[0005] In some substrate processing systems, the substrates are moved from a substrate cassette to a reactor and then back to a substrate cassette or another location. To improve throughput and reduce substrate handling, a single reactor may include multiple, sequential processing station assemblies. In this type of substrate processing system, the substrate is moved to the reactor, processed sequentially in the processing station assemblies and then moved to a substrate cassette or another location. This processing arrangement tends to increase throughput by reducing substrate handling.

[0006] Referring now to FIG. 1, an example of a substrate processing system 8 includes a multi-station, sequential processing (MSSP) reactor 10 with multiple stations 14-1, 14-2, 14-3 and 14-4 (collectively stations 14) and pedestals 16-1, 16-2, 16-3 and 16-4 (collectively pedestals 16). While four stations are shown, additional or fewer stations can be used. A vacuum transfer chamber 18 is in communication with the reactor 10 via valves (not shown) and includes a substrate handling robot 22. A load lock 24 is in communication with the vacuum transfer chamber 18 via valves (not shown).

[0007] A substrate handler 26 includes a substrate handling robot 28 and substrate cassettes 30. The substrate handling robot 28 loads a substrate from one of the substrate cassettes 30 into the load lock 24 for cleaning. When the load lock 24 is ready, the substrate handling robot 22 transfers the substrate to one of the stations 14 of the reactor 10.

[0008] Referring now to FIG. 2, an example of an indexing mechanism 54, which is a two-axis wafer transfer mechanism, is shown. The mechanism includes a transfer plate

controller 300 may communicate with a coolant pump 317 to control flow of coolant. The controller 300 may communicate with a heater control 319 to control a temperature of the pedestals. The controller 300 may communicate with a lift pin actuator 323 to control a position of lift pins. The controller 300 may also communicate with sensors 325 such as temperature and pressure sensors to monitor operating conditions that are associated with one or more of the processing station assemblies and/or pedestals.

[0068] Referring now to FIG. 9, an example of the pedestal 240 and the pedestal housing 280 is shown. A substrate 340 may be positioned on the pedestal 240. One or more lift pins 342 may be used to raise and lower the substrate onto and off of the pedestal 240. Bellows 346 may be used to provide a seal for the moveable lift pins 342. A lift crank mechanism 348 may be used to adjust a position of the lift pins 342, although other mechanisms may be used.

[0069] Electrical connections may be provided via a housing of the arm 276 to supply RF pedestal bias or heat control signals to the pedestal 240. Cooling fluid may also be provided by conduits to a coolant coil 370 via the housing of the arm 276. The cooling loop may be provided to cool the arm housing to prevent expansion due to elevated temperatures. In some examples, the coolant coil 370 may be made of stainless steel, although other materials may be used.

[0070] An isolation plate 380 may be provided to improve isolation below the pedestal 240. In some examples, the isolation plate 380 includes a central opening, is annular and has a radially inner thickness that is greater than a radially outer thickness. In some examples, the isolation plate 380 is made of a dielectric material such as

ceramic. In some examples, the isolation plate 380 is spaced from the pedestal 240 by a gap that is greater than zero. Spacers 382 such as annular spacers may be provided. In some examples, the gap is greater than zero and less than twice the plasma sheath distance, although other gap dimensions may be used.

[0071] As can be appreciated, slip rings and connectors may be used to supply the RF bias, heater power, and coolant to the pedestals 240.

[0072] Referring now to FIGs. 10 and 11, examples of methods for unloading and loading substrates are shown. In FIG. 10, control determines whether substrates need to be unloaded at 400. At 404, control determines whether the pedestal carousel assembly needs to be rotated to perform unloading. If 404 is true, control rotates the pedestal carousel assembly 272 at 408. Control continues from 404 (if false) and 408 with 412 where control lowers the pedestal carousel assembly 272 in the direction away from the upper housing portion. At 416, control raises the lift pins to raise the substrate off of the pedestal 240. At 420, control unloads the substrates using the substrate handler 315. As can be appreciated, two or more of the rotation of the pedestal carousel assembly 272, lowering of the pedestal carousel assembly 272 and raising of the lift pins in operations 408, 412 and 416 can be performed at the same time to reduce cycle times. As can be appreciated, since two openings 208-1 and 208-2 are provided, the pedestal carousel assembly 272 can be arranged to allow to two substrates to be loaded or unloaded at the same time.

