CLAIMS

What is claimed is:

1. In a semiconductor processing apparatus including a process station, a method for forming a thin conformal film on a substrate positioned in the process station, the method comprising:

in a first phase:

generating precursor radicals off of a surface of the substrate by igniting a plasma using only an inert gas flow prior to introduction of a precursor flow to the plasma in the semiconductor processing apparatus, the plasma configured to crack the precursor molecules into precursor radicals, and then

adsorbing the precursor radicals to the surface to form surface active species, wherein the precursor flow comprises at least one of an orthosilicate, an alkoxysilane, an alkylsilane, a cyclic siloxane, and an alkynyl silane;

in a first purge phase, purging residual precursor from the process station;

in a second phase, supplying a reactive oxygen plasma to the surface, the reactive oxygen plasma being configured to react with the surface active species and generate the thin conformal film; and

in a second purge phase, purging residual reactant from the process station.

2. The method of claim 1, further comprising forming a substantially conformal layer of surface active species during the first phase.

3. The method of claim 1, wherein generating the precursor radicals further comprises generating precursor radicals in a gas phase with a high-frequency direct plasma.

4. The method of claim 1, further comprising adjusting a deposition rate for the thin conformal film by adjusting a duration of a high-frequency plasma during the first phase.

5. The method of claim 1, further comprising adjusting a deposition rate for the thin conformal film by adjusting a number of pulses of a high-frequency plasma during the first phase.

6. The method of claim 1, further comprising adjusting one or more of an electrical and a physical property of the thin conformal film by adjusting one or more of a plasma frequency and a plasma duration during the second phase.

7. The method of claim 1, wherein the second phase comprises generating the reactive oxygen plasma by using a high-frequency plasma and a low frequency plasma concurrently.

8. The method of claim 7, wherein generating the reactive oxygen plasma comprises pulsing the high-frequency plasma and the low-frequency plasma concurrently.

9. The method of claim 1, wherein the second phase comprises generating the reactive oxygen plasma by alternately pulsing a high-frequency plasma and a low frequency plasma.

10. The method of claim 1, further comprising, in a third phase, doping the thin conformal film with a dopant supplied by a doping plasma, wherein the doping plasma is generated with one or more of a high-frequency and a low-frequency plasma.

11. ~~A~~In a semiconductor processing apparatus including a process station, a method for forming a thin conformal film on a substrate positioned in the process station, the method, comprising:

~~a processing station;~~

~~a substrate holder disposed inside of the processing station, the substrate holder configured to support a substrate; and~~

~~a plasma source fluidly coupled to the processing station; and~~

~~a system controller configured to execute instructions held in memory, the instructions comprising:~~

in a first phase~~, instructions to~~:

~~generate~~generating precursor radicals ~~with a cracking plasma~~ off of a surface of the substrate from a precursor, and

~~supply~~adsorbing the precursor radicals to the surface~~, the precursor radicals forming a conformal layer of~~ to form surface active species ~~on the surface;~~ ;

in a first purge phase, ~~instructions to purge~~purging residual precursor from the process station;

in a second phase, ~~instructions to:~~

~~generate a reactive species with~~supplying a reactive plasma~~, and~~

~~supply the reactive species~~ to the surface ~~so that~~, the reactive ~~species~~plasma being configured to react with the surface active species~~, forming a conformal film layer;~~ and generate the thin conformal film, wherein the reactive plasma is generated by alternately pulsing a high-frequency plasma and a low frequency plasma; and

in a second purge phase, ~~instructions to purge~~purging residual reactant from the process station.

~~12. The semiconductor processing apparatus of claim 11, wherein the plasma source comprises a high-frequency direct plasma source and/or a low-frequency direct plasma source.~~

~~13. The semiconducting processing apparatus of claim 11, wherein the plasma source comprises one or more of a parallel plate plasma source, an inductively coupled plasma source, a helicon wave plasma source, an electron cyclotron resonance plasma source, a magnetron enhanced plasma source, and a direct current glow discharge plasma source.~~

~~14. The semiconducting process apparatus of claim 11, further comprising instructions to, in a third phase:~~

~~generate a doping plasma above the surface using one or more of a high-frequency plasma and a low frequency plasma, the doping plasma comprising a dopant; and~~

