CLAIMS

1. A substrate processing method, comprising:

providing a substrate in a chamber, the substrate including a silicon-containing film including a silicon oxide film and a mask on the silicon-containing film;

etching the silicon-containing film with plasma generated from a first process gas containing a hydrogen fluoride gas and at least one carbon-containing gas selected from the group consisting of a fluorocarbon gas and a hydrofluorocarbon gas,

wherein the hydrogen fluoride gas has a highest flow rate among non-inert components of the first process gas.

2. The substrate processing method according to claim 1, wherein

the hydrogen fluoride gas has a flow rate of not less than 70 vol% of a total flow rate of the non-inert components of the first process gas.

3. The substrate processing method according to claim 1 or 2, wherein

the fluorocarbon gas is at least one selected from the group consisting of CF_4, C_2F_2, C_2F_4, C_3F_8, C_4F_6, C_4F_8, and C_5F_8.

4. The substrate processing method according to claim 1 or 2, wherein

the fluorocarbon gas includes a C_4F_8 gas.

5. The substrate processing method according to claim 1 or 2, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of CHF_3, CH_2F_2, CH_3F, C_2HF_5, $C_2H_2F_4$, $C_2H_3F_3$, $C_2H_4F_2$, C_3HF_7, $C_3H_2F_2$, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, $C_4H_5F_5$, $C_4H_2F_6$, $C_5H_2F_{10}$ andc-$C_5H_3F_7$.

6. The substrate processing method according to claim 1 or 2, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of a $C_3H_2F_4$ gas and a $C_4H_2F_6$ gas.

7. The substrate processing method according to any one of claims 1 to 6, wherein

the first process gas further contains at least one selected from the group consisting of an oxygen-containing gas and a halogen-containing gas.

8. The substrate processing method according to any one of claims 1 to 7, wherein

the first process gas further contains at least one selected from the group consisting of a phosphorus-containing gas, a sulfur-containing gas, and a boron-containing gas.

9. The substrate processing method according to claim 8, wherein

the method uses a capacitively coupled plasma processing apparatus including the chamber.

10. The substrate processing method according to claim 8 or 9, wherein

a flow rate of the non-inert components of the first process gas is not less than 100 sccm.

11. The substrate processing method according to any one claims 1 to 10, wherein

the hydrogen fluoride gas has a flow rate of not more than 96 vol% of a total flow rate of the non-inert components of the first process gas.

12. The substrate processing method according to any one of claims 1 to 11, wherein

the silicon-containing film includes at least one selected from the group consisting of a silicon oxide film, a film stack including a silicon oxide film and a silicon nitride film, and a film stack including a silicon oxide film and a polysilicon film.

13. The substrate processing method according to any one of claims 1 to 12, wherein

the mask is a carbon-containing mask or a metal-containing

mask.

14. The substrate processing method according to claim 13, wherein

the carbon-containing mask comprises at least one selected from the group consisting of spin-on carbon, tungsten carbide, amorphous carbon, and boron carbide.

15. The substrate processing method according to any one of claims 1 to 14, further including

generating plasma from a second process gas in the chamber and cleaning an inside of the chamber.

16. The substrate processing method according to claim 15, wherein

the second process gas contains at least one selected from the group consisting of a fluorine-containing gas, an oxygen-containing gas, a hydrogen-containing gas, and a nitrogen-containing gas.

17. The substrate processing method according to any one of claims 1 to 16, further including

generating plasma from a third process gas in the chamber before the providing the substrate and depositing a precoat on an inner wall of the chamber.

18. The substrate processing method according to claim 17,

wherein

the third process gas contains a carbon-containing gas.

19. A substrate processing method, comprising:

providing a substrate in a chamber, the substrate including a silicon-containing film and a mask on the silicon-containing film; and

etching the silicon-containing film with plasma generated from a first process gas containing a hydrogen fluoride gas, a carbon-containing gas, and an oxygen-containing gas or a halogen-containing gas,

wherein the hydrogen fluoride gas has a flow rate of not less than 70 vol % and not more than 96 vol% of a total flow rate of non-inert components of the first process gas.

20. The substrate processing method according to claim 19, wherein

the carbon-containing gas contains at least one selected from the group consisting of a fluorocarbon gas, a hydrofluorocarbon gas, and a hydrocarbon gas.

21. The substrate processing method according to claim 20, wherein

the fluorocarbon gas is at least one selected from the group consisting of CF_4, C_2F_2, C_2F_4, C_3F_8, C_4F_6, C_4F_8, and C_5F_8.

