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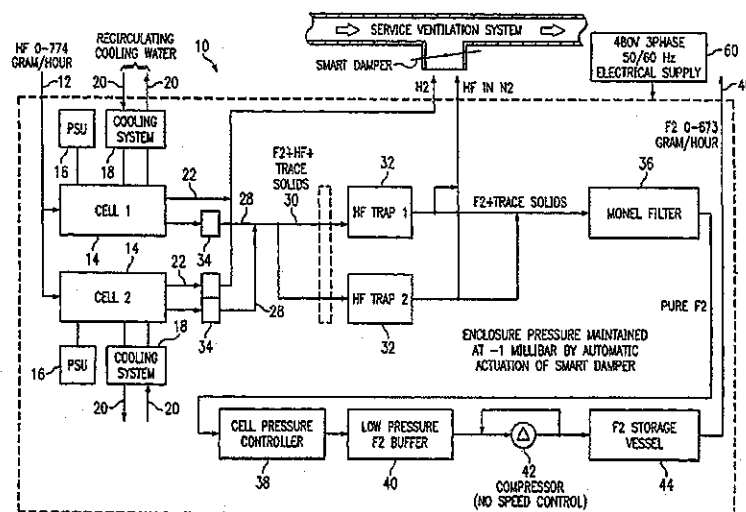
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(54) Title: GENERATION, DISTRIBUTION, AND USE OF MOLECULAR FLUORINE WITHIN A FABRICATION FACILITY



(57) Abstract: An integrated solution to molecular fluorine generation and use at a fabrication facility is disclosed. The integrated solution and portions of the systems and methods include novel aspects. Some embodiments of the method and system described herein can provide the ability to generate molecular fluorine at or near a process tool. Other embodiments of the system and method described herein can comprise a fluorine generator cabinet having multiple fluorine cells. The methods and systems are particularly useful for the fabrication of devices such as microelectronic devices, integrated microelectronic circuits, ceramic substrate based devices, flat panel displays or other devices. In one specific embodiment, F₂ may be generated on-site at a fabrication facility and used to clean a deposition chamber of a process tool.

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DESCRIPTIONGENERATION, DISTRIBUTION, AND USE OF MOLECULAR FLUORINE WITHIN A
FABRICATION FACILITY

TECHNICAL FIELD

The present invention generally relates to systems and methods for purifying gases, process gas generation cabinets, gas distribution systems, containment carts, methods for cleaning process chambers, and methods related to generation and use of molecular fluorine.

DESCRIPTION OF THE RELATED ART

A variety of fluorine-containing gases are used during fabrication or cleaning processes. For example, nitrogen trifluoride (NF_3) gas may be used to etch substrates or clean chambers of process tools used in deposition processes. Some conventional fabrication deposition processes include depositing layers of materials using Chemical Vapor Deposition (CVD), such as Low Pressure Chemical Vapor Deposition (LPCVD), Plasma Enhanced Chemical Vapor Deposition (PECVD), Vapor Phase Epitaxy (VPE), Metalorganic Chemical Vapor Deposition (MOCVD), and the like, or Physical Vapor Deposition (PVD), such as evaporation, sputtering, and the like.

A variety of methods can be used to etch substrates or clean chambers. In one embodiment, a plasma including NF_3 can be used to react with a deposited material on the substrate or on the walls of the chamber. NF_3 has problems in that it is available in limited supply and at a high cost

Diatomic fluorine (F_2) can be produced by the electrolysis of hydrogen fluoride (HF) and a salt. F_2 is produced at the anode of a fluorine generation cell. F_2 produced by a fluorine cell is typically passed through an inorganic, nonvolatile absorbent material, such as sodium fluoride (NaF) or the like, to remove residual HF and then through a filter to remove particulates.

Typical prior art fluorine generation cells provide an F_2 and HF mixture to a single large HF trap. The HF trap can comprise NaF or other suitable material to remove HF from the F_2 . The large single HF trap because as the HF trap will eventually become saturated and, consequently, will need to be shut down and regenerated.

Prior art methods for regenerating the single HF trap can interfere with continuous operations, such as those seen in the semiconductor industry. Further, prior art HF traps are typically purged with nitrogen during the regeneration process. Purging with nitrogen can introduce contaminants that can dilute the F_2 .

Not only are currently existing fluorine systems very large systems, but because F_2 is a highly toxic gas, they also require complex treatment (abatement) systems. The most common treatment systems are not space or cost efficient because of the considerable utility, space requirements, and up-front installment expenses associated with them. Further, standard procedures for handling fluorine

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abatement usually require separate and independent abatement systems for each fluorine generator, further increasing costs to a fabrication plant operator.

A general belief is that absorbent materials used for abatement are inferior to other treatment methods because their efficiency rapidly decreases due to the formation of a surface coating of reaction products. A continued flow of air through a fluorine abatement system will expose the absorbent material in the fluorine abatement system to moisture and other contaminants, which can break down the absorbent material.

Further, prior art fluorine generation systems typically require, for a bulk distribution system, a very large on-site fluorine storage tank. Storing large amounts of F_2 on-site is a very important safety concern because of fluorine's corrosive nature. A large, expensive prior art abatement system is used in the event of a breach. A further disadvantage of using one large fluorine generator is that the gas feed lines must be maintained at a positive pressure. Therefore, if a leak occurs in an F_2 gas feed line, the large, expensive prior art abatement system encompasses all of the gas lines from the single tank to the point of use.

Another problem associated with the generation of a process gas, such as F_2 , is the use of hazardous liquids, which require secondary containment, both in transportation and for on-site storage. A standard prior art secondary containment system consists of constructing a containment dike around the affected equipment with the containment dike capable of containing 110% of the hazardous liquid. However, constructing a secondary containment around a very large piece of equipment can be expensive and difficult. Further, a typical fluorine generation cell weighs approximately 1,000 pounds. If a cabinet containing the fluorine generator is located behind a secondary containment, such as the dike discussed above, the fluorine generation cell will require heavy equipment to maneuver it into place inside the cabinet. For example, a forklift may be required, which requires significant maneuvering room (e.g., approximately ten feet) around the fluorine generator cabinet. Such open spaces can be difficult to find or expensive to maintain.

SUMMARY

The conceptual groundwork involves providing safe delivery of hazardous materials for fabrication processes. An integrated solution to molecular fluorine generation and use at a fabrication facility is described herein. The integrated solution and portions of the systems and methods include novel aspects. Therefore, the invention is not to be construed only as the total integrated system or only limited to very specific uses.

Some embodiments of the method and system described herein can provide the ability to generate a process gas, such as molecular fluorine, at or near a fabrication facility more efficiently and at a lower cost than prior art methods. Those embodiments can thus reduce or eliminate the hazards associated with the transportation, storage and handling of cylinders containing toxic gas under high

pressure, as is currently required by prior art methods and systems for generation and distribution of process gases.

Other embodiments of the system and method described herein can comprise a fluorine generator cabinet having multiple fluorine cells. In one embodiment, the fluorine generator cabinet can have two fluorine cells, the idea being that at least one of the fluorine cells is in operation at all times, while one or more of the other cells is regenerating. This configuration provides system redundancy so that process gas generation can be maintained in the event a cell requires maintenance or in the event of a cell failure.

A distribution system may be coupled to the fluorine generator and operable to distribute desirable quantities and concentrations of molecular fluorine to one or more process tools. As such, molecular fluorine may be used during a fabrication process for the fabrication of devices such as microelectronic devices, integrated microelectronic circuits, ceramic substrate based devices, flat panel displays or other devices which may be fabricated as described herein.

In a first aspect of this invention, there is provided a system for continuous purification of a gas flow comprising:

- a first HF trap coupled to a gas supply line, wherein the gas supply line conducts the gas flow;
- a second HF trap coupled to the gas supply line in parallel to the first HF trap; and
- a switching mechanism operable to switch gas flow from the first HF trap to the second HF trap at the occurrence of a predefined event.

In a second aspect of this invention, there is provided a method for purifying fluorine gas comprising:

- directing a fluorine gas flow to a first HF trap;
- determining if the first HF trap is approximately saturated; and
- if the fluorine trap is determined to be approximately saturated:
 - switching the fluorine gas flow to a standby HF trap;
 - regenerating the first HF trap; and
 - replacing the first HF trap.

In a third aspect of this invention, there is provided a process gas generation cabinet comprising:

- a cabinet housing encompassing a process gas generator, the housing further comprising:
 - one or more input vents to direct air to the process gas generator;
 - a normal output port; and
 - an emergency output port; and
 - an exhaust system comprising:
 - an exhaust channel;
 - a normal operating channel coupled to the normal output port and the exhaust channel,
- the normal operating channel further comprising a normal operating valve;

an emergency channel coupled to the emergency output port of the cabinet housing and the exhaust channel, the emergency channel further comprising:

an emergency exhaust valve; and

an absorbent packed material ; and

a fluorine sensor located upstream from the normal operating valve, the fluorine sensor operable to close the normal operating valve and open the emergency exhaust valve if fluorine levels in the cabinet housing exceed a preset level.

In a fourth aspect of this invention, there is provided a gas distribution system comprising:

a process gas generator;

a gas routing mechanism connected to the process gas generation system;

a negative pressure storage tank connected to the gas routing mechanism, the negative pressure storage tank operable to store process gas produced by the process gas generator;

a negative pressure line coupled to the negative pressure storage tank;

a compressor coupled to the negative pressure line operable to:

draw process gas from the negative pressure storage tank;

compress the process gas to produce a positive pressure process gas; and

output the positive pressure process gas; and

a positive pressure storage tank in fluid communication with the compressor, the positive pressure storage tank operable to store the positive pressure process gas.

In a fifth aspect of this invention, there is provided a gas distribution system comprising:

a process gas generator;

a gas routing mechanism connected to the process gas generation system;

a negative pressure storage tank connected to the gas routing mechanism, the negative pressure storage tank operable to store process gas produced by the process gas generator;

a negative pressure line coupled to the negative pressure storage tank;

a plurality of compressors coupled to the negative pressure line, each of the plurality of compressors operable to:

draw process gas from the negative pressure storage tank;

compress the process gas to produce a positive pressure process gas; and

output the positive pressure process gas; and

a positive pressure storage tank associated with each of the plurality of compressors, each positive pressure storage tank in fluid communication with the associated compressor, and wherein each positive pressure storage tank is operable to store the positive pressure process gas received from the associated compressor.

In a sixth aspect of this invention, there is provided a containment cart comprising:

a liquid-tight outer container configured to store a process gas generation cell containing an electrolyte liquid, the liquid-tight outer container sized to contain the process gas generation cell and at least all the electrolyte liquid inside the process gas generation cell, wherein the outer container comprises a material inert to the electrolyte liquid; and

rolling hardware coupled to the bottom surface of the liquid tight container.

In a seventh aspect of this invention, there is provided a method for cleaning a process chamber for semiconductor or flat panel display manufacturing, comprising the steps of:

converting a feed gas to a cleaning gas in a remote location, wherein the feed gas does not clean the process chamber; and

delivering the cleaning gas to the process chamber.

In an eighth aspect of this invention, there is provided a method for generating and using a fluorine-containing compound comprising:

reacting a fluorine-containing reactant in a first reactor to form a first fluorine-containing compound; and

flowing the first fluorine-containing compound to a second reactor, wherein the first and second reactors are located at a fabrication facility.

In a ninth aspect of this invention, there is provided a method for using a first process tool comprising:

placing a first substrate within a chamber of the first process tool;

reacting a fluorine-containing reactant in a reactor to form molecular fluorine;

generating a fluorine-containing plasma from the molecular fluorine, wherein generating is performed in a plasma generator that is located outside the chamber; and

flowing the first fluorine-containing plasma to the chamber while the substrate is in the chamber, wherein reacting and flowing are performed simultaneously during at least one point in time.

