water contact.

[0060] Fig. 19 illustrates a front view of body chamber **10** with carrier **14** inside.

[0061] Body chamber interior spray bar **144** (Fig. 20) is preferably a direct drive that also preferably uses limit switches. Interior spray bar **144** is preferably a simple fusion welded pipe and elbows that are drilled with the smaller hole sizes on the top and larger hole sizes on the sides. Spray bar **144** preferably freely rotates in hole **138** in front skirt **140** of base frame **146**. Interior

spray bar **144** preferably rotates in a sweeping motion at approximately 180° from side to side. The two different sweeping motions are preferably used so that the wafer carrier is not pushed one way or the other, which can damage the edges if done forcefully. Movement by a wafer carrier body is also preferably prevented with the use of corner supports **142**, in which tabs on both sides keep the wafer carrier in position. Capacitive sensors **143** are optionally implemented to aid in the detection of movement. Sensors **143** can be extremely close but not touching a carrier to detect if the carrier becomes displaced from corner supports **142**. If this happens damage can occur not only to the wafer carrier body but also to the interior and exterior spray bars.

[0062] Figs. 21A-B illustrate a side and front view of butterfly valve **150** which preferably acts as a pressure valve.

[0063] In order to have the wafer carrier bodies dry within the allotted time, it is preferable to keep chamber **10** warm. In one embodiment, wafer carriers **14** preferably have a coating on the poly-carbonate that aids in the prevention of damage to the carrier during transportation and which coating cannot be heated above 60°C (140°F) otherwise warping may occur. Therefore, to maintain the heat needed at a reasonable temperature heating blankets **108** (see Fig. 13) are optionally added to the exterior of the chamber. Blankets **108** are preferably set at about 180°F and heat chamber **10** to approximately 160°F. An infrared sensor on the side of chamber **10** can be provided which monitors the temperature of wafer carrier **14** closest to the top where the carrier can become the hottest. The heating of chamber **10** becomes critical after the wash cycle during the purge and air knife cycle where the temperature of wafer carrier **14** and chamber **10** drops drastically. Spray of fluid from both spray bars is preferably bidirectional. Therefore, by having the dry cycle also heated it returns to the desired interior temperature of the chamber which maintains the allotted process time. In an embodiment of the present invention, a preferred method and timing for cleaning the wafer carrier bodies is:

1. Body chamber door opens (T=0)
2. Robot places wafer carrier body onto frame (T=40 seconds)
3. Body chamber door closes and locks (T=60 seconds)
4. Wash cycle (T=61 seconds)
5. Purge cycle (T=121 seconds)
6. Air Knife cycle (T=131 seconds)
7. Heated CDA Dry cycle (T=371 seconds)
8. Spray bars return to home position (T=731 seconds)
9. Body chamber door opens (T=732 seconds)

[0064] From load port to load port, the total process time including cleaning process is between approximately 10 minutes and approximately 21 minutes, more preferably between approximately 10 minutes and approximately 17 minutes and most preferably between approximately 12 minutes and approximately 14 minutes with a cleaning process time of approximately 12 minutes. With this process cycle, an optimum output of about 21 wafer carriers per hour at start up and about 25 wafer carriers per hour continuously can be met. Embodiments of the present invention are preferably modular and scalable and can fit any operation. Alternatively outputs can vary depending on situational needs.

[0065] During the wash and dry cycles, lid **158** (see Fig. 22) is spun at different speeds and directions. Due to the intricacy of lid **158**, washing and drying preferably uses spinning manipulations to reach all areas of the fixture. Throughout the wash cycle lid **158** is preferably spun slowly to allow water to enter the door and wash out any particles that have become trapped. In one embodiment, during the dry cycle the door is preferably spun clockwise (CW) for five minutes and counter-clockwise (CCW) for the remainder of the dry cycle at approximately 300 rotations per minute (RPM). The spinning of lid **158** at high speeds aids in expelling the droplets of water that can become trapped inside the door during the wash cycle. In one embodiment, the motor used preferably has the ability to slow down but not stop in the proper home position. Therefore, there is a stopping device can be actuated by air to lock the motor into the correct home position.

