

DETAILED DESCRIPTION

[0042] As discussed above, semiconductor processing operations may be performed on semiconductor wafers in semiconductor processing chambers of semiconductor processing tools (also simply referred to herein as “tools”). Such tools are typically equipped with a controller, e.g., that includes one or more processors and one or more memory devices. The controller may be operatively connected with various subsystems of the semiconductor processing tool so as to allow the controller to control those subsystems. The one or more memory devices may, for example, include devices such as non-volatile memory, volatile memory, hard disks, and/or optical media, or any other suitable computer-readable storage device. The one or more memory devices may store computer-executable instructions which, when executed by the one or more processors, cause the one or more processors to control the various subsystems of the semiconductor processing tool in a particular manner, e.g., according to a process recipe.

[0043] The various systems discussed herein are designed for use in semiconductor processing tools that use process recipes in which halogen-containing gases and ammonia-containing gases are introduced into the semiconductor processing chamber(s) thereof in order to process a semiconductor wafer or wafers. Such gases may, depending on the particular operations being performed, be introduced in one or more repeated, sequential gas flows—optionally with a flow of a gas that is inert with respect to the active process gases used interposed between each such gas flow—or may, in some cases, be flowed into the semiconductor processing chamber at least partially in parallel, i.e., simultaneously.

[0044] Such halogen-containing gases may include, for example, gases containing chlorine, fluorine, iodine, etc., which may then react with ammonia to form one or more compounds. While the discussion below focuses on chlorine-containing gases, it will be understood that other halogen chemistries featuring other halogens may be used, and that this disclosure encompasses the use of the systems discussed herein with respect to those other chemistries as well. It will also be understood that the systems discussed herein may also be used in conjunction with semiconductor processing tools that may, for example, not utilize halogen-containing and/or ammonia-containing chemistries but which may nonetheless benefit from one or more of the systems discussed herein.

[0070] As discussed above, another feature that semiconductor processing tool 100 may have is a remote plasma generator 132, which may be used to provide a plasma to the semiconductor processing chamber 102 in between wafer processing operations in order to perform a plasma clean operation. As discussed above, the remote plasma generator 132 may, for example, be fluidically connected to the semiconductor processing chamber 102 by a conduit 134 that may be used to convey the plasma generated by the remote plasma generator 132 into the semiconductor processing chamber 102. When a plasma cleaning operation is not being performed, the remote plasma generator 132 may be fluidically isolated from the semiconductor processing chamber 102 using the conduit valve 152, which may be controlled so as to close and seal the semiconductor processing chamber 102 off from the remote plasma generator 132 during such periods of time.

[0071] As discussed earlier, when plasma is flowing through the conduit 134, the heat from the plasma may cause the conduit 134 to reach temperatures that may be potentially hazardous and/or may compromise the structure of the conduit. To prevent such an occurrence, the semiconductor processing tool 100 may be equipped with a conduit cooling system 138 that is configured to cool at least a portion of the conduit. The conduit cooling system 138 may, for example, be transitionable between at least a first cooling state and a second cooling state. In the first cooling state, the conduit cooling system 138 may have a higher heat-removal rate than in the second cooling state. For example, if the conduit cooling system 138 removes heat by flowing a coolant fluid past surfaces of the conduit 134 and into a coolant return, the conduit cooling system may, in at least some instances, reduce the flow rate of the coolant in the second cooling state as opposed to the flow rate of the coolant in the first cooling state, thereby allowing less heat to be removed in the second cooling state as compared with the first cooling state. In some such implementations, the flow of coolant past the conduit 134 may simply be shut off in the second cooling state, thereby providing no cooling via the conduit cooling system 138.

[0072] The controller 136 may be configured to cause the conduit cooling system 138 to be in the first cooling state during periods of time during which plasma from the remote plasma generator 132 is being flowed through the conduit 134 and into the semiconductor processing chamber 102. For example, the controller 136 may be operatively connected with the conduit

cooling system valve 150, which may be controlled to adjust the amount of coolant that may flow through the conduit cooling system 138.

