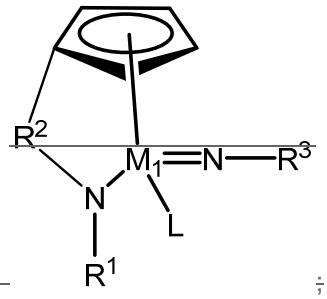
CLAIMS

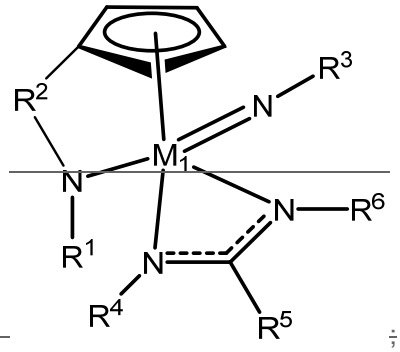
1. A precursor having a chemical structure selected from the group consisting of:

A



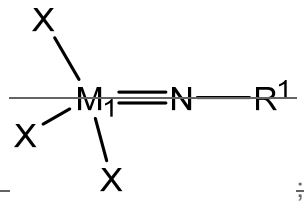
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B



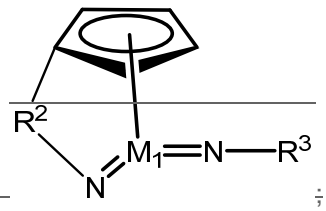
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C



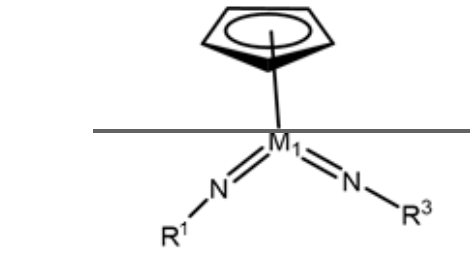
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D



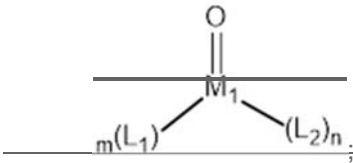
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E



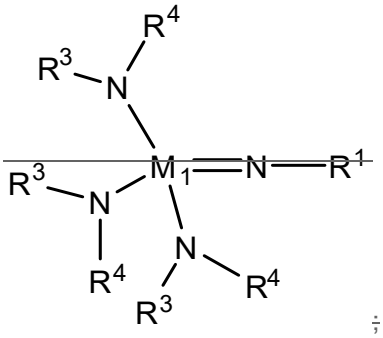
;

F



; and

G



;

wherein:

M_1 is selected from the group consisting of vanadium, tantalum, niobium, chromium, molybdenum and tungsten;

X is a halide selected from chloride (Cl), bromide (Br) and iodide (I);

R^1 is a linear or branched C_1-C_{10} alkyl, an amino group or an ether group for A and B; and is a linear or branched C_1-C_{10} alkyl, an amino group or an ether group but not tert-butyl for C and G;

R^2 is a linear or branched C_2-C_{10} alkylene;

R^3, R^4 and R^6 are independently selected from the group consisting of a linear or branched C_1-C_{10} alkyl, an amino group and an ether group;

~~R^5 is selected from the group consisting of hydrogen and a linear or branched C_1-C_{10} alkyl;~~

~~L is selected from the group consisting of R^1, OR^1 and NR^1R^3;~~

~~L_1 is a substituted or unsubstituted cyclopentadienyl ligand;~~

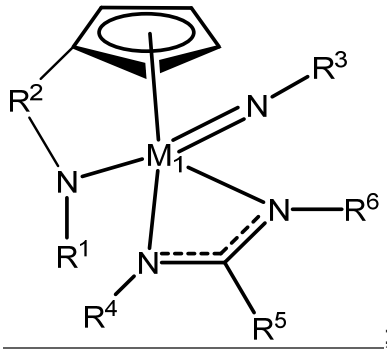
~~L_2 is NR^1R^3;~~

~~m has a value of 0, 1 or 2; and~~

~~n has a value of 1, 2, 3 or 4.~~

~~2.~~1. ~~The~~ A precursor ~~of claim 1, wherein the precursor has the~~having a chemical structure B:

B

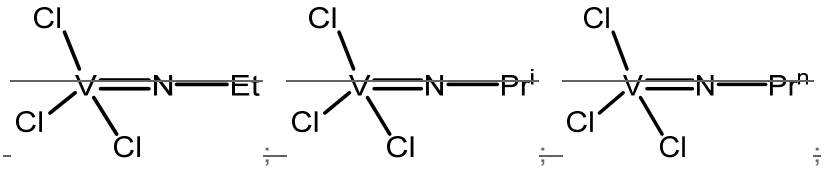


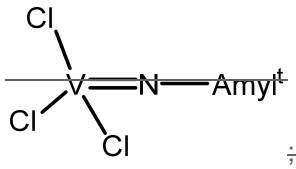
;

wherein M_1 is vanadium; R^2 is a linear C_2 alkylene; R^1 and R^3 are methyl; R^5 is hydrogen and R^4 and R^6 are selected from the same linear C_1 to C_2 alkyl.

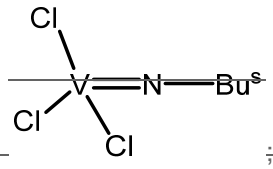
~~3. The precursor of claim 1, wherein the precursor has the structure C; wherein: M_1 is vanadium; and R^1 is selected from the group consisting of sec-butyl (Bu^s) and tert-amyl ($Amyl^t$).~~

~~4. The precursor of claim 1, wherein the precursor has structure C and is selected from the group consisting of :~~

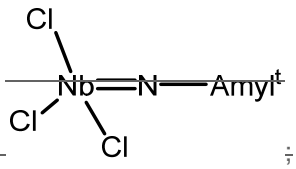




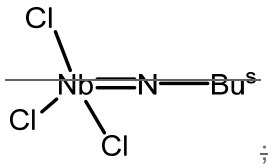
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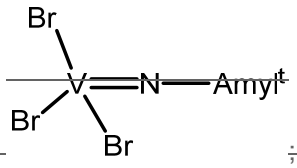
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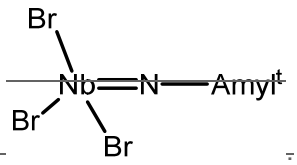
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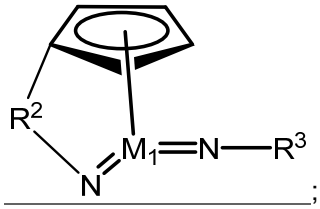
; and



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5.2. The A precursor of claim 1, wherein the precursor has thehaving a chemical structure D:

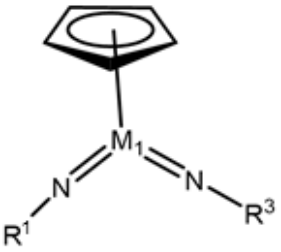
D



;

wherein: M_1 is vanadium; R^2 is a linear or branched C_2 to C_3 alkylene and R^3 is a linear C_1 to C_2 alkyl.

6.3. The A precursor of claim 1, wherein the precursor has thehaving a chemical structure E:



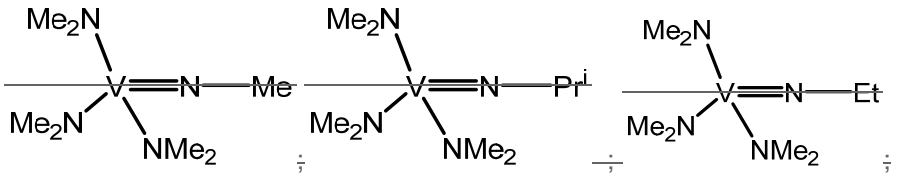
;

wherein: M_1 is vanadium; and R^1 and R^3 are selected from the same linear or branched chin C_1 to C_3 alkyl.

7. The precursor of claim 1, wherein the precursor has the structure F; wherein m has a value of zero, n has a value of 3 and R^1 and R^3 are independently selected from the group consisting of methyl and ethyl groups.