[0066] During the drying cycle, compressed gas, most preferably air, can be aimed or directed upon and within the fixture, as interior access allows, encouraging removal of residual washing fluid. The compressed gas is optionally heated and aimed or directed through at least one cyclic rotating distribution pipe, tube, manifold or other gas distribution member known in the art. Portions of the distribution system for the compressed air may alternatively oscillate rather than rotate.

[0067] Figs. 22-23 illustrate embodiments of lid chamber **156**. Lid **158** may have a complicated interior design with an intricate locking mechanism and wafer combs that separate and support the individual wafers during transportation. On the front of lid **158** there are two holes that are used for guiding the robot endifector to the key holes (see Figs. 15 and 16). To ensure that lid **158** is secured tightly on wafer carrier **14** there is a gasket on the interior. Embodiments of lid chamber **156** can have similar structure to a body chamber applied to the lid chamber 156.

[0068] Fig. 22 illustrates lid chamber **156** with door **160**, wafer carrier lid **158**, panels **162**, air and water inlet **164**, and Fig. 23 also illustrates door bolt **168** and door hinge **166**. Cleaning lid **158** includes but is not limited to injecting air into holes (described above) and through openings. Fig. 23 illustrates heating blankets **163**.

[0069] Fig. 24 illustrates lid chamber **156** with door assembly **170** and door lock **172**. Fig. 25 illustrates a front view of an embodiment of lid chambers **156** and water inlet **174**.

[0070] Fig. 26 illustrates lid chamber **156** comprising air inlet **176** and water inlet **174**. Fig. 27 illustrates lid chamber **156** with installed door lock assembly **172**, butterfly valve **178** and support **180**. Fig. 28 illustrates a back view of an embodiment of lid chamber **156** and Fig. 29 illustrates the back view with panel removed and showing air inlet components **182**.

[0071] Fig. 30 illustrates an embodiment of lid chamber **156**. Once separated from the wafer carrier body, lid **158** is placed into washing and drying chamber **156** which is outfitted with bracketed fixture **157**. Bracketed fixture **157** (Fig. 35) contains a gripping apparatus used to hold lid **158** securely in place while spun during cycles. Bracketed fixture **157** is preferably powder coated aluminum and gripping apparatus **159** is preferably made entirely of Polyvinylidene fluoride (PVDF) or the like. Gripping apparatus **159** (Fig. 35) grips lid **158** which comprises a complicated structure that contains slots for lid **158** locking mechanism. When the locking mechanism is actuated it preferably opens a pathway for air to flow into the interior of lid **158**. This is preferably utilized because during the wash cycle water enters the interior of the lid, trapping droplets that need to be blown out. Therefore, the bracketed fixture is preferably outfitted to be connected to motor **188** via motor shafts **184** and **190** as seen in Figs. 32-34. The air preferably enters through a connection in the motor which connection is preferably made of Ultem where it connects to the gripping mechanism via tubes, as seen in Figs. 33-35.

[0072] Wafer carrier lid chamber **156** can be comprised of the same material as the body chamber. In similar style to the body chamber, lid chamber **156** preferably contains four spray bars **186, 189** (see Figs. 32-35) that wash and dry door **158** and chamber **156**. Two lower spray bars **189** preferably wash and dry the lid using nozzles **187**. In one embodiment, nozzles are preferably utilized in the lid chamber because the door is comprised of thin a poly-carbonate material that is easily damaged by high pressure, therefore by using nozzles the pressure can be controlled. The two upper spray bars preferably aid in the drying of the chamber walls. Similar to the body chamber, the lid chamber optionally has heating blankets directly placed on the exterior walls to keep the chamber heated and aid in the drying process.

[0073] Fig. 36 illustrates an embodiment of a mini-environment. In order to keep this process as clean as possible it is preferable to have a mini-environment that maintains an air particle count close to ISO standard 3 or Class 1. Mini-environment **194** preferably houses ultra-low particle air (ULPA) filters **195** that create an ultra clean laminar flow from the ceiling to the floor. The laminar flow aids in the prevention of particles coagulating underneath the grated mini-environment

floor and pushes any large particles that may be attached to the wafer carrier out of the environment instead of being collected in the individual chamber. In one embodiment, the mini-environment is preferably made of about 2" by about 2" stainless steel beams that are powder coated and the floor is comprised of grated polypropylene flats. In one embodiment, the mini-environment preferably houses a six axis clean room robot **198**. Robot **198** manipulates the wafer carrier bodies **196** and doors into their appropriate chambers **200** for cleaning.

