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(54) Title: ENDPOINT DETECTION SYSTEM AND METHODS OF USING THE SAME

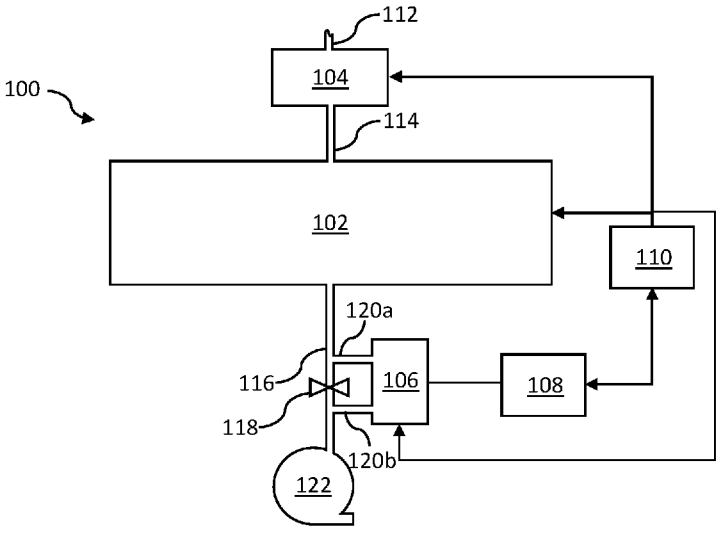


FIG. 1

(57) Abstract: A system includes a byproduct analysis processor for use with a byproduct detector in fluid communication with a foreline of a processing chamber having a plasma source configured to generate a reactive species adapted to clean an interior of the processing chamber during a chamber cleaning process. The processor can obtain detection data representing a cleaning byproduct concentration exhausted from an interior of the processing chamber and determine an endpoint of the chamber cleaning process based and/or determine a fault condition associated with the processing chamber based on the detection data.

[Continued on next page]

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ENDPOINT DETECTION SYSTEM AND METHODS OF USING THE SAME

BACKGROUND

I. Technical Field

[0001] Embodiments of the present disclosure generally relate to endpoint detection systems and methods of using the same and, more particularly, to endpoint detection systems and methods for determining processing chamber cleaning endpoints and providing process chamber diagnostics using endpoint detection systems.

II. Background

[0002] Modern semiconductor processing techniques, such as those used in manufacturing semiconductor devices, solar panels, display devices, etc., are typically performed as batch processes involving many deposition and etching steps performed within one or more chambers for maintaining a controlled environment. If one step is performed out of specification, the entire batch of semiconductor devices can contain significant defects. When a batch is defective, it can be extremely difficult to identify the root cause of the failure. Although many components of a semiconductor processing chamber have self-diagnostic functions, adequate process-level fault detection or diagnostic tools are not known to exist.

SUMMARY

[0003] One embodiment can be broadly characterized as a system that includes a byproduct analysis processor for use with a byproduct detector in fluid communication with a foreline of a processing chamber having a plasma source configured to generate a reactive species adapted to clean an interior of the processing chamber during a chamber cleaning process. The processor can be configured to obtain detection data representing a cleaning byproduct concentration exhausted from an interior of the processing chamber and determine an endpoint of the chamber cleaning process based, at least in part, on one or more of: a time-derivative of the obtained detection data and a time-integral of the obtained detection data.

[0004] Another embodiment can be broadly characterized as a system that includes a byproduct analysis processor for use with a byproduct detector in fluid communication with a foreline of a processing chamber having a plasma source configured to generate a reactive species adapted to clean an interior of the processing chamber during a chamber cleaning process. The process can be configured to obtain detection data representing a cleaning byproduct concentration exhausted from an interior of the processing chamber, compare the

detection data with reference data associated with the chamber cleaning process and output a signal when a result of the comparison indicates a predetermined relationship between the detection data and the reference data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 illustrates semiconductor processing system according to some embodiments of the present invention.

[0006] FIG. 2 is a flow chart illustrating how an active endpoint detection process may be used to facilitate a chamber cleaning process, according to one embodiment.

[0007] FIG. 3 graphically illustrates a representation of raw detection data that may be recorded in association with the timing data.

[0008] FIG. 4 graphically illustrates a representation of derivative detection data that may be recorded in association with the timing data.

[0009] FIG. 5 graphically illustrates a representation of integral detection data that may be recorded in association with the timing data.

[0010] FIG. 6 is a flow chart illustrating a fault detection process, according to one embodiment, that may be executed by the byproduct analysis processor and/or system host shown in FIG. 1.

[0011] FIGS. 7 and 8 are graphs illustrating an example of measured and reference cleaning traces corresponding to raw detection data and integral detection data, respectively, associated with the same chamber cleaning process.

[0012] FIGS. 9 and 10 are graphs illustrating another example of measured and reference cleaning traces corresponding to raw detection data and integral detection data, respectively, associated with the same chamber cleaning process.

DETAILED DESCRIPTION

[0013] Example embodiments are described herein with reference to the accompanying FIGS. Unless otherwise expressly stated, in the drawings the sizes, positions, etc., of components, features, elements, etc., as well as any distances therebetween, are not necessarily to scale, but are exaggerated for clarity.

[0014] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly

indicates otherwise. It should be recognized that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. Unless otherwise specified, a range of values, when recited, includes both the upper and lower limits of the range, as well as any sub-ranges therebetween. Unless indicated otherwise, terms such as "first," "second," etc., are only used to distinguish one element from another. For example, one node could be termed a "first node" and similarly, another node could be termed a "second node", or vice versa. The section headings used herein are for organizational purposes only and are not to be construed as limiting the subject matter described.

[0015] Unless indicated otherwise, the term "about," "thereabout," etc., means that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art.

[0016] Spatially relative terms, such as "below," "beneath," "lower," "above," and "upper," and the like, may be used herein for ease of description to describe one element or feature's relationship to another element or feature, as illustrated in the FIGS. It should be recognized that the spatially relative terms are intended to encompass different orientations in addition to the orientation depicted in the FIGS. For example, if an object in the FIGS. is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. An object may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may be interpreted accordingly.

[0017] Like numbers refer to like elements throughout. Thus, the same or similar numbers may be described with reference to other drawings even if they are neither mentioned nor described in the corresponding drawing. Also, even elements that are not denoted by reference numbers may be described with reference to other drawings.

[0018] It will be appreciated that many different forms and embodiments are possible without deviating from the spirit and teachings of this disclosure and so this disclosure should

not be construed as limited to the example embodiments set forth herein. Rather, these examples and embodiments are provided so that this disclosure will be thorough and complete, and will convey the scope of the disclosure to those skilled in the art.

[0019] FIG. 1 illustrates semiconductor processing system according to some embodiments of the present invention.

[0020] Referring to FIG. 1, a semiconductor processing system, such as system 100, includes a process chamber 102, a plasma source 104, an byproduct detector 106, an byproduct analysis processor 108, and a system host 110. The system 100 may also include one or more other components such as a precursor gas delivery pipe 112, a reactive species delivery pipe 114, a foreline 116, a throttle valve 118, bypass lines 120 and a vacuum pump 122. Although not shown, the system 100 may also include one or more other components such as a heater, an in-situ plasma generator, a susceptor, etc. Further, although not shown, the system 100 may include more than one plasma source 104.

[0021] As is known in the art, the process chamber 102 defines an interior volume, which accommodates a semiconductor wafer and in which a plurality of deposition and etching processes may be performed on the wafer. Accordingly, components such as a wafer chuck, a showerhead, and the like, are typically arranged within the interior of process chamber. The system host 110 is communicatively coupled to various components of the system 100, such as controllers of components within the process chamber 102, a controller associated with the plasma source 104, etc., to effect a deposition process, an etching process, a conditioning process, or the like or any combination thereof.