[0073] The controller 136 may also be configured to cause the conduit cooling system 138 to conversely be in the second cooling state during periods of time during which plasma from the remote plasma generator 132 is not being flowed through the conduit 134 and into the semiconductor processing chamber 102, e.g., such as during periods of time when the conduit valve 152 is in a closed state.

[0074] In the depicted implementation, the coolant that is flowed into the conduit cooling system 138 is obtained by routing coolant from coolant supply 170 that was previously flowed through remote plasma generator coolant flow paths 160 of the remote plasma generator cooling system 140 through the conduit cooling system valve 150 and through the conduit cooling system 138 before delivering the coolant to the coolant return 172 via the outlet flow path 162.

[0075] The fluidic circuit for the remote plasma generator cooling system 140 and the conduit cooling system 138 is shown in a more schematic representation in FIG. 4. As can be seen, the remote plasma generator 132 may be equipped with remote plasma generator cooling system 140 that may have one or more flow paths that convey fluid that is introduced to the remote plasma generator cooling system 140 past various systems internal to the remote plasma generator 132 that may require cooling. Such cooling systems may be standard equipment on remote plasma generators that require such cooling. If the remote plasma generator 132 requires active cooling via such a cooling system, the coolant that is used may optionally be routed, upon exiting the remote plasma generator 132, to the conduit cooling system valve 150. In this particular example, the conduit cooling system valve 150 is at least a three-way valve that is capable of switching a stream of fluid that is delivered thereto via an inlet port (a first port) between at least two outlet ports (second and third ports) thereof. One such outlet port, e.g., the second port, may be fluidically connected to one or more inlets 146 of the conduit cooling system 138. When the conduit cooling system valve 150 is in a first state, the conduit cooling system valve 150 may be configured to cause an amount of fluid that is flowable through the one or more conduit coolant flow paths via a fluid inlet for a given

CLAIMS

1. A semiconductor processing tool comprising:

a semiconductor processing chamber;

a remote plasma generator;

a conduit configured to provide fluidic communication between the remote plasma generator and the semiconductor processing chamber;

a conduit cooling system configured to controllably cool the conduit; and

a controller, wherein:

the conduit cooling system is configured to be transitionable between at least a first cooling state and a second cooling state,

the conduit cooling system has a higher heat-removal rate in the first cooling state than in the second cooling state, and

the controller is configured to:

cause the conduit cooling system to be in the first cooling state during first periods of time when plasma from the remote plasma generator is flowing into the semiconductor processing chamber via the conduit, and

cause the conduit cooling system to be in the second cooling state during second periods of time when the remote plasma generator is not flowing plasma into the semiconductor processing chamber via the conduit.

2. The semiconductor processing tool of claim 1, wherein the controller is further configured to cause the semiconductor processing chamber to perform one or more film deposition operations by, at least in part, flowing ammonia-containing gas and one or more halogen-containing gases into the semiconductor processing chamber.

3. The semiconductor processing tool of either claim 1 or claim 2, further comprising:
a fluid inlet; and
a conduit cooling system valve, wherein:

the conduit cooling system includes one or more conduit coolant flow paths that
5 extend along at least a portion of the conduit,

the conduit cooling system valve is fluidically connected with the one or more
conduit coolant flow paths and configured to be transitionable between a first state and
a second state, and

the conduit cooling system valve, in the first state, is configured to cause an
10 amount of fluid from the fluid inlet that is flowable through the one or more conduit
coolant flow paths for a given back pressure at the fluid inlet to be higher as compared
with the amount of the fluid from the fluid inlet that is flowable through the one or
more conduit coolant flow paths for the given back pressure at the fluid inlet when the
conduit cooling system valve is in the second state.

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4. The semiconductor processing tool of claim 3, wherein the conduit cooling system valve
is configured to cause no fluid from the fluid inlet to be flowable through the one or more
conduit coolant flow paths when in the second state.

