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

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2019-114560, filed on June 20, 2019, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a method of manufacturing a semiconductor device, a substrate processing apparatus, and a program.

BACKGROUND

[0003] As a process of manufacturing a semiconductor device, a process of forming a film on a substrate, of which an underlayer is exposed, is often carried out.

SUMMARY

[0004] The present disclosure provides some embodiments of a technique capable of suppressing oxidation of an underlayer while allowing a film formed on a substrate to become a low-dielectric-constant film.

[0005] According to one or more embodiments of the present disclosure, there is provided a technique that includes (a) forming a first film having a first thickness on an underlayer by supplying a first process gas to a substrate, wherein the first film contains silicon, carbon, and nitrogen and does not contain oxygen, the underlayer is exposed on a surface of the substrate and is at least one selected from the group of a conductive metal-element-containing film and a nitride film, and the first process gas does not include oxidizing gas; and (b) forming a second film having a second thickness on the first film by supplying a second process gas to the substrate, wherein the second film contains silicon, oxygen, and nitrogen, the second thickness is

WHAT IS CLAIMED IS:

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

(a) forming a first film having a first thickness and a carbon concentration within a range of 30 to 50 at% on an underlayer by supplying a first process gas to a substrate, wherein the first film contains silicon, carbon, and nitrogen and does not contain oxygen, the underlayer is exposed on a surface of the substrate and is at least one selected from the group of a conductive metal-element-containing film and a nitride film, and the first process gas does not include oxidizing gas; and

(b) forming a second film having a second thickness on the first film by supplying a second process gas to the substrate, wherein the second film contains silicon, oxygen, and nitrogen, the second thickness is larger than the first thickness, and the second process gas includes oxidizing gas,

wherein in (b), oxygen atoms, which are derived from the oxidizing gas and diffuse from a surface of the first film toward the underlayer, are absorbed by the first film and the first film is modified.

2. The method according to Claim 1, wherein the carbon concentration is higher than a nitrogen concentration in the first film formed in (a).

3. The method according to Claim 2, wherein the first process gas includes silicon-containing gas and nitrogen-and-carbon-containing gas, and

wherein in (a), a silicon carbonitride film is formed as the first film by non-simultaneously supplying the silicon-containing gas and the nitrogen-and-carbon-containing gas to the substrate.

4. The method according to Claim 3, wherein the silicon-containing gas includes halosilane-based gas, and the nitrogen-and-carbon-containing gas includes at least one selected from the group of amine-based gas and organic hydrazine-based gas.

5. The method according to Claim 1, wherein the first thickness is in a range of 0.05 nm to 0.15 nm.

6. The method according to Claim 1, wherein the second process gas includes silicon-containing gas, nitrogen-containing gas, and oxygen-containing gas, and

wherein in (b), a silicon oxycarbonitride film or a silicon oxynitride film is formed as the second film by non-simultaneously supplying the silicon-containing gas, the nitrogen-containing gas, and the oxygen-containing gas to the substrate.

7. The method according to Claim 6, wherein the nitrogen-containing gas includes nitrogen-and-carbon-containing gas, and

wherein in (b), the silicon oxycarbonitride film is formed as the second film.

8. The method according to Claim 7, wherein the silicon-containing gas includes halosilane-based gas, and the nitrogen-and-carbon-containing gas includes at least one selected from the group of amine-based gas and organic hydrazine-based gas.

9. The method according to Claim 6, wherein the nitrogen-containing gas includes nitrogen-and-hydrogen-containing gas, and

wherein in (b), the silicon oxynitride film is formed as the second film.

10. The method according to Claim 9, wherein the silicon-containing gas includes halosilane-based gas, and the nitrogen-and-hydrogen-containing gas includes hydrogen nitride-based gas.

11. The method according to Claim 1, wherein in (b), at least a portion of carbon atoms contained in the first film is substituted with the oxygen atoms.

12. The method according to Claim 1, wherein in (b), the first film is modified into a silicon oxycarbonitride film or a silicon oxynitride film.

13. The method according to Claim 1, wherein in (b), the first film is modified into a silicon oxycarbonitride film or a silicon oxynitride film whose oxygen concentration is higher than a nitrogen concentration.

14. The method according to Claim 1, wherein the first film is entirely modified into a silicon oxycarbonitride film or a silicon oxynitride film when (b) is completed.

15. The method according to Claim 1, wherein in (b), the first film is modified into a silicon oxynitride film that does not contain carbon.

16. The method according to Claim 1, wherein (a) and (b) are performed in the same process chamber.

17. The method according to Claim 1, further comprising (c) forming the nitride film as the underlayer on the surface of the substrate before performing (a),

wherein at least (c) and (a) are sequentially performed in the same process chamber.

18. The method according to Claim 17, wherein (b) is performed in a process chamber different from the process chamber in which (c) and (a) are performed.

19. The method according to Claim 1, further comprising (d) forming a third film having a third thickness on the second film by supplying the first process gas after performing (b),

wherein the third film contains silicon, carbon, and nitrogen and does not contain oxygen, and the third thickness is smaller than the second thickness.

20. A substrate processing apparatus, comprising:

a process chamber in which a substrate is processed;

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

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

a controller configured to be capable of controlling the first process gas supply system and the second process gas supply system to perform a process in the process chamber, the process comprising:

(a) forming a first film having a first thickness and a carbon concentration within a range of 30 to 50 at% on an underlayer by supplying the first process gas to the substrate, wherein the first film contains silicon, carbon, and nitrogen and does not contain oxygen, and the underlayer is exposed on a surface of the substrate and is at least one selected from the group of a conductive metal-element-containing film and a nitride film; and

(b) forming a second film having a second thickness on the first film by supplying the second process gas to the substrate, wherein the second film contains silicon, oxygen, and nitrogen, and the second thickness is larger than the first thickness,

wherein in (b), oxygen atoms, which are derived from the oxidizing gas and diffuse from a surface of the first film toward the underlayer, are absorbed by the first film and the first film is modified.

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

(a) forming a first film having a first thickness and a carbon concentration within a range of 30 to 50 at% on an underlayer by supplying a first process gas to a substrate, wherein the first film contains silicon, carbon, and nitrogen and does not contain oxygen, the underlayer is exposed on a surface of the substrate and is at least one selected from the group of a conductive metal-element-containing film and a nitride film, and the first process gas does not include oxidizing gas; and

(b) forming a second film having a second thickness on the first film by supplying a second process gas to the substrate, wherein the second film contains silicon, oxygen, and nitrogen, the second thickness is larger than the first thickness, and the second process gas includes oxidizing gas,

wherein in (b), oxygen atoms, which are derived from the oxidizing gas and diffuse from a surface of the first film toward the underlayer, are absorbed by the first film and the first film is modified.

22. A substrate processing method, comprising:

(a) forming a first film having a first thickness and a carbon concentration within a range of 30 to 50 at% on an underlayer by supplying a first process gas to a substrate, wherein the first film contains silicon, carbon, and nitrogen and does not contain oxygen, the underlayer is exposed on a surface of the substrate and is at least one selected from the group of a conductive metal-element-containing film and a nitride film, and the first process gas does not include oxidizing gas; and

(b) forming a second film having a second thickness on the first film by supplying a second process gas to the substrate, wherein the second film contains silicon, oxygen, and nitrogen, the second thickness is larger than the first thickness, and the second process gas includes oxidizing gas,

wherein in (b), oxygen atoms, which are derived from the oxidizing gas and diffuse from a surface of the first film toward the underlayer, are absorbed by the first film and the first film is modified.