CLAIMS

What is claimed is:

1. A chuck for a plasma processor comprising:

a temperature-controlled base having a temperature below the desired temperature of a workpiece;

a layer of thermal insulation material disposed over said base;

a flat support for holding said workpiece, said flat support disposed over said layer of thermal insulation material; and

a heater coupled to an underside of said flat support, said heater including a plurality of planar heating elements corresponding to a plurality of heating regions in said flat support,

wherein said heater has a temperature rate change of at least 1°C per second.

2. The chuck of claim 1 wherein power applied to each planar heating element is controlled independently.

3. The chuck of claim 1 further comprising a thermal conductor disposed between said flat support and said workpiece.

4. The chuck of claim 1 wherein said temperature-controlled base is maintained at a constant temperature of less than 20°C.

5. The chuck of claim 1 further comprising a plurality of sensors corresponding with said plurality of heating regions, each sensor measuring and sending a signal representative of the temperature of its corresponding heating region.

6. The chuck of claim 5 further comprising a controller for receiving said signal from said sensor and for adjusting the power of each planar heating element based on a set point for each heating region.

7. The chuck of claim 1 wherein said heater includes a plurality of electrically resistive heaters.

8. The chuck of claim 1 wherein said heater includes a plurality of induction heaters.

9. The chuck of claim 1 wherein said heater includes a plurality of heating lamps.

10. The chuck of claim 1 wherein said heater includes a plurality of thermoelectric modules.

11. The chuck of claim 1 wherein said flat support includes an electrostatic chuck.

12. A chuck for a plasma processor comprising:

a temperature-controlled base having a temperature below the desired temperature of a workpiece;

a layer of thermal insulation material disposed over said base;

a flat support for holding said workpiece, said flat support disposed over said layer of thermal insulation material; and

a heater embedded within said flat support, said heater including a plurality of planar heating elements corresponding to a plurality of heating regions in said flat support,

wherein the temperature of said heater and said flat support are adapted to be capable of change of at least 1°C per second.

13. The chuck of claim 12 wherein the power of each planar heating element is controlled independently.

14. The chuck of claim 12 further comprising a thermal conductor disposed between said flat support and said workpiece.

15. The chuck of claim 12 wherein said temperature-controlled base is maintained at a constant temperature of less than 20°C.

16. The chuck of claim 12 further comprising a plurality of sensors corresponding with said plurality of heating regions, each sensor measuring and sending a signal representative of the temperature of its corresponding heating region.

17. The chuck of claim 16 further comprising a controller for receiving said signal from said sensor and for adjusting the power of each planar heating element based on a set point for each heating region.

18. The chuck of claim 16wherein said heater includes a plurality of electrically resistive heaters.

19. The chuck of claim 16 wherein said heater includes a plurality of induction heaters.

20. The chuck of claim 16 wherein said heater includes a plurality of heating lamps.

21. The chuck of claim 16 wherein said heater includes a plurality of thermoelectric modules.

22. The chuck of claim 16 wherein a thickness of said flat support, a power density of said heater, and a thermal resistance of said layer of insulation material permit a temperature change in said flat support of at least 1°C per second.

23. The chuck of claim 16 wherein said flat support includes an electrostatic chuck.

24. A method for controlling the spatial temperature across a workpiece comprising:

providing a base maintained at a constant temperature, said constant temperature being below the temperature of the workpiece, said base having a layer of thermal insulation material mounted on top of said base;

holding the workpiece against a top face of a flat support having a plurality of spatial regions, said flat support mounted on top of said layer of thermal insulation material;

independently heating each spatial region of said flat support with a plurality of heaters mounted to an underside of said flat support; and

changing the temperature of at least one spatial region of said flat support during an etching process at a rate of at least 1°C per second.

25. The method of claim 24 further comprising monitoring the temperature of said plurality of spatial regions with a sensor placed in each region.

26. The method of claim 25 further comprising adjusting the temperature of each spatial region based on said monitoring.

27. The method of claim 24 wherein said plurality of heaters includes a plurality of electrically resistive heaters.

28. The method of claim 24 wherein said plurality of heaters includes a plurality of induction heaters.

29. The method of claim 24 wherein said plurality of heaters includes a plurality of heating lamps.

30. The method of claim 24 wherein said plurality of heaters includes a plurality of thermoelectric modules.

31. A method for controlling the spatial temperature across a workpiece comprising:

providing a base maintained at a constant temperature, said constant temperature being below the temperature of the workpiece, said base having a layer of thermal insulation material mounted on top of said base;

holding the workpiece against a top face of a flat support having a plurality of spatial regions, said flat support mounted on top of said layer of thermal insulation material;

independently heating each spatial region of said flat support with a plurality of heaters embedded within said flat support; and

changing the temperature of at least one spatial region of said flat support during an etching process at a rate of at least 1°C per second.