[0073] In FIG. 11, control determines whether substrates need to be loaded at 430. In 440, control determines whether the pedestals 240 and the lift pins are in a desired position for loading. If 440 is false, control rotates the pedestal carousel assembly 272,

CLAIMS

1. A reactor for processing a plurality of substrates, comprising:

a chamber volume housing comprising an upper chamber housing and a lower chamber housing;

wherein the lower chamber housing has a pedestal carousel assembly disposed therein, and wherein the lower chamber housing is configured to rotate about a vertical axis relative to the upper chamber housing;

wherein the upper chamber housing is arranged adjacent to the lower chamber housing and is rotationally fixed;

P processing station assemblies arranged symmetrically around the axis, where P is an integer greater than one, wherein the P processing station assemblies are arranged within respective cavities defined between the upper chamber housing and the lower chamber housing;

P pedestal assemblies arranged in the pedestal carousel assembly of the lower chamber housing symmetrically around the axis, each of the P pedestal assemblies including a pedestal, wherein the P pedestal assemblies are arranged in respective portions of the cavities in the lower housing chamber; and

a rotational actuator to rotate the lower chamber housing including the pedestal carousel assembly relative to the axis to selectively index the P pedestal assemblies with the P processing station assemblies,

wherein each of the P processing station assemblies processes substrates arranged on corresponding ones of the P pedestal assemblies at the same time.

2. The reactor of claim 1, further comprising a platen including P openings, wherein the P pedestal assemblies are located in the P openings of the platen.

3. The reactor of claim 1, wherein indexing of the P pedestal assemblies between the P processing station assemblies during processing is performed by rotating the P pedestal assemblies in a single plane and without a change in an axial location of the P pedestal assemblies.

4. The reactor of claim 1, further comprising:

an aperture through a wall of the chamber housing to allow loading and unloading of the substrates;

an axial actuator to adjust an axial position of the pedestal carousel assembly; and

a controller configured to communicate with the axial actuator and the rotational actuator, to lower the pedestal carousel assembly in an axial direction and to align one of the P pedestal assemblies with the aperture during loading and to raise the pedestal carousel assembly in an opposite axial direction for processing.

5. The reactor of claim 2, wherein the platen includes P annular raised portions located around the P openings, and wherein the P annular raised portions circumscribe the P processing station assemblies when aligned to provide a fluid restriction between volume inside and outside of the P processing station assemblies and the P pedestal assemblies.

6. The reactor of claim 5, further comprising a pump to selectively pump fluid outside of the restriction created by the P annular raised portions during processing.

7. The reactor of claim 6, further comprising a controller to control the pump, to supply process gases to the P processing station assemblies during processing and to evacuate process gases in the P processing station assemblies before the pedestal carousel assembly indexes the P pedestal assemblies to a next index position.

8. The reactor of claim 4, wherein at least one of the P pedestal assemblies further comprises lift pins that move with the P pedestal assemblies and that raise and lower a substrate relative to a pedestal of one of the P pedestal assemblies.

9. The reactor of claim 1, further comprising:

a lift pin actuator;

a substrate handler; and

a controller in communication with the lift pin actuator and the substrate handler and configured to:

lower the pedestal carousel assembly;

position the lift pins of at least one pedestal in a raised position; and

position a substrate on the at least one pedestal.

10. The reactor of claim 9, wherein the controller is further configured to:

raise the pedestal carousel assembly;

position the lift pins of the at least one pedestal in a lowered position;

process the substrate in one of the P processing station assemblies; and

index the substrate to other ones of the P processing station assemblies and process the substrate in the other ones of the P processing station assemblies.

11. The reactor of claim 10, wherein, when unloading, the controller lowers the pedestal carousel assembly at the same time as the controller raises the lift pins of the at least one pedestal and wherein, when loading, the controller raises the pedestal carousel assembly at the same time as the controller lowers the lift pins of the at least one pedestal.

12. The reactor of claim 1, wherein at least one of the P processing station assemblies includes a showerhead.

13. The reactor of claim 12, wherein the showerhead is made of a dielectric material and includes an embedded electrode.

14. The reactor of claim 1, wherein the reactor performs atomic layer deposition (ALD) in at least one of the P processing station assemblies.

15. The reactor of claim 1, wherein the reactor performs plasma-enhanced atomic layer deposition (PEALD) in at least one of the P processing station assemblies.

16. The reactor of claim 1, further comprising a controller configured to position the pedestal carousel assembly in a cleaning position, wherein the pedestal carousel assembly aligns the P pedestal assemblies with the P processing station assemblies to clean areas inside the P pedestal assemblies and the P processing station assemblies.