~~8. The precursor of claim 1, wherein the precursor has the structure F; wherein m has a value of 1, n has a value of 2 and R^1 and R^3 are independently selected from the group consisting of methyl and ethyl groups.~~

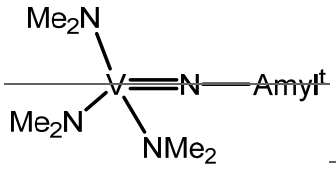
~~9. The precursor of claim 1, wherein the precursor has the structure G and is selected from the group consisting of :~~



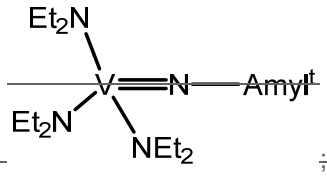
~~;~~

~~;~~

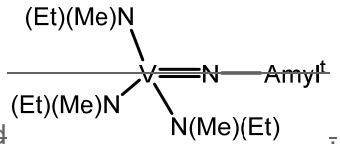
~~;~~



~~;~~



~~; and~~



~~.~~

~~10. The precursor of claim 1, wherein the precursor is selected from the group consisting of trichloro(tert-amylimino)vanadium; trichloro(sec-butylimino)vanadium; and tert-amylimino-tris(dimethylamino)vanadium.~~

~~11.~~4. The precursor of any one of claims 1 to 3~~claim 1~~, wherein at least one cyclopentadienyl ligand is bound to a transition metal in η^5-coordination by π bonding.

~~12.~~5. The precursor of any one of claims 1 to 3~~claim 1~~, wherein the precursor is substantially free of halide ions, metal impurities, or both of halide ions and metal impurities.

~~13.~~6. The precursor of any one of claims 1 to 3~~claim 1~~, wherein the precursor has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.

~~14.~~7. The precursor of any one of claims 1 to 3~~claim 1~~, wherein the precursor is in a liquid form at ambient temperature.

~~15. The precursor of claim 1, wherein the precursor has chemical structure selected from the group consisting of B, C, D, E, F, and G.~~

~~16.~~8. A composition comprising the precursor of any one of claims 1 to 3~~claim 1~~ and a solvent therefor.

~~17.~~9. The composition of claim ~~16~~8, wherein the solvent is a hydrocarbon solvent selected from the group consisting of an ether, a tertiary amine, an alkyl hydrocarbon, an aromatic hydrocarbon, a siloxane, a tertiary aminoether, and combinations thereof.

~~18.~~10. The composition of claim ~~16~~8, wherein the organometallic compound and the hydrocarbon solvent each comprise a boiling point, wherein a difference between the boiling point of the organometallic compound and the boiling point of the solvent is less than 40 degrees Celsius; 30 degrees Celsius; 20 degrees Celsius; or 10 degrees Celsius.

~~19.~~11. The composition of claim ~~16~~8, wherein the composition has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.

~~20.~~12. The composition of claim ~~16~~8, wherein the composition is in a liquid form at ambient temperature.

~~21.~~13. The composition of claim ~~16~~8, further comprising a melting point depression additive comprising a low volatility inert substance selected from the group consisting of a long chain, branched or cyclic saturated hydrocarbon C_nH_{n+2}, wherein n has a value of 10 to about 20; a substituted arene; an organoamine; an aminoether; an ether; and combinations thereof.

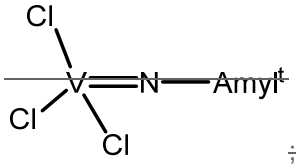
~~22.~~14. A method for forming a transition metal-containing film on at least one surface of a substrate comprising:

a. providing the at least one surface of the substrate in a reaction chamber;

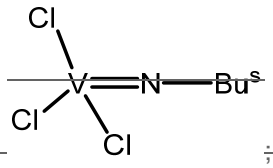
b. forming a transition metal-containing film on the at least one surface by a deposition process chosen from a chemical vapor deposition process and an atomic layer

deposition process using the precursor of any one of claims 1 to 3~~claim 1~~ or the composition of claim ~~16~~ 8 as a metal source compound for the deposition process.

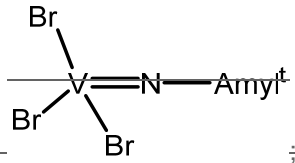
~~23. The method of claim 22, wherein the precursor of claim 1 or the precursor of the composition of claim 16 in step b is selected from the group consisting of~~



