**CLAIMS**

**1.** An etching composition suitable for the ~~selective~~ removal of titanium nitride ~~over~~ and molybdenum from a microelectronic device, comprising

**(a)** about 10 wt% to about 80 wt% water;

**(b)** about 0.5 wt% to about 15 wt% neat $HNO_3$;

**(c)** a base ~~that is~~ comprising one or more of

**(i)** about 1 wt% to about 7 wt% of one or more alkanolamine; and

**(ii)** about 0.7 wt% to about 2 wt% of neat $NH_4OH$; and

**(d)** a halogen ion source ~~that is~~comprising one or more of

**(i)** about 1 wt% to about 30 wt% of one or more chloride ion source; and

**(ii)** about 0.02 wt% to about 0.15 wt% of one or more fluoride ion source.

**2.** The etching composition of claim 1, wherein the halogen ion source ~~that is~~ comprising one or more of:

**(i)** about 3 wt% to about 30 wt% $NH_4Cl$;

**(ii)** about 1 wt% to about 25 wt% of neat HCl;

**(iii)** about 0.02 wt% to about 0.15 wt% of neat HF; and

**(iv)** about 0.02 wt% to about 0.15 wt% of neat $NH_4F$.

**3.** The etching composition of claim 1, wherein the base comprises about 1 wt% to about 7 wt% of alkanolamine.

**4.** The etching composition of claim 1, wherein the base comprises about 0.7 wt% to about 2 wt% of neat $NH_4OH$.

~~**5.** The etching composition of claim 1, wherein the halogen ion source comprises about 3 wt% to about 30 wt% $NH_4Cl$.~~

~~**6.** The etching composition of claim 1, wherein the halogen ion source comprises about 1 wt% to about 21 wt% of neat HCl.~~

~~**7.** The etching composition of claim 1, wherein the halogen ion source comprises about 0.02 wt% to about 0.15 wt% of neat HF.~~

~~**8.** The etching composition of claim 1, wherein the halogen ion source comprises about 0.02 wt% to about 0.15 wt% of neat $NH_4F$.~~

~~**9**~~**5.** The etching composition of ~~any of claims 1-8~~claim 1, wherein the base is one or more alkanolamine selected from the group of N-methylethanolamine (NMEA), monoethanolamine (MEA), diethanolamine, mono-, 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.

~~**10.** The etching composition of any of claims 1-8, wherein the base is one or more alkanolamine selected from the group of triethanolamine (TEA), diethanolamine, N-methyl diethanolamine, diisopropanolamine, monoethanol amine, amino(ethoxy) ethanol (AEE), N-methyl ethanol amine, monoisopropanol amine, cyclohexylaminediethanol, and mixtures thereof.~~

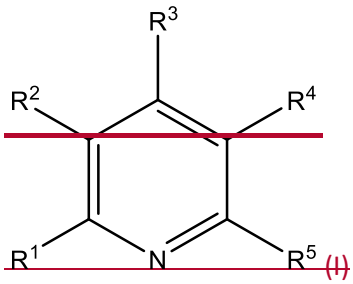
~~**11**~~**6.** The etching composition of ~~any of claims 1-8~~claim 1, wherein the base comprises amino(ethoxy) ethanol.

~~**12**~~**7.** The etching composition of ~~any of claims 1-8~~claim 1 further comprising about 70 wt % and about 80 wt % of neat acetic acid.

~~**13**~~**8.** The etching composition of ~~any of claims 1-8~~claim 1 further comprising at least one heteroaromatic compound.

~~**14.** The etching composition of any of claims 1-8 further comprising at least one heteroaromatic compound that is a six-membered heteroaromatic ring having one or more nitrogen atoms as one or more heteroatoms constituting the ring.~~

~~**15.** The etching composition of any of claims 1-8 further comprising at least one heteroaromatic compound that is a six-membered heteroaromatic ring having one or more nitrogen atoms as one or more heteroatoms constituting the ring comprises a pyridine compound represented by Formula (I):~~



~~(I)~~

~~wherein $R^1$ to $R^5$ each independently represent hydrogen, an amino group-containing substituent, or a hydrocarbon derivation group which is other than any amino group-containing substituent and has 1 to 10 carbon atoms, provided that at least one of $R^1$ to $R^5$ represents the amino group-containing substituent; and these substituents may be bonded to one another to form a cyclic structure.~~

~~**16.** The etching composition of any of claims 1-8 further comprising at least one heteroaromatic compound that is a six-membered heteroaromatic ring having one or more nitrogen atoms as one or more heteroatoms constituting the ring selected from the group of 3-aminopyridine, 2-aminopyridine, 4-~~