In a tenth aspect of this invention, there is provided a method for using a chamber comprising:

flowing molecular fluorine to a chamber; and

generating a fluorine-containing plasma using the molecular fluorine, wherein generating the fluorine-containing plasma is performed within the chamber.

The foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as defined in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the accompanying figures.

FIG.1 includes a simplified block diagram of one embodiment of the system and process flow for on-site generation and distribution of a process gas;

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FIG. 2 includes a simplified block diagram of another embodiment of the method and system for providing on-site generation and distribution of a process gas at or near a fabrication facility;

FIG. 3 includes a more detailed block diagram of an embodiment of the system for on-site generation and distribution of a process gas;

FIG. 4 illustrates one embodiment of a process gas generation cabinet incorporating a dual exhaust system;

FIG. 5 illustrates the air flow through cabinet of FIG. 4 under an emergency breach situation;

FIG. 6 includes a simplified, diagrammatic representation of a bulk distribution system for fluorine, or other process gas;

FIG. 7 shows one embodiment of a secondary containment system (cart) housing a process gas generation cell;

FIG. 8A shows a view and front face elevation of one embodiment of the cabinet of FIG. 4;

FIG. 8B shows a front view of the interior of one embodiment of the cabinet of FIG. 4;

FIG. 8C shows a sectional side view of one embodiment of the cabinet of FIG. 4;

FIG. 9A shows a plan view from the top of one embodiment of the cabinet of FIG. 4;

FIG. 9B shows a plan on top of the cabinet with the top of the enclosure removed to show the interior of the cabinet of FIG. 4;

FIG. 9C shows a plan on the process gas compression, purge, and cooling systems of one embodiment of the cabinet of FIG. 4; and

FIG. 9D shows a plan on the process gas generation cells, filters, and hydrogen fluoride traps of one embodiment of the cabinet of FIG. 4.

FIG. 10 includes an illustration a system for on-site generation and distribution of molecular fluorine according to an embodiment described herein.

FIG. 11 includes a process flow diagram for the on-site generation and distribution of a fluorine-containing compound according to an embodiment described herein.

FIG. 12 illustrates a method for generating and distributing fluorine for a fabrication process according to one embodiment of the present invention;

FIGs. 13 and 14 includes process flow diagrams for generating and using a fluorine-containing compound according to embodiments described herein.

Skilled artisans appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the present invention.

DETAILED DESCRIPTION

Reference is now made in detail to the exemplary embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts (elements).

The conceptual groundwork involves providing safe delivery of hazardous materials for fabrication processes. The embodiments of the method and system described herein can provide the ability to generate a process gas, such as molecular fluorine, at or near a fabrication facility more efficiently and at a lower cost than prior art methods. The embodiments can thus reduce or eliminate the hazards associated with the transportation, storage and handling of cylinders containing toxic gas under high pressure, as is currently required by prior art methods and systems for generation and distribution of process gases.

The embodiments can also provide a compact and fully automated (one-button) system for generating high-purity process gases on demand at or near a fabrication facility. For example, the embodiments can generate molecular fluorine gas only as required by one or several fabrication tools, such as chemical vapor deposition ("CVD") reactors. The "supply only when needed" ability of the embodiments can dramatically reduce the amount of on-site process gas required when compared to

prior art systems that maintain large inventories of process gas cylinders. Further, embodiments can reduce or eliminate disadvantages and problems of prior art systems for containment of toxic liquids associated with the generation of a process gas and can reduce the abatement system requirements needed to safely treat generated process gases in the event of a process gas leak.

The embodiments of the system and method described herein can comprise a fluorine generator cabinet having multiple fluorine cells. In one embodiment, the fluorine generator cabinet can have two fluorine cells, the idea being that at least one of the fluorine cells is in operation at all times, while one or more of the other cells is regenerating. This configuration provides system redundancy so that process gas generation can be maintained in the event a cell requires maintenance or in the event of a cell failure.

A distribution system may be coupled to the fluorine generator and operable to distribute desirable quantities and concentrations of molecular fluorine to one or more process tools. As such, molecular fluorine may be used during a fabrication process for the fabrication of devices such as microelectronic devices, integrated microelectronic circuits, ceramic substrate based devices, flat panel displays or other devices which may be fabricated as described later in this specification.

A molecular fluorine generator may come in a variety of sizes to fit better the desires of the particular fabrication facility. The generator may service one process tool, a plurality of process tool along a process bay, the entire fabrication facility, or nearly any other configuration within the facility. The process can be used in conjunction with a fabrication or cleaning operation. The process is particularly well suited for cleaning deposition chambers as used in the microelectronics industry.

A few terms are defined or clarified to aid in understanding the descriptions that follow. The term "fabrication facility" is intended to a facility where microelectronic components, assemblies, or modules are fabricated. An example can include a semiconductor wafer fabrication facility, an integrated circuit assembly or packaging facility, a microelectronic module assembly facility, thin-film transistor liquid crystal or flat panel display fabrication facility, or the like. Fabrication facility is not intended to include a chemical plant, plastics manufacturing facility (where microelectronic devices are not produced), or nuclear fuel process plant within its definition.

The term "lot" is intended to mean a unit comprising a plurality of substrates that are processed together (substantially at the same time or sequentially) through the same or similar process operations. Within a fabrication facility, substrates are usually processed on a lot-by-lot basis. The size of a lot may vary, but are usually no greater than approximately 50 substrates.

The term "molecular fluorine" is intended to mean a molecule that only contains fluorine atoms. F_2 is an example of molecular fluorine.

The term "process bay" is intended to mean a room of a fabrication facility where substrates may be transported between process tools.

The term "process tool" is intended to mean a piece of equipment that has at least one reactor in which substrates are capable of being processed.

The term "reactor" is intended to mean an apparatus where chemical bonds are changed. Chemical bonds may be made or broken (decomposition or plasma generation). An example includes an electrolytic cell, a process chamber, plasma generator, or the like. A non-limiting example of a process chamber includes a semiconductor process chamber, such as a chemical or physical vapor deposition chamber.

The term "utility bay" is intended to mean an area adjacent to a process bay where utilities are supplied to process tools, and where mechanical service to the process tools may be made without entering the process bay. The utility bay can be located between immediately adjacent process bays or below the process bay. The process bays may be located within a clean room, and utility bays may be located may be located outside the clean room or within the clean room but at a location not as clean as the process bays.

As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, process, article, or apparatus that comprises a list of elements is not necessarily limited only those elements but may include other elements not expressly listed or inherent to such process, process, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

Attention is now directed to details of non-limiting embodiments. Embodiments described herein can comprise one or more fluorine generators producing molecular fluorine, such as F_2 , through the electrolysis of HF in an electrolytic salt. This process is extremely efficient and can produce high-purity F_2 and diatomic hydrogen (H_2), with the F_2 directed to process tools and the H_2 directed to an exhaust system. Further, the embodiments are capable of delivering a process gas, such as molecular fluorine, at both sub-atmospheric (negative) and super-atmospheric (positive) pressure. Embodiments are also capable of producing varying amounts of a process gas on demand. A typical on demand production amount can be in the range of approximately 125 to 700 grams per hour. The embodiments of the method and system can provide for in-fab, on-tool, or fab-wide generation and distribution of a process gas. Embodiments can also comprise a fully automated programmable logic controller ("PLC") controlled system with a touch-screen operator interface. The interface can be a hardware-based interface with faults and alarms. Further, a PLC embodiment can be capable of interfacing with a process tool and can be housed in its own compact, self-contained cabinet.

The embodiments of the system and method can comprise a fluorine generator cabinet having multiple fluorine cells. In one embodiment, the fluorine generator cabinet can have two fluorine cells,

the idea being that at least one of the fluorine cells may be in operation at all times, while one or more of the other cells is being regenerating. This configuration provides system redundancy so that process gas generation can be maintained in the event cell maintenance or in the event of a cell failure.

FIG. 1 is a simplified block diagram of one embodiment of the system and process flow for on-site generation and distribution of a process gas. Process gas generation system 10 includes input supply line 12 to process gas generation cells 14. In one embodiment, input supply line 12 can be used to supply HF to an electrolyte within process gas generation cells 14. The process gas generated by process gas generation cells 14 can be F_2 and the electrolyte within process gas generation cells 14 can be HCl, potassium bichloride and HF. Alternatively, the electrolyte may include HF and potassium fluoride. During operation, the cells 14 can produce F_2 gas and trace amounts of H_2 . Some percentage of HF is also output from process gas generation cells 14 with the F_2 and H_2 .

Each process gas generation cell 14 can be coupled to a pressure sensing unit 16 and a cooling system 20. Pressure sensing unit 16 monitors the pressure within a process generation cell 14. Cooling system 18 provides cooling to its respective process generation cell 14 using recirculating cooling water through cooling water lines 20. Although not shown, the cells 14 may fitted with a steam heating coil, and associated plumbing such as a submersible pump, and a feed pipe for adding HF to the electrolyte within the tank. With heating, cooling, or both, the on-site fluorine generator 100 may be maintained at a constant temperature. For example, cooling of an electrolyte may be performed by using cooling or heating tubes placed in the electrolyte of an electrolytic cell and/or by cooling the outer walls of the electrolytic cell.

H_2 is output from each process gas generation cell 14 along hydrogen output line 22. Combined hydrogen output header 24 is coupled to and receives H_2 from each hydrogen output line 22. Hydrogen output header 24 is coupled to exhaust system 25. H_2 is routed to exhaust system 25 and then to service ventilation system 26, which exhausts the H_2 to the outside atmosphere.

F_2 , including trace amounts of HF and trace solids, is output from process gas generation cells 14 along process gas output lines 28 to a combined process gas output header 30. Each process gas generation cell 14 can further comprise an output manifold 34, shown as a separate unit in FIGs. 1, 2, and 3, but which can be integral to a process gas generation cell 14. Process gas (including F_2) flows through an output manifold 34 before being directed to combined gas output header 30. As is more clearly shown in FIG. 3, process gas generation system 10 can further comprise various valves operable in various open/closed combinations, to direct process gas from each manifold 34 to one or another (or to multiple) HF traps 32. Process gas output header 30 is coupled as an input to each of multiple HF traps 32.

Although FIG. 1 shows only two HF traps 32, embodiments can comprise multiple HF traps, as may be desired for a given application. The process gas is thus output from process gas generation

cells 14 to one or another HF trap 32 through a manifold 34. Manifolds 34 can be used to route a process gas to either of HF traps 32, such that if either HF trap is out of service for regeneration or repair, the other can receive process gas from either process gas generation cell 14.

The sodium fluoride in HF traps 32 reacts with the trace amounts of HF to trap the HF and remove it from the process gas mixture. By using multiple contaminant traps 32, the embodiments can avoid the costly shutdowns of fluorine generation system 10 required by prior art methods to regenerate or maintain the containment traps. HF traps 32 are contemplated to be small and compact units. In operation, one HF trap 32 is always on-line, with the other HF trap 32 (or other ones) regenerating or being maintained. Manifolds 34 in combination with valves and valve control systems (as known in the art), are operable to route process gas from a fluorine generation cell 14 to an operable HF trap 32, and thus keep generation system 10 operational.

While the description herein is made with reference to molecular fluorine gas generation, it is contemplated that other process gasses can be generated using the embodiments of the method and system. In operation, the F_2 provided to an HF trap 32 contains trace amounts of HF, which are removed by the HF trap 32. Eventually the sodium fluoride in the HF trap 32 can become saturated by the removed HF. The HF trap 32 can then be regenerated to return it to operation. When this occurs, process gas generation system 10 can be configured to route the process gas to another HF trap 32, e.g., a secondary HF trap 32. Process gas generation system 10 can thus continue to operate while the first HF trap 32 is regenerated.