[0022] The plasma source 104 is operative to generate low-energy ions and/or radicals from precursor gases (e.g., supplied thereto via the precursor gas delivery pipe 112) and deliver the low-energy ions and/or radicals into the interior of the process chamber 102 (e.g., to the showerhead within the process chamber 102) via reactive species delivery pipe 114. Generally, the plasma source 104 may be provided as a toroidal- or microwave-based remote plasma source capable of generating ions and/or radicals from precursor gases containing fluorine, NF_3, CF_4, SF_6, oxygen, nitrogen, hydrogen, or the like or any combination thereof. Although FIG. 1 illustrates the plasma source 104 as a remote plasma source, it will be appreciated that the plasma source 104 can, alternatively, be provided as an in-situ plasma source (e.g., arranged within the interior of the process chamber 102).

[0023] The supply of ions or radicals by the plasma source 104 (whether external to, or within, the process chamber 102) can facilitate semiconductor processes such as chemical vapor deposition (CVD), atomic layer deposition (ALD), etc., of films (e.g., of materials such as silicon oxide, silicon nitride, hafnium oxide, polysilicon, etc.) on the wafer. In these processes, the radicals are supplied to the surface of the wafer where heat-induced chemical reactions take place to form the desired film. In another embodiment, however, deposition can be thermal in nature (e.g., via thermal decomposition of process gases).

[0024] Unwanted deposition of material on areas inside the processing chamber, e.g., interior walls of the processing chamber, showerhead, chuck, etc., also occurs during such deposition processes, and can typically be removed using an in-situ chamber cleaning process. Conventional chamber cleaning processes apply a plasma to a precursor gas to generate reactive species, such as fluorine radicals, which react with the unwanted material to generate byproducts (e.g., SiF_4) that can be removed from the interior of the process chamber 102. A chamber cleaning process can comprise a single cleaning stage (e.g., characterized by one or more chamber cleaning parameters such as chamber temperature, chamber pressure, duration, composition of reactive species into the chamber, amount or concentration of reactive species into the chamber, flow rate or reactive species into the chamber, etc.) or multiple cleaning stages (e.g., where at least one chamber cleaning parameter varies as between different stages of the chamber cleaning process). A multi-stage chamber cleaning process may be advantageously employed when, for example, different regions within the interior of the process chamber 102 have different accessibility to the reactive species, when different surfaces of the chamber are coated with films of different compositions and/or different thicknesses, etc. As should be appreciated, a chamber cleaning process is an example of an etching process that may be controlled by the system host 110.

[0025] The duration of a chamber cleaning process is often a significant factor affecting semiconductor manufacturing processes and equipment productivity. If performed for an insufficiently long duration, reactant products and other byproducts produced by the chamber cleaning process can undesirably accumulate within the processing chamber and flake off as particles, which may result in increased device defectivity and process drift. If the chamber cleaning process is performed for an excessively long duration, surfaces within the interior of the processing chamber can become prematurely degraded. Excessively long chamber cleaning processes also generally have a deleterious impact on throughput. Thus, chamber cleaning

requires a method for detecting the "endpoint" when the procedure can be stopped to ensure that the interior of processing chamber 102 is suitably cleaned with little to no damage to surface within the processing chamber.

[0026] To facilitate detection of the endpoint of a chamber cleaning process, the byproduct detector 106 is connected to a foreline 116 via bypass pipes (i.e., an inlet bypass pipe 120a and an outlet bypass pipe 120b) to receive chamber clean exhaust gas, which will typically include one or more cleaning byproducts of the chamber cleaning process. A throttle valve 118 is coupled to the foreline 116 at a location between the inlet bypass pipe 120a and outlet bypass pipe 120b, which can be actuated to create a pressure drop across the byproduct detector 106 during a chamber cleaning process. The vacuum pump 122 is typically connected to the foreline 116 at a location downstream of the outlet bypass pipe 120b and can be operated to help maintain the interior of the process chamber 102 at a desired pressure (or within a desired pressure range) during a deposition, etching or conditioning process by regulating the rate at which material (e.g., particulates, gases, radicals, etc.) are removed from the interior of the process chamber 102 and into the foreline 116. Although not illustrated, an isolation valve may be coupled to each of the inlet bypass pipe 120a and outlet bypass pipe 120b to protect the byproduct detector 106 from gases flowing through the foreline 116 when chamber cleaning processes are not being performed (e.g., during a deposition process, or the like).

[0027] Generally, the byproduct detector 106 can be configured in any manner suitable or otherwise known in the art to measure the concentration of the cleaning byproduct(s) within the chamber clean exhaust gas. For example, and according to embodiments of the present invention, the byproduct detector 106 can be provided as a non-dispersive infra-red (NDIR) detector which, as is known in the art, detects the concentration of the cleaning byproducts within the chamber clean exhaust gas using the characteristic infrared optical absorbance fingerprints of the cleaning byproducts. In other examples, the byproduct detector 106 can be provided as an optical emission spectroscopy (OES) sensor, etc.

[0028] The byproduct detector 106 is further configured to generate detection data representative of the detected concentration of the cleaning byproduct(s). The detection data can be output to the byproduct analysis processor 108, e.g., in the form of one or more detection signals. Thus, the byproduct detector 106 is communicatively coupled to an input of the byproduct analysis processor 108, so that the byproduct analysis processor 108 can receive the

detection signals output by the byproduct detector 106. As described in greater detail with respect to FIG. 2, the byproduct analysis processor 108 is configured to implement an active endpoint detection process based, at least in part, on detection data output by the byproduct detector 106 in order to determine whether an "endpoint" in the chamber cleaning process has been reached.

[0029] Generally, the system host 110 includes one or more processors operative to generate the commands (e.g., upon executing one or more instructions) and output the commands (e.g., as one or more control signals) to the aforementioned components of the semiconductor processing system 100. Likewise, the endpoint detector processor 108 includes one or more processors operative to perform various operations of data and signals described herein. A processor can be provided as a programmable processor (e.g., including one or more general purpose computer processors, microprocessors, digital signal processors, or any other suitable form of circuitry including programmable logic devices (PLDs), central processing units (CPUs), graphics processing units (GPUs), accelerated processing units (APUs), real-time processing units (RPUs), field-programmable gate arrays (FPGAs), field-programmable object arrays (FPOAs), application-specific integrated circuits (ASICs) - including digital, analog and mixed analog/digital circuitry - or the like, or any combination thereof) operative to execute the instructions. Execution of instructions can be performed on one processor, distributed among multiple processors, made parallel across processors within a device or across a network of devices, or the like or any combination thereof. Although the endpoint detector processor 108 and system host 110 are illustrated in FIG. 1 as separate components, it will be appreciated that the endpoint detector processor 108 and system host 110 may be provided as a single component (e.g., as a single, common processor or as a common collection of processors).

[0030] Generally, the instructions may be embodied as software (e.g., an executable code, file, library file, or the like or any combination thereof), hardware configuration (e.g., in the case of FPGAs, ASICs, etc.), or the like or any combination thereof, which can be readily specified by artisans, from the descriptions provided herein (e.g., written in C, C++, Visual Basic, Java, Python, Tel, Perl, Scheme, Ruby, assembly language, hardware description language such as LUCID, VHDL or VERILOG, etc.). Software is commonly stored in one or more data structures conveyed by tangible media such as computer memory, which is accessible (e.g., via one or more wired or wireless communications links) by a processor. Examples of tangible media

include magnetic media (e.g., magnetic tape, hard disk drive, etc.), optical discs, volatile or non-volatile semiconductor memory (e.g., RAM, ROM, NAND-type flash memory, NOR-type flash memory, SONOS memory, etc.), or the like or any combination thereof, and may be accessed locally, remotely (e.g., across a network), or any combination thereof.

[0031] FIG. 2 is a flow chart illustrating how an active endpoint detection process may be used to facilitate a chamber cleaning process, according to one embodiment.

