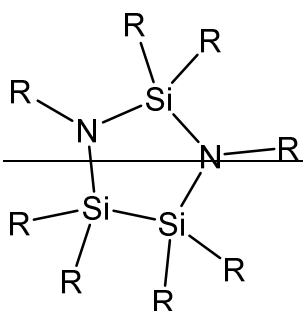
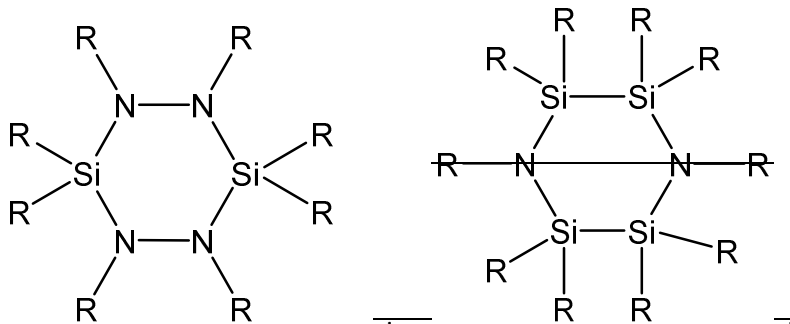


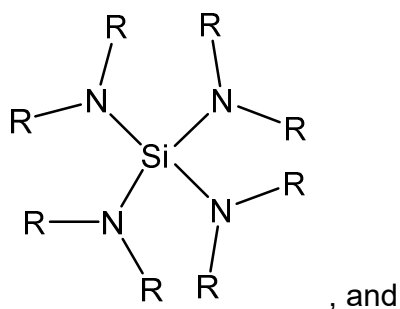
What is claimed is:

Claims

1. A method for depositing a silicon nitride film, comprising:
introducing a silicon-nitrogen precursor and a plasma-activated co-reactant into a processing chamber;
producing a plasma within the processing chamber;
reacting the silicon-nitrogen precursor and the plasma-activated co-reactant in the plasma to produce a flowable silicon nitride material on a substrate within the processing chamber; and
treating the flowable silicon nitride material to produce a solid silicon nitride material on the substrate,
wherein the silicon-nitrogen precursor is selected from the group consisting of:
a cyclic aminosilane having a N/Si atomic ratio of greater than 1 and the chemical formula of:



an aminosilane having a N/Si atomic ratio of 4 or greater
and the chemical formula of:



any combination thereof, wherein each R is independently selected from H, an alkyl, an aryl, an amino, a silyl, an isocyanate, an isothiocyanate, isomers thereof, or salts thereof, or any two R groups are joined to form a cyclic group.

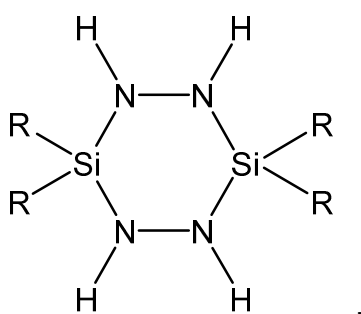
2. The method of claim 1, wherein:

each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, NR'₂, SiH_x, N=C=S, N=C=O, or isomers thereof, or any two R groups are joined to form a cyclic group;

each R' is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, or isomers thereof; and

x is an integer of 1, 2, or 3.

3. The method of claim 1, wherein the silicon-nitrogen precursor is:

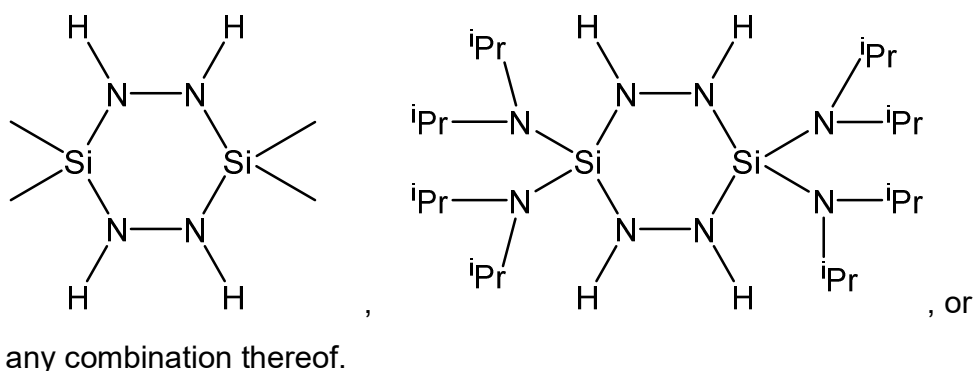


wherein:

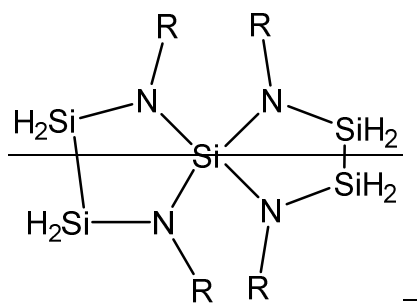
each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, NR'₂, or isomers thereof; and

each R' is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, or isomers thereof.

