

ETCHING METHOD, PLASMA PROCESSING APPARATUS, AND SUBSTRATE PROCESSING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims priority from Japanese Patent Application Nos. 2019-167063 and 2020-121613, filed on September 13, 2019 and July 15, 2020, respectively, with the Japan Patent Office, the disclosures of which are incorporated by reference in their entireties.

TECHNICAL FIELD

[0002] The present disclosure relates to an etching method, a plasma processing apparatus, and a substrate processing system.

BACKGROUND

[0003] Japanese Laid-Open Patent Publication No. 2015-012178 discloses a plasma etching of an organic film. The plasma etching of Japanese Laid-Open Patent Publication No. 2015-012178 uses a mixed gas containing oxygen gas, carbonyl sulfate gas, and chlorine gas. The organic film is etched in the manner that sulfur and silicon chloride adhere to the side wall surface of the organic film. Accordingly, a recess formed by the etching of the organic film is suppressed from being laterally expanded. That is, a bowing is suppressed so that the shape of the recess is improved.

SUMMARY

[0004] An aspect of the present disclosure provides an etching method. The etching method includes (a) performing a plasma etching on an organic film. A mask is provided on the organic film. A recess is formed in the organic film by the plasma etching. The etching method further includes (b) forming an organic protective film on a side wall surface of the organic film that defines the recess. The etching method further includes (c) performing an additional plasma etching on the organic film after (b) is performed.

[0004a] In one aspect, there is provided an etching method, comprising: (a) performing a plasma etching on an organic film to form a recess in the organic film, the organic film having a mask formed thereon and being formed on another film; (b) forming an organic protective film on a side wall surface of the recess in the organic film; (c) performing an additional plasma etching on the organic film after (b); (d) performing a plasma etching on the another film after the another film is partially exposed by (c); and (e) forming an additional organic protective film on another side wall surface of the recess in the another film, after (d) is performed, wherein (d) is additionally performed after (e) is performed.

[0004b] In another aspect, the present disclosure provides a plasma processing apparatus, comprising a chamber configured to accommodate a substrate including an organic film, the organic film having a mask formed thereon and being formed on another film; a substrate support provided inside the chamber; a gas supply configured to supply a precursor gas into the chamber, the precursor gas containing carbon and a processing gas; a radio-frequency (RF) power supply configured to generate a RF power for generating plasma from a gas in the chamber; and a controller configured to control the gas supply and the RF power supply, wherein the controller controls the gas supply to supply the processing gas into the chamber, and controls the RF power supply to supply the RF power to generate plasma from the processing gas in order to (a) perform a plasma etching on the organic film to form a recess in the organic film, the controller controls the gas supply to supply the precursor gas into the

chamber in order to (b) perform a film forming process to form an organic protective film on a side wall surface of the recess in the organic film, and the controller controls the gas supply to supply the processing gas into the chamber, and controls the RF power supply to supply the RF power to generate plasma from the processing gas in order to (c) perform an additional plasma etching on the organic film, the controller controls the gas supply and the RF power supply to (d) perform a plasma etching on the another film after the another film is partially exposed by (c); the controller controls the gas supply to (e) form an additional organic protective film on another side wall surface of the recess in the another film, after (d) is performed, and the controller controls the gas supply and the RF power supply to repeat (d) after (e) is performed.

[0004c] In yet another aspect, the present disclosure provides a substrate processing system for etching an organic film of a substrate including the organic film and a mask formed on the organic film, the organic film having a mask formed thereon and being formed on another film the substrate processing system comprising a plurality of plasma processing apparatuses; a transfer module configured to provide a depressurizable space, connected to the plurality of plasma processing apparatuses, and transfer the substrate to the plurality of plasma processing apparatuses through the depressurizable space; and a controller configured to control the transfer module to transfer the substrate to a first plasma processing apparatus of the plurality of plasma processing apparatuses; control the first plasma processing apparatus to generate plasma from a processing gas in order to (a) perform a plasma etching on the organic film to form a recess in the organic film; control the transfer module to transfer the substrate, that has been subjected to the plasma etching of (a), to a second plasma processing apparatus of the plurality of plasma processing apparatuses; control the second plasma processing apparatus to (b) perform a film forming process to form an organic protective film on a side wall surface of the recess in the organic film; control the transfer module to transfer the substrate, that has been subjected to the film forming process of (b), to the first plasma processing apparatus; and control the first plasma processing apparatus to generate plasma from the processing gas in order to (c) perform an additional plasma etching on the organic film; control the first plasma processing apparatus to (d) perform a plasma etching on the another film after the another film is partially exposed by (c); control the transfer module to transfer the substrate which has been subjected to (d) to the second plasma processing apparatus; control the second plasma processing apparatus to (e) form an additional organic protective film on another side wall surface of the recess in the another film, after (d) is performed; control the transfer module to transfer the substrate which has been subjected to (e) to the first plasma processing apparatus, and control the first plasma processing apparatus to repeat (d) after (e) is performed.