[0032] Referring to FIG. 2, a chamber cleaning process may be initiated by the system host 110, e.g., in response to instructions or data stored at or otherwise accessible to the system host 110, in response to instructions input by an operator via a user interface (not shown) of the semiconductor processing system 100, etc. In one embodiment, the chamber cleaning process to be initiated is a single-stage cleaning process. In another embodiment, the chamber cleaning process to be initiated has multiple cleaning stages (i.e., "n" cleaning stages, where n is an integer greater than 1). In this case, the system host 110 will set the first cleaning stage (i.e., n = 1) of the multi-stage chamber cleaning process to be initiated. See 200.

[0033] Generally, the system host 110 will initiate a chamber cleaning process or stage of a chamber cleaning process at 202 by outputting one or more control signals to appropriate component(s) of the semiconductor processing system 100. For example, the system host 110 may output a control signal to the plasma source 104 (and other associated components) to generate reactive species which are thereafter introduced into the interior of the process chamber 102. The system host 110 may also output a control signal to the byproduct detector 106 to begin measuring the concentration of any cleaning byproduct(s) advected thereto via the foreline 116 and bypass line 120 upon initiation of the chamber cleaning process. The system host 110 may also output a control signal to the byproduct analysis processor 108 to begin recording any detection data that may be output by the byproduct detector 106 upon initiation of the chamber cleaning process.

[0034] At 204, the byproduct detector 106 generates detection data representative of the detected concentration of the cleaning byproduct(s) exhausted from the interior of the process chamber 102 during the chamber cleaning process. As mentioned previously, the detection data can be output to the byproduct analysis processor 108, e.g., in the form of one or more detection signals, and the byproduct analysis processor 108 processes or otherwise interprets the received

detection data detection signals to obtain the detection data output by the byproduct detector 106 (also referred to herein as "raw detection data").

[0035] At 206, the byproduct analysis processor 108 records (e.g., stored, on computer memory) the raw detection data in association with the timing data representing the amount of time that has elapsed since initiation of the chamber cleaning process (or current cleaning stage of the chamber cleaning process). FIG. 3 graphically illustrates a representation of the raw detection data that may be recorded in association with the timing data. That is, the trace 300 exemplarily illustrated in FIG. 3 (also referred to herein as a "raw data trace") represents the measured concentration of cleaning byproduct(s) (as represented by the raw detection data output by the byproduct detector 106) during the chamber cleaning process (or current cleaning stage of the chamber cleaning process) as a function of the amount of elapsed time. Additionally or alternatively, however, the raw data trace 300 could represent one or more a partial pressure of the cleaning byproduct(s), a voltage level, or any direct signal output by the byproduct detector 106 that is correlatable to any cleaning byproduct(s) as measured by the byproduct detector 106.

[0036] Referring back to FIG. 2, at 208, the byproduct analysis processor 108 calculates the time-derivative of the raw detection data, to thereby compute the rate at which the detected concentration of cleaning byproducts within the exhaust gas changes. The time-derivative of the raw detection data is recorded (e.g., stored, as discussed above) as derivative detection data in association with the timing data at 206. FIG. 4 graphically illustrates a representation of the derivative detection data that may be recorded at 206 in association with the timing data. That is, the trace 400 exemplarily illustrated in FIG. 4 (also referred to herein as a "derivative data trace") represents the rate at which the measured concentration of cleaning byproduct(s) changes during the chamber cleaning process (or current cleaning stage of the chamber cleaning process) as a function of the amount of elapsed time. Changes in the rate at which the measured concentration of cleaning byproduct(s) changes may indicate that different regions within the interior of the process chamber 102 are being cleaned (e.g., as indicated in FIG. 4 by the portion of the derivative data trace within dashed circle 404). It should be appreciated, however, that the derivative variation at the transition might not be as obvious as shown in FIG. 4, e.g., depending on processes that were performed prior to the chamber cleaning process.

[0037] Referring back to FIG. 2, at 210, the byproduct analysis processor 108 calculates the time-integral of the raw detection data, to thereby generate integral detection data representing

the amount of material within the interior of the process chamber 102 has been etched during the chamber cleaning process. The integral detection data is recorded (e.g., stored, as discussed above) in association with the timing data at 206. FIG. 5 graphically illustrates a representation of the integral detection data that may be recorded at 206 in association with the timing data. That is, the trace 500 exemplarily illustrated in FIG. 5 (also referred to herein as a "integral data trace") represents the cumulative amount of cleaning byproduct(s) removed from the process chamber 102 during the chamber cleaning process (or current cleaning stage of the chamber cleaning process) as a function of the amount of elapsed time. Use of the data supporting the integral data trace can be beneficial when, for example, the chamber cleaning process includes multiple stages. In this example, the integral data trace can be analyzed or otherwise interpreted to detect the end point of each stage of the chamber cleaning process.

[0038] Referring back to FIG. 2, at 212, the byproduct analysis processor 108 processes or otherwise analyzes the raw detection data, the derivative detection data and/or the integral detection data to determine whether an endpoint in the chamber cleaning process (or current cleaning stage of the chamber cleaning process) has been reached. In one example embodiment, the byproduct analysis processor 108 determines whether an endpoint has been reached by processing or analyzing the raw detection data to determine whether, after initiation of a chamber cleaning process, the concentration of cleaning byproducts within the exhaust gas is zero (or is otherwise within some negligible concentration range) for a predetermined period of time (e.g., 30 seconds, 1 minute, etc.) depending on the nature of any deposition or etch processes that preceded the chamber cleaning process. In another example embodiment, the byproduct analysis processor 108 determines whether an endpoint has been reached by processing the derivative detection data to determine whether, after initiation of a chamber cleaning process, the rate at which the detected concentration of cleaning byproducts within the exhaust gas changes remains within a predetermined range (e.g., depending on the parameters associated with the chamber cleaning process and the nature of any deposition or etch processes that preceded the chamber cleaning process) for the predetermined period of time. In another example embodiment, the byproduct analysis processor 108 determines whether an endpoint has been reached by processing the integral detection data to determine whether, after initiation of a chamber cleaning process, the cumulative amount of cleaning byproduct(s) removed from the process chamber 102 has remained constant (or substantially constant) for a predetermined amount for the

predetermined period of time. For example, and based on the raw, derivative and/or integral detection data recorded in association with timing data as graphically represented in the traces 300, 400 and 500 of FIGS. 3, 4 and 5, respectively, the byproduct analysis processor 108 may determine that the endpoint has been reached at 23.5 a.u. (or thereabout), e.g., as respectively indicated by lines 302, 402 and 502.

[0039] As mentioned above, the byproduct analysis processor 108 processes or otherwise analyzes the raw detection data, the derivative detection data and/or the integral detection data to determine whether an endpoint in the chamber cleaning process (or current cleaning stage of the chamber cleaning process) has been reached. It can be advantageous to determine whether an endpoint has been reached by processing or otherwise analyzing detection data of two or more of the raw detection data conveyed by the detection signal, the derivative detection data and/or the integral detection data. For example, chamber cleaning processes always have some randomness or other variability, especially when the clean involves multiple stages. In addition, the byproduct detector 106 itself might be susceptible to operational drift (i.e., gradual deviation of the output detection data from its calibrated state over time). Using only the raw detection data, only the derivative detection data or only the integral raw detection data can sometimes cause inaccurate determination of the endpoint. For example, during a clean, if the byproduct detector 106 experiences operational drift, the raw detection data and the derivative detection data may not be sufficiently accurate to determine the endpoint of a chamber cleaning process (this can lead to the interior of the chamber being either not fully cleaned or undesirably etched). Accordingly, step 212 of the active endpoint detection process can involve processing or otherwise interpreting the integral detection data to determine whether the amount of material removed from the interior of the chamber 102 is within a within a normal or expected range; if it is, then the active endpoint detection process can proceed to determine the endpoint based on raw or derivative detection data. In another example, and especially when the chamber cleaning process involves multiple stages, endpoint determination based on the raw detection data can often vary from one multi-stage cleaning process to another. In this case, step 212 of the active endpoint detection process can involve processing or otherwise interpreting the derivative detection data to determine whether the rate at which the measured concentration of cleaning byproduct(s) changes is within a normal or expected range; if it is, then the active endpoint detection process can proceed to determine the endpoint based on the raw detection data. By

using a combination of the aforementioned detection data, the determination of whether an endpoint has been reached can be made accurately, and in a manner that is relatively insensitive to variations in chamber cleaning process parameters or variations in preceding deposition or etching processes, thus helping to reduce the amount of reactive gas and electricity used during the chamber cleaning process, and improve the wafer processing throughput. Analyzing the two or more of the raw detection data conveyed by the detection signal, the derivative detection data and the integral detection data (each generically and collectively referred to herein as "obtained detection data") also enables endpoints of cleaning stages within a multi-stage chamber cleaning process to be detected.

