To avoid using halides, SiO_2 ALD has been attempted using a variety of reactants such as alkoxysilanes, aminosilanes and isocyanates, using a variety of different catalysts and reaction conditions. These methods suffer from a number of disadvantages, such as requiring large reactant exposures, long deposition times or resulting in contamination of the deposited film.

SUMMARY

A class of organometallic compounds is provided. The compounds correspond in structure to Formula 1:

$$(A)_x\text{-}M\text{-}(OR^3)_{4-x}$$

wherein:

A is selected from the group consisting of $-NR^1R^2$, $-N(R^4)(CH_2)_nN(R^5R^6)$,

$-N{=}C(NR^4R^5)(NR^6R^7)$, $OCOR^1$, halo and Y;

R^1 and R^2 are independently selected from the group consisting of H and a cyclic or acyclic alkyl group having from 1 to 8 carbon atoms, with the proviso that at least one of R^1 and R^2 must be other than H;

R^4, R^5, R^6 and R^7 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms;

Y is selected from the group consisting of a 3- to 13-membered heterocyclic radical containing at least one nitrogen atom;

R^3 is a cyclic or acyclic alkyl group having from 1 to 6 carbon atoms;

M is selected from the group consisting of Si, Ge, Sn, Ti, Zr and Hf;

x is an integer from 1 to 3; and

n is an integer from 1 to 4.

In an aspect, there is provided an organometallic compound of Formula 1:

$$(A)_x\text{-}M\text{-}(OR^3)_{4-x}$$

wherein:

A is selected from the group consisting of $-N(R^4)(CH_2)_nN(R^5R^6)$,
$OCOR^1$, halo and Y, wherein halo is selected from the group consisting of chloro, bromo and iodo;

R^1 is an alkyl group having from 1 to 8 carbon atoms;

R^4, R^5, and R^6 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms;

Y is selected from the group consisting of a 3- to 13-membered heterocyclic radical containing at least one nitrogen atom;

R^3 is a cyclic or acyclic alkyl group having from 1 to 6 carbon atoms;

M is selected from the group consisting of Si, Ge and Sn;

x is an integer from 1 to 3; and

n is an integer from 1 to 4;

with the provisos that x cannot be 3 when A is halo, that x is 3 when Y is pyrrodinyl, and that the compound of Formula 1 is not diacetoxy-ditbutoxysilane.

In another aspect, there is provided a method for forming a metal oxide film by a vapour deposition process, the method comprising the steps of:

a. Providing at least one substrate having functional O-H groups covering the surface,
b. delivering to said substrate at least one compound of Formula 1 in the gaseous phase:

$$(A)_x\text{-}M\text{-}(OR^3)_{4-x}$$

wherein:

A is selected from the group consisting of $-NR^1R^2$, $-N(R^4)(CH_2)_nN(R^5R^6)$,

$-N=C(NR^4R^5)(NR^6R^7)$, $OCOR^1$, halo and Y;

R^1 and R^2 are independently selected from the group consisting of H and a cyclic or acyclic alkyl group having from 1 to 8 carbon atoms, with the proviso that at least one of R^1 and R^2 must be other than H;

R^4, R^5, R^6 and R^7 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms;

Y is selected from the group consisting of a 3- to 13-membered heterocyclic radical containing at least one nitrogen atom;

R^3 is a cyclic or acyclic alkyl group having from 1 to 6 carbon atoms;

M is selected from the group consisting of Si, Ge and Sn;

x is an integer from 1 to 3; and

n is an integer from 1 to 4;

with the proviso that when A is $-NR^1R^2$, R^3 is methyl, and

with the proviso that the compound of Formula 1 is not diacetoxy-di-t-butoxysilane;

c. purging the substrate with purge gas,
d. delivering to said substrate an oxygen source in the gaseous phase,
e. purging the substrate with purge gas,
f. repeating steps b) through e) until a desired thickness of metal oxide has been deposited.

Such compounds may be useful as precursors for metal oxide vapour phase deposition. The compounds as defined above comprise one or more ligands which are strong Lewis bases. Exemplary bases comprise acetates, halides and neutral, nitrogen-containing species with high proton affinity such as phosphazenes, amidines and guanidines.

I Claim:

1. An organometallic compound of Formula 1:

$$(A)_x\text{-}M\text{-}(OR^3)_{4-x}$$

wherein:

A is selected from the group consisting of $-N(R^4)(CH_2)_nN(R^5R^6)$, $OCOR^1$, halo and Y, wherein halo is selected from the group consisting of chloro, bromo and iodo;

R^1 is an alkyl group having from 1 to 8 carbon atoms;

R^4, R^5, and R^6 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms;

Y is selected from the group consisting of a 3- to 13-membered heterocyclic radical containing at least one nitrogen atom;

R^3 is a cyclic or acyclic alkyl group having from 1 to 6 carbon atoms;

M is selected from the group consisting of Si, Ge and Sn;

x is an integer from 1 to 3; and

n is an integer from 1 to 4;

with the provisos that x cannot be 3 when A is halo, that x is 3 when Y is pyrrolidinyl, and that the compound of Formula 1 is not diacetoxy-ditbutoxysilane.

2. The compound of claim 1, wherein M is Si.

3. The compound of any one of claim 1 or 2, wherein A is selected from the group consisting of acetate, tetraethylguanidinyl, dimethylethylenediaminyl, bromo, iodo, and Y.

4. The compound of claim 3, wherein A is Y.

5. The compound of claim 4, wherein Y is selected from the group consisting of aziridinyl, azetidinyl, pyrrolidinyl, pyrrolyl, piperidinyl, pyridinyl, azepanyl, and azepinyl, preferably aziridinyl, azetidinyl and pyrrolidinyl.

6. The compound of any one of claims 1-5, wherein R^3 is an acyclic alkyl group having from 1 to 4 carbon atoms.

7. The compound of claim 6, wherein R^3 is an acyclic alkyl group having 1 or 2 carbon atoms.

8. The compound of claim 7, wherein R^3 is a methyl group.

9. The compound of any one of claims 1-8, wherein R^4, R^5, and R^6 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms.

10. The compound of claim 9, wherein R^4, R^5, and R^6 are independently selected from an acyclic alkyl group having 1 or 2 carbon atoms.

11. The compound of any one