In some embodiments, the stripping compositions of this disclosure contain at least one quaternary ammonium hydroxide. In some embodiments, the preferred quaternary ammonium hydroxide is a compound represented by the general formula $[NR_1R_2R_3R_4]^+OH$, where R_1, R_2, R_3, and R_4 are independently a linear, branched or cyclic alkyl group optionally substituted by hydroxy, a substituted or unsubstituted phenyl group, or a substituted or unsubstituted benzyl group(e.g., a benzyl group substituted or unsubstituted on its phenyl group). Substituents on the phenyl group and on the phenyl group of the benzyl group may include halogen, hydroxyl, alkoxy, or alkyl. In some embodiments, the quaternary ammonium hydroxide is a tetralkylammonium hydroxide. In some embodiments, the quaternary ammonium hydroxide is a tetralkanol ammonium hydroxide. In some embodiments, the quaternary ammonium hydroxide is a mixture of two or more quaternary ammonium hydroxides in any ratio.

In some embodiments, the preferred quaternary ammonium hydroxide is a compound of the general formula $[NR_1R_2R_3R_4]^+OH$, where R_1, R_2, R_3, and R_4 are independently a C_1-C_4 alkyl group, a hydroxyethyl group, a phenyl group, or a benzyl group.

Examples of suitable quaternary ammonium hydroxide compounds include, but are not limited to, tetramethylammonium hydroxide (TMAH), tetraethylammonium hydroxide (TEAH), tetrapropylammonium hydroxide, tetrabutylammonium hydroxide (TBAH), ethyltrimethylammonium hydroxide, diethyldimethylammonium hydroxide, methyltripropylammonium hydroxide, butyltrimethylammonium hydroxide, methyltributylammonium hydroxide, pentyltrimethylammonium hydroxide, (2-hydroxyethyl)trimethylammonium hydroxide (choline), (2-hydroxyethyl)triethylammonium hydroxide, ~~(2-hydroxyethyl)triethyl-ammonium hydroxide,~~ (3-hydroxypropyll)triethylammonium hydroxide, tris-2-hydroxyethylammonium hydroxide, tetraethanolammonium hydroxide, phenyltrimethylammonium hydroxide, benzyltrimethylammonium hydroxide and mixtures thereof.

In some embodiments, the stripping compositions of the present disclosure may specifically exclude one or more of the following components (e.g., such as certain components described above), in any combination, if more than one. Such excluded components are selected from the group consisting of polymers, oxygen scavengers, amidoximes, oxidizing agents (e.g., peroxides, oxoammonium compounds, inorganic oxidizing agents, and peracids), abrasives (e.g., silica or alumina), fluoride containing compounds, amines, alkali metal and alkaline earth bases (such as NaOH, KOH, magnesium hydroxide, calcium hydroxide and LiOH), metal halide compounds, phosphinic acids, tetrahydrofurfuryl alcohol, glycols, furanyl alcohol, glycerine, saccharides, aryl ethers, N-hydroxy formamide, alkanolamines, N-alkylalkanolamines, sulfonated polymers, metal sulfonates, hydroxylamine, 2-aminobenzothiazole, thiobenzotriazole, sulfonated polyesters, urea compounds, silicate bases, silanes, silicon compounds, surfactants other than a defoaming surfactant, pyrrolidone, steric hindered amide solvents such as 1,3-dimethyl-2-piperidone and 1,5-dimethyl-2-piperidone, sulfur compounds other than DMSO or dimethylsulfone or triazole compounds containing sulfur-containing substituents, tetrazolium salts, boric acid and salts or derivatives of boric acid, benzimidazoles, non-triazole containing phenolic compounds, chelating agents, buffering agents, azoles (e.g., diazoles, triazoles, or tetrazoles), salts (e.g., sulfate salts, sulfonate salts, halide salts (e.g., chloride salts), nitrate salts, acetate salts, phosphate salts, and metal salts such as metal halides, potassium salts (e.g., potassium nitrate), sodium salts, and silver salts), and corrosion inhibitors other than the Cu or Al corrosion inhibitors described in this disclosure.

In some embodiments, the stripping compositions of this disclosure contain, consist of, or consist essentially of:

(1) at least about 30% by weight (e.g., at least about 40% by weight, at least about 50% by weight or at least about 60% by weight) and/or at most about 90% by weight (e.g., at most about 85% by weight, at most about 80% by weight or at most about 75% by weight) of at least one water soluble polar aprotic solvent (e.g., DMSO);

substrate. In some embodiments, the stripping method further includes forming a semiconductor device (e.g., an integrated circuit device such as a semiconductor chip) from the semiconductor substrate obtained by the method described above.

