

WHAT IS CLAIMED IS:

1. An etching composition, comprising:
 - 1) at least one oxidizing agent;
 - 5 2) at least one first carboxylic acid, wherein the first carboxylic acid comprises at least one unit of unsaturation;
 - 3) at least one chelating agent;
 - 4) at least one leveling agent; and
 - 5) water.
- 10 2. The composition of claim 1, wherein the composition has a pH between about 1 and about 5.
3. The composition of claim 1, wherein the at least one oxidizing agent
- 15 comprises hydrogen peroxide.
4. The composition of claim 1, wherein the at least one oxidizing agent is in the amount of from about 0.01% to about 20% by weight of the composition.
- 20 5. The composition of claim 1, wherein the at least one oxidizing agent is in the amount of from about 0.1% to about 10% by weight of the composition.
6. The composition of claim 1, wherein the at least one oxidizing agent is in the amount of from about 0.5% to about 1% by weight of the composition.
- 25 7. The composition of claim 1, wherein the at least one first carboxylic acid comprises a carboxylic acid having three to ten carbon atoms.
8. The composition of claim 1, wherein the at least one first carboxylic
- 30 acid comprises crotonic acid, maleic acid, fumaric acid, propenoic acid, 3-pentenoic acid, 5-hexenoic acid, 6-heptenoic acid, 7-octenoic acid, 8-nonenoic acid, or 9-undecylenic acid.

9. The composition of claim 1, wherein the at least one first carboxylic acid is in the amount of from about 0.005% to about 3% by weight of the composition.

5 10. The composition of claim 1, further comprising at least one second carboxylic acid.

11. The composition of claim 10, wherein the at least one second carboxylic acid comprises a monocarboxylic acid.

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12. The composition of claim 11, wherein the monocarboxylic acid is a C₁ to C₁₀ monocarboxylic acid.

13. The composition of claim 12, wherein the monocarboxylic acid is
15 glycolic acid, gluconic acid, acetic acid, gallic acid, or lactic acid.

14. The composition of claim 10, wherein the at least one second carboxylic acid comprises a polycarboxylic acid.

20 15. The composition of claim 14, wherein the polycarboxylic acid is a C₂ to C₁₀ polycarboxylic acid.

16. The composition of claim 15, wherein the polycarboxylic acid is oxalic acid, malonic acid, succinic acid, glutaric acid, citric acid, tartaric acid, malic acid,
25 phthalic acid, or 1,2,3-benzenetricarboxylic acid.

17. The composition of claim 10, wherein the at least one second carboxylic acid is in the amount of from about 0.005% to about 3% by weight of the composition.

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18. The composition of claim 1, wherein the at least one leveling agent comprises a sulfur-containing polymer or a nitrogen-containing polymer.

19. The composition of claim 1, wherein the at least one leveling agent comprises poly(4-styrene sulfonic acid), polyethylene imine, polyglycine, poly(allylamine), polyaniline, sulfonated polyaniline, polyurea, polyacrylamide, poly(melamine-co-formaldehyde), polyaminoamide, or polyalkanolamine.

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20. The composition of claim 1, wherein the at least one leveling agent is in the amount of from about 0.01% to about 3% by weight of the composition.

21. The composition of claim 1, further comprising at least one metal
10 corrosion inhibitor.

22. The composition of claim 21, wherein the at least one metal corrosion inhibitor comprises a substituted or unsubstituted azole.

15 23. The composition of claim 22, wherein the azole is a triazole, an imidazole, a thiadiazole, or a tetrazole.

24. The composition of claim 21, wherein the at least one metal corrosion inhibitor comprises a benzotriazole optionally substituted by at least one substituent
20 selected from the group consisting of alkyl groups, aryl groups, halogen groups, amino groups, nitro groups, alkoxy groups, and hydroxyl groups.