- 20 5. The semiconductor processing tool of claim 3, wherein:

the conduit cooling system valve is a two-way valve with a first port and one or more
second ports, and

fluid entering the valve via the first port cannot exit the valve except via the one or
more second ports.

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6. The semiconductor processing tool of claim 3, wherein:

the conduit cooling system valve has a first port, a second port, and a third port,

the second port is fluidically connected with the one or more conduit coolant flow paths,

5 the conduit cooling system valve is configured to cause a greater portion of fluid that is flowed into the conduit cooling system valve via the first port to flow out of the second port when the conduit cooling system valve is in the first state than is flowed out of the second port when the conduit cooling system valve is in the second state, and

10 the conduit cooling system valve is configured to cause a smaller portion of fluid that is flowed into the conduit cooling system valve via the first port to flow out of the third port when the conduit cooling system valve is in the first state than is flowed out of the third port when the conduit cooling system valve is in the second state.

7. The semiconductor processing tool of claim 6, further comprising a remote plasma generator cooling system configured to controllably cool the remote plasma generator,
15 wherein:

the remote plasma generator cooling system includes one or more remote plasma generator coolant flow paths,

the one or more remote plasma generator coolant flow paths are fluidically connected with the conduit cooling system valve via the first port, and

20 the conduit cooling system valve is configured to permit fluid flow through the one or more remote plasma generator coolant flow paths regardless of which of the first and second states the conduit cooling system valve is in.

8. The semiconductor processing tool of claim 7, further comprising a fluid outlet, an outlet flow path, and a bypass flow path, wherein:

the one or more conduit coolant flow paths are fluidically connected with the fluid outlet by the outlet flow path such that the one or more conduit coolant flow paths are

fluidically interposed between the fluid outlet and the conduit cooling system valve with respect to fluid flow through the conduit cooling system,

the third port of the conduit cooling system valve is fluidically connected with the outlet flow path by the bypass flow path, and

5 the one or more conduit coolant flow paths are fluidically interposed between the conduit cooling system valve and a location where the bypass flow path fluidically connects with the outlet flow path.

9. The semiconductor processing tool of claim 3, wherein the one or more conduit coolant
10 flow paths include a tube that is helically wound around the conduit.

10. The semiconductor processing tool of claim 3, wherein the one or more conduit coolant
flow paths include a conduit coolant flow path formed between the portion of the conduit and
a sleeve that encloses the portion of the conduit.

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11. The semiconductor processing tool of claim 1, wherein the conduit includes one or
more conduit valves that are configured to be controllably switched between an open state and
a closed state, wherein:

the one or more conduit valves, in the closed state, seal off the semiconductor
20 processing chamber from the remote plasma generator, and

the one or more conduit valves, in the open state, place the remote plasma generator in
fluidic communication with the semiconductor processing chamber.

12. The semiconductor processing tool of claim 11, wherein the controller is further
25 configured to:

cause the one or more conduit valves to be in the open state during the first periods of
time, and

cause the one or more conduit valves to be in the closed state during the second periods of time.

13. A semiconductor processing tool comprising:

5 a semiconductor processing chamber;

a baffle plate; and

an exhaust foreline, wherein:

10 the semiconductor processing chamber includes an interior volume defined, at least in part, by one or more sidewalls of the semiconductor processing chamber and a floor of the semiconductor processing chamber,

the floor includes a plenum channel that extends around an interior region of the floor of the semiconductor processing chamber,

the baffle plate covers the plenum channel and has a plurality of openings arranged along a circular path,

15 the baffle plate divides the interior volume into a plenum volume defined by the plenum channel and a first side of the baffle plate and a chamber volume that is on a second side of the baffle plate from the first side,

each opening fluidically connects the plenum volume with the chamber volume, and

20 the openings have a first total cross-sectional area,

the exhaust foreline has a second cross-sectional area where the exhaust foreline connects with the semiconductor processing chamber, and

the first total cross-sectional area is between 30% and 55% of the second cross-sectional area.

