Claims

1. A compound having the formula $(L_1)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, (ii) a substituted or unsubstituted cationic 2 electron donor ligand, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1 and L_2 is equal to 0.

2. The compound of claim 1 wherein M is selected from tungsten (W), tantalum (Ta), molybdenum (Mo), niobium (Nb), vanadium (V) or chromium (Cr), L_1 is a substituted or unsubstituted anionic 6 electron donor ligand selected from cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, and L_2 is (i) a substituted or unsubstituted anionic 2 electron donor ligand selected from hydrido, halo and an alkyl group having from 1 to 12 carbon atoms, (ii) a substituted or unsubstituted cationic 2 electron donor ligand selected from nitrosyls, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand selected from carbonyl, phosphino, amino, alkenyl, alkynyl, nitrile and isonitrile.

3. The compound of claim 1 selected from the following: (i) M is tungsten (W) with a (+2) oxidation number, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand with a (-1) electrical charge, one L_2 ligand is a substituted or unsubstituted anionic 2 electron donor ligand with a (-1) electrical charge, and the remaining three L_2 ligands are the same or different and are each a substituted or unsubstituted neutral 2 electron donor ligand with a zero (0) electrical charge; (ii) M is tungsten (W) with a (0) oxidation number, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand with a (-1) electrical charge, one L_2 ligand is a substituted or unsubstituted cationic 2 electron donor

ligand with a (+1) electrical charge, and the remaining two L_2 ligands are the same or different and are each a substituted or unsubstituted neutral 2 electron donor ligand with a zero (0) electrical charge; and (iii) M is tungsten (W) with a (0) oxidation number, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand with a (-1) electrical charge, one L_2 ligand is a substituted or unsubstituted anionic 2 electron donor ligand with a (-1) electrical charge, and the remaining two L_2 ligands are the same or different and are each a substituted or unsubstituted cationic 2 electron donor ligand with a (+1) electrical charge.

4. The compound of claim 1 selected from:

(i) a compound having the formula $L_1M''(L_3)_x(L_4)_{y'}(L_5)_{z'}$ wherein M'' is a Group 6 metal having an oxidation state of $\underline{n}$, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_3 is the same or different and is a substituted or unsubstituted cationic 2 electron donor ligand, L_4 is the same or different and is a substituted or unsubstituted neutral 2 electron donor ligand, L_5 is the same or different and is a substituted or unsubstituted anionic 2 electron donor ligand; $\underline{n}$ is an integer of 0 or 2, $\underline{z'}$ is an integer of 0 or 1, $\underline{x}$ is an integer equal to $\underline{z'} - \underline{n} + 1$ provided that $\underline{x}$ is greater than or equal to 0, and $\underline{y'}$ is an integer equal to $7\underline{n}/2 + 2\underline{x} - 4\underline{z'}$ provided that $\underline{y'}$ is greater than or equal to 0; and wherein the sum of the oxidation number of M'' and the electric charges of L_1, L_3, L_4 and L_5 is equal to 0;

(ii) a compound having the formula $(L_1)_yM(CO)_{x'}(L_6)_{z-y-x'}$ wherein M is a Group 5 metal or a Group 6 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_6 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, or (ii) a substituted or unsubstituted cationic 2 electron donor ligand; $\underline{x'}$ is an integer of from 0 to 3, $\underline{y}$ is an integer of 1, and $\underline{z}$ is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1, L_6 and CO groups is equal to 0.;

(iii) a compound having the formula $L_1M'L_4(L_5)_3$ wherein M' is a Group 5 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_4 is a substituted or unsubstituted neutral 2 electron donor ligand, and L_5

is the same or different and is a substituted or unsubstituted anionic 2 electron donor ligand; and wherein the sum of the oxidation number of M' and the electric charges of L_1, L_4 and L_5 is equal to 0;

(iv) a compound having the formula $L_1M'L_3(L_4)_2$ wherein M' is a Group 5 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_3 is a substituted or unsubstituted cationic 2 electron donor ligand, and L_4 is the same or different and is a substituted or unsubstituted neutral 2 electron donor ligand; and wherein the sum of the oxidation number of M' and the electric charges of L_1, L_3 and L_4 is equal to 0;

(v) a compound having the formula $(L_1)_yM(NO)_{x''}(L_7)_{z-y-x''}$ wherein M is a Group 5 metal or a Group 6 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_7 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, or (ii) a substituted or unsubstituted neutral 2 electron donor ligand; x'' is an integer of from 0 to 2, y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1, L_7 and NO groups is equal to 0;