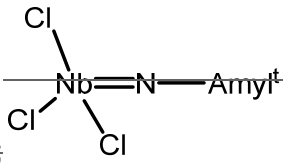
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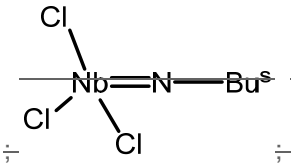
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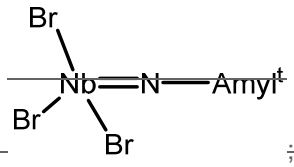
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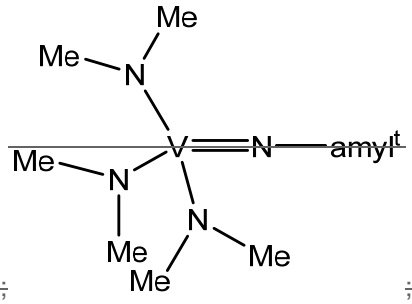
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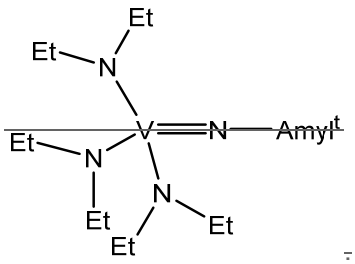
;



;



; ~~and~~



.

~~24.~~15. The method of claim ~~22~~14, wherein the precursor of any one of claims 1 to 3~~claim 1~~ or the precursor in the composition of claim ~~16~~ 8 is in a liquid form at ambient temperature; and has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.

~~25. The method of claim 22, wherein the precursor of claim 1 or the precursor in the composition of claim 16 in step b is selected from the group consisting of trichloro(tert-amylimino)Vanadium, trichloro(sec-butylimino)vanadium, and tert-amylimino-tris(dimethylamino)vanadium; and the transition metal-containing film is vanadium- containing film.~~

26.16. The method of claim 2214, further comprising introducing into the reaction chamber at least one oxygen-containing source selected from the group consisting of water, diatomic oxygen, hydrogen peroxide, oxygen plasma, ozone, NO, N_2O, NO_2, carbon monoxide, carbon dioxide and combinations thereof.

27.17. The method of claim 2214, further comprising introducing into the reaction chamber at least one nitrogen-containing source selected from the group consisting of ammonia, hydrazine, monoalkylhydrazine, dialkylhydrazine, nitrogen, nitrogen/hydrogen, ammonia plasma, nitrogen plasma, nitrogen/hydrogen plasma, and combinations thereof.

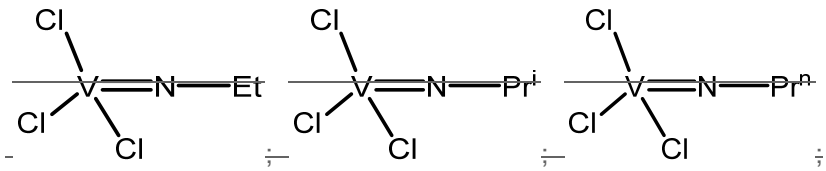
28.18. The method of claim 2214, further comprising introducing into the reaction chamber at least one reducing agent source selected from the group consisting of hydrogen, hydrogen plasma, a mixture of hydrogen and helium, a mixture of hydrogen and argon, hydrogen/helium plasma, hydrogen/argon plasma, boron-containing compounds, silicon-containing compounds and combinations thereof.

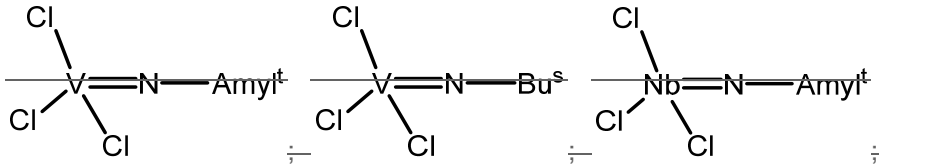
29.19. The method of claim 2214, further comprising introducing into the reaction chamber at least one purge gas selected from the group consisting of argon (Ar), nitrogen (N_2), helium (He), neon, and combinations thereof.

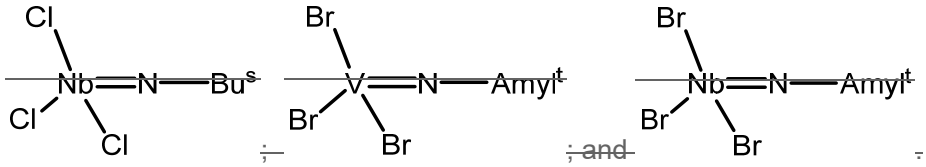
30. The method of claim 27, wherein the precursor of claim 1 or the precursor in the composition of claim 16 in step b is selected from the group consisting of trichloro(tert-amylimino)Vanadium, trichloro(sec-butylimino)vanadium, and tert-amylimino-tris(dimethylamino)vanadium; the nitrogen-containing source is ammonia; and the transition metal-containing film is vanadium nitride film.

