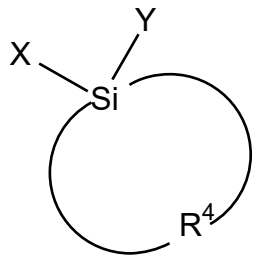
CLAIMS

1. A method for producing a dielectric film represented by the formula $Si_vO_wC_xH_yF_z$, where v+w+x+y+z = 100%, v is from 10 to 35 atomic%, w is from 10 to 65 atomic%, x is from 5 to 40 atomic%, y is from 10 to 50 atomic% and z is from 0 to 15 atomic%, said method comprising:

providing a substrate within a reaction chamber;

introducing into the reaction chamber gaseous reagents including at least one structure-forming precursor comprising an alkoxysilacyclic or an acyloxysilacyclic compound, and a porogen, wherein the alkoxysilacyclic or the acyloxysilacyclic compound has a structure represented by Formula I:



(I),

wherein X and Y are independently selected from the group consisting of OR^1, OR^2, and $OC(O)R^3$, wherein R^{1-3} are each independently selected from the group consisting of a linear or branched C_1 to C_{10} alkyl group, a linear or branched C_2 to C_{10} alkenyl group, a linear or branched C_2 to C_{10} alkynyl group, a C_3 to C_{10} cyclic alkyl group, a C_3 to C_{10} hetero-cyclic alkyl group, a C_5 to C_{10} aryl group, and a C_3 to C_{10} hetero-aryl group; and R^4 is a C_3 to C_{10} alkyl di-radical which forms a four-membered, five-membered, or six-membered saturated cyclic ring with the Si atom, optionally at least one oxygen source, and optionally at least one porogen;

applying energy to the gaseous reagents in the reaction chamber to induce reaction of the gaseous reagents to deposit a preliminary film on the substrate, wherein the preliminary film contains the porogen; and

removing from the preliminary film at least a portion of the porogen to provide the porous dielectric film comprising pores and a dielectric constant of about 2.6 or less.

2. The method of claim 1 wherein the structure-forming precursor further comprises a hardening additive.

3. The method of claim 1 wherein the alkoxysilacyclic or acyloxysilacyclic compound comprises at least one selected from the group consisting of 1,1-dimethoxy-1-silacyclopentane, 1,1-diethoxy-1-silacyclopentane, 1,1-di-n-propoxy-1-silacyclopentane, 1,1-di-iso-propoxy-1-silacyclopentane, 1,1-dimethoxy-1-silacyclobutane, 1,1-diethoxy-1-silacyclobutane, 1,1-di-n-propoxy-1-silacyclobutane, 1,1-di-iso-propoxy-1-silacyclobutane, 1,1-dimethoxy-1-silacyclohexane, 1,1-di-iso-propoxy-1-silacyclohexane, 1,1-di-n-propoxy-1-silacyclohexane, 1-methoxy-1-acetoxy-1-silacyclopentane, 1,1-diacetoxy-1-silacyclopentane, 1-methoxy-1-acetoxy-1-silacyclobutane, 1,1-diacetoxy-1-silacyclobutane, 1-methoxy-1-acetoxy-1-silacyclohexane, 1,1-diacetoxy-1-silacyclohexane, 1-ethoxy-1-acetoxy-1-silacyclopentane, 1-ethoxy-1-acetoxy-1-silacyclobutane, and combinations thereof.

4. The method of claim 1 wherein the porogen is cyclooctane.

5. The method of claim 2 wherein the hardening additive comprises tetraethoxysilane.

6. The method of claim 2 wherein the hardening additive comprises tetramethoxysilane.

7. The method of claim 1 which is a plasma enhanced chemical vapor deposition method.

8. The method of claim 1 where the reaction mixture comprises the at least one oxidant selected from the group consisting of O_2, N_2O, NO, NO_2, CO_2, water, H_2O_2, ozone, and combinations thereof.

9. The method of claim 1 where the reaction mixture does not comprise an oxidant.

10. The method of claim 1 where the reaction chamber in the applying step comprises at least one gas selected from the group consisting of He, Ar, N_2, Kr, Xe, NH_3, H_2, CO_2, and CO.

11. The method of claim 1 wherein the removing step comprises at least one treatment selected from the group consisting of thermal treatment, an ultraviolet (UV) treatment, an electron beam treatment, a gamma radiation treatment, and a combination thereof.