[0040] If, at 212, the byproduct analysis processor 108 determines that an endpoint has not been reached, then the chamber cleaning process is allowed to proceed, and steps 204, 206, 208, 210 and 212 will continue to be performed as discussed above. If, at 212, the byproduct analysis processor 108 determines that an endpoint has been reached, then the byproduct analysis processor 108 outputs an endpoint detection signal (e.g., to the system host 110). Upon receipt of endpoint detection signal, the system host 110 may terminate the chamber cleaning process (e.g., if the chamber cleaning process comprises only a single cleaning stage) at 214. However, if the chamber cleaning process comprise multiple cleaning stages, the system host 110 will determine whether the cleaning stage whose endpoint was determined to have been reached at 212 is the final stage in the multi-stage cleaning process. See 216. If the cleaning stage whose endpoint was determined to have been reached at 212 is the final stage, then the system host 110 may terminate the multi-stage chamber cleaning process at 214. If the cleaning stage whose endpoint was determined to have been reached at 212 is not the final stage, then the system host 110 increments the number of the cleaning stage to be initiated at 218 and initiates the next cleaning stage at 202.

[0041] Although example embodiments described above detail how the various obtained detection data can be used to facilitate an active endpoint detection process to determine whether an endpoint has been reached, it will be apricated that the obtained detection data can be used for other purposes. For example, one or more of the aforementioned obtained detection data can be used in a quantitative fault detection process, e.g., whereby detection data generated during a chamber clean is used to determine whether any preceding processes performed in the process chamber 102 (e.g., a deposition process, an etching process, a conditioning process, or the like or

any combination thereof) were performed out of specification. In this sense, a fault detection process can provide information on the chamber cleaning process, of the quality of any preceding deposition or etching processes, or the like or any combination thereof. Such information can be used to monitor the manner in which the preceding processes were performed (e.g., whether any preceding process was performed out of specification), to provide a warning that a preceding process may have been performed out of specification, etc. Such information can also be stored (e.g., at the byproduct analysis processor 108, at the system host 110, etc.) for troubleshooting purposes in the future. An example fault detection process is described in greater detail with respect to FIG. 6, which can be executed by the byproduct analysis processor 108, the system host 110 or any combination thereof.

[0042] Referring to FIG. 6, a fault detection process can begin by obtaining the detection data recorded at step 206. See 600. The detection data obtained at 600 can include the aforementioned raw detection data, derivative detection data, integral detection data or any combination thereof. Optionally, the timing data associated with the detection data may also be obtained at 600.

[0043] At 602, one or more cleaning profile statistics are calculated based, at least in part, on the obtained detection data. Generally, a cleaning profile statistic includes a similarity measure quantifying the similarity between detection data generated from endpoint detection process (herein referred to as "measured detection data") performed during a chamber cleaning process and corresponding reference detection data (e.g., representing detection data calculated or otherwise obtained during from a chamber cleaning process following one or more "golden" or "ideal," typical, expected or model chamber cleaning process intended to be performed within the process chamber 102). Accordingly, calculation of a cleaning profile statistic can be conceptually considered as involving a comparison between the measured detection data (e.g., the raw detection data, or the derivative or integral thereof) and corresponding reference detection data.

[0044] In one embodiment, a cleaning profile statistic includes a correlation coefficient, e.g., calculated after an endpoint has been reached according to the following equation 1:

$$r = \frac{\Sigma_{t=0}^{T}(S_{in}(t)-\overline{S_{in}})(S_{ref}(t)-\overline{S_{ref}})}{\sqrt{[\Sigma_{t=0}^{T}(S_{in}(t)-\overline{S_{in}})^2(S_{ref}(t)-\overline{S_{ref}})^2}} \qquad \text{[equation 1]}$$

where S_{in}(t) is the value of the measured detection data obtained at time, t, during a chamber cleaning process, S_{ref}(t) is the value of the reference detection data at time, t, of the chamber cleaning process, T is total amount of time associated with the chamber cleaning process (e.g., as determined according to the process described above with respect to FIG. 2 or as otherwise set), $\overline{S_{in}}$ is the average value of the measured detection data over the course of the chamber cleaning process and $\overline{S_{ref}}$ is the average value of the reference detection data over the course of the chamber cleaning process. Both the measured detection data and the reference detection data may be raw detection data, derivative detection data, integral detection data, or any combination thereof, as discussed above. Although the correlation coefficient has been described above as being calculated according to the equation 1, it will be appreciated that the correlation coefficient can be calculated according to any known or otherwise suitable technique and that many such techniques are known within the field of spectroscopy.

[0045] In another embodiment, a cleaning profile statistic includes a peak height coefficient, which represents the overall rate at which the interior of the process chamber 102 is cleaned during a chamber cleaning process. The peak height coefficient can be calculated by generating a mathematical representation of the raw detection data and associated timing data (i.e., graphically illustrated above as the aforementioned raw data trace 300). The mathematical representation may be generated by fitting an interpolating cubic spline to the raw detection data and associated timing data recorded at 206 in FIG. 2 generated over the course of a chamber cleaning process, which may also be referred to herein as a "measured raw cleaning trace." Next, a cross-correlation between the measured cleaning trace and a corresponding trace associated with the reference detection data (also be referred to herein as a "reference raw cleaning trace") is calculated, and the time associated with the maximum cross-correlation (i.e., delay time, Δt) is determined. The time axis of the reference raw cleaning trace is then shifted by an amount equal to the delay time, Δt, and a linear regression between the measured raw cleaning trace and the reference raw cleaning trace (shifted by the delay time) is then performed. Subsequently, the slope of the linear regression is determined to be the peak height coefficient.

[0046] In yet another embodiment, a cleaning profile statistic includes an accumulated material coefficient, which represents the amount of material that is removed from the interior of the chamber 102 during a chamber cleaning process. The accumulated material coefficient can be calculated by generating a mathematical representation of the integral detection data and

associated timing data (i.e., graphically illustrated above as the aforementioned integral data trace 500). The mathematical representation may be generated by fitting an interpolating cubic spline to the raw detection data and associated timing data recorded at 206 in FIG. 2 generated over the course of a chamber cleaning process, which may also be referred to herein as a "measured integral cleaning trace." Next, a cross-correlation between the measured integral cleaning trace and a corresponding trace associated with the reference integral detection data (also be referred to herein as a "reference integral cleaning trace") is calculated, and the time associated with the maximum cross-correlation (i.e., delay time, Δt) is determined. The time axis of the reference integral cleaning trace is then shifted by an amount equal to the delay time, Δt, and the similarity between the measured integral cleaning trace and the reference integral cleaning trace (shifted by the delay time) is then performed by any suitable or known technique.

