CLAIMS

1. A method for depositing a silicon-containing film, the method comprising:

placing a substrate comprising at least one surface feature into a reactor;

introducing into the reactor at least one organoaminosilane compound having the structure of Formula I:

$$(R^1R^2N)_{4-n}Si\text{-}R^3_n \quad (I),$$

wherein R^1, R^2 and R^3 are selected from the group consisting of hydrogen, C_1 to C_{10} linear or branched alkyl, cyclic alkyl, alkenyl, alkynyl, and aryl; and n=0, 1, 2, 3, wherein at least one of R^1, R^2 and R^3 is not hydrogen; and at least one multifunctional organoamine compound having the structure of Formula II:

$$NR^4R^5R^6 \quad (II)$$

wherein R_4, R_5 and R_6 are each independently selected from the group consisting of H, a C_1-C_4 alkylmonoamino group, a C_1-C_4 alkyldiamino group, and a C_1-C_4 alkyltriamino group, wherein at least one of R^4, R^5 and R^6 is not hydrogen; and

at least partially reacting the at least one organoaminosilane compound and the multifunctional organoamine compound, optionally in the presence of an energy source, to form a flowable liquid oligomer wherein the flowable liquid oligomer forms a coating on the substrate and at least partially fills at least a portion of the at least one surface feature.

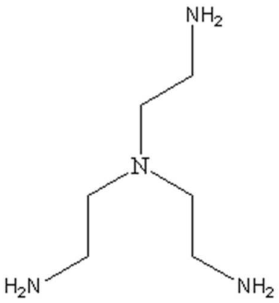
2. A method for depositing a silicon-containing film, the method comprising:

placing a substrate comprising at least one surface feature into a reactor;

introducing into the reactor at least one organoaminosilane compound having the structure of Formula I:

$$(R^1R^2N)_{4-n}Si\text{-}R^3_n \quad (I),$$

wherein R^1, R^2 and R^3 are selected from the group consisting of hydrogen, C_1 to C_{10} linear or branched alkyl, cyclic alkyl, alkenyl, alkynyl, and aryl; and n=0, 1, 2, 3, wherein at least one of R^1, R^2 and R^3 is not hydrogen; and at least one multifunctional organoamine compound selected from the group consisting of:



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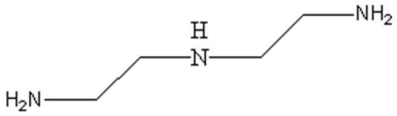

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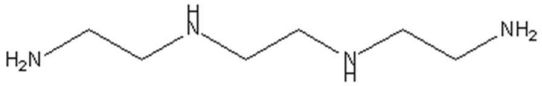

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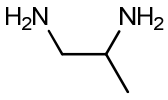

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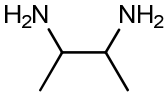

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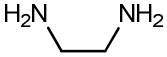

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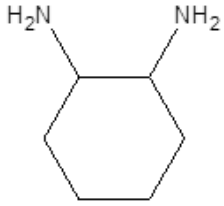

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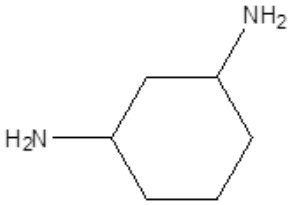

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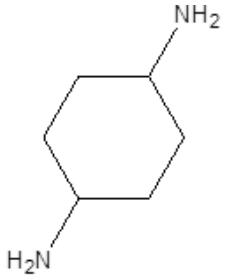

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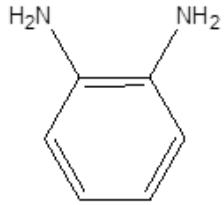

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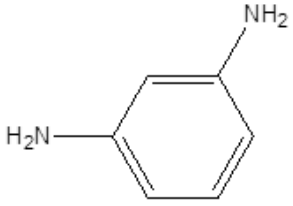

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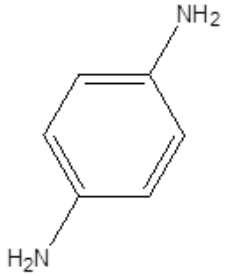


1,4-benzenediamine .

; and

at least partially reacting the at least one organoaminosilane compound and the multifunctional organoamine compound, optionally in the presence of an energy source, to form a flowable liquid oligomer wherein the flowable liquid oligomer forms a coating on the substrate and at least partially fills at least a portion of the at least one surface feature.