The semiconductor substrates to be stripped in this method have at least one photoresist (e.g., a positive or negative photoresist) that needs to be removed. Semiconductor substrates typically are constructed of silicon, silicon germanium, Group III-V compounds like GaAs, or any combination thereof. The semiconductor substrates may additionally contain exposed integrated circuit structures such as interconnect features like metal lines and dielectric materials. Metals and metal alloys used for interconnect features include, but are not limited to, aluminum, aluminum alloyed with copper, copper, titanium, tantalum, cobalt, nickel, silicon, polysilicon, titanium nitride, tantalum nitride, tin, tungsten, SnAg, SnAg/Ni, CuNiSn, CuCoCu, and CoSn. Said semiconductor substrate may also contain layers of interlayer dielectrics, silicon oxide, silicon nitride, silicon carbide, titanium oxide, and carbon doped silicon oxides.

The semiconductor substrate can be contacted with a stripping composition by any suitable method, such as placing the stripping composition into a tank and immersing and/or submerging the semiconductor substrate into the stripping composition, spraying the stripping composition onto the semiconductor substrate, streaming the stripping composition onto the semiconductor substrate, or any combinations thereof. In some embodiments, the semiconductor substrate is immersed into the stripping composition.

The stripping compositions of the present disclosure can be effectively used up to a temperature of about 90°C (e.g., from about 25°C to about 80°C, from about 30°C to about 60°C, or from about 40°C to about 60°C). For safety reasons, the maximum temperature is generally kept significantly below the flash points of the solvents being employed.

~~WHAT IS CLAIMED IS~~CLAIMS:

1. A composition, comprising:

1) at least one water soluble polar aprotic organic solvent;

2) at least one quaternary ammonium hydroxide;

3) at least one carboxylic acid;

4) at least one Group II metal cation;

5) at least one copper corrosion inhibitor selected from the group consisting of 6-substituted-2,4-diamino-1,3,5-triazines; and

6) water;

wherein the composition is free of an alcohol solvent and a compound comprising at least three hydroxyl groups.

2. The composition of claim 1 or 23, wherein the at least one quaternary ammonium hydroxide comprises a compound of the formula $[NR_1R_2R_3R_4]^+OH$, in which each of R_1, R_2, R_3, and R_4, independently, is a linear, branched, or cyclic alkyl group optionally substituted by hydroxy, a substituted or unsubstituted phenyl group, or a substituted or unsubstituted benzyl group.

3. The composition of claim 2, wherein each of R_1, R_2, R_3, and R_4, independently, is a C_1-C_4 alkyl group, a hydroxyethyl group, a phenyl group, or a benzyl group.

4. The composition of any one of claims 1-3 and 23, wherein the composition comprises the at least one quaternary ammonium hydroxide in an amount of from about 0.1 wt% to about 15 wt%.

5. The composition of any one of claims 1-4, wherein the at least one carboxylic acid is selected from the group consisting of monocarboxylic acids, bicarboxylic acids, tricarboxylic acids, α-hydroxyacids and β-hydroxyacids of

monocarboxylic acids, α-hydroxyacids and β-hydroxyacids of bicarboxylic acids, and α-hydroxyacids and β-hydroxyacids of tricarboxylic acids.

6. The composition of claim 5, wherein the at least one carboxylic acid comprises citric acid, maleic acid, fumaric acid, lactic acid, glycolic acid, oxalic acid, tartaric acid, succinic acid, or benzoic acid.

7. The composition of claim 6, wherein the at least one carboxylic acid comprises citric acid.

8. The composition of any one of claims 1-7, wherein the composition comprises the at least one carboxylic acid in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 1.5 wt%.

9. The composition of any one of claims 1-8, wherein the at least one Group II metal cation comprises Mg^{2+}, Ca^{2+}, Sr^{2+}, or Ba^{2+}.

10. The composition of claim 9, wherein the at least one Group II metal cation comprises Ca^{2+}.

11. The composition of any one of claims 1-10, wherein the composition comprises the at least one Group II metal cation in an amount of from ~~about~~ 5 ppm to ~~about~~ 40 ppm.

12. The composition of any one of claims 1-11 and 23, wherein the at least one copper corrosion inhibitor comprises a 6-substituted-2,4-diamino-1,3,5-triazine, the substituent at the 6-position being a linear or branched, substituted or unsubstituted C_1-C_{12} alkyl group, a substituted or unsubstituted C_3-C_{12} cycloalkyl group, a substituted or unsubstituted aryl group, $-SCH_2R^{100}$, $-N(R^{100}R^{101})$, or imidyl, in which each of R^{100} and R^{101}, independently, is a linear or branched, substituted or unsubstituted C_1-C_{12} alkyl group optionally containing a nitrogen or oxygen atom in the alkyl chain, a substituted or

unsubstituted C_3-C_{12} cycloalkyl group optionally containing a nitrogen or oxygen atom in the cycloalkyl ring, a substituted or unsubstituted aryl group, or R^{100} and R^{101}, together with the atom to which they are attached, form a ring.