[0047] In view of the above, it will be appreciated that the various aforementioned detection data and cleaning profile statistics are not only directly informative of a chamber cleaning process that is currently being performed, but are also indirectly informative of the manner in which any preceding processes were performed. Referring back to FIG. 6, the cleaning profile statistics calculated at 602 is monitored to determine whether one or more, or any combination thereof, of the cleaning profile statistics is within a predetermined tolerance range. See 604. If the cleaning profile statistic(s) are within tolerance, then the fault detection process ends at 606. However, if the cleaning profile statistic(s) are outside tolerance, then a determination is made as to whether such cleaning profile statistic(s) are outside a fault level. See 608. If the cleaning profile statistic(s) are outside a predetermined fault level, then an interrupt signal is output (e.g., either to the system host 110 from the byproduct analysis processor 108 or by the system host 110) to terminate all processes being performed by the semiconductor processing system 100. See 610. If the cleaning profile statistic(s) are not outside the fault level, then a warning signal/flag is sent (e.g., from the byproduct analysis processor 108 to the system host 110, from the system host 110 to an operator via the user interface of the semiconductor processing system 100, etc., to notify that a preceding process was or may have been performed out of specification) or saved (e.g., at the byproduct analysis processor 108 or system host 110 for future troubleshooting that may be necessary or for any other purposes of future reference). See 612. In view of the above, it will be appreciated that one or both of steps 604 and 608 can be considered acts of monitoring the manner in which processes preceding the current chamber

cleaning process were performed (e.g., whether any of the preceding processes were performed out of specification).

[0048] Although example embodiments described above detail how the various obtained detection data can be used to detect process deviations by quantitative analysis of the cleaning byproduct(s) generated during a chamber cleaning process, the aforementioned detection data can also be used – either alone or in conjunction with diagnostic data obtained from other components of the semiconductor processing system 100, to qualitatively detect potential deviations in processes performed within the process chamber 102, which may have occurred prior to initiating a chamber cleaning process.

[0049] For example, the inventors have observed that the shape of a measured cleaning trace (e.g., trace 300, 400 or 500) generated during one chamber cleaning process may differ from the shape of a corresponding measured cleaning trace generated during another chamber cleaning process, even if both chamber cleaning processes were preceded by the same type of deposition, etching or conditioning process. A change in the shape of a measured cleaning trace across different chamber cleaning processes can thus indicate the existence of variability or other error in preceding processes performed within the process chamber 102.

[0050] In another example, the shape of a measured cleaning trace derived from any detection data generated during a chamber cleaning process can be compared with a corresponding reference cleaning trace associated with the chamber cleaning process to discern a potential process deviation. In some embodiments, the comparison can include an analysis (e.g., performed at the byproduct analysis processor 108 and/or system host 110, implemented using any known or suitable principal component analysis (PCA), machine learning (ML) or artificial intelligence (AI) technique. As with the fault detection process described above with respect to FIG. 6, the results of the analysis can result in the generation of a warning or other flag indicating that a preceding process may have been performed out of specification. Likewise, the results of the analysis may be stored (e.g., at the byproduct analysis processor 108 or system host 110 for future troubleshooting that may be necessary or for any other purposes of future reference).

[0051] For example, FIG. 7 shows an example of a measured cleaning trace (dashed line) generated from the raw detection data during a chamber cleaning process while FIG. 8 shows an example of a measured cleaning trace (dashed line) generated from the integral detection data

during the chamber cleaning process. In each of FIGS. 7 and 8, the solid line represents a reference cleaning trace corresponding to the either the raw detection data (as in FIG. 7) or the integral detection data (as in FIG. 8). As can be seen from FIG. 7, analysis of the entire measured cleaning trace provides more information than just the time at which a cleaning endpoint is detected. FIG. 7 illustrates that the endpoint of the measured cleaning trace occurs later than the endpoint of the reference cleaning trace, and the peak height of the measured cleaning trace is lower than the peak height of the reference cleaning trace. In addition, in FIG. 8, the reference cleaning trace indicates that the total amount of etched material is higher than indicated by the reference cleaning trace. This analysis provides useful clues as to what could be happening within the process chamber during processing. For example, one explanation is that the plasma dissociation efficiency may have changed/radical level in the chamber is lower than normal, as while the total etched material is slightly higher in the current clean, the etch rate is overall lower when compared to the reference clean profile. The fact that the total etched material is higher might indicate some variation in the deposition process. However, depending on the process, these variations may be within the allowable variation run to run or batch to batch processing.

[0052] FIGS. 9 and 10 illustrate measured and reference cleaning traces corresponding to raw and integral detection data, respectively, in a similar manner as discussed above with respect to FIGS. 7 and 8, but for a different chamber cleaning process. As with FIGS. 7 and 8, in each of FIGS. 9 and 10, the solid line represents a reference cleaning trace and the dashed line represents a measured cleaning trace. An analysis of FIG. 9 suggests that the endpoints of the measured and reference cleaning traces are almost identical and an analysis of FIG. 10 indicates that the total amount of material etched as shown by the measured and reference cleaning traces is also essentially the same. Analyzing only the endpoints of the measured and reference cleaning traces suggests that the chamber cleaning process is consistent with the "model" chamber cleaning process. However the different shapes of the measured and reference cleaning traces in FIG. 9 suggests the presence of some variability in a process that was performed prior to the chamber cleaning process. The low value of the correlation to the reference trace (92.5%) might imply that an area of the chamber was not cleaned as in the normal reference run and might require some extra clean or different clean settings.

[0053] The foregoing is illustrative of embodiments and examples of the invention, and is not to be construed as limiting thereof. Although a few specific embodiments and examples

have been described with reference to the drawings, those skilled in the art will readily appreciate that many modifications to the disclosed embodiments and examples, as well as other embodiments, are possible without materially departing from the novel teachings and advantages of the invention. For example, although example embodiments described above detail how detection data output by the byproduct detector 106 can be used in an active endpoint detection process to determine whether an endpoint has been reached, it will be appreciated that the aforementioned detection data can be generated and recorded in during a strictly time-based chamber cleaning process (e.g., whereby a chamber cleaning process or process stage is performed for a predetermined amount of time, without regard to the detection data that is obtained and recorded during the cleaning process).

[0054] Further, any of the aforementioned detection data generated and recorded during the time-based cleaning process may be processed in any manner as discussed above (e.g., to provide information on the status or quality of the chamber cleaning process, of the quality of any preceding deposition or etching processes, or the like or any combination thereof.

[0055] Further still, although FIG. 1 illustrates the output of the byproduct analysis processor 108 being communicatively coupled to an input of the system host 110, the output of the byproduct analysis processor 108 may, additionally or alternatively, be coupled to an input of the plasma source 104. In this way, and in embodiments in which the byproduct analysis processor 108 performs the processes described with respect to any of FIGS. 2 and 6, byproduct analysis processor 108 can directly control the operation of the plasma source(s) 104 based, at least in part, on the detection data generated during a chamber cleaning process.

[0056] Accordingly, all such modifications are intended to be included within the scope of the invention as defined in the claims. For example, skilled persons will appreciate that the subject matter of any sentence, paragraph, example or embodiment can be combined with subject matter of some or all of the other sentences, paragraphs, examples or embodiments, except where such combinations are mutually exclusive. The scope of the present invention should, therefore, be determined by the following claims, with equivalents of the claims to be included therein.

WHAT IS CLAIMED IS:

1. A system, comprising:

a byproduct analysis processor for use with a byproduct detector in fluid communication with a foreline of a processing chamber having a plasma source configured to generate a reactive species adapted to clean an interior of the processing chamber during a chamber cleaning process, the processor being configured to:

obtain detection data representing a cleaning byproduct concentration exhausted from an interior of the processing chamber; and

determine an endpoint of the chamber cleaning process based, at least in part, on at least one selected from the group of: a time-derivative of the obtained detection data and a time-integral of the obtained detection data.

2. The system of claim 1, wherein the processor is further configured to process the obtained detection data to determine the at least one selected from the group of: the time-derivative of the obtained detection data and the time-integral of the obtained detection data.

3. The system of claim 1, wherein the processor is configured to determine the endpoint of the chamber cleaning process based, at least in part, on the time-derivative of the obtained detection data.

4. The system of claim 1, wherein the processor is configured to determine the endpoint of the chamber cleaning process based, at least in part, on the time-integral of the obtained detection data.

5. The system of claim 4, wherein the processor is configured to determine the endpoint of the chamber cleaning process when the time-derivative of the obtained detection data is within a predetermined range for a predetermined period of time.

