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

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2020-052448, filed on March 24, 2020, 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] In the related art, as a process of manufacturing a semiconductor device, an oxide film-forming process including formation of a nitride film over a substrate and change of the nitride film to an oxide film by oxidizing the nitride film may be often carried out.

SUMMARY

[0004] Some embodiments of the present disclosure provide a technique capable of improving a film quality of an oxide film formed over a substrate.

[0005] According to some embodiments of the present disclosure, there is provided a technique that includes: forming a first film to have a first predetermined film thickness over a substrate by performing a first cycle a first predetermined number of times, the first cycle including non-simultaneously performing: (a1) forming an oxynitride film by supplying a first film-forming gas to the substrate; and (a2) changing the oxynitride film into a first oxide film by supplying a first oxidizing gas to the substrate to oxidize the oxynitride film.

WHAT IS CLAIMED IS:

1. A method of processing a substrate, comprising:

forming a first film to have a first predetermined film thickness over the substrate by performing a first cycle a first predetermined number of times, the first cycle including non-simultaneously performing:

(a1) forming an oxynitride film by supplying a first film-forming gas to the substrate; and

(a2) changing the oxynitride film into a first oxide film by supplying a first oxidizing gas to the substrate to oxidize the oxynitride film; and

forming a second film to have a second predetermined film thickness over the substrate by performing a second cycle a second predetermined number of times, the second cycle including non-simultaneously performing:

(b1) forming a nitride film by supplying a second film-forming gas to the substrate; and

(b2) changing the nitride film into a second oxide film by supplying a second oxidizing gas to the substrate to oxidize the nitride film,

wherein an oxide film formed by stacking the first film and the second film is formed over the substrate by performing the act of forming the first film and the act of forming the second film a third predetermined number of times.

2. The method of Claim 1, wherein at least one selected from the group of a film expansion coefficient when changing the oxynitride film into the first oxide film in (a2) and a film stress of the first oxide film formed in (a2) is regulated by controlling at least one selected from the group of an oxygen concentration of the oxynitride film formed in (a1) and a nitrogen concentration of the oxynitride film formed in (a1).

3. The method of Claim 1, wherein at least one selected from the group of an oxygen concentration of the oxynitride film formed in (a1) and a nitrogen concentration of the oxynitride film formed in (a1) is changed whenever the first cycle is performed a second

predetermined number of times.

4. The method of Claim 1, wherein a thickness of the oxynitride film formed in (a1) is changed whenever the first cycle is performed a second predetermined number of times.

5. The method of Claim 1, wherein the first film and the second film have thicknesses different from each other.

6. The method of Claim 1, wherein a film stress of the first film is a tensile stress, and

wherein a film stress of the second film is a compressive stress.

7. The method of Claim 1, wherein an absolute value of a film stress of one film of the first film and the second film is larger than an absolute value of a film stress of the other film of the first film and the second film, and

wherein a thickness of the one film is smaller than a thickness of the other film.

8. The method of Claim 1, further comprising performing a set a fourth predetermined number of times, the set including performing:

forming one film of the first film and the second film;

forming the other film of the first film and the second film; and

forming the one film of the first film and the second film,

wherein an absolute value of a film stress of the one film is smaller than an absolute value of a film stress of the other film.

9. The method of Claim 1, further comprising sequentially performing:

forming one film of the first film and the second film;

forming the other film of the first film and the second film; and

forming the one film of the first film and the second film,

wherein an absolute value of a film stress of the one film is smaller than an absolute

value of a film stress of the other film.

10. The method of Claim 1, wherein (a1) includes performing a set a second predetermined number of times, the set including performing:

supplying a precursor gas as the first film-forming gas to the substrate;

supplying a nitriding gas as the first film-forming gas to the substrate; and

supplying an oxidizing gas as the first film-forming gas to the substrate.

11. The method of Claim 10, wherein the act of supplying the precursor gas includes:

supplying a first precursor gas as the precursor gas to the substrate; and

supplying a second precursor gas as the precursor gas to the substrate.

12. The method of Claim 1, wherein (b1) includes performing a set a fourth predetermined number of times, the set including performing:

supplying a precursor gas as the second film-forming gas to the substrate; and

supplying a nitriding gas as the second film-forming gas to the substrate.

13. The method of Claim 12, wherein the act of supplying the precursor gas includes:

supplying a first precursor gas as the precursor gas to the substrate; and

supplying a second precursor gas as the precursor gas to the substrate.

14. The method of Claim 11, wherein the first precursor gas is more difficult to decompose than the second precursor gas under same conditions.

15. The method of Claim 11, wherein the first precursor gas contains one silicon atom in one molecule, and the second precursor gas contains two or more silicon atoms in one molecule.

16. The method of Claim 1, wherein the act of forming the first film and the act of forming the second film are performed in the same process chamber.

17. The method of Claim 1, wherein the act of forming the first film and the act of forming the second film are performed in different process chambers.

18. A substrate processing apparatus comprising:

a process chamber in which a substrate is processed;

a first film-forming gas supply system configured to supply a first film-forming gas to the substrate in the process chamber;

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

a second film-forming gas supply system configured to supply a second film-forming gas to the substrate in the process chamber; and

a second oxidizing gas supply system configured to supply a second oxidizing gas to the substrate in the process chamber,

a controller configured to be capable of controlling the first film-forming gas supply system, the first oxidizing gas supply system, the second film-forming gas supply system, and the second oxidizing gas supply system to perform a process comprising:

forming a first film to have a first predetermined film thickness over the substrate in the process chamber by performing a first cycle a first predetermined number of times, the first cycle including non-simultaneously performing:

(a1) forming an oxynitride film by supplying the first film-forming gas to the substrate; and

(a2) changing the oxynitride film into a first oxide film by supplying the first oxidizing gas to the substrate to oxidize the oxynitride film;

forming a second film to have a second predetermined film thickness over the substrate in the process chamber by performing a second cycle a second predetermined number of times, the second cycle including non-simultaneously performing:

(b1) forming a nitride film by supplying the second film-forming gas to the substrate; and

(b2) changing the nitride film into a second oxide film by supplying the

second oxidizing gas to the substrate to oxidize the nitride film; and

forming an oxide film by stacking the first film and the second film over the substrate by performing the act of forming the first film and the act of forming the second film a third predetermined number of times.

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

forming a first film to have a first predetermined film thickness over a substrate in a process chamber of the substrate processing apparatus by performing a first cycle a first predetermined number of times, the first cycle including non-simultaneously performing:

(a1) forming an oxynitride film by supplying a first film-forming gas to the substrate; and

(a2) changing the oxynitride film into a first oxide film by supplying a first oxidizing gas to the substrate to oxidize the oxynitride film;

forming a second film to have a second predetermined film thickness over the substrate in the process chamber by performing a second cycle a second predetermined number of times, the second cycle including non-simultaneously performing:

(b1) forming a nitride film by supplying a second film-forming gas to the substrate; and

(b2) changing the nitride film into a second oxide film by supplying a second oxidizing gas to the substrate to oxidize the nitride film; and

forming an oxide film by stacking the first film and the second film over the substrate by performing the act of forming the first film and the act of forming the second film a third predetermined number of times.

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

forming a first film to have a first predetermined film thickness over a substrate by performing a first cycle a first predetermined number of times, the first cycle including non-simultaneously performing:

(a1) forming an oxynitride film by supplying a first film-forming gas to the substrate; and

(a2) changing the oxynitride film into a first oxide film by supplying a first oxidizing gas to the substrate to oxidize the oxynitride film; and

forming a second film to have a second predetermined film thickness over the substrate by performing a second cycle a second predetermined number of times, the second cycle including non-simultaneously performing:

(b1) forming a nitride film by supplying a second film-forming gas to the substrate; and

(b2) changing the nitride film into a second oxide film by supplying a second oxidizing gas to the substrate to oxidize the nitride film,

wherein an oxide film formed by stacking the first film and the second film is formed over the substrate by performing the act of forming the first film and the act of forming the second film a third predetermined number of times.