~~aminopyridine, 2-amino-3-methylpyridine, 2-amino-4-methylpyridine, 2-amino-5-methylpyridine, 2-(aminomethyl)pyridine, 3-amino-4-methylpyridine, 5-amino-2-methylpyridine, 4-amino-3-methylpyridine, 3-amino-2-methylpyridine, 4-amino-2-methylpyridine, 3-amino-5-methylpyridine, 2-(methylamino)pyridine, 4-(methylamino)pyridine, 3-(aminomethyl)pyridine, 4-(aminomethyl)pyridine, 2,3-diaminopyridine, 3,4-diaminopyridine, 2,6-diaminopyridine, 2-amino-5-cyanopyridine, 2-amino-3-cyanopyridine, 2-aminopyridine-3-carboxyaldehyde, pyridine-2-carboxamide, 2-amino-4,6-dimethylpyridine, 4-(2-aminoethyl)pyridine, 3-(2-aminoethyl)pyridine, 2-(2-aminoethyl)pyridine, 4-dimethylaminopyridine, 2-dimethylaminopyridine, 2-(ethylamino)pyridine, 2-amino-3-(hydroxymethyl)pyridine, 4-acetamidopyridine, 2-acetamidopyridine, 3-acetamidopyridine, 4-(ethylaminomethyl)pyridine, 2-aminoquinoline, 3-aminoquinoline, 5-aminoquinoline, 6-aminoquinoline, 8-aminoquinoline, 4-dimethylamino-1-neopentylpyridinium chloride and mixtures thereof.~~

~~**17.** The etching composition of any of claims 1-8 further comprising at least one heteroaromatic compound that is a six-membered heteroaromatic ring having one or more nitrogen atoms as one or more heteroatoms constituting the ring selected from the group of 2-aminopyridine, 2,6-diaminopyridine, 2-(aminomethyl)pyridine, 2,6-(aminomethyl)pyridine, 2,6-(aminoethyl)pyridine, 2-amino-4-picoline, 2,6-diamino-4-picoline, 2-amino-3,5-lutidine, 2-aminoquinoline, 8-aminoquinoline, 2-aminoisoquinoline, acriflavine, 4-aminophenanthridine, 4,5-(aminomethyl)phenothiazine, 4,5-(aminomethyl)dibenzoxazine, 10-amino-7,8-benzoquinoline, bis(2-pyridylmethane)amine, tris(2-pyridyl)amine, bis(4-(2-pyridyl)-3-azabutane)amine, bis(N,N-(2-(2-pyridyl)ethane)aminomethane)amine, 4-(N,N-dialkylaminomethyl)morpholine and mixtures thereof.~~

~~**18.** The etching composition of any of claims 1-8 further comprising at least one heteroaromatic compound that is a six-membered heteroaromatic ring having one or more nitrogen atoms as one or more heteroatoms constituting the ring comprising 8-aminoquinoline.~~

~~**19**~~**9.** The etching composition of ~~any of claims 1-8~~claim 1 further comprising at least one water-miscible solvent selected from the group of diethylene glycol butyl ether, sulfolane, and propylene carbonate.

~~**20.** The etching composition of any of claims 1-8 further comprising diethylene glycol butyl ether.~~

~~**21.** The etching composition of any of claims 1-8 further comprising sulfolane.~~

~~**22.** The etching composition of any of claims 1-8 further comprising propylene carbonate.~~

~~**23**~~**10.** The etching composition of ~~any of claims 1-8~~claim 1 further comprising (i) 8-aminoquinoline and (ii) at least one water-miscible solvent selected from the group of diethylene glycol butyl ether, sulfolane and propylene carbonate.

~~**24.** The etching composition of any of claims 1-8, wherein the composition has a titanium nitride~~