3. The method of claim 1 or claim 2 wherein the energy source is present.

4. The method of claim 3 wherein the energy source is heat.

5. The method of claim 3 wherein the energy source is plasma.

6. The method of claim 5 wherein the plasma is selected from the group consisting of a nitrogen plasma, a plasma comprising nitrogen and helium, a plasma comprising nitrogen and argon, an ammonia plasma, a plasma comprising ammonia and helium, a

plasma comprising ammonia and argon, helium plasma, argon plasma, hydrogen plasma, a plasma comprising hydrogen and helium, a plasma comprising hydrogen and argon, a plasma comprising ammonia and hydrogen, an organic amine plasma, a plasma comprising oxygen, a plasma comprising oxygen and hydrogen, and mixtures thereof.

7. The method of claim 5 wherein the plasma is selected from the group consisting of a carbon plasma or a hydrocarbon plasma, a plasma comprising hydrocarbon and helium, a plasma comprising hydrocarbon and argon, a carbon dioxide plasma, a carbon monoxide plasma, a plasma comprising a hydrocarbon and hydrogen, a plasma comprising a hydrocarbon and nitrogen, a plasma comprising hydrocarbon and oxygen, and mixture thereof.

8. The method of claim 1 or claim 2 further comprising the step of subjecting the coating to a thermal treatment at one or more temperatures between 100 °C to 1000 °C to densify at least a portion of the coating and form a hardened layer.

9. The method of claim 8 further comprising the step of exposing the hardened layer to energy selected from the group consisting of a plasma, infrared light, chemical treatment, an electron beam, or UV light to form the final silicon-containing film.

10. The method of claim 9 wherein the above steps define one cycle for the method and the cycle can be repeated until the desired thickness of the silicon-containing film is obtained.

11. The method of claim 1 or claim 2 wherein the at least one organoaminosilane compound having the structure of Formula (I) is selected from the group consisting of Bis(tertiarybutylamino)silane (BTBAS), di-isopropylaminosilane (DIPAS), tris-n-propylaminosilane, tetrakis-n-propylaminosilane, and tris-isopropylaminosilane.

12. The method of claim 1 or claim 2 wherein the multifunctional organoamine compound is ethylenediamine.

13. The method of claim 12 wherein the at least one organoaminosilane compound is BTBAS.

14. The method of claim 12 wherein the at least one organoaminosilane compound is DIPAS.

15. The method of claim 12 wherein the at least one organoaminosilane compound is tetrakis-n-propylaminosilane.

16. The method of claim 12 wherein the at least one organoaminosilane compound is tris-isopropylaminosilane.

17. The method of claim 1 or claim 2 wherein the silicon-containing film is selected from the group consisting of a silicon nitride, a silicon carbide, and a carbon-doped silicon nitride.

18. The method of claim 1 or claim 2 wherein the at least one surface feature is selected from the group consisting of pores, trenches, shallow trench isolation (STI), vias, and reentrant features.

19. The method of claim 18 wherein the at least one surface feature has a width of 100 µm or less.

20. The method of claim 19 wherein the at least one surface feature has a width of 1 µm or less.

21. The method of claim 20 wherein the at least one surface feature has a width of 0.5 µm or less.

22. The method of claim 21 wherein the at least one surface feature has a width of 50 nm or less.

23. The method of claim 18 wherein the at least one surface feature has an aspect ratio of 0.1:1 or greater.

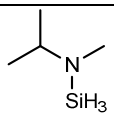
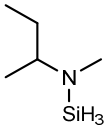
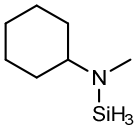
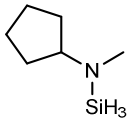
24. The method of claim 23 wherein the at least one surface feature has an aspect ratio of 1:1 or greater.

25. The method of claim 24 wherein the at least one surface feature has an aspect ratio of 10:1 or greater.

26. The method of claim 25 wherein the at least one surface feature has an aspect ratio of 20:1 or greater.

27. The method of claim 26 wherein the at least one surface feature has an aspect ratio of 40:1 or greater.

28. The method of claim 1 or claim 2 wherein the at least one organoaminosilane compound having the structure of Formula (I) is selected from the group consisting of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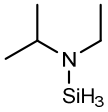	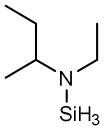	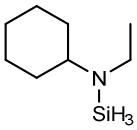	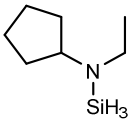
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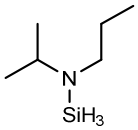	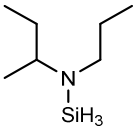	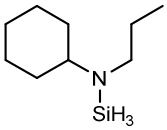	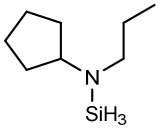
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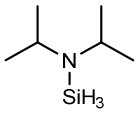	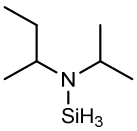	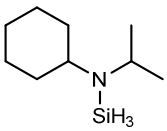	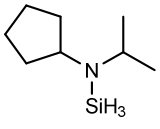