4. The method of claim 3, wherein the silicon-nitrogen precursor is:



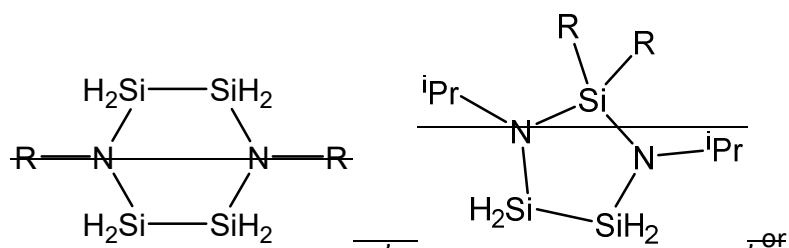
5. The method of claim 1, wherein the silicon-nitrogen precursor is:



wherein

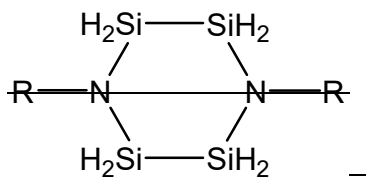
~~each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, NR₂, or isomers thereof; and~~
~~each R' is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, or isomers thereof.~~

6. The method of claim 1, wherein the silicon-nitrogen precursor is:



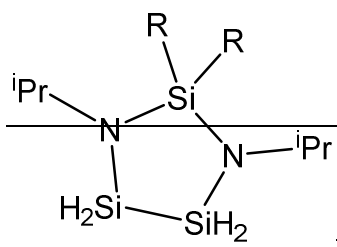
wherein each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, Ph, CH₂-Ph, or isomers thereof.

7. The method of claim 6, wherein the silicon-nitrogen precursor is:



wherein each R is independently selected from ⁱPr, ^tBu, or CH₂-Ph.

8. The method of claim 6, wherein the silicon-nitrogen precursor is:



wherein each R is independently selected from CH₃ or Ph.

9. The method of claim 1, wherein the plasma-activated co-reactant comprises ammonia, oxygen (O₂), or a combination of ammonia and oxygen.

6. The method of claim 5, wherein the plasma-activated co-reactant further comprises argon, helium, nitrogen (N₂), hydrogen (H₂), or any combination thereof, and wherein the silicon-nitrogen precursor has an N/Si atomic ratio of about 0.67 to about 5.

107. The method of claim 1, wherein the silicon-nitrogen precursor comprises the cyclic aminosilane and has an N/Si atomic ratio of about 1.2 to about 5.

8. The method of claim 1, further comprising:
at least partially filling a trench formed in the substrate with the flowable silicon nitride material; and
curing the flowable silicon nitride material to produce the solid silicon nitride material in the trench.

~~11~~9. The method of claim ~~10~~8, wherein the flowable silicon nitride material has a thickness of about 10 Å to about 500 Å when curing the flowable silicon nitride material to produce the solid silicon nitride material in the trench.

~~12~~10. The method of claim ~~11~~9, further comprising sequentially repeating the at least partially filling the trench with the flowable silicon nitride material and the curing the flowable silicon nitride material to produce the solid silicon nitride material in the trench at least 1 time to about 20 times.

11. The method of claim 10, wherein the silicon nitride film comprises a plurality of layers of the solid silicon nitride material sequentially formed on one another, and wherein the silicon nitride film has a thickness of about 50 Å to about 500 Å.

~~13~~12. The method of claim 1, further comprising:
depositing the flowable silicon nitride material as a layer on the substrate;
treating the layer comprising the flowable silicon nitride material to produce a layer of the solid silicon nitride material; and
repeating the depositing and treating to produce the silicon nitride film comprising a plurality of the layers of the solid silicon nitride material sequentially formed on one another.

~~14. — A method for depositing a silicon nitride film, comprising:~~

13. The method of claim 1, wherein the treating the flowable silicon nitride material to produce the solid silicon nitride material, further comprises exposing the flowable silicon

nitride material to a thermal annealing process, a plasma annealing process, or a UV annealing process.

