CLAIMS

1. An apparatus for processing substrates, the apparatus comprising:

one or more process chambers, each process chamber comprising a chuck;

one or more gas inlets into the process chambers and associated flow-control hardware; and

a controller having at least one processor and a memory,

wherein the at least one processor and the memory are communicatively connected with one another,

the at least one processor is at least operatively connected with the flow-control hardware, and

the memory stores computer-executable instructions for controlling the at least one processor to at least control the flow-control hardware to:

cause introduction of a first reactant in vapor phase to the one or more process chambers from the one or more gas inlets;

cause introduction of a second reactant in vapor phase to the one or more chambers from the one or more gas inlets;

cause stopping of the introduction of the first reactant; cause stopping of the introduction of the second reactant; and

after causing stopping of the introduction of the first reactant and stopping of the introduction of the second reactant, cause generation of a plasma using a combination of an inert gas and an additional gas at a flow rate ratio between the inert gas and the additional gas of between ~~about~~ 50:1 and ~~about~~ 1:1.

2. The apparatus of claim 1, wherein the controller comprises instructions to cause introduction of the inert gas and the additional gas after causing stopping of the introduction of the first reactant and stopping of the introduction of the second reactant, without breaking vacuum from causing introduction of the first reactant in vapor phase to the one or more process chambers from the one or more gas inlets and causing introduction of the second reactant in vapor phase to the one or more process chambers from the one or more gas inlets.

3. An apparatus for processing substrates, the apparatus comprising:

one or more process chambers, each process chamber comprising a chuck;

one or more gas inlets into the process chambers and associated flow-control hardware; and

a controller having at least one processor and a memory,

wherein the at least one processor and the memory are communicatively connected with one another,

the at least one processor is at least operatively connected with the flow-control hardware, and

the memory stores computer-executable instructions for controlling the at least one processor to at least control the flow-control hardware to:

cause introduction of a first reactant in vapor phase to the one or more process chambers from the one or more gas inlets;

cause introduction of a second reactant in vapor phase to the one or more chambers from the one or more gas inlets;

cause stopping of the introduction of the first reactant; cause stopping of the introduction of the second reactant; and

after causing stopping of the introduction of the first reactant and stopping of the introduction of the second reactant, cause generation of a plasma using a combination of an inert gas and an additional gas at a flow rate ratio between the inert gas and the additional gas of between ~~about~~ 10:1 and ~~about~~ 20:1.

4. The apparatus of claim 3, wherein the controller comprises instructions to cause introduction of the inert gas and the additional gas after causing stopping of the introduction of the first reactant and stopping of the introduction of the second reactant, without breaking vacuum from causing introduction of the first reactant in vapor phase to the one or more process chambers from the one or more gas inlets and causing introduction of the second reactant in vapor phase to the one or more process chambers from the one or more gas inlets.

5. The apparatus of any of claims 1 and 3, wherein the one or more process chambers comprise four process chambers and wherein the controller comprises instructions for generation of the plasma using a plasma power between ~~about~~ 3000W and ~~about~~ 6500W.

6. A method for processing substrates, the method comprising:

providing a semiconductor substrate to a reaction chamber;

performing cycles of atomic layer deposition to deposit a film, each cycle comprising:

introducing a first reactant in vapor phase into the reaction chamber to adsorb the first reactant onto a surface of the semiconductor substrate;

introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and

generating a first plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber; and

after every n cycles of the atomic layer deposition, exposing the film to a second plasma generated from flowing argon and a second gas,

wherein either

(1) the second gas is selected from the group consisting of hydrogen, oxygen, and combinations thereof and a ratio of flow rate of argon to the second gas is between ~~about~~ 50:1 and ~~about~~ 1:1, or

(2) the second gas is nitrous oxide and a ratio of flow rate of argon to the second gas is between ~~about~~ 10:1 and ~~about~~ 20:1.

7. The method of claim 6, further comprising flowing one or more additional gases during the exposing of the film to the second plasma, the one or more additional gases selected from the group consisting of oxygen, nitrous oxide, and helium.

8. A method for processing substrates, the method comprising:

providing a semiconductor substrate to a reaction chamber;

performing cycles of atomic layer deposition to deposit a film, each cycle comprising:

introducing a first reactant in vapor phase into the reaction chamber to adsorb the first reactant onto a surface of the semiconductor substrate;

introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and

generating a first plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber; and

after every n cycles of the atomic layer deposition, exposing the film to a second plasma generated from flowing argon and a second gas having an argon to second gas flow rate ratio of between ~~about~~ 50:1 and ~~about~~ 1:1 to achieve a wet etch rate of less than ~~about~~ 40 A/min in 100:1 HF.

9. The method of claim 8, wherein the second gas is selected from the group consisting of hydrogen and oxygen and combinations thereof.

10. The method of claim 8, further comprising flowing a third gas during the exposing of the film to the second plasma, wherein the third gas is selected from the group consisting of nitrous oxide, helium, and combinations thereof.