~~molybdenum metal etch selectivity ratio of from about 1:3 to about 15.1:1.~~

~~25~~11. The etching composition of claim 1, wherein the composition comprises

**(a)** about 60 wt% to about 70 wt% water;

**(b)** about 4.8 wt% of neat $HNO_3$;

**(c)** a base comprising about 1 wt % of amino(ethoxy) ethanol; and

**(d)** a halogen ion source comprising

**(i)** about 27 wt% $NH_4Cl$;

**(ii)** about 2.1 wt% neat of HCl; and

**(iii)** about 0.025 wt% of neat HF.

~~26~~12. The etching composition of claim 1, wherein the composition comprises

**(a)** about 60 wt% to about 71 wt% water;

**(b)** about 4.8 wt% of neat $HNO_3$;

**(c)** a base comprising about 1 wt % of amino(ethoxy) ethanol; and

**(d)** a halogen ion source comprising

**(i)** about 22.5 wt% $NH_4Cl$;

**(ii)** about 1.05 wt% of neat HCl; and

**(iii)** about 0.025 wt% of neat HF.

~~27~~13. The etching composition of claim 1, wherein the composition comprises

**(a)** about 60 wt% to about 72 wt% water;

**(b)** about 9.6 wt% of neat $HNO_3$;

**(c)** a base comprising about 2 wt % of amino(ethoxy) ethanol; and

**(d)** a halogen ion source comprising

**(i)** about 16.5 wt% $NH_4Cl$; and

**(ii)** about 0.02 wt% of neat HF.

~~28~~14. The etching composition of claim 1, wherein the composition comprises

**(a)** about 60 wt% to about 70 wt% water;

**(b)** about 9.6 wt% of neat $HNO_3$;

**(c)** a base comprising about 2 wt % of amino(ethoxy) ethanol; and

**(d)** a halogen ion source comprising

**(i)** about 20 wt% $NH_4Cl$; and

**(ii)** about 0.035 wt% of neat HF.

~~29~~15. The etching composition of claim 1, wherein the composition comprises

**(a)** about 60 wt% to about 70 wt% water;

**(b)** about 9.6 wt% of neat $HNO_3$;

**(c)** a base comprising about 0.7 wt % of neat $NH_4OH$; and

**(d)** a halogen ion source comprising

**(i)** about 20 wt% $NH_4Cl$; and

**(ii)** about 0.035 wt% of neat HF.

~~30~~16. The etching composition of claim 1, wherein the composition comprises

**(a)** about 70 wt% to about 80 wt% water;

**(b)** about 0.6 wt% of neat $HNO_3$;

**(c)** a base comprising about 1.45 wt % of neat $NH_4OH$; and

**(d)** a halogen ion source comprising

**(i)** about 21 wt% neat HCl; and

**(ii)** about 0.12 wt% of neat $NH_4F$.

~~31~~17. The etching composition of claim 1, wherein the composition comprises

**(a)** about 10 wt% to about 15 wt% water;

**(b)** about 4.8 wt% of neat $HNO_3$;

**(c)** a base comprising about 7 wt % of amino(ethoxy) ethanol;

**(d)** a halogen ion source comprising about 0.05 wt% of neat HF; and

**(e)** about 75 wt % of neat acetic acid.

~~32~~18. The etching composition of claim 1, wherein the composition comprises

**(a)** about 10 wt% to about 15 wt% water;

**(b)** about 4.8 wt% of neat $HNO_3$;

**(c)** a base comprising about 6 wt % of amino(ethoxy) ethanol;

**(d)** a halogen ion source comprising about 0.05 wt% of neat HF; and

**(e)** about 76 wt % of neat acetic acid.

~~33~~19. The etching composition of claim 1, wherein the composition comprises

**(a)** about 10 wt% to about 15 wt% water;

**(b)** about 4.8 wt% of neat $HNO_3$;

**(c)** a base comprising about 6 wt % of amino(ethoxy) ethanol;

**(d)** a halogen ion source comprising about 0.04 wt% of neat HF; and

**(e)** about 78 wt % of neat acetic acid.

~~34~~20. The etching composition of claim 1, wherein the composition comprises

**(a)** about 10 wt% to about 15 wt% water;

**(b)** about 9 wt% of neat $HNO_3$;

**(c)** a base comprising about 2.03 wt % of neat $NH_4OH$;

**(d)** a halogen ion source comprising about 0.05 wt% of neat HF; and

**(e)** about 77 wt % of ~~sulfolone~~sulfolane.

~~**35.** An etching composition suitable for the selective removal of titanium nitride over molybdenum from a microelectronic device, comprising~~

~~**(a)** about 88 wt% to about 96 wt% water;~~

~~**(b)** about 2 wt% to about 15 wt% of neat $HNO_3$;~~

~~**(c)** a halogen ion source comprising about 0.02 wt% to about 0.10 wt% of one or more fluoride ion source;~~

~~**(d)** about 70 wt% to about 95 wt% of one or more water-miscible solvents selected from diethyl glycol butyl ether, sulfolane and propylene carbonate.~~

~~**36.** The etching composition of claim 35, wherein the halogen ion source comprises about 0.02 wt% to about 0.10 wt% of neat HF.~~

~~**37.** The etching composition of claim 35, wherein the halogen ion source comprises about 0.05 of neat HF.~~

~~**38.** The etching composition of claim 35, wherein the one or more water-miscible solvents comprises about 70 wt% to about 80 wt% of diethyl glycol butyl ether.~~

~~**39.** The etching composition of claim 35, wherein the one or more water-miscible solvents comprises about 70 wt% to about 80 wt% of sulfolane.~~

~~**40.** The etching composition of claim 35, wherein the one or more water-miscible solvents comprises about 85 wt% to about 95 wt% of propylene carbonate.~~

~~**41.** The etching composition of claim 35, further comprising 8-aminoquinoline.~~