[0004d] In a further aspect, there is provided an etching method, comprising (a) performing a plasma etching on a first organic film of a substrate, having a mask formed on the first organic film, to form a recess in the first organic film by the plasma etching; (b) forming a second organic film on a sidewall surface of the recess in the first organic film; and (c) performing an additional plasma etching on the first organic film after (b), wherein the second organic film in (b) is formed by (b1) supplying a first precursor gas to the substrate; and (b2) supplying a second precursor gas to the substrate.

[0004e] In yet another aspect, there is provided an etching method, comprising (a) performing a plasma etching on a first organic film of a substrate, having a mask formed on the first organic film, to form a recess in the first organic film by the plasma etching; (b) forming a second organic film on a sidewall of surface of the recess in the first organic film; and (c) performing an additional plasma etching on the first organic film after (b), wherein the second organic film in (b) is formed by (b1) supplying a first gas containing a precursor organic compound to the

substrate; (b2) supplying a second gas to the substrate; and (b3) supplying energy to the precursor organic compound or to the second gas.

[0005] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a flowchart of an etching method according to an embodiment.

[0007] FIG. 2 is a partial enlarged cross-sectional view of an example of a substrate.

[0008] FIG. 3 is a view schematically illustrating a plasma processing apparatus according to an embodiment.

[0009] FIG. 4 is a view illustrating an example of a layout of a plurality of heaters in the plasma processing apparatus illustrated in FIG. 3.

[0010] FIG. 5A is a partial enlarged cross-sectional view of an example of the substrate in a state after step ST1 of the etching method illustrated in FIG. 1 is performed, and FIG. 5B is a partial enlarged cross-sectional view of an example of the substrate in a state after step ST2 of the etching method illustrated in FIG. 1 is performed.

[0011] FIG. 6A is a partial enlarged cross-sectional view of an example of the substrate in a state after step ST3 of the etching method illustrated in FIG. 1 is performed, and FIG. 6B is a partial enlarged cross-sectional view of an example of the substrate in a state when an etching of

WHAT IS CLAIMED IS:

1. An etching method, comprising:
 - (a) performing a plasma etching on an organic film to form a recess in the organic film, the organic film having a mask formed thereon and being formed on another film;
 - (b) forming an organic protective film on a side wall surface of the recess in the organic film;
 - (c) performing an additional plasma etching on the organic film after (b);
 - (d) performing a plasma etching on the another film after the another film is partially exposed by (c); and
 - (e) forming an additional organic protective film on another side wall surface of the recess in the another film, after (d) is performed, wherein (d) is additionally performed after (e) is performed.
2. The etching method according to claim 1, wherein (b) and (c) are alternately repeated.
3. The etching method according to claim 1, wherein the mask contains silicon.
4. The etching method according to claim 1, wherein (b) is started when an aspect ratio, of a depth of the recess divided by a width of the recess, is 5 or lower.
5. The etching method according to claim 4, wherein the organic protective film is conformally formed on a surface of a substrate, that includes the organic film, after (a) is performed.
6. The etching method according to claim 1, further comprising:
 - (f) performing an ashing process to remove the organic film after (d) is performed.
7. A plasma processing apparatus, comprising:
 - a chamber configured to accommodate a substrate including an organic film, the organic film having a mask formed thereon and being formed on another film;
 - a substrate support provided inside the chamber;
 - a gas supply configured to supply a precursor gas into the chamber, the precursor gas containing carbon and a processing gas;
 - a radio-frequency (RF) power supply configured to generate a RF power for generating plasma from a gas in the chamber; and
 - a controller configured to control the gas supply and the RF power supply, wherein the controller controls the gas supply to supply the processing gas into the chamber, and controls the RF power supply to supply the RF power to generate plasma from the processing gas in order to (a) perform a plasma etching on the organic film to form a recess in the organic film,
 - the controller controls the gas supply to supply the precursor gas into the chamber in order to (b) perform a film forming process to form an organic protective film on a side wall surface of the recess in the organic film, and
 - the controller controls the gas supply to supply the processing gas into the chamber, and controls the RF power supply to supply the RF power to generate plasma from the processing gas in order to (c) perform an additional plasma etching on the organic film,
 - the controller controls the gas supply and the RF power supply to (d) perform a plasma etching on the another film after the another film is partially exposed by (c);
 - the controller controls the gas supply to (e) form an additional organic protective film

on another side wall surface of the recess in the another film, after (d) is performed, and
the controller controls the gas supply and the RF power supply to repeat (d) after (e) is performed.

