CLAIMS

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

water;

oxidizer;

water-miscible organic solvent selected from the group consisting of ethylene glycol, propylene glycol, butyl diglycol, 1,4-butanediol, tripropylene glycol methyl ether, dipropylene glycol monomethyl ether, propylene glycol propyl ether, diethylene glycol n-butyl ether, hexyloxypropylamine, poly(oxyethylene)diamine, dimethylsulfoxide, tetrahydrofurfuryl alcohol, glycerol, alcohols, sulfoxides, sulfolane, diols, glycol ethers, or mixtures thereof;

fluoride ion source;

surfactant; and

buffer composition comprising at least one of a polyfunctional organic acid, a salt of a polyfunctional organic acid or an amine compound.

2. The etching solution of claim 1 wherein the oxidizer is hydrogen peroxide.

3. The etching composition of claim 1 wherein the water-miscible solvent is selected from the group consisting of ethylene glycol, propylene glycol, butyl diglycol, 1,4-butanediol, tripropylene glycol methyl ether, dipropylene glycol monomethyl ether, propylene glycol propyl ether, diethylene glycol n-butyl ether, hexyloxypropylamine, poly(oxyethylene)diamine, dimethylsulfoxide, tetrahydrofurfuryl alcohol, glycerol, alcohols, sulfoxides, sulfolane, or mixtures thereof.

4. The etching composition of claim 3 wherein the water-miscible solvent is butyl diglycol.

5. The etching composition of claim 1 wherein the surfactant comprises polyalkyleneimine or acetylenic diols or modified acetylenic diols or mixtures thereof.

6. The etching composition of claim 5 wherein the polyalkyleneimine is polyethyleneimine.

7. The etching composition of claim 1 wherein the fluoride ion source is selected from the group consisting 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.

8. The etching composition of claim 7 wherein the fluoride ion source is selected from the group consisting of ammonium fluoride, ammonium bifluoride, tetramethylammonium fluoride, tetraethylammonium fluoride, methyltriethylammonium fluoride, and tetrabutylammonium fluoride.

9. The etching composition of claim 7 wherein said fluoride ion source comprises ammonium fluoride or ammonium bifluoride.

10. The etching composition of claim 1, wherein the buffer composition comprises an amine compound and a polyfunctional organic acid.

11. The etching composition of claim 10, wherein the amine compound comprises alkanolamine and the polyfunctional organic acid comprises polyprotic acids having at least three carboxylic acid groups.

12. The etching composition of claim 11, wherein the alkanolamine is selected from the group consisting of diethanolamine, di- and triisopropanolamine, 2-(2-aminoethylamino)ethanol, 2-(2-aminoethoxy)ethanol, triethanolamine, N-ethyl ethanolamine, N,N-dimethylethanolamine, N,N-diethyl ethanolamine, N-methyl diethanolamine, N-ethyl diethanolamine, cyclohexylaminediethanol, and mixtures thereof.

13. The etching composition of claim 11, wherein the polyprotic acid is selected from the group consisting of citric acid, 2-methylpropane-1,2,3-triscarboxylic, benzene-1,2,3-tricarboxylic [hemimellitic], propane-1,2,3-tricarboxylic [tricarballylic], 1,cis-2,3-propenetricarboxylic acid [aconitic], e.g., butane-1,2,3,4-tetracarboxylic, cyclopentanetetra-1,2,3,4-carboxylic, benzene-1,2,4,5-tetracarboxylic [pyromellitic], benzenepentacarboxylic, and benzenehexacarboxylic [mellitic], and mixtures thereof.

14. The etching composition of claim 1, wherein the buffer composition comprises an ammonium compound and a polyfunctional organic acid.

15. 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:

contacting the microelectronic device comprising silicon and silicon-germanium with an aqueous composition comprising: water; oxidizer; water-miscible organic solvent selected from the group consisting of ethylene glycol, propylene glycol, butyl diglycol, 1,4-butanediol, tripropylene glycol methyl ether, dipropylene glycol monomethyl ether, propylene glycol propyl ether, diethylene glycol n-butyl ether, hexyloxypropylamine, poly(oxyethylene)diamine, dimethylsulfoxide, tetrahydrofurfuryl alcohol, glycerol, alcohols, sulfoxides, sulfolane, diols, glycol ethers, or mixtures thereof; fluoride ion source; a surfactant; and buffer composition comprising at least one of a polyfunctional organic acid, a salt of a polyfunctional organic acid or an amine compound; and

rinsing the microelectronic device after the silicon-germanium is at least partially removed, wherein the selectivity of the etch for silicon-germanium over silicon is greater than about 10.

16. The method of claim 15 further comprising the step of drying the semiconductor device.

17. The method of claim 15 wherein the selectivity of the etch for silicon-germanium over silicon is greater than 15.

18. The method of claim 15 wherein the contacting step is performed at a temperature of from about 25 °C to about 100 °C.

19. The method of claim 15 wherein the water-miscible solvent is butyl diglycol.

20. The method of claim 15 wherein the surfactant comprises polyalkyleneimine.

21. The method of claim 15 wherein the fluoride ion source is selected from the group consisting of hydrofluoric acid, ammonium fluoride, quaternary ammonium fluorides such as, for example, 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.

22. The method of claim 20 wherein the fluoride ion source is selected from the group consisting of ammonium fluoride, ammonium bifluoride, tetramethylammonium fluoride, tetraethylammonium fluoride, methyltriethylammonium fluoride, and tetrabutylammonium fluoride.