APPARATUS AND METHOD FOR REDUCING ELECTRICAL NOISE IN A THERMALLY CONTROLLED CHUCK

Related Application

This application is based on U. S. Provisional Patent Application serial number 60/526,030, filed on November 26, 2003, the contents of which are incorporated herein in their entirety by reference.

Background of the Invention

In the semiconductor integrated circuit industry, the cost of individual integrated circuit chip die is continuing to decrease in comparison to IC package costs. Consequently, it is becoming more important to perform many IC process steps while the die are still in the wafer, rather than after the relatively expensive packaging steps have been performed.

Typically, in IC processing, semiconductor wafers are subjected to a series of test and evaluation steps. For each step, the wafer is held in a stationary position at a process station where the process is performed. For example, circuit probe testing is increasingly performed over a wide temperature range to temperature screen the ICs before assembly into a package. The wafer is typically held stationary relative to a vacuum support surface of a prober machine which electrically tests the circuits on the wafer. The prober includes a group of electrical probes which, in conjunction with a tester, apply predetermined electrical excitations to various predetermined portions of the circuits on the wafer and sense the circuits' responses to the excitations.

In a typical prober system, the wafer is mounted on the top surface of a wafer chuck, which is held at its bottom surface to a support structure of the prober. A vacuum system is typically connected to the chuck. A series of channels or void regions in communication with the top surface of the chuck conduct the vacuum to the wafer to hold it in place on the top surface of the chuck. The prober support structure for the chuck is then used to locate the wafer under the probes as required to perform the electrical testing on the wafer circuits.

The chuck can also include a temperature control system which raises and lowers the temperature of the chuck surface and the wafer as required to perform the desired temperature screening of the wafer. It is important to the accuracy of such testing that the temperature of

the wafer and, therefore, the temperature of the chuck surface, be controlled as accurately and precisely as possible.

Various approaches to controlling the wafer temperature have been employed. For example, the chuck can include a circulation system through which a temperature control fluid is circulated. The temperature of the fluid is controlled such that the temperature of the chuck and, therefore, the temperature of the wafer, are controlled. Such temperature-controlled chucks can also include heaters such as electrical resistive heaters within the chuck. By applying power to the resistive heating element, heat is introduced into the chuck.

In some applications, such as where a wafer is being tested on a circuit prober, the presence of electrical noise in the system can degrade the performance accuracy of the testing. Therefore, it is important to minimize the electrical noise introduced into the system. One source of electrical noise is the temperature control fluid that circulates through the chuck. The motion and other behavior of the fluid in the chuck or in the lines carrying the fluid to and from the chuck can create electrical noise by triboelectric effects whereby electrical charge is produced by friction between two objects.

Summary of the Invention

It is a feature of the invention to provide a temperature control system for controlling temperature in a workpiece or wafer chuck in which the electrical noise effects introduced by the fluid are reduced.

In one aspect, the invention is directed to a temperature control system and a method for controlling temperature in a workpiece chuck. The system includes a temperature control device for controlling temperature of a temperature control fluid and a fluid inlet and a fluid outlet, the temperature control fluid being carried to and from the chuck via the fluid inlet and the fluid outlet. A controller controls the temperature control device, such as by controlling a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature and/or by controlling the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, e.g., the boiling temperature of the temperature control fluid, the

temperature control fluid is prevented from entering the chuck.

In one embodiment, a flow controlling device is controllable to change the flow rate of the temperature control fluid.

In one embodiment, the system includes a first fluid carrying path connected to one of the inlet and the outlet and a second fluid carrying path connected to the other of the inlet and the outlet. The flow controlling device can be connected in one of the first and second fluid carrying paths. The flow controlling device can include a fixed-orifice flow reducing device in one of the first and second fluid carrying paths and a controllable valve in parallel with the fixed-orifice flow reducing device. The controller can control the controllable valve to be open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

Alternatively, the flow controlling device can include a first controllable valve connected in one of the first and second fluid carrying paths and a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve. The controller can control the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

In one embodiment, a capillary tube can be connected between the first and second fluid carrying paths to balance pressures in the first and second fluid carrying paths.