11. The method of claim 10, wherein ratio of flow rate of argon to flow rate of the third gas is between ~~about~~ 10:1 and ~~about~~ 20:1.

12. The method of claim 6, wherein the second plasma is generated at a power between ~~about~~ 750W and ~~about~~ 1625W per substrate.

13. The method of any of claims 6-12, wherein the film comprises silicon oxide.

14. The method of claim 6, wherein exposing the deposited film to the second plasma further comprises introducing a mixture of argon and oxygen gas having a flow rate ratio of argon to oxygen gas is ~~about~~ 12:1.

~~15. A method for processing substrates, the method comprising:~~

~~providing a semiconductor substrate to a reaction chamber;~~

~~performing cycles of atomic layer deposition to deposit a film, each cycle comprising:~~

~~introducing a first reactant in vapor phase into the reaction chamber to adsorb the first reactant onto a surface of the semiconductor substrate;~~

~~introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and~~

~~generating a first plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber; and~~

~~after every n cycles of the atomic layer deposition, exposing the film to a second plasma generated using a power between about 1000W and about 2000W at a chamber pressure between about 1 Torr and about 10 Torr to reduce stress of the film to less than about -290 MPa to 55 MPa.~~

~~16. A method for processing substrates, the method comprising:~~

~~providing a semiconductor substrate to a reaction chamber;~~

~~performing n cycles of atomic layer deposition to deposit a film, each cycle comprising:~~

~~introducing a first reactant in vapor phase into the reaction chamber to adsorb the first reactant onto a surface of the semiconductor substrate;~~

~~introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and~~

~~generating a first plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber; and~~

~~after every n cycles of the atomic layer deposition, exposing the deposited film to a second plasma using a power between about 3000W and about 6500W at a~~

chamber pressure between about 1 Torr and about 5 Torr to reduce electrical leakage to less than about 1E-9 A/cm^2 at 2 MV field,.

17. A method for processing substrates, the method comprising:

providing a semiconductor substrate to a reaction chamber;

performing n cycles of atomic layer deposition to deposit a film, each cycle comprising:

introducing a first reactant in vapor phase into the reaction chamber to adsorb the first reactant onto a surface of the semiconductor substrate;

introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and

generating a first plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber; and

after every n cycles of the atomic layer deposition, exposing the deposited film to a second plasma using a power between about 3000W and about 6500W at a chamber pressure between about 1 Torr and about 5 Torr to yield a treated film, wherein the treated film has a breakdown voltage greater than 10 MV/cm.

18. A method for processing substrates, the method comprising:

providing a semiconductor substrate to a reaction chamber;

performing n cycles of atomic layer deposition to deposit a silicon-containing film, each cycle comprising:

introducing a first reactant in vapor phase into the reaction chamber to adsorb the first reactant onto a surface of the semiconductor substrate;

introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and

generating a first plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber;

after every n cycles of the atomic layer deposition, exposing the deposited silicon-containing film to a second plasma; and

introducing fluorine-containing reactive species to form a fluorine-terminated silicon surface.

19. A method for processing substrates, the method comprising:

providing a semiconductor substrate to a reaction chamber;

performing n cycles of atomic layer deposition to deposit a film, each cycle comprising:

introducing a first reactant in vapor phase into the reaction chamber under

~~conditions allowing the first reactant to adsorb onto a surface of the semiconductor substrate;~~

~~introducing a dose of a second reactant in vapor phase into the reaction chamber for a dose time; and~~

~~generating a plasma in the reaction chamber while the second reactant in vapor phase is in the reaction chamber; and~~

~~during the nth cycle of atomic layer deposition, introducing the dose of the second reactant for an extended dose time of at least 1.5 times longer than the dose time used for the first through (n-1)th cycles of atomic layer deposition.~~

~~20. The method of any of claims 15-19, wherein the film comprises silicon oxide.~~

~~21~~15. The method of any of claims 6-12~~ and 15-19~~, wherein the exposing of the film to the second plasma and the performing of the cycles of the atomic layer deposition are performed without breaking vacuum.

~~22~~16. The method of any of claims 6-12~~ and 15-19~~, wherein the exposing of the film to the second plasma comprises pulsing the second plasma.

~~23. The method of any of claims 15-19, wherein the first reactant is a silicon-containing precursor.~~

~~24. The method of any of claims 15-19, wherein the second reactant comprises one or more oxygen-containing gases.~~

~~25. The method of claim 24, wherein the oxygen-containing gas is selected from the group consisting of oxygen, nitrous oxide, water, carbon dioxide, and combinations thereof.~~

~~26. The method of any of claims 15-22, wherein n is an integer between and including 5 and 10.~~

~~27. The method of any of claims 15-19, wherein the second plasma is generated by igniting an inert gas.~~

~~28. The method of any of claims 15-19, wherein the second plasma is generated using a plasma density between about 0.4421 W/cm^2 and about 1.7684 W/cm^2.~~