(vi) a compound having the formula $L_1M'(L_3)_2L_5$ wherein M' is a Group 5 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_3 is the same or different and is a substituted or unsubstituted cationic 2 electron donor ligand, and L_5 is a substituted or unsubstituted anionic 2 electron donor ligand; and wherein the sum of the oxidation number of M' and the electric charges of L_1, L_3 and L_5 is equal to 0;

(vii) a compound having the formula $(L_8)_yM(L_4)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, L_4 is the same or different and is a substituted or unsubstituted neutral 2 electron donor ligand, L_8 is a substituted chelated diene ligand, y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_4 and L_8 is equal to 0; and

(viii) a compound having the formula $(L_8)M''(L_4)_4$ wherein M'' is a Group 6 metal, L_4 is the same or different and is a substituted or unsubstituted neutral 2 electron donor ligand, and L_8 is a substituted chelated diene ligand; and

wherein the sum of the oxidation number of M'' and the electric charges of L_4 and L_8 is equal to 0.

5. The compound of claim 4 selected from:

(i) a compound having the formula $L_1M''(L_3)_x(L_4)_y(L_5)_z$, wherein M'' is selected from tungsten (W), molybdenum (Mo), or chromium (Cr), L_1 is selected from substituted or unsubstituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_3 is selected from substituted or unsubstituted nitrosyls, L_4 is selected from substituted or unsubstituted carbonyls, phosphines, amines, nitriles, alkynes and alkenes, and L_5 is selected from substituted or unsubstituted hydrido, halo and an alkyl groups having from 1 to 12 carbon atoms;

(ii) a compound having the formula $(L_1)_yM(CO)_x(L_6)_{z-y-x}$, wherein M is selected from tungsten (W), tantalum (Ta), molybdenum (Mo), niobium (Nb), vanadium (V) or chromium (Cr), L_1 is selected from substituted or unsubstituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, and L_6 is selected from (i) substituted or unsubstituted hydrido, halo and an alkyl group having from 1 to 12 carbon atoms, and (ii) substituted or unsubstituted nitrosyls;

(iii) a compound having the formula $L_1M'L_4(L_5)_3$ wherein M' is selected from tantalum (Ta), niobium (Nb) and vanadium (V), L_1 is selected from substituted or unsubstituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_4 is selected from substituted or unsubstituted carbonyls, phosphines, amines, nitriles, alkynes and alkenes, and L_5 is selected from substituted or unsubstituted hydrido, halo and an alkyl groups having from 1 to 12 carbon atoms;

(iv) a compound having the formula $L_1M'L_3(L_4)_2$ wherein M' is selected from tantalum (Ta), niobium (Nb) and vanadium (V), L_1 is selected from substituted or unsubstituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_3 is selected from substituted

or unsubstituted nitrosyls, and L_4 is selected from substituted or unsubstituted carbonyls, phosphines, amines, nitriles, alkynes and alkenes;

(v) a compound having the formula $(L_1)_yM(NO)_x(L_7)_{z-y-x}$ wherein M is selected from tungsten (W), tantalum (Ta), molybdenum (Mo), niobium (Nb), vanadium (V) or chromium (Cr), L_1 is selected from substituted or unsubstituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, and L_7 is selected from (i) substituted or unsubstituted hydrido, halo and an alkyl group having from 1 to 12 carbon atoms, and (ii) substituted or unsubstituted carbonyl, phosphino, amino, alkenyl, alkynyl, nitrile and isonitrile;

(vi) a compound having the formula $L_1M'(L_3)_2L_5$ wherein M' is selected from tantalum (Ta), niobium (Nb) and vanadium (V), L_1 is selected from substituted or unsubstituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_3 is selected from substituted or unsubstituted nitrosyls, and L_5 is selected from substituted or unsubstituted hydrido, halo and an alkyl groups having from 1 to 12 carbon atoms;

(vii) a compound having the formula $(L_8)_yM(L_4)_{z-y}$ wherein M is selected from tungsten (W), tantalum (Ta), molybdenum (Mo), niobium (Nb), vanadium (V) or chromium (Cr), L_4 is selected from substituted or unsubstituted carbonyl, phosphino, amino, alkenyl, alkynyl, nitrile and isonitrile, and L_8 is selected from alkyl substituted 1,4-cyclohexadienyl, alkyl substituted 1,3-cyclopentadienyl, alkyl substituted 1,5-cycloheptadienyl, and alkyl substituted 1,6-cyclooctadienyl; and

(viii) a compound having the formula $(L_8)M''(L_4)_4$ wherein M'' is selected from tungsten (W), molybdenum (Mo), or chromium (Cr), L_4 is selected from substituted or unsubstituted carbonyls, phosphines, amines, alkenes, alkynes, nitriles and isonitriles, and L_8 is selected from alkyl substituted 1,4-cyclohexadiene, alkyl substituted 1,3-cyclopentadiene, alkyl substituted 1,5-cycloheptadiene, and alkyl substituted 1,6-cyclooctadiene.

