

technique for improving the selectivity of a silicon-containing film to a mask in plasma etching.

Solution to Problem

5 [0005] According to a first aspect of the present invention, there is provided an etching method comprising (a) providing a substrate in a chamber in a plasma processing apparatus. The substrate includes a silicon-containing film and a mask. The mask is located under the silicon-containing film. The etching method further includes (b) etching the silicon-containing film with a chemical species in plasma generated from a process gas in the chamber. The process gas contains a hydrogen fluoride gas and a carbon-containing gas. A flow rate of the hydrogen fluoride gas is highest among flow rates of all gases except a noble gas in the process gas.

10 [0005a] According to a second aspect of the present invention, there is provided an etching method, comprising:

(a) providing a substrate in a chamber in a plasma processing apparatus, the substrate including a silicon-containing film and a mask on the silicon-containing film; and

20 (b) etching the silicon-containing film with a chemical species in plasma generated from a process gas in the chamber,

wherein the process gas contains a hydrogen fluoride gas and further contains a phosphorus-containing gas or an amine gas, and

25 a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.

[0005b] According to a third aspect of the present invention, there is provided a plasma processing apparatus comprising:

a chamber;

a substrate support disposed in the chamber;

5 a gas supply configured to supply a gas into the chamber;

a plasma generator configured to generate plasma from the gas in the chamber; and

a controller configured to control the gas supply and the plasma generator,

10 wherein the controller is configured to perform etching of a silicon-containing film of a substrate with chemical species from a plasma generated from a process gas in the chamber, in a state where the substrate is placed on the substrate support,

15 the process gas contains a hydrogen fluoride gas and a carbon-containing gas, and

a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.

[0005c] According to a fourth aspect of the present invention, there is provided a plasma processing apparatus comprising:

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a chamber;

a substrate support disposed in the chamber;

a gas supply configured to supply a gas into the chamber;

a plasma generator configured to generate plasma from the gas in

25 the chamber; and

a controller configured to control the gas supply and the plasma

generator,

wherein the controller is configured to perform etching of a silicon-containing film of a substrate with chemical species from a plasma generated from a process gas in the chamber, in a state where the substrate is placed on the substrate support,

the process gas contains a hydrogen fluoride gas and further contains a phosphorus-containing gas or an amine gas, and

a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.

Advantageous Effects of Invention

[0006] The technique according to one exemplary embodiment improves the selectivity of a silicon-containing film to a mask in plasma etching.

Brief Description of Drawings

[0007] FIG. 1 is a flowchart of an etching method according to one exemplary embodiment.

FIG. 2 is a partially enlarged cross-sectional view of an example substrate to be processed with the etching method shown in FIG. 1.

FIG. 3 is a schematic diagram of a plasma processing apparatus according to one exemplary embodiment.

FIG. 4 is a partially enlarged cross-sectional view of an example substrate processed with the etching method shown in FIG. 1.

FIG. 5 is an example timing chart of the etching method according to

CLAIMS

[Claim 1] An etching method, comprising:

(a) providing a substrate in a chamber in a plasma processing apparatus, the substrate including a mask and a silicon-containing film under the mask; and

(b) etching the silicon-containing film with a chemical species in plasma generated from a process gas in the chamber,

wherein the process gas contains a hydrogen fluoride gas and a carbon-containing gas, and

a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.

[Claim 2] The etching method according to claim 1, wherein the process gas further contains a phosphorus-containing gas.

[Claim 3] The etching method according to claim 2, wherein the phosphorus-containing gas contains one or more among respective gases of phosphorus oxide, phosphorus halide, phosphoryl halide, phosphine, calcium phosphide, phosphoric acid, sodium phosphate, hexafluorophosphoric acid, and fluorophosphine.

[Claim 4] The etching method according to claim 2, wherein the phosphorus-containing gas contains one or more among respective gases of P_4O_{10} , P_4O_8 , P_4O_6 , PF_3 , PF_5 , PCl_3 , PCl_5 , PBr_3 , PBr_5 , PI_3 , POF_3 , $POCl_3$, $POBr_3$, PH_3 , Ca_3P_2 , H_3PO_4 , Na_3PO_4 , HPF_2 , H_2PF_3 , and HPF_6 .

[Claim 5] The etching method according to claim 1, wherein the process gas further contains an amine gas.

[Claim 6] The etching method according to any one of claims 1 to 5,

wherein the carbon-containing gas contains at least one of a fluorocarbon and/or a hydrofluorocarbon having one to six carbon atoms per molecule.

5 [Claim 7] The etching method according to any one of claims 1 to 6, wherein in said (b), a flow rate of the carbon-containing gas is decreased in a stepwise manner.

[Claim 8] The etching method according to claim 7, wherein a pressure in the chamber in said (b) is set to not less than 0.666 Pa and not more than 2.666 Pa.

10 [Claim 9] The etching method according to any one of claims 1 to 8, wherein the carbon-containing gas contains one or more among respective gases of CF₄, C₂F₂, C₂F₄, C₃F₈, C₄F₆, C₄F₈, C₅F₈, CHF₃, CH₂F₂, CH₃F, C₂HF₅, C₂H₂F₄, C₂H₃F₃, C₂H₄F₂, C₃HF₇, C₃H₂F₂, C₃H₂F₆, C₃H₂F₄, C₃H₃F₅, C₄H₅F₅, C₄H₂F₆, C₅H₂F₁₀, c-C₅H₃F₇, CH₄, C₂H₆, C₃H₆, C₃H₈, and C₄H₁₀.