In one embodiment, a first valve is connected in the first fluid carrying path, and a second valve is connected in the second fluid carrying path. The first and second valves are closed when the temperature of the chuck is above a predetermined temperature, e.g., the boiling temperature of the temperature control fluid, such that the temperature control fluid is prevented from flowing into the chuck.

The various techniques of the invention result in controlling flow and other behavior of the temperature control fluid used to control temperature in a chuck. The result is that electrical noise introduced by the fluid is reduced, and, accordingly, wafer processing such as prober testing over temperature, can be carried out more accurately.

Brief Description of the Drawings

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

FIG. 1 contains a top-level schematic block diagram of a temperature control system and workpiece chuck connected to control temperature of a workpiece such as a semiconductor wafer mounted on the workpiece chuck.

FIG. 2 is a schematic diagram of the temperature control system used to control temperature in a workpiece chuck, in accordance with an embodiment of the invention.

FIG. 3 is a schematic diagram of the temperature control system used to control temperature in a workpiece chuck, in accordance with another embodiment of the invention.

Detailed Description of Preferred Embodiments of the Invention

FIG. 1 contains a top-level schematic block diagram of a temperature control system and workpiece chuck connected to control temperature of a workpiece such as a semiconductor wafer mounted on the workpiece chuck. The system 9 includes a temperature control system such as a chiller 11, which controls the temperature of a temperature control fluid. The chiller 11 can be of the type manufactured and sold by Temptronic Corporation of Sharon, Massachusetts, the assignee of the present application. Specifically, the chiller can be a Model Number TP03500A Atlas Chiller, or similar system, which is modified to include features of the invention used to reduce electrical noise as described herein.

The temperature control fluid is routed to and from a test system, such as, for example, a wafer prober 13, along a hose or pipe 15. The hose or pipe 15 can be of the type described in U.S. Patent number 6,070,413, assigned to Temptronic Corporation of Sharon, Massachusetts, and incorporated herein in its entirety by reference. The hose or pipe 15 actually includes at least two fluid carrying hoses or pipes, one of which carries the temperature control fluid from the chiller 11 to the prober 13 and the other of which carries the temperature control fluid from the prober 13 back to the chiller 11. The workpiece or wafer 21 being tested by the prober 13 is mounted on a chuck 19. The chuck 19 and/or the approach by which temperature of the chuck 19 and wafer 21 is controlled can include any

features disclosed in any of U.S. patent numbers 4,734,872; 6,073,681; 6,540,014; 6,415,858; 6,505,478; 6,802,368; 6,091,060; 6,019,164; 6,328,096; 6,375,176; 6,700,099; 6,552,561; 6,744,270; 6,745,575, all of which are assigned to Temptronic Corporation of Sharon, Massachusetts and all of which are incorporated herein in their entirety by reference.

FIG. 2 is a schematic diagram of the temperature control system used to control temperature in a workpiece chuck, in accordance with an embodiment of the invention. Referring to FIG. 2, the temperature control system or chiller 11 is connected to the prober 13 via the hose or pipe 15, which carries the temperature control fluid back and forth to the chuck 19 in the prober 13. The chiller 11 includes a heat exchanger 23 used in controlling the temperature of the temperature control fluid. A pump 25 circulates the fluid through the system. The fluid is carried from the heat exchanger 23 to a fluid outlet of the chiller 11 on a first fluid carrying path 27. The fluid circulates through the chuck 19 and returns to the chiller 11 via the hose or pipe 15. The fluid is pumped along a second fluid carrying path 29 from a fluid inlet of the chiller 11 back to the heat exchanger 23. The chiller 11 includes a controller 7, which controls the functions of the chiller 11 to implement generation and delivery of the temperature control fluid, including, for example, the opening and closing of valves, and the timing of the opening and closing of the valves.