22. The substrate processing method according to claim 20,

wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of CHF_3, CH_2F_2, CH_3F, C_2HF_5, $C_2H_2F_4$, $C_2H_3F_3$, $C_2H_4F_2$, C_3HF_7, $C_3H_2F_2$, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, $C_4H_5F_5$, $C_4H_2F_6$, $C_5H_2F_{10}$, and c-$C_5H_3F_7$.

23. The substrate processing method according to claim 20, wherein

the hydrocarbon gas is at least one selected from the group consisting of CH_4, C_2H_6, C_3H_6, C_3H_8, and C_4H_{10}.

24. The substrate processing method according to claim 19, wherein

the carbon-containing gas includes a hydrofluorocarbon gas having three or more carbon atoms.

25. The substrate processing method according to any one of claims 19 to 24, wherein

the silicon-containing film includes at least one selected from the group consisting of a film stack including a silicon oxide film and a silicon nitride film, a polysilicon film, a film with a low dielectric constant, and a film stack including a silicon oxide film and a polysilicon film.

26. The substrate processing method according to any one of claims 19 to 25, wherein

the mask is a carbon-containing mask or a metal-containing mask.

27. The substrate processing method according to any one of claims 19 to 26, further including

controlling a temperature of a substrate support on which the substrate is placed to 0 °C or lower before the etching.

28. A plasma processing apparatus comprising,

a chamber having a gas inlet and a gas outlet;

a plasma generator; and

a controller,

wherein the controller performs processing including

providing a substrate in the chamber, the substrate including a silicon-containing film including a silicon oxide film and a mask provided on the silicon-containing film, and

etching the silicon-containing film with plasma generated from a first process gas containing a hydrogen fluoride gas and at least one carbon-containing gas selected from the group consisting of a fluorocarbon gas and a hydrofluorocarbon gas,

wherein the controller performs control so that the hydrogen fluoride gas has a highest flow rate among non-inert components of the first process gas in said etching.

29. The plasma processing apparatus according to claim 28, wherein

the hydrogen fluoride gas has a flow rate of not less than 70 vol% of a total flow rate of the non-inert components of the first process gas.

30. The plasma processing apparatus according to claim 28 or 29, wherein

the fluorocarbon gas is at least one selected from the group consisting of CF_4, C_2F_2, C_2F_4, C_3F_8, C_4F_6, C_4F_8, and C_5F_8.

31. The plasma processing apparatus according to claim 28 or 29, wherein

the fluorocarbon gas includes a C_4F_8 gas.

32. The plasma processing apparatus according to claim 28 or 29, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of CHF_3, CH_2F_2, CH_3F, C_2HF_5, $C_2H_2F_4$, $C_2H_3F_3$, $C_2H_4F_2$, C_3HF_7, $C_3H_2F_2$, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, $C_4H_5F_5$, $C_4H_2F_6$, $C_5H_2F_{10}$, and c-$C_5H_3F_7$.

33. The plasma processing apparatus according to claim 28 or 29, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of a $C_3H_2F_4$ gas and a $C_4H_2F_6$ gas.

34. The plasma processing apparatus according to any one

of claims 28 to 33, wherein

the first process gas further contains at least one selected from the group consisting of an oxygen-containing gas and a halogen-containing gas.

35. The plasma processing apparatus according to any one of claims 28 to 34, wherein

the first process gas further contains at least one selected from the group consisting of a phosphorus-containing gas, a sulfur-containing gas, and a boron-containing gas.

36. The plasma processing apparatus according claim 35, wherein

the plasma processing apparatus is a capacitively coupled plasma processing apparatus.

37. The plasma processing apparatus according claim 35 or 36, wherein

the controller controls a flow rate of the non-inert components of the first process gas to a flow rate of not less than 100 sccm.

38. The plasma processing apparatus according any one of claims 28 to 37, wherein

the hydrogen fluoride gas has a flow rate of not more than 96 vol% of a total flow rate of the non-inert components of the first process gas.

39. The plasma processing apparatus according any one of claims 28 to 38, wherein

the silicon-containing film includes at least one selected from the group consisting of a silicon oxide film, a film stack including a silicon oxide film and a silicon nitride film, and a film stack including a silicon oxide film and a polysilicon film.

40. The plasma processing apparatus according any one of claims 28 to 39, wherein

the mask is a carbon-containing mask or a metal-containing mask.