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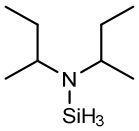
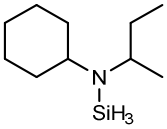
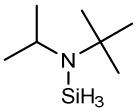
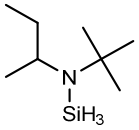
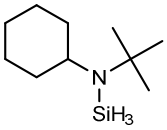
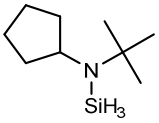
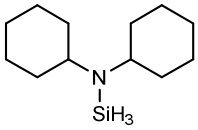
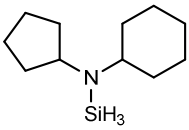
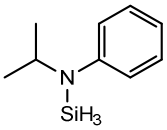
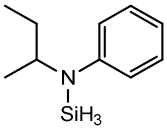
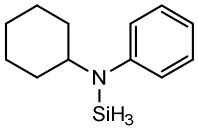
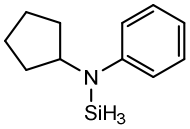
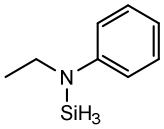
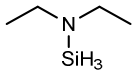
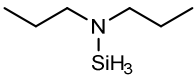
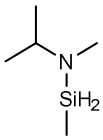
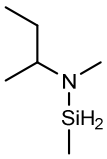
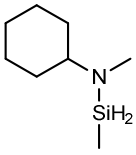
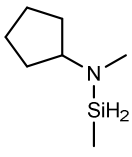
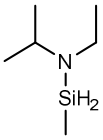
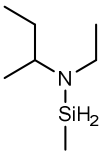
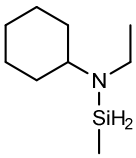
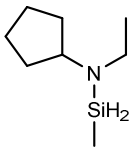
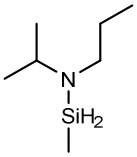
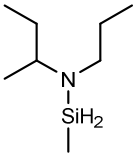
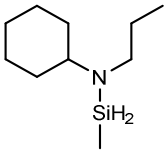
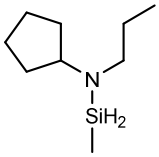
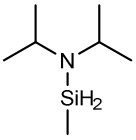
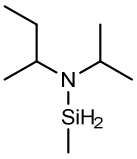
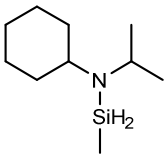
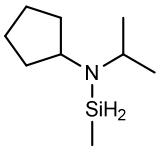
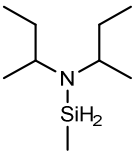
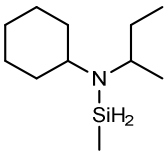
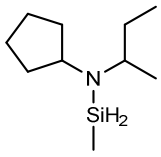
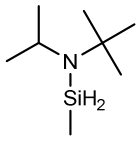
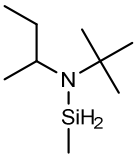
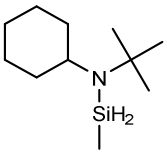
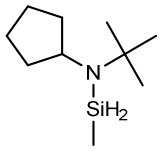
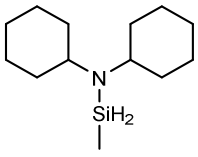
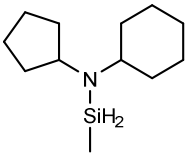
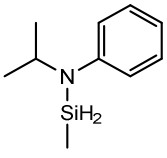
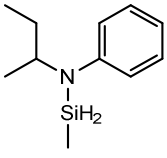
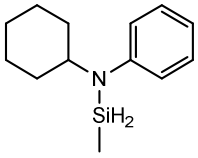
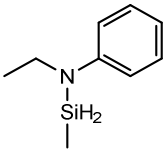
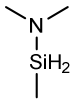
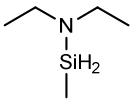
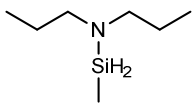
 N,N-di-sec-butylaminosilane,	 N-sec-butyl-N-cyclohexylaminosilane,	 N-sec-butyl-N-cyclopentylaminosilane,	 N-tertbutyl-N-iso-propylaminosilane,
 N-sec-butyl-N-tert-butylaminosilane,	 N-tert-butyl-N-cyclohexylaminosilane,	 N-tert-butyl-N-cyclopentylaminosilane,	 N,N-dicyclohexylaminosilane,
 N-cyclohexyl-N-cyclopentylaminosilane,	 N-phenyl-N-iso-propylaminosilane,	 N-sec-butyl-N-phenylaminosilane,	 N-cyclohexyl-N-phenylaminosilane,
 N-cyclopentyl-N-phenylaminosilane ,	 N-ethyl-N-phenylaminosilane,	 N,N-dimethylaminosilane,	 N,N-diethylaminosilane, and
 N,N-di-n-propylaminosilane.			

