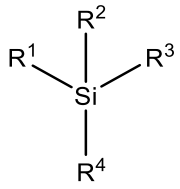
CLAIMS

1. A process of synthesizing non-spherical primary silica nanoparticles comprises :

a) providing a mixture of at least two organoalkoxysilanes, wherein each organoalkoxysilane independently has a structure represented by Formula I:



(I),

wherein

R^1, R^2, R^3, and R^4 are each independently selected from the group consisting of OR or R, wherein R is a substituted or unsubstituted linear or branched C_1-C_{12} alkyl group, a C_3-C_8 cycloaliphatic group, a C_2-C_6 alkylene group, a halogen, or an aryl group, and at least two, preferably at least three of R^1, R^2, R^3, and R^4 are OR;

wherein at least one of the at least two organoalkoxysilanes has at least three of, preferably all, R^1, R^2, R^3, and R^4 as OR; and

the at least two organoalkoxysilanes have different reaction speeds with water under alkaline conditions;

b) providing a water-miscible organic solvent;

c) providing an alkaline catalyst;

d) obtaining a reaction mixture comprising a) to c); wherein the reaction mixture contains water and has a molar ratio (ROR) of water (H_2O) and hydrolysable groups (OR) on the at least two organoalkoxysilanes greater than 0, and below 3.0, or below 2.0; such as from 0.5 to 1.5, according to a formula: ROR = $M(H_2O)/M(OR)$;

e) forming non-spherical primary silica nanoparticles by reacting the at least two organoalkoxysilanes with the water in the reaction mixture under an alkaline condition;

and

optionally,

f) replacing at least a portion of the water-miscible organic solvent by water after the non-spherical primary silica nanoparticles are formed to obtain a non-spherical primary silica nanoparticles dispersion; and

g) adding water in step d) if there is not enough water from a) to c) to meet the ROR in step d),

wherein step d) can be performed by (1) adding the water-miscible organic solvent into the mixture of at least two organoalkoxysilanes to obtain a first mixture, and adding the alkaline catalyst into the first mixture; (2) adding the alkaline catalyst into the water-miscible organic solvent to obtain a first mixture, and adding the mixture of at least two organoalkoxysilanes into the first mixture in one portion; or (3) adding the water-miscible organic solvent into the mixture of at least two organoalkoxysilanes to obtain a first mixture, adding the water-miscible organic solvent into the alkaline catalyst to obtain a second mixture, and mixing the first and the second mixtures in a mixer in a flow reactor.

2. The process of claim 1 wherein the non-spherical primary silica nanoparticles have shapes selected from the group consisting of elongated, bent, branched, and combinations thereof; and contain a nitrogen level of < 0.2, < 0.1, <0.05, < 0.02, < 0.01, < 0.006, < 0.005, or < 0.004 mmol/g SiO_2.

3. The process of claim 1 wherein the first mixture and the reaction mixture are heated and maintained at a temperature from 30 °C to 70 °C, from 40 °C to 60 °C, or from 48 °C to 52 °C.

4. The process of claim 1 wherein the process is carried out in a closed vessel optionally under moderate pressure or a flow reactor.

5. The process of claim 1 wherein each of the at least two organoalkoxysilanes is selected from the group consisting of tetramethoxysilane, tetraethoxysilane, tetraisopropoxysilane, tetrabutoxysilane, tetraoctoxysilane, methyltrimethoxysilane, methyltriethoxysilane, methyltriisopropoxysilane, ethyltrimethoxysilane, ethyltriethoxysilane, ethyltriisopropoxysilane, octyltrimethoxysilane, octyltriethoxysilane, vinyltrimethoxysilane, vinyltriethoxysilane, phenyltrimethoxysilane, phenyltriethoxysilane, triethylmethoxysilane, fluorotriisopropoxysilane, fluorotrimethoxysilane, fluorotriethoxysilane, dimethyldimethoxysilane, dimethyldiethoxysilane, diethyldimethoxysilane, diethyldiethoxysilane, trimethylmethoxysilane,

trimethylethoxysilane, trimethylisopropoxysilane, trimethylbutoxysilane trifluoromethyltrimethoxysilane, and trifluoromethyltriethoxysilane.

