CLAIMS

1. A plasma generation and axial exhaust assembly, comprising:

an upper support plate;

a number of support structures affixed to the upper support plate so as to extend in a substantially perpendicular direction away from the upper support plate;

a central cylindrically-shaped plasma generation microchamber affixed to a first portion of the number of support structures at a location substantially centered upon the upper support plate; and

a plurality of annular-shaped plasma generation microchambers affixed to corresponding portions of the number of support structures, the plurality of annular-shaped plasma generation microchambers positioned in a concentric manner about the central cylindrically-shaped plasma generation microchamber,

wherein adjacently positioned ones of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers are spaced apart from each other so as to form a number of axial exhaust vents therebetween, wherein each axial exhaust vent is fluidly connected to a fluid flow region between the number of support structures and between the upper support plate and each of the plurality of annular-shaped plasma generation microchambers, wherein the fluid flow region is fluidly connected to a peripheral exhaust vent formed at a periphery of the upper support plate between the upper support plate and an outermost one of the plurality of annular-shaped plasma generation microchambers.

2. A plasma generation and axial exhaust assembly as recited in claim 1, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a plasma generation region fluidly connected to a process gas supply.

3. A plasma generation and axial exhaust assembly as recited in claim 2, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes an upper electrode disposed in exposure to the plasma generation region, and a lower electrode disposed in exposure to the plasma generation region.

4. A plasma generation and axial exhaust assembly as recited in claim 3, wherein each of the upper and lower electrodes is electrically connected to a separate independently controllable power supply.

5. A plasma generation and axial exhaust assembly as recited in claim 3, wherein each of the upper and lower electrodes is physically separated by an electrically insulating sidewall enclosure, wherein the sidewall enclosure forms a peripheral boundary of the plasma generation region.

6. A plasma generation and axial exhaust assembly as recited in claim 5, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a number of output

passages formed to direct a fluid flow from the plasma generation region in a direction substantially perpendicular to and away from the upper support plate.

7. A plasma generation and axial exhaust assembly as recited in claim 6, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes an upper ground plate affixed to its corresponding portion of the number of support structures, and an upper insulator sheet disposed between the upper ground plate and the upper electrode.

8. A plasma generation and axial exhaust assembly as recited in claim 7, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a lower insulator sheet disposed on a lower surface of the lower electrode opposite from the plasma generation region, and a lower ground plate disposed on a lower surface of the lower insulator sheet opposite from the lower electrode.

9. A plasma generation and axial exhaust assembly as recited in claim 8, wherein each of the upper insulator sheet and the lower insulator sheet has an electrical resistance within a range extending from about 50 picoFarads to about 70 picoFarads.

10. A plasma generation and axial exhaust assembly as recited in claim 5, wherein the sidewall enclosure has an electrical resistance within a range extending from about 3 picoFarads to about 10 picoFarads.

11. A semiconductor substrate processing system, comprising:

a substrate support defined to support a substrate in exposure to a processing region; and

a top plate assembly positioned above and spaced apart from the substrate support, such that the processing region exists between the top plate assembly and the substrate support, the top plate assembly including a central plasma generation microchamber at a location substantially centered on the top plate assembly, the top plate assembly also including a plurality of annular-shaped plasma generation microchambers positioned in a concentric manner about the central plasma generation microchamber,

wherein adjacently positioned ones of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers are spaced apart from each other so as to form a number of axial exhaust vents therebetween, and

wherein each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers is defined to generate a corresponding plasma therein and supply reactive constituents of its plasma to the processing region between the top plate assembly and the substrate support.

12. A semiconductor substrate processing system as recited in claim 11, wherein the number of axial exhaust vents are fluidly connected to a peripheral exhaust vent within the chamber outside a periphery of the substrate support.

13. A semiconductor substrate processing system as recited in claim 11, wherein each of the central plasma generation microchamber and the plurality of annular-shaped

plasma generation microchambers includes a plasma generation region bounded by an upper electrode, a lower electrode, and an electrically insulating sidewall enclosure extending between the upper and lower electrodes so as to enclose the plasma generation region.

14. A semiconductor substrate processing system as recited in claim 13, wherein each of the upper and lower electrodes of each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers is electrically connected to receive power from a respective independently controllable power supply.

15. A semiconductor substrate processing system as recited in claim 13, wherein each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers is fluidly connected to receive a process gas from a respective process gas supply.

16. A semiconductor substrate processing system as recited in claim 13, wherein each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes an upper ground plate and an upper insulator sheet disposed between the upper ground plate and the upper electrode.

17. A semiconductor substrate processing system as recited in claim 16, wherein each of the central plasma generation microchamber and the plurality of annular-shaped

plasma generation microchambers includes a lower insulator sheet disposed on a lower surface of the lower electrode opposite from the plasma generation region, and a lower ground plate disposed on a lower surface of the lower insulator sheet opposite from the lower electrode.