[0074] The term "laminar flow" as defined throughout the specification includes but is not limited to nonturbulent flow.

[0075] Figs. 37-39 illustrate embodiments of lid and body cabinets **202**. Lid and body cabinets **202** are preferably comprised of an about two inch by about two inch 304 stainless steel frame that is preferably encapsulated entirely by Corzan G2 and/or the like. Each lid and body cabinet preferably holds about six lid and body chambers **204**, respectively. The facilities enter cabinet **202** optionally through the top and come down the middle of the tool beside the exhaust duct. The cabinet is preferably fully exhausted at **206** to prevent over heating from the heating blankets and clean dry air (CDA) heaters. The cabinet preferably has grated drain **208** at the bottom of the interior face to catch any water that may leak from the chambers. In one embodiment, cabinet **202** also preferably has a drain with a leak sensor that is capable of draining all the water if all six chambers were to leak simultaneously (see Fig. 38). Alternatively, lid and body chamber cabinets can hold any number of lid and/or body chambers.

[0076] Cabinet **202** is preferably modular. Fig. 38 illustrates an embodiment of cabinet **202** where each chamber **210** is associated with a set of valves and electrical components that can be removed for maintenance and replacement. Individual chambers **210** are also preferably removable if needed for maintenance and replacement. In one embodiment, chambers **210** are preferably all the same except for the side on which the door opens, either to the left or to the right. If necessary, chambers **210** can be moved around within cabinet **202** with the change of a door direction. Optionally chambers **210** can be rotationally molded to give partially smooth corners, reducing seams and allowing for seam placement, thereby reducing the possibility of contamination. Fig. 39 illustrates a cross section of mini-environment **212** comprising robot **214**, chambers **216** and wafer carrier **218**.

[0077] The distribution system for the compressed gas may also utilize restricted orifices in the distributing members. The orifices are preferably combined with standardized nozzles in various sizes. The orifices are preferably sized to maintain adequate pressure and thus force, for transferring residual washing fluid away from the fixture, and promote evaporation. The distribution system members having nozzles can optionally employ various spray pattern-shaping features.

[0078] The compressed air distribution system, or a similar but separate gas distribution system, can optionally be used to cool the fixture, if required, through the use of refrigerated air, nitrogen, carbon dioxide, nitrous oxide, ammonia, or other known cooling gases but most preferably nitrogen gas. Using a dual purpose washing and drying chamber as illustrated in Figs. 1-35, the body temperature of the fixture being dried can be cooled. By turning off heating elements and by using un-heated and/or refrigerated gas as previously described, the fixture body temperature can be cooled before removal from the drying chamber. The refrigerated, un-heated, or heated gas can be introduced into the drying chamber through a compressed gas drying distribution system, a similar but separate gas distribution system, or a purged washing fluid distribution system.

[0079] In an embodiment of the present invention, a carrier or lid that has previously been washed can be removed from a washing chamber either manually or more preferably by a robot. The fixture can also optionally be manipulated through a series of tipping, rotation, and shaking motions to remove residual washing fluid.

[0080] The carrier or lid is preferably then placed in a chamber for drying, which may be the chamber used for washing if such chamber is also at least a dual purpose chamber for drying. Or the carrier or lid may be placed in a separate drying chamber, more preferably, a dedicated drying chamber which circulates heated air. Preferably the embodiments of the present invention are fully automated. However, alternative embodiments include manual and semi-automatic embodiments.