6. The compound of claim 1 which is selected from

tris(carbonyl)(methylcyclopentadienyl)hydridotungsten, $(MeCp)W(CO)_3H$;
tris(carbonyl)(ethylcyclopentadienyl)hydridotungsten, $(EtCp)W(CO)_3H$;
tris(carbonyl)(pentamethylcyclopentadienyl)hydridotungsten, $Cp^*W(CO)_3H$;
tris(carbonyl)(methylcyclopentadienyl)methyltungsten, $(MeCp)W(CO)_3CH_3$;
tris(carbonyl)(ethylcyclopentadienyl)methyltungsten, $(EtCp)W(CO)_3CH_3$;
tris(carbonyl)(pentamethylcyclopentadienyl)methyltungsten, $Cp^*W(CO)_3CH_3$;
tris(carbonyl)(methylcyclopentadienyl)ethyltungsten, $(MeCp)W(CO)_3C_2H_5$;
tris(carbonyl)(ethylcyclopentadienyl)ethyltungsten, $(EtCp)W(CO)_3C_2H_5$;
tris(carbonyl)(pentamethylcyclopentadienyl)ethyltungsten, $Cp^*W(CO)_3C_2H_5$;
tris(acetonitrile)(methylcyclopentadienyl)hydridotungsten, $(MeCp)W(NCCH_3)_3H$;
tris(acetonitrile)(ethylcyclopentadienyl)hydridotungsten, $(EtCp)W(NCCH_3)_3H$;
tris(acetonitrile)(pentamethylcyclopentadienyl)hydridotungsten,
$Cp^*W(NCCH_3)_3H$;
tris(carbonyl)(cycloheptadienyl)hydridotungsten, $(C_7H_9)W(CO)_3H$;
tris(carbonyl)(2,4-dimethylpentadienyl)hydridotungsten, $((CH_3)_2C_5H_5)W(CO)_3H$;
tris(carbonyl)(2,5-dimethylpyrrolyl)hydridotungsten, $((CH_3)_2C_4H_2N)W(CO)_3H$;
methylcyclopentadienylbis(nitrosyl)hydridotungsten, $(EtCp)W(NO)_2H$;
ethylcyclopentadienylbis(nitrosyl)hydridotungsten, $(MeCp)W(NO)_2H$;
pentamethylcyclopentadienylbis(nitrosyl)hydridotungsten, $Cp^*W(NO)_2H$;
methylcyclopentadienylbis(nitrosyl)methyltungsten, $(EtCp)W(NO)_2CH_3$;
ethylcyclopentadienylbis(nitrosyl)methyltungsten, $(MeCp)W(NO)_2CH_3$;
pentamethylcyclopentadienylbis(nitrosyl)methyltungsten, $Cp^*W(NO)_2CH_3$;
methylcyclopentadienylbis(nitrosyl)ethyltungsten, $(EtCp)W(NO)_2C_2H_5$;
ethylcyclopentadienylbis(nitrosyl)ethyltungsten, $(MeCp)W(NO)_2C_2H_5$;
pentamethylcyclopentadienylbis(nitrosyl)ethyltungsten, $Cp^*W(NO)_2C_2H_5$;
cycloheptadienylbis(nitrosyl)hydridotungsten, $(C_7H_9)W(NO)_2H$;
(2,4-dimethylpentadienyl)bis(nitrosyl)hydridotungsten, $((CH_3)_2C_5H_5)W(NO)_2H$;
(2,5-dimethylpyrrolyl)bis(nitrosyl)hydridotungsten, $((CH_3)_2C_4H_2N)W(NO)_2H$;
methylcyclopentadienylnitrosylbis(hydrido)tungsten, $(MeCp)W(NO)H_2$;
ethylcyclopentadienylnitrosylbis(hydrido)tungsten, $(EtCp)W(NO)H_2$;