32. The method of claim 31 further comprising monitoring the temperature of said plurality of spatial regions with a sensor placed in each region.

33. The method of claim 32 further comprising adjusting the temperature of each spatial region based on said monitoring.

34. The method of claim 31 wherein said plurality of heaters includes a plurality of electrically resistive heaters.

35. The method of claim 31 wherein said plurality of heaters includes a plurality of induction heaters.

36. The method of claim 31 wherein said plurality of heaters includes a plurality of heating lamps.

37. The method of claim 31 wherein said plurality of heaters includes a plurality of thermoelectric modules.

38. An apparatus for controlling the spatial temperature across a workpiece comprising:

means for providing a base maintained at a constant temperature, said constant temperature being below the temperature of the workpiece, said base having a layer of thermal insulation material mounted on top of said base;

means for holding the workpiece against a top face of a flat support having a plurality of spatial regions, said flat support mounted on top of said layer of thermal insulation material;

means for independently heating each spatial region of said flat support with a plurality of heaters mounted to an underside of said flat support; and

means for changing the temperature of at least one spatial region of said flat support during an etching process at a rate of at least 1°C per second.

39. An apparatus for controlling the spatial temperature across a workpiece comprising:

means for providing a base maintained at a constant temperature, said constant temperature being below the temperature of the workpiece, said base having a layer of thermal insulation material mounted on top of said base;

means for holding the workpiece against a top face of a flat support having a plurality of spatial regions, said flat support mounted on top of said layer of thermal insulation material;

means for independently heating each spatial region of said flat support with a plurality of heaters embedded within said flat support; and

means for changing the temperature of at least one spatial region of said flat support during an etching process at a rate of at least 1°C per second.

40. A workpiece chuck assembly for a plasma processor, the chuck comprising:

a single-piece base element thermally separated by at least one lateral thermal break into at least two portions, including at least a first portion and a second portion; and

a wafer support element disposed over the first portion and the second portion, the wafer support including at least a first thermal element configured to affect the temperature of the workpiece disposed above the first portion of the base and a second thermal element configured to affect the temperature of the workpiece disposed above the second portion of the base.

41. The chuck assembly according to claim 40, wherein said first thermal element and said second thermal element are substantially flat.

42. The chuck assembly according to claim 40, wherein said first thermal element and said second thermal element are disposed in the shape of a coil.

43. The chuck assembly according to claim 40, wherein said first thermal element includes a plurality of serially-connected resistive elements.

44. The chuck assembly of claim 40, further comprising an insulator disposed between the base element and the wafer support element.

45. The chuck assembly of claim 40, further comprising a thermally conductive medium disposed over the wafer support element.

46. The chuck assembly of claim 40, wherein the wafer support element further comprises a first temperature sensor disposed above the first portion of the base and a second temperature sensor disposed above the second portion of the base.

47. The chuck assembly of claim 46, further comprising a controller responsive to said first and second temperature sensors and configured to control temperature in the first and second portions of the base.

48. The chuck assembly of claim 40, wherein said first thermal element comprises thermoelectric modules configured to heat or to cool.

49. A workpiece chuck assembly for a plasma processor, the chuck comprising:

a single-piece base element thermally separated by a vertically disposed lateral thermal break into at least two disk-shaped portions, including at least an inner disk-shaped portion and an outer disk-shaped portion; and

a wafer support element disposed over the inner and outer disk-shaped portions, the wafer support element including at least a first thermal element configured to affect the temperature of the workpiece disposed above the inner disk-shaped portion and a second thermal element configured to affect the temperature of the workpiece disposed above the outer disk-shaped portion.

50. The chuck assembly of claim 49, wherein at least one of the thermal elements is in the shape of a coil

51. The chuck assembly of claim 49, wherein at least one of the thermal elements includes a plurality of serially-connected resistive elements.

52. The chuck assembly of claim 49, further comprising an insulator disposed between the base element and the wafer support element.

53. The chuck assembly of claim 49, further comprising a thermally conductive medium disposed over the wafer support element.

54. The chuck assembly of claim 49, wherein at least one of the thermal elements comprises a thermoelectric module configured to heat or to cool.