25. The composition of claim 21, wherein the at least one metal corrosion inhibitor comprises a compound selected from the group consisting of benzotriazole,
25 5-aminobenzotriazole, 1-hydroxybenzotriazole, 5-phenylthiol-benzotriazole, 5-chlorobenzotriazole, 4-chlorobenzotriazole, 5-bromobenzotriazole, 4-bromobenzotriazole, 5-fluorobenzotriazole, 4-fluorobenzotriazole, naphthotriazole, tolyltriazole, 5-phenyl-benzotriazole, 5-nitrobenzotriazole, 4-nitrobenzotriazole, 3-amino-5-mercapto-1,2,4-triazole, 2-(5-amino-pentyl)-benzotriazole, 1-amino-
30 benzotriazole, 5-methyl-1H-benzotriazole, benzotriazole-5-carboxylic acid, 4-methylbenzotriazole, 4-ethylbenzotriazole, 5-ethylbenzotriazole, 4-propylbenzotriazole, 5-propylbenzotriazole, 4-isopropylbenzotriazole, 5-isopropylbenzotriazole, 4-n-butylbenzotriazole, 5-n-butylbenzotriazole, 4-isobutylbenzotriazole, 5-isobutylbenzotriazole, 4-pentylbenzotriazole, 5-

pentylbenzotriazole, 4-hexylbenzotriazole, 5-hexylbenzotriazole, 5-methoxybenzotriazole, 5-hydroxybenzotriazole, dihydroxypropylbenzotriazole, 1-[N,N-bis(2-ethylhexyl)aminomethyl]-benzotriazole, 5-t-butyl benzotriazole, 5-(1',1'-diimethylpropyl)-benzotriazole, 5-(1',1',3'-trimethylbutyl)benzotriazole, 5-n-octyl
5 benzotriazole, and 5-(1',1',3',3'-tetramethylbutyl)benzotriazole.

26. The composition of claim 21, wherein the at least one metal corrosion inhibitor is in the amount of from about 0.005% to about 3% by weight of the composition.

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27. The composition of claim 1, wherein the at least one chelating agent comprises a polyaminopolycarboxylic acid.

28. The composition of claim 1, wherein the at least one chelating agent
15 comprises butylenediaminetetraacetic acid, diethylenetriaminepentaacetic acid, ethylenediaminetetrapropionic acid, triethylenetetraminehexaacetic acid, 1,3-diamino-2-hydroxypropane-N,N,N',N'-tetraacetic acid, propylenediaminetetraacetic acid, ethylenediaminetetraacetic acid, trans-1,2-diaminocyclohexane tetraacetic acid, ethylenediamine diacetic acid, ethylenediamine dipropionic acid, 1,6-hexamethylene-
20 diamine-N,N,N',N'-tetraacetic acid, N,N-bis(2-hydroxybenzyl)ethylenediamine-N,N-diacetic acid, diaminopropane tetraacetic acid, iminodiacetic acid; 1,4,7,10-tetraazacyclododecane-tetraacetic acid, diaminopropanol tetraacetic acid, or (hydroxyethyl)ethylenediaminetriacetic acid.

29. The composition of claim 1, wherein the at least one chelating agent is in the amount of from about 0.005% to about 3% by weight of the composition.

30. The composition of claim 1, wherein the water is in the amount of from about 60% to about 99% by weight of the composition.

31. The composition of claim 1, 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.

32. The composition of claim 31, wherein the at least one organic solvent is in the amount of from about 0.5% to about 30% by weight of the composition.

33. The composition of claim 1, further comprising at least one pH
5 adjusting agent.

34. The composition of claim 33, wherein the at least one pH adjusting agent comprises a base or an acid.

10 35. The composition of claim 34, wherein the base is a quaternary ammonium hydroxide, ammonium hydroxide, an amine, an imine, or a guanidine salt.

36. An etching composition, comprising:
15 1) at least one oxidizing agent;
2) at least one first carboxylic acid, wherein the first carboxylic acid comprises at least one unit of unsaturation;
3) at least one second carboxylic acid, wherein the second carboxylic acid is selected from the group consisting of monocarboxylic acids and polycarboxylic
20 acids, wherein the monocarboxylic acids or polycarboxylic acids optionally comprise at least one hydroxyl group;
4) at least one leveling agent; and
5) water.

25 37. A method, comprising:
contacting a semiconductor substrate containing a Co feature with a composition of claim 1 to remove at least a portion of the Co feature.

30 38. The method of claim 37, wherein the semiconductor substrate further comprises a TiN feature and the method removes at least a portion of the TiN feature.

39. The method of claim 37, further comprising rinsing the semiconductor substrate with a rinse solvent after the contacting step.

40. The method of claim 39, further comprising drying the semiconductor substrate after the rinsing step.

41. The method of claim 37, wherein the method does not substantially form a cobalt oxide hydroxide layer on the semiconductor substrate.

42. An article formed by the method of claim 41, wherein the article is a semiconductor device.

43. The article of claim 42, wherein the semiconductor device is an integrated circuit.