In accordance with the invention, a first valve 14 is connected in the first fluid carrying path 27, and a second valve 16 is connected in the second fluid carrying path 29. A fixed-orifice flow reducer 12 is connected in the first fluid carrying path 27, and a third valve 10 is connected in the first fluid carrying path 27 in parallel with the fixed-orifice flow reducer 12. A capillary tube 18 is connected between the first and second fluid carrying paths. As shown in FIG. 2, the capillary tube 18 is located between the chuck 19 and the valves 10, 12, 14, 16.

One or more approaches in accordance with the invention are utilized in the work chuck thermal control system of the invention to reduce the triboelectric electrical noise in the chuck. The use of these approaches is controlled by the chiller control system and is synchronized to the appropriate thermal control range where their use is most beneficial. These approaches all reduce electrical noise independently in different modes of system operation.

The first approach significantly reduces the flow of coolant through the chuck 19 from

the flow rate used to temperature transition the chuck 19. It includes the valve 10 and the flow reducer 12. This reduction in coolant flow results in reduced movement (vibration) of the chuck and other chuck components, which in turn results in reduced electrical noise level on the chuck. In one embodiment, the reduction in flow is achieved by switching the coolant flow from a high flow line to one with a flow restriction. In one embodiment, the restriction is an orifice that has significantly lower flow area than the high flow line.

In the thermal chuck of the invention, rapid temperature transitions during testing are highly desirable. One way to achieve rapid temperature transition is to provide high rate of flow of the temperature control fluid. However, high flow rate induces high electrical noise due to vibrations in the chuck and the triboelectric effect. In accordance with the invention, the flow reducer 12 and valves 10, 14 and 16 are used to achieve a high fluid flow rate during temperature transitions and a relatively low flow rate while maintaining the temperature of the chuck and wafer at a desired set point temperature. During temperature transitions, valves 10, 14 and 16 are opened, allowing fluid to flow at its maximum rate through the valves 10, 14 and 16, as well as the flow reducer 12. When the temperature of the chuck 19 reaches the desired set point, the valve 10 is closed, and the valves 14 and 16 remain open. As a result, the total fluid flow is reduced to that allowed by the fixed-orifice flow reducer 12. In one embodiment, the flow rate at constant temperature is about half of the flow rate during transitions. The lower flow rate while temperature is held constant results in much lower electrical noise, which provides increased accuracy in prober testing of the wafer at the desired set point temperature.

The second approach also involves the use of valves 14 and 16. This approach prevents coolant fluid from entering the chuck after the chuck temperature is above the boiling point of the cooling fluid. If the coolant fluid is allowed to enter a work chuck that is at a temperature above the boiling point of the coolant fluid, the coolant vaporizes violently and the resulting pressure pulsation induces vibrations in the chuck causing electrical noise. The coolant fluid can enter the work chuck by periodically flowing from a coolant fluid storage reservoir through the work chuck supply and/or return line. The flow is typically induced by the pressure created by the coolant fluid boiling itself or by fluid buoyancy differences throughout the system. The capillary tube 18 placed between the chuck inlet and outlet also balances the pressure between these lines preventing the coolant fluid in one line

from being closer to the chuck than the fluid in the other line. This reduces the possibility that fluid will reenter the high-temperature chuck and flash boil to create noise-inducing motion.

FIG. 3 is a schematic diagram of the temperature control system used to control temperature in a workpiece chuck, in accordance with another embodiment of the invention. In this embodiment, the valve 10 and flow reducer 12 of FIG. 2 are replaced with a pair of valves 45 and 47 connected in parallel in the first fluid carrying path 27. In this embodiment, during temperature transitions, both valves 45 and 47 are opened to allow for maximum rate of flow of the temperature control fluid. When the chuck reaches a set point temperature, one of the valves, e.g., valve 45, is closed, and the other valve, e.g., valve 47, remains open. As a result, the temperature control fluid is allowed to flow through only the open valve 47 at a reduced flow rate, resulting in a reduction in electrical noise caused by fluid at a comparatively high flow rate. It should be noted that in the embodiment of FIG. 3, the valve 14 is optional. The valve 14 can be omitted, because valves 45 and 47 can be used to meet the purpose of valve 14.

