

WHAT IS CLAIMED IS:

1. An etching method comprising:

loading a substrate having a recess and an etching target portion existing on an inner surface of the recess into a processing container, the etching target portion being made of SiN or Si, and a carbon-containing damage layer being formed on a surface of the etching target portion;

performing an oxygen-containing plasma process on the substrate inside the processing container to preferentially modify the surface of the etching target portion at a top portion of the recess such that a thickness of the modified layer is thicker at the top portion of the recess than at a remaining portion of the recess, and to remove carbons from the carbon-containing damage layer; and

subsequently, dry-etching the etching target portion in an isotropic manner.
2. The etching method of Claim 1, wherein the recess is a groove or a hole.
3. The etching method of Claim 2, wherein the recess has a diameter or a width of 300 nm or less and an aspect ratio of 25 or more.
4. The etching method of any one of Claims 1 to 3, wherein the substrate has a stacked structure of an SiO₂ and an SiN, the recess is formed in the stacked structure, the SiO₂ and the SiN of the stacked structure exist on the inner surface of the recess, and a portion of the SiN of the stacked structure is the etching target portion.
5. The etching method of any one of Claims 1 to 3, wherein the substrate has a stacked structure of an SiO₂ and a first SiN, the stacked structure has a second SiN on the inner surface of the recess, the etching target portion is all of the second SiN and a

portion of the first SiN of the stacked structure, and

wherein the dry-etching includes etching the second SiN and the portion of the first SiN of the stacked structure.

6. The etching method of any one of Claims 1 to 5, wherein the oxygen-containing plasma process is performed using an O₂ gas alone, or at least one of the O₂ gas, an H₂ gas and a noble gas.

7. The etching method of any one of Claims 1 to 6, wherein the oxygen-containing plasma process is performed by a remote plasma, and is performed with respect to the substrate mainly using oxygen radicals in an oxygen-containing plasma.

8. The etching method of any one of Claims 1 to 7, wherein the oxygen-containing plasma process is performed at a pressure ranging from 0.13 to 400 Pa.

9. The etching method of any one of Claims 1 to 8, wherein the dry-etching is performed by a fluorine-containing gas.

10. The etching method of Claim 9, wherein the fluorine-containing gas includes an NF₃ gas.

11. The etching method of Claim 9 or 10, wherein the dry-etching is performed by the fluorine-containing gas and an O₂ gas.

12. The etching method of Claim 11, wherein the dry-etching is performed in a state where a ratio of a flow rate of the fluorine-containing gas to a flow rate of the O₂ gas is 0.01 or more and 1.0 or less.

13. The etching method of any one of Claims 1 to 12, wherein the dry-etching is performed by a plasma process mainly using radicals.
14. The etching method of any one of Claims 1 to 13, wherein the dry-etching is performed at a pressure ranging from 0.13 to 400 Pa.
15. The etching method of any one of Claims 1 to 14, wherein the oxygen-containing plasma process and the dry-etching are performed in the same processing container.
16. The etching method of any one of Claims 1 to 15, wherein the oxygen-containing plasma process and the dry-etching are repeated a multiple number of times.
17. An etching apparatus comprising:
- a processing container in which a substrate having a recess and an etching target portion existing on an inner surface of the recess is accommodated, the etching target portion being made of SiN or Si, and a carbon-containing damage layer being formed on a surface of the etching target portion;
 - a separation part configured to separate the processing container into an upper plasma production space and a lower process space;
 - a gas supplying part configured to supply an oxygen gas and a fluorine-containing gas into the upper plasma production space;
 - a plasma production mechanism configured to produce a plasma of at least one selected from the group of the oxygen gas and the fluorine-containing gas in the upper plasma production space;
 - a stage configured to mount the substrate loaded into the lower process space

thereon;

an exhaust mechanism configured to vacuum-exhaust an interior of the processing container and

a controller,

wherein the controller performs a control to execute:

loading the substrate into the processing container;

preferentially modifying the surface of the etching target portion at a top portion of the recess such that a thickness of the modified layer is thicker at the top portion of the recess than at a remaining portion of the recess, and removing carbons from the carbon-containing damage layer, with oxygen radicals by producing an oxygen-containing plasma in the upper plasma production space and by transferring mainly the oxygen radicals in the oxygen-containing plasma from the upper plasma production space into the lower process space; and

etching the etching target portion with fluorine radicals by producing a fluorine-containing plasma in the upper plasma production space and by transferring mainly the fluorine radicals in the fluorine-containing plasma from the upper plasma production space to the lower process space.

18. The etching apparatus of Claim 17, wherein the controller performs a control to repeat the modifying and the etching a multiple number of times.

19. The etching apparatus of Claim 17 or 18, wherein the controller performs a control to add an oxygen gas in the etching.