Regeneration of an HF trap 32 can comprise heating the sodium trap to approximately 300 degrees, generating a vacuum at the HF trap 32 to remove impurities, and then placing the HF trap 32 in standby mode. In a similar manner, when a next HF trap 32 becomes saturated, the system can be switched back to the first HF trap 32 while the next HF trap 32 is regenerated. The system can then switch back and forth between HF traps 32 without interrupting the process gas flow.

Embodiments can include, as part of a control mechanism, a switching mechanism to insure that the process gas is directed to an operational HF trap 32 at any given time. Process gas generation system 10 can further comprise a control platform and switching mechanism that can detect when one HF trap is full and switch the system to a standby trap.

As part of regenerating an HF trap 32, embodiments of the method and system can purge the HF trap 32, once heated, by generating a vacuum on the trap. This process is unlike that of prior art systems that purge the HF trap 32 with diatomic nitrogen (N_2). Purging with N_2 can introduce contaminants to the process gas and thus dilute the process gas provided to a process tool. Providing a pure molecular fluorine gas product (or any other process gas) to a process tool is very important to the semiconductor industry because even tiny amounts of a contaminant can create adverse results in a fabricated product. Embodiments avoid purging HF traps 32 with nitrogen to avoid introducing

impurities to the process gas, and can instead pull a vacuum on an HF trap 32 to remove HF impurities from the HF trap 32.

Embodiments can also comprise a nitrogen purge mechanism (as will be shown in greater detail as part of FIG. 3). A nitrogen purge can be used when all of the HF traps 32 have reached the end of their useful lives, or when performing a scheduled maintenance on the overall process gas generation system 10. When all of the HF traps 32 are replaced, it is desirable to purge process gas generation system 10 to remove any contaminants introduced while the system piping was open.

Returning now to FIG. 1, at the output of HF traps 32, molecular fluorine gas, including small amounts of trace solids, is output through output filter 36 and provided to either a low pressure buffer tank 40 or directly to a compressor. Both of these embodiments are shown, respectively, in FIGs. 1 and 2. As shown in FIG. 1, filtered F_2 gas is output from filter 36 and forwarded to cell pressure controller 38. Cell pressure controller 38 can cycle process gas generation cells 14 on and off based on process gas demand as measured at the input to low pressure buffer tank 40. F_2 gas is provided to buffer tank 40 through cell pressure controller 38, and from low pressure buffer tank 40, F_2 is provided to compressor 42. Compressor 42 is coupled to low pressure buffer tank 40 and, at its output, to process gas storage tank 44. Compressor 42 compresses the F_2 gas to, for example, about 100 kilopascals (KPa) or 15 psi in process gas storage tank 44. From process gas storage tank 44, the process gas can be provided to one or more process tools via process gas feed line 46. Process gas feed line 46 can be at positive pressure.

Output filter 36 can be a monel filter or other suitable filter as known to those in the art. Compressor 42 can be a non-speed controlled compressor. Cell pressure controller 38 can be any cell pressure controller as known to those in the art.

Although not shown in FIGs. 1 and 2, process gas generation system 10 can include other commonly used piping components as known to those in the art, such as regulator valves, seal pots, pressure transducers, thermal couples, miscellaneous filters at various points in the gas piping, and a valve control system. The valves can be air-operated valves as known to those in the art.

FIG. 2 is a simplified block diagram of another embodiment of the method and system for providing on-site generation and distribution of a process gas at or near a fabrication facility. FIG. 2 is in most respects, identical to FIG. 1. The notable exception between the two figures is that downstream of output filter 36, F_2 gas is provided directly to compressor 50, and from compressor 50 directly to process gas storage tank 44. Compressor 50 can be speed-controlled to maintain pressure at process gas generation cells 14 at a set value, which can be arbitrarily determined for a given application. As in FIG. 1, molecular fluorine gas is provided from process gas storage tank 44 to one or more process tools via process gas feed line 46. The embodiments of FIGs. 1 and 2 can provide process gas to process tools at a positive pressure. Process gas generation system 10 of FIGs. 1 and 2

can also include a power supply, such as a 480 volt, three-phase 50/60 hertz electrical power supply 60, to provide electrical power to the electrical components of process gas generation system 10.

Embodiments of the method and system for on-site generation and distribution of a process gas can produce F_2 or another process gas at a set pressure, for example, at a maximum pressure of approximately 80 Pa or 8 millibars gauge pressure. Compressors 42 and 50 of FIGs. 1 and 2, respectively, can be configured to maintain the pressure at process gas generation cells 14 at or below the set pressure to assure the flow of process gas from process gas generation cells 14. For example, compressors 42 and 50 can have suction capability of, for example, approximately minus 50 Pa or minus 0.5 bars gauge pressure. In the embodiment of FIG. 1, compressor 42 is located between a low-pressure fluorine buffer tank 40 upstream of its inlet and a high pressure process gas storage tank 44 downstream of its outlet. Cell pressure controller 38 (of FIG. 1) upstream of low-pressure buffer tank 40 can be set to cycle (e.g., vary the pumping rate of) compressor 42 only when the pressure as measured at process gas generation cells 14 is above a setpoint determined to ensure that compressor 42 does not continue to operate when electrolysis (process gas generation) is off. This set point could, for example, be set at approximately minus 10 KPa or minus 100 millibars gauge pressure. Compressor 42 is cycled to maintain vacuum at low pressure buffer tank 40 (and hence at process gas generation cells 14) and to maintain a set pressure at process gas storage tank 44.

Embodiments of the process generation system 10 can produce, for example, up to approximately 700 grams per hour of a process gas, such as F_2 . Further, process gas storage tank 44 can be, for example, a nominal 125 to 250 liter storage tank maintained at about 100 KPa or 15 psig. HF conversion efficiency at process gas generation cells 14 is on the order of about 1 kilogram of F_2 for every 1.15 kilograms of HF. Embodiments are capable of producing 99.9999 percent pure F_2 with less than 100 parts per billion total metals, and with less than 10 parts per billion sodium, cadmium and potassium impurities.

FIG. 3 is a slightly more detailed block diagram of an embodiment of the system for on-site generation and distribution of a process gas. Process gas generation system 100 of FIG. 3 is the equivalent of the process gas generation 10 shown in FIGs. 1 and 2. Process gas generation system 100, however, includes various additional components, as known to those in the art, for the proper operation of a process gas generation system. These components include valves 110, pressure transducers 120, thermocouples 130, level sensors 140, sample cylinders 150, filters 160 and various interconnecting piping and manifolds. FIG. 3 is an exploded diagrammatic view of the simplified process gas generation systems 10 of FIGs. 1 and 2.

Other embodiments can comprise a fluorine generator housed in a single enclosure. The enclosure can comprise a cabinet coupled to a vacuum source operable to maintain air flow through the cabinet, for example, at a velocity of approximately 45 to 60 meters per minute or 150 to 200 feet per minute at any cabinet opening. The cabinet can thus be maintained at a negative pressure. The

vacuum source can be part of a cabinet abatement system having the capacity to treat the accidental release of process gas from any part of the generator or cabinet. The air flow through the cabinet is exhausted to the abatement system, which can be capable of neutralizing any process gas release up to the maximum amount of gas designed to be present at any time in the generator or its cabinet.

Embodiments can comprise a cabinet having an integrally housed abatement system to handle the accidental release of a process gas. For example, one embodiment can comprise a fluorine abatement system (FAS) placed in line with the main house exhaust of a fabrication facility. The effluent gas stream from the fluorine generator cabinet can be configured to always run through the fluorine abatement system and then to the house exhaust system for further treatment. An alternative embodiment can comprise an exhaust configuration such that the FAS can be inactive during normal operation and placed on-line (activated) only when an accidental release of a process gas has occurred inside of the cabinet. This can be accomplished using an electronic valve triggered by a process gas (e.g., fluorine) sensor to direct cabinet exhaust through alternate paths of a dual-exhaust system. Such a process gas sensor is well known in the art and commonly available.

A dual-exhaust FAS cabinet embodiment is preferred because of back pressure and moisture concerns that arise when running an air stream constantly through a fluorine abatement system. This is because moisture in the air flowing through the absorbent materials in a FAS can degrade the absorbent material regardless of whether or not a process gas, such as F_2 , is present in the exhaust air passing through the material. Therefore, it is desirable to have the least possible amount of air flow through the FAS during normal (non-leaking) operations.

FIGs. 4 and 5 illustrate one embodiment of a process gas generator cabinet 200 incorporating a dual exhaust system. Cabinet 200 of FIG. 4 houses a fluorine generator, such as described in the embodiments of FIGs. 1, 2 and 3. The cabinet 200 can include vents 210 for receiving intake airflow 220, which circulates through the interior of cabinet 200 and is output through, in normal operation, normal operating valve 230. After passing through normal operating valve 230, exhaust 240 is forwarded through connecting piping coupled to cabinet 200 to house exhaust system 250. House exhaust system 250 can carry cabinet exhaust 240, as well as various other fabrication facility exhausts, to the outside atmosphere. House exhaust system 250 can pass through various other filtering components before venting to the outside atmosphere. House exhaust system 250 can correspond to, for example, service ventilation system 26 of FIGs. 1 and 2.

The embodiments of the method and system for on-site generation and distribution of a process gas contemplate that there will be no purposeful venting of large amounts of a process gas to the atmosphere. As shown in FIGs. 4 and 5, there is no purposeful venting of process gas (F_2) into either cabinet 200 or into the room housing cabinet 200. For example, when switching from one HF trap 32 to another HF trap 32, vacuum is pulled on the regenerating HF trap 32 and minute amounts of F_2 from the HF inside HF traps 32 can be brought into exhaust 240. It is contemplated that the amounts

of F_2 and HF brought into house exhaust 250 by exhaust 240 during such a regeneration event can be adequately handled by the house exhaust system 250 abatement system. Unlike the prior art, embodiments do not require large and complex external absorbers because large amounts of process gas are not dumped into either the room containing cabinet 200 or into house exhaust system 250. Under normal operating conditions, there is no substantial amount of fluorine in the atmosphere outside or inside of cabinet 200 housing process gas generation system 10.

Fluorine sensor 260 can be used to control normal operating valve 230 and emergency exhaust valve 270 to determine the path of the air flow of cabinet 200. During normal operation, exhaust 240 passes through normal operating valve 230 before being forwarded to house exhaust system 250. If, however, fluorine sensor 260 detects fluorine above a preset level in the cabinet air, fluorine sensor 260 can shut normal operating valve 230 and open emergency exhaust valve 270 to direct exhaust flow 240 through absorbent packed exhaust 280. This configuration is illustrated in FIG. 5, which shows the air flow through cabinet 200 during an emergency breach situation wherein air and fluorine gas are exhausted from cabinet 200. Normal operating valve 230 and emergency exhaust valve 270 can be electronic gate valves, or air-activated valves, as known to those in the art. Process gas generation system 10 within cabinet 200 can further comprise an appropriate valve control system as known in the art.