In accordance with the invention, when a temperature-controlled workpiece or wafer chuck is transitioned in temperature, high transition rate is achieved by using a high flow rate of temperature control fluid through the chuck. When the chuck temperature reaches a desired set point temperature, the chuck temperature is maintained at the set point. Under this steady-state condition, the flow rate of the temperature control fluid is reduced, such that electrical noise that may be introduced by the moving fluid is reduced. In embodiments of the invention described herein, this dual-flow-rate approach is achieved by using a flow control device connected in one or more of the lines carrying the temperature control fluid to and from the chuck. This flow control device can be a pair of valves or a valve and a fixed-orifice flow restrictor connected in parallel. At least one on the valves can be controlled such that it is open during temperature transitions to achieve high-rate transition and closed during steady-state temperature maintenance such that electrical noise is reduced. In another embodiment of the invention, the dual-flow-rate approach is achieved by using a variable-speed pump as the pump 25. The pump can be set to a relatively high speed during temperature transitions such that the fluid flow rate is relatively high. At steady-state temperature set point maintenance, the pump can operate at a reduced speed such that the

fluid flow rate is reduced, resulting in reduced electrical noise in the chuck during testing.

It should be noted that throughout the foregoing description and the following claims, the application refers to the temperature control fluid. The temperature control fluid can be in a gaseous state or a liquid state. As referred to herein, the fluid is assumed to be in a liquid state, however, it is known that the fluid can also be in a gaseous state in the system, such as where the liquid state of the fluid boils in the chuck to enter its gaseous state. Unless otherwise specified herein, when the temperature control fluid is referred to, such as where the fluid is prevented from entering the chuck in certain embodiments of the invention, it is the liquid state of the fluid that is being referred to. For example, where the fluid, i.e., liquid state of the fluid, is prevented from entering the chuck, it is understood that the gaseous state of the fluid may be present in the chuck.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined in the following claims.

CLAIMS

1. A temperature control system for a workpiece chuck, comprising:

a temperature control device for controlling temperature of a temperature control fluid;

a fluid inlet and a fluid outlet, the temperature control fluid being carried to and from the chuck via the fluid inlet and the fluid outlet; and

a controller for controlling the temperature control device, the controller controlling a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature.

2. The temperature control system of claim 1, further comprising a flow controlling device being controllable to change the flow rate of the temperature control fluid.

3. The temperature control system of claim 2, further comprising:

a first fluid carrying path connected to one of the inlet and the outlet; and

a second fluid carrying path connected to the other of the inlet and the outlet; wherein the flow controlling device is connected in one of the first and second fluid carrying paths.

4. The temperature control system of claim 3, wherein the flow controlling device comprises:

a fixed-orifice flow reducing device in one of the first and second fluid carrying paths; and

a controllable valve in parallel with the fixed-orifice flow reducing device.

5. The temperature control system of claim 4, wherein the controller controls the controllable valve to be open when temperature in the chuck is in transition and

closed when the temperature in the chuck is to be maintained at a desired set point.

6. The temperature control system of claim 3, wherein the flow controlling device comprises:

a first controllable valve connected in one of the first and second fluid carrying paths; and

a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve.

7. The temperature control system of claim 6, wherein the controller controls the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

8. The temperature control system of claim 1, further comprising:

a first fluid carrying path connected to one of the inlet and the outlet;

a second fluid carrying path connected to the other of the inlet and the outlet; and

a capillary tube connected between the first and second fluid carrying paths.

