

CLAIMS

1. A plasma processing method performed using a plasma processing apparatus, wherein the plasma processing apparatus includes:

a chamber including a side wall having an inner wall surface;

a substrate support including a lower electrode provided in the chamber;

an upper electrode provided above the substrate support;

a radio frequency power source for generating plasma in the chamber; and

a direct-current power source device electrically connected to the upper electrode, the direct-current power source device being configured to generate a pulsed negative direct-current voltage periodically at a cycle, the cycle including a first period and a second period which is an entire remaining period in the cycle,

the plasma processing method comprising:

generating plasma from a film formation gas in the chamber by supplying radio frequency power from the radio frequency power source; and

forming a protective film on the inner wall surface by depositing a chemical species from the plasma of the film formation gas on the inner wall surface, wherein

in said forming a protective film, the pulsed negative direct-current voltage is applied from the direct-current power source device to the upper electrode in the first period and an output voltage of

the direct-current power source device is set to zero volts in the second period, whereby the pulsed negative direct-current voltage is applied from the direct-current power source device to the upper electrode in periodically at the cycle.

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2. The plasma processing method according to claim 1, wherein the film formation gas includes a silicon-containing gas.

3. The plasma processing method according to claim 2,
10 wherein the silicon-containing gas is a silicon halide gas.

4. The plasma processing method according to claim 3, wherein the silicon halide gas is a silicon tetrachloride gas.

15 5. The plasma processing method according to claim 1, wherein the film formation gas includes a carbon-containing gas.

6. The plasma processing method according to claim 5,
wherein the carbon-containing gas is a hydrocarbon gas or a
20 fluorocarbon gas.

7. The plasma processing method according to any one of
claims 1 to 6, wherein an effective value of the output voltage of the
direct-current power source device in said forming a protective film is
25 smaller than 0 V and equal to or larger than -848 V, and

the effective value is a product of a square root of a duty ratio

and a value of the pulsed negative direct-current voltage in the first period, the duty ratio being a ratio of a time length of the first period to a time length of the cycle.

5 8. The plasma processing method according to claim 7, further comprising performing plasma processing on a substrate in the chamber after said forming a protective film, wherein

in said performing plasma processing,

plasma is generated from a processing gas in the
10 chamber by supplying radio frequency power from the radio frequency power source,

the effective value of the output voltage of the direct-current power source device is set to a value smaller than the effective value in said forming a protective film, and

15 the substrate is processed by a chemical species from the plasma generated from the processing gas.

9. The plasma processing method according to claim 7 or 8, further comprising removing the protective film, wherein

20 in said removing the protective film,

plasma is generated from a cleaning gas in the chamber by supplying radio frequency power from the radio frequency power source,

the effective value of the output voltage of the
25 direct-current power source device is set to a value larger than the effective value in the said forming a protective film, and

the protective film is processed by a chemical species from the plasma generated from the cleaning gas.

10. A plasma processing apparatus comprising:

5 a chamber including a side wall having an inner wall surface;
a substrate support including a lower electrode provided in the chamber;

an upper electrode provided above the substrate support;

10 a radio frequency power source for generating plasma in the chamber;

a direct-current power source device electrically connected to the upper electrode; and

a controller configured to control the radio frequency power source and the direct-current power source device,

15 wherein the direct-current power source device is configured to generate a pulsed negative direct-current voltage periodically at a cycle, the cycle including a first period and a second period which is an entire remaining period in the cycle, and

the controller is configured to

20 control the radio frequency power source to supply radio frequency power to generate plasma from a film formation gas in the chamber, and

control the direct-current power source device to apply the pulsed negative direct-current voltage to the upper electrode in the first period and to set an output voltage of the direct-current power source device to zero volts in the second period, thereby periodically

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applying the pulsed negative direct-current voltage to the upper electrode to form a protective film on the inner wall surface by depositing a chemical species from the plasma of the film formation gas on the inner wall surface.

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11. The plasma processing method according to claim 7, further comprising

performing plasma processing on a substrate in the chamber after said forming a protective film, wherein

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in said performing plasma processing,

plasma is generated from a processing gas in the chamber by supplying radio frequency power from the radio frequency power source to etch the substrate placed on the substrate support by a chemical species from the plasma generated from the processing gas,

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the pulsed negative direct-current voltage is applied from the direct-current power source device to the upper electrode periodically at the cycle during generation of the plasma from the processing gas to etch the substrate, and

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the effective value of the output voltage of the direct-current power source device is set to a value smaller than the effective value in said forming a protective film.

12. The plasma processing method according to claim 11, further comprising

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removing the protective film after said performing plasma processing, wherein

in said removing the protective film,

plasma is generated from a cleaning gas in the chamber by supplying radio frequency power from the radio frequency power source,

5 the pulsed negative direct-current voltage is applied from the direct-current power source device to the upper electrode periodically at the cycle during generation of the plasma from the cleaning gas to remove the protective film by a chemical species from the plasma generated from the cleaning gas, and

10 the effective value of the output voltage of the direct-current power source device is set to a value larger than the effective value in the said forming a protective film.

13. The plasma processing method according to any one of
15 claims 1 to 9 and 11 to 12, wherein

a frequency which is a reciprocal of the cycle is 400 kHz or more and 1 MHz or less.

14. The plasma processing method according to any one of
20 claims 1 and 11 to 13, wherein

the film formation gas includes a silicon-containing gas or a carbon-containing gas, an oxygen gas, and a noble gas.

15. The plasma processing method according to any one of
25 claims 1 to 9 and 11 to 14, wherein

a duty ratio of the pulsed negative direct-current voltage is 0.2

or more and 0.5 or less.

16. The plasma processing method according to any one of claims 1 to 9 and 11 to 15, further comprising

5 sputtering ions to the protective film formed on a surface of the upper electrode, by applying the pulsed negative direct-current voltage to the upper electrode in said forming a protective film.

17. The plasma processing method according to any one of claims 1 to 9 and 11 to 16, wherein

10 a thickness of the protective film formed on the inner wall surface is adjusted according to an effective value of the output voltage which is applied from the direct-current power source device to the upper electrode in said forming a protective film.

18. The plasma processing method according to any one of claims 1 to 9 and 11 to 17, wherein

15 the pulsed negative direct-current voltage is applied to the upper electrode after a start of supplying the radio frequency power.

19. The plasma processing method according to claim 9 or 12, wherein

20 the cleaning gas includes a fluorocarbon gas and an oxygen-containing gas.