13. The composition of claim 12, wherein the at least one copper corrosion inhibitor comprises 6-phenyl-2,4-diamino-1,3,5-triazine or 6-methyl-2,4-diamino-1,3,5-triazine.

14. The composition of any one of claims 1-13 and 23, wherein the composition comprises the at least one copper corrosion inhibitor in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 10 wt%.

15. The composition of any one of claims 1-14 and 23, wherein the at least one water soluble polar aprotic organic solvent comprises dimethyl sulfoxide, sulfolane, dimethylsulfone, N,N-dimethylformamide, N,N-dimethylacetamide, N-methylpyrrolidone, gamma-butyrolactone, propylene carbonate, 1,3-dimethyl-2-imidazolidinone, or a mixture thereof.

16. The composition of any one of claims 1-15 and 23, wherein the composition comprises the at least one water soluble polar aprotic organic solvent in an amount of from ~~about~~ 30 wt% to ~~about~~ 90 wt%.

17. The composition of any one of claims 1-16 and 23, wherein the composition comprises the water in an amount of from ~~about~~ 1 wt% to ~~about~~ 25 wt%.

18. The composition of any one of claims 1-17 and 23, further comprising at least one defoaming surfactant.

19. The composition of claim 18, wherein the composition comprises the at least one defoaming surfactant in an amount of from ~~about~~ 0.01 wt% to ~~about~~ 3 wt%.

~~20. The composition of claim 1, further comprising at least one alcohol solvent.~~

~~21. The composition of claim 20, wherein the at least one alcohol solvent comprises an alkane diol, a glycol, an alkoxyalcohol, a saturated aliphatic monohydric alcohol, an unsaturated non-aromatic monohydric alcohol, an alcohol containing a ring structure, or a mixture thereof.~~

~~22. The composition of claim 20, wherein the composition comprises the at least one alcohol solvent in an amount of from about 5 wt% to about 60 wt%.~~

~~23~~20. The composition of any one of claims 1~~-19~~ and 23, wherein the composition has a pH of at least ~~about~~ 13.

~~24~~21. The composition of claim 1, wherein the composition comprises dimethyl sulfoxide, tetramethylammonium hydroxide, citric acid, calcium citrate, 6-phenyl-2,4-diamino-1,3,5-triazine, a defoaming agent, and water.

~~25~~22. The composition of claim 1, wherein the composition comprises

dimethyl sulfoxide in an amount of from ~~about~~ 30 wt% to ~~about~~ 90 wt% of the composition;

tetramethylammonium hydroxide in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 15 wt% of the composition;

citric acid in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 1.5 wt% of the composition;

calcium citrate in an amount of from ~~about~~ 5 ppm to ~~about~~ 40 ppm of the composition;

6-phenyl-2,4-diamino-1,3,5-triazine in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 10 wt% of the composition;

a defoaming agent in an amount of from ~~about~~ 0.01 wt% to ~~about~~ 3 wt% of the composition; and

water in an amount of from ~~about~~ 1 wt% to ~~about~~ 25 wt% of the composition.

~~26~~23. A composition, comprising:

1) at least one water soluble polar aprotic organic solvent;

2) at least one quaternary ammonium hydroxide;

3) at least one copper corrosion inhibitor selected from the group consisting of 6-substituted-2,4-diamino-1,3,5-triazines; and

4) water;

wherein the composition is free of an alcohol solvent, a carboxylic acid, a Group II metal cation, and a compound comprising at least three hydroxyl groups.

~~27. The composition of claim 26, further comprising at least one defoaming surfactant.~~

~~28~~24. The composition of claim ~~27~~23, wherein the composition comprises dimethyl sulfoxide, tetramethylammonium hydroxide, 6-phenyl-2,4-diamino-1,3,5-triazine, a defoaming agent, and water.

~~29~~25. The composition of claim ~~28~~24, wherein the composition comprises

dimethyl sulfoxide in an amount of from ~~about~~ 30 wt% to ~~about~~ 90 wt% of the composition;

tetramethylammonium hydroxide in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 15 wt% of the composition;

6-phenyl-2,4-diamino-1,3,5-triazine in an amount of from ~~about~~ 0.1 wt% to ~~about~~ 10 wt% of the composition;

a defoaming agent in an amount of from ~~about~~ 0.01 wt% to ~~about~~ 3 wt% of the composition; and

water in an amount of from ~~about~~ 1 wt% to ~~about~~ 25 wt% of the composition.

~~30~~26. A method, comprising:

contacting a semiconductor substrate containing a photoresist or a photoresist residue with the composition of any one of claims 1-25 to remove the photoresist or photoresist residue.

~~31~~27. The method of claim ~~30~~26, further comprising rinsing the semiconductor substrate with a rinse solvent after the contacting step.

~~32~~28. The method of claim ~~31~~27, further comprising drying the semiconductor substrate after the rinsing step.

~~33. The method of claim 30, wherein the method does not substantially remove Cu or Al in the semiconductor substrate.~~