8. The plasma processing apparatus according to claim 7, wherein the controller is configured to control the gas supply and the RF power supply to alternately repeat (b) and (c).

9. The plasma processing apparatus according to claim 7, wherein the mask contains silicon.

10. The plasma processing apparatus according to claim 7, wherein the controller controls the gas supply to start (b) when an aspect ratio, of a depth of the recess divided by a width of the recess, is 5 or lower.

11. The plasma processing apparatus according to claim 10, wherein the organic protective film is conformally formed on a surface of a substrate, that includes the organic film, after (a) is performed.

12. The plasma processing apparatus according to claim 7, wherein the controller is further configured to control the gas supply and the RF power supply to (f) perform an ashing process to remove the organic film after (d) is performed.

13. A substrate processing system for etching an organic film of a substrate including the organic film, the organic film having a mask formed thereon and being formed on another film, the substrate processing system comprising:

- a plurality of plasma processing apparatuses;

- a transfer module configured to provide a depressurizable space, connected to the plurality of plasma processing apparatuses, and transfer the substrate to the plurality of plasma processing apparatuses through the depressurizable space; and

- a controller configured to:

- control the transfer module to transfer the substrate to a first plasma processing apparatus of the plurality of plasma processing apparatuses;

- control the first plasma processing apparatus to generate plasma from a processing gas in order to (a) perform a plasma etching on the organic film to form a recess in the organic film;

- control the transfer module to transfer the substrate, that has been subjected to the plasma etching of (a), to a second plasma processing apparatus of the plurality of plasma processing apparatuses;

- control the second plasma processing apparatus to (b) perform a film forming process to form an organic protective film on a side wall surface of the recess in the organic film;

- control the transfer module to transfer the substrate, that has been subjected to the film forming process of (b), to the first plasma processing apparatus;

- control the first plasma processing apparatus to generate plasma from the processing gas in order to (c) perform an additional plasma etching on the organic film;

- control the first plasma processing apparatus to (d) perform a plasma etching on the another film after the another film is partially exposed by (c);

- control the transfer module to transfer the substrate which has been subjected to (d) to the second plasma processing apparatus;

control the second plasma processing apparatus to (e) form an additional organic protective film on another side wall surface of the recess in the another film, after (d) is performed;

control the transfer module to transfer the substrate which has been subjected to (e) to the first plasma processing apparatus, and

control the first plasma processing apparatus to repeat (d) after (e) is performed.

14. The substrate processing system according to claim 13, wherein the controller is further configured to control the transfer module to transfer the substrate back and forth between the first plasma processing apparatus and the second plasma processing apparatus so that the first plasma processing apparatus and the second plasma processing apparatus alternately repeat (b) and (c).

15. The substrate processing system according to claim 13, wherein the controller controls the second plasma processing apparatus to start (b) when an aspect ratio, of a depth of the recess divided by a width of the recess, is 5 or lower.

16. The substrate processing system according to claim 13, wherein the organic protective film is conformally formed on a surface of the substrate after (a) is performed.

17. An etching method, comprising:

(a) performing a plasma etching on a first organic film of a substrate, having a mask formed on the first organic film, to form a recess in the first organic film by the plasma etching;

(b) forming a second organic film on a sidewall surface of the recess in the first organic film; and

(c) performing an additional plasma etching on the first organic film after (b), wherein the second organic film in (b) is formed by:

(b1) supplying a first precursor gas to the substrate; and

(b2) supplying a second precursor gas to the substrate.

18. An etching method, comprising:

(a) performing a plasma etching on a first organic film of a substrate, having a mask formed on the first organic film, to form a recess in the first organic film by the plasma etching;

(b) forming a second organic film on a sidewall of surface of the recess in the first organic film; and

(c) performing an additional plasma etching on the first organic film after (b), wherein the second organic film in (b) is formed by:

(b1) supplying a first gas containing a precursor organic compound to the substrate;

(b2) supplying a second gas to the substrate; and

(b3) supplying energy to the precursor organic compound or to the second gas.