~~**42.** The etching composition of claim 35, further comprising triethanolamine.~~

~~**43.** The etching composition of claim 35, comprising~~

~~**(a)** about 90 wt% to about 92 wt% water;~~

~~**(b)** about 12 wt% of neat $HNO_3$;~~

~~**(c)** a halogen ion source comprising about 0.05 wt% of HF;~~

**(d)** about 79 wt% of diethyl glycol butyl ether.

**44.** The etching composition of claim 35, comprising

**(a)** about 88 wt% to about 90 wt% water;

**(b)** about 15 wt% of neat $HNO_3$;

**(c)** a halogen ion source comprising about 0.05 wt% of HF;

**(d)** about 74 wt% of of diethyl glycol butyl ether; and

**(e)** about 0.05 wt% of 8-aminoquinoline.

**45.** An etching composition suitable for the selective removal of titanium nitride over molybdenum from a microelectronic device, comprising

**(a)** about 4 wt% to about 5 wt% water;

**(b)** about 2.0 to about 3.0 wt% of neat $HNO_3$;

**(c)** a halogen ion source comprising about 0.10 wt% to about 0.12 wt% of HF;

**(d)** about 90 wt% to about 93 wt% of propylene carbonate; and

**(e)** about 0.4 wt% to about 0.6 wt% of triethanolamine.

**46.** The etching composition of claim 45, comprising

**(a)** about 4 wt% to about 5 wt% water;

**(b)** about 2.4 of neat $HNO_3$;

**(c)** a halogen ion source comprising about 0.12 wt% of HF;

**(d)** about 92 wt% to about 93 wt% of propylene carbonate; and

**(e)** about 0.6 wt% of triethanolamine.

**47.** An etching composition suitable for the selective removal of titanium nitride over molybdenum from a microelectronic device, comprising

**(a)** about 35 wt% to about 50 wt% water;

**(b)** about 6.0 to about 12.0 wt% of neat $HNO_3$;

**(c)** a base comprising about 15 wt% to about 45 wt% of $NH_4H_2PO_4$; and

**(d)** a halogen ion source comprising one or more of (i) about 1 wt% to about 7.5 wt% of neat HCl and (ii) about 2.5 wt% to about 5 wt% $NH_4Cl$.

**48.** The etching composition of claim 47, comprising

**(a)** about 44 wt% to about 45 wt% water;

**(b)** about 12.0 wt% of neat $HNO_3$;

**(c)** a base comprising about 40 wt% of $NH_4H_2PO_4$; and

**(d)** a halogen ion source comprising about 3.0 wt% to about 3.5 wt% of neat HCl.

**49.** The etching composition of claim 47, comprising

**(a)** about 46 wt% to about 48 wt% water;

**(b)** about 6.0 wt% of neat $HNO_3$;

**(c)** a base comprising about 40 wt% of $NH_4H_2PO_4$; and

**(d)** a halogen ion source comprising about 6.5 wt% to about 7.5 wt% of neat HCl.

**50.** The etching composition of claim 47, comprising

**(a)** about 46 wt% to about 48 wt% water;

**(b)** about 9.0 wt% of neat $HNO_3$;

**(c)** a base comprising about 45 wt% of $NH_4H_2PO_4$; and

**(d)** a halogen ion source comprising (i) about 5 wt% to about 5.5 wt% of neat HCl and (ii) about 2.5 wt% to about 3.5 wt% $NH_4Cl$.

**51.** An etching composition suitable for the selective removal of titanium nitride over molybdenum from a microelectronic device, comprising

**(a)** about 35 wt% to about 80 wt% water;

**(b)** about 0.1 wt% to about 5 wt% neat $HNO_3$;

**(c)** a base that includes one or more of:

**(i)** about 1 wt% to about 7 wt% of one or more alkanolamine, and

**(ii)** about 0.7 wt% to about 2 wt% of neat $NH_4OH$; and

**(d)** a halogen ion source that includes one or more of:

**(i)** about 3 wt% to about 30 wt% $NH_4Cl$,

~~**(ii)** about 1 wt% to about 21 wt% of neat HCl,~~

~~**(iii)** about 0.02 wt% to about 0.15 wt% of neat HF, and~~

~~**(iv)** about 0.02 wt% to about 0.15 wt% of neat $NH_4F$.~~

~~52~~**21.** A method of selectively enhancing the etch rate of titanium nitride and molybdenum on a composite semiconductor device comprising titanium nitride and molybdenum, the method comprising the step of:

(i) contacting the composite semiconductor device comprising titanium nitride and molybdenum with a composition of ~~any of claims 1-51~~claim 1,

wherein the titanium nitride is selectively etched over the molybdenum metal at a ratio of from about 1:3 to about 15.1:1.