pentamethylcyclopentadienylnitrosylbis(hydrido)tungsten, $Cp^*W(NO)H_2$;
methylcyclopentadienylnitrosylbis(methyl)tungsten, $(MeCp)W(NO)(CH_3)_2$;
ethylcyclopentadienylnitrosylbis(methyl)tungsten, $(EtCp)W(NO)(CH_3)_2$;
pentamethylcyclopentadienylnitrosylbis(methyl)tungsten, $Cp^*W(NO)(CH_3)_2$;
methylcyclopentadienylnitrosylbis(ethyl)tungsten, $(MeCp)W(NO)(C_2H_5)_2$;
ethylcyclopentadienylnitrosylbis(ethyl)tungsten, $(EtCp)W(NO)(C_2H_5)_2$;
pentamethylcyclopentadienylnitrosylbis(ethyl)tungsten, $Cp^*W(NO)(C_2H_5)_2$;
cycloheptadienylnitrosylbis(ethyl)tungsten, $(C_7H_9)W(NO)(C_2H_5)_2$;
2,4-dimethylpentadienylnitrosylbis(ethyl)tungsten, $((CH_3)_2C_5H_5)W(NO)(C_2H_5)_2$;
and
2,5-dimethylpyrrolylnitrosylbis(ethyl)tungsten, $((CH_3)_2C_4H_2N)W(NO)(C_2H_5)_2$.

7. A process for producing a compound having the formula $(L_1)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, (ii) a substituted or unsubstituted cationic 2 electron donor ligand, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1 and L_2 is equal to 0; which process comprises reacting a metal halide, a salt and a reducing agent in the presence of a first solvent and under reaction conditions sufficient to produce an intermediate reaction material, and reacting said intermediate reaction material with a base material in the presence of a second solvent and under reaction conditions sufficient to produce said organometallic compound.

8. The process of claim 7 wherein said metal halide comprises tungsten hexachloride, molybdenum hexachloride, chromium hexachloride, tantalum pentachloride, niobium pentachloride or vanadium pentachloride; said salt comprises sodium cyclopentadiene, potassium cyclopentadiene, lithium cyclopentadiene or magnesocene; said reducing agent comprises

sodium bis(2-methoxyethoxy)aluminum dihydride, sodium borohydride or lithium aluminum hydride; said first solvent comprises dimethoxyethane (DME), toluene or mixtures thereof; said intermediate reaction material is selected from $Li[(EtCp)W(CO)_3]$, $Na[(EtCp)W(CO)_3]$, and PPN[(2,5-dimethylpyrrolyl)$W(CO)_3$]; said base material comprises sodium hydroxide, potassium hydroxide or ethyl acetate; and said second solvent comprises toluene, hexane or mixtures thereof.

9. A method for producing a film, coating or powder by decomposing an organometallic precursor compound, said organometallic precursor compound having the formula $(L_1)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, (ii) a substituted or unsubstituted cationic 2 electron donor ligand, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1 and L_2 is equal to 0; thereby producing said film, coating or powder.

10. The method of claim 9 wherein the decomposing of said organometallic precursor compound is thermal, chemical, photochemical or plasma-activated.

11. The method of claim 9 wherein said film, coating or powder is produced by chemical vapor deposition, atomic layer deposition, plasma assisted chemical vapor deposition or plasma assisted atomic layer deposition.

12. A a method for processing a substrate in a processing chamber, said method comprising (i) introducing an organometallic precursor compound into said processing chamber, (ii) heating said substrate to a temperature of about 100°C to about 400°C, and (iii) dissociating said organometallic precursor

compound in the presence of a processing gas to deposit a metal layer on said substrate; said organometallic precursor compound having the formula $(L_1)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, L_1 is a substituted or unsubstituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, (ii) a substituted or unsubstituted cationic 2 electron donor ligand, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1 and L_2 is equal to 0.

13. The method of claim 12 wherein tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride is deposited on said substrate.

14. The method of claim 12 wherein said metal layer is deposited on said substrate by chemical vapor deposition , atomic layer deposition, plasma assisted chemical vapor deposition or plasma assisted atomic layer deposition.

15. The method of claim 12 wherein dissociating the organometallic precursor compound further comprises generating a plasma at a power density between about 0.6 Watts/cm^2 and about 3.2 Watts/cm^2.

16. The method of claim 12 further comprising exposing the deposited metal layer to a plasma generated at a power density between about 0.6 Watts/cm^2 and about 3.2 Watts/cm^2.

17. The method of claim 12 furthering comprising depositing a second metal layer on the metal layer wherein the second metal layer comprises copper and is deposited by an electroplating technique.