6. The system of claim 1, wherein the processor is configured to determine the endpoint of the chamber cleaning process based, at least in part, on the time-integral of the obtained detection data.

7. The system of claim 6, wherein the processor is configured to determine the endpoint of the chamber cleaning process when the time-integral of the obtained detection data at least substantially constant for a predetermined period of time.

8. The system of claim 1, further comprising the byproduct detector.

9. The system of claim 8, wherein the byproduct detector is a non-dispersive infra-red (NDIR) detector.

10. A system, comprising:

a byproduct analysis processor for use with a byproduct detector in fluid communication with a foreline of a processing chamber having a plasma source configured to generate a reactive species adapted to clean an interior of the processing chamber during a chamber cleaning process, the processor being configured to:

obtain detection data representing a cleaning byproduct concentration exhausted from an interior of the processing chamber;

compare the detection data with reference data associated with the chamber cleaning process; and

output a signal when a result of the comparison indicates a predetermined relationship between the detection data and the reference data.

11. The system of claim 10, wherein the detection data includes at least one selected from the group consisting of: raw detection data output by the byproduct detector, a time-derivative of the raw detection data and a time-integral of the raw detection data.

12. The system of claim 10, wherein the detection data has the predetermined relationship with the reference data when a statistic associated with the detection data is outside a predetermined tolerance range.

13. The system of claim 12, wherein the processor is configured to output a warning signal indicating that a process performed within the processing chamber before the chamber cleaning process was or may have been improperly performed.

14. The system of claim 10, wherein the detection data has the predetermined relationship with the reference data when a statistic associated with the detection data is outside a predetermined fault level.

15. The system of claim 14, wherein the processor is configured to output an interrupt signal indicating that processes performed by the processing chamber should be terminated.

16. The system of claim 10, further comprising the byproduct detector.

17. The system of claim 16, wherein the byproduct detector is a non-dispersive infra-red (NDIR) detector.

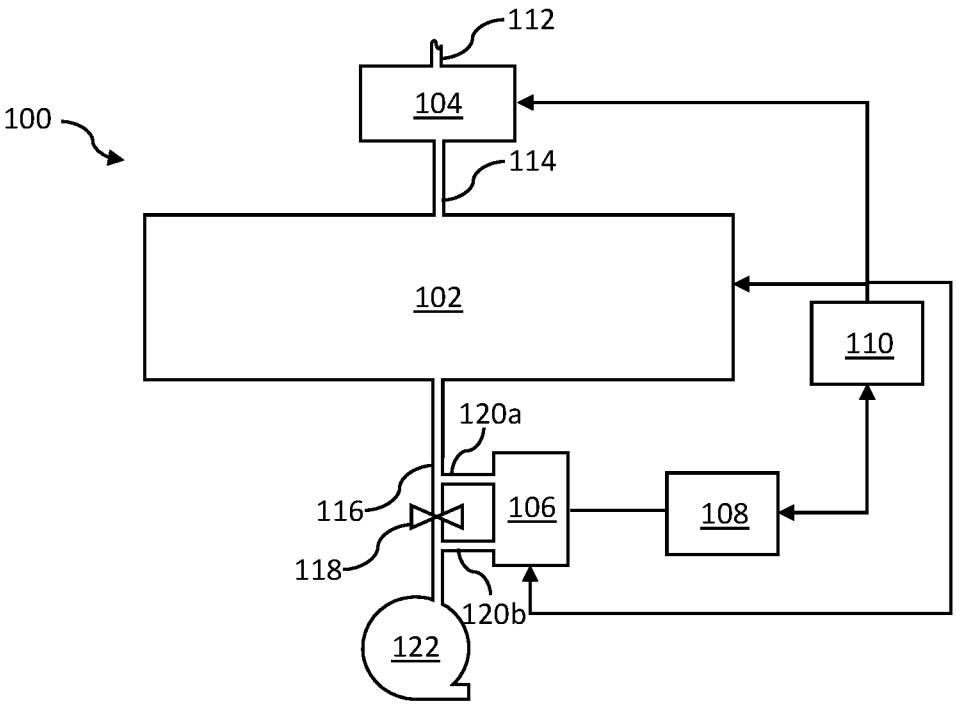


FIG. 1

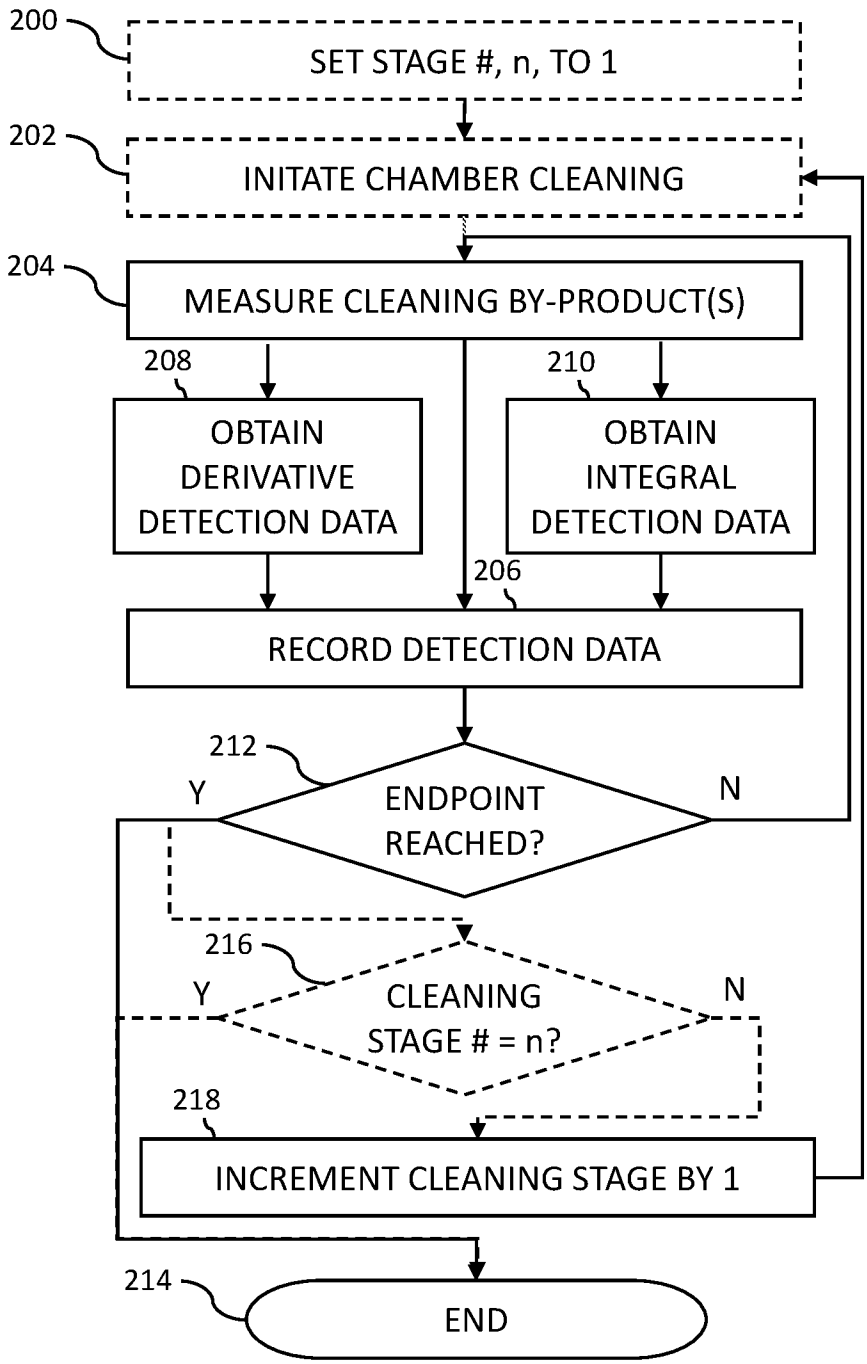

200
SET STAGE #, n, TO 1
202
INITATE CHAMBER CLEANING
204
MEASURE CLEANING BY-PRODUCT(S)
208
OBTAIN DERIVATIVE DETECTION DATA
210
OBTAIN INTEGRAL DETECTION DATA
206
RECORD DETECTION DATA
212
ENDPOINT REACHED?
Y
N
216
CLEANING STAGE # = n?
Y
N
218
INCREMENT CLEANING STAGE BY 1
214
END