14. The method of claim 1, wherein the silicon-nitrogen precursor comprises the cyclic aminosilane and has an N/Si atomic ratio of about 2 to about 4.

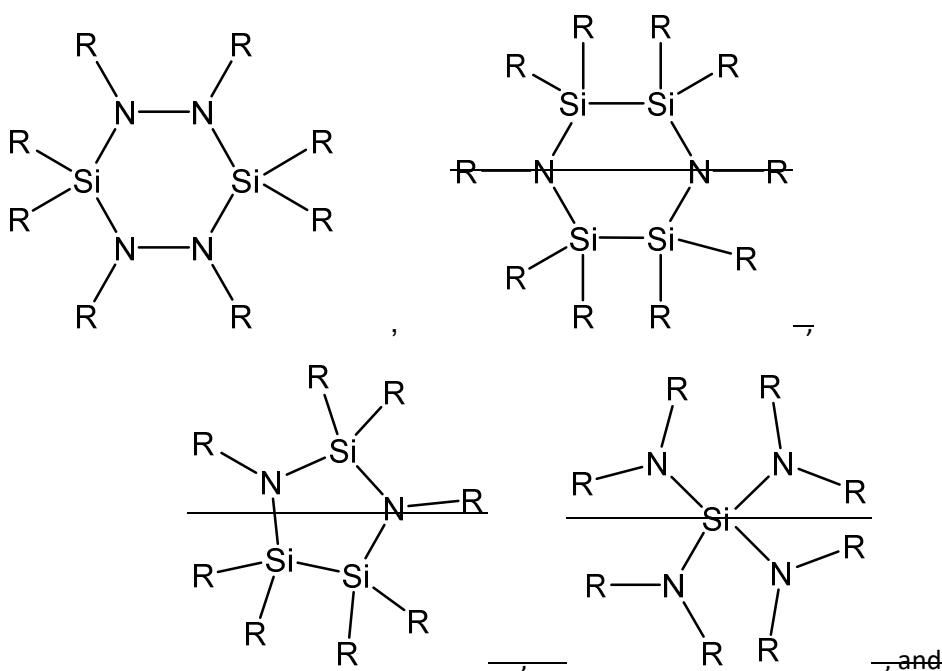
15. A method for depositing a silicon nitride film, comprising:

exposing a substrate to a silicon-nitrogen precursor, a plasma-activated co-reactant, and a plasma within a processing chamber to produce a flowable silicon nitride material on the substrate; and

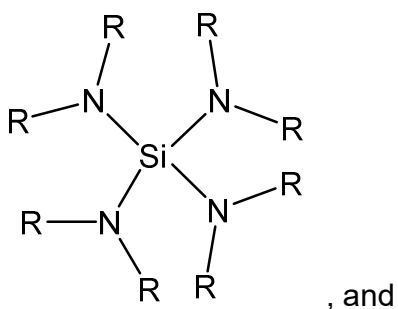
treating the flowable silicon nitride material to produce a solid silicon nitride material on the substrate,

wherein the silicon-nitrogen precursor is selected from the group consisting of:

a cyclic aminosilane having a N/Si atomic ratio of greater than 1 and the chemical formula of:

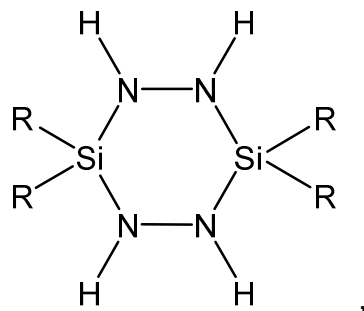


an aminosilane having a N/Si atomic ratio of 4 or greater and the chemical formula of:



any combination thereof, wherein each R is independently selected from H, an alkyl, an aryl, an amino, a silyl, an isocyanate, an isothiocyanate, isomers thereof, or salts thereof, or any two R groups are joined to form a cyclic group.

16. The method of claim 15, wherein the silicon-nitrogen precursor is:



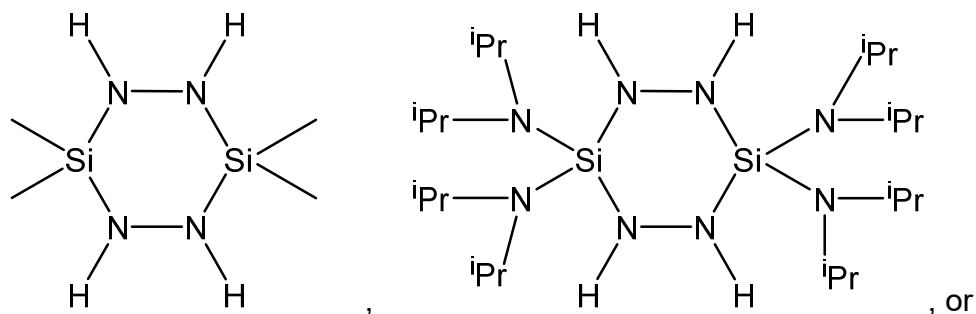
wherein:

each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉,

NR'₂, or isomers thereof; and

each R' is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, or isomers thereof.