18. A method for forming a metal material on a substrate from an organometallic precursor compound, said organometallic precursor compound

having the formula $(Li)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, L] is a substituted or unsubstituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, (ii) a substituted or unsubstituted cationic 2 electron donor ligand, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of Li and L_2 is equal to 0, said method comprising vaporizing said organometallic precursor compound to form a vapor, and contacting the vapor with the substrate to form said metal material thereon, wherein tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride is deposited on said substrate, and the substrate is thereafter metallized with copper or integrated with a ferroelectric thin film.

19. A method of fabricating a microelectronic device structure, said method comprising vaporizing an organometallic precursor compound to form a vapor, contacting said vapor with a substrate to deposit a metal-containing film on the substrate, and thereafter metallizing the substrate with copper or integrating it with a ferroelectric thin film, said organometallic precursor compound having the formula $(Li)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal or a Group 6 metal, Li is a substituted or unsubstituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, (ii) a substituted or unsubstituted cationic 2 electron donor ligand, or (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1 , and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of Li and L_2 is equal to 0.

CLAIMS

1. A compound having the formula $(L_1)_yM(L_2)_{z-y}$ wherein M is a Group 5 metal selected from tantalum (Ta), niobium (Nb) or vanadium (V), or a Group 6 metal selected from tungsten (W) or chromium (Cr), L_1 is a substituted anionic 6 electron donor ligand, L_2 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, and at least one of (ii) a substituted or unsubstituted cationic 2 electron donor ligand, and (iii) a substituted or unsubstituted neutral 2 electron donor ligand; y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1 and L_2 is equal to 0.

2. The compound of claim 1 wherein M is selected from tungsten (W), tantalum (Ta), niobium (Nb), vanadium (V) or chromium (Cr), L_1 is a substituted anionic 6 electron donor ligand selected from cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, and L_2 is (i) a substituted or unsubstituted anionic 2 electron donor ligand selected from hydrido, halo and an alkyl group having from 1 to 12 carbon atoms, and at least one of (ii) a substituted or unsubstituted cationic 2 electron donor ligand selected from nitrosyls, and (iii) a substituted or unsubstituted neutral 2 electron donor ligand selected from carbonyl, phosphino, amino, alkenyl, alkynyl, nitrile and isonitrile.

3. The compound of claim 1 selected from the following: (i) M is tungsten (W) with a (+2) oxidation number, L_1 is a substituted anionic 6 electron donor ligand with a (-1) electrical charge, one L_2 ligand is a substituted or unsubstituted anionic 2 electron donor ligand with a (-1) electrical charge, and the remaining three L_2 ligands are the same or different and are each a substituted or unsubstituted neutral 2 electron donor ligand with a zero (0) electrical charge; and

(ii) M is tungsten (W) with a (0) oxidation number, L_1 is a substituted anionic 6 electron donor ligand with a (-1) electrical charge, one L_2 ligand is a substituted or unsubstituted anionic 2 electron donor ligand with a (-1) electrical charge, and the remaining two L_2 ligands are the same or different and are each a substituted or unsubstituted cationic 2 electron donor ligand with a (+1) electrical charge.

4. The compound of claim 1 selected from:

(i) a compound having the formula $L_1M''(L_3)_x(L_4)_{y'}(L_5)_{z'}$ wherein M'' is a Group 6 metal selected from tungsten (W) or chromium (Cr) having an oxidation state of n, L_1 is a substituted anionic 6 electron donor ligand, L_3 is the same or different and is a substituted or unsubstituted cationic 2 electron donor ligand, L_4 is the same or different and is a substituted or unsubstituted neutral 2 electron donor ligand, L_5 is the same or different and is a substituted or unsubstituted anionic 2 electron donor ligand; n is an integer of 0 or 2, z' is an integer of 0 or 1, x is an integer equal to z' – n + 1 provided that x is greater than or equal to 0, and y' is an integer equal to 7n/2 + 2x – 4z' provided that y' is greater than or equal to 0; and wherein the sum of the oxidation number of M'' and the electric charges of L_1, L_3, L_4 and L_5 is equal to 0;

(ii) a compound having the formula $(L_1)_yM(CO)_{x'}(L_6)_{z-y-x'}$ wherein M is a Group 5 metal selected from tantalum (Ta), niobium (Nb) or vanadium (V), or a Group 6 metal selected from tungsten (W) or chromium (Cr), L_1 is a substituted anionic 6 electron donor ligand, L_6 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, and optionally (ii) a substituted or unsubstituted cationic 2 electron donor ligand; x' is an integer of from 0 to 3, y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1, L_6 and CO groups is equal to 0.;

