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

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2021-043042, filed on March 17, 2021, 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 method, a program, and a substrate processing apparatus.

BACKGROUND

[0003] As a process of manufacturing a semiconductor device, a process of forming a film on a substrate is performed.

SUMMARY

[0004] Some embodiments of the present disclosure provide a technique capable of improving the characteristics of a film formed on a substrate.

[0005] According to one embodiment of the present disclosure, there is provided a technique that includes: (a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing: (a-1) supplying a first precursor gas containing the predetermined element to the substrate; (a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and (a-3) supplying a nitriding gas to the substrate; and (b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film

WHAT IS CLAIMED IS:

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

(a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate; and

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxygen-containing gas and a hydrogen-containing ~~oxidizing~~ gas to the substrate heated at a reduced pressure atmosphere.

2. The substrate processing method of Claim 1, wherein the oxide film having a predetermined thickness is formed on the substrate by performing, a predetermined number of times, a cycle that includes performing (a) and (b).

3. The substrate processing method of Claim 2, wherein a thickness of the nitride film formed in (a) is made to a thickness at which an effect of oxidation in (b) is applied over an entirety of the nitride film in a thickness direction.

4. The substrate processing method of any one of Claims 1 to 3, wherein (a) and (b) are performed in a same process chamber.

5. The substrate processing method of any one of Claims 1 to 4, wherein as the first

precursor gas, a gas whose dissociation energy required for decomposing one molecule into a plurality of molecules is larger than a dissociation energy of the second precursor gas is used.

6. The substrate processing method of any one of Claims 1 to 5, wherein the first precursor gas does not contain a bond between atoms of the predetermined element in one molecule, and

wherein the second precursor gas contains a bond between atoms of the predetermined element in one molecule.

7. The substrate processing method of Claim 6, wherein the first precursor gas contains only one atom of the predetermined element in one molecule, and

wherein the second precursor gas contains two or more atoms of the predetermined element in one molecule.

8. The substrate processing method of any one of Claims 1 to 7, wherein the first precursor gas is at least one gas selected from the group consisting of a $SiCl_4$ gas, a SiH_2Cl_2 gas, a SiH_3Cl gas, and a $SiHCl_3$ gas, and

wherein the second precursor gas is at least one gas selected from the group consisting of a Si_2Cl_6 gas, a Si_2H_5Cl gas, a $Si_2H_4Cl_2$ gas, a $Si_2H_3Cl_3$ gas, a $Si_2H_2Cl_4$ gas, a Si_3H_5Cl gas, and a $Si_3H_4Cl_2$ gas.

9. A substrate processing~~The~~ method ~~of any one of Claims 1 to 8~~, comprising:

(a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate; and

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxidizing gas to the substrate,

wherein in (a-1), a temperature of the substrate is set to a temperature at which the first precursor gas is not thermally decomposed, and

wherein in (a-2), a temperature of the substrate is set to a temperature at which the second precursor gas is thermally decomposed.

10. A substrate processing~~The~~ method ~~of any one of Claims 1 to 9~~, ~~further~~ comprising:

(a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate;

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxidizing gas to the substrate; and

(c) supplying a hydrogen nitride-based gas to the substrate before performing (a).

11. The substrate processing method of Claim 10, wherein a cycle that includes performing (a) and (b) is performed a predetermined number of times, and (c) is performed whenever the cycle is performed.

12. The substrate processing method of Claim 10 or Claim 11, wherein the nitriding gas is the hydrogen nitride-based gas.

13. The substrate processing method of any one of Claims 10 to 12, wherein the hydrogen nitride-based gas is at least one gas selected from the group consisting of a NH_3 gas, a N_2H_2 gas, a N_2H_4 gas, and a N_3H_8 gas.

14. The substrate processing method of any one of Claims 10 to 13, wherein the oxidizing gas is at least one gas selected from the group consisting of an O_2 gas, an O_3 gas, an O_2 gas and a H_2 gas, a H_2O gas, a gas containing O radicals, a gas containing OH radicals, and a gas containing plasma-excited O_2.

15. The substrate processing method of any one of Claims 1 to 8~~13~~, wherein the oxygen-containing gas includes~~in (b),~~ an O_2 gas and the hydrogen-containing gas includes a H_2 gas~~ are supplied to the substrate heated at a reduced pressure atmosphere~~.

