

SYSTEMS AND METHODS FOR A SPRAY MEASUREMENT APPARATUS

FIELD

[0001] The present disclosure generally relates to a spray measurement apparatus, and in particular to systems and methods for a spray measurement apparatus capable of detecting liquid capture levels of one or more spray nozzles within a batch chemical process chamber for understanding spray distribution patterns.

BACKGROUND

[0002] Batch chemical process chambers for semiconductor wet chemical processing require a plurality of spray nozzles to spray a chemical onto a number of wafers stacked in an array inside the process chamber in a uniform manner. The malfunctioning of one or more spray nozzles or a misadjusted spray nozzle(s) can lead to non-uniformity in spray distribution, thereby preventing consistent or in-specification batch process completion. In addition, once an issue in the spray nozzle assembly is identified, it can be difficult and time-consuming to disassemble the batch process chamber to identify which nozzle(s) are malfunctioning and to take corrective action. As such, there lacks a system for easily and accurately monitoring and measuring spray distribution within a batch chemical process chamber.

[0003] It is with these observations in mind, among others, that various aspects of the present disclosure were conceived and developed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 is a perspective view of a spray measurement apparatus disposed within a rotor and batch process chamber and aligned to an array or spray nozzles;

[0005] FIG. 2 is a perspective view of the spray measurement apparatus with the casing in phantom showing a jig device for use in measuring spray distribution;

[0006] FIG. 3 is an end view of the spray measurement apparatus with the proximal end plate removed to illustrate the interior components;

[0007] FIG. 4 is a top view of the spray measurement apparatus showing the blocker plates of the jig device;

[0008] FIG. 5 is a bottom view of the spray measurement apparatus showing the casing in phantom to illustrate the interior components;

[0009] FIG. 6 is a side view of the spray measurement apparatus showing the casing in phantom to illustrate the interior components;

[0010] FIG. 7 is an exploded view of the spray measurement apparatus;

[0011] FIG. 8 is an enlarged exploded view of the spray measurement apparatus showing the jig device;

[0012] FIG. 9 is an enlarged exploded view of the spray measurement apparatus showing the array of pressure transducers;

[0013] FIG. 10 is an enlarged exploded view of the spray measurement apparatus showing the controller, pressure transducer, and battery;

[0014] FIG. 11 is an enlarged perspective view of underside of the casing for the spray measurement apparatus;

[0015] FIG. 12 is a top view of the casing for the spray measurement apparatus showing the tank of the casing; and

[0016] FIG. 13 is an illustration showing one arrangement of a plurality of spray nozzles measured by the spray measurement system.

[0017] Corresponding reference characters indicate corresponding elements among the view of the drawings. The headings used in the figures do not limit the scope of the claims. The drawings are an example of one embodiment of this invention.

DETAILED DESCRIPTION

[0018] In one aspect, a spray measurement apparatus having a jig device capable of measuring spray output and determining spray distribution of a plurality of individual spray nozzles is disclosed. In another aspect, the spray measurement apparatus is operable to measure liquid levels of multiple liquid capture channels associated with respective spray nozzles to understand spray distribution patterns. In yet another aspect, the spray measurement apparatus includes a controller in communication with a batch system, wherein the controller enables the spray measurement apparatus to rotate about a horizontal axis to a specific orientation within the batch chemical process chamber for inspection and utilization of other analytical models. In a further aspect, the spray measurement system allows for verification of the uniformity of spray across an entire semiconductor wafer load to ensure consistent process completion on all semiconductor wafers. In some embodiments, the spray measurement apparatus includes a jig device having a plurality of blocker plates disposed within a respective slot corresponding to a particular wafer location that allows for identification of one or more malfunctioning spray nozzles during operation of the spray management apparatus. Referring to the drawings, embodiments of spray measurement system are illustrated and generally indicated as **100** in FIGS. **1-13**.

[0019] As shown in FIGS. **1-2**, in some embodiments the spray measurement system **100** comprises a rotor **10**, a spray measurement apparatus **101** disposed within the rotor **10**, and a controller **131** which is operable to control and monitor operation of the spray measurement system **100**. In some embodiments, the spray measurement apparatus **101** includes a casing **103** configured to receive a jig device **102** that is operable for measuring spray output and determining spray distribution of multiple spray nozzles **12** in the batch chemical process chamber (not shown) as shall be discussed in greater detail below. In addition, the casing **103** is configured to allow the spray measurement apparatus **100** to be disposed within a rotor **10**, wherein the rotor **10** is disposed within a batch chemical process chamber during operation when measuring the spray output. The spray measurement apparatus **100** is operable to be rotated by the rotor **10** along a horizontal axis **Z** to a specific rotation angle in order to collect spray output from the spray nozzle array **12** at the specific rotation angle to determine spray distribution.