12. The method of claim 11 wherein the UV treatment occurs during at least a portion of the thermal treatment.

13. The method of claim 1 wherein the porogen precursor is selected from the group consisting of:

a.) a substituted or unsubstituted cyclic hydrocarbon having the formula C_nH_{2n} wherein n = 4 to 14,

b.) a substituted or unsubstituted hydrocarbon of the general formula $C_nH_{(2n+2)-2y}$ wherein n = 2 to 20 and y = 0 to n, wherein n = 4 to 14,

c.) a substituted or unsubstituted singly or multiply unsaturated cyclic hydrocarbon having the formula C_nH_{2n-2x} wherein x is the number of unsaturated sites in the molecule and n = 4 to 14,

d.) a substituted or unsubstituted bicyclic hydrocarbon having the formula C_nH_{2n-2} wherein n = 4 to 14,

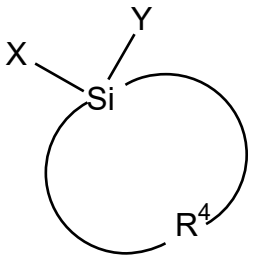
e.) a substituted or unsubstituted multiply unsaturated bicyclic hydrocarbon having the formula $C_nH_{2n-(2+2x)}$, where x is the number of unsaturated sites in the molecule, and n = 4 to 14, wherein the number of carbons in the bicyclic structure is between 4 and 12, and

f.) a substituted or unsubstituted tricyclic hydrocarbon having the formula C_nH_{2n-4} where n = 4 to 14, where the number of carbons in the tricyclic structure is between 4 and 12.

14. The method of claim 1 wherein the porogen precursor in claim 13 comprises at least one selected from the group consisting of cyclohexane, 1,2,4-trimethylcyclohexane, 1-methyl-4-(1- methylethyl)cyclohexane, cyclooctane, methylcyclooctane, ethylene, propylene, acetylene, neohexane, 1,3-butadiene, 2-methyl-1,3-butadiene, 2,3-dimethyl-2,3-butadiene, substituted dienes, para-cymene, cyclooctene, 1,5-cyclooctadiene, cyclohexene, vinyl-cyclohexane, dimethylcyclohexene, alpha-terpinene, pinene, limonene, vinyl-cyclohexene, norbornane, spiro-nonane, camphene, norbornene, norbornadiene, 5-ethylidene-2-norbornene, decahydronaphthalene, adamantine, and combinations thereof.

15. A combination comprising (i) a porogen and (ii) an alkoxysilacyclic or an acyloxysilacyclic compound for chemical vapor deposition of a dielectric film, wherein the

alkoxysilacyclic or an acyloxysilacyclic compound has a structure represented by the following Formula I:



(I),

wherein X and Y are independently selected from the group consisting of OR^1, OR^2, and $OC(O)R^3$, wherein R^{1-3} are each independently selected from the group consisting of a linear or branched C_1 to C_{10} alkyl group, a linear or branched C_2 to C_{10} alkenyl group, a linear or branched C_2 to C_{10} alkynyl group, a C_3 to C_{10} cyclic alkyl group, a C_3 to C_{10} hetero-cyclic alkyl group, a C_5 to C_{10} aryl group, and a C_3 to C_{10} hetero-aryl group; and R^4 is a C_3 to C_{10} alkyl di-radical which forms either a four-membered, five-membered, or six-membered saturated cyclic ring with the Si atom,

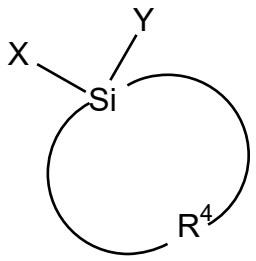
wherein the (i) porogen and (ii) the alkoxysilacyclic or an acyloxysilacyclic compound are provided separately or in a premixed form and

wherein the compound is substantially free of one or more impurities selected from the group consisting of a halide, water, and combinations thereof.