31.20. The method of claim 2214, wherein the solvent in the composition of claim 16 8 is selected from the group consisting of: toluene, mesitylene, isopropylbenzene, 4-isopropyl toluene, 1,3-diisopropylbenzene, octane, dodecane, 1,2,4-trimethylcyclohexane, n-butylcyclohexane, and decahydronaphthalene and combinations thereof.

32. The method of claim 22, wherein step b comprises introducing into the reaction chamber the precursor of claim 1 or the precursor in the composition of claim 16 selected from the group consisting of :

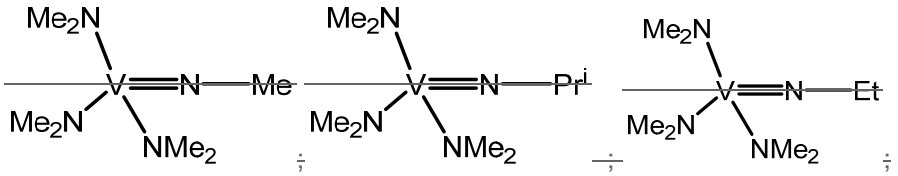


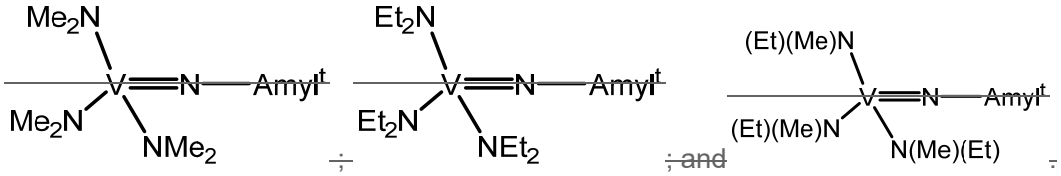




33. The method of claim 32, wherein the precursor of claim 1 or the precursor in the composition of claim 16 is in a liquid form at ambient temperature and has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.

34. The method of claim 22, wherein step b comprises introducing into the reaction chamber the precursor of claim 1 or the precursor in the composition of claim 16 selected from the group consisting of :





~~35. The method of claim 34, wherein the precursor of claim 1 or the precursor in the composition of claim 16 is in a liquid form at ambient temperature and has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.~~

~~36.~~21. A method of forming a transition metal-containing film via an atomic layer deposition process or ALD-like process, the method comprising the steps of:

a. providing a substrate in a reaction chamber;

b. introducing into the reaction chamber the precursor of any one of claims 1 to 3~~claim 1~~ or the composition of claim ~~16~~8;

c. purging the reaction chamber with a first purge gas;

d. introducing into the reaction chamber a source gas;

e. purging the reaction chamber with a second purge gas;

f. performing the step b after the step a;

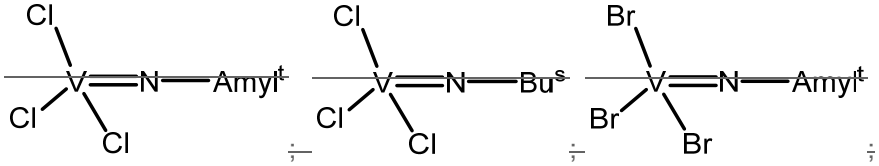
g. performing the step c after the step b;

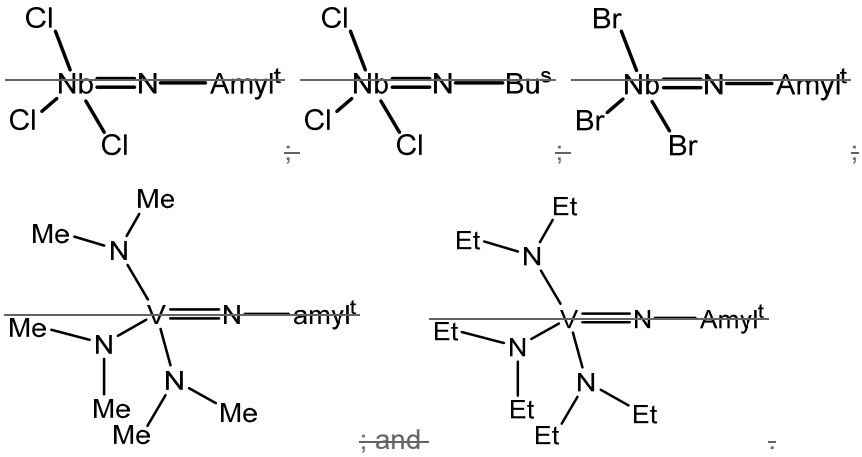
h. performing the step d after the step c;

i. performing the step e after the step d;

j. repeating the steps b through e until a desired thickness of the transition metal-containing film is obtained.