[0020] Referring to FIGS. 1-5, in some embodiments the casing **103** forms an external surface **105** and an interior surface **106** that collectively define a top portion **107**, first side portion **108**, second side portion **109** and bottom portion **110** of casing **103**. As shown specifically in FIGS. 1-3, the top portion **107** of casing **103** defines a top opening **127** in communication with an upper chamber **128** (FIGS. 6 and 11) in which the jig device **102** is partially disposed within and accessed through the top opening **127**. As shown specifically in FIG. 4, the casing **103** defines a first side bar portion **143** and an opposing second side bar portion **144** on opposite sides of the casing **103** that provide a structural surface which allows the spray measurement apparatus **100** to be engaged and secured within the rotor **10** within the batch chemical process chamber along the first and second side bar portions **143** and **144**.

[0021] Referring to FIG. 7, the casing **103** further defines a proximal opening **111** and a distal opening **112** that communicate with opposite ends of a lower chamber **129** formed within the casing **103**. As shown, a proximal end plate **114** is configured to engage and seal off the proximal opening **111**, while a distal end plate **115** is configured to engage and seal off the distal opening **112**. In some embodiments, securing members **142**, such as screws, are used to engage the proximal end plate **114** and distal end plate **115** to the casing **103**. In some embodiments, a handle **141** is secured to the proximal end plate **114** for handling of the spray measurement apparatus **101**.

[0022] As further shown in FIGS. 7 and 12, the upper chamber **128** of casing **103** communicates with a tank **121** disposed within the casing **103** and may be integral with the structure of the casing **103** or a separate component. The tank **121** defines a plurality of inner channels **122** and a pair of end channels **123** formed in an array that extend along the longitudinal axis of the casing **103**. The inner channels **122** and end channels **123** of the tank **121** each provide a respective liquid capture site corresponding to one or more spray nozzles **12** such that the liquid spray from particular spray nozzles **12** may be captured within a respective inner channel **122** or end channel **123** for measurement as shall be discussed in greater detail below.

[0023] As shown in FIGS. 4-8, the jig device **102** provides a means for isolating particular wafer locations such that activation of particular spray nozzles **12** allows for the measurement of liquid collected from these spray nozzles **12** to

determine spray distribution patterns including whether any spray nozzles **12** have malfunctioned or require adjustment. In some embodiments, the jig device **102** includes a plurality of blocker plates **116** aligned in an array in which each blocker plate **116** corresponds to a section of the spray nozzle array **12** among a plurality of possible sections of the spray nozzle array **12** within a batch chemical process chamber.

[0024] In some embodiments, the jig device **102** further includes a slot assembly **104** that defines a plurality of slots **113** in which an individual blocker plate **116** is positioned within a respective slot **113**. As shown in FIGS. **6** and **7**, the slot assembly **104** includes a plurality of slot plates **117** interposed between respective slot blocks **119** arranged on both ends of the slot plates **117** that collectively define each of the plurality of slots **113** formed in an array between a proximal plate **124** and a distal plate **125** when the slot assembly **104** is assembled during manufacturing. As shown, each of the slot plates **117** defines an aligned plate opening **155** configured to receive a rod **126** during assembly, while each set of the slot blocks **118** defines an aligned block opening **156** configured to also receive a rod **126** during assembly. When the slot assembly **104** is assembled, a respective rod **126** is inserted through each of the aligned set of block openings **156** and each of the aligned plate openings **155** to assemble each respective slot **113** of the slot assembly **104**. In addition, the underside of the jig assembly **104** is engaged to a first support member **119** and a second support member **120** to secure the jig device **102** within the upper chamber **128** of the casing **103**.

[0025] When the jig device **102** is assembled, a respective blocker plate **116** is disposed within a respective slot **113** along the slot assembly **104** and may be withdrawn or inserted into the slot **113** as desired. As further shown, each of the blocker plates **116** defines a respective protrusion **148** along the edge of the blocker plate **116** and is configured to allow a user to grasp the protrusion **148** to either withdraw or insert an individual blocker plate **116** relative to a respective slot **113**. As such, any number of blocker plates **116** may be withdrawn from the slot assembly **104** of the jig device **102** when measuring spray nozzle output and determining spray distribution for an individual spray nozzle **12** or a group of spray nozzles **12** as shall be described in greater detail below.

