METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE, METHOD OF PROCESSING SUBSTRATE, SUBSTRATE PROCESSING APPARATUS, AND PROGRAM

TECHNICAL FIELD

[0001] The present disclosure relates to a method of manufacturing a semiconductor device, a method of processing a substrate, a substrate processing apparatus, and a program.

BACKGROUND

[0002] As a process of manufacturing a semiconductor device, a process of forming a low dielectric constant film on a heated substrate by supplying a process gas including an oxidizing gas to the substrate may be performed (*see*, e.g., Patent Documents 1 to 4).

[Prior Art Documents]

[0003] Patent Documents

Patent Document 1: Japanese Patent Laid-Open Publication No. 2011-238894

Patent Document 2: Japanese Patent Laid-Open Publication No. 2014-38923

Patent Document 3: Japanese Patent Laid-Open Publication No. 2014-60302

Patent Document 4: Japanese Patent Laid-Open Publication No. 2013-140944

SUMMARY

[0004] The present disclosure provides some embodiments of a technique capable of suppressing an oxidation of a film formed on a substrate when a base of the film is a metal-element-containing film, while the film is a low dielectric constant film.

[0005] According to one or more embodiments of the present disclosure, there is provided a technique that includes: (a) loading a substrate where a conductive metal-element-containing film is exposed on a surface of the substrate into a process chamber under a first temperature; (b) supplying a reducing gas to the substrate while raising a temperature of the substrate to a second

WHAT IS CLAIMED IS:

1. A method of manufacturing a semiconductor device, comprising:

(a) loading a substrate where a conductive metal-element-containing film is exposed on a surface of the substrate into a process chamber under a first temperature;

(b) supplying a reducing gas to the substrate while raising a temperature of the substrate to a second temperature higher than the first temperature in the process chamber;

(c) forming a first film, which contains silicon and at least one selected from the group of nitrogen and carbon and does not contain oxygen, on the metal-element-containing film, by supplying a first process gas, which does not include an oxidizing gas, to the substrate under the second temperature in the process chamber; and

(d) forming a second film, which contains silicon, oxygen, carbon, and nitrogen, on the first film such that the second film is thicker than the first film, by supplying a second process gas, which includes an oxidizing gas, to the substrate under a third temperature higher than the first temperature in the process chamber.

2. The method of Claim 1, wherein the first temperature is set to a room temperature or higher and 200 degrees C or lower.

3. The method of Claim 1, wherein the first temperature is set to a room temperature or higher and 150 degrees C or lower.

4. The method of Claim 1, wherein at least one selected from the group of a hydrogen gas and a deuterium gas is used as the reducing gas.

5. The method of Claim 1, wherein in (b), a native oxide film formed on a surface of the metal-element-containing film is removed by the temperature rise under a reducing gas atmosphere.

6. The method of Claim 5, wherein in (b), an oxidation of the surface of the metal-element-containing film where the native oxide film has been removed is prevented.

7. The method of Claim 6, wherein the second temperature is set to 500 degrees C or higher and 800 degrees C or lower.

8. The method of Claim 6, wherein the second temperature is set to 600 degrees C or higher and 700 degrees C or lower.

9. The method of Claim 1, wherein the first film includes at least one selected from the group of a silicon nitride film, a silicon carbide film, and a silicon carbonitride film.

10. The method of Claim 1, wherein a thickness of the first film is 0.16nm or more and 1nm or less.

11. The method of Claim 1, wherein a thickness of the first film is 0.16nm or more and 0.48nm or less.

12. The method of Claim 1, wherein a thickness of the first film is 0.16nm or more and 0.32nm or less.

13. The method of Claim 1, wherein the first process gas includes:

a gas serving as a silicon source or a gas serving as a silicon source and a carbon source; and

a gas serving as at least one selected from the group of a nitrogen source and a carbon source, and

wherein in (c), a cycle which includes supplying the respective gases of the first process gas is performed one to three times.

14. The method of Claim 1, wherein the first process gas includes:

a gas serving as a silicon source or a gas serving as a silicon source and a carbon source; and

a gas serving as at least one selected from the group of a nitrogen source and a carbon source,

wherein in (c), the respective gases of the first process gas are intermittently supplied to the substrate,

wherein the second process gas includes:

a gas serving as a silicon source or a gas serving as a silicon source and a carbon source;

a gas serving as at least one selected from the group of a nitrogen source and a carbon source; and

a gas serving as an oxygen source, and

wherein in (d), the respective gases of the second process gas are intermittently and non-simultaneously supplied to the substrate.