As shown in FIG. 5, exhaust 240 comprises a molecular fluorine gas and air mixture prior to passing through absorbent packed exhaust 280. After flowing through absorbent packed exhaust 280, however, exhaust 240 comprises air with only trace amounts of molecular fluorine which can then be vented to house exhaust system 250. The absorbent material in absorbent-packed exhaust 280 can be recharged or replaced to restore its effectiveness. The embodiments can further be configured such that fluorine sensor 260 is operable to shut down process gas generation system 10 if it detects fluorine in the interior of cabinet 200. Beyond shutting down process gas generating system 10, fluorine sensor 260 can also redirect exhaust 240, as previously described. The source of the process gas leak can then be identified and repaired. A fabrication facility employing an embodiment can thus be relieved of the need for an external exhaust system and its associated external abatement system because the abatement system of cabinet 200 is capable of containing any potential fluorine gas leak from process gas generation system 10 within cabinet 200. Embodiments can thus provide the advantage of an in-situ emergency absorbent exhaust system that can eliminate the need for a dedicated external exhaust abatement system. FIG. 5 is otherwise identical to FIG. 4 and is intended to illustrate the different flow path of exhaust 240 through absorbent packed exhaust 280, as opposed to through normal operating valve 230.

Fluorine sensor 260 can be set to detect a threshold limit of fluorine, at which point it will switch from normal exhaust mode to emergency exhaust mode as described above. For example, the threshold can be set at three parts per million, or other arbitrarily determined limit as determined for a

given application. When the threshold fluorine limit is exceeded, fluorine sensor 260 can cause normal operating valve 230 to close and can cause emergency exhaust valve 270 to open, thus redirecting the flow of exhaust 240 through absorbent packed exhaust 280, which can contain enough absorbent material (e.g., aluminum oxide) to neutralize any fluorine present inside of cabinet 200 (i.e., released from process gas generation system 10), plus a preset safety factor (e.g., two times the total fluorine in process gas generation system 10).

The dual exhaust aspect of the embodiments can thus provide the advantage over a prior art system that exhaust 240 can be directed through an abatement system's absorbent material only if there is excessive fluorine (or other process gas) present in the air flow. Because exhaust 240 is not passed continually through the absorbent material, the absorbent material will have a much longer useful life than in prior art systems. The absorbent packed exhaust 280 can, therefore, be maintained in an activated state for a time when it is actually needed. Fluorine sensor 260, emergency exhaust valve 270, normal operating valve 230 and absorbent packed exhaust 280, together operate to direct exhaust 240 through the absorbent material only in the event of a fluorine release. Because fluorine sensor 260 is in line with the flow of exhaust 240 under normal operating conditions, it is in a position to detect excessive fluorine concentrations at all times. Once the fluorine is removed by absorbent packed exhaust 280, clean air is exhausted to house exhaust 250, thereby preventing the dumping of a process gas into house exhaust 250 and eliminating the need for a complex and expensive house abatement system. The embodiments can avoid the cost and space demands of traditional abatement systems and still conform to safety and fire codes for fabrication facilities.

FIG. 6 is a simplified, diagrammatic representation of a process gas bulk distribution embodiment of the method and system. Negative pressure multi-point distribution system 300 can comprise a negative pressure bulk storage tank 310, which can be of a size much smaller than that of prior art systems. Negative pressure bulk storage tank 310 can store and then supply a process gas through a negative pressure process gas line 320 to individual tool compressors 330. Individual tool compressors 330 can each supply, under positive pressure, the process gas to one or more process tools 350.

Negative pressure multi-point distribution system 300 can also comprise one or more process gas generation cells 14 for generating and then supplying, as described with respect to FIGs. 1, 2 and 3, purified fluorine gas to negative pressure bulk storage tank 310 through feed line 360. Although greatly simplified, the portion of multi-point distribution system 300 within the dotted lines can be, for example, cabinet 200 of FIGs. 4 and 5, containing process gas generation system 10 of FIGs. 1, 2 and 3. Although all the connections, pumps, filters and manifolds of process gas generation system 10 are not shown, the same system can be used to provide a process gas to negative pressure bulk storage tank 310 via a feed line 360.

Multi-point distribution system 300 of FIG. 6 is analogous to process gas generation system 10 of the previous FIG. 5. The embodiment of FIG. 6 is a scaled up version with the negative pressure piping portion (e.g., the section between cell pressure controller 34 and compressor 42 of FIG. 1) stretched out such that a much longer negative-pressure piping run can be incorporated. The positive pressure lines from the outlet of compressor 42 to the process tool, as shown in FIG. 1, are conversely shortened such that in the embodiment of FIG. 6, the positive pressure lines are substantially local to the process tool. This configuration can greatly increase safety over the prior art because long runs of positive pressure fluorine gas delivery piping can be eliminated. The negative pressure multi-point distribution system 300 can also comprise an exhaust system 380, which can contain an abatement system as described in accordance with the teachings herein.

The negative pressure multi-point distribution system 300 of the embodiments can provide for bulk distribution of a process gas to multiple tools without the need for a very large process gas storage tank as required by the prior art. This is because a gas under vacuum can be delivered much easier and faster than by a positive pressure process. Negative pressure process gas lines 320 can thus be significantly smaller lines. The prior art requirement of having to store many cylinders (or one large cylinder) to provide bulk process gas can also be eliminated, as can the corresponding abatement systems necessary to neutralize the large amounts of gas stored on site.

Instead, embodiments of the bulk distribution aspect of the method and system for on-site generation and distribution of a process gas can use individual tool compressors 330 and positive pressure storage tanks 340 for each process tool 350. Together they can provide the ability to deliver a process gas to a process tool 350 in a much safer manner, under vacuum, rather than under a positive pressure. The need for a large process gas storage tank is thus eliminated and the emergency treatment requirements in case of an accidental release of a process gas are greatly simplified. Positive pressure storage tanks can be, for example, a nominal 10 liter storage tanks. Compressors 330 can be metal bellows, approximately 280 KPa or 40 psig output pressure compressors as known in the art.

As shown in FIG. 6, process gas generation system 10 can be housed in a cabinet 200 with its own exhaust system 380. Inside of the cabinet is located a relatively small negative pressure bulk storage tank 310. For example, negative pressure bulk storage tank 310 can be a 200 liter storage tank. Unlike prior art systems that require a very large storage tank that provides process gas at a positive pressure, the embodiments of the bulk distribution aspect can instead provide an individual tool compressor 330 feeding a positive pressure storage tank 340, which can in turn provide process gas at a positive pressure to a process tool 350. Each process tool 350 can thus have an associated compressor and small storage tank that can provide the process tool 350 with enough process gas to run at peak (e.g., approximately 20 liters). Positive pressure storage tanks 340 can be sized as desired for a given application (e.g., approximately 10 liters).

Bulk distribution embodiments (e.g., as shown in FIG. 6) can comprise one or more large fluorine generators feeding multiple process tools. Cabinet 200 can house a process gas generation system 10, as described with respect to FIGs. 1-5. Process gas generation system 10 provides process gas to negative pressure bulk storage tank 310, which, in turn, provides process gas to process gas delivery lines 320, that are coupled to individual tool compressors 330. Further, negative pressure multi-point distribution system 300 can comprise an exhaust system 380 which can comprise an abatement system sufficient to abate all of the fluorine housed within cabinet 200.

Negative pressure process gas distribution lines 320 are coupled to negative pressure bulk storage tank 310 and to each individual tool compressor 330 to deliver process gas. An advantage of the bulk distribution embodiments is that negative pressure bulk storage tank 310 can provide process gas through process gas distribution lines 320 at a negative pressure, while still providing process gas at a positive pressure to each process tool 350. Each individual tool compressor 330 pulls a vacuum on process gas distribution lines 320, which are coupled to negative pressure bulk storage tank 310. A vacuum is thus pulled on negative pressure bulk storage tank 310. At the same time that individual tool compressors 330 are pulling a vacuum at their inlet, they are pumping process gas at a positive pressure at their outlet (i.e., to a positive pressure storage tank 340). Process gas can then be provided at a positive pressure from positive pressure storage tanks 340 to each process tool 350.

Process gas generation system 10 inside of cabinet 200 is generating process gas and providing it to negative pressure bulk storage tank 310. Because individual tool compressors 330 create a vacuum at negative pressure bulk storage tank 310, process gas generation system 10 is generating process gas at a vacuum at a fluorine cell 14. Process gas generation system 10 can produce a process gas at a rate that meets the demand from each individual tool compressor 330. If negative pressure bulk storage tank 310 should reach a positive pressure, this is an indication that individual tool compressors 330 are not demanding process gas at least at the rate of process gas generation. Process gas generation system 10 is operable to shut itself down once a preset pressure (e.g., a positive pressure) is detected at negative pressure bulk storage tank 310. This can be accomplished, for example, by use of a pressure transducer communicatively connected to and operable to shut down process gas generation system 10.

Referring now to FIGs. 1, 2 and 3, in contrast to negative pressure multi-point distribution system 300 of FIG. 6, and to further explain the operation of the embodiment of FIG. 6, in FIG. 1, process gas generation system 10 comprises a positive pressure delivery system through output line 46. At the outlet to low pressure storage tank 40, compressor 42 is pulling a vacuum on low pressure storage tank 40. Process gas generation cells 14 of process gas generation system 10 generate the process gas at a low pressure (e.g., approximately 7 KPa or 1 psi (8 millibars)). Cell pressure controller 38 can measure the pressure at process gas generation cells 14, and cycle the process gas

generation cells on and off (via, for example, a programmable logic controller control system, as known in the art) to control the flow of molecular fluorine gas to low pressure buffer tank 40 by opening and closing the inlet valves to HF traps 32. Compressor 42 thus maintains low pressure storage tank 40 at a vacuum.

Compressor 42 can be a continuous cycle compressor, and thus, in operation, can maintain a vacuum at low pressure storage tank 40 while also maintaining a positive pressure (e.g., approximately 100 KPa or 15 psig) at process gas storage tank 44. As process gas is generated by process gas generation cells 14, it is provided to low-pressure buffer tank 40, where it will increase pressure if there is substantially no demand for the process gas. If the pressure at low-pressure buffer tank 40 reaches a preset level (e.g., approximately 7 KPa or 1 psi), cell pressure controller 38 is operable to provide a signal to process gas generation system 10 and shut down the gas generation process. This is because a pressure increase inside of low-pressure buffer tank 40 is an indication that process gas demand is lower than the process gas generation rate. Process gas generation system 10 is shut down because as pressure increases inside gas generation cells 14, electrolyte can be pushed out with the molecular fluorine gas and react violently outside of the process gas generation cell 14. When process gas demand increases, the pressure inside process gas storage tank 44 decreases, causing flow into process gas storage tank 44 from low pressure buffer tank 40. Low pressure buffer tank 40 drops in pressure (vacuum increases), and cell pressure controller 38 will detect the vacuum increase and cycle process gas generation system 10 back on and open the inlet valves to HF traps 32. This process can repeat itself continuously in normal operation.

The operation of negative pressure multi-point distribution system 300 of FIG. 6 of process gas generation system 10 is thus analogous to the operation. Negative pressure bulk storage tank 310 of FIG. 6 can correspond to low-pressure buffer tank 40 of FIGs. 1, 2 and 3, but on a larger scale. Each of the individual tool compressors 330, which can correspond to internal compressor 42 of FIGs. 1, 2 and 3, is taking a vacuum on negative pressure bulk storage tank 310. As a result, a vacuum is maintained inside of negative pressure bulk storage tank 310, which is being fed process gas by process gas generation system 10. Should negative pressure bulk storage tank 310 reach a preset pressure (e.g. a positive pressure), as described above, process gas generation can be cycled off. Gas generation is cycled off to match demand and to protect process gas generation cells 14 because, as discussed above, a pressure increase in negative pressure bulk storage tank 310 indicates that process gas demand is less than the process gas supply rate. Once process tools 350 start demanding process gas, a vacuum will once again be pulled inside of negative pressure bulk storage tank 310 by individual compressors 330. As the pressure decreases in bulk storage tank 310 (e.g., the vacuum increases), a control signal can be generated by a control system to cycle process gas generation system 10 back on and restart generation of process gas. This can be accomplished, for example, by a

pressure transducer communicatively coupled to both negative pressure bulk storage tank 310 and to the control system for process gas generation system 10.

