

WHAT IS CLAIMED IS:

1. An etching method, comprising:

providing a substrate in a chamber of a plasma processing apparatus, the substrate including a silicon-containing film that at least includes a silicon oxide film and a silicon nitride film;

supplying a process gas to the chamber, the process gas containing a halogen component and a phosphorous containing gas as a phosphorus component; and

etching the silicon-containing film with a plasma generated from the process gas,

wherein

the etching includes setting a flow rate proportion of the phosphorus-containing gas with respect to a total flow rate of the process gas so as to establish a predetermined ratio of an etching rate of an alternate stack of the silicon oxide film and the silicon nitride film to an etching rate of the silicon oxide film, and

the setting includes setting the flow rate proportion so as to establish the predetermined ratio to be in an inclusive range of 0.8 through 1.2.

2. The etching method according to claim 1, further comprising:

forming a protective film on a surface of a side wall of a recess formed in the silicon-containing film by the etching, the protective film containing phosphorus provided by the phosphorous-containing gas.

3. The etching method according to claim 2, wherein the etching and the forming the protective film are performed at a

same time.

4. The etching method according to any one of claims 1 to 3,
wherein

the phosphorous-containing gas contains at least one molecule
5 selected from the group consisting of PF_3 , PCl_3 , PF_5 , PCl_5 , POCl_3 , PH_3 ,
 PBr_3 , and PBr_5 .

5. The etching method according to any one of claims 1 to 4,
wherein

the process gas further contains carbon and hydrogen.

10 6. The etching method according to claim 5, wherein
a hydrogen component of the process gas contains at least one
molecule selected from the group consisting of H_2 , HF , C_xH_y , CH_xF_y , and
 NH_3 , where x and y are natural numbers.

7. The etching method according to any one of claims 1 to 6,
15 wherein

the process gas further comprises a halogen component that
contains fluorine.

8. The etching method according to any one of claims 1 to 7,
wherein

20 the process gas further contains oxygen.

9. The etching method according to claim 1, wherein
the silicon-containing film further includes a silicon film.

10. The etching method according to claim 1, wherein
the silicon-containing film includes a single layer film and a
25 multilayer film, and

the etching includes etching the single layer film and the

multilayer film at a same time.

11. The etching method according to claim 10, wherein the multilayer film includes

5 a stack of one or more silicon oxide films and one or more silicon nitride films,

a stack of one or more silicon oxide films and one or more polycrystalline silicon films, or

a stack of one or more silicon oxide films, one or more polycrystalline silicon films, and one or more silicon nitride films.

10 12. The etching method according to claim 10, wherein the single layer film is a silicon oxide film, a silicon nitride film, or a polycrystalline silicon film.

13. The etching method according to any one of claims 1 to 12, wherein

15 the substrate further includes a mask on the silicon-containing film.

14. The etching method according to claim 1, further comprising:

20 setting a temperature of the substrate to lower than or equal to 0 °C at a start of the etching.

15. A plasma processing apparatus, comprising:

a chamber;

a controller;

25 a substrate support that supports a substrate in the chamber, the substrate includes at least includes a silicon oxide film and a silicon nitride film;

a controllable gas supply configured to be controlled by the controller to supply, into the chamber, a process gas used to etch a silicon-containing film, the process gas containing a halogen component and a phosphorous containing gas as a phosphorus component; and

5 a radio-frequency power supply configured to generate radio-frequency power usable to generate plasma from the process gas in the chamber, wherein

 the controller is configured to control the controllable gas supply to set a flow rate proportion of the phosphorus-containing gas with respect
10 to a total flow rate of the process gas so as to establish a predetermined ratio of an etching rate of an alternate stack of the silicon oxide film and the silicon nitride film to an etching rate of the silicon oxide film to be in an inclusive range of 0.8 through 1.2.

 16. The plasma processing apparatus of claim 15, wherein
15 the controller is further configured to controllably adjust an output level of the radio-frequency power supply during a time interval while the controller controls the flow rate proportion.