[0026] Referring to FIGS. **2**, **12** and **13**, the jig device **102** is in fluid flow communication with the plurality of inner channels **122** and end channels **123**

defined by tank **121** for capturing liquid that is sprayed by one or more of the spray nozzles **12** onto specific locations in which one or more blocker plates **116** have been removed from the jig device **102**. In this manner, the spray measurement output and spray distribution pattern for a single spray nozzle **12** or a batch of spray nozzles **12** grouped together may be determined by measuring the amount of liquid collected in a respective channel **122**. In some embodiments, the end channels **123** may be used to measure the spray measurement output and spray distribution pattern of the all the spray nozzles **12** collectively, while the inner channels **122** formed between end channels **123** may be used to measure the spray measurement output and spray distribution pattern of individual or select group of spray nozzles **12** when particular blocker plates **116** corresponding to those spray nozzles **12** are removed from the jig device **102** during testing of the spray nozzles **12**. As shown in FIG. **12**, the upper chamber **128** forms a shoulder **154** configured to abut the jig device **102** when inserted in the casing **103**.

[0027] In some embodiments, the spray measurement apparatus **101** further includes a plurality of pressure transducers **130** in fluid flow communication with one or more channels **122** and **123** for measuring the amount of liquid deposited within particular a channel **122** and **123** after the spray nozzles **12** have been activated. In some embodiments, each pressure transducer **130** includes a first port **157** in communication with atmosphere and a second port **158** in communication with a respective channel **122** or **123** through a respective hose **145** in fluid flow communication with one of the channels **122** or **123**. In some embodiments, each hose **145** is connected to a hose connector **146** for establishing fluid flow communication with a respective channel **122** and **123** through an opening **153** formed at the bottom of each channel **122** and **123** as illustrated in FIG. **12**. In operation, each pressure transducer **130** collects pressure data indicative of the amount of liquid collected from a particular channel **122** and **123**.

[0028] In one embodiment shown in FIG. **12**, the tank **121** may define two end channels **123A** and **123B** as well as inner channels **122A-122G**, although the number of channels **122** and **123** may be any of a plurality of channels **122** and **123** that may correspond to one or more spray nozzles **12** for purposes of measuring liquid collection. In one embodiment, the jig device **102** may include blocker plates **116A-116X** in which each block plate **116A-116X** corresponds to a particular wafer

location during processing; however, any number of blocker plates **116** may be used to accommodate the number of wafer locations to be covered.

[0029] In one method of measuring spray output and determining spray distribution patterns using the spray measurement system **100**, the spray measurement apparatus **101** is rotated about a horizontal axis **Z** to a specific testing angle away from the vertical. The spray nozzles **12**, which remain stationary, spray a liquid and the liquid is collected into any of a plurality of channels **122** and **123**. The spray measurement system **100** is subsequently rotated about a horizontal axis **Z** back to 0 degrees from vertical, wherein the pressure transducers **130** measure an amount of pressure in each of the channels **122** and **123**, wherein the amount of pressure in each of the channels **122** and **123** corresponds to a volume of liquid collected in each of the channels **122** and **123**. As the testing process continues, another testing angle is subsequently chosen and the process is repeated.

[0030] In another method of measuring spray output and determining spray distribution patterns using the spray measurement system **100**, a user may remove one or more blocker plates **116**, for example blocker plates **116J-116M**, from the jig device **102** to determine if particular spray nozzles **12** associated with the location(s) of blocker plates **116J-116M** are functioning properly and applying a uniform spray distribution pattern. Once liquid collection data has been collected from channel **122D**, a verification that all of the spray nozzles **12** associated with location of blocker plates **116J-116M** are functioning properly or that one or more spray nozzles **12** require replacement or adjustment.

[0031] As shown in FIGS. **1, 2, 3, 5-7, 9, and 10**, the spray measurement system **100** also includes a controller **131** in operative communication with each of the pressure transducers **130**. In addition, the controller **131** includes a data connection interface (not shown) that provides a means for collecting data or allowing the user to interact with the controller **131** to operate the spray measurement system **100**. For example, the data connection interface may be operable to record the respective pressure related to the amount of liquid collected in the two end channels **123A** and **123B** as well as inner channels **122A-122G**. In some embodiments, the controller **131** collects and stores data regarding the amount of liquid collected from particular channels **122** and **123** as well as data collected on different spray measurements at different testing angles within the batch chemical process chamber. In some embodiments, the controller **131** may be in wireless or

wired communication with external devices (not shown) for controlling the operation of the spray measurement system **100**. In some embodiments, the controller **131** may be incorporated with the entire batch chemical process chamber and would thereby control the rotation of the spray measurement apparatus **100** by the rotor **10**.