18. A semiconductor substrate processing system as recited in claim 17, wherein the sidewall enclosure has an electrical resistance within a range extending from about 3 picoFarads to about 10 picoFarads.

19. A semiconductor substrate processing system as recited in claim 18, wherein each of the upper insulator sheet and the lower insulator sheet has an electrical resistance within a range extending from about 50 picoFarads to about 70 picoFarads.

20. A semiconductor substrate processing system as recited in claim 17, wherein the top plate assembly includes an upper support plate and a number of support structures affixed to the upper support plate so as to extend in a substantially perpendicular direction away from the upper support plate toward the substrate support, wherein the central plasma generation microchamber is affixed to some of the number of support structures, and wherein each of the plurality of annular-shaped plasma generation microchambers is affixed to some of the number of support structures.

21. A semiconductor substrate processing system as recited in claim 20, wherein each axial exhaust vent is fluidly connected to a fluid flow region between the number of

support structures and between the upper support plate and each of the plurality of annular-shaped plasma generation microchambers, wherein the fluid flow region is fluidly connected to a peripheral exhaust vent formed at a periphery of the upper support plate between the upper support plate and an outermost one of the plurality of annular-shaped plasma generation microchambers.

CLAIMS

1. A plasma generation microchamber, comprising:

an upper electrode having a lower surface that forms an upper boundary of a plasma generation region;

a lower electrode having an upper surface that forms a lower boundary of the plasma generation region;

a sidewall enclosure formed to extend between the upper and lower electrodes so as to enclose a periphery of the plasma generation region between the upper and lower electrodes, wherein the sidewall enclosure is formed of an electrically insulating material;

an upper insulator sheet disposed on an upper surface of the upper electrode opposite from the plasma generation region;

an upper ground plate disposed on an upper surface of the upper insulator sheet opposite from the upper electrode;

a lower insulator sheet disposed on a lower surface of the lower electrode opposite from the plasma generation region;

a lower ground plate disposed on a lower surface of the lower insulator sheet opposite from the lower electrode,

wherein each of the upper ground plate, upper insulator sheet, and upper electrode include a number of fluidly connected passages for supply of a process gas to the plasma generation region, and

wherein each of the lower ground plate, lower insulator sheet, and lower electrode include a number of output passages for output of the process gas and reactive constituents from the plasma generation region into a substrate processing region.

2. A plasma generation microchamber as recited in claim 1, wherein each of the upper and lower electrodes is defined as a solid plate of electrically conductive material with the exception of the number of fluidly connected passages for supply of the process gas to the plasma generation region.

3. A plasma generation microchamber as recited in claim 1, wherein each of the number of output passages for output of the process gas and reactive constituents is defined as a cylindrical hole extending in a substantially perpendicular direction between a lower surface of the lower ground plate and the upper surface of the lower electrode.

4. A plasma generation microchamber as recited in claim 3, wherein each of the number of output passages for output of the process gas and reactive constituents has a diameter

within a range extending from about 0.5 millimeter to about 2 millimeters.

5. A plasma generation microchamber as recited in claim 3, wherein a distance as measured perpendicularly between the lower surface of the lower ground plate and the upper surface of the lower electrode in within a range extending from about 2 millimeters to about 5 millimeters.

6. A plasma generation microchamber as recited in claim 1, wherein the upper electrode is electrically connected to a first power supply and wherein the lower electrode is electrically connected to a second power supply, wherein each of the first and second power supplies is independently controllable.

7. A plasma generation microchamber as recited in claim 6, wherein a phase difference between the first and second power supplies is 180 degrees.

8. A plasma generation microchamber as recited in claim 1, wherein each of the upper electrode, upper insulator sheet, upper ground plate, lower electrode, lower insulator sheet, and lower ground plate has a circular area when viewed perpendicular to its upper or lower surface, and wherein the sidewall enclosure is ring-shaped when viewed perpendicular to its upper or lower surface, such that the plasma generation microchamber is cylindrically-shaped.

9. A plasma generation microchamber as recited in claim 1, wherein each of the upper electrode, upper insulator sheet, upper ground plate, lower electrode, lower insulator sheet, and lower ground plate has an annular area when viewed perpendicular to its upper or lower surface, and wherein the sidewall enclosure includes an inner ring-shaped sidewall and an outer ring-shaped sidewall when viewed perpendicular to their upper or lower surface, such that the plasma generation microchamber is annular-shaped.