[0081] Embodiments of the present invention can include single washing and drying chambers. Alternatively, washing and drying can be performed in separate chambers similar to those described in Figs. 1-35. In another embodiment, the nominal washing and drying cycle duration for a wafer carrier is preferably in the range of from about five minutes to about one hour and more preferably from about ten minutes to about 40 minutes and most preferably from about 15 minutes to about 30 minutes. In one embodiment, the present invention utilizes a wafer carrier cleaning apparatus wherein the drying process duration is minimized and the efficiency of the process is increased through implementing one or more of the following alternative methods:

[0082] After the washing cycle, the wafer carrier can be robotically removed from the washing chamber and optionally a robot performs a series of manipulations of the wafer carrier, which can include tipping, rolling, jiggling and shaking, wherein residual washing fluid is removed from the wafer carrier. The rate, duration and degree of manipulation are preferably controlled by the programmed robotic commands. The wafer carrier can then be transferred to the same or a different chamber for drying, preferably by the same robot.

[0083] One possible example of such a manipulation, either manually, or by a robot, can include the following described actions in order to reduce the fixture drying duration. Although the series begins with a clockwise (CW) rotation, the direction of rotations may obviously be reversed and instead initiated with a counter-clockwise (CCW) rotation. The following describes one alternative embodiment of a drying method:

1. Open chamber door (T=0 seconds)

2. Take out wafer carrier body (T=4 seconds)

3. Rotate arm to have gripper pointing downward at approximately a 30° angle (T=5 seconds

4. Roll the wafer carrier body slowly CW to where it's inverted (approximately 180°) at about 120°/second (T=6 seconds)

5. Roll the wafer carrier body slowly approximately 360° CCW at about 120°/second (T=9 seconds)

6. Roll the wafer carrier body slowly approximately 360° CW at about 120°/second (T=12 seconds)

7. Roll the wafer carrier body slowly approximately 360° CCW at about 120°/second (T=15 seconds)

8. Jiggle the wafer carrier body to shake off any drips

9. Roll the wafer carrier body slowly CW to level at about 120°/second (T=17 seconds)

10. Rotate arm to have gripper pointing upward at approximately a 30° angle (T=18 seconds)

11. Roll the wafer carrier body slowly CW to where it's inverted (approximately 180°) at about 120°/second (T=20 seconds)

12. Roll the wafer carrier body slowly approximately 360° CCW at about 120°/second (T=23 seconds)

13. Jiggle the wafer carrier body to shake off any drips

14. Return wafer carrier body to normal, level position exterior of chamber (T=24 seconds)

15. Place wafer carrier body back in chamber and close door (T=30 seconds)

[0084] Using an alternative washing and drying chamber as illustrated in Figs. 1-35, a typical 30 minute drying cycle can be reduced by a first application of the above described series of manipulations or other manipulations which physically remove excess liquids from the wafer carrier.

[0085] After the washing cycle, and preferably after the previously mentioned series of robotic manipulations, the wafer carrier can be placed into a dedicated drying chamber which has an initially dry interior, unlike a typical dual purpose washing and drying chamber.

[0086] Cool air or other gases are introduced into the drying chamber at selected intervals to accelerate the cool down phase of the drying cycle and to reduce the temperature of the wafer carrier.

[0087] A cam-drive or other movable system is used to oscillate the motion of the compressed air or gas distribution system along with or instead of a simple rotary motion.

[0088] Spray nozzles can be employed which control the volume, pressure, temperature and direction of the introduced compressed gas. Nozzles optionally offer greater control over plain-drilled holes for compressed gas supply requirements and greater control over pressure, volume, temperature and aiming characteristics.

[0089] In one embodiment, a wafer carrier washing and drying cycle can include separating the two parts of the wafer carrier (the body and the cassette), placing the wafer carrier into a dual washing and drying chamber (preferably robotically), washing, drying, removing the wafer carrier from the chamber, and rejoining the cassette and body pieces.

[0090] Using a direct drive motor or other system to rotate the air distribution bars, pipes, manifolds or other air distribution members can allow compressed gas to flow across the fixture being dried as well as the interior drying chamber walls.

[0091] Using an oscillating cam-drive motor system can distribute more of the compressed air to the body of the fixture being dried without blowing directly and beneficially on the walls of the

chamber. An approximate 70°-110° range of reciprocating rotation can allow for efficiently directing compressed gas onto the fixture body.