17. The method of claim 16, wherein the silicon-nitrogen precursor is:



any combination thereof.

18. A method for depositing a silicon nitride film, comprising:

~~15. A method for depositing a silicon nitride film, comprising:~~

introducing a silicon-nitrogen precursor and a plasma-activated co-reactant into a processing chamber;

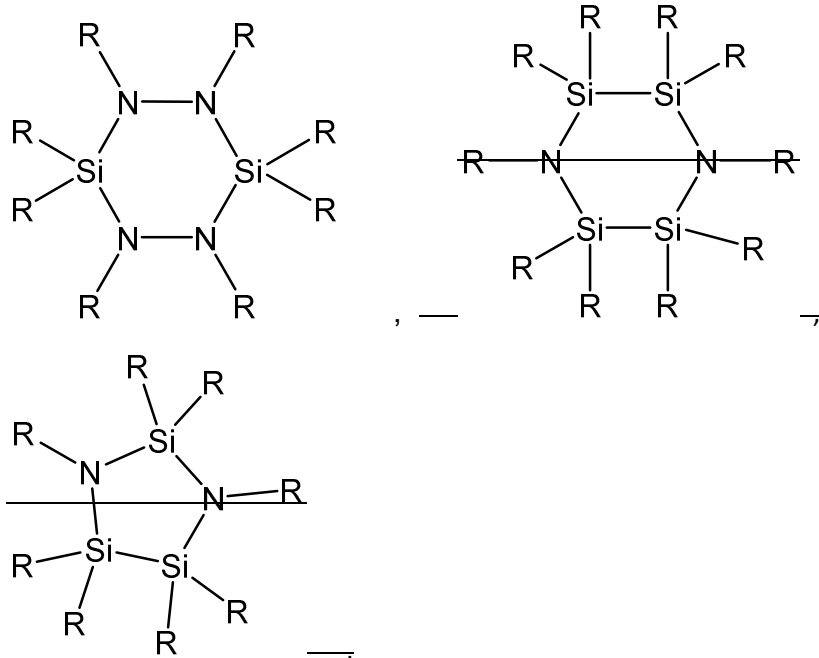
reacting the silicon-nitrogen precursor and the plasma-activated co-reactant with a plasma to produce a flowable silicon nitride material on a substrate within the processing chamber;

at least partially filling a trench formed in the substrate with the flowable silicon nitride material; and

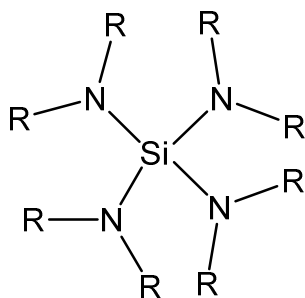
treating the flowable silicon nitride material to produce a solid silicon nitride material in the trench,

wherein the silicon-nitrogen precursor is selected from the group consisting of:

a cyclic aminosilane having a N/Si atomic ratio of greater than 1 and the chemical formula of:



an aminosilane having a N/Si atomic ratio of 4 or greater and the chemical formula



of:

, and

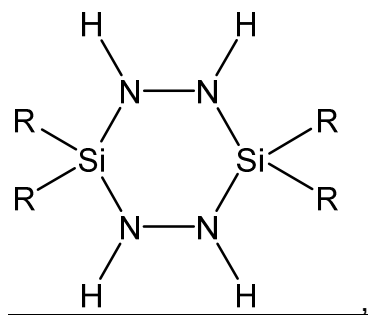
any combination thereof, wherein:

each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, NR'₂, SiH_x, N=C=S, N=C=O, or isomers thereof, or any two R groups are joined to form a cyclic group;

each R' is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, or isomers thereof; and

x is an integer of 1, 2, or 3.

19. The method of claim 18, wherein the silicon-nitrogen precursor is:



wherein:

each R is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, NR'₂, or isomers thereof; and

each R' is independently selected from H, CH₃, C₂H₅, C₃H₇, C₄H₉, or isomers thereof.

20. The method of claim 19, wherein the silicon-nitrogen precursor is:

