CLAIMS:

1. A cleaning composition, comprising:

1) at least one redox agent, wherein the at least one redox agent comprises hydroxylamine;

2) at least one chelating agent, the chelating agent being a polyaminopolycarboxylic acid;

3) at least one corrosion inhibitor, the corrosion inhibitor being a substituted or unsubstituted benzotriazole;

4) at least one sulfonic acid; and

5) water.

2. The composition of claim 1, wherein the at least one redox agent is from 0.1% to 5% by weight of the composition.

3. The composition of claim 1 or 2, wherein the polyaminopolycarboxylic acid is selected from the group consisting of mono- or polyalkylene polyamine polycarboxylic acids, polyaminoalkane polycarboxylic acids, polyaminoalkanol polycarboxylic acids, and hydroxyalkylether polyamine polycarboxylic acids.

4. The composition of claim 3, wherein the polyaminopolycarboxylic acid is diethylenetriamine pentaacetic acid.

5. The composition of any one of claims 1 to 4, wherein the polyaminopolycarboxylic acid is from 0.01% to 0.5% by weight of the composition.

6. The composition of any one of claims 1 to 5, wherein the at least one corrosion inhibitor comprises a benzotriazole optionally substituted by at least one substituent selected from the group consisting of alkyl groups, aryl groups, halogen groups, amino groups, nitro groups, alkoxy groups, and hydroxyl groups.

7. The composition of claim 6, wherein the at least one corrosion inhibitor comprises 5-methyl-1H-benzotriazole.

8. The composition of any one of claims 1 to 7, wherein the at least one corrosion inhibitor is from 0.05% to 1% by weight of the composition.

9. The composition of any one of claims 1 to 8, wherein the at least one sulfonic acid comprises a sulfonic acid of formula (I):

$$R\text{-}SO_3H \quad (I),$$

in which R is C_1-C_{12} alkyl, C_1-C_{12} cycloalkyl, or aryl, wherein the alkyl, cycloalkyl, or aryl is optionally substituted by at least one substituent selected from the group consisting of halo, OH, NH_2, NO_2, COOH, C_1-C_{12} cycloalkyl, C_1-C_{12} alkoxy optionally substituted by halo, and aryl optionally substituted by OH.

10. The composition of claim 9, wherein the at least one sulfonic acid comprises methanesulfonic acid.

11. The composition of any one of claims 1 to 10, wherein the at least one sulfonic acid is from 1% to 10% by weight of the composition.

12. The composition of any one of claims 1 to 11, further comprising at least one pH adjusting agent, the pH adjusting agent being a base free of a metal ion.

13. The composition of claim 12, wherein the at least one pH adjusting agent comprises a cyclic amine or an alkanolamine.

14. The composition of claim 12 or 13, wherein the at least one pH adjusting agent comprises 1,8-diazabicyclo[5.4.0]undec-7-ene or monoethanolamine.

15. The composition of claim 12, 13 or 14, wherein the at least one pH adjusting agent is from 0.1% to 3% by weight of the composition.

16. The composition of any one of claims 1 to 15, wherein the water is from 55% to 98% by weight of the composition.

17. The composition of any one of claims 1 to 16, further comprising at least one organic solvent selected from the group consisting of water soluble alcohols, water soluble ketones, water soluble esters, and water soluble ethers.

18. The composition of claim 17, wherein the at least one organic solvent comprises ethylene glycol butyl ether.

19. The composition of claim 17 or 18, wherein the at least one organic solvent is from 0.1% to 40% by weight of the composition.

20. The composition of any one of claims 1 to 19, wherein the composition has a pH of from about 4 to about 7.

21. The composition of any one of claims 1 to 20, wherein the composition comprises hydroxylamine, diethylenetriamine pentaacetic acid, 5-methyl-1H-benzotriazole, 1,8-diazabicyclo[5.4.0]undec-7-ene, methanesulfonic acid, and water.

22. The composition of claim 21, wherein the composition comprises:

hydroxylamine in an amount of from 0.1% to 5% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from about 0.01% to about 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.05% to 1% by weight of the composition;

methanesulfonic acid in an amount of from 1% to 10% by weight of the composition;

1,8-diazabicyclo[5.4.0]undec-7-ene in an amount of from 0.1% to 3% by weight of the composition; and

water in an amount of from 75% to 98% by weight of the composition;

wherein the composition has a pH of from about 4 to about 7.

23. The composition of claim 22, wherein the composition comprises:

hydroxylamine in an amount of from 0.5% to 2% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.1% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.1% to 0.5% by weight of the composition;

methanesulfonic acid in an amount of from 2% to 5% by weight of the composition;

1,8-diazabicyclo[5.4.0]undec-7-ene in an amount of from 0.5% to 2% by weight of the composition; and

water in an amount of from 85% to 95% by weight of the composition;

wherein the composition has a pH of from 4.5 to 6.

24. The composition of any one of claims 21 to 23, further comprising ethylene glycol butyl ether.

25. The composition of claim 24, wherein the composition comprises:

hydroxylamine in an amount of from 0.1% to 5% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.01% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.05% to 1% by weight of the composition;

methanesulfonic acid in an amount of from 1% to 10% by weight of the composition;

1,8-diazabicyclo[5.4.0]undec-7-ene in an amount of from 0.1% to 3% by weight of the composition;

ethylene glycol butyl ether in an amount of from 0.5% to 10% by weight of the composition; and

water in an amount of from 75% to 98% by weight of the composition;

wherein the composition has a pH of from 4 to 7.