16. A substrate processing~~The~~ method~~ of any one of Claims 1 to 15~~, comprising:

(a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate; and

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide

film containing the predetermined element by supplying an oxidizing gas to the substrate,

wherein in (a), at least one selected from the group of a ratio of a supply time of the first precursor gas in (a-1) to a supply time of the second precursor gas in (a-2), a ratio of a supply flow rate of the first precursor gas in (a-1) to a supply flow rate of the second precursor gas in (a-2), and a ratio of a processing pressure in (a-1) to a processing pressure in (a-2) is adjusted such that a ratio of the predetermined element in the nitride film becomes larger than a ratio of the predetermined element in a nitride film that has a stoichiometric composition.

17. The substrate processing method of Claim 16, wherein the supply time of the second precursor gas in (a-2) is set to be longer than the supply time of the first precursor gas in (a-1).

18. The substrate processing method of Claim 16, wherein the supply flow rate of the second precursor gas in (a-2) is set to be larger than the supply flow rate of the first precursor gas in (a-1).

19. The substrate processing method of Claim 16, wherein the processing pressure in (a-2) is set to be higher than the processing pressure in (a-1).

20. A ~~substrate processing~~ method of manufacturing a semiconductor device, comprising:

(a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate; and

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxygen-containing gas and a hydrogen-containing ~~oxidizing~~ gas to the substrate heated at a reduced pressure atmosphere.

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 nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate; and

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxygen-containing gas and a hydrogen-containing ~~oxidizing~~ gas to the substrate heated at a reduced pressure atmosphere.

22. A substrate processing apparatus, comprising:

~~a process chamber in which a substrate is processed;~~

a first precursor gas supply system configured to supply a first precursor gas containing a predetermined element to athe substrate ~~in the process chamber~~;

a second precursor gas supply system configured to supply a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate ~~in the process chamber~~;

a nitriding gas supply system configured to supply a nitriding gas to the substrate ~~in the~~

~~process chamber~~;

an oxidizing gas supply system configured to supply an oxygen-containing gas and a hydrogen-containing~~oxidizing~~ gas to the substrate ~~in the process chamber~~; and

a controller configured to be capable of controlling the first precursor gas supply system, the second precursor gas supply system, the nitriding gas supply system, and the oxidizing gas supply system so as to perform~~–~~ a process comprising:

(a) forming a nitride film containing a predetermined element by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying the first precursor gas to the substrate;

(a-2) supplying the second precursor gas to the substrate; and

(a-3) supplying the nitriding gas to the substrate; and

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying the oxygen-containing gas and the hydrogen-containing gas to the substrate heated at a reduced pressure atmosphere~~the method of Claim 1 in the process chamber~~.

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

(a) forming a nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate;

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxidizing gas to the substrate; and

(c) supplying a hydrogen nitride-based gas to the substrate before performing (a).

24. 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 nitride film containing a predetermined element on a substrate by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying a first precursor gas containing the predetermined element to the substrate;

(a-2) supplying a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate; and

(a-3) supplying a nitriding gas to the substrate;

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying an oxidizing gas to the substrate; and

(c) supplying a hydrogen nitride-based gas to the substrate before performing (a).

25. A substrate processing apparatus, comprising:

a first precursor gas supply system configured to supply a first precursor gas containing a predetermined element to a substrate;

a second precursor gas supply system configured to supply a second precursor gas containing the predetermined element and having a thermal decomposition temperature lower than a thermal decomposition temperature of the first precursor gas to the substrate;

a hydrogen nitride-based gas supply system configured to supply a hydrogen nitride-based gas to the substrate;

an oxidizing gas supply system configured to supply an oxidizing gas to the substrate; and

a controller configured to be capable of controlling the first precursor gas supply system, the second precursor gas supply system, the hydrogen nitride-based gas supply system, and the oxidizing gas supply system so as to perform a process comprising:

(a) forming a nitride film containing a predetermined element by performing a cycle a predetermined number of times, the cycle including sequentially performing:

(a-1) supplying the first precursor gas to the substrate;

(a-2) supplying the second precursor gas to the substrate; and

(a-3) supplying the hydrogen nitride-based gas to the substrate;

(b) oxidizing the nitride film formed in (a) and modifying the nitride film into an oxide film containing the predetermined element by supplying the oxidizing gas to the substrate; and

(c) supplying the hydrogen nitride-based gas to the substrate before performing (a).