Individual tool compressors 330 can each provide a positive pressure at their outlet to a positive pressure storage tank 340. Operation of process gas generation system 10 within cabinet 200 is controlled by the increase/decrease of pressure inside of negative pressure bulk storage tank 310. Positive pressure storage tanks 340 can be sized to provide the necessary supply of process gas for a given operation to a process tool 350.

The negative pressure multi-point distribution system embodiments of the method and system for on-site generation and distribution of a process gas can provide an advantage of minimizing the size of the process gas storage tank. Unlike prior art systems, a large process gas storage tank is not required, and therefore the corresponding complex and expensive abatement system necessary to ensure that the entire contents of such a tank can be neutralized are also not required. A further advantage is that all overhead process gas distribution lines 320 can be under vacuum (i.e., at a negative pressure). If a line should break, molecular fluorine (or other process gas) and atmospheric gases will be sucked back into negative pressure bulk storage tank 310 instead of being expelled out into a fabrication facility. A minimal amount of a process gas is thus exposed to the atmosphere of a fabrication facility, such that the in-house abatement systems can handle such a release.

Each individual process tool 350 can have its own cabinet with its own abatement system that can direct exhaust to an in-house scrubber. For example, a dual-exhaust system within a cabinet 200, as previously described with regards to FIGs. 4 and 5, can be provided at each process tool 350. Individual abatement systems for each process tool 350 and its related tool compressor 330 and storage tank 340 can thus be provided to neutralize the process gas stored within each positive pressure storage tank 340. The overhead process gas distribution lines 320, because they are at a negative pressure, avoid the possibility that a process gas release into a fabrication facility will occur from negative pressure bulk storage tank 310. Individual tool-specific positive pressure storage tanks 340 eliminate the pressurized source supply line requirements of prior art systems and their corresponding, expensive abatement systems.

Process gas generation system 10 of the embodiments can be sized based on the needs of a particular application. For example, one embodiment of the process gas generation system 10 can be sized to produce approximately 700 grams of process gas per hour. The process gas generation cells 14 can be, for example, 10-blade cells, 30-blade cells, or 150-blade cells, depending on the application. The embodiments are directed to minimizing the amount of process gas storage on-site and further to delivering a process gas, such as F_2 , on demand. Thus, the embodiments of the process gas generation system can deliver, for example, from approximately 0 to 700 grams of a process gas per hour. This means that they can generate process gas in amounts anywhere up to their maximum

capacity, depending on the demand. Demand, in turn, can be measured by the pressure within the supply lines and within the storage tanks of the process gas generation system 10.

By providing a positive pressure storage tank 340 and an individual tool compressor 330 for each process tool 350, the embodiments of the bulk distribution aspect can provide the ability to deliver process gas on demand and, for the majority of a process gas piping run, under negative pressure, while still providing the process gas at a positive pressure to each process tool 350. Positive pressure process gas is delivered from a tool-specific positive pressure storage tank 340 to a process tool 350 while being delivered to the vicinity of positive pressure storage tank 340 at a negative pressure (i.e., to individual tool compressors 330). The dual purposes of delivering positive pressure process gas to a process tool 350, while maintaining negative pressure in process gas delivery lines 320 for safety reasons, can thus be met by the embodiments.

It is contemplated that a positive pressure storage tank 340 and an individual tool compressor 330 can be housed within a single unit attached directly to a process tool 350. Further, each such unit could have its own individual abatement system, as previously discussed. A unit comprising a compressor, a mini storage tank, and a process tool may be used.

It is an aspect of other embodiments of the method and system for on-site generation and distribution of a process gas to provide for a mobile and compact containment vessel for hazardous liquids associated with process gas generation. Hazardous liquids require secondary containment, transportation, and storage. The process gas generators 14 of the embodiments can contain an electrolyte in a liquid stage during normal operation that will require secondary containment. Secondary containment systems of the prior art are large and unwieldy and require heavy equipment, typically a forklift or other such device, to move them. The embodiments contemplate a liquid-tight, sealed, outer container (for example, welded stainless steel) around each process gas generation cell 14. The outer sealed container can act as both a secondary containment system and as a shipping crate for each process gas generation cell 14. This configuration can eliminate the need for a dike, such as that used in prior art methods and systems, and avoid the manufacturing problems associated with such liquid-tight enclosures. The secondary containment system contemplated by the embodiments can be equipped with casters or other such rolling hardware to eliminate the need for the additional working space required for a forklift or other heavy machinery to install or remove process gas generation cells 14.

FIG. 7 shows a containment cart 400 housing a process gas generation cell 14 containing electrolyte liquid 410. Containment cart 400 is sized to contain all of the electrolyte liquid 410 inside of a process gas generation cell 14 in the event of a leak or other rupture. With reference to FIG. 1, HF is provided as an input to the electrolyte liquid 410 to generate, in this case, F_2 gas, which is output along with trace amounts of HF and waste metals from process gas generation cell 14. In the embodiment shown in FIG. 7, containment cart 400 surrounds process gas generation cell 14 of

process gas generation system 10. A process gas generation cell 14 can be, for example, approximately 0.9 to 1.2 meters or three feet to four feet tall, approximately 0.5 meters or 20 inches wide, and approximately 1.5 meters or five feet long, and made out of nominal 13 mm or half-inch thick monel or nickel. A typical process gas generation cell 14 can weigh on the order of approximately 1,000 pounds (mass of approximately 450 kilograms). In prior art methods, the entire process gas generation system is first built and then a dike is constructed around the process gas generation system of sufficient height to contain any and all electrolyte liquid that might be spilled. The dike containment is intended to contain the electrolyte liquid until it can be easily cleaned up. A containment system is typically designed to capture 110% of the amount of hazardous liquid contained in the process gas generation system.

Referring to FIG. 7, if a breach occurs in process gas generation cell 14, resulting in a release of electrolyte liquid 410 into containment cart 400, containment cart 400 is of sufficient capacity to fully contain substantially all of the electrolyte liquid 410. Although containment cart 400 is shown as a rectangle, various other shapes may be used. Containment cart 400 can be made of a material that is substantially inert to the electrolyte within process gas generation cell 14, such as stainless steel, nickel, or other suitable material.

Containment cart 400 of FIG. 7 also comprises rolling hardware 450, which can be coasters, wheels, or other such mechanisms as known in the art, to provide a means of transporting containment cart 400 by a rolling motion. Unlike prior art methods requiring the building of an expensive dike, and the consequent requirement of having to get over that dike with a heavy piece of equipment, such as process gas generation cell 14, containment cart 400 of the embodiments does not require either a forklift or a dike to be built around process gas generation system 10. Containment cart 400 can, because the need for a dike lip is eliminated, be rolled directly into a cabinet 200 containing process gas generation system 10. Further, containment cart 400 can be sized to capture approximately 110% of the electrolyte liquid within process gas generation cell 14.

Containment cart 400 can also function as a shipping crate. Containment cart 400, for example, can be manufactured by welding together five pieces of metal to form a rectangle with a floor and then covered with a removable lid 460. The bottom of containment cart 400 should be constructed to withstand the weight of process gas generation cell 14. Containment cart 14 can comprise a level sensor 430 for detecting the presence of an electrolyte liquid within containment cart 400 to indicate that a leak has occurred within process gas generation cell 14. Level sensor 430 can be located within a sump 440, shaped to channel spilled electrolyte to level sensor 430. Supports 420 can be included to support process gas generation cell 14 within containment cart 400.

FIGs. 8A-8C and FIGs. 9A-9D show side and top view perspectives of one embodiment of cabinet 200. FIG. 8A shows a view and front face elevation of cabinet 200, including touchscreen 810, viewing window 820, and vent input grills 830. Touchscreen 810 can be an interface, such as a

graphical user interface, for the control systems of process gas generation system 10, which will be described in greater detail below. FIG. 8B shows a front view of the interior of cabinet 10 with the doors removed. PLC instrumentation and power distribution system 840 is shown at the top of FIG. 8B. Other components of process gas generation system 10, as described with respect to previous figures, are also shown within FIG. 8B and numbered accordingly. Services duct 850 provides access to the interior of cabinet 200. FIG. 8C shows a sectional side view of cabinet 200, including various components of process gas generation system 10 previously described, as well as nitrogen purge system 860, which can be used when replacing HF traps 32.

FIGs. 9A, 9B, 9C and 9D show further cross section and elevation views of cabinet 200 and corresponding interior components of process gas generation system 10. FIG. 9A is a plan view from the top of cabinet 200 showing control system and access doors 910 and services duct 920, as well as cable glands and connectors 930. FIG. 9B shows a plan on top of cabinet 200 with the top of the enclosure of cabinet 200 removed to show the interior of cabinet 200. Similarly, FIG. 9C shows a plan on the process gas compression, purge, and cooling systems, and FIG. 9D shows a plan on the process gas generation cells 14, filters 35, and HF traps 32.

The embodiments can further comprise a control system to provide for the supervised control, status monitoring, fault handling, and alarm enunciation of various process gas generation system equipment items can be monitored by such a control system. For example, the status of process gas generation cells 14, HF traps 32, compressors 42 and 45, cooling systems 18, and other ancillary equipment items. The main control system can be implemented utilizing a single industrial programmable logic controller (PLC), with a recessed touch screen graphical monitor providing the primary operator interface. The primary operator interface can be touch screen 810 of FIG. 8A. Other subsystems that also provide control and monitoring functions can be interfaced to the main control system to provide status indication of key control parameters. The control system physical design can be based on a modular system allowing quick change-out of key components for maintenance and breakdown purposes, ensuring the mean time to repair is kept to a minimum. The main control system can be housed on a single control platform located at, for example, the top of a space envelope defined for cabinet 200.

A safety interlock system, as known to those in the art, can also be built into the embodiments of the on-site generation and distribution of process gas method and system. For example, abnormal and emergency conditions that warrant a more reliable, higher integrity response of the control system than that afforded by a programmable system such as a PLC control system can be designed and implemented with the embodiments. The design and implementation of such control systems is well known in the art. System architecture and components can be designed to allow for interconnection of external systems and for future development of control strategies for a process gas generation system 10 in accordance with the teachings. A single programmable logic controller can be used to

provide the instrumentation interface for the gas generation process via discrete digital and analog input and output modules housed in a multi-slot frame, to include a PLC processor module and power supply modules.

The main control system operator interface 810 can be implemented using a single touch screen monitor mounted in a recess on the front face of cabinet 200. The interface can provide a clear visual representation of the process plant utilizing simplified flow diagrams and tables to depict process streams to aid the operator. Logging onto the system (for example, via a password) can present the operator with a home page detailing the main system equipment process/items, system status, alarm banner and main function keys. A standard border/backdrop can be provided on each screen to provide connectivity between system configured pages that will be navigable via menus or hot function keys. Appropriate system change-out and maintenance flags/prompts can be generated to alert impending service requirements in order to maximize process gas generation system availability.

Embodiments can also comprise software comprising computer executable instructions for managing process control and instrumentation and display systems.