26. The composition of claim 25, wherein the composition comprises:

hydroxylamine in an amount of from 0.5% to 2% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.1% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.1% to 0.5% by weight of the composition;

methanesulfonic acid in an amount of from 2% to 5% by weight of the composition;

1,8-diazabicyclo[5.4.0]undec-7-ene in an amount of from 0.5% to 2% by weight of the composition;

ethylene glycol butyl ether in an amount of from 1% to 5% by weight of the composition; and

water in an amount of from 85% to 95% by weight of the composition;

wherein the composition has a pH of from 4.5 to 6.

27. The composition of any one of claims 1 to 26, wherein the composition comprises hydroxylamine, diethylenetriamine pentaacetic acid, 5-methyl-1H-benzotriazole, monoethanolamine, methanesulfonic acid, and water.

28. The composition of claim 27, wherein the composition comprises:

hydroxylamine in an amount of from 0.1% to 5% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.01% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.05% to 1% by weight of the composition;

methanesulfonic acid in an amount of from 1% to 10% by weight of the composition;

monoethanolamine in an amount of from 0.1% to 3% by weight of the composition; and

water in an amount of from 75% to 98% by weight of the composition;

wherein the composition has a pH of from 4 to 7.

29. The composition of claim 28, wherein the composition comprises:

hydroxylamine in an amount of from 0.5% to 2% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.1% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.1% to 0.5% by weight of the composition;

methanesulfonic acid in an amount of from 2% to 5% by weight of the composition;

monoethanolamine in an amount of from 0.5% to 2% by weight of the composition; and

water in an amount of from 85% to 95% by weight of the composition;

wherein the composition has a pH of from 4.5 to 6.

30. The composition of claim 27, further comprising ethylene glycol butyl ether.

31. The composition of claim 30, wherein the composition comprises:

hydroxylamine in an amount of from 0.1% to 5% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.01% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.05% to 1% by weight of the composition;

methanesulfonic acid in an amount of from 1% to 10% by weight of the composition;

monoethanolamine in an amount of from 0.1% to 3% by weight of the composition;

ethylene glycol butyl ether in an amount of from 0.5% to 10% by weight of the composition; and

water in an amount of from 75% to 98% by weight of the composition;

wherein the composition has a pH of from 4 to 7.

32. The composition of claim 31, wherein the composition comprises:

hydroxylamine in an amount of from 0.5% to 2% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.1% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.1% to 0.5% by weight of the composition;

methanesulfonic acid in an amount of from 2% to 5% by weight of the composition;

monoethanolamine in an amount of from 0.5% to 2% by weight of the composition;

ethylene glycol butyl ether in an amount of from 1% to 5% by weight of the composition; and

water in an amount of from 85% to 95% by weight of the composition;

wherein the composition has a pH of from 4.5 to 6.

33. The composition of any one of claims 1 to 32, wherein the composition comprises hydroxylamine, diethylenetriamine pentaacetic acid, 5-methyl-1H-benzotriazole, ethylene glycol butyl ether, methanesulfonic acid, and water.

34. The composition of claim 33, wherein the composition comprises:

hydroxylamine in an amount of from 0.1% to 5% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.01% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.05% to 1% by weight of the composition;

methanesulfonic acid in an amount of from 1% to 10% by weight of the composition;

ethylene glycol butyl ether in an amount of from 1% to 40% by weight of the composition; and

water in an amount of from 55% to 98% by weight of the composition;

wherein the composition has a pH of from 4 to 7.

35. The composition of claim 34, wherein the composition comprises:

hydroxylamine in an amount of from 0.5% to 2% by weight of the composition;

diethylenetriamine pentaacetic acid in an amount of from 0.1% to 0.5% by weight of the composition;

5-methyl-1H-benzotriazole in an amount of from 0.1% to 0.5% by weight of the composition;

methanesulfonic acid in an amount of from 1% to 5% by weight of the composition;

ethylene glycol butyl ether in an amount of from 3% to 40% by weight of the composition; and

water in an amount of from 55% to 95% by weight of the composition;

wherein the composition has a pH of from 4.5 to 6.5.

36. A method of cleaning residues from a semiconductor substrate, comprising:

contacting a semiconductor substrate containing post etch residues and/or post ash residues with the cleaning composition of any one of claims 1-35.

37. A method of treating a semiconductor substrate having a metal layer on a surface, comprising:

oxidizing the metal layer to form an oxidized metal layer, and

removing the oxidized metal layer from the semiconductor substrate by contacting the cleaning composition of any one of claims 1-35 with the oxidized metal layer.

38. The method of claim 37, wherein the metal layer comprises cobalt, ruthenium, molybdenum, copper, tungsten, titanium, aluminum, or an alloy thereof.

39. The method of claim 37 or 38, wherein the oxidizing step comprises contacting a chemical liquid with the metal layer on the semiconductor substrate, in which the chemical liquid is selected from the group consisting of water, a hydrogen peroxide aqueous solution, an aqueous solution of ammonia and hydrogen peroxide, an aqueous solution of hydrofluoric acid and hydrogen peroxide, an aqueous solution of sulfuric acid and hydrogen peroxide, an aqueous solution of hydrochloric acid and hydrogen peroxide, oxygen dissolved water, ozone dissolved water, a perchloric acid aqueous solution, and a sulfuric acid aqueous solution.

40. The method of claim 37, 38 or 39, wherein the oxidizing step comprises contacting an oxidizing gas with the metal layer, heating the metal layer under an oxidizing atmosphere, or performing plasma treatment on the metal layer using an oxidizing gas.