[0032] In some embodiments, a battery **147** may provide power to all of the components of the spray measurement system **100**, such as the controller **131** and pressure transducers **130**. In some embodiments, the battery **147** may be rechargeable. In other embodiments, power may be provided through a power cable (not shown).

[0033] In some embodiments, a first array of pressure transducers **130A-130D** may be secured to a second side plate **136** and a second array of pressure transducers **103E-130H** may be secured to a first side plate **135** as shown in FIG. **9**. In addition, a pressure transducer **130I** may also be used to accommodate nine total end channels **122** and inner channels **123** for the embodiment or casing **103** illustrated in FIG. **12**. As further shown, the first side plate **135** includes a first bracket **139** that is engaged to a first rail member **133** mounted to the interior surface **106** of casing **103**, while the second side plate **136** includes a second bracket **140** that is engaged to a second rail member **134** also mounted on the interior surface **106** of casing **103**.

[0034] Referring to FIG. **11**, the bottom portion **110** of casing **103** defines a plurality of openings **153** each configured to receive a respective plug **151**. In some embodiments, bottom portion **110** of casing **103** further defines an indentation **152** configured to act as a mount when securing the casing **103** within the rotor **10** of the batch chemical process chamber.

[0035] It should be understood from the foregoing that, while particular embodiments have been illustrated and described, various modifications can be made thereto without departing from the spirit and scope of the invention as will be apparent to those skilled in the art. Such changes and modifications are within the scope and teachings of this invention as defined in the claims appended hereto.

CLAIMS

What is claimed is:

1. A spray measurement system (**100**), comprising:
 - a rotor (**10**) disposed within a batch chemical processing chamber, wherein the rotor (**10**) is operable to rotate around a horizontal axis Z, wherein the rotor (**10**) is operable to rotate in a clockwise or counterclockwise direction A and an opposite clockwise or counterclockwise direction B;
 - a spray measurement apparatus (**101**) in operative association with the rotor(**10**), the spray measurement apparatus (**101**) comprising:
 - a jig device (**102**) , comprising a plurality of slots (**113**), wherein each of the plurality of slots (**113**) is operable to receive a blocker plate (**116**); and
 - one or more channels (**122, 123**) corresponding with one or more of the plurality of slots (**113**), wherein each of the one or more channels (**122, 123**) is in operative association with a respective pressure transducer (**130**) for measuring an amount of liquid collected in the one or more channels (**122, 123**);
 - wherein the spray measurement apparatus (**101**) is operable to be rotated between a vertical resting position and a predetermined testing angle by the rotor (**10**);
 - and;
 - a controller (**131**) in operative association with the rotor (**10**), wherein the controller (**131**) is operable to rotate the rotor (**10**) around the horizontal axis Z, wherein the controller (**131**) is operable to rotate the rotor (**10**) in the clockwise or counterclockwise direction A and the opposite clockwise or counterclockwise direction B between the vertical resting position and a predetermined testing angle;
- wherein the spray measurement apparatus (**101**) is operable to be rotated to a predetermined testing angle and receive an amount of liquid sprayed

by a spray nozzle array (12) into the one or more of the channels (122, 123), wherein a data collection interface is operable to record the amount of liquid collected in each of the one or more channels (122, 123).

2. The system (100) of claim 1, wherein the spray nozzle array (12) remains in a fixed position angled above the spray measurement apparatus (101), wherein the spray nozzle array (12) is operable to spray the amount of liquid at the spray measurement apparatus (101).
3. The system (100) of claim 1, wherein each of the plurality of blocker plates (116) prevent liquid from entering a corresponding slot (113) of the plurality of slots (113), and wherein the manual removal of blocker plates (116) allows liquid to enter a corresponding slot of the plurality of slots (113).
4. The system (100) of claim 1, wherein the spray measurement apparatus (101) is secured within the rotor (10) using first and second side bar portions formed along respective opposite sides of a casing.
5. The system (100) of claim 1, wherein the controller (131) is operable to record and analyze information collected by the data collection interface.
6. The system (100) of claim 1, wherein a malfunctioning spray nozzle (12) of the spray nozzle array (12) is identified by measuring an amount of liquid collected in each of the plurality of channels (122, 123).
7. A spray measurement apparatus (101), comprising:
 - a casing (103) defining a top portion (107), a bottom portion (110), and opposing first and second side portions (108, 109), wherein the top portion (107) forms a top opening (127) in communication with an upper chamber (128) formed by a tank (121) disposed within the casing (103), wherein the tank (121) defines a plurality of channels (122, 123);