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14. The semiconductor processing tool of claim 13, wherein each opening is an arcuate slot following an arcuate path that has a center point that is coincident with a center of the circular path.

5 15. The semiconductor processing tool of claim 14, wherein each arcuate slot is the same size and shape.

16. The semiconductor processing tool of claim 14 or claim 15, wherein each arcuate slot has a radial width of between 0.18" and 0.14".

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17. The semiconductor processing tool of claim 13, wherein the baffle plate has a thickness of between 0.25" and 0.5".

18. The semiconductor processing tool of claim 13, further comprising:

15 a pedestal configured to support a semiconductor wafer within the semiconductor processing chamber; and

a showerhead configured to distribute one or more processing gases across the pedestal, wherein:

20 the one or more sidewalls define a nominal inner perimeter of the semiconductor processing chamber,

a third cross-sectional area is defined in between the nominal inner perimeter and an outermost perimeter of the pedestal, and

the first total cross-sectional area is smaller than the third cross-sectional area.

25 19. The semiconductor processing tool of claim 18, wherein the first total cross-sectional area is the smallest cross-sectional area that gas can flow through when the gas is flowed from

the showerhead, into the interior volume, past the pedestal, through the baffle plate, into the plenum channel, and into the exhaust foreline.

20. A semiconductor processing tool comprising:

5 a semiconductor processing chamber that includes an interior volume defined, at least in part, by one or more sidewalls of the semiconductor processing chamber and a floor of the semiconductor processing chamber;

a pedestal configured to support a semiconductor wafer within the semiconductor processing chamber;

10 a showerhead having one or more inlets and a plurality of gas distribution ports;

one or more gas supply valves configured to control a flow or flows of one or more process gases into the semiconductor processing chamber via the gas distribution ports of the showerhead;

15 an exhaust foreline fluidically connected with the interior volume of the semiconductor processing chamber such that the pedestal is interposed between the showerhead and a location where the exhaust foreline fluidically connected with the semiconductor processing chamber;

an exhaust foreline heating system configured to heat at least a first portion of the exhaust foreline; and

20 a controller configured to:

control the one or more gas supply valves to cause one or more process gases to be flowed into the semiconductor processing chamber according to a process recipe and via the gas distribution ports of the showerhead during a first time period, and

25 cause the exhaust foreline heating system to maintain the first portion of the exhaust foreline at a temperature of at least 100°C during at least part of the first time period.

21. The semiconductor processing tool of claim 20, wherein the exhaust foreline is made of 316L stainless steel.

22. The semiconductor processing tool of either claim 20 or claim 21, wherein:

5 the exhaust foreline has one or more interior surfaces that are in fluidic communication with the interior volume of the semiconductor processing chamber, and

the one or more interior surfaces are electropolished or nickel-plated.

23. The semiconductor processing tool of claim 20, further comprising:

10 a plenum channel heating system; and

a baffle plate, wherein:

the floor includes a plenum channel that extends around an interior region of the floor of the semiconductor processing chamber,

15 the baffle plate covers the plenum channel and has a plurality of openings arranged along a circular path,

the plenum channel heating system is located along a bottom surface or surfaces of the semiconductor processing chamber and is configured to heat a portion of the semiconductor processing chamber that is beneath the baffle plate, and

20 the controller is further configured to cause the plenum channel heating system to maintain the portion of the semiconductor processing chamber that is beneath the baffle plate at a temperature of at least 100 °C during at least part of the first time period.

24. The semiconductor processing tool of claim 20, wherein the controller is further

25 configured to cause the exhaust foreline heating system to maintain the first portion of the

exhaust foreline at a temperature of between 100°C and 130°C during at least part of the first time period.

25. The semiconductor processing tool of claim 20, wherein the process recipe includes at
5 least one flow of a halogen-containing gas and at least one flow of an ammonia-containing gas.