

CLAIMS

1. A substrate processing method, comprising:

placing a substrate on a substrate support in a chamber, the substrate comprising a dielectric film and a mask defining at least one opening on the dielectric film; and

5 etching the dielectric film through the mask with plasm generated from a reaction gas containing an HF gas and at least one $C_xH_yF_z$ gas selected from the group consisting of a $C_4H_2F_6$ gas, a $C_4H_2F_8$ gas, a $C_3H_2F_4$ gas, and a $C_3H_2F_6$ gas,

wherein the etching includes setting the substrate support at a temperature of 0 °C or lower and setting the HF gas to a flow rate greater than a flow rate of the $C_xH_yF_z$ gas.

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

the flow rate of the $C_xH_yF_z$ gas is less than or equal to 20% by volume of a total flow rate of the reaction gas.

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

the flow rate of the HF gas is greater than or equal to 70% by volume of a total flow rate

15 of the reaction gas.

4. The substrate processing method according to any one of claims 1 to 3, wherein

the reaction gas further contains a halogen-containing gas.

5. The substrate processing method according to claim 4, wherein

the halogen-containing gas is at least one selected from the group consisting of a chlorine-

containing gas, a bromine-containing gas, and an iodine-containing gas.

6. The substrate processing method according to claim 4, wherein

the halogen-containing gas is at least one gas selected from the group consisting of Cl_2 ,

SiCl_2 , SiCl_4 , CCl_4 , SiH_2Cl_2 , Si_2Cl_6 , CHCl_3 , SO_2Cl_2 , BCl_3 , PCl_3 , PCl_5 , POCl_3 , Br_2 , HBr , CBr_2F_2 ,

5 $\text{C}_2\text{F}_5\text{Br}$, PBr_3 , PBr_5 , POBr_3 , BBr_3 , HI , CF_3I , $\text{C}_2\text{F}_5\text{I}$, $\text{C}_3\text{F}_7\text{I}$, IF_5 , IF_7 , I_2 , and PI_3 .

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

the reaction gas contains a phosphorus-containing gas.

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

the reaction gas contains an oxygen-containing gas.

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

the reaction gas further contains at least one selected from the group consisting of a boron-

containing gas and a sulfur-containing gas.

10. The substrate processing method according to any one of claims 1 to 9, wherein

the plasma is generated from a process gas containing the reaction gas and an inert gas.

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

the dielectric film is a silicon-containing film.

12. The substrate processing method according to claim 11, wherein

the silicon-containing film includes at least one selected from the group consisting of a

silicon oxide film, a silicon nitride film, and a polysilicon film.

13. The substrate processing method according to any one of claims 1 to 12, wherein
the substrate includes a mask including an organic film defining at least one opening on
the dielectric film or a metal-containing film defining at least one opening on the dielectric film.

14. The substrate processing method according to any one of claims 1 to 13, wherein
5 the etching includes applying an electrical bias to the substrate support,
a period during which the electrical bias is applied to the substrate support includes a first
period and a second period alternating with the first period, and

a level of the electrical bias in the first period is zero or at a first level, and a level of the
electrical bias in the second period is at a second level higher than the first level.

10 15. The substrate processing method according to claim 14, wherein
the etching includes providing radio-frequency power for generating plasma to the
substrate support or to an upper electrode facing the substrate support,

a period during which the radio-frequency power is provided includes a third period and a
fourth period alternating with the third period,

15 the radio-frequency power in the third period is zero or at a third level, and the radio-
frequency power in the fourth period is at a fourth level higher than the third level, and

the second period and the fourth period at least partially overlap.

16. The substrate processing method according to claim 14 or claim 15, wherein
the electrical bias is a pulsed voltage.

17. The substrate processing method according to any one of claims 1 to 16, wherein
the etching includes providing a direct-current voltage or low-frequency power to an upper
electrode facing the substrate support.

18. The substrate processing method according to any one of claims 1 to 17, wherein
5 the etching includes

a first process of setting the chamber to a first pressure, applying a first electrical bias
to the substrate support, and etching the dielectric film, and

a second process of setting the chamber to a second pressure, applying a second
electrical bias to the substrate support, and etching the dielectric film, and

10 the first pressure differs from the second pressure or the first electrical bias differs from the
second electrical bias, or the first pressure differs from the second pressure and the first
electrical bias differs from the second electrical bias.

19. The substrate processing method according to claim 18, wherein
the first pressure is higher than the second pressure.

15 20. The substrate processing method according to claim 18 or claim 19, wherein
an absolute value of the first electrical bias is greater than an absolute value of the second
electrical bias.

21. The substrate processing method according to any one of claims 18 to 20, wherein
the first process and the second process are repeated alternately.

22. A substrate processing apparatus, comprising:

a chamber;

a substrate support in the chamber, the substrate support being adjustable in temperature;

a plasma generator configured to provide electric power to generate plasma in the chamber;

5 and

a controller,

wherein the controller performs a control operation including introducing, using the electric power provided from the plasma generator, a reaction gas containing an HF gas and at least one

$C_xH_yF_z$ gas selected from the group consisting of a $C_4H_2F_6$ gas, a $C_4H_2F_8$ gas, a $C_3H_2F_4$ gas,

10 and a $C_3H_2F_6$ gas into the chamber to generate plasma to etch a dielectric film of a substrate through a mask defining at least one opening on the dielectric film, the substrate being supported on the substrate support, and

the control operation includes setting the substrate support at a temperature of 0 °C or lower and setting the HF gas to a flow rate greater than a flow rate of the $C_xH_yF_z$ gas.