CLAIMS

1. A method for chemically modifying metal oxide particles, comprising:

a) adjusting the pH of a liquid dispersion of metal oxide particles to a pH value where the zeta potential of the metal oxide particles is from at least about -20 mV to at most about 20 mV; and

b) adding a quaternary silane to the liquid dispersion of metal oxide particles to form chemically modified metal oxide particles.

2. The method of claim 1, wherein the metal oxide particles comprise silica, titania, alumina, ceria, zirconia, or mixtures thereof.

3. The method of claim 1, wherein the metal oxide particles comprise colloidal silica, fumed silica, core-shell particles comprising a silica shell, or mixtures thereof.

4. The method of any one of claims 1-3, wherein the metal oxide particles in the liquid dispersion have a mean particle size of from 1 nm to 5000 nm.

5. The method of any one of claims 1-4, wherein the liquid dispersion is an aqueous dispersion.

6. The method of any one of claims 1-5, wherein the liquid dispersion of metal oxide particles has a weight percent of from about 1% to about 50% by weight of the metal oxide particles.

7. The method of any one of claims 1-6, wherein after the adjusting, and prior to adding the quaternary silane, the pH of the liquid dispersion of the metal oxide particles is below the isoelectric point of the metal oxide particles.

8. The method of any one of claims 1-7, wherein the liquid dispersion of metal oxide particles has a pH from about 1 to about 7 after the adjusting.

9. The method of any one of claims 1-8, wherein an acid is added to the liquid dispersion of metal oxide particles during the adjusting.

10. The method of claim 9, wherein the acid is selected from the group consisting of formic acid, acetic acid, malonic acid, citric acid, propionic acid, malic acid, adipic acid, succinic acid, lactic acid, oxalic acid, hydroxyethylidene diphosphonic acid, 2-phosphono-1,2,4-butane tricarboxylic acid, aminotrimethylene phosphonic acid, hexamethylenediamine tetra(methylenephosphonic acid), bis(hexamethylene)triamine phosphonic acid, amino acetic acid, peracetic acid, phenoxyacetic acid, glycine, bicine, diglycolic acid, glyceric acid, tricine, histidine, phenylalanine, proline, aspartic acid, glutamic acid, arginine, benzoic acid, nitric acid, sulfuric acid, sulfurous acid, phosphoric acid, phosphonic acid, hydrochloric acid, periodic acid, tartaric acid, boric acid, phthalic acid, and mixtures thereof.

11. The method of any one of claims 1-10, wherein the quaternary silane is a silane compound that includes an ammonium group or a phosphonium group.

12. The method of any one of claims 1-11, wherein the quaternary silane is a silane compound that has a terminal ammonium group or a terminal phosphonium group.

13. The method of any one of claims 1-12, wherein the quaternary silane is selected from the group consisting of n-trimethoxysilylpropyl-n,n,n-trimethylammonium chloride, n-triethoxysilylpropyl-n,n,n-trimethylammonium chloride, n-trimethoxysilylethyl-n,n,n-trimethylammonium chloride, n-triethoxysilylethyl-n,n,n-trimethylammonium chloride, n-trimethoxysilylpropyl-n,n,n-triethylammonium chloride, n-triethoxysilylpropyl-n,n,n-triethylammonium chloride, n-trimethoxysilylethyl-n,n,n-tripropylammonium chloride, n-triethoxysilylethyl-n,n,n-tripropylammonium chloride octadecyldimethyl (3-trimethoxysilylpropyl) ammonium chloride, n,n-didecyl-n-(3-trimethoxysilylpropyl) ammonium chloride, and mixtures thereof.

14. The method of any one of claims 1-13, wherein the quaternary silane compound is added to the liquid dispersion of metal oxide particles after being dissolved in a water miscible solvent to form a water miscible solution.

15. The method of claim 14, wherein the quaternary silane is from about 0.1% to about 75% by weight of the water miscible solution.

16. The method of claim 14, wherein the water miscible solvent is selected from the group consisting of methanol, ethanol, propanol, iso-propanol, butanol, ethylene glycol, propylene glycol, acetone, toluene, dimethylformamide, tetrahydrofuran, or mixtures thereof.

17. The method of any one of claims 1-16, wherein adding the quaternary silane is performed while agitating the liquid dispersion of metal oxide particles.

18. The method of any one of claims 1-17, wherein adding the quaternary silane is performed at a consistent rate.

19. The method of any one of claims 1-18, wherein from about 0.1% to about 20% by weight of quaternary silane is added to the liquid dispersion with respect to the weight of metal oxide particles in the liquid dispersion.

20. The method of any one of claims 1-19, wherein the chemically modified metal oxide particles have an isoelectric point of at least 7.

21. The method of any one of claims 1-20, wherein the chemically modified metal oxide particles have a mean particle size from about 1% to at most about 20% different from the mean particle size of the metal oxide particles.

22. The method of any one of claims 1-21, wherein the weight percent of the chemically modified particles after the adding is at most 5% different from the weight percent of the metal oxide particles in the liquid dispersion.

23. A chemically modified metal oxide particle dispersion made by the method of any of claims 1-22.

24. The chemically modified metal oxide particle dispersion of claim 23, wherein the chemically modified metal oxide particles in the dispersion have a mean particle size of from about 1 nm to about 100 nm.