~~dope the conformal film layer with the dopant.~~

~~15~~12. A method of filling a through-silicon via in an integrated semiconductor device substrate, the through-silicon via comprising an opening in a first surface of the integrated semiconductor device substrate, a sidewall extending inwardly from the first surface, and a bottom, the method comprising:

generating precursor radicals off of a surface of the substrate by igniting a plasma using only an inert gas flow prior to introduction of a precursor flow to the plasma in the semiconductor processing apparatus, the plasma configured to crack the precursor molecules into precursor radicals, and then adsorbing the precursor radicals to the surface to form surface active species;

wherein the precursor flow comprises at least one of an orthosilicate, an alkoxysilane, an alkylsilane, a cyclic siloxane, and an alkynyl silane;

forming a thin conformal dielectric layer covering the sidewall and bottom of the through-silicon via, wherein forming the thin conformal dielectric layer comprises:

in a first phase, generating precursor radicals away from the substrate from a precursor, and adsorbing the precursor radicals on the sidewall and bottom of the through-silicon via,

in a first purge phase, purging residual precursor from the process station,

in a second phase, supplying a reactive oxygen plasma to the sidewall and bottom of the through-silicon via, the reactive oxygen plasma configured to react with the precursor radicals adsorbed on the sidewall and bottom of the through-silicon via, and

in a second purge phase, purging residual reactant from the process station; and

filling the through-silicon via with a conductive metal.

~~16~~13. The method of claim ~~15~~12, wherein forming the thin conformal dielectric layer further comprises depositing the thin conformal dielectric layer in a bottom corner of the through-silicon via so that a bottom corner thickness of the thin conformal dielectric layer

is at least approximately 10% of an open field thickness of the thin conformal dielectric layer, wherein the through-silicon via has an aspect ratio of at least approximately 10:1.

~~17~~14. The method of claim ~~15~~12, wherein the precursor radicals are generated from a precursor comprising tetraethyl orthosilicate.

~~18~~15. The method of claim ~~17~~14, wherein the reactive oxygen plasma comprises atomic oxygen radicals.

~~19~~16. The method of claim ~~18,~~ 15, wherein forming the thin conformal dielectric layer further comprises forming a thin conformal dielectric layer having a compressive stress of at least approximately -131 MPa and a refractive index of at least approximately 1.46.

~~20~~17. The method of claim ~~15~~12, wherein the first phase comprises using a high-frequency plasma to generate the precursor radicals, and wherein the second phase comprises using one or more of a high-frequency plasma and a low-frequency plasma to generate the reactive species.

18. The method of claim 1, wherein the precursor flow comprises tetraethyl orthosilicate.

~~21~~19. A method ~~of claim 1~~ for processing a substrate, the method ~~further~~ comprising:

applying photoresist to the substrate;

exposing the photoresist to light via a stepper;

patterning the resist with a pattern and transferring the pattern to the substrate; ~~and~~

selectively removing the photoresist from the substrate; and

placing the substrate into a process station of a semiconductor processing apparatus; and

the method further comprising, in the semiconductor processing apparatus, forming a thin conformal film on the substrate positioned in the process station by:

in a first phase:

generating precursor radicals off of a surface of the substrate from a precursor, and

adsorbing the precursor radicals to the surface to form surface active species;

in a first purge phase, purging residual precursor from the process station,

in a second phase, supplying a reactive plasma to the surface, the reactive plasma being configured to react with the surface active species and generate the thin conformal film, wherein the thin conformal film is selected from the group consisting of a silicon oxide film, a silicon nitride film, a silicon carbide film, and a silicon boride film, and

in a second purge phase, purging residual reactant from the process station.

~~22. A semiconductor processing system, comprising:~~

~~a stepper tool; and~~

~~a processing tool, comprising:~~

~~a processing station,~~

~~a substrate holder disposed inside of the processing station, the substrate holder configured to support the substrate,~~

~~a plasma source fluidly coupled to the processing station, and~~

~~a system controller configured to execute instructions held in memory, the instructions comprising:~~

~~in a first phase, instructions to:~~

~~generate precursor radicals with a cracking plasma off of a surface of the substrate, and~~

~~supply the precursor radicals to the surface, the precursor radicals forming a conformal layer of surface active species on the surface,~~

~~in a first purge phase, instructions to purge residual precursor from the process station,~~

~~in a second phase, instructions to:~~

~~generate a reactive species with a reactive plasma, and~~

~~supply the reactive species to the surface so that the reactive species react with the surface active species, forming a conformal film layer, and~~

~~in a second purge phase, instructions to purge residual reactant from the process station.~~

20. The method of claim 19, further comprising forming a substantially conformal layer of surface active species during the first phase.

21. The method of claim 19, wherein generating the precursor radicals further comprises generating precursor radicals in a gas phase with a high-frequency direct plasma.

22. The method of claim 19, further comprising adjusting a deposition rate for the thin conformal film by adjusting a duration of a high-frequency plasma during the first phase.