15 [Claim 10] An etching method, comprising:

(a) providing a substrate in a chamber in a plasma processing apparatus, the substrate including a silicon-containing film and a mask on the silicon-containing film; and

20 (b) etching the silicon-containing film with a chemical species in plasma generated from a process gas in the chamber,

wherein the process gas contains a hydrogen fluoride gas and further contains a phosphorus-containing gas or an amine gas, and

25 a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.

[Claim 11] The etching method according to claim 10, wherein the

phosphorus-containing gas contains one or more among respective gases of phosphorus oxide, phosphorus halide, phosphoryl halide, phosphine, calcium phosphide, phosphoric acid, sodium phosphate, hexafluorophosphoric acid, and fluorophosphine.

5 [Claim 12] The etching method according to claim 10, wherein the phosphorus-containing gas contains one or more among respective gases of P_4O_{10} , P_4O_8 , P_4O_6 , PF_3 , PF_5 , PCl_3 , PCl_5 , PBr_3 , PBr_5 , PI_3 , POF_3 , $POCl_3$, $POBr_3$, PH_3 , Ca_3P_2 , H_3PO_4 , Na_3PO_4 , HPF_2 , H_2PF_3 , and HPF_6 .

10 [Claim 13] The etching method according to any one of claims 1 to 12, wherein the process gas further contains one or more among respective gases of NF_3 , O_2 , CO_2 , CO , N_2 , He , Ar , Kr , and Xe .

[Claim 14] The etching method according to any one of claims 1 to 13, wherein the process gas further contains a halogen-containing gas.

15 [Claim 15] The etching method according to claim 14, wherein the halogen-containing gas contains one or more among respective gases of Cl_2 , Br_2 , HCl , HBr , HI , BCl_3 , CH_xCl_y , CF_xBr_y , CF_xI_y , ClF_3 , IF_5 , IF_7 , and BrF_3 , where x and y are integers greater than or equal to 1.

[Claim 16] The etching method according to any one of claims 1 to 13, wherein the process gas further includes a chlorine-containing gas.

20 [Claim 17] The etching method according to claim 16, wherein the chlorine-containing gas comprises one or more among respective gases of Cl_2 , HCl , BCl_3 and CH_xCl_y , where x and y are integers greater than or equal to 1.

25 [Claim 18] The etching method according to claim 16, wherein the chlorine-containing gas contains HCl .

[Claim 19] The etching method according to any one of claims 1 to

18, wherein the process gas further contains an iodine-containing gas.

[Claim 20] The etching method according to claim 19, wherein the iodine-containing gas contains one or more among respective gases of HI, IF_t, and C_xF_yI_z, where t, x, y, and z are integers greater than or equal to 1.

5 [Claim 21] The etching method according to any one of claims 1 to 12, wherein in said (b), a pressure in the chamber is decreased in a stepwise manner.

[Claim 22] The etching method according to any one of claims 1 to 21, wherein the silicon-containing film includes a silicon oxide film
10 and/or a silicon nitride film.

[Claim 23] The etching method according to claim 22, wherein the silicon-containing film further includes a polycrystalline silicon film.

[Claim 24] The etching method according to any one of claims 1 to 23, wherein the mask is a carbon-containing mask.

15 [Claim 25] The etching method according to any one of claims 1 to 23, wherein the mask is a metal-containing mask.

[Claim 26] The etching method according to any one of claims 1 to 25, wherein

the substrate is placed on a substrate support in the chamber, and
20 in said (b), a radio frequency power having a first frequency is supplied to the substrate support or an upper electrode disposed above the substrate support, and an electrical bias having a second frequency is supplied to the substrate support.

[Claim 27] The etching method according to claim 26, wherein the
25 electrical bias is a high-frequency power having the second frequency or a pulse wave of a voltage periodically generated at the second frequency.

[Claim 28] The etching method according to claim 27, wherein a pulse wave of the electrical bias is periodically supplied to the substrate support at a third frequency.

5 [Claim 29] The etching method according to any one of claims 26 to 28, wherein said (b) is started after a temperature of the substrate support is set to 0 °C or less.

[Claim 30] The etching method of any one of claims 1 to 29, wherein the process gas further contains Xe.

10 [Claim 31] The etching method according to any one of claims 1 to 30, wherein a recess having an aspect ratio of 20 or more is formed in the silicon-containing film by said (b).

[Claim 32] The etching method according to according to any one of claims 1 to 31, wherein the mask has a thickness of 3 μm or more.

15 [Claim 33] A plasma processing apparatus comprising:
a chamber;
a substrate support disposed in the chamber;
a gas supply configured to supply a gas into the chamber;
a plasma generator configured to generate plasma from the gas in the chamber; and
20 a controller configured to control the gas supply and the plasma generator,
wherein the controller is configured to perform etching of a silicon-containing film of a substrate with chemical species from a plasma generated from a process gas in the chamber, in a state where the
25 substrate is placed on the substrate support,
the process gas contains a hydrogen fluoride gas and a carbon-

containing gas, and

a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.

5 [Claim 34] A plasma processing apparatus comprising:

a chamber;

a substrate support disposed in the chamber;

a gas supply configured to supply a gas into the chamber;

10 a plasma generator configured to generate plasma from the gas in the chamber; and

a controller configured to control the gas supply and the plasma generator,

15 wherein the controller is configured to perform etching of a silicon-containing film of a substrate with chemical species from a plasma generated from a process gas in the chamber, in a state where the substrate is placed on the substrate support,

the process gas contains a hydrogen fluoride gas and further contains a phosphorus-containing gas or an amine gas, and

20 a flow rate of the hydrogen fluoride gas is highest among flow rates of all gases in the process gas containing no noble gas or among flow rates of all gases except a noble gas in the process gas.