FIG. 2

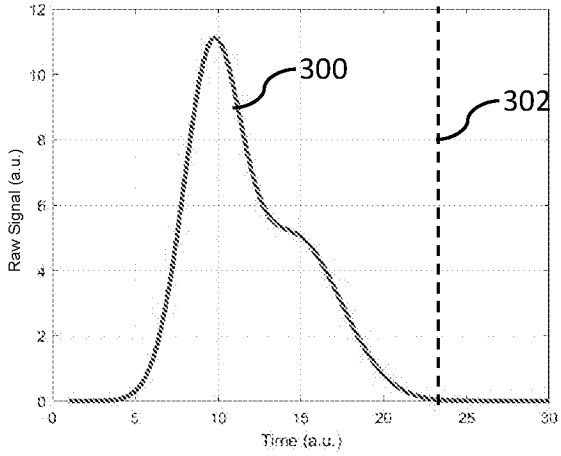


FIG. 3

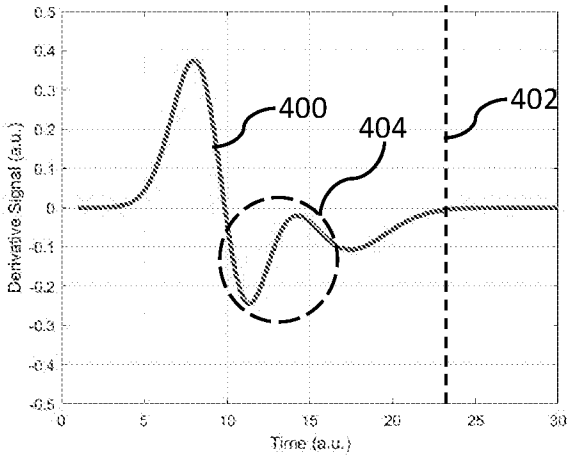


FIG. 4

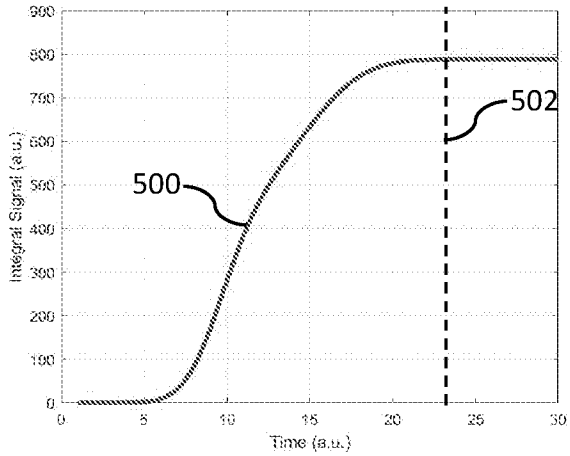


FIG. 5

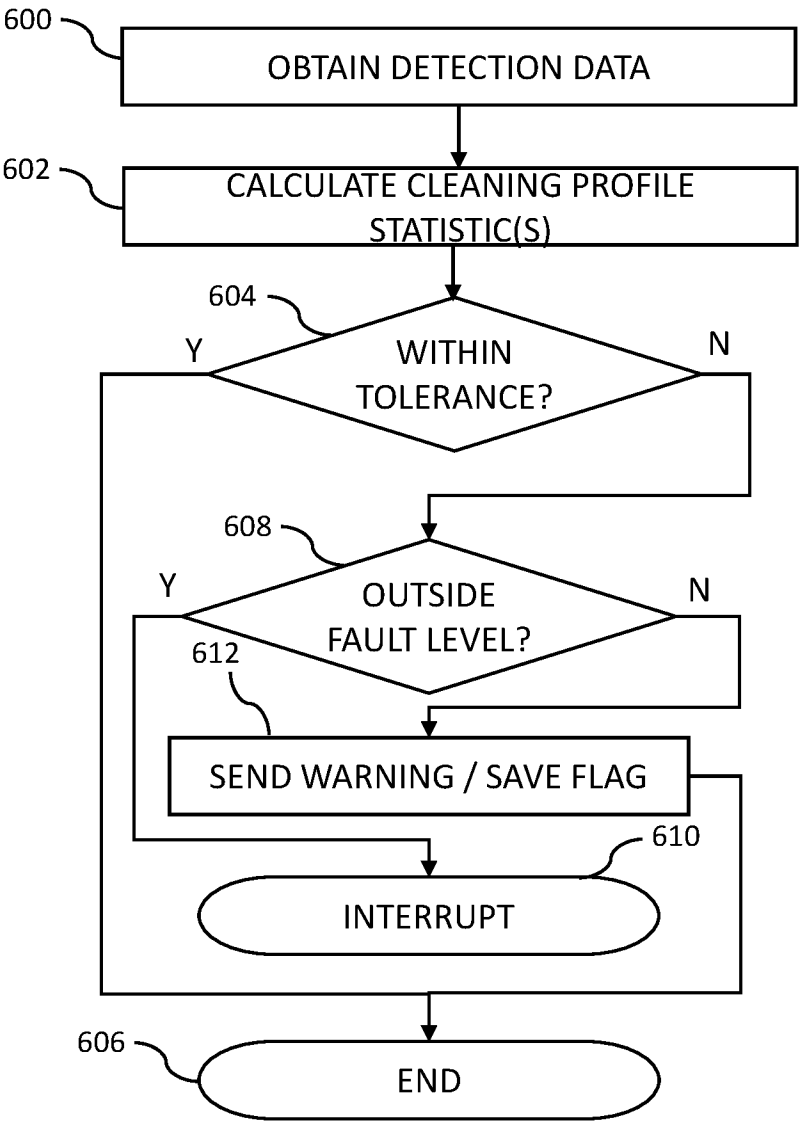

600
OBTAIN DETECTION DATA
602
CALCULATE CLEANING PROFILE STATISTIC(S)
604
WITHIN TOLERANCE?
Y
N
608
OUTSIDE FAULT LEVEL?
Y
N
612
SEND WARNING / SAVE FLAG
610
INTERRUPT
606
END

FIG. 6

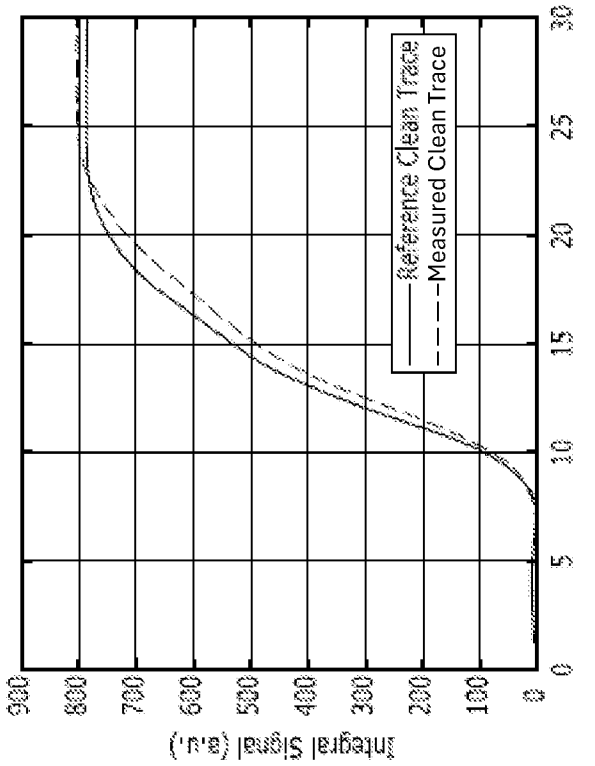

Integral Signal (a.u.)
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
Time (a.u.)
Reference Clean Trace
Measured Clean Trace

