CLAIMS

~~What is claimed is:~~

1. A method forming spacers from a non-silicon oxide, silicon containing spacer layer with horizontal surfaces and sidewall surfaces over a substrate, comprising:

(a) forming a silicon oxide layer over plasma etch chamber surfaces before placing a substrate in the plasma etch chamber;

(b) providing a plasma oxidation treatment to form a silicon oxide coating over the spacer layer, wherein the silicon oxide coating provides a horizontal coating on the horizontal surfaces and sidewall coatings on the sidewall surfaces of the spacer layer~~;~~,

~~(b)~~ wherein the providing the plasma oxidation treatment, comprises: providing an oxygen plasma; and sputtering silicon to form silicon oxide with the oxygen plasma, wherein the plasma oxidation treatment sputters silicon oxide from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma oxidation treatment;

(c) providing an anisotropic main etch that selectively etches horizontal surfaces of the spacer layer and silicon oxide coating with respect to sidewall surfaces of the spacer layer and the sidewall coatings of the silicon oxide coating; and

~~(c)~~ (d) etching the spacer layer, wherein the sidewall coatings of the silicon oxide coating protect sidewall surfaces of the spacer layer.

2. The method, as recited in claim 1, further comprising:

placing the substrate in a plasma etch chamber before providing the plasma oxidation treatment, wherein the chamber has an antenna; and

removing the substrate from the plasma etch chamber after etching the spacer layer, wherein the providing the plasma oxidation treatment, providing the anisotropic main etch, and etching the spacer layer are performed in the same plasma etch chamber using the antenna.

~~3. The method, as recited in claim 2, wherein the providing the plasma oxidation treatment, comprises:~~

~~providing an oxygen plasma; and~~

~~at least one of sputtering silicon to form silicon oxide with the oxygen plasma or transforming silicon of the spacer layer into silicon oxide.~~

~~4. The method, as recited in claim 3~~

3. The method, as recited in claim 2, wherein the providing the plasma oxidation treatment comprises the sputtering the silicon, which ~~comprise~~comprises providing a bias voltage of ~~greater than 25~~at least 100 volts to the substrate.

~~5~~4. The method, as recited in claim ~~3~~2, wherein the providing the oxygen plasma, comprises:

providing an oxidation gas consisting essentially of oxygen, or oxygen and an inert ~~dilulent~~diluent; and

forming a plasma from the oxidation gas.

~~6~~5. The method, as recited in claim ~~5~~4, wherein the spacer layer is one of silicon or silicon nitride.

~~7~~6. The method, as recited in claim ~~6, further comprising forming a silicon oxide layer over plasma etch chamber surfaces before placing the substrate in the plasma etch chamber.~~

~~8. The method, as recited in claim 7, wherein the plasma oxidation treatment sputters silicon oxide from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma oxidation treatment.~~

~~9. The method, as recited in claim 8, further comprising removing the silicon oxide coating after etching the spacer layer and before removing the substrate from the plasma etch chamber.~~

~~10. The method, as recited in claim 7~~1, further comprising:

removing the substrate from the plasma etch chamber; and

cleaning the plasma etch chamber surfaces after the substrate is removed, wherein the forming the silicon oxide layer over the etch chamber surfaces is repeatedly performed before placing each substrate into the plasma etch chamber and the cleaning the plasma etch chamber surfaces is repeatedly performed after each removing the substrate.

~~11. The method, as recited in claim 1, wherein the providing the plasma oxidation treatment, comprises:~~

~~providing an oxygen plasma; and~~

~~at least one of sputtering silicon to form silicon oxide with the oxygen plasma or transforming silicon of the spacer layer into silicon oxide.~~

~~12. The method, as recited in claim 11~~

7. The method, as recited in claim 1, wherein the providing the oxygen plasma, comprises:

providing an oxidation gas consisting essentially of oxygen; and

forming a plasma from the oxidation gas.

~~13~~ 8. The method, as recited in claim ~~12~~7, wherein the spacer layer is silicon or silicon nitride.

~~14.~~9. ~~The~~ A method~~, as recited in claim 11, further~~ forming spacers from a non-silicon oxide, silicon containing spacer layer with horizontal surfaces and sidewall surfaces over a substrate, comprising:

(a) forming a silicon oxide layer over plasma etch chamber surfaces before placing the substrate in the plasma etch chamber~~.~~;

~~15. The method, as recited in claim 14, wherein the plasma oxidation~~

(b) providing a plasma treatment to form a silicon oxide coating over the spacer layer, wherein the silicon oxide coating provides a horizontal coating on the horizontal surfaces and sidewall coatings on the sidewall surfaces of the spacer layer, wherein the plasma treatment sputters silicon oxide from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma ~~oxidation~~ treatment~~.~~;

~~16. The method, as recited in any of claims 1-2, wherein the providing the plasma oxidation treatment, comprises: providing an oxygen plasma; and at least one of sputtering silicon to form silicon oxide with the oxygen plasma or transforming silicon of the spacer layer into silicon oxide.~~

~~17. The method, as recited in any of claims 1-2 and 16, wherein the providing the plasma oxidation treatment comprises the sputtering the silicon, which comprise providing a bias voltage of greater than 25 volts to the substrate.~~

~~18. The method, as recited in any of claims 1-2 and 16-17, wherein the providing the oxygen plasma, comprises: providing an oxidation gas consisting essentially of oxygen, or oxygen and an inert dilulent; and forming a plasma from the oxidation gas.~~

~~19. The method, as recited in any of claims 1-2 and 16-18, wherein the spacer layer is one of silicon or silicon nitride.~~

~~20. The method, as recited in any of claims 1-2 and 16-19, further comprising forming a silicon oxide layer over plasma etch chamber surfaces before placing the substrate in the plasma etch chamber.~~

~~21. The method, as recited in any of claims 1-2 and 16-20, wherein the plasma oxidation treatment sputters silicon oxide from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma oxidation treatment.~~

~~22. The method, as recited in any of claims 1-2 and 16-21~~

(c) providing an anisotropic main etch that selectively etches horizontal surfaces of the spacer layer and silicon oxide coating with respect to sidewall surfaces of the spacer layer and the sidewall coatings of the silicon oxide coating; and

(d) etching the spacer layer, wherein the sidewall coatings of the silicon oxide coating protect sidewall surfaces of the spacer layer.

10. The method, as recited in claim 9, further comprising removing the silicon oxide coating after etching the spacer layer and before removing the substrate from the plasma etch chamber.

~~23. The method, as recited in any of claims 1-2 and 16-22, further comprising:~~

~~removing the substrate from the plasma etch chamber; and~~

~~cleaning the plasma etch chamber surfaces after the substrate is removed, wherein the forming the silicon oxide layer over the etch chamber surfaces is repeatedly performed before placing each substrate into the plasma etch chamber and the cleaning the plasma etch chamber surfaces is repeatedly performed after each removing the substrate.~~

~~24~~11. A method for forming spacers from a non-silicon oxide, silicon containing spacer layers with horizontal surfaces and sidewall surfaces over a plurality of substrates, comprising:

(a) forming a silicon oxide layer over plasma etch chamber surfaces before placing a substrate in the plasma etch chamber;

(b) placing a substrate of the plurality of substrates with a spacer layer that is silicon containing but non-silicon oxide containing in a plasma etch chamber before providing the plasma oxidation treatment, wherein the chamber has an antenna;

~~(b)~~(c) providing a plasma oxidation treatment to form a silicon oxide coating over the spacer layer, wherein the silicon oxide coating provides a horizontal coating on the horizontal surfaces and sidewall coatings on the sidewall surfaces of the spacer layer, comprising:

providing an oxygen plasma; and

~~providing at least one of~~ sputtering silicon to form silicon oxide with the oxygen plasma~~ or transforming silicon of~~, wherein the ~~spacer layer into~~plasma oxidation treatment sputters silicon oxide~~;~~

~~(c)~~from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma oxidation treatment;

(d) providing a anisotropic main etch that selectively etches horizontal surfaces of the spacer layer and silicon oxide coating with respect to sidewall surfaces of the spacer layer and the sidewall coatings of the silicon oxide coating;

~~(d)~~(e) etching the spacer layer, wherein the sidewall coatings of the silicon oxide coating protect sidewall surfaces of the spacer layer;

~~(e)~~(f) removing the substrate from the plasma etch chamber after etching the spacer layer, wherein the providing the plasma oxidation treatment, providing the anisotropic main etch, and etching the spacer layer are performed in the same plasma etch chamber using the antenna;

(~~f~~g) repeating steps (a) to (~~e~~f) until each of the plurality of substrates is processed.

~~25~~12. The method, as recited in claim ~~24~~11, further comprising:

~~forming a silicon oxide layer over plasma etch chamber surfaces before placing the substrate in the plasma etch chamber; and~~

cleaning the plasma etch chamber surfaces after the substrate is removed, wherein the forming the silicon oxide layer over the etch chamber surfaces is repeatedly performed before placing each substrate of the plurality of substrates into the plasma etch chamber and the cleaning the plasma etch chamber surfaces is repeatedly performed after each removing the substrate of the plurality of substrates from the chamber.

13. A method forming spacers from a non- silicon oxide, silicon containing spacer layer with horizontal surfaces and sidewall surfaces over a substrate, comprising:

(a) providing a plasma oxidation treatment to form a silicon oxide coating over the spacer layer, wherein the silicon oxide coating provides a horizontal coating on the horizontal surfaces and sidewall coatings on the sidewall surfaces of the spacer layer,

wherein the providing the plasma oxidation treatment, comprises: providing an oxygen plasma; and sputtering silicon to form silicon oxide with the oxygen plasma, wherein the sputtered silicon deposits on the sidewalls to form the sidewall coatings;

(b) providing an anisotropic main etch that selectively etches horizontal surfaces of the spacer layer and silicon oxide coating with respect to sidewall surfaces of the spacer layer and the sidewall coatings of the silicon oxide coating; and

(c) etching the spacer layer, wherein the sidewall coatings of the silicon oxide coating protect sidewall surfaces of the spacer layer.

~~26~~14. An apparatus for forming spacers from non-silicon oxide, silicon containing spacer layer with horizontal surfaces and sidewall surfaces over a substrate, comprising:

a plasma processing chamber, comprising:

a chamber wall forming a plasma processing chamber enclosure;

a substrate support for supporting a substrate within the plasma processing chamber enclosure;

a pressure regulator for regulating the pressure in the plasma processing chamber enclosure;

at least one antenna for providing power to the plasma processing chamber enclosure for sustaining a plasma;

at least one bias electrode for providing a bias voltage;

a gas inlet for providing gas into the plasma processing chamber enclosure; and

a gas outlet for exhausting gas from the plasma processing chamber enclosure;

a gas source in fluid connection with the gas inlet, comprising;

an oxygen gas source; and

an anisotropic etch gas source;

a controller controllably connected to the gas source, the at least one antenna, and at least one bias electrode, comprising:

at least one processor; and

non-transitory computer readable media~~, comprising:~~

having computer~~-readable code~~-executable instructions for ~~placing~~performing a ~~substrate with a spacer layer of the plurality of substrates in a plasma etch chamber before~~ method comprising: providing ~~the~~a plasma oxidation treatment~~;~~

~~computer readable code for providing a plasma oxidation treatment~~ of a spacer layer to form a silicon oxide coating over the spacer layer, wherein the silicon oxide coating provides a horizontal silicon oxide coating on ~~the~~ horizontal surfaces and sidewall silicon oxide coatings on ~~the~~ sidewall surfaces of the spacer layer, the plasma oxidation treatment comprising:

~~computer readable code for~~ providing an oxygen plasma; and

~~computer readable code for providing at least one of~~ sputtering silicon to form silicon oxide ~~with~~using the oxygen plasma~~ or transforming~~, wherein the sputtering of silicon ~~of~~deposits silicon oxide on the ~~spacer layer into silicon oxide;~~

~~computer readable code for~~sidewalls to form the sidewall coatings;

providing ~~a~~an anisotropic main etch that selectively etches horizontal surfaces of the spacer layer and silicon oxide coating with respect to sidewall surfaces of the spacer layer and the sidewall coatings of the silicon oxide coating;

~~computer readable code for~~ etching the spacer layer, wherein the sidewall coatings of the silicon oxide coating protect sidewall surfaces of the spacer layer;

~~computer readable code for~~removing the substrate from the plasma etch chamber after etching the spacer layer, wherein the providing the plasma oxidation treatment, the anisotropic main etch, and etching the spacer layer are performed in the same plasma etch chamber using the antenna.

15. The apparatus, as recited in claim 14, the method further comprising:

placing the substrate in a plasma etch chamber before providing the plasma oxidation treatment; and

removing the substrate from the plasma etch chamber after etching the spacer layer, wherein the providing the plasma oxidation treatment, providing the anisotropic main etch, and etching the spacer layer are performed in the same plasma etch chamber using the antenna.

16. The apparatus, as recited in claim 15, wherein the providing the plasma oxidation treatment comprises the sputtering the silicon, which comprise providing a bias voltage of greater than 100 volts to the substrate.

17. The apparatus, as recited in claim 15, wherein the for providing the oxygen plasma, comprises:

providing an oxidation gas consisting essentially of oxygen, or oxygen and an inert diluent; and

forming a plasma from the oxidation gas.

18. The apparatus, as recited in claim 17, wherein the spacer layer is one of silicon or silicon nitride.

19. The apparatus, as recited in claim 18, the method further comprising forming a silicon oxide layer over surfaces of the plasma processing chamber before placing the substrate in the plasma processing chamber.

20. The apparatus, as recited in claim 19, wherein the providing the plasma oxidation treatment sputters silicon oxide from surfaces of the plasma processing chamber to provide silicon for the silicon oxide layer formed during the plasma oxidation treatment.

21. The apparatus, as recited in claim 20, the method further comprising removing the silicon oxide coating after etching the spacer layer and before removing the substrate from the plasma etch chamber.

22. The apparatus, as recited in claim 18, the method further comprising:

removing the substrate from the plasma etch chamber; and

cleaning the plasma etch chamber surfaces after the substrate is removed, wherein the forming the silicon oxide layer over the etch chamber surfaces is repeatedly performed before placing each substrate into the plasma etch chamber and the cleaning of the plasma etch chamber surfaces is repeatedly performed after each removing of the substrate.

23. The apparatus, as recited in claim 14, wherein the providing the oxygen plasma, comprises:

providing an oxidation gas consisting essentially of oxygen; and

forming a plasma from the oxidation gas.

24. The apparatus, as recited in claim 23, wherein the spacer layer is silicon or silicon nitride.

25. The apparatus, as recited in claim 14, the method further comprising forming a silicon oxide layer over plasma etch chamber surfaces before placing the substrate in the plasma etch chamber.

26. The apparatus, as recited in claim 25, wherein the providing the plasma oxidation treatment sputters silicon oxide from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma oxidation treatment.

27. An apparatus for forming spacers from a non-silicon oxide, silicon containing spacer layers with horizontal surfaces and sidewall surfaces over a plurality of substrates, comprising:

a plasma processing chamber, comprising:

a chamber wall forming a plasma processing chamber enclosure;

a substrate support for supporting a substrate within the plasma processing chamber enclosure;

a pressure regulator for regulating the pressure in the plasma processing chamber enclosure;

at least one antenna for providing power to the plasma processing chamber enclosure for sustaining a plasma;

at least one bias electrode for providing a bias voltage;

a gas inlet for providing gas into the plasma processing chamber enclosure; and

a gas outlet for exhausting gas from the plasma processing chamber enclosure;
a gas source in fluid connection with the gas inlet, comprising;

an oxygen gas source; and

an anisotropic etch gas source;

a controller controllably connected to the gas source, the at least one antenna, and at least one bias electrode, comprising:

at least one processor; and

non-transitory computer readable media having computer-executable instructions for performing a method comprising:

forming of a silicon oxide layer over the plasma etch chamber surfaces before a placing of the substrate in the plasma etch chamber; placing a substrate of the plurality of substrates with a spacer layer that is silicon containing but non-silicon oxide containing in the plasma processing chamber enclosure before providing the plasma oxidation treatment;

providing a plasma oxidation treatment to form a silicon oxide coating over the spacer layer, wherein the silicon oxide coating provides a horizontal silicon oxide coating on horizontal surfaces and sidewall silicon oxide coatings on sidewall surfaces of the spacer layer, the plasma oxidation treatment comprising:

providing an oxygen plasma; and

providing sputtering silicon to form silicon oxide with the oxygen plasma, wherein the plasma oxidation treatment sputters

silicon oxide from the plasma etch chamber to provide silicon for the silicon oxide layer formed during the plasma treatment;

providing a anisotropic main etch that selectively etches horizontal surfaces of the spacer layer and silicon oxide coating with respect to sidewall surfaces of the spacer layer and the sidewall coatings of the silicon oxide coating;

etching the spacer layer, wherein the sidewall coatings of the silicon oxide coating protect sidewall surfaces of the spacer layer;

removing the substrate from the plasma etch chamber after etching the spacer layer, wherein the providing the plasma oxidation treatment, providing the anisotropic main etch, and etching the spacer layer are performed in the same plasma etch chamber using the antenna; and

repeating the previous steps until each of the plurality of substrates is processed.

28. The apparatus, as recited in claim 27, the method further comprising:

cleaning the plasma etch chamber surfaces after the substrate is removed, wherein the forming the silicon oxide layer over the etch chamber surfaces is repeatedly performed before placing each substrate of the plurality of substrates into the plasma etch chamber and the cleaning the plasma etch chamber surfaces is repeatedly performed after each removing of the substrate of the plurality of substrates from the chamber.