(iii) a compound having the formula $L_1M'L_4(L_5)_3$ wherein M' is a Group 5 metal selected from tantalum (Ta), niobium (Nb) or vanadium (V), L_1

is a substituted anionic 6 electron donor ligand, L_4 is a substituted or unsubstituted neutral 2 electron donor ligand, and L_5 is the same or different and is a substituted or unsubstituted anionic 2 electron donor ligand; and wherein the sum of the oxidation number of M' and the electric charges of L_1, L_4 and L_5 is equal to 0;

(iv) a compound having the formula $(L_1)_yM(NO)_{x''}(L_7)_{z-y-x''}$ wherein M is a Group 5 metal selected from tantalum (Ta), niobium (Nb) or vanadium (V), or a Group 6 metal selected from tungsten (W) or chromium (Cr), L_1 is a substituted anionic 6 electron donor ligand, L_7 is the same or different and is (i) a substituted or unsubstituted anionic 2 electron donor ligand, and optionally (ii) a substituted or unsubstituted neutral 2 electron donor ligand; x'' is an integer of from 0 to 2, y is an integer of 1, and z is the valence of M; and wherein the sum of the oxidation number of M and the electric charges of L_1, L_7 and NO groups is equal to 0; and

(v) a compound having the formula $L_1M'(L_3)_2L_5$ wherein M' is a Group 5 metal selected from tantalum (Ta), niobium (Nb) or vanadium (V), L_1 is a substituted anionic 6 electron donor ligand, L_3 is the same or different and is a substituted or unsubstituted cationic 2 electron donor ligand, and L_5 is a substituted or unsubstituted anionic 2 electron donor ligand; and wherein the sum of the oxidation number of M' and the electric charges of L_1, L_3 and L_5 is equal to 0.

5. The compound of claim 4 selected from:

(i) a compound having the formula $L_1M''(L_3)_x(L_4)_{y'}(L_5)_{z'}$ wherein M'' is selected from tungsten (W) or chromium (Cr), L_1 is selected from substituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_3 is selected from substituted or unsubstituted nitrosyls, L_4 is selected from substituted or unsubstituted carbonyls, phosphines, amines, nitriles, alkynes and alkenes, and L_5 is selected from substituted or

unsubstituted hydrido, halo and an alkyl groups having from 1 to 12 carbon atoms;

(ii) a compound having the formula $(L_1)_yM(CO)_{x'}(L_6)_{z-y-x'}$ wherein M is selected from tungsten (W), tantalum (Ta), niobium (Nb), vanadium (V) or chromium (Cr), L_1 is selected from substituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, and L_6 is selected from (i) substituted or unsubstituted hydrido, halo and an alkyl group having from 1 to 12 carbon atoms, and optionally (ii) substituted or unsubstituted nitrosyls;

(iii) a compound having the formula $L_1M'L_4(L_5)_3$ wherein M' is selected from tantalum (Ta), niobium (Nb) and vanadium (V), L_1 is selected from substituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_4 is selected from substituted or unsubstituted carbonyls, phosphines, amines, nitriles, alkynes and alkenes, and L_5 is selected from substituted or unsubstituted hydrido, halo and an alkyl groups having from 1 to 12 carbon atoms;

(iv) a compound having the formula $(L_1)_yM(NO)_{x''}(L_7)_{z-y-x''}$ wherein M is selected from tungsten (W), tantalum (Ta), niobium (Nb), vanadium (V) or chromium (Cr), L_1 is selected from substituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, and L_7 is selected from (i) substituted or unsubstituted hydrido, halo and an alkyl group having from 1 to 12 carbon atoms, and optionally (ii) substituted or unsubstituted carbonyl, phosphino, amino, alkenyl, alkynyl, nitrile and isonitrile; and

(v) a compound having the formula $L_1M'(L_3)_2L_5$ wherein M' is selected from tantalum (Ta), niobium (Nb) and vanadium (V), L_1 is selected from substituted cyclopentadienyl, cycloheptadienyl, pentadienyl, pyrrolyl, imidazolyl, pyrazolyl and boratabenzyl, L_3 is selected from substituted or unsubstituted

nitrosyls, and L_5 is selected from substituted or unsubstituted hydrido, halo and an alkyl groups having from 1 to 12 carbon atoms.