[0092] One measure of a successfully dried wafer carrier can include comparing the humidity inside a sealed wafer carrier immediately after the drying cycle with the humidity inside the same wafer carrier after approximately two hours of stabilization. An increase in humidity of less than about 10% and more preferably less than about 7%, and most preferably less than about 5% can be regarded as a successfully dried wafer carrier. For example, if a wafer carrier has 31% interior humidity immediately after drying and approximately two hours later has 36% or less interior humidity, the wafer carrier is acceptably dried. If a drying process leaves visibly noticeable washing fluid inside a wafer carrier, the increase in measured humidity is typically found to be about 10% to about 22% and thus considered a failed or incomplete drying process. Externally visible washing fluid droplets are also grounds for rejecting a drying process and indicate the need for additional gas nozzles or other methods.

[0093] The compressed gas distribution members may have orifices enlarged by increasing the drilled diameters. Increasing an orifice diameter can increase the volume of gas delivered to the fixture body, but without gas supply changes, and depending upon initial supply configurations, such modification can reduce the gas flow velocity, thereby reducing the efficiency of the drying system and thus increasing the drying duration. For example, by doubling the diameter of the drying bar holes directed at the exterior of a fixture, from about 1/32 of an inch in diameter to about 1/16 of an inch in diameter and increasing the fixture interior drying member orifices from about 1/16 of an inch in diameter to about 3/32 of an inch in diameter, increases the required drying time compared to the drying time resulting from the smaller dimensions.

[0094] For a combined washing and drying chamber, the exterior surface (upper) wash spray bar is preferably purged to prevent liquid from dripping onto the wafer carrier. A shortened length of piping between the valve and the spray bar can also help reduce the amount of liquid that can drip onto the wafer carrier following a cleaning process. The interior and exterior surfaces of a wafer carrier body can preferably be washed at the same time, thus saving about 1 to 1½ minutes. As one possible example, a wash cycle using a carousel system can have an approximate two minute interior wash followed by an approximate one minute exterior wash.

[0095] Cooling down the drying chamber quickly can lessen humidity in the chamber at a post-processing humidity measurement. With a single unit non-carouseled chamber, the wafer carrier body holder need not be wall-mounted. Thus, expensive coated machined parts are preferably replaced by simpler and cheaper wafer carrier body holders.

[0096] An approximate 12 second delay can be introduced after washing and before the wafer carrier is removed from the cleaning chamber. This allows the inner spray bar to settle into its rest position. Some specific models of wafer carrier's can benefit from one or more gas nozzles directed along the lower front ridge of the body to remove accumulated drips.

[0097] Preheating the wafer carrier can increase process reliability. This can include washing with hot water and/or venting heated gas onto the dirty wafer carrier bodies as they are awaiting processing. A flexible shaft coupler can reduce motor problems.

[0098] Similar to enlarging orifice diameters, enlarging holes in drying bars, without other changes and depending upon initial supply configurations, can reduce the effectiveness of drying a wafer carrier body by decreasing the velocity and thus the force of the gas delivered from distribution member orifices. Controlling orifice size by employing standard nozzles is preferable to plain holes drilled in the distribution members.

[0099] Pre-heating a wafer carrier using one or more hot fluids, particularly those that are gases, or those which readily evaporate, before the drying process is started, reduces the drying process duration. For example, if heated water is used to warm the wafer carrier during the wash cycle, it increases the likelihood the wafer carrier body can be properly dried compared to washing with room-temperature water.

[00100] Cooling the drying chamber and/or the wafer carrier body, has a measurable effect on the post-processing humidity results. Where passing the drying cycle is important, a cooling method may improve drying results. A dry wafer carrier body that is barely warm to the touch will normally pass a two-hour post-processing humidity test.

[00101] Reheating the wafer carrier drying chamber after a drying cycle cool down is complete is typically beneficial. The wafer carrier drying chamber is often at a temperature of about 30°-35°C after use. In order for the chamber to quickly reheat before the next cycle is begun, turning off the pulling gas improves the chamber heating time. For example, instead of taking approximately 8-10 minutes to heat a chamber, shutting off the pulling gas can reduce the reheating time to approximately 5-6 minutes.