~~37. The method of claim 36, wherein the precursor of claim 1 or the precursor in the composition of claim 16 in step b is selected from the group consisting of~~





~~38. The method of claim 36, wherein the precursor of claim 1 or the precursor in the composition of claim 16 in step b is selected from the group consisting of trichloro(tert-amylimino)Vanadium, trichloro(sec-butylimino)vanadium, and tert-amylimino-tris(dimethylamino)vanadium; and the transition metal-containing film is vanadium- containing film.~~

~~39.~~22. The method of claim ~~36~~21, wherein the source gas is selected from the group consisting of: an oxygen-containing source gas selected from water, diatomic oxygen, hydrogen peroxide, oxygen plasma, ozone, NO, N_2O, NO_2, carbon monoxide, carbon dioxide, and combinations thereof.

~~40.~~23. The method of claim ~~36~~21, wherein the source gas is selected from the group consisting of: a nitrogen-containing source gas selected from ammonia, hydrazine, monoalkylhydrazine, dialkylhydrazine, nitrogen, nitrogen/hydrogen, ammonia plasma, nitrogen plasma, nitrogen/hydrogen plasma, and combinations thereof.

~~41. The method of claim 40, wherein the precursor of claim 1 or the precursor in the composition of claim 16 in step b is selected from the group consisting of trichloro(tert-amylimino)Vanadium, trichloro(sec-butylimino)vanadium, and tert-amylimino-tris(dimethylamino)vanadium; the nitrogen-containing source is ammonia; and the transition metal-containing film is vanadium nitride film.~~

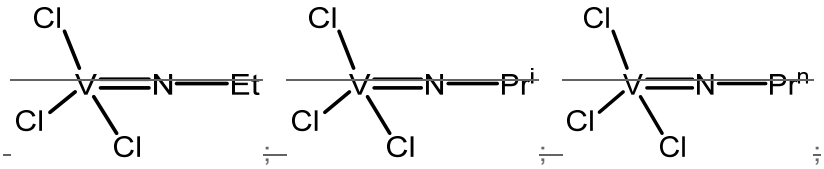
42.24. The method of claim 3621, wherein the first and second purge gases are selected from the group consisting of: argon, nitrogen, helium, neon, and combinations thereof.

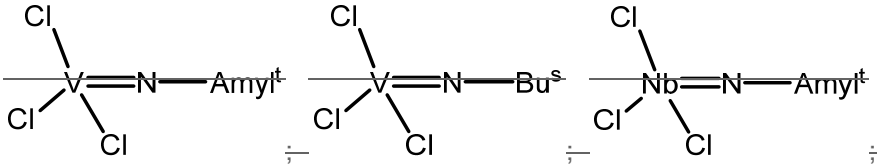
43.25. The method of claim 3621, further comprising applying energy to at least one of the precursor, the source gas, the substrate, and combinations thereof; wherein the energy is selected from the group consisting of thermal, plasma, pulsed plasma, helicon plasma, high density plasma, inductively coupled plasma, X-ray, e-beam, photon, remote plasma, and combinations thereof.

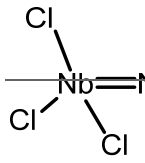
44.26. The method of claim 3621, wherein the step b further comprises introducing into the reaction chamber the precursor of any one of claims 1 to 3~~claim 1~~ or the composition of claim ~~16~~ 8 using a stream of carrier gas to deliver a vapor of the precursor into the reaction chamber.

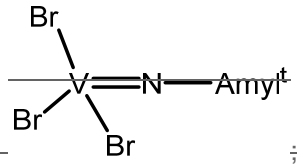
45.27. The method of claim 3621, wherein the precursor of any one of claims 1 to 3~~claim 1~~ or the precursor in the composition of claim ~~16~~ 8 is in a liquid form at ambient temperature and has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.