The embodiments of the method and system for on-site generation and distribution of a process gas can provide various advantages over the prior art, including: (1) redundant process gas generation cells and contaminant traps (e.g., HF traps 32) such that one trap can be operating while another is regenerating; (2) the ability to pull a vacuum to regenerate a contaminant trap and thus avoid purging the containment trap with nitrogen and introducing contaminants into the process gas; (3) the ability to be housed in a compact generator cabinet having a dual exhaust system that can be used to avoid continuous airflow through an absorbent material and thus avoid premature degradation of the absorbent material; (4) the ability to provide an on-demand supply of a process gas under negative pressure; (5) providing individual compressors and storage tanks for each process tool, such that a process gas under negative pressure in a supply line can still be provided at a positive pressure to the process tool; and (6) providing a mobile, compact and self-contained containment system for hazardous liquids associated with a process gas generation cell so that the large and expensive secondary containment systems of the prior art can be eliminated.

Attention is now directed to methods of generating and using on-site generation of molecular fluorine. In one embodiment, the on-site generation of molecular fluorine can be accomplished using a fluorine generator as previously described. The generator previously described is exemplary of just one embodiment of an on-site reactor capable of producing F_2 gas. After reading this specification, skilled artisans appreciate that many other alternatives may be used.

A distribution system may be coupled to the fluorine generator and operable to distribute the molecular fluorine to one or more process tools. Molecular fluorine may be used with or without a plasma as an aggressive agent during a semiconductor process or cleaning operation and may be

advantageous over conventional chemicals or gas compositions due to the absence of fluorocarbons. However, in some embodiments, the molecular fluorine may be used in conjunction with a fluorocarbon or other etching compound.

Some embodiments may include using molecular fluorine to reduce process time associated with fabricating a semiconductor device. Additionally, the molecular fluorine may be used during the fabrication of components, assemblies, devices, such as microelectronic devices, integrated microelectronic circuits, ceramic substrate based devices, flat panel displays, or other devices. Many of these components, assemblies and devices include one or more microelectronic device substrates. Examples of microelectronic device substrates include semiconductor wafers, glass plates for use in thin-film transistor ("TFT") displays, substrates used for organic light-emitting diodes ("OLEDs"), or other similar substrates commonly used in the fabrication of microelectronic devices.

FIG. 10 includes an illustration of a system for on-site generation and distribution of molecular fluorine. The system, illustrated generally as 1000, can include an on-site molecular fluorine generator 1001 can be fluidly coupled to a first distribution line 1002 and a second distribution line 1004 operable to distribute molecular fluorine within a fabrication facility. Distribution lines, illustrated in FIG. 10, may include associated tubing, plumbing, fittings, and fluid transfer or control devices such as pumps, valves, etc. configured to flow molecular fluorine within the fabrication facility.

For example, first distribution line 1002 may be a double-lined distribution line designed to flow hazardous materials safely to a reactor (e.g., a plasma generator or a chamber of a process tool), a system, or a process bay. As such, desirable quantities of hazardous materials, such as F_2 , may be safely distributed to a process tool, system or cell. In one embodiment, system 1000 may be located proximal or distal to a plurality of process tools that may use molecular fluorine. Process tool 1003 may be coupled to on-site fluorine generator 1001 via first distribution line 1002. On-site molecular fluorine generator 1001 may further be coupled to second process tool 1010 via second distribution line 1004 and single tool distribution line 1005.

On-site molecular fluorine generator 1001 may also be coupled to a multi-port distribution line 1006 via second distribution line 1004. Multi-port distribution line 1006 may be coupled to several process bays that use molecular fluorine for various fabrication or cleaning processes. For example, multi-port distribution line 1006 may be coupled to a first process bay 1011 having process tools 1014, 1015, and 1016. The first process bay may be for thin-film deposition, ion implant, etch, or lithography.

Multi-port distribution line 1006 may also be coupled to a second process bay 1012 that may include process tools 1017 and 1018, which may use molecular fluorine. The process tools 1017 and 1018 may be coupled in a parallel configuration and may be operable as identical or different tools. For example, second process bay 1012 may be a deposition process bay having a plurality of

deposition process tools. As such, on-site molecular fluorine generator 1001 may provide second process bay 1012 with molecular fluorine for cleaning deposition chambers of tools 1017 and 1018. The cleaning may be performed between each substrate processed in a chamber, or between each lot, or any other interval.

Multi-port distribution line 1006 may further be coupled to a third process bay 1013 that may include process tools 1019 and 1020. Process tool 1020 can be serially connected to process tool 1019.

In one non-limiting specific embodiment, the distance between the fluorine generator 1001 may be no more than approximately 200 meters from each of the process tools connected to it. The fabrication facility may include a plurality of generators similar to fluorine generator 1001. Because fluorine generator 1001 may be compact and portable, fluorine generator 1001 may be less than approximately 50 meters from all process tools to which it is connected or coupled. In other words, fluorine generator 1001 can be as close to any particular process tool as the physical bodies of the fluorine generator 1001 and a process tool will allow. Fluorine generator 1001 may be dedicated to a single process tool or automatically to a process bay. Alternatively, one fluorine generator 1001 may service two or more adjacent process bays.

Typically, the generator may be located within a utility bay adjacent to a process bay that it services. In still another embodiment, the fluorine generator 1001 may lie between and service two adjacent process bays. In still another embodiment, the fluorine generator 1001 may be moved from process tool to process tool as desired. After reading this specification, skilled artisans appreciate that many other configurations are possible.

FIG. 11 illustrates a process tool having an integrated fluorine generation and distribution system. FIG. 11 includes an illustration a process tool 1100 having a local (at the tool) fluorine generator. The process tool, illustrated generally as 1100, includes a molecular fluorine generator 1101 operable to generate molecular fluorine for use in association with a fabrication process. Generator 1101 can be coupled to an accumulator 1102 that is coupled to a process chamber 1103 used in fabricating a device, such as a semiconductor device. In one non-limiting embodiment, system 1100 may be configured as an etch tool capable of etching a substrate using molecular fluorine as part of an etch species. As such, molecular fluorine may react with regions of a substrate to provide etched locations of the substrate.

In another embodiment, system 1100 may be configured as deposition process tool operable to deposit a thin layer of material (e.g., conductive layer, barrier layer, etc.) on a substrate. As such, F_2 may be introduced during or post deposition of a substrate to remove undesirable contaminants from a process chamber associated with system 1100. For example, system 1100 may be operable as a process tool, and may be configured to use F_2 in the place of, or in addition to, NF_3 . As such, F_2 may

be used during a semiconductor process to remove undesirable contaminants, metals, compounds, by-products, etc. which may be residual from a deposition process.

In another embodiment, system 1100 may be configured as deposition process tool capable of depositing a thin layer of material (e.g., dielectric layer, conductive layer, barrier layer, etc.) over a substrate. As such, molecular fluorine may be introduced during or after the deposition to remove undesirable contaminants from a process chamber associated with system 1100. Alternatively, the molecular fluorine may be used to remove a deposited material before it becomes too thick and starts to generate particles as it begins to peel due to stress within the deposited film. In this manner, molecular fluorine may be used to remove undesirable contaminants, metals, compounds, by-products, or other materials from a deposition process.

In an alternate embodiment, the accumulator 1102 can be used to locally store molecular fluorine at the process tool 1100, where the molecular fluorine is generated elsewhere within the fabrication facility and flows to the process tool 1100 through the distribution lines previously described. The process tool 1100 may further comprise a controller to monitor the accumulator 1102 and replenish the molecular fluorine at least to a desired level.

FIG. 12 illustrates a method for generating and distributing molecular fluorine for a fabrication process. The method may be used in association with the system illustrated in FIG. 1 or other systems operable to generate and distribute molecular fluorine for fabrication processes.

The method begins generally at step 1200. At step 1201, an on-site generator produces molecular fluorine utilizing a fluorine generation process. The on-site generator may be located distal or proximal to process equipment as a facility may allow for, and may be operable to produce variable amounts and concentrations of molecular fluorine using an electrolyte process as described above or other fluorine generating processes. For example, an on-site generator may include several electrolyte cells with each electrolyte cell producing a volume of molecular fluorine. As such, one or more of the cells may be used to provide desirable volumes of molecular fluorine to one or more process tools.

Upon generating the molecular fluorine, the method proceeds step 1202 where the method distributes the molecular fluorine to one or more process tools. For example, a distribution system may be coupled to plural process tools and operable to fluidly communicate desirable amounts of molecular fluorine to one or more of the process tools. As such, an on-site generator operable to produce large quantities of F_2 may distribute the F_2 to a plurality of process tools operable to be used within a fabrication facility.

Upon distributing the molecular fluorine to one or more process tools, the method proceeds to step 1203 where a process tool uses the molecular fluorine during a fabrication process. In one embodiment, a process tool which in one instance may be operable to use NF_3 may be operable to use molecular fluorine during processing. For example, a vapor deposition tool may use NF_3 during a cleaning step to remove undesirable contaminants during or after deposition of, for example, a

conductive thin film. As such, the method may be operable to provide a desirable amount of molecular fluorine within a process tool's process chamber during or after depositing a thin film onto a substrate. For example, a single wafer thin film process tool may include a reaction chamber operable to deposit a thin film on a substrate. As such, contaminants from a variety of species associated with the deposition process may be residual within the reaction chamber. Molecular fluorine may then be introduced into the reaction chamber to clean or remove contaminants within the reaction chamber (e.g., walls, handler, etc.) As such, F_2 may reduce contaminants associated with a thin film process while providing a relatively contamination free environment within the reaction chamber for current or subsequent processing.

Upon utilizing the F_2 gas, the method proceeds to step 1204 where the method ends. In this manner, this fabrication process advantageously utilizes F_2 which has been generated and distributed on-site, proximal, or distal to a process tool operable to utilize F_2 .

In one embodiment, the method may be modified to use an accumulator associated with a process tool for storing the distributed F_2 . As such, an on-site generator may produce fluorine and distribute molecular fluorine to an accumulator associated with a process tool. The method may also monitor an accumulator for certain volume levels and replenish the level of molecular fluorine stored within the accumulator upon the accumulator depleting to a level.

In another embodiment, the method may be modified to purge a chamber associated with the process tool of undesirable residual gas and subsequent processing. For example, a process tool may introduce F_2 into a chamber in addition to other elements as a part of a fabrication process. The chamber may then be purged and additional processing of a device may occur. As such, the method may be modified to purge a chamber, fabricate a device, and utilize F_2 as desired.

In another embodiment, the method may be modified to recycle the used F_2 gas. As such, a recycle system may be operable to receive the used F_2 and recycle the F_2 gas such that unwanted contaminants within the F_2 gas may be removed and the F_2 may be reused for subsequent processing. The recycled F_2 may then be used in association with a distribution system operable to distribute F_2 for a fabrication process.

FIGs. 13 and 14 includes a process flow diagrams directed more toward specific methods in accordance with other embodiments. The methods may be used in association with the system illustrated in FIG. 1. Referring to FIG. 13, the process can comprise reacting a fluorine-containing reactant to form a fluorine-containing compound (block 1302). Referring to FIG. 1, HF, which can be a fluorine-containing reactant can be decomposed within either or both of the electrolytic cells 14. The decomposition produces H_2 gas and F_2 gas, which is a fluorine-containing compound. The process can further comprise flowing the fluorine-containing compound (F_2 gas) to a process tool (block 1322). The process tool can comprise a chamber, in which the F_2 gas may be used in a reaction within the chamber. The process can further comprise using the fluorine-containing

compound at the process tool (block 1324). In non-limiting examples, the F_2 gas can be used to etch a substrate within the chamber or to clean the chamber by removing material that has deposited along walls or other surfaces inside the chamber (e.g., substrate handler, deposition shields, clamps, etc.). Molecular fluorine can be useful for removing silicon-containing or metal-containing materials from the chamber, such as dielectrics, metals, metal silicides, and the like.

