CLAIMS

What is claimed is:

1. An etching solution suitable for the selective removal of silicon-germanium over silicon from a microelectronic device comprising:

(i) water;

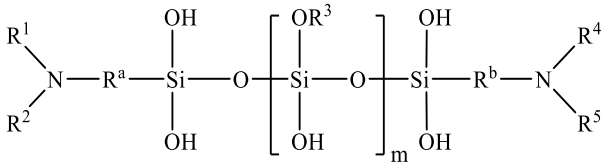
(ii) at least one oxidizer;

(iii) at least one fluoride ion source;

(iv) at least one polyfunctional acid;

(v) at least one corrosion inhibiting surfactant;

(vi) at least one silane silicon oxide etch inhibitor comprising 0.1 wt% to 3 wt % of silicic acid or a silicon-containing compound of Formula I:



Formula I

where (i) each of R^a and R^b is $-C_3H_6-$, (ii) each of R^1, R^2, R^4 and R^5 is -H and (iii) m= 0-20; and

(vii) optionally at least one water-miscible organic solvent.

2. The etching solution of claim 1, wherein the etching solution comprises 50 wt% to 90 wt % of water.

3. The etching solution of claim 1, wherein the oxidizer comprises 1.5 wt% to 20 wt % of one or more of hydrogen peroxide, periodic acid, potassium iodate, potassium permanganate, ammonium persulfate, ammonium molybdate, ferric nitrate, nitric acid, potassium nitrate, ammonia and mixtures thereof.

4. The etching solution of claim 1, wherein the etching solution comprises 10 wt% to 20 wt % of neat H_2O_2.

5. The etching solution of any of claim 1, wherein the fluoride ion source comprises 0.01 wt% to 8 wt % of one or more of hydrofluoric acid, ammonium fluoride, ammonium bifluoride, quaternary ammonium fluorides, fluoroborates, fluoroboric acid, tetrabutylammonium tetrafluoroborate, aluminum hexafluoride, and a fluoride salt of an aliphatic primary, secondary or tertiary amine having

the formula:

$$R^1NR^2R^3R^4F,$$

wherein R^1, R^2, R^3 and R^4 individually represent H or a (C_1-C_4) alkyl group.

6. The etching solution of claim 1, wherein the fluoride ion source comprises 0.01 wt% to 8 wt % of one or more of ammonium fluoride, ammonium bifluoride, tetramethylammonium fluoride, tetraethylammonium fluoride, methyltriethylammonium fluoride, tetrabutylammonium fluoride and combinations thereof.

7. The etching solution of claim 1, wherein the fluoride ion source comprises one or more of ammonium fluoride and ammonium bifloride.

8. The etching solution of claim 1, wherein the etching solution comprises 0.04 wt% to 2.5 wt % of neat NH_4F.

9. The etching solution of claim 1, wherein the at least one polyfunctional acid comprises 0.1 wt% to 5 wt % of one or more polyfunctional organic acid selected from the group of oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, citric acid, 2-methylpropane-1,2,3-triscarboxylic acid, benzene-1,2,3-tricarboxylic acid, propane-1,2,3-tricarboxylic acid, 1,cis-2,3-propenetricarboxylic acid, butane-1,2,3,4-tetracarboxylic acid, cyclopentanetetra-1,2,3,4-carboxylic acid, benzene-1,2,4,5-tetracarboxylic acid, benzenepentacarboxylic acid and benzenehexacarboxylic acid.

10. The etching solution of claim 1, wherein the etching solution comprises 0.1 wt% to 5 wt % of citric acid.

11. The etching solution of claim 1, wherein the at least one polyfunctional acid comprises 0.1 wt% to 5 wt % one or more polyfunctional inorganic acid selected from the group of boric acid, carbonic acid, phosphorous acid, phosphorous acid, silicic acid, sulfurous acid, sulfuric acid, phosphoric acid, pyrophosphoric acid and orthosilicic acid.

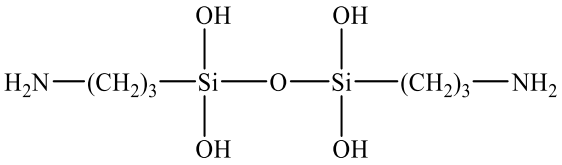
12. The etching solution of claim 1, wherein the etching solution comprises 0.1 wt% to 5 wt % of H_3PO_4.

13. The etching solution of claim 1, wherein the at least one corrosion inhibiting surfactant comprises 0.01 wt% to 3 wt % of one or more of a polyalkyleneimine, an acetylenic diol, a modified acetylenic diol, polypropylene glycols, polyethylene or polypropylene glycol ethers or mixtures thereof.

14. The etching solution of claim 1, wherein the at least one corrosion inhibiting surfactant comprises one or more of a polyethylene glycol, a polyethyleneimine and a zwitterionic surfactant.

15. The etching solution of claim 1, wherein the at least one silane silicon oxide etch inhibitor further comprises one or more of methyltrimethoxysilane, ethyltrimethoxysilane, triethoxy(ethyl)silane, vinyltrimethoxysilane, trimethoxyphenylsilane, triethoxymethylsilane, trimethoxy(octyl)silane, propyltrimethoxysilane, isobutyl(trimethoxy)silane, trimethoxysilane, n-propyltriethoxysilane, trimethoxy(octadecyl)silane, hexadecyltrimethoxysilane, methyl(tripropyl)silane, ethyl(tripropyl)silane and propyl(tripropyl)silane.

16. The etching solution of claim 1, wherein the etching solution comprises 0.1 wt% to 3 wt % of a silicon-containing compound having the following formula:



17. The etching solution of claim 1, comprises 1 wt% to 50 wt % of the at least one water-miscible solvent selected from the group of ethylene glycol, propylene glycol, butyl diglycol, 1,4-butanediol, tripropylene glycol methyl ether, dipropylene glycol monomethyl ether, propylene glycol propyl ether, diethylene gycol n-butyl ether, hexyloxypropylamine, poly(oxyethylene)diamine, dimethylsulfoxide, tetrahydrofurfuryl alcohol, glycerol, alcohols, sulfoxides, sulfolane and mixtures thereof.

18. The etching solution of claim 1, wherein the etching solution comprises 5 wt% to 50 wt % of propylene glycol.

19. The etching solution of claim 1, wherein the etching solution comprises 5 wt% to 50 wt % of dipropylene glycol monomethyl ether (DPM).

20. A method of selectively enhancing the etch rate of silicon-germanium relative to silicon on a microelectronic device comprising silicon and silicon-germanium, the method comprising the steps of:

(a) contacting a microelectronic (composite semiconductor) device including silicon and silicon-germanium with one or more etching solution of claim 1;

(b) rinsing the microelectronic (composite semiconductor) device after the silicon-germanium is at least partially removed; and

(c) optionally drying the microelectronic.