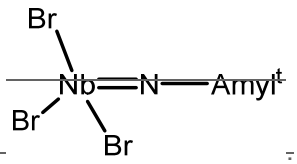
~~46. The method of claim 36, wherein step b comprises introducing into the reaction chamber the precursor of claim 1 or the precursor in the composition of claim 16 selected from the group consisting of :~~





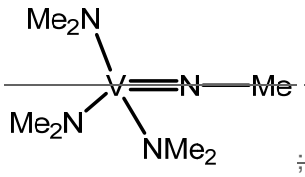


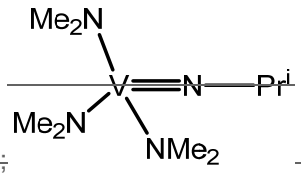


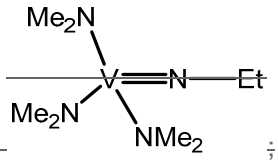


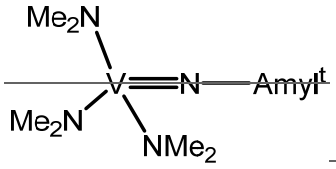
~~47. The method of claim 46, wherein the precursor of claim 1 or the precursor in the composition of claim 16 is in a liquid form at ambient temperature; and has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.~~

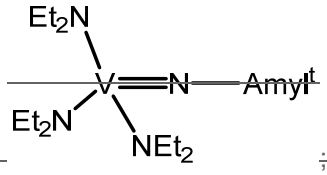
~~48. The method of claim 36, wherein step b comprises introducing into the reaction chamber the precursor of claim 1 or the precursor in the composition of claim 16 selected from the group consisting of :~~

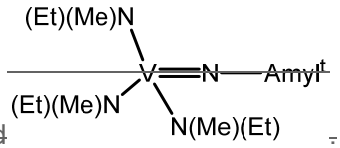












~~49. The method of claim 48, wherein the precursor of claim 1 or the precursor in the composition of claim 16 is in a liquid form at ambient temperature and has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.~~

~~50.~~28. The method of claim ~~36~~21, wherein the solvent in the composition of claim ~~16~~ 8 is selected from the group consisting of: toluene, mesitylene, isopropylbenzene, 4-isopropyl toluene, 1,3-diisopropylbenzene, octane, dodecane, 1,2,4-trimethylcyclohexane, n-butylcyclohexane, and decahydronaphthalene and combinations thereof.

51.29. A precursor supply package, comprising a vessel and the precursor of any one of claims 1 to 3claim 1 or the composition of claim 168, wherein the vessel is adapted to contain and dispense the precursor.

52.30. The precursor supply package of Claim 5129, wherein the precursor of any one of claims 1 to 3claim 1 or the precursor in the composition of claim 16 8 has a melting point of 120 degrees Celsius or less, 70 degrees Celsius or less, 60 degrees Celsius or less, 50 degrees Celsius or less, 40 degrees Celsius or less, or 30 degrees Celsius or less.

53.31. The precursor supply package of Claim 5129, wherein the precursor of any one of claims 1 to 3claim 1 or the precursor in the composition of claim 16 8 is in liquid form under delivery conditions.

54.32. A vanadium nitride film formed using the precursor of any one of claims 1 to 3claim 1 or the precursor in the composition of claim 168, wherein resistivity of the vanadium nitride film is < 550 μOhm-cm, preferably < 250 μOhm-cm-, and more preferably < 140 μOhm-cm.

55.33. The vanadium nitride film of claim 5432, wherein the vanadium nitride film is deposited by the method of claim 22 14 or the method of claim 3621.

56.34. The vanadium nitride film of claim 5533, wherein

the method of claim 22 14 further comprising introducing into the reaction chamber at least one reducing agent source selected from the group consisting of hydrogen, hydrogen plasma, a mixture of hydrogen and helium, a mixture of hydrogen and argon, hydrogen/helium plasma, hydrogen/argon plasma, boron-containing compounds, silicon-containing compounds and combinations thereof; or

the source gas in claim 36 21 is selected from the group consisting of hydrogen, hydrogen plasma, a mixture of hydrogen and helium, a mixture of hydrogen and argon, hydrogen/helium plasma, hydrogen/argon plasma, boron-containing compounds, silicon-containing compounds, and combinations thereof.

57.35. The vanadium nitride film of claim 5533, wherein

the method of claim 22 14 further comprising introducing hydrogen plasma into the reaction chamber; or

the source gas in claim ~~36~~ 21 is hydrogen plasma.