FIG. 14 includes a process flow diagram for a process similar to FIG. 13. However, unlike FIG. 13, FIG. 14 contemplates the use of a plasma. The process can include the reacting and flow acts (blocks 1302 and 1322) as previously described. The process can further comprising generating a fluorine-containing plasma from the fluorine-containing compound (block 1462). The plasma may be generated using a conventional technique to form neutral fluorine radicals ($F^\bullet$) and ionic fluorine radicals (F^+ , F^- , F_2^+ , F_2^- , or any combination thereof).

The plasma may be generated within a chamber of the process tool or outside the chamber. In the latter, a plasma generator may be connected between the distribution lines and specific process tool where the fluorine-containing plasma is to be provided. In one specific embodiment, the plasma generator may be part of or attached to the process tool.

The process can further comprising using the fluorine-containing plasma within the chamber of the tool (block 1464). The fluorine-containing plasma may be used in manners similar to those previously described with block 1342 in FIG. 13 (e.g., etching substrates, cleaning deposition chambers, or the like).

In another embodiment, the process may further comprise recycling the unused molecular fluorine gas. As such, a recycle system (not shown) may receive the unused molecular fluorine and recycle the molecular fluorine gas such that unwanted contaminants within the molecular fluorine gas may be removed and the molecular fluorine may be reused for subsequent processing. The recycled molecular fluorine may be used in association with a distribution system to reduce the amount of new molecular fluorine gas produced by the electrolytic cells 14 in FIG. 1.

Examples

Plasma etch example

An aluminum-containing layer can be formed to a thickness of approximately 800 nm. After subsequent patterning, bond pads having areal dimensions of 15 microns by 15 microns, nominally, may be formed. A passivation layer may be formed over the bond pads and have a thickness of approximately 900 nm. The passivation layer may comprise approximately 200 nm of silicon oxide and approximately 700 nm of silicon nitride. One or both of the silicon oxide and silicon nitride layers may be formed using plasma-enhanced chemical vapor deposition.

A patterned photoresist layer can be formed over the passivation layer. In one non-limiting embodiment, the photoresist layer may be JSR positive photoresist material available from JSR

Company of Japan and has a thickness of approximately 3500 nm. The patterned photoresist comprise opening over the bond pads.

The passivation layer can be etched with an etchant gas composition comprising F_2 , carbon tetrafluoride (CF_4), trifluoromethane (CHF_3), argon (Ar), and sulfur hexafluoride (SF_6). Note that the F_2 may have been previously generated at the fabrication facility where the etching is taking place. The etch can be performed to expose the bond pads. The plasma may be formed within an Applied Materials MxP+ brand tool from Applied Materials, Inc. of Santa Clara, California. The tool may be operated under the following conditions: (1) a reactor chamber pressure of approximately 150 mtorr; (2) a source radio frequency power of approximately 0 watts at a source radio frequency of 13.56 MHZ (i.e., without a bias power); (3) a semiconductor substrate temperature of approximately 250 degrees Celsius; and (4) an oxygen flow rate of approximately 8000 standard cubic centimeters per minute (sccm).

During the etch operation, via veils may be formed along the sidewalls of the bond pads and may include a fluorocarbon polymer residue that may or may not include aluminum. The via veils can be stripped from the semiconductor substrates through immersion within a stripping solvent comprising monoethanolamine available as ACT (from Ashland Specialty Chemical Division of Ashland, Inc. or Covington, Kentucky) or EKC (from EKC Technology Inc. of Hayward, California) stripper.

Plasma cleaning process example

In a more specific exemplary process, a gas capable of reacting with the deposits to be removed may be flowed into a space to be cleaned, e.g., the vacuum deposition chamber. The deposits may be a silicon-containing material, a metal containing material (e.g., a metal, a metal alloy, a metal silicide, etc.) or the like. The gas can be excited to form a plasma within the chamber or remote to the chamber. If formed outside the chamber, the plasma can flow to the chamber using a conventional downstream plasma process. The plasma or neutral radicals generated from the plasma can react with the deposits on the exposed surfaces within the chamber.

The gas employed in the etching process typically is a gaseous source of a halogen. The gaseous source may include F_2 , NF_3 , SF_6 , CF_4 , C_2F_6 , combinations thereof, or the like. Additionally, chlorine-containing or bromine-containing gases may be used. In a non-limiting specific embodiment, F_2 may have previously been generated at the fabrication facility where the chamber clean is taking place. Nearly any mixture of the gases described in this paragraph may also be employed. An inert or noble diluent gas including argon, neon, helium, or the like, can also be combined with the gas or mixture of gases.

After reading this specification, skilled artisans are capable of determining an appropriate flow rate of the gas (or gases), temperature and pressure conditions within the vacuum deposition chamber.

or other space by taking into account the volume of space from which deposits are to be removed, the quantity of deposits to be removed, and potentially other factors. If desired, a conventional purging act may be performed after the etching or cleaning gases are used to remove the deposits. Typical process parameters are set forth in United States Patent No. 5,207,836 ("Chang"), which is incorporated herein by reference.

In one non-limiting embodiment, tungsten may be deposited within a chamber, and F_2 may be used to remove the tungsten that deposits on the interior walls and internal parts of the chamber. The F_2 may be generated at the fabrication facility where the tungsten deposition occurs.

Turning to the deposition portion, a silicon wafer can be introduced into the vacuum deposition chamber of a Precision 5000 xZ apparatus available from Applied Materials, Inc.. The chamber can be heated to a process temperature of approximately 475°C . After conventional pre-nucleation with tungsten hexafluoride (WF_6) and silane (Si_4), chamber purge pressurization and stabilization of the wafer on the heater plate, tungsten can be deposited carried out using WF_6 at a flow rate approximately 95 sccm at a pressure of approximately 90 Torr. After removing the wafer, the chamber may be purged and pumped ($Ar/N_2/H_2$ purge). The deposition process may be repeated until approximately 25 silicon wafers are processed.

After the deposition, the chamber may be cleaned to remove the deposits that have built up during the processing of the wafer. The deposition chamber can be heated to a temperature of approximately 475°C for a period of 23 seconds. An aluminum nitride wafer may be inserted to protect a wafer chuck where wafers would normally reside during the deposition process. Concurrently or subsequently, F_2 can be introduced into the chamber at approximately 150 sccm and a base pressure of approximately 300 mTorr. A plasma can be formed from the F_2 gas. During a first portion of the cleaning process, the plasma power may be maintained at approximately 600 watts for approximately 230 seconds. During a first portion of the cleaning process, the plasma power may be maintained at approximately 200 watts for approximately 220 seconds. After two purge/pump cycles (each cycle including approximately 30 seconds of $Ar/N_2/H_2$ purge, and approximately three seconds of pumping (evacuating), the chamber has been clean. At this time, the deposition procedure can be repeated.

The chamber cleaning may be performed between substrates (e.g., silicon wafers), between lots of substrates, or at nearly any interval. The timing of the cleaning may depend on the stress of the film being deposited and its thickness.

The systems and methods previously described can provide advantages over conventional processes and may be applicable to many different fabrication industries. Note that the advantages are described with respect to embodiments and are not to be construed as causing portions of the embodiments to be deemed critical, required, or essential features of the invention.

A technical advantage of the embodiments of the method and system for on-site generation and distribution of a process gas is that they can provide redundant process gas generation cells and contaminant traps, such that at least one of each can be operating at any given time to supply a fabrication process. Another technical includes the ability to house a process gas generation system in a compact generator cabinet having a dual exhaust system to avoid continuous airflow through an abatement system's absorbent material.

Still another technical advantage of the embodiments of the method and system for on-site generation and distribution of a process gas includes the ability to provide an on-demand supply of the process gas under negative pressure. A further technical advantage of the embodiments includes the ability to provide individual compressors and storage tanks for each process tool, such that the process gas can be provided at a positive pressure to the process tool with the process gas supply line under negative pressure. Yet another technical advantage of the embodiments includes providing a mobile, compact and self-contained secondary containment system for hazardous liquids associated with a process gas generation cell.

For at least some of the embodiments, a technical advantage includes providing a safe generation and distribution system for hazardous materials such as molecular fluoride. A further technical advantage includes using molecular fluorine at a desirable concentration for processes that use molecular fluorine.

Still another technical advantage includes providing an on-site fluorine generator which may be located proximal, distal or integrated as a part of a processing tool. Yet another technical advantage includes providing a semiconductor process operable to exploit desirable characteristics of F_2 . A still further technical advantage includes providing a fluorine distribution system operable to distribute molecular fluorine to a plurality of process tools.

An example may provide a better illustration of some of the advantages. In that example, a process tool having a diffusion furnace tube is to be cleaned. Molecular fluorine can be produced on-site at a fabrication facility, thereby obviating the need to transport gas cylinders from a chemical plant. If gas cylinders would be used the gas cylinders could become damaged or other fail to contain the gas, a large amount of gas may be released into the atmosphere and cause significant damage. Also, some materials, such as molecular fluorine, may have a limited shelf life. By producing the molecular fluorine on-site, the transportation hazards are avoided.

Further, molecular fluorine may be produced in smaller amounts or on an as-desired basis. Should there be an accidental release of molecular fluorine, it will be a relatively smaller amount compared to a gas cylinder, and the exhaust system of the fabrication facility may be better suited to handle the smaller amounts. Therefore, embodiments can be used for a safe generation and distribution system for hazardous materials, such as molecular fluorine.

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Additionally, the generator can be portable and moved from process bay to process bay, from utility bay to utility bay, or from process tool to process tool. Expensive plumbing for hazardous materials may be reduced. Also, the number of generators can be better tailored to the desires of the facility.

The on-site molecular fluorine generator may be located proximal, distal, or integrated as a part of a process tool. Such flexibility allows configurations to be specifically adapted to the specific desires of a particular fabrication facility.

In the foregoing specification, the invention has been described with reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the present invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present invention.

Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or element of any or all the claims.

CLAIMS

1. A system for continuous purification of a gas flow comprising:
 - a first HF trap coupled to a gas supply line, wherein the gas supply line conducts the gas flow;
 - a second HF trap coupled to the gas supply line in parallel to the first HF trap; and
 - a switching mechanism operable to switch gas flow from the first HF trap to the second HF trap at the occurrence of a predefined event.
2. The system of claim 1, wherein the gas flow comprises:
 - molecular fluorine; and
 - trace hydrogen fluorine.
3. The system of claim 1, wherein the switching mechanism is operable to switch gas flow from the first HF trap to the second HF trap when the first HF trap is approximately saturated.
4. The system of claim 3, further comprising:
 - a first manifold operable to direct the gas flow from the gas supply line to the first HF trap;
 - and
 - a second manifold operable to direct the gas flow from the gas supply line to the second HF trap.
5. The system of claim 1, further comprising one or more fluorine generation cells, wherein the one or more fluorine generation cells are coupled to the gas supply line and wherein the one or more fluorine generation cells provide the gas flow.
6. The system of claim 1, further comprising:
 - a gas output line coupled to the first HF trap and the second HF trap; and
 - an output filter coupled to the gas output line.
7. The system of claim 6, further comprising:
 - a low pressure buffer tank in fluid communication with the first HF trap and the second HF trap, wherein the low pressure buffer tank is located downstream of the output filter; and
 - a compressor in fluid communication with and downstream of the low pressure buffer tank, wherein the compressor is operable to compress gas from the low pressure buffer tank.
8. The system of claim 1, further comprising:

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a low pressure buffer tank in fluid communication with the first HF trap and the second HF trap; and

a compressor in fluid communication with and downstream of the low pressure buffer tank, wherein the compressor is operable to compress gas from the low pressure buffer tank.