16. The combination of claim 15 wherein the alkoxysilacyclic or acyloxysilacyclic compound comprises at least one selected from the group consisting of 1,1-dimethoxy-1-silacyclopentane, 1,1-diethoxy-1-silacyclopentane, 1,1-di-n-propoxy-1-silacyclopentane, 1,1-di-iso-propoxy-1-silacyclopentane, 1,1-dimethoxy-1-silacyclobutane, 1,1-diethoxy-1-silacyclobutane, 1,1-di-n-propoxy-1-silacyclobutane, 1,1-di-iso-propoxy-1-silacyclobutane, 1,1-dimethoxy-1-silacyclohexane, 1,1-di-iso-propoxy-1-silacyclohexane, 1,1-di-n-propoxy-1-silacyclohexane, 1-methoxy-1-acetoxy-1-silacyclopentane, 1,1-diacetoxy-1-silacyclopentane, 1-methoxy-1-acetoxy-1-silacyclobutane, 1,1-diacetoxy-1-silacyclobutane, 1-methoxy-1-acetoxy-1-silacyclohexane, 1,1-diacetoxy-1-silacyclohexane, 1-ethoxy-1-acetoxy-1-silacyclopentane, 1-ethoxy-1-acetoxy-1-silacyclobutane, and combinations thereof.

17. The combination of claim 15, wherein the halide comprises chloride ions.

18. Use of an alkoxysilacyclic or acyloxysilacyclic compound for depositing a low k dielectric film via vapor deposition having the following Formula I:



(I)

wherein X and Y are independently selected from the group consisting of OR^1, OR^2, and $OC(O)R^3$, wherein R^{1-3} are each independently selected from the group consisting of a linear or branched C_1 to C_{10} alkyl group, a linear or branched C_2 to C_{10} alkenyl group, a linear or branched C_2 to C_{10} alkynyl group, a C_3 to C_{10} cyclic alkyl group, a C_3 to C_{10} hetero-cyclic alkyl group, a C_5 to C_{10} aryl group, and a C_3 to C_{10} hetero-aryl group; and R^4 is a C_3 to C_{10} alkyl di-radical which forms a four-membered, five-membered, or six-membered saturated cyclic ring with the Si atom.

19. The use of claim 18, wherein the compound is substantially free of one or more impurities selected from the group consisting of a halide, water, and combinations thereof.

20. The use of claim 18, wherein the alkoxysilacyclic or acyloxysilacyclic compound comprises at least one selected from the group consisting of 1,1-dimethoxy-1-silacyclopentane, 1,1-diethoxy-1-silacyclopentane, 1,1-di-n-propoxy-1-silacyclopentane, 1,1-di-iso-propoxy-1-silacyclopentane, 1,1-dimethoxy-1-silacyclobutane, 1,1-diethoxy-1-silacyclobutane, 1,1-di-n-propoxy-1-silacyclobutane, 1,1-di-iso-propoxy-1-silacyclobutane, 1,1-dimethoxy-1-silacyclohexane, 1,1-di-iso-propoxy-1-silacyclohexane, 1,1-di-n-propoxy-1-silacyclohexane, 1-methoxy-1-acetoxy-1-silacyclopentane, 1,1-diacetoxy-1-silacyclopentane, 1-methoxy-1-acetoxy-1-silacyclobutane, 1,1-diacetoxy-1-silacyclobutane, 1-methoxy-1-acetoxy-1-silacyclohexane, 1,1-diacetoxy-1-silacyclohexane, 1-ethoxy-1-acetoxy-1-silacyclopentane, 1-ethoxy-1-acetoxy-1-silacyclobutane, and combinations thereof.

21. The use of claim 19, wherein the halide comprises chloride ions.

22. The use of claim 21, wherein the chloride ions are less than 50 ppm.

23. The use of claim 21, wherein the chloride ions are less than 10 ppm.

24. The use of claim 21, wherein the chloride ions are less than 5 ppm.

25. The use of claim 18, which the vapor deposition is a chemical vapor deposition.

26. The use of claim 25, wherein the chemical vapor deposition is a plasma enhanced chemical vapor deposition.

27. The combination of claim 15 further comprising at least one member selected from the group consisting of carrier gases and oxidants.

28. The combination of claim 27 wherein the member comprises at least one member selected from the group consisting of helium and oxygen.

29. The combination of claim 15 further comprising at least one hardening additive.

30. The combination of claim 29 wherein the hardening additive comprises at least one tetraalkoxysilane.

31. A film formed by the method of any one of claims 1 to 14 wherein the film structure comprises at least one of $–CH_2–$ methylene and $–CH_2CH_2-$ ethylene bridges.