41. The plasma processing apparatus according claim 40, wherein

the carbon-containing mask comprises at least one selected from the group consisting of spin-on carbon, tungsten carbide, amorphous carbon, and boron carbide.

42. The plasma processing apparatus according any one of claims 28 to 41, wherein

the controller further performs generating plasma from a second process gas in the chamber and cleaning an inside of the chamber.

43. The plasma processing apparatus according claim 42, wherein

the second process gas contains at least one selected from the group consisting of a fluorine-containing gas, an oxygen-containing gas, a hydrogen-containing gas, and a nitrogen-containing gas.

44. The plasma processing apparatus according any one of claims 28 to 43, wherein

the controller further performs generating plasma from a third process gas in the chamber before the providing the substrate and depositing a precoat on an inner wall of the chamber.

45. The plasma processing apparatus according claim 44, wherein

the third process gas contains a carbon-containing gas.

46. A plasma processing apparatus comprising,

a chamber having a gas inlet and a gas outlet;

a plasma generator; and

a controller,

wherein the controller performs processing including

providing a substrate in a chamber, the substrate including a silicon-containing film and a mask on the silicon-containing film, and

etching the silicon-containing film with plasma generated from a first process gas containing a hydrogen fluoride gas, a carbon-containing gas, and an oxygen-containing gas or a halogen-containing gas other than a hydrogen fluoride,

wherein the controller performs control so that the hydrogen fluoride gas has a flow rate of not less than 70 vol % and not more than 96 vol% of a total flow rate of non-inert components of the first process gas.

47. The plasma processing apparatus according to claim 46, wherein

the carbon-containing gas contains at least one selected from the group consisting of a fluorocarbon gas, a hydrofluorocarbon gas, and a hydrocarbon gas.

48. The plasma processing apparatus according to claim 47, wherein

the fluorocarbon gas is at least one selected from the group consisting of CF_4, C_2F_2, C_2F_4, C_3F_8, C_4F_6, C_4F_8, and C_5F_8.

49. The plasma processing apparatus according to claim 47, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of CHF_3, CH_2F_2, CH_3F, C_2HF_5, $C_2H_2F_4$, $C_2H_3F_3$, $C_2H_4F_2$, C_3HF_7, $C_3H_2F_2$, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, $C_4H_5F_5$, $C_4H_2F_6$, $C_5H_2F_{10}$, and c-$C_5H_3F_7$.

50. The plasma processing apparatus according to claim 47, wherein

the hydrocarbon gas is at least one selected from the group

consisting of CH_4, C_2H_6, C_3H_6, C_3H_8, and C_4H_{10}.

51. The plasma processing apparatus according to claim 46, wherein

the carbon-containing gas includes a hydrofluorocarbon gas having three or more carbon atoms.

52. The plasma processing apparatus according to any one of claims 46 to 51, wherein

the silicon-containing film includes at least one selected from the group consisting of a film stack including a silicon oxide film and a silicon nitride film, a polysilicon film, a film with a low dielectric constant, and a film stack including a silicon oxide film and a polysilicon film.

53. The plasma processing apparatus according to any one of claims 46 to 52, wherein

the mask is a carbon-containing mask or a metal-containing mask.

54. The plasma processing apparatus according to any one of claims 46 to 53, wherein

the controller further performs controlling a temperature of a substrate support on which the substrate is placed to 0 °C or lower before the etching.

55. A substrate processing method, comprising:

providing a substrate in a chamber, the substrate including a silicon-containing film and a mask on the silicon-containing film; and

etching the silicon-containing film in the chamber with plasma generated from a first process gas containing a hydrogen fluoride gas and at least one carbon-containing gas selected from the group consisting of a C_4F_8 gas, a $C_3H_2F_4$ gas, and a $C_4H_2F_6$ gas,

wherein the hydrogen fluoride gas has a highest flow rate among non-inert components of the first process gas.

56. The substrate processing method according to claim 55, wherein

the first process gas further contains at least one additive gas selected from the group consisting of an oxygen-containing gas, a halogen-containing gas, and a phosphorus-containing gas.

57. The substrate processing method according to claim 56, wherein

the method uses a capacitively coupled plasma processing apparatus including the chamber.

58. The substrate processing method according to claim 56 or 57, wherein

a flow rate of the non-inert components of the first process gas is not less than 100 sccm.

