CLAIMS:

1. A method for coating a substrate, the method comprising:

(a) adding at least one compound of Formula $[Z^1Z^2SiCH_2]_3$ (Ia) into an aqueous mixture that contains essentially no structure directing agent or porogen to form a solution, wherein each Z^1 represents a hydroxyl group, a C_1-C_4 alkoxy group or an oxygen atom bonded to a silicon atom of another compound and each Z^2 represents, a hydroxyl group, a C_1-C_4 alkoxy group, a C_1-C_4 alkyl group or an oxygen atom bonded to a silicon atom of another compound;

(b) adding an adsorbent material to the solution to form a slurry;

(c) coating the slurry onto a substrate;

(d) aging the slurry; and

(e) drying the slurry to obtain a coating comprising the adsorbent material and a binder comprising an organosilica material which is a polymer comprising independent units of Formula $[Z^3Z^4SiCH_2]_3$ (I), wherein each Z^3 represents a hydroxyl group, a C_1-C_4 alkoxy group or an oxygen atom bonded to a silicon atom of another unit or an active site on the substrate and each Z^4 represents a hydroxyl group, a C_1-C_4 alkoxy group, a C_1-C_4 alkyl group, an oxygen atom bonded to a silicon atom of another unit or an active site on the substrate.

2. The method of claim 1, wherein each Z^1 represents a C_1-C_2 alkoxy group.

3. The method of claim 2, wherein each Z^2 represents a C_1-C_4 alkoxy group.

4. The method of claim 3, wherein each Z^2 represents a C_1-C_2 alkoxy group.

5. The method of claim 1, wherein the at least one compound of Formula (Ia) is 1,1,3,3,5,5-hexaethoxy-1,3,5-trisilacyclohexane.

6. The method of claim 1, wherein each Z^3 represents a hydroxyl group, a C_1-C_2 alkoxy group, or an oxygen bonded to a silicon atom of another unit or an active site on the substrate, and Z^4 represents a hydroxyl group, a C_1-C_2 alkyl group, a C_1-C_2

alkoxy group, or an oxygen bonded to a silicon atom of another unit or an active site on the substrate.

7. The method of claim 6, wherein each Z^3 represents a hydroxyl group, ethoxy, or an oxygen bonded to a silicon atom of another unit or an active site on the substrate, and each Z^4 represents a hydroxyl group, ethoxy, or an oxygen bonded to a silicon atom of another unit or an active site on the substrate.

8. The method of claim 1, further comprising adding to the aqueous mixture at least a second compound selected from the group consisting of:

(i) a further compound of Formula (Ia);

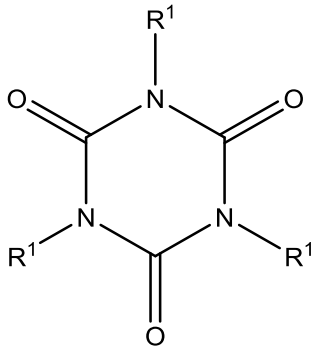
(ii) a compound of Formula $R^1OR^2R^3R^4Si$ (II), wherein each R^1 represents a C_1-C_4 alkyl group; and R^2, R^3, and R^4 are each independently selected from the group consisting of a C_1-C_4 alkyl group, a C_1-C_4 alkoxy group, a nitrogen-containing C_1-C_{10} alkyl group, a nitrogen-containing heteroalkyl group, and a nitrogen-containing optionally substituted heterocycloalkyl group;

(iii) a compound of Formula $Z^5Z^6Z^7Si–R–SiZ^5Z^6Z^7$ (III), wherein each Z^5 independently represents a C_1-C_4 alkoxy group; each Z^6 and Z^7 independently represent a C_1-C_4 alkoxy group or a C_1-C_4 alkyl group; and R is selected from the group consisting a C_1-C_8 alkylene group, a C_2-C_8 alkenylene group, a C_2-C_8 alkynylene group, a nitrogen-containing C_1-C_{10} alkylene group, an optionally substituted C_6-C_{20} aralkyl and an optionally substituted C_4-C_{20} heterocycloalkyl group;