6. The process of claim 1 wherein two organoalkoxysilanes are used in the mixture of at least two organoalkoxysilanes and one of the organoalkoxysilane is present from about 50 to about 99 mole% and the other organoalkoxysilane is presentat from about 50 to about 1 mole%.

7. The process of claim 1 wherein the at least two organoalkoxysilanes comprise tetramethoxysilane and tetraethoxysilane, and the tetramethoxysilane is present at from about 2 to about 25 mole% or 7.5 to 12.5 mole% based on total molar of the at least two organoalkoxysilanes.

8. The process of claim 1 wherein the at least two organoalkoxysilanes comprise tetramethoxysilane and tetraethoxysilane, and the molar ratio (ROR) of water (H_2O) and hydrolysable groups (OR) on the at least two organoalkoxysilanes is 0.75.

9. The process of claim 1 wherein the alkaline catalyst is selected from the group consisting of ammonia (NH_3), ammonium hydroxide, an organic amine, an alkanolamine, a quaternary ammonium hydroxide compound, and combinations thereof.

10. The process of claim 1 wherein pH of the reaction mixture is from 7 to 14, 10 to 14, or 12 to 14

11. The process of claim 1 wherein the alkaline catalyst comprises NH_3 or an organic amine and the reaction mixture is at a pH of greater than 8 or greater than 9.

12. The process of claim 1 wherein step (d) occurs in a continuous flow reactor or a batch reactor.

13. The process of claim 1 wherein the replacing step f) comprises adding water in an amount to achieve a molar ratio (ROR) of water (H_2O) and hydrolysable

groups (OR) on the organoalkoxysilanes (ROR) greater than or equal to 1.0 or greater than or equal 2.0.

14. The process of claim 1 further comprising a second growth step of adding an organoalkoxysilane and water and optionally an alkaline catalyst to the reaction mixture immediately after step d).

15. The process of claim 1 wherein the replacing step f) comprises at least one of distillation and membrane filtration.

16. The process of claim 1 further comprising a step of changing the pH of the non-spherical primary silica nanoparticles dispersion obtained in step f) from alkaline to acidic by passing the dispersion through an ion exchanger and optionally adding an acid.

17. The process of claim 1 further comprising the step of modifying surface of the non-spherical primary silica nanoparticles by treating the surface with a surface-modifying agent selected from the group consisting of an organosilane, an organic polymer, an inorganic polymer, a surfactant, an inorganic salt, metal ions, and combinations thereof.

18. The process of claim 17 wherein the organosilane used to modify the surface is selected from the group consisting of an amino-functional alkyl-alkoxysilane, a cyano-functional alkyl-alkoxysilane, an alkyl- and aryl- functional alkoxysilane, sulfur-containing silanes, carboxy-group containing silanes, phosphorous-containing silanes, alkyl silanes, and combinations thereof.

19. The process of claim 1, wherein the non-spherical primary silica nanoparticles is produced at a weight% yield of 3.0 wt.% - 8.0 wt.%, 4.0 wt.% - 7.0 wt.%, 4.5 wt.% - 6.5 wt.%, or 5.5 wt.% - 6.5 wt.% based on the total weight of silica nanoparticles which can be produced by total weight of the reaction mixture.

20. The process of claim 1, wherein the non-spherical primary silica nanoparticles is produced at a yield of at least 50%, 75% or 85% based on total weight of particles

21. Non-spherical primary silica nanoparticles, wherein the non-spherical primary silica nanoparticles have shapes selected from the group consisting of elongated, bent, branched, and combinations thereof; and contain a nitrogen level of < 0.01, < 0.006, < 0.005, or < 0.004 mmol/g SiO_2.

22. A Chemical Mechanical Planarization (CMP) composition comprising:
non-spherical primary silica nanoparticles having shapes selected from the group consisting of elongated, bent, branched, and combinations thereof; and contain a nitrogen level of < 0.01, < 0.006, < 0.005, or < 0.004 mmol/g SiO_2.

23. The Chemical Mechanical Planarization (CMP) composition of claim 22 further comprises at least one of: colloidal stabilizer, soluble or solid catalyst, chelating agent, corrosion inhibitor, surfactant, biocide, organic or inorganic salts, and pH adjuster.