[00102] Chamber size can effect drying time. Independent of whether the chamber has separate or common wash and dry cycles, a smaller chamber has less volume and if provided with a same amount of power as a larger chamber, the smaller chamber can increase the likelihood that drying will be quicker. The tighter confines of a smaller chamber can also force air to flow closer to

the surfaces of the wafer carrier body. Another advantage of a smaller chamber size is that a smaller footprint may be desirable for vendors that need a production version of such tool.

[00103] The wafer carrier holding features can be a source for entrapment of undesirable residual washing liquid and can be addressed by design improvements. A few of the possible overall design improvements includes but is not limited to:

[00104] 1) Making the wafer carrier holder out of plastic instead of a machined and specialty-coated aluminum structure.

[00105] 2) Making the wafer carrier holder feet similar to the single wafer carrier test cell feet can reduce a potential source for entrapment of moisture in the wafer carrier. This improvement can be combined with other wafer carrier body holding system improvements.

[00106] 3) Dried units are preferably subject to visual inspection for washing fluid droplets as well as the follow-on humidity test. In one embodiment, any washing fluid droplets in the interior of the wafer carrier body are considered as failures where the visibly-noticeable fluid typically increases the humidity upwards of about 10%.

[00107] Alternative embodiments of the present invention include but are not limited to using a dedicated drying chamber or ensuring the interior of a dual purpose washing and drying chamber is dry before placement of the fixture to be dried into the chamber, can reduce the drying cycle duration. Eliminating the washing fluid from the walls of the chamber before its use as a drying chamber increases the efficiency of the drying process. Eliminating the excess liquids from the interior surfaces of the chamber allows for improved drying conditions for the fixture. Reducing the dimensions of a dual purpose chamber can also reduce the amount of possible fluid-covered area and improve drying efficiency. Furthermore, reducing the dimensions of a drying chamber can increase gas circulation velocities, thereby improving efficiency.

Industrial Applicability:

[00108] The invention is further illustrated by the following non-limiting examples. The following examples include a wash cycle followed by a drying cycle, with a wafer carrier and wafer carrier lid installed in chamber similar to those illustrated in Figs. 1-35. Additionally a chamber cabinet and mini-environment has been constructed similar to those illustrated in Figs. 36-39.

Example 1

[00109] A body chamber was made and was comprised of Polyvinyldiene fluoride (PVDF) sheets with the dimensions of 25.5 inches deep by 21 inches wide and 26 inches high. The body

chamber had a side opening door and pulley driven drive for the exterior spray bar on the right side of the chamber. The body chamber also had an interior spray bar that was directly driven. The wafer carrier body sat on a frame that allowed for the interior to be cleaned by the interior spray bar. The corner supports were slightly angled to prevent water collection and particle coagulation. All exposed sides of the frame were chamfered at the top to prevent water collection and particle coagulation as well. The exterior spray bar comprised slots 0.010 inches wide by 0.080 inches long that were positioned along the sides of the pipe facing the wafer carrier body and chamber walls. The slots were created using a laser and acted as water nozzles during the wash cycle and as fanning air nozzles during the air knife and dry cycles. The interior spray bar comprised 0.03125 inch and 0.0625 inch holes and two fanning water nozzles that covered the interior of the wafer carrier body.

[00110] The pulley drive connected to the exterior spray bar manifold which also comprised the inlet connections for the air and water. This was an important aspect of the body chamber because it aided in the prevention of misalignment of the spray bar due to pressure changes and expansion and contraction of the piping material (which is PVDF). Another important aspect of the body chamber was the butterfly exhaust valve that controlled the pressure inside the chamber. During the wash cycle it was not as important to have a large pressure relief as during the air knife cycle, due to the high pressure and volume of air. The butterfly valve was actuated via air to open then the pressure was released to close. The design of the diaphragm allowed for a minimal amount of exhaust to be pulled when closed.

[00111] The body chamber exterior spray bar was a unique apparatus. The exterior spray bar was comprised of numerous parts all made of PVDF and Teflon. The manifold connected the pulley drive, air and water inlet, and spray bar together. Three large holes allowed for air and water to flow into the spray bar without creating pressure from the rotation. The holding brackets were welded onto the pipe and prevented interference of the slots so that there was full contact of air and water to the carrier body. The driving side of the pulley drive utilized limit switches to prevent the exterior spray bar from over rotating and damaging the pipe. The exterior spray bar rotated approximately 270° from back to front and front to back in a sweeping motion.