a jig device (**102**) disposed within the upper chamber (**128**), the jig device (**102**) comprising:
a slot assembly (**104**) comprising:
a plurality of slot plates (**117**) interposed between a plurality of slot blocks (**119**) for defining respective slots (**113**); and
a plurality of blocker plates (**116**) disposed within the slot assembly (**104**), wherein each of the plurality of blocker plates (**116**) is configured to be disposed within a respective slot (**113**) of the slot assembly (**104**), and wherein a respective slot (**113**) is associated with one of the plurality of channels (**122, 123**) such that a liquid sprayed by one or more spray nozzles (**12**) at that respective slot (**113**) is collected at one of the plurality of channels (**122, 123**);
a plurality of pressure transducers (**130**) in operative communication with the plurality of channels (**122, 123**) for measuring the spray output of the one or more spray nozzles (**12**) at a respective slot (**113**) in which at least one blocker plate (**116**) has been removed, wherein each respective channel (**122, 123**) is associated with a respective one of the plurality of pressure transducers (**130**); and
a data collection interface in operative communication with the plurality of pressure transducers for measuring the amount of liquid collected in the plurality of channels (**122, 123**).

8. The apparatus (**101**) of claim 7, wherein a pressure value determined by one of the plurality of pressure transducers (**130**) is used to calculate a volume of liquid in one of the plurality of channels (**122, 123**).
9. The apparatus (**101**) of claim 7, wherein the data collection interface is in operative communication with a controller (**131**), and wherein the controller

(131) is operable to record and analyze information collected by the data collection interface.

10. The apparatus (101) of claim 9, wherein the controller (131) is placed inside the casing (103) of the spray measurement apparatus (101).
11. The apparatus (101) of claim 9, wherein the controller (131) is external to the spray measurement apparatus (101).
12. The apparatus (101) of claim 7, wherein power is supplied to the spray measurement apparatus (101) by a battery (147).
13. The apparatus (101) of claim 7, wherein power is supplied to the spray measurement apparatus (101) by a wired connection.
14. A method of measuring spray output using a spray measurement system (100), comprising:
 - rotating a rotor (10) in operative association with a spray measurement apparatus (101) having a plurality of channels (122, 123), wherein the rotor (10) and spray measurement apparatus (101) are rotated in a clockwise or counterclockwise direction A along a horizontal axis Z, wherein the rotor (10) and spray measurement apparatus (101) are rotated from a vertical position to a predetermined testing angle;
 - spraying an amount of liquid from a fixed spray nozzle array (12) at the spray measurement apparatus (101), wherein a volume of liquid from the fixed spray nozzle array (12) is collected into one or more of the plurality of channels (122, 123) of the spray measurement apparatus (101);
 - rotating the rotor (10) in operative association with the spray measurement apparatus (101) in an opposite counterclockwise or clockwise direction B along the horizontal axis Z such that the spray measurement apparatus (101) having collected an amount of the liquid is returned to a vertical position; and

measuring the volume of liquid in one or more of the plurality of channels (**122**, **123**).

15. The method of claim 14, further comprising:
configuring one or more channels (**122**, **123**) for testing of one or more of spray nozzles (**12**) by adding or removing one or more of a plurality of blocker plates (**116**), wherein each of the plurality of blocker plates (**116**) is configured to be disposed within a respective slot (**113**) of a slot assembly (**104**) of the spray measurement apparatus (**101**), wherein a respective slot (**113**) is associated with one of the plurality of channels (**122**, **123**) such that the amount of liquid sprayed by one or more spray nozzles (**12**) at that respective slot (**113**) is collected at one of the plurality of channels (**122**, **123**).
16. The method of claim 14, wherein the method of measuring spray output is repeated, wherein each repetition of the method of measuring spray output is at a different testing angle.
17. The method of claim 16, wherein a malfunctioning spray nozzle from the spray nozzle (**12**) array is identified by measuring the volume of liquid collected in each of the plurality of channels (**122**, **123**) across one or more testing angles.
18. The method of claim 14, wherein the volume of liquid in a respective channel of the spray measurement apparatus (**101**) is measured by measuring the amount of pressure in the respective channel using a respective pressure transducer, wherein the amount of pressure in the channel corresponds to the volume of liquid collected in the channel.
19. The method of claim 18, wherein a data collection interface in operative communication with the pressure transducers (**130**) is operable to record and analyze data pertaining to the amount of pressure in each of the plurality of channels (**122**, **123**).

20. The method of claim 14, wherein a controller (**131**) in operative communication with the rotor (**10**) is operable to rotate the rotor (**10**), thereby rotating the spray measurement apparatus (**101**).