9. The temperature control system of claim 8, wherein the capillary tube is adapted to balance pressures in the first and second fluid carrying paths.

10. The temperature control system of claim 8, further comprising a first valve in the first fluid carrying path and a second valve in the second fluid carrying path.

11. The temperature control system of claim 10, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

12. The temperature control system of claim 11, wherein the predetermined temperature is

above a boiling point of the temperature control fluid.

13. The temperature control system of claim 1, further comprising:

a first fluid carrying path connected to one of the inlet and the outlet;

a second fluid carrying path connected to the other of the inlet and the outlet;

a first valve in the first fluid carrying path; and

a second valve in the second fluid carrying path.

14. The temperature control system of claim 13, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

15. The temperature control system of claim 14, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

16. The temperature control system of claim 1, wherein the controller controls the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, the temperature control fluid is prevented from entering the chuck.

17. The temperature control system of claim 16, wherein the predetermined temperature is above a boiling temperature of the temperature control fluid.

18. A temperature control system for a workpiece chuck, comprising:

a temperature control device for controlling temperature of a temperature control fluid;

a fluid inlet and a fluid outlet, the temperature control fluid being carried to and from the chuck via the fluid inlet and the fluid outlet; and

a controller for controlling the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, the temperature control fluid is prevented from entering the chuck.

19. The temperature control system of claim 18, wherein the predetermined temperature is above a boiling temperature of the temperature control fluid.

20. The temperature control system of claim 18, further comprising:

a first fluid carrying path connected to one of the inlet and the outlet;

a second fluid carrying path connected to the other of the inlet and the outlet;

a first valve in the first fluid carrying path; and

a second valve in the second fluid carrying path.

21. The temperature control system of claim 20, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

22. The temperature control system of claim 21, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

23. The temperature control system of claim 18, further comprising:

a first fluid carrying path connected to one of the inlet and the outlet;

a second fluid carrying path connected to the other of the inlet and the outlet; and

a capillary tube connected between the first and second fluid carrying paths.

24. The temperature control system of claim 23, wherein the capillary tube is adapted to balance pressures in the first and second fluid carrying paths.

25. The temperature control system of claim 23, further comprising a first valve in the first fluid carrying path and a second valve in the second fluid carrying path.

26. The temperature control system of claim 25, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

27. The temperature control system of claim 26, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

28. The temperature control system of claim 1, wherein:

the controller controls a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature; and

the system further comprises a flow controlling device being controllable to change the flow rate of the temperature control fluid.

29. The temperature control system of claim 28, further comprising:

a first fluid carrying path connected to one of the inlet and the outlet; and

a second fluid carrying path connected to the other of the inlet and the outlet; wherein the flow controlling device is connected in one of the first and second fluid carrying paths.

30. The temperature control system of claim 29, wherein the flow controlling device comprises:

a fixed-orifice flow reducing device in one of the first and second fluid carrying paths; and

a controllable valve in parallel with the fixed-orifice flow reducing device.

31. The temperature control system of claim 30, wherein the controller controls the controllable valve to be open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

32. The temperature control system of claim 29, wherein the flow controlling device comprises:

a first controllable valve connected in one of the first and second fluid carrying paths; and

a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve.

33. The temperature control system of claim 32, wherein the controller controls the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

34. A temperature control system for a workpiece chuck, comprising:

a temperature control device for controlling temperature of a temperature control fluid;

a fluid inlet and a fluid outlet, the temperature control fluid being carried to and from the chuck via the fluid inlet and the fluid outlet;

a first fluid carrying path connected to one of the inlet and the outlet;

a second fluid carrying path connected to the other of the inlet and the outlet;

a controller for controlling the temperature control device, the controller (i) controlling a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature, and (ii) controlling the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, the temperature control fluid is prevented from entering the chuck; and

a flow controlling device being controllable by the controller to change the flow rate of the temperature control fluid.