6. The compound of claim 1 which is selected from tris(carbonyl)(methylcyclopentadienyl)hydridotungsten, $(MeCp)W(CO)_3H$; tris(carbonyl)(ethylcyclopentadienyl)hydridotungsten, $(EtCp)W(CO)_3H$; tris(carbonyl)(pentamethylcyclopentadienyl)hydridotungsten, $Cp^*W(CO)_3H$; tris(carbonyl)(methylcyclopentadienyl)methyltungsten, $(MeCp)W(CO)_3CH_3$; tris(carbonyl)(ethylcyclopentadienyl)methyltungsten, $(EtCp)W(CO)_3CH_3$; tris(carbonyl)(pentamethylcyclopentadienyl)methyltungsten, $Cp^*W(CO)_3CH_3$; tris(carbonyl)(methylcyclopentadienyl)ethyltungsten, $(MeCp)W(CO)_3C_2H_5$; tris(carbonyl)(ethylcyclopentadienyl)ethyltungsten, $(EtCp)W(CO)_3C_2H_5$; tris(carbonyl)(pentamethylcyclopentadienyl)ethyltungsten, $Cp^*W(CO)_3C_2H_5$; tris(acetonitrile)(methylcyclopentadienyl)hydridotungsten, $(MeCp)W(NCCH_3)_3H$; tris(acetonitrile)(ethylcyclopentadienyl)hydridotungsten, $(EtCp)W(NCCH_3)_3H$; tris(acetonitrile)(pentamethylcyclopentadienyl)hydridotungsten, $p^*W(NCCH_3)_3H$; tris(carbonyl)(2,4-dimethylpentadienyl)hydridotungsten, $((CH_3)_2C_5H_5)W(CO)_3H$; tris(carbonyl)(2,5-dimethylpyrrolyl)hydridotungsten, $((CH_3)_2C_4H_2N)W(CO)_3H$; methylcyclopentadienylbis(nitrosyl)hydridotungsten, $(EtCp)W(NO)_2H$; ethylcyclopentadienylbis(nitrosyl)hydridotungsten, $(MeCp)W(NO)_2H$; pentamethylcyclopentadienylbis(nitrosyl)hydridotungsten, $Cp^*W(NO)_2H$; methylcyclopentadienylbis(nitrosyl)methyltungsten, $(EtCp)W(NO)_2CH_3$; ethylcyclopentadienylbis(nitrosyl)methyltungsten, $(MeCp)W(NO)_2CH_3$; pentamethylcyclopentadienylbis(nitrosyl)methyltungsten, $Cp^*W(NO)_2CH_3$; methylcyclopentadienylbis(nitrosyl)ethyltungsten, $(EtCp)W(NO)_2C_2H_5$; ethylcyclopentadienylbis(nitrosyl)ethyltungsten, $(MeCp)W(NO)_2C_2H_5$; pentamethylcyclopentadienylbis(nitrosyl)ethyltungsten, $Cp^*W(NO)_2C_2H_5$; cycloheptadienylbis(nitrosyl)hydridotungsten, $(C_7H_9)W(NO)_2H$; (2,4-dimethylpentadienyl)bis(nitrosyl)hydridotungsten, $((CH_3)_2C_5H_5)W(NO)_2H$;

(2,5-dimethylpyrrolyl)bis(nitrosyl)hydridotungsten, $((CH_3)_2C_4H_2N)W(NO)_2H$; methylcyclopentadienylnitrosylbis(hydrido)tungsten, $(MeCp)W(NO)H_2$; ethylcyclopentadienylnitrosylbis(hydrido)tungsten, $(EtCp)W(NO)H_2$; pentamethylcyclopentadienylnitrosylbis(hydrido)tungsten, $Cp^*W(NO)H_2$; methylcyclopentadienylnitrosylbis(methyl)tungsten, $(MeCp)W(NO)(CH_3)_2$; ethylcyclopentadienylnitrosylbis(methyl)tungsten, $(EtCp)W(NO)(CH_3)_2$; pentamethylcyclopentadienylnitrosylbis(methyl)tungsten, $Cp^*W(NO)(CH_3)_2$; methylcyclopentadienylnitrosylbis(ethyl)tungsten, $(MeCp)W(NO)(C_2H_5)_2$; ethylcyclopentadienylnitrosylbis(ethyl)tungsten, $(EtCp)W(NO)(C_2H_5)_2$; pentamethylcyclopentadienylnitrosylbis(ethyl)tungsten, $Cp^*W(NO)(C_2H_5)_2$; cycloheptadienylnitrosylbis(ethyl)tungsten, $(C_7H_9)W(NO)(C_2H_5)_2$; 2,4-dimethylpentadienylnitrosylbis(ethyl)tungsten, $((CH_3)_2C_5H_5)W(NO)(C_2H_5)_2$; and 2,5-dimethylpyrrolylnitrosylbis(ethyl)tungsten, $((CH_3)_2C_4H_2N)W(NO)(C_2H_5)_2$.

7. A process for producing the compound of claim 1, which process comprises reacting a metal halide, a salt and a reducing agent in the presence of a first solvent and under reaction conditions sufficient to produce an intermediate reaction material with a base material in the presence of a second solvent and under reaction conditions sufficient to produce said compound.

8. The process of claim 7 wherein said metal halide comprises tungsten hexachloride, chromium hexachloride, tantalum pentachloride, niobium pentachloride or vanadium pentachloride; said salt comprises sodium cyclopentadiene, potassium cyclopentadiene, lithium cyclopentadiene or magnesocene; said reducing agent comprises

sodium bis(2-methoxyethoxy)aluminum dihydride, sodium borohydride or lithium aluminum hydride; said first solvent comprises dimethoxyethane (DME), toluene or mixtures thereof; said intermediate reaction material is selected from

$Li[(EtCp)W(CO)_3]$, $Na[(EtCp)W(CO)_3]$, and PPN[(2,5-dimethylpyrrolyl)$W(CO)_3$]; said base material comprises sodium hydroxide, potassium hydroxide or ethyl acetate; and said second solvent comprises toluene, hexane or mixtures thereof.

9. A method for producing a film, coating or powder by decomposing the-organometallic precursor compound of claim 1, thereby producing said film, coating or powder.

10. The method of claim 9 wherein the decomposing of said organometallic precursor compound of claim 1 is thermal, chemical, photochemical or plasma-activated.

11. The method of claim 9 wherein said organometallic precursor compound of claim 1 is vaporized and the vapor is directed into a deposition reactor housing a substrate.

12. The method of claim 11 wherein said substrate is comprised of a material selected from the group consisting of a metal, a metal silicide, a semiconductor, an insulator and a barrier material.

13. The method of claim 11 wherein said substrate is a patterned wafer.

14. The method of claim 9 wherein said film, coating or powder is produced by chemical vapor deposition, atomic layer deposition, plasma assisted chemical vapor deposition or plasma assisted atomic layer deposition.

15. The method of claim 9 wherein tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride is deposited on said substrate.

16. A method for processing a substrate in a processing chamber, said method comprising (i) introducing ~~an~~ the organometallic precursor compound of claim 1 into said processing chamber, (ii) heating said substrate to a temperature of about 100°C to about 400°C, and (iii) dissociating said organometallic precursor compound of claim 1 in the presence of a processing gas to deposit a metal layer on said substrate.

17. The method of claim 16 wherein tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride is deposited on said substrate.

18. The method of claim 16 wherein said metal layer is deposited on said substrate by chemical vapor deposition , atomic layer deposition, plasma assisted chemical vapor deposition or plasma assisted atomic layer deposition.

19. The method of claim 16 wherein said processing gas is selected from hydrogen, argon, helium, or combinations thereof.

20. The method of claim 16 wherein dissociating the organometallic precursor compound of claim 1 further comprises generating a plasma at a power density between about 0.6 Watts/cm^2 and about 3.2 Watts/cm^2.

21. The method of claim 16 further comprising exposing the deposited metal layer to a plasma generated at a power density between about 0.6 Watts/cm^2 and about 3.2 Watts/cm^2.

22. The method of claim 16 furthering comprising depositing a second metal layer on the metal layer.

23. The method of claim 22 wherein the second metal layer comprises copper and is deposited by an electroplating technique.

24. A method for forming a metal material on a substrate from the organometallic precursor compound of claim 1, said method comprising vaporizing said organometallic precursor compound of claim 1 to form a vapor, and contacting the vapor with the substrate to form said metal material thereon.

25. The method of claim 24 wherein the metal material comprises tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride.

26. The method of claim 24 wherein the substrate comprises a microelectronic device structure.

27. The method of claim 24 wherein tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride is deposited on said substrate, and the substrate is thereafter metallized with copper or integrated with a ferroelectric thin film.

28. A method of fabricating a microelectronic device structure, said method comprising vaporizing ~~an~~ the organometallic precursor compound of claim 1 to form a vapor, contacting said vapor with a substrate to deposit a metal-containing film on the substrate, and thereafter metallizing the substrate with copper or integrating it with a ferroelectric thin film.

29. The method of claim 28 wherein the metal-containing film comprises tungsten, tungsten nitride, tungsten carbide, or tungsten carbonitride.