55. The chuck assembly of claim 49, wherein the wafer support element further comprises a first temperature sensor disposed above the first portion of the base and a second temperature sensor disposed above the second portion of the base.

56. The chuck assembly of claim 55, further comprising a controller responsive to said first and second temperature sensors and configured to control temperature in the first and second portions of the base.

Claims

What is claimed is:

1. A method for controlling the spatial temperature across a semiconductor wafer during a multistep plasma etching process wherein wafer temperature is changed for the particular layer being etched comprising:

maintaining a base at a constant temperature, said constant temperature being below the temperature of the wafer, said base having a layer of thermal insulation material mounted on top of said base;

electrostatically clamping the wafer against a top face of a flat support having a plurality of spatial regions, said flat support mounted on top of said layer of thermal insulation material;

plasma etching a layer on the wafer under conditions such that local concentration of reactants varies across the wafer;

independently heating each spatial region of said flat support with a plurality of heaters mounted to an underside of said flat support so as to induce a radial temperature gradient which compensates for the variation in the local concentration of the reactants; and

changing the temperature of at least one spatial region of said flat support during the multistep plasma etching process at a rate of at least 1 ℃ per second.

2. The method of claim 1 further comprising monitoring the temperature of said plurality of spatial regions with a sensor placed in each region.

3. The method of claim 2 further comprising adjusting the temperature of each spatial region based on said monitoring.

4. The method of claim 1 wherein said plurality of heaters includes a plurality of electrically resistive heaters.

5. The method of claim 1 wherein said multistep plasma etching process is carried out for a time period of 20 seconds to 2 minutes.

6. The method of claim 1 wherein said multistep plasma etching process comprises etching multiple layers and altering the radial temperature profile on a step-by-step basis and within each step of the multistep plasma etching process.

7. The method of claim 1 wherein the temperature of one or more of the spatial regions of said flat support during the multistep etching process is changed less than 10℃.

8. A method for controlling the spatial temperature across a semiconductor wafer during a multistep plasma etching process wherein wafer temperature is changed for the particular layer being etched comprising:

maintaining a base at a constant temperature, said constant temperature being below the temperature of the wafer, said base having a layer of thermal insulation material mounted on top of said base;

electrostatically clamping the wafer against a top face of a flat support having a plurality of spatial regions, said flat support mounted on top of said layer of thermal insulation material;

plasma etching a layer on the wafer under conditions such that local concentration of reactants varies across the wafer;

independently heating each spatial region of said flat support with a plurality of heaters embedded within said flat support so as to induce a radial temperature gradient which compensates for the variation in the local concentration of the reactants; and

changing the temperature of at least one spatial region of said flat support during the multistep plasma etching process at a rate of at least 1℃ per second.

9. The method of claim 8 further comprising monitoring the temperature of said plurality of spatial regions with a sensor placed in each region.

10. The method of claim 9 further comprising adjusting the temperature of each spatial region based on said monitoring.

11. The method of claim 8 wherein said plurality of heaters includes a plurality of electrically resistive heaters.

12. The method of claim 8 wherein said multistep plasma etching process is carried out for a time period of 20 seconds to 2 minutes.

13. The method of claim 8 wherein said multistep plasma etching process comprises etching multiple layers and altering the radial temperature profile on a step-by-step basis and within each step of the multistep plasma etching process.

14. The method of claim 8 wherein the temperature of one or more of the spatial regions of said flat support during the multistep etching process is changed less than 10℃.

15. The method of claim 1, wherein heat flux impinging on the wafer from the plasma is less than $2W/cm^2$.

16. The method of claim 8, wherein heat flux impinging on the wafer from the plasma is less than $2W/cm^2$.

17. The method of claim 1, wherein an outer edge of the wafer extends radially outward from an outer edge of the flat support and heat flux impinging on the outer edge of the wafer flows radially inward.

18. The method of claim 8, wherein an outer edge of the wafer extends radially outward from an outer edge of the flat support and heat flux impinging on the outer edge of the wafer flows radially inward.

19. The method of claim 1, wherein the layer of thermal insulation provides a thermal impedance break between the base and the flat support, the layer of thermal insulation having a thermal conductivity of 0.05 to 0.20 W/mK.

20. The method of claim 8, wherein the layer of thermal insulation provides a thermal impedance break between the base and the flat support, the layer of thermal insulation having a thermal conductivity of 0.05 to 0.20 W/mK.