35. The temperature control system of claim 34, wherein the flow controlling device is connected in one of the first and second fluid carrying paths.

36. The temperature control system of claim 35, wherein the flow controlling device comprises:

a fixed-orifice flow reducing device in one of the first and second fluid carrying paths; and

a controllable valve in parallel with the fixed-orifice flow reducing device.

37. The temperature control system of claim 36, wherein the controller controls the controllable valve to be open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

38. The temperature control system of claim 35, wherein the flow controlling device comprises:

a first controllable valve connected in one of the first and second fluid carrying paths; and

a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve.

39. The temperature control system of claim 38, wherein the controller controls the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

40. The temperature control system of claim 34, further comprising a capillary tube connected between the first and second fluid carrying paths.

41. The temperature control system of claim 40, wherein the capillary tube is adapted to balance pressures in the first and second fluid carrying paths.

42. The temperature control system of claim 34, further comprising:

a first valve in the first fluid carrying path; and

a second valve in the second fluid carrying path.

43. The temperature control system of claim 42, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

44. The temperature control system of claim 43, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

45. A method of controlling temperature in a workpiece chuck, comprising:

controlling temperature of a temperature control fluid with a temperature control device;

carrying the temperature control fluid to and from the chuck via a fluid inlet and a fluid outlet; and

providing a controller for controlling the temperature control device, the controller controlling a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature.

46. The method of claim 45, further comprising providing a flow controlling device being controllable to change the flow rate of the temperature control fluid.

47. The method of claim 46, further comprising:

connecting a first fluid carrying path to one of the inlet and the outlet; and

connecting a second fluid carrying path to the other of the inlet and the outlet; and

connecting the flow controlling device in one of the first and second fluid carrying paths.

48. The method of claim 47, wherein the flow controlling device comprises:

a fixed-orifice flow reducing device in one of the first and second fluid

carrying paths; and

a controllable valve in parallel with the fixed-orifice flow reducing device.

49. The method of claim 48, wherein the controller controls the controllable valve to be open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

50. The method of claim 47, wherein the flow controlling device comprises:

a first controllable valve connected in one of the first and second fluid carrying paths; and

a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve.

51. The method of claim 50, wherein the controller controls the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

52. The method of claim 45, further comprising:

connecting a first fluid carrying path to one of the inlet and the outlet;

connecting a second fluid carrying path to the other of the inlet and the outlet; and

connecting a capillary tube between the first and second fluid carrying paths.

53. The method of claim 52, wherein the capillary tube is adapted to balance pressures in the first and second fluid carrying paths.

54. The method of claim 52, further comprising providing a first valve in the first fluid carrying path and a second valve in the second fluid carrying path.

55. The method of claim 54, wherein the first and second valves are closed when the

temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

56. The method of claim 55, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

57. The method of claim 45, further comprising:

connecting a first fluid carrying path to one of the inlet and the outlet;

connecting a second fluid carrying path to the other of the inlet and the outlet;

providing a first valve in the first fluid carrying path; and

providing a second valve in the second fluid carrying path.

58. The method of claim 57, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

59. The method of claim 58, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

60. The method of claim 45, wherein the controller controls the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, the temperature control fluid is prevented from entering the chuck.

61. The method of claim 60, wherein the predetermined temperature is above a boiling temperature of the temperature control fluid.

62. A method of controlling temperature in a workpiece chuck, comprising:

controlling temperature of a temperature control fluid with a temperature control device;

carrying the temperature control fluid to and from the chuck via a fluid inlet and a fluid outlet; and

providing a controller for controlling the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, the temperature control fluid is prevented from entering the chuck.

63. The method of claim 62, wherein the predetermined temperature is above a boiling temperature of the temperature control fluid.

64. The method of claim 62, further comprising:

connecting a first fluid carrying path to one of the inlet and the outlet;

connecting a second fluid carrying path to the other of the inlet and the outlet;

providing a first valve in the first fluid carrying path; and

providing a second valve in the second fluid carrying path.