59. The substrate processing method according to any one of claims 19 to 27 and 55 to 58, further including

generating plasma from a precoat gas in the chamber before the providing the substrate to deposit a precoat on an inner wall of the chamber.

60. The substrate processing method according to any one of claims 19 to 27 and 55 to 59, further including

generating plasma from a cleaning gas in the chamber to clean an inside of the chamber.

61. A plasma processing apparatus comprising,

a chamber having a gas inlet and a gas outlet;

a plasma generator; and

a controller,

wherein the controller performs processing including

providing a substrate in a chamber, the substrate including a silicon-containing film and a mask on the silicon-containing film, and

etching the silicon-containing film in the chamber with plasma generated from a first process gas containing a hydrogen fluoride gas and at least one carbon-containing gas selected from the group consisting of a C_4F_8 gas, a $C_3H_2F_4$ gas, and a $C_4H_2F_6$ gas,

wherein the controller performs control so that the hydrogen fluoride gas has a highest flow rate among non-inert components of the first process gas.

62. The plasma processing apparatus according to claim 61, wherein

the first process gas further contains at least one additive gas selected from the group consisting of an oxygen-containing gas, a halogen-containing gas, and a phosphorus-containing gas.

63. The plasma processing apparatus according to claim 62, wherein

the plasma processing apparatus is a capacitively coupled plasma processing apparatus.

64. The plasma processing apparatus according to claim 62 or 63, wherein

the controller controls a flow rate of the non-inert components of the first process gas to a flow rate of not less than 100 sccm.

65. The plasma processing apparatus according to any one of claims 46 to 54 and 61 to 64, wherein

the controller further performs generating plasma from a precoat gas in the chamber before the providing the substrate to deposit a precoat on an inner wall of the chamber.

66. The plasma processing apparatus according to any one of claims 46 to 54 and 61 to 65, wherein

the controller further performs generating plasma from a cleaning

gas in the chamber to clean an inside of the chamber.

67. An etching gas composition for etching a silicon-containing film, comprising:

a hydrogen fluoride gas; and

at least one carbon-containing gas selected from the group consisting of a fluorocarbon gas and a hydrofluorocarbon gas,

wherein the hydrogen fluoride gas has a highest flow rate among non-inert components of the etching gas composition.

68. The etching gas composition according to claim 67, wherein

the hydrogen fluoride gas has a flow rate of at least 70 vol% of a total flow rate of non-inert components of the etching gas composition.

69. The etching gas composition according to claim 67 or 68, wherein

the fluorocarbon gas is at least one selected from the group consisting of CF_4, C_2F_2, C_2F_4, C_3F_8, C_4F_6, C_4F_8, and C_5F_8.

70. The etching gas composition according to claim 67 or 68, wherein

the fluorocarbon gas includes a C_4F_8 gas.

71. The etching gas composition according to claim 67 or 68, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of CHF_3, CH_2F_2, CH_3F, C_2HF_5, $C_2H_2F_4$, $C_2H_3F_3$, $C_2H_4F_2$, C_3HF_7, $C_3H_2F_2$, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, $C_4H_5F_5$, $C_4H_2F_6$, $C_5H_2F_{10}$, and c-$C_5H_3F_7$.

72. The etching gas composition according to claim 67 or 68, wherein

the hydrofluorocarbon gas is at least one selected from the group consisting of a $C_3H_2F_4$ gas and a $C_4H_2F_6$ gas.

73. The etching gas composition according to any one of claims 67 to 72, further comprising:

at least one selected from the group consisting of an oxygen-containing gas and a halogen-containing gas.

74. The etching gas composition according to any one of claims 67 to 73, further comprising:

at least one selected from the group consisting of a phosphorus-containing gas, a sulfur-containing gas, and a boron-containing gas.

75. The etching gas composition according to any one of claims 67 to 74, wherein

the hydrogen fluoride gas has a flow rate of not more than 96 vol% of a total flow rate of the non-inert components of the etching gas composition.

76. The etching gas composition according to any one of claims 67 to 75, wherein

the etching gas composition is a gas for etching a silicon oxide film.

77. The etching gas composition according to any one of claims 67 to 75, wherein

the etching gas composition is a gas for etching a silicon oxide film and a silicon nitride film.

78. The etching gas composition according to any one of claims 67 to 75, wherein

the etching gas composition is a gas for manufacturing a NAND flash memory with a three-dimensional structure.

79. The etching gas composition according to any one of claims 67 to 75, wherein

the etching gas composition is used for generating plasma therefrom in the etching.