29. The method of claim 1 or claim 2 wherein the at least one organoaminosilane compound having the structure of Formula (I) is an organoaminocarbosilane selected from the group consisting of

 N-methyl-N-iso-propylamino-methylsilane,	 N-sec-butyl-N-methylamino-methylsilane,	 N-cyclohexyl-N-methylamino-methylsilane,	 N-methyl-N-cyclopentylamino-methylsilane,

 N-ethyl-N-iso-propylamino-methylsilane,	 N-sec-butyl-N-ethylamino-methylsilane,	 N-ethyl-N-cyclohexylamino-methylsilane,	 N-ethyl-N-cyclopentylamino-methylsilane,
 N-n-propyl-N-iso-propylamino-methylsilane,	 N-sec-butyl-N-n-propylamino-methylsilane,	 N-cyclohexyl-N-n-propylamino-methylsilane,	 N-cyclopentyl-N-n-propylamino-methylsilane,
 N,N-di-iso-propylamino-methylsilane,	 N-sec-butyl-N-iso-propylamino-methylsilane,	 N-cyclohexyl-N-iso-propylamino-methylsilane,	 N-cyclopentyl-N-iso-propylamino-methylsilane,
 N,N-di-sec-butylamino-methylsilane,	 N-sec-butyl-N-cyclohexylamino-methylsilane,	 N-sec-butyl-N-cyclopentylamino-methylsilane,	 N-tert-butyl-N-iso-propylamino-methylsilane,
 N-sec-butyl-N-tert-butylamino-methylsilane,	 N-tert-butyl-N-cyclohexylamino-methylsilane,	 N-tert-butyl-N-cyclopentylamino-methylsilane,	 N,N-dicyclohexylamino-methylsilane,
 N-cyclohexyl-N-cyclopentylamino-methylsilane,	 N-phenyl-N-iso-propylamino-methylsilane,	 N-sec-butyl-N-phenylamino-methylsilane,	 N-cyclohexyl-N-phenylamino-methylsilane,
			

N-cyclopentyl-N-phenylamino-methylsilane,	N-ethyl-N-phenylamino-methylsilane,	N,N-dimethylamino-methylsilane,	N,N-diethylamino-methylsilane, and
 N,N-di-n-propylamino-methylsilane.			

30. The method of claim 1 wherein the at least one multifunctional organoamine compound having the structure of Formula (II) is selected from the group consisting of ethylenediamine, 1,2-diaminopropane, 1,3-diaminopropane, and butane-1,4-diamine.

31. The method of claim 3 further comprising exposing the at least one organoaminosilane compound and the multifunctional organoamine compound to a plasma energy source.

32. The method of claim 1 or claim 2 further comprising the step of thermally annealing the flowable liquid oligomer at one or more temperatures ranging from 100 °C to 1000 °C to densify at least a portion of the materials, followed by broadband UV treatment at the temperature ranging from 100 ^{o}C to 1000 ^{o}C.

33. The method of claim 1 or claim 2 wherein the resultant silicon-containing film is exposed to a post-deposition treatment selected from the group consisting of hydrogen plasma, helium plasm, argon plasma, ammonia plasma, water (H_2O) plasma, oxygen plasma, ozone (O_3) plasma, NO plasma, N_2O plasma, carbon monoxide (CO) plasma, carbon dioxide (CO_2) plasma and combinations thereof, chemical treatment, ultraviolet light exposure, Infrared exposure**,** and electron beam exposure.