17. The reactor of claim 2, further comprising a controller configured to position the pedestal carousel assembly in a cleaning position, wherein the pedestal carousel assembly is not aligned with the P processing station assemblies to clean areas between the P processing station assemblies and the P pedestal assemblies and portions of the platen located between the P pedestal assemblies.

18. The reactor of claim 2, further comprising a controller configured to position the pedestal carousel assembly in a cleaning position, wherein the pedestal carousel assembly is lowered and the platen is raised relative to the P pedestal assemblies to define a gap between the platen and the P pedestal assemblies to allow cleaning of the P processing station assemblies, the P pedestal assemblies, and surfaces in a cavity below the platen.

19. The reactor of claim 18, wherein the lower chamber housing includes at least one of a ledge and a post to lift the platen as the pedestal carousel assembly is lowered to define the gap.

20. The reactor of claim 1, wherein:

the upper chamber housing includes P openings, and wherein the P processing station assemblies are located in the P openings.

21. The reactor of claim 20, further comprising:

an exhaust opening formed in the upper chamber housing and aligned with the axis; and

an exhaust conduit connected to the exhaust opening.

22. The reactor of claim 21, further comprising P radial exhaust conduits extending radially outwardly from the exhaust conduit and fluidly connected to the P processing station assemblies.

23. The reactor of claim 20, further comprising a bearing surface located between the upper chamber housing and the lower chamber housing to provide sealing between the upper chamber housing and the lower chamber housing and to allow rotation of the lower chamber housing relative to the upper chamber housing.

24. The reactor of claim 23, wherein the bearing surface includes a gas bearing.

25. The reactor of claim 24, wherein the gas bearing is differentially pumped.

26. The reactor of claim 20, further comprising a ferrofluidic seal assembly arranged between the upper chamber housing and the lower chamber housing.

27. The reactor of claim 1, further comprising:

first and second apertures through at least one wall of the chamber housing; and

a controller configured to lower the pedestal carousel assembly to allow unloading of first and second substrates from first and second pedestals of first and second ones of the P pedestal assemblies and loading of third and fourth substrates onto the first and second pedestals of the first and second ones of the P pedestal assemblies.

28. The reactor of claim 27, wherein the controller is configured to rotate the pedestal carousel assembly to allow unloading of fifth and sixth substrates from third and fourth pedestals of third and fourth ones of the P pedestal assemblies and loading of seventh and eighth substrates onto the third and fourth pedestals of the third and fourth ones of the P pedestal assemblies.

29. The reactor of claim 27, wherein the controller is configured to raise the pedestal carousel assembly and index the P pedestal assemblies with the P processing station assemblies.

30. The reactor of claim 1, wherein the pedestal carousel assembly is rotated during cleaning.

31. The reactor of claim 1, wherein the pedestal carousel assembly is moved midway between index positions during cleaning.

32. The reactor of claim 1, wherein a pedestal of at least one of the P pedestals assemblies includes an isolation plate arranged below and spaced from the pedestal to define a gap that is less than twice a plasma sheath distance.

33. The reactor of claim 1, wherein a pedestal of at least one of the P pedestal assemblies includes at least one of a heater or a cooler.

34. The reactor of claim 1, wherein the reactor performs chemical vapor deposition (CVD) in at least one of the P processing station assemblies.

35. The reactor of claim 34, wherein the reactor performs plasma-enhanced CVD (PECVD) in at least one of the P processing station assemblies.

36. The reactor of claim 1, further comprising a remote plasma source to supply plasma to at least one of the P processing station assemblies.

37. The reactor of claim 1, wherein the reactor performs ultraviolet (UV) processing in at least one of the P processing station assemblies.

38. The reactor of claim 1, wherein the reactor performs physical vapor deposition (PVD) in at least one of the P processing station assemblies.

39. The reactor of claim 20, further comprising a seal arranged between the lower chamber housing and a lower portion of a hub of the pedestal carousel assembly.

40. The reactor of claim 2, wherein:

the pedestal carousel assembly has a process position where the P pedestal assemblies and the P processing stations define P axially-symmetric chamber housing volumes without viewport apertures or gauge ports to improve process uniformity.

41. The reactor of claim 40, wherein:

each of the P axially-symmetric chamber housing volumes are defined in part by a low conductance restriction having a diameter in a plane parallel to the platen that is less than 15% larger than the P openings, and

the pedestal carousel assembly has a cleaning position where the low conductance restrictions are removed and reactive gases flow via paths having a higher conductance than the low conductance restriction around the P processing station assemblies, the P pedestal assemblies and a surface of the platen facing the P processing station assemblies.