9. A method for purifying fluorine gas comprising:

directing a fluorine gas flow to a first HF trap;

determining if the first HF trap is approximately saturated; and

if the fluorine trap is determined to be approximately saturated:

switching the fluorine gas flow to a standby HF trap;

regenerating the first HF trap; and

replacing the first HF trap.

10 The method of claim 9, further comprising placing the first HF trap in standby mode relative to the standby fluorine trap.

11 The method of claim 9, wherein the step of regenerating the first HF trap comprises:

heating the first HF trap; and

purging the first HF trap with nitrogen.

12. A process gas generation cabinet comprising:

a cabinet housing encompassing a process gas generator, the housing further comprising:

one or more input vents to direct air to the process gas generator;

a normal output port; and

an emergency output port; and

an exhaust system comprising:

an exhaust channel;

a normal operating channel coupled to the normal output port and the exhaust channel, the normal operating channel further comprising a normal operating valve;

an emergency channel coupled to the emergency output port of the cabinet housing and the exhaust channel, the emergency channel further comprising:

an emergency exhaust valve; and

an absorbent packed material; and

a fluorine sensor located upstream from the normal operating valve, the fluorine sensor operable to close the normal operating valve and open the emergency exhaust valve if fluorine levels in the cabinet housing exceed a preset level.

13. The process gas generator cabinet of claim 12, wherein the exhaust channel comprises a house exhaust system.
14. The process gas generator cabinet of claim 12, wherein the fluorine sensor is operable to shut down the process gas generator if fluorine levels in the cabinet housing exceed the preset level.
15. The process gas generator cabinet of claim 12, wherein the absorbent packed material comprises aluminum oxide.
16. The process gas generator cabinet of claim 12, wherein the fluorine gas sensor is located inline with the normal operating valve.
17. The process gas generator cabinet of claim 12, wherein the cabinet housing further encompasses a negative pressure storage tank operable to store process gas produced by the process gas generator.
18. A gas distribution system comprising:
 - a process gas generator;
 - a gas routing mechanism connected to the process gas generation system;
 - a negative pressure storage tank connected to the gas routing mechanism, the negative pressure storage tank operable to store process gas produced by the process gas generator;
 - a negative pressure line coupled to the negative pressure storage tank;
 - a compressor coupled to the negative pressure line operable to:
 - draw process gas from the negative pressure storage tank;
 - compress the process gas to produce a positive pressure process gas; and
 - output the positive pressure process gas; and
 - a positive pressure storage tank in fluid communication with the compressor, the positive pressure storage tank operable to store the positive pressure process gas.
19. The gas distribution system of claim 18, wherein the positive pressure storage tank is further operable to provide positive pressure process gas to a manufacturing tool.
20. The gas distribution system of claim 18, further comprising a cabinet housing encompassing the process gas generator, the gas routing mechanism and the negative pressure storage tank.

21. The gas distribution system of claim 18, wherein the gas routing mechanism comprises a manifold.
22. The gas distribution system of claim 18, further comprising a positive pressure line coupled to the compressor and to the positive pressure storage tank.
23. A gas distribution system comprising:
- a process gas generator;
 - a gas routing mechanism connected to the process gas generation system;
 - a negative pressure storage tank connected to the gas routing mechanism, the negative pressure storage tank operable to store process gas produced by the process gas generator;
 - a negative pressure line coupled to the negative pressure storage tank;
 - a plurality of compressors coupled to the negative pressure line, each of the plurality of compressors operable to:
 - draw process gas from the negative pressure storage tank;
 - compress the process gas to produce a positive pressure process gas; and
 - output the positive pressure process gas; and
 - a positive pressure storage tank associated with each of the plurality of compressors, each positive pressure storage tank in fluid communication with the associated compressor, and wherein each positive pressure storage tank is operable to store the positive pressure process gas received from the associated compressor.
24. The gas distribution system of claim 23, wherein each the positive pressure storage tank is operable to provide the positive pressure process gas to an associated tool.
25. A containment cart comprising:
- a liquid-tight outer container configured to store a process gas generation cell containing an electrolyte liquid, the liquid-tight outer container sized to contain the process gas generation cell and at least all the electrolyte liquid inside the process gas generation cell, wherein the outer container comprises a material inert to the electrolyte liquid; and
 - rolling hardware coupled to the bottom surface of the liquid tight container.
26. The containment cart of claim 25, further comprising a removable lid coupled to the liquid-tight outer container with a liquid-tight seal.

27. The containment cart of claim 25, further comprising one or more supports to support the process gas generation cell within the liquid-tight outer container.
28. The containment cart of claim 25, further comprising a level sensor operable to detect the presence of spilled electrolyte liquid within the liquid tight outer container.
29. The containment cart of claim 28, further comprising a sump configured to channel spilled electrolyte liquid to the level sensor.
30. The containment cart of claim 25, wherein the liquid-tight outer container is formed from stainless steel.
31. The containment cart of claim 25, further comprising:
- a removable lid coupled to the liquid-tight outer container with a liquid-tight seal;
 - one or more supports to support the process gas generation cell within the liquid-tight outer container;
 - a level sensor operable to detect the presence of spilled electrolyte liquid within the liquid-tight outer container; and
 - a sump configured to the spilled electrolyte liquid to the level sensor.
32. A method for cleaning a process chamber for semiconductor or flat panel display manufacturing, comprising the steps of:
- converting a feed gas to a cleaning gas in a remote location, wherein the feed gas does not clean the process chamber; and
 - delivering the cleaning gas to the process chamber.
33. The method of claim 32, further comprising the step of activating the cleaning gas outside the chamber prior to delivering the cleaning gas to the process chamber.
34. The method of claim 33, wherein the step of activating is performed through a means selected from the group consisting of a remote plasma source, a heat source, and an electrical source.
35. The method of claim 34, wherein the remote plasma source is selected from the group consisting of a microwave energy source and a radio-frequency energy source.
36. The method of claim 32, wherein the feed gas is HF.

37. The method of claim 32, wherein the cleaning gas is F_2 .
38. The method of claim 37, wherein the conversion is done by electrolysis.
39. A method of claim 32, further comprising the step of transferring the resulting gas mixture to a trap, and the cleaning gas remains in a gaseous form; and
40. The method of claim 39, prior to the step of delivering the cleaning gas to the process chamber, further comprising the step of pumping the cleaning gas into a storage unit.
41. The method of claim 40, after the step of pumping the cleaning gas into a storage unit, further comprising the step of: activating the cleaning gas outside the chamber before delivering the cleaning gas to the chamber.
42. The method of claim 41, wherein the step of activating is performed through a means selected from the group consisting of a remote plasma source, a heat source, and an electrical source.
43. The method of claim 42, wherein the remote plasma source is selected from the group consisting of a microwave energy source and a radio-frequency energy source.
44. The method of claim 39, wherein the feed gas is HF.
45. The method of claim 44, wherein the cleaning gas is F_2 .
46. The method of claim 45, wherein the conversion is done by electrolysis.
47. A method for generating and using a fluorine-containing compound comprising:
 reacting a fluorine-containing reactant in a first reactor to form a first fluorine-containing compound; and
 flowing the first fluorine-containing compound to a second reactor, wherein the first and second reactors are located at a fabrication facility.
48. The method of claim 47, wherein:
 the fluorine-containing reactant comprises HF; and
 the first fluorine-containing compound comprises molecular fluorine.

49. The method of claim 47, wherein:
the first reactor comprises an electrolytic cell; and
a method tool comprises the second reactor.
50. The method of claim 47, wherein the second reactor comprises an etch chamber.
51. The method of claim 47, wherein the second reactor comprises a deposition chamber.
52. The method of claim 47, wherein the second reactor is the only process tool connected to the first reactor during flowing.
53. The method of claim 47, wherein the second reactor is one of a plurality of process tools coupled to the first reactor.
54. The method of claim 47, further comprising generating a fluorine-containing plasma from the first fluorine-containing compound, wherein:
the second reactor comprises a plasma generator; and
the method further comprises flowing the fluorine-containing plasma to a process chamber.
55. The method of claim 54, wherein:
the molecular fluorine comprises diatomic fluorine;
the fluorine-containing plasma comprises neutral fluorine radicals; and
the process chamber comprises a deposition chamber.
56. The method of claim 47, further comprising generating a fluorine-containing plasma from the first fluorine-containing compound, wherein:
a process tool comprises the second reactor; and
generating is performed within the second reactor.
57. The method of claim 47, wherein flowing is performed while a substrate is located within a chamber of the second reactor.
58. The method of claim 47, wherein the first and second reactors are located within approximately 200 meters of each other.

59. The method of claim 47, wherein the first and second reactors are located within approximately 50 meters of each other.
60. The method of claim 47, wherein the first reactor is coupled to a plurality of process tools for a process bay.
61. The method of claim 47, wherein the first reactor is coupled to a plurality of process tools for process bays that lie on opposite sides of a utility bay.
62. The method of claim 47, further comprising placing a microelectronic device substrate into the second reactor.
63. The method of claim 47, wherein the fluorine-containing compound is diatomic fluorine.
64. A method for using a first process tool comprising:
 placing a first substrate within a chamber of the first process tool;
 reacting a fluorine-containing reactant in a reactor to form molecular fluorine;
 generating a fluorine-containing plasma from the molecular fluorine, wherein generating is performed in a plasma generator that is located outside the chamber; and
 flowing the first fluorine-containing plasma to the chamber while the substrate is in the chamber, wherein reacting and flowing are performed simultaneously during at least one point in time.
65. The method of claim 64, wherein the fluorine-containing reactant comprises HF.
66. The method of claim 64, wherein the reactor comprises an electrolytic cell.
67. The method of claim 64, wherein flowing comprises flowing a second fluorine-containing gas to the chamber.
68. The method of claim 64, wherein the first process tool is one of a plurality of process tools for a process bay, and are the only process tools coupled to the reactor.
69. The method of claim 64, wherein the first reactor is coupled to a plurality of process tools for process bays that lie on opposite sides of a utility bay.

70. The method of claim 64, wherein the first reactor is coupled to a plurality of process tools for a process bay.
71. The method of claim 64, further comprising recycling the first fluorine-containing gas after flowing.
72. The method of claim 64, wherein the molecular fluorine is diatomic fluorine.
73. A method for using a chamber comprising:
 flowing molecular fluorine to a chamber; and
 generating a fluorine-containing plasma using the molecular fluorine, wherein generating the fluorine-containing plasma is performed within the chamber.
74. The method of claim 73, further comprising reacting a fluorine-containing reactant in a reactor to form the molecular fluorine.
75. The method of claim 74, wherein the fluorine-containing reactant comprises HF.
76. The method of claim 74, wherein the reactor comprises an electrolytic cell.
77. The method of claim 74, wherein:
 a first process tool comprises the chamber; and
 the first process tool is one of a plurality of process tools for a process bay, and are the only process tools coupled to the reactor.
78. The method of claim 74, wherein:
 a first process tool comprises the chamber; and
 the first reactor is coupled to a plurality of process tools for process bays that lie on opposite sides of a utility bay, and are the only process tools coupled to the reactor.
79. The method of claim 73, wherein flowing comprises flowing a second gas to the chamber.
80. The method of claim 73, further comprising:
 placing a substrate within the chamber;
 depositing a film over the substrate; and
 removing the substrate from the chamber after depositing the film and before flowing.

81. The method of claim 73, further comprising:

depositing a material over a first plurality of substrates; and

depositing the material over a second plurality of substrates,

wherein:

flowing and generating are performed after depositing a material over a first plurality of substrates and before depositing the material over a second plurality of substrates; and

flowing and generating is not performed between each substrate in a first plurality of substrates or each substrate in the second plurality of substrates.

82. The method of claim 73, wherein the molecular fluorine is diatomic fluorine.