(iv) a compound of Formula $M^1(OZ^8)_3$ (IV), wherein M^1 represents a Group 13 metal and each Z^8 independently represents a C_1-C_6 alkyl;

(v) a compound of Formula $(Z^9O)_2M^2$-O–$Si(OZ^{10})_3$ (V), wherein M^2 represents a Group 13 metal and Z^9 and Z^{10} each independently represent a C_1-C_6 alkyl group; and

(vi) a cyclic compound of Formula



(VI)

wherein each R^1 independently is a $X^1OX^2X^3SiX^4$ group, wherein each X^1 represents a C_1-C_4 alkyl group; X^2 and X^3 each independently represent a C_1-C_4 alkyl group, a C_1-C_4 alkoxy group; and X^4 represents a C_1-C_8 alkylene group bonded to a nitrogen atom of the cyclic compound; and

(vii) a combination thereof.

9. The method of claim 8, wherein the second compound is a compound of Formula (Ia), wherein each Z^1 represents a C_1-C_2 alkoxy group and Z^2 represents C_1-C_2 alkoxy group or a C_1-C_2 alkyl group.

10. The method of claim 9, wherein the compound of Formula (Ia) is 1,3,5-trimethyl-1,3,5-triethoxy-1,3,5-trisilacyclohexane.

11. The method of claim 8, wherein the second compound is a compound of Formula (II), wherein each R^1 represents a C_1-C_2 alkyl group and R^2, R^3, and R^4 are each independently a C_1-C_2 alkyl group, C_1-C_2 alkoxy group, a nitrogen-containing C_3-C_{10} alkyl group, a nitrogen-containing C_4-C_{10} heteroaralkyl group, or a nitrogen-containing optionally substituted C_4-C_{10} heterocycloalkyl group.

12. The method of claim 11, wherein the compound of Formula (II) is selected from the group consisting of tetraethyl orthosilicate, methyltriethoxysilane, (N,N-dimethyl-aminopropyl)trimethoxysilane, N-(2-aminoethyl)-3-aminopropyltriethoxysilane, 4-methyl-1-(3-triethoxysilylpropyl)-piperazine, 4-(2-(triethoxysilyl)ethyl)pyridine, 1-(3-(triethoxysilyl)propyl)-4,5-dihydro-1H-imidazole, and (3-aminopropyl)triethoxysilane.

13. The method of claim 8, wherein the second compound is a compound of Formula (III), wherein each Z^5 represents a C_1-C_2 alkoxy group; each Z^6 and Z^7 independently represent a C_1-C_2 alkoxy group, or a C_1-C_2 alkyl group; and R is selected from the group consisting of a C_1-C_4 alkylene group, a C_2-C_4 alkenylene group, a C_2-C_4 alkynylene group, and a nitrogen-containing C_4-C_{10} alkylene group.

14. The method of claim 13, wherein the compound of Formula (III) is selected from the group consisting of 1,2-bis(methyldiethoxysilyl)ethane, bis(triethoxysilyl)methane, 1,2-bis-(triethoxysilyl)ethylene, N,N'-bis[(3-trimethoxysilyl)propyl]ethylenediamine, bis[(methyl-diethoxysilyl)propyl]amine, and bis[(methyldimethoxysilyl)propyl]-N-methylamine.

15. The method of claim 8, wherein the second compound is a compound of Formula (IV), wherein M^1 is Al or B and each Z^8 represents a C_1-C_4 alkyl group.

16. The method of claim 8, wherein the second compound is a compound of Formula (V), wherein M^2 is Al or B; and Z^9 and Z^{10} each independently represent a C_1-C_4 alkyl group.

17. The method of claim 15, wherein the second compound is selected from the group consisting of aluminum trimethoxide, aluminum triethoxide, aluminum isopropoxide, and aluminum-tri-sec-butoxide.

18. The method of claim 8, wherein the second compound is a compound of Formula (VI), wherein each X^1 represents a C_1-C_2 alkyl group; X^2 and X^3 each independently represent a C_1-C_2 alkyl group or a C_1-C_2 alkoxy group; and each X^4 represents a C_1-C_4 alkylene group bonded to a nitrogen atom of the cyclic compound.