23. The method of claim 19, further comprising adjusting a deposition rate for the thin conformal film by adjusting a number of pulses of a high-frequency plasma during the first phase.

24. The method of claim 19, further comprising adjusting one or more of an electrical and a physical property of the thin conformal film by adjusting one or more of a plasma frequency and a plasma duration during the second phase.

25. The method of claim 19, wherein the second phase comprises generating the reactive plasma by using a high-frequency plasma and a low frequency plasma concurrently.

26. The method of claim 25, wherein generating the reactive plasma comprises pulsing the high-frequency plasma and the low-frequency plasma concurrently.

27. The method of claim 19, wherein the second phase comprises generating the reactive plasma by alternately pulsing a high-frequency plasma and a low frequency plasma.

28. The method of claim 19, further comprising, in a third phase, doping the thin conformal film with a dopant supplied by a doping plasma, wherein the doping plasma is generated with one or more of a high-frequency and a low-frequency plasma.

~~23~~29. A method of forming a through-silicon via in a substrate, the method comprising:

forming the through-silicon via, comprising:

applying a photoresist to the substrate,

exposing the photoresist to light,

patterning the resist with a pattern and transferring the pattern to the substrate, and

selectively removing the photoresist from the substrate; and

forming a thin conformal dielectric layer covering a sidewall and a bottom of the through silicon via, comprising:

in a first phase, generating precursor radicals away from the substrate from a precursor and adsorbing the precursor radicals on the sidewall and bottom of the through-silicon via,

in a first purge phase, purging residual precursor from the process station,

in a second phase, supplying a reactive plasma to the sidewall and bottom of the through-silicon via, the reactive plasma configured to react with the precursor radicals adsorbed on the sidewall and bottom of the through-silicon via and to form a thin conformal dielectric layer, wherein the thin conformal dielectric layer is selected from the group consisting of a silicon oxide film, a silicon nitride film, a silicon carbide film, and a silicon boride film, and

in a second purge phase, purging residual reactant from the process station.

30. The method of claim 29, wherein forming the thin conformal dielectric layer further comprises depositing the thin conformal dielectric layer in a bottom corner of the through-silicon via so that a bottom corner thickness of the thin conformal dielectric layer is at least approximately 10% of an open field thickness of the thin conformal dielectric layer, wherein the through-silicon via has an aspect ratio of at least approximately 10:1.

31. The method of claim 29, wherein the precursor radicals are generated from a precursor comprising tetraethyl orthosilicate.

32. The method of claim 29, wherein the reactive plasma comprises atomic oxygen radicals.

33. The method of claim 32, wherein forming the thin conformal dielectric layer further comprises forming a thin conformal dielectric layer having a compressive stress of at least approximately −131 MPa and a refractive index of at least approximately 1.46.

34. The method of claim 29, wherein the first phase comprises using a high-frequency plasma to generate the precursor radicals, and wherein the second phase comprises using one or more of a high-frequency plasma and a low-frequency plasma to generate the reactive species.

35. A method for processing a substrate, the method comprising:
applying photoresist to the substrate;
exposing the photoresist to light via a stepper;
patterning the resist with a pattern and transferring the pattern to the substrate;
selectively removing the photoresist from the substrate; and
placing the substrate into a process station of a semiconductor processing apparatus; and
the method further comprising, in the semiconductor processing apparatus, forming a thin conformal film on the substrate positioned in the process station, by :
in a first phase:

generating precursor radicals off of a surface of the substrate from a precursor, and

adsorbing the precursor radicals to the surface to form surface active species,

in a first purge phase, purging residual precursor from the process station,

in a second phase, supplying a reactive plasma to the surface, the reactive plasma being configured to react with the surface active species and generate the thin conformal film, wherein the second phase comprises generating the reactive plasma by alternately pulsing a high-frequency plasma and a low frequency plasma, and

in a second purge phase, purging residual reactant from the process station.

36. In a semiconductor processing apparatus including a process station, a method for forming a thin conformal film on a substrate positioned in the process station, the method comprising:

in a first phase:

generating precursor radicals off of a surface of the substrate from a precursor, and

adsorbing the precursor radicals to the surface to form surface active species,

in a first purge phase, purging residual precursor from the process station,

in a second phase, supplying a reactive plasma to the surface, the reactive plasma being configured to react with the surface active species and generate the thin conformal film, wherein the thin conformal film is selected from the group consisting of a silicon oxide film, a silicon nitride film, a silicon carbide film, and a silicon boride film, and

in a second purge phase, purging residual reactant from the process station.