

THE FOLLOWING IS CLAIMED

- 1) A method for forming a silicon nitride or carbon-doped silicon nitride via a plasma enhanced ALD process, the method comprising:
- 5 a) providing a substrate comprising a surface feature in a reactor and heating the reactor to one or more temperatures ranging up to about 600°C, and optionally maintaining the reactor at a pressure of 100 torr or less;
- 10 b) introducing into the reactor at least one silicon precursor having one or two Si-C-Si linkages and selected from the group consisting of 1,1,1,3,3,3-hexachloro-2-methyl-1,3-disilapropane, 1,1,1,3,3,3-hexachloro-2,2-dimethyl-1,3-disilapropane, 1,1,1,3,3-pentachloro-1,3-disilabutane, 1,1,1,3,3-pentachloro-2-methyl-1,3-disilabutane, 1,1,1,3,3-pentachloro-2,2-dimethyl-1,3-disilabutane, 1,1,1,3,3-pentachloro-2-ethyl-1,3-disilabutane, 1,1,1,3,3-pentachloro-1,3-disilapentane, 1,1,1,3,3-pentachloro-2-methyl-1,3-disilapentane, 1,1,1,3,3-pentachloro-2,2-dimethyl-1,3-disilapentane, 1,1,1,3,3-pentachloro-2-ethyl-1,3-disilapentane, 1,1,1,3,3,5,5-heptachloro-1,3,5-trisilahexane, 1,1,1,5,5-pentachloro-3,3-dimethyl-1,3,5-trisilahexane, 1,1,1,5,5-pentachloro-1,3,5-trisilahexane, 2,2,4,6,6-pentachloro-4-methyl-2,4,6-trisilaheptane, whereby the silicon precursor reacts on at least a portion of the surface feature of the substrate to provide a chemisorbed layer;
- 15 20 25 30 c) purging the reactor of any unreacted silicon precursors and/or any reaction by-products using inert gas;
- d) providing a plasma comprising an ammonia source into the reactor to react with the chemisorbed layer to form a silicon nitride film; and
- e) purging the reactor of any further reaction by-products with inert gas;

wherein the steps b through e are repeated until a desired thickness of the silicon nitride film is deposited.

- 2) The method according to claim 1, wherein the silicon nitride film is a carbon-doped silicon nitride film.
- 5 3) The method according to claim 1, further comprising:
treating the silicon nitride film with a spike anneal at a temperature ranging between 400 and 1000°C.
- 4) The method according to claim 1, further comprising:
10 exposing the silicon nitride film to a UV light source either during or after deposition of the silicon nitride film.
- 5) The method according to claim 1, further comprising:
exposing the silicon nitride film to a plasma comprising one or more gases selected from the group consisting of hydrogen, inert gas, nitrogen, and combinations thereof.
- 15 6) The method according to claim 1, further comprising:
treating the silicon nitride film with an oxygen source at one or more temperatures ranging from ambient temperature to 1000 °C to convert the silicon nitride into a silicon oxynitride film, either in situ or in a separate chamber from the reactor.
- 20 7) The method according to claim 6, wherein the silicon nitride film is a carbon-doped silicon nitride film, and wherein the step of treating the silicon nitride film with an oxygen source converts the carbon-doped silicon nitride into a carbon-doped silicon oxynitride film.
- 8) A film formed according to the method of claim 1 having a dielectric constant (k)
25 of about 6 or less, and a carbon content of about 5 atomic weight % or less as measured by X-ray photoelectron spectroscopy.
- 9) A film of claim 8 having a carbon content of about 5 atomic weight percent or less as measured by X-ray photoelectron spectroscopy.
- 10) A film of claim 9 having a carbon content of about 3 atomic weight percent or
30 less as measured by X-ray photoelectron spectroscopy.

- 11) A film of claim 10 having a carbon content of about 2 atomic weight percent or less as measured by X-ray photoelectron spectroscopy.
- 12) A film of claim 11 having a carbon content of about 1 atomic weight percent or less as measured by X-ray photoelectron spectroscopy.
- 5 13) The method of claim 1 further comprising performing a thermal anneal on the silicon nitride or carbon-doped silicon nitride film at temperatures from about 300 to about 1000°C.
- 14) The method of claim 1 further comprising performing a plasma treatment on the silicon nitride film with an inert gas plasma or hydrogen/inert plasma or nitrogen plasma
10 at a temperature ranging between about 25°C and about 600°C.
- 15) The method of claim 2 further comprising performing a plasma treatment on the carbon-doped silicon nitride film with an inert gas plasma or hydrogen/inert plasma or nitrogen plasma at a temperature ranging between about 25°C and about 600°C.
- 16) The method of claim 6 further comprising performing a plasma treatment on the
15 silicon oxynitride film with an inert gas plasma or hydrogen/inert plasma or nitrogen plasma at a temperature ranging between about 25°C and about 600°C.
- 17) The method of claim 7 further comprising performing a plasma treatment on the carbon-doped silicon oxynitride film with an inert gas plasma or hydrogen/inert plasma or nitrogen plasma at a temperature ranging between about 25°C and about 600°C.
- 20 18) A method for forming a silicon nitride or carbon-doped silicon nitride via a plasma enhanced ALD process, the method comprising:
- a) providing a substrate comprising a surface feature in a reactor;
 - b) introducing into the reactor at least one silicon precursor
25 having one or two Si-C-Si linkages and selected from the group consisting of 1,1,1,3,3,3-hexachloro-2-methyl-1,3-disilapropane, 1,1,1,3,3,3-hexachloro-2,2-dimethyl-1,3-disilapropane, 1,1,1,3,3,3-pentachloro-1,3-disilabutane, 1,1,1,3,3,3-pentachloro-2-methyl-1,3-disilabutane, 1,1,1,3,3,3-pentachloro-2,2-dimethyl-1,3-disilabutane, 1,1,1,3,3,3-pentachloro-2-ethyl-1,3-disilabutane, 1,1,1,3,3,3-pentachloro-1,3-disilapentane, 1,1,1,3,3,3-pentachloro-2-methyl-1,3-
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- 5 disilapentane, 1,1,1,3,3-pentachloro-2,2-dimethyl-1,3-disilapentane, 1,1,1,3,3-pentachloro-2-ethyl-1,3-disilapentane, 1,1,1,3,3,5,5-heptachloro-1,3,5-trisilahexane, 1,1,1,5,5-pentachloro-3,3-dimethyl-1,3,5-trisilahexane, 1,1,1,5,5-pentachloro-1,3,5-trisilahexane, and 2,2,4,6,6-pentachloro-4-methyl-2,4,6-trisilaheptane whereby the silicon precursor reacts on at least a portion of the surface feature of the substrate to provide a chemisorbed layer;
- 10 c) purging the reactor of any unreacted silicon precursors and/or any reaction by-products, using inert gas;
- d) providing a first plasma source into the reactor to react with the chemisorbed layer to form a silicon nitride film that is optionally carbon-doped;
- 15 e) purging the reactor of any further reaction by-products using inert gas;
- f) providing a second plasma source into the reactor to further react and form the silicon nitride film that is optionally carbon-doped;
- 20 g) purging the reactor of any further reaction by-products using inert gas;
- wherein the steps b through g are repeated until the silicon nitride film that is optionally carbon-doped reaches a desired thickness, and wherein the reactor is maintained at one or more temperatures ranging from about 25°C to about 600°C.
- 25 19) The method according to claim 18, wherein the plasma is a plasma comprising an ammonia source and the second plasma is a plasma comprising a nitrogen source.
- 20) The method according to claim 18, wherein the first plasma is a plasma comprising a nitrogen source and the second plasma is a plasma comprising an ammonia source.
- 30 21) A stainless steel container housing a composition comprising at least one silicon precursor having one or two Si-C-Si linkages and selected from the group consisting of 1,1,1,3,3,3-hexachloro-2-methyl-1,3-disilapropane, 1,1,1,3,3,3-hexachloro-2,2-dimethyl-

1,3-disilapropane, 1,1,1,3,3-pentachloro-1,3-disilabutane, 1,1,1,3,3-pentachloro-2-methyl-1,3-disilabutane, 1,1,1,3,3-pentachloro-2,2-dimethyl-1,3-disilabutane, 1,1,1,3,3-pentachloro-2-ethyl-1,3-disilabutane, 1,1,1,3,3-pentachloro-1,3-disilapentane, 1,1,1,3,3-pentachloro-2-methyl-1,3-disilapentane, 1,1,1,3,3-pentachloro-2,2-dimethyl-1,3-disilapentane, 1,1,1,3,3-pentachloro-2-ethyl-1,3-disilapentane, 1,1,1,3,3,5,5-heptachloro-1,3,5-trisilahexane, 1,1,1,5,5-pentachloro-3,3-dimethyl-1,3,5-trisilahexane, 1,1,1,5,5-pentachloro-1,3,5-trisilahexane, and 2,2,4,6,6-pentachloro-4-methyl-2,4,6-trisilaheptane.

22) The stainless steel container of claim 21 further housing an inert head-space gas selected from the group consisting of helium, argon, nitrogen and combinations thereof.

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23) A silicon nitride or carbon-doped silicon nitride film suitable for semiconductor industry or display applications and deposited using the method of claim 1.

24) A silicon nitride or carbon-doped silicon nitride film suitable for semiconductor industry or display applications and deposited using the method of claim 18.

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