19. The method of claim 18, wherein the compound of Formula (VI) is tris(3-trimethoxysilylpropyl)isocyanurate.

20. The method of claim 1, wherein the aqueous mixture comprises a base and has a pH from about 8 to about 15.

21. The method of claim 20, wherein the base is ammonium hydroxide or a metal hydroxide.

22. The method of claim 1, wherein the aqueous mixture comprises an acid and has a pH from about 0.01 to about 6.0.

23. The method of claim 22, wherein the acid is an inorganic acid.

24. The method of claim 23, wherein the inorganic acid is hydrochloric acid.

25. The method of claim 1, wherein the slurry is aged in step (d) for up to 24 hours at a temperature of about 20ºC to about 125ºC.

26. The method of claim 1, wherein the slurry is dried at a temperature of about 70ºC to about 150ºC.

27. The method of claim 1, wherein step (c) is repeated one or more times to produce a thicker coating.

28. The method of claim 1, further comprising pre-treating the substrate.

29. The method of claim 28, wherein pre-treating the substrate comprises applying a solution comprising an oxidizing agent and an inorganic acid to the substrate.

30. The method of claim 29, wherein the oxidizing agent is hydrogen peroxide.

31. The method of claim 29, wherein the inorganic acid is sulfuric acid.

32. The method of claim 1, wherein the organosilica material has an average pore diameter of about 2.0 nm to about 25.0 nm.

33. The method of claim 1, wherein the organosilica material has a surface area of about 200 m^2/g to about 2500 m^2/g.

34. The method of claim 1, wherein the organosilica material has a pore volume of 0.1 cm^3/g about 3.0 cm^3/g.

35. The method of claim 1 further comprising agitating the slurry before coating.

36. The method of claim 1, wherein the adsorbent material is selected from the group consisting of a microporous adsorbent material, a mesoporous adsorbent material, an analogous periodic mesoporous adsorbent material, a metal oxide, a carbon, and a combination thereof.

37. The method of claim 1, wherein the adsorbent material is a zeolite.

38. The method of claim 37, wherein the zeolite is selected from the group consisting of a cationic form of zeolite A, Y, dealuminized Y, or Linde L; chabazite; erionite; mordenite; zeolite Beta; a ZSM-type zeolite; MCM-22; MCM-49; Nu-87; UTD-1; CIT-5; EMC-2; and Cloverite.

39. The method of claim 1, wherein the solution is stirred for at least 18 hours before adding the adsorbent material.

40. The method of claim 1, further comprising adding a C_1-C_4 alcohol to the solution.

41. The method of claim 39, wherein the C_1-C_4 alcohol is ethanol.

42. The method of claim 1, further comprising adding an additional amount of the compound of Formula (Ia) to the slurry.

43. The method of claim 42, wherein the compound of Formula (Ia) is 1,1,3,3,5,5-hexaethoxy-1,3,5-trisilacyclohexane.

44. The method of claim 1, further comprising supplying a purge gas to the substrate after coating.

45. The method of claim 44, wherein the purge gas is an inert gas.

46. The method of claim 45, wherein the inert gas is nitrogen.

47. The method of claim 1, wherein the substrate is selected from the group consisting of a capillary tube, a microchannel, a monolith, a spherical silica particle and a silicon wafer.

48. The method of claim 1, wherein the method does not comprise a calcination step.

49. The method of claim 1, wherein the coating has a thickness of up to about 150 μm.

50. The method of claim 48, wherein the coating comprises about 1% to about 50% organosilica material as a binder.

51. An organosilica material-coated substrate made according to claim 1.

52. A gas separation process comprising contacting a gas mixture comprising CH_4 and at least one contaminant selected from the group consisting CO_2, H_2O, H_2S, NO_x, and SO_x with the organosilica material-coated substrate of claim 51.

53. The gas separation process of claim 52, wherein the process comprises PSA, TSA, PPSA, PTSA, RCPSA, RCTSA, RCPPSA or RCPTSA.