10. A plasma generation and axial exhaust assembly, comprising:

an upper support plate;

a number of support structures affixed to the upper support plate so as to extend in a substantially perpendicular direction away from the upper support plate;

a central cylindrically-shaped plasma generation microchamber affixed to a first portion of the number of support structures at a location substantially centered upon the upper support plate; and

a plurality of annular-shaped plasma generation microchambers affixed to corresponding portions of the number of support structures, the plurality of annular-shaped plasma generation microchambers positioned in a concentric manner about the central cylindrically-shaped plasma generation microchamber,

wherein adjacently positioned ones of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers are spaced apart from each other so as to form a number of axial exhaust vents therebetween, wherein each axial exhaust vent is fluidly connected to a fluid flow region between the number of support structures and between the upper support plate and each of the plurality of annular-shaped plasma generation microchambers, wherein the fluid flow region is fluidly connected to a peripheral exhaust vent formed at a periphery of the upper support plate between the upper support plate and an outermost one of the plurality of annular-shaped plasma generation microchambers.

11. A plasma generation and axial exhaust assembly as recited in claim 10, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a plasma generation region fluidly connected to a process gas supply.

12. A plasma generation and axial exhaust assembly as recited in claim 11, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes an upper electrode disposed in exposure to the plasma generation region, and a lower electrode disposed in exposure to the plasma generation region.

13. A plasma generation and axial exhaust assembly as recited in claim 12, wherein each of the upper and lower electrodes is electrically connected to a separate independently controllable power supply.

14. A plasma generation and axial exhaust assembly as recited in claim 12, wherein each of the upper and lower electrodes is physically separated by an electrically insulating sidewall enclosure, wherein the sidewall enclosure forms a peripheral boundary of the plasma generation region.

15. A plasma generation and axial exhaust assembly as recited in claim 14, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a number of output passages formed to direct a fluid flow from the plasma generation region in a direction substantially perpendicular to and away from the upper support plate.

16. A plasma generation and axial exhaust assembly as recited in claim 15, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes an upper ground plate affixed to its

corresponding portion of the number of support structures, and an upper insulator sheet disposed between the upper ground plate and the upper electrode.

17. A plasma generation and axial exhaust assembly as recited in claim 16, wherein each of the central cylindrically-shaped plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a lower insulator sheet disposed on a lower surface of the lower electrode opposite from the plasma generation region, and a lower ground plate disposed on a lower surface of the lower insulator sheet opposite from the lower electrode.

18. A semiconductor substrate processing system, comprising:

a substrate support defined to support a substrate in exposure to a processing region; and

a top plate assembly positioned above and spaced apart from the substrate support, such that the processing region exists between the top plate assembly and the substrate support, the top plate assembly including a central plasma generation microchamber at a location substantially centered on the top plate assembly, the top plate assembly also including a plurality of annular-shaped plasma generation microchambers positioned in a concentric manner about the central plasma generation microchamber,

wherein adjacently positioned ones of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers are spaced apart from each other so as to form a number of axial exhaust vents therebetween, and

wherein each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers is defined to generate a corresponding plasma therein and supply reactive constituents of its plasma to the processing region between the top plate assembly and the substrate support.

19. A semiconductor substrate processing system as recited in claim 18, wherein each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers includes a plasma generation region bounded by an upper electrode, a lower electrode, and an electrically insulating sidewall enclosure extending between the upper and lower electrodes so as to enclose the plasma generation region.

20. A semiconductor substrate processing system as recited in claim 19, wherein each of the upper and lower electrodes of each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers is electrically connected to receive power from a respective independently controllable power supply.

21. A semiconductor substrate processing system as recited in claim 19, wherein each

of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers is fluidly connected to receive a process gas from a respective process gas supply.

22. A semiconductor substrate processing system as recited in claim 18, wherein the number of axial exhaust vents are fluidly connected to a peripheral exhaust vent within the chamber outside a periphery of the substrate support.

23. A method for processing a semiconductor substrate, comprising:

placing a substrate on a substrate support in exposure to a substrate processing region;

supplying one or more process gases and radiofrequency power to each of a central plasma generation microchamber and a plurality of annular-shaped plasma generation microchambers positioned above the substrate support in exposure to the substrate processing region, whereby the radiofrequency power transforms the one or more process gases into a plasma in each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers;

flowing reactive constituents of the plasma from each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers into the substrate processing region so as to expose the substrate to the reactive constituents; and

removing process gases from the substrate processing region through axial exhaust vents located between adjacently positioned ones of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers.

24. A method for processing a semiconductor substrate as recited in claim 23, wherein the supply of the one or more process gases and radiofrequency power is separately and independently controlled for each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers.

25. A method for processing a semiconductor substrate as recited in claim 23, further comprising:

operating upper and lower electrodes in each of the central plasma generation microchamber and the plurality of annular-shaped plasma generation microchambers in a push-pull manner to generate ballistic electrons and direct the ballistic electrons into the substrate processing region.

26. A method for processing a semiconductor substrate as recited in claim 23, further comprising:

applying a bias power to a bias electrode disposed within the substrate support to influence movement of charged species within the substrate processing region.

27. A method for processing a semiconductor substrate as recited in claim 23, further comprising:

removing process gases from the substrate processing region through a radial exhaust vent located at a periphery of the substrate support.