65. The method of claim 64, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

66. The method of claim 65, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

67. The method of claim 62, further comprising:

connecting a first fluid carrying path to one of the inlet and the outlet;

connecting a second fluid carrying path to the other of the inlet and the outlet; and

connecting a capillary tube between the first and second fluid carrying paths.

68. The method of claim 67, wherein the capillary tube is adapted to balance pressures in the first and second fluid carrying paths.

69. The method of claim 67, further comprising providing a first valve in the first fluid carrying path and a second valve in the second fluid carrying path.

70. The method of claim 69, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

71. The method of claim 70, wherein the predetermined temperature is above a boiling point of the temperature control fluid.

72. The method of claim 62, wherein:

the controller controls a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature; and

a flow controlling device is controllable by the controller to change the flow rate of the temperature control fluid.

73. The method of claim 72, further comprising:

connecting a first fluid carrying path to one of the inlet and the outlet; and

connecting a second fluid carrying path to the other of the inlet and the outlet; wherein the flow controlling device is connected in one of the first and second fluid carrying paths.

74. The method of claim 73, wherein the flow controlling device comprises:

a fixed-orifice flow reducing device in one of the first and second fluid carrying paths; and

a controllable valve in parallel with the fixed-orifice flow reducing device.

75. The method of claim 74, wherein the controller controls the controllable valve to be open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

76. The method of claim 73, wherein the flow controlling device comprises:

a first controllable valve connected in one of the first and second fluid carrying paths; and

a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve.

77. The method of claim 76, wherein the controller controls the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

78. A method of controlling temperature in a workpiece chuck, comprising:

controlling temperature of a temperature control fluid with a temperature control device;

carrying the temperature control fluid to and from the chuck via a fluid inlet and a fluid outlet;

connecting a first fluid carrying path to one of the inlet and the outlet;

connecting a second fluid carrying path to the other of the inlet and the outlet;

providing a controller for controlling the temperature control device, the controller (i) controlling a flow rate of the temperature control fluid through the chuck, such that the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is in transition is higher than the flow rate of the temperature control fluid through the chuck when the temperature of the chuck is being maintained at a set point temperature, and (ii) controlling the temperature control device such that, when a temperature of the chuck is above a predetermined temperature, the temperature control fluid is prevented from entering the chuck; and

providing a flow controlling device being controllable by the controller to change the flow rate of the temperature control fluid.

79. The method of claim 78, wherein the flow controlling device is connected in one of

the first and second fluid carrying paths.

80. The method of claim 79, wherein the flow controlling device comprises:

a fixed-orifice flow reducing device in one of the first and second fluid carrying paths; and

a controllable valve in parallel with the fixed-orifice flow reducing device.

81. The method of claim 80, wherein the controller controls the controllable valve to be open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

82. The method of claim 79, wherein the flow controlling device comprises:

a first controllable valve connected in one of the first and second fluid carrying paths; and

a second controllable valve connected in the one of the first and second fluid carrying paths in parallel with the first controllable valve.

83. The method of claim 82, wherein the controller controls the first and second controllable valves such that one of the first and second controllable valves is open when temperature in the chuck is in transition and closed when the temperature in the chuck is to be maintained at a desired set point.

84. The method of claim 78, further comprising connecting a capillary tube between the first and second fluid carrying paths.

85. The method of claim 84, wherein the capillary tube is adapted to balance pressures in the first and second fluid carrying paths.

86. The method of claim 78, further comprising:

providing a first valve in the first fluid carrying path; and

providing a second valve in the second fluid carrying path.

87. The method of claim 86, wherein the first and second valves are closed when the temperature of the chuck is above a predetermined temperature such that the temperature control fluid is prevented from flowing into the chuck.

88. The method of claim 87, wherein the predetermined temperature is above a boiling point of the temperature control fluid.