15. The method of Claim 1, wherein in (d), the first film formed in (c) is modified into a film having a dielectric constant lower than a dielectric constant of the first film before performing (d).

16. The method of Claim 1, wherein in (c), a silicon carbonitride film is formed as the first film, and

wherein in (d), a silicon oxycarbonitride film is formed as the second film, and the first film is modified from the silicon carbonitride film into a silicon oxycarbonitride film.

17. The method of Claim 16, wherein the first process gas includes:

a gas serving as a silicon source;

a gas serving as a carbon source; and

a gas serving as a nitrogen source,

wherein in (c), the respective gases of the first process gas are intermittently supplied to the substrate, and

wherein the second process gas includes:

a gas serving as a silicon source;

a gas serving as a carbon source;

a gas serving as a nitrogen source; and

a gas serving as an oxygen source, and

wherein in (d), the respective gases of the second process gas are intermittently and non-simultaneously supplied to the substrate.

18. The method of Claim 1, wherein the second temperature and the third temperature are set to be the same temperature.

19. A method of processing a substrate, comprising:

(a) loading the substrate where a conductive metal-element-containing film is exposed on a surface of the substrate into a process chamber under a first temperature;

(b) supplying a reducing gas to the substrate while raising a temperature of the substrate to a second temperature higher than the first temperature in the process chamber;

(c) forming a first film, which contains silicon and at least one selected from the group of nitrogen and carbon and does not contain oxygen, on the metal-element-containing film, by supplying a first process gas, which does not include an oxidizing gas, to the substrate under the second temperature in the process chamber; and

(d) forming a second film, which contains silicon, oxygen, carbon, and nitrogen, on the first film such that the second film is thicker than the first film, by supplying a second process gas, which includes an oxidizing gas, to the substrate under a third temperature higher than the first temperature in the process chamber.

20. A substrate processing apparatus comprising:

a process chamber in which a substrate is processed;

a heater configured to heat the substrate in the process chamber;

a reducing gas supply system configured to supply a reducing gas to the substrate in the process chamber;

a first process gas supply system configured to supply a first process gas, which does not include an oxidizing gas, to the substrate in the process chamber;

a second process gas supply system configured to supply a second process gas, which includes an oxidizing gas, to the substrate in the process chamber;

a transfer system configured to transfer the substrate into the process chamber; and

a controller configured to be capable of controlling the heater, the reducing gas supply system, the first process gas supply system, the second process gas supply system, and the transfer system so as to perform a process including:

(a) loading the substrate where a conductive metal-element-containing film is exposed on a surface of the substrate into the process chamber under a first temperature;

(b) supplying the reducing gas to the substrate while raising a temperature of the substrate to a second temperature higher than the first temperature in the process chamber;

(c) forming a first film, which contains silicon and at least one selected from the group of nitrogen and carbon and does not contain oxygen, on the metal-element-containing film, by supplying the first process gas to the substrate under the second temperature in the process chamber; and

(d) forming a second film, which contains silicon, oxygen, carbon, and nitrogen, on the first film such that the second film is thicker than the first film, by supplying the second process gas to the substrate under a third temperature higher than the first temperature in the process chamber.

21. A program that causes, by a computer, a substrate processing apparatus to perform a process comprising:

(a) loading a substrate where a conductive metal-element-containing film is exposed on a surface of the substrate into a process chamber of the substrate processing apparatus under a first temperature;

(b) supplying a reducing gas to the substrate while raising a temperature of the substrate to a second temperature higher than the first temperature in the process chamber;

(c) forming a first film, which contains silicon and at least one selected from the group of nitrogen and carbon and does not contain oxygen, on the metal-element-containing film, by supplying a first process gas, which does not include an oxidizing gas, to the substrate under the second temperature in the process chamber; and

(d) forming a second film, which contains silicon, oxygen, carbon, and nitrogen, on the first film such that the second film is thicker than the first film, by supplying a second process gas, which includes an oxidizing gas, to the substrate under a third temperature higher than the first temperature in the process chamber.