FIG. 8

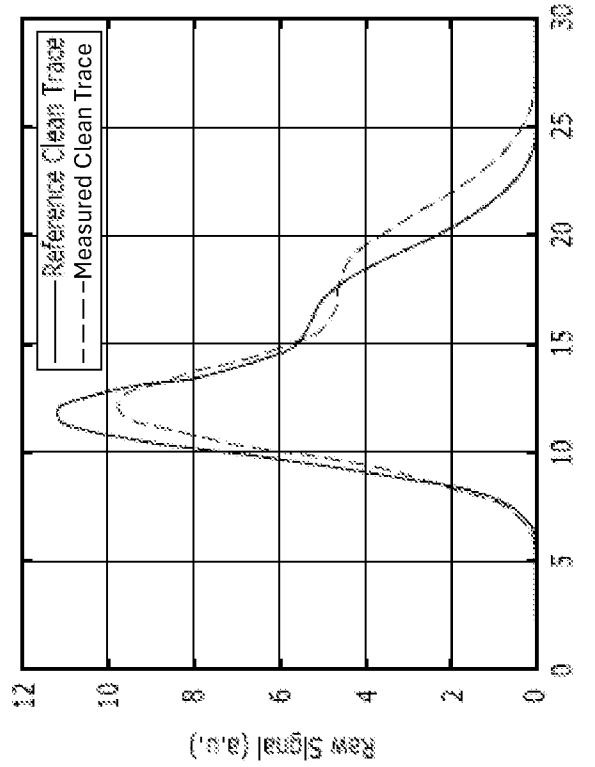

Raw Signal (a.u.)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
Time (a.u.)
Reference Clean Trace
Measured Clean Trace

FIG. 7

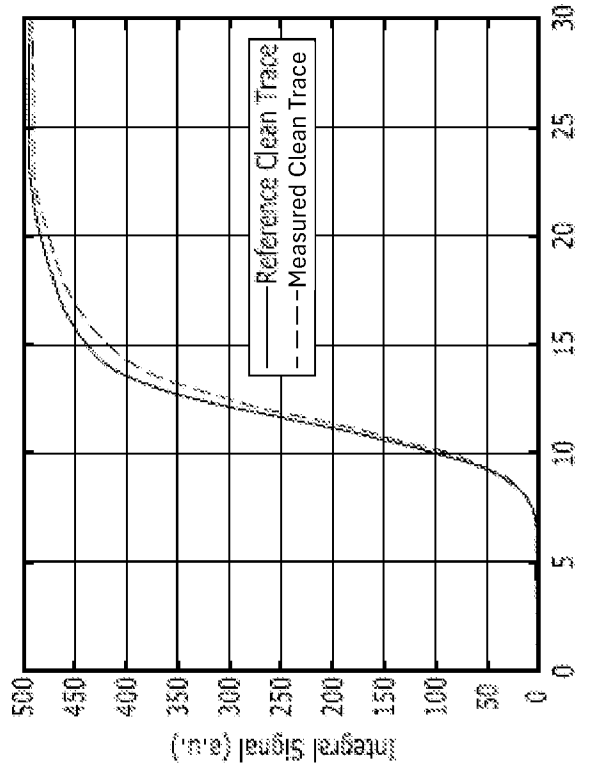

Reference Clean Trace
Measured Clean Trace
Integral Signal (a.u.)
Time (a.u.)
0
50
100
150
200
250
300
350
400
450
500
0
5
10
15
20
25
30

FIG. 10

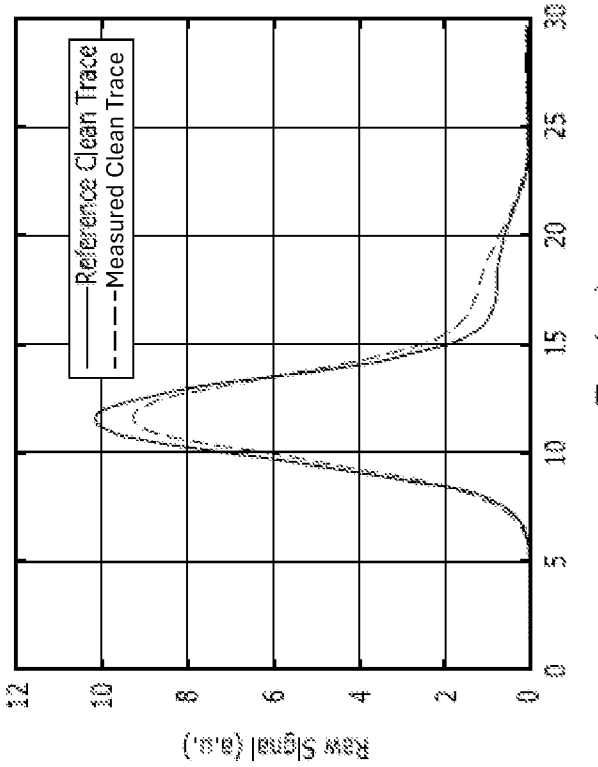

Reference Clean Trace
Measured Clean Trace
Raw Signal (a.u.)
Time (a.u.)
0
2
4
6
8
10
12
0
5
10
15
20
25
30

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/032905

A. CLASSIFICATION OF SUBJECT MATTER

H01J 37/32(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01J 37/32(2006.01); B08B 7/00(2006.01); B44C 1/22(2006.01); C23C 16/22(2006.01); C23C 16/44(2006.01); G01B 11/06(2006.01); G01N 29/07(2006.01); G01N 29/11(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: endpoint, detection, chamber, byproduct, cleaning

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0368794 A1 (HITACHI KOKUSAI ELECTRIC INC.) 24 December 2015 (2015-12-24) paragraphs [0074], [0147], [0178]-[0192] and figures 3, 5, 14	1-9
Y		10-17
Y	US 2004-0235303 A1 (VINCENT WONG et al.) 25 November 2004 (2004-11-25) paragraph [0049] and figure 2	10-17
A	US 2018-0166260 A1 (APPLIED MATERIALS, INC.) 14 June 2018 (2018-06-14) claims 1-9 and figure 1	1-17
A	US 2013-0193108 A1 (BO ZHENG et al.) 01 August 2013 (2013-08-01) claims 1-10 and figures 5A-5C	1-17
A	EP 3792625 A1 (PFEIFFER VACUUM et al.) 17 March 2021 (2021-03-17) claims 1-17 and figure 1	1-17

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2024	**30 September 2024**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2024/032905

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2015-0368794 A1	24 December 2015	JP 6403577 B2	10 October 2018
		TW 201443984 A	16 November 2014
		TW I562215 B	11 December 2016
		US 10724137 B2	28 July 2020
		WO 2014-123028 A1	14 August 2014
US 2004-0235303 A1	25 November 2004	CN 100410421 C	13 August 2008
		CN 1507502 A	23 June 2004
		KR 10-0881045 B1	30 January 2009
		KR 10-2004-0007533 A	24 January 2004
		TW 546707 B	11 August 2003
		US 2003-0000546 A1	02 January 2003
		US 2006-0130873 A1	22 June 2006
		US 6815362 B1	09 November 2004
		US 7028696 B2	18 April 2006
		WO 02-090615 A1	14 November 2002
		WO 02-090615 A9	27 December 2002
US 2018-0166260 A1	14 June 2018	CN 108231518 A	29 June 2018
		CN 108231518 B	12 August 2022
		KR 10-2018-0066869 A	19 June 2018
		KR 10-2519096 B1	05 April 2023
		TW 201830511 A	16 August 2018
		TW I794194 B	01 March 2023
		US 10777394 B2	15 September 2020
US 2013-0193108 A1	01 August 2013	US 8747686 B2	10 June 2014
EP 3792625 A1	17 March 2021	FR 3100847 A1	19 March 2021
		FR 3100847 B1	10 September 2021
		JP 2021-075780 A	20 May 2021