

CLAIMS

What is claimed is:

1. A method of depositing a film on a substrate, comprising:
 - forming a silicon nitride film over a surface of the substrate in a first processing volume with a deposition process; and
 - treating the film in a second processing volume, wherein treating the film comprises exposing the film to a plasma induced by a modular high-frequency plasma source, wherein a sheath potential of the plasma is less than 100 V, and wherein a power density of the high-frequency plasma source is approximately 5 W/cm² or greater.
2. The method of claim 1, wherein the first deposition process comprises chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), atomic layer deposition (ALD), or plasma enhanced ALD (PEALD).
3. The method of claim 1, wherein the deposition process comprises:
 - depositing a film comprising silicon onto the surface of the substrate;
 - an in-situ plasma treatment of the film comprising silicon, wherein the plasma treatment includes a plasma comprising nitrogen and helium to form the silicon nitride film; and
 - a pulsed plasma etch.

4. The method of claim 1, wherein the first processing volume and the second processing volume are in the same tool.
5. The method of claim 1, wherein the first processing volume and the second processing volume are in different tools.
6. The method of claim 1, further comprising:

sequentially repeating the operations of forming the silicon nitride film over the surface of the substrate in the first processing volume and treating the silicon nitride film in a second processing volume until a desired film thickness is obtained.
7. The method of claim 6, wherein each iteration of forming the silicon nitride film over the surface of the substrate increases a thickness of the silicon nitride film by less than approximately 1 nm.
8. The method of claim 6, wherein the desired film thickness is 50 nm or less.
9. The method of claim 1, wherein the substrate is a patterned substrate.

10. The method of claim 1, wherein the substrate is an unpatterned substrate.
11. The method of claim 1, wherein the modular high-frequency plasma source comprises:
 - a plurality of high-frequency plasma source modules, wherein each high-frequency plasma source module, comprises:
 - an oscillator module, wherein the oscillator module comprises:
 - a voltage control circuit; and
 - a voltage controlled oscillator;
 - an amplification module, wherein the amplification module is coupled to the oscillator module; and
 - an applicator, wherein the applicator is coupled to the amplification module.
12. The method of claim 11, wherein the high-frequency is 0.1 MHz to 300 GHz.

1313. A method of depositing a film on a substrate, comprising:

_____ depositing a film comprising silicon over a surface of the substrate in a first processing volume;

_____ treating the film with a first plasma process, wherein the first plasma process is an

RF induced plasma comprising nitrogen and helium to form a silicon nitride film;
_____ exposing the silicon nitride film to a second plasma process, wherein the second
plasma process is an RF induced plasma comprising species suitable for etching the
silicon nitride film; and
_____ treating the silicon nitride film with a third plasma process in a second processing
volume, wherein the third plasma process comprises a plasma induced by a modular
high-frequency plasma source.

14. The method of claim 13, wherein the film comprising silicon is deposited with chemical
vapor deposition (CVD), plasma enhanced CVD (PECVD), atomic layer deposition
(ALD), or plasma enhanced ALD (PEALD).

15. The method of claim 13, wherein the method is repeated a plurality of times to provide a
film with a desired thickness.

16. The method of claim 13, wherein the modular microwave plasma source comprises:
_____ a plurality of high-frequency plasma source modules, wherein each high-
frequency plasma source module, comprises:
_____ an oscillator module, wherein the oscillator module comprises:
_____ a voltage control circuit; and
_____ a voltage controlled oscillator;

an amplification module, wherein the amplification module is coupled to the oscillator module; and

an applicator, wherein the applicator is coupled to the amplification module.

17. A method of forming a high quality silicon nitride film, comprising:

(a) depositing a film comprising silicon over a surface of a substrate with a plasma enhanced chemical vapor deposition (PECVD) process in a first processing volume;

(b) treating the film comprising silicon in-situ with a first RF plasma, wherein the first RF plasma comprises nitrogen and helium to form a silicon nitride film;

(c) etching the silicon nitride with a second RF plasma, wherein the second RF plasma comprises one or more of fluorine, chlorine, nitrogen, and carbon; and

(d) treating the silicon nitride film with a microwave plasma, wherein the microwave plasma is induced by a modular microwave plasma source.

1418. The method of claim 1317, wherein one or more of operations (a), (b), (c), and (d) are repeated a plurality of times.

1519. The method of claim 1317, wherein one or more of operations (a), (b), and (c) may be repeated a plurality of times before operation (d) is implemented.

20. The method of claim 17, wherein the modular microwave plasma source comprises:
a plurality of microwave plasma source modules, wherein each microwave
plasma source module, comprises:
an oscillator module, wherein the oscillator module comprises:
a voltage control circuit; and
a voltage controlled oscillator;
an amplification module, wherein the amplification module is coupled to
the oscillator module; and
an applicator, wherein the applicator is coupled to the amplification
module.