[00112] The body chamber interior spray bar was constructed as a direct drive that also used limit switches. The interior spray bar was a simple fusion welded pipe and elbows that were drilled with the smaller hole sizes on the top and larger hole sizes on the sides. The spray bar freely rotated in a hole in the front skirt of the base frame. The interior spray bar rotated in a sweeping motion at approximately 180° from side to side, perpendicular to the exterior spray bar. The two different sweeping motions were used so that the wafer carrier was not pushed one way or the other. Movement by the wafer carrier body was also prevented with the use of the corner supports

in which tabs on both sides kept the wafer carrier in position. Capacitive sensors were implemented to aid in the detection of movement. The sensors were extremely close but not touching the carrier to detect if the carrier became displaced from the corner supports. If this happened, damage could occur not only to the wafer carrier body but also to the interior and exterior spray bars.

[00113] In order to have the wafer carrier bodies dry within the allotted time, it was necessary to keep the chamber as warm as possible. The wafer carriers had a coating on the poly-carbonate that aided in the prevention of damage to carrier during transportation and use that cannot be heated above 60°C (140°F). Otherwise, warping would occur. Therefore, to maintain the heat needed at a reasonable temperature heating blankets were added to the exterior of the chamber. These blankets were set at 180°F and heated the chamber to about 160°F. An infrared sensor on the side of the chamber monitored the temperature of the wafer carrier closest to the top where the carrier may become the hottest. The heating of the chamber became critical after the wash cycle during the purge and air knife cycle, where the temperature of the wafer carrier and chamber dropped drastically. Therefore, by having the dry cycle heated, it returned to the desired interior temperature of the chamber, maintaining the allotted process time. The process for cleaning the wafer carrier bodies were as follows:

10. Body chamber door opened (T=0)
11. Robot placed wafer carrier body onto frame (T=40 seconds)
12. Body chamber door closed and locked (T=60 seconds)
13. Wash cycle (T=61 seconds)
14. Purge cycle (T=121 seconds)
15. Air Knife cycle (T=131 seconds)
16. Heated CDA Dry cycle (T=371 seconds)
17. Spray bars returned to home position (T=731 seconds)
18. Body chamber door opened (T=732 seconds)

[00114] From load port to load port, the total process time was 14 minutes with a cleaning process time of 12 minutes. With this process cycle, an output of 21 wafer carriers per hour at start up and 25 wafer carriers per hour continuously was met.

Mini-Environment:

[00115] In order to keep this process as clean as possible it was necessary to have a mini-environment that maintained an air particle count close to ISO standard 3 or Class 1. The mini-environment housed ultra-low particle air (ULPA) filters that created an ultra clean laminar flow from the ceiling to the floor. The laminar flow aided in the prevention of particles coagulating underneath the grated mini-environment floor and pushed any large particles that may have been attached to

the wafer carrier out of the environment instead of being collected in the individual chamber. The mini-environment was made of 2" by 2" stainless steel beams that were powder coated and the floor was comprised of grated polypropylene flats. The mini-environment housed a six axis clean room robot by Staubli. This robot manipulated the wafer carrier bodies and doors into their appropriate chambers for cleaning.

Lid and Body Cabinets:

[00116] The lid and body cabinets were comprised of a two inch by two inch 304 stainless steel frame that were encapsulated entirely by Corzan G2. For each cabinet, the dimensions were 108 inches tall by 60 inches deep by 82.5 inches wide. Each lid and body cabinet held six lid and body chambers, respectively. The facilities entered the cabinet through the top and down the middle of the tool beside the exhaust duct. The cabinet was fully exhausted to prevent over heating from the heating blankets and clean dry air (CDA) heaters. The cabinet had a grated drain at the bottom of the interior face to catch any water that may have leaked from the chambers. The cabinet also had a drain with a leak sensor that was capable of draining all the water if all six chambers were to leak simultaneously.

[00117] Each chamber was associated with a set of valves and electrical that could be removed for maintenance and replacement. The individual chambers were also removable if needed for maintenance and replacement. The body chambers were all the same except for the side the door opens, either to the left or to the right, as shown in the cabinet drawings. This was the same for all the lid chambers as well. Therefore, if necessary, the chambers could be moved around within the cabinet with the change of a door direction.

Separate washing and drying chambers versus combined chamber:

[00118] In one experiment, using a dual purpose washing and drying chamber as illustrated in Fig. 2 and preheated to a temperature of about 135° F (57° C), a series of manipulations, as previously described, was performed manually. The total reduction in over-all drying time was found to be about 4 minutes. Preheating the chamber reduced residual fluid from the chamber walls, prior to the insertion of the wafer carrier.

Example 2

In-chamber cooling gas supplied during the drying process:

[00119] It was found that turning off chamber heat sources dropped the temperature of the chamber by nearly 10°C in the first minute but with diminishing effects thereafter. Delivering the

cooling gas simultaneously to the exterior and the interior of the fixture body, lowered the fixture body temperature rapidly. ¼ inch nozzles and two 18 inch air knives, emitting clean dry air at approximately room temperature, were used and were found to cool a wafer carrier in approximately two minutes.

[00120] The preceding examples can be repeated with similar success by substituting the generically or specifically described components and/or operating conditions of this invention for those used in the preceding examples.

[00121] Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above are hereby incorporated by reference.

CLAIMS

What is claimed is:

1. An apparatus for washing and drying a carrier, the apparatus comprising:

a chamber capable of holding a carrier;

said chamber comprising a carrier-exterior spray system and a carrier-interior spray system internal to said chamber;

said carrier-exterior spray system comprising at least one slot which sprays a fluid onto an exterior surface of the carrier; and

said interior spray system comprising at least one slot which sprays the fluid into an interior of the carrier.

2. The apparatus of claim 1 wherein the carrier comprises a semi-conductor wafer carrier.

3. The apparatus of claim 1 wherein the carrier comprises a carrier lid.

4. The apparatus of claim 1 wherein said fluid comprises a liquid.

5. The apparatus of claim 1 wherein said fluid comprises a gas.

6. The apparatus of claim 1 wherein said spray systems move perpendicular to each other to prevent carrier movement.

7. The apparatus of claim 1 wherein said spray systems oscillate in a sweeping motion.

8. The apparatus of claim 1 further comprising a motor for rotating the carrier.

9. The apparatus of claim 1 further comprising at least one heating system.

10. The apparatus of claim 9 wherein the heating system comprises at least one heating pad.

11. The apparatus of claim 1 wherein said apparatus is disposed within a mini clean environment.

12. The apparatus of claim 1 wherein a plurality of apparatuses are disposed within a cabinet.

13. The apparatus of claim 1 wherein said carrier-exterior spray system it at least partially rotatable.

14. The apparatus of claim 1 wherein said carrier-interior spray system is at least partially rotatable.

15. A method of washing and drying a carrier, the method comprising:

disposing a carrier into a chamber;

spraying a liquid on an exterior of the carrier with an exterior spray system;

spraying a liquid on an interior of the carrier with an interior spray system;

spraying a gas on an exterior of the carrier with the exterior spray system; and

spraying a gas on an interior of a carrier with the interior spray system.

16. The method of claim 15 wherein disposing a carrier comprises disposing a semi-conductor wafer carrier.

17. The method of claim 15 wherein disposing a carrier comprises disposing a carrier lid.

18. The method of claim 15 further comprising heating an exterior of the chamber.

19. The method of claim 15 wherein the exterior and interior of the carrier are sprayed in a perpendicular motion to one another.

20. The method of claim 15 wherein at least one of the spraying steps comprises spraying in a sweeping motion.

21. The apparatus of claim 1 further wherein said chamber comprises walls and at least one heating system which heats one or more walls.

22. The apparatus of claim 1 further comprising a vent valve.

23. The apparatus of claim 22 wherein said vent valve is a butterfly valve.

24. The apparatus of claim 1 wherein said carrier-exterior spray system comprises a spray bar, manifold and air and water inlets.

25. The apparatus of claim 24 wherein said carrier-exterior spray system further comprises a pulley drive.