Claims

1. A method for forming a silicon nitride or carbon-doped silicon nitride film having a carbon content of 5 at. % or less is deposited using a plasma enhanced ALD process, the method comprising:

a) placing a substrate comprising a surface feature into a reactor;

b) heating the reactor to one or more temperatures ranging from ambient temperature to about 600°C and optionally maintaining the reactor at a pressure of 100 torr or less;

c) introducing into the reactor at least one silicon precursor having one Si-C-Si linkage selected from the group consisting of 1,1,1,3,3,3-hexachloro-1,3-disilapropane, 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, and 1,1,1,3,3,3-hexachloro-2-ethyl-1,3-disilapropane;

d) purging the reactor with an inert gas;

e) providing a plasma comprising an ammonia source into the reactor to form a silicon nitride or carbon-doped silicon nitride film;

f) purging the reactor with an inert gas; and

g) repeating steps c to f to provide a desired thickness of the silicon nitride or carbon-doped silicon nitride film.

2. The method according to claim 1, further comprising;

h) post-deposition treating the silicon nitride or carbon-doped silicon nitride film with a thermal anneal or a spike anneal at temperatures from 400 to 1000°C or a UV light source exposure; wherein the UV light source exposure step can be carried out either during film deposition, or once deposition has been completed, and/or

i) post-deposition exposing the silicon nitride or carbon-doped silicon nitride film to a plasma comprising hydrogen or inert gas or nitrogen to improve at least one of the film's physical properties.

3. The method according to claim 1 further comprising:

treating the silicon nitride or carbon-doped 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:

exposing the silicon nitride or carbon-doped silicon nitride film to a UV light source either during or after deposition of the silicon nitride or carbon-doped silicon nitride film.

5. The method according to claim 1 further comprising:

exposing the silicon nitride or carbon-doped silicon nitride film to a plasma comprising hydrogen or inert gas or nitrogen.

6. The method according to claim 1 further comprising:

treating the silicon nitride or carbon-doped silicon nitride film with an oxygen source at one or more temperatures ranging from ambient temperature to 1000°C to convert the silicon nitride or carbon-doped silicon nitride into a silicon oxynitride film or a carbon-doped silicon oxynitride film, either in situ or in a separate chamber from the reactor.

7. The method according to claim 1, wherein the silicon nitride film has a carbon content of 3 atomic percent or less as measured by X-ray photoelectron spectroscopy.

8. The method according to claim 7, wherein the silicon nitride film has a carbon content of 2 atomic percent or less as measured by X-ray photoelectron spectroscopy.

9. The method according to claim 8, wherein the silicon nitride film has a carbon content of 1 atomic percent or less as measured by X-ray photoelectron spectroscopy.

10. The method of claim 1 further comprising performing a thermal anneal on the

silicon nitride film or the carbon doped silicon nitride film at temperatures from 300 °C to 1000 °C.

11. The method of claim 1 further comprising performing a plasma treatment on the silicon nitride film or the carbon doped silicon nitride film with an inert gas plasma or hydrogen/inert plasma, or nitrogen plasma at a temperature ranging between 25°C and 600°C.

12. The method of claim 6 further comprising performing a plasma treatment on the silicon oxynitride film or the carbon-doped silicon oxynitride film with an inert gas plasma or hydrogen/inert plasma, or nitrogen plasma at a temperature ranging between 25°C and 600°C.

13. The method of claim 1 further comprising:

f-1) providing a plasma comprising a nitrogen source into the reactor to further form the silicon nitride or carbon-doped silicon nitride film; and

f-2) purging the reactor with an inert gas,

wherein the step g) of repeating steps c to f further includes repeating steps f-1 and f-2 such that steps c to f-2 are repeated to bring the silicon nitride or carbon-doped silicon nitride film to a predetermined thickness.

14. The method according to claim 1, wherein the at least one silicon precursor having one Si-C-Si linkage is 1,1,1,3,3,3-hexachloro-2-methyl-1,3-disilapropane.

15. The method according to claim, wherein the silicon nitride film has an oxygen content of 5 at. % or less, and a carbon content of 5 at. % or less as measured by X-ray photoelectron spectroscopy.