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

## TECHNICAL FIELD

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

## BACKGROUND

**[0002]** As one of processes of manufacturing a semiconductor device, a process of forming an oxide layer in the inner surface of a recessed structure formed on a substrate is sometimes performed (*see*, e.g., Patent Document 1).

[Prior Art Document]

**[0003]** Patent Document

Patent Document 1: International Publication No. 2016/125606

## SUMMARY

**[0004]** The present disclosure provides some embodiments of a technique capable of allowing the thickness of an oxide layer formed on the inner surface of a recess structure formed on a substrate to have a desired thickness distribution.

**[0005]** According to one embodiment of the present disclosure, there is provided a technique, including:

(a) nitriding an inner surface of a recessed structure formed on a substrate to modify at least a portion of the inner surface into a nitride layer; and

(b) oxidizing the inner surface including the nitride layer to modify the inner surface into an oxide layer,

wherein (a) includes setting a thickness distribution of the nitride layer in the inner

surface such that, in (b), a thickness distribution of the oxide layer in the inner surface becomes a desired distribution.

**[0006]** According to the present disclosure, it is possible to provide a technique capable of allowing the thickness of an oxide layer formed on the inner surface of a recess structure formed on a substrate to have a desired thickness distribution.

## BRIEF DESCRIPTION OF DRAWINGS

**[0007]** FIG. 1 is a schematic configuration diagram of a substrate processing apparatus 100 suitably used in one embodiment of the present disclosure, in which the portion of a process furnace 202 is shown in a vertical sectional view.

FIG. 2 is an explanatory diagram illustrating the principle of plasma generation in the substrate processing apparatus 100 suitably used in one embodiment of the present disclosure.

FIG. 3 is a schematic configuration diagram of a controller 221 included in the substrate processing apparatus 100 suitably used in one embodiment of the present disclosure, in which the control system of the controller 221 is shown in a block diagram.

FIG. 4A is a partially enlarged sectional view of a wafer 200 in which a trench 301 is provided.

FIG. 4B is a partially enlarged sectional view of the wafer 200 after at least a portion of the inner surface of the trench 301 has been modified into a nitride layer 401. FIG. 4C is a partially enlarged sectional view of the wafer 200 in the process of modifying the inner surface of the trench 301 including the nitride layer 401 into an oxide layer 402. FIG. 4D is a partially enlarged sectional view of the wafer 200 after the inner surface of the trench 301 including the nitride layer 401 has been modified into an oxide layer 402.

## DETAILED DESCRIPTION

<One Embodiment of the Present Disclosure>

**[0008]** One embodiment of the present disclosure will be described below mainly with reference to FIGS. 1 to 3 and 4A to 4D. The drawings used in the following description are all

schematic. The dimensional relationship of each element, the ratio of each element, and the like shown in the drawings do not necessarily match the real ones. Moreover, the dimensional

WHAT IS CLAIMED IS:

1. A method of processing a substrate, comprising: (a) nitriding an inner surface of a recessed structure formed on the substrate to modify at least a portion of the inner surface into a nitride layer; and

(b) oxidizing the inner surface including the nitride layer to modify the inner surface into an oxide layer,

wherein (a) includes setting a thickness distribution of the nitride layer in the inner surface such that, in (b), a thickness distribution of the oxide layer in the inner surface becomes a desired distribution.

2. The method of Claim 1, wherein (a) includes:

exciting a nitrogen-containing gas to generate a nitriding species; and

supplying the nitriding species to the substrate.

3. The method of Claim 2, wherein (a) further includes exciting the nitrogen-containing gas by plasma or heat.

4. The method of Claim 2, wherein the nitrogen-containing gas is a hydrogen-free gas.

5. The method of Claim 1, wherein (a) includes setting the thickness distribution of the nitride layer such that a thickness of the nitride layer becomes gradually smaller from an opening of the recessed structure to a bottom of the recessed structure.

6. The method of Claim 1, wherein (a) includes modifying an entire surface of the inner surface to the nitride layer.

7. The method of Claim 1, wherein (a) includes modifying the inner surface near an opening of the recessed structure to the nitride layer, and not modifying the inner surface near a bottom of the recessed structure to the nitride layer.

8. The method of Claim 1, wherein the inner surface nitrided in (a) contains silicon.

9. The method of Claim 1, wherein (b) includes exciting an oxygen-containing gas to generate an oxidizing species; and

supplying the oxidizing species to the substrate.

10. The method of Claim 9, wherein (b) further includes exciting the oxygen-containing gas by plasma or heat.

11. The method of Claim 9, wherein the oxygen-containing gas is a gas containing hydrogen.

12. The method of Claim 11, wherein (b) further includes controlling the thickness distribution of the oxide layer by adjusting a ratio of hydrogen to oxygen contained in the oxygen-containing gas.

13. The method of Claim 1, wherein (b) includes modifying the nitride layer to the oxide layer over an entirety of a thickness direction of the nitride layer.

14. The method of Claim 1, wherein (b) includes setting the thickness distribution of the oxide layer such that a thickness of the oxide layer becomes gradually larger from an opening of the recessed structure toward a bottom of the recessed structure and becomes largest at the bottom of the recessed structure.

15. The method of Claim 14, wherein in (a), the thickness distribution of the nitride layer is set such that, in (b), the thickness of the oxide layer becomes gradually larger from the opening of the recessed structure toward the bottom of the recessed structure and becomes largest at the bottom of the recessed structure.

16. The method of Claim 1, wherein (b) includes setting a thickness distribution of the oxide layer such that a thickness of the oxide layer becomes uniform over an entire surface of the inner surface.

17. The method of Claim 16, wherein (a) includes setting a thickness distribution of the nitride layer such that, in (b), the thickness of the oxide layer becomes uniform over the entire surface of the inner surface.

18. A method of manufacturing a semiconductor device comprising the method of Claim 1.

19. A substrate processing apparatus, comprising:

a process chamber configured to accommodate a substrate;

a nitrogen-containing gas supplier configured to supply a nitrogen-containing gas into the process chamber;

an oxygen-containing gas supplier configured to supply an oxygen-containing gas into the process chamber;

an excitation part configured to excite the gases supplied from the nitrogen-containing gas supplier and the oxygen-containing gas supplier; and

a controller configured to be capable of controlling the nitrogen-containing gas supplier, the oxygen-containing gas supplier, and the excitation part to perform in the process chamber:

(a) supplying a nitriding species generated by exciting the nitrogen-containing

gas to the substrate having a recessed structure formed on a surface of the substrate, nitriding an inner surface of the recessed structure, and modifying at least a portion of the inner surface into a nitride layer; and

(b) supplying an oxidizing species generated by exciting the oxygen-containing gas to the substrate, oxidizing the inner surface including the nitride layer, and modifying the inner surface into an oxide layer,

wherein (a) includes setting a thickness distribution of the nitride layer in the inner surface such that, in (b), a thickness distribution of the oxide layer in the inner surface becomes a desired distribution.

20. 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) nitriding an inner surface of a recessed structure formed on a substrate to modify at least a portion of the inner surface into a nitride layer; and

(b) oxidizing the inner surface including the nitride layer to modify the inner surface into an oxide layer,

wherein (a) includes setting a thickness distribution of the nitride layer in the inner surface such that, in (b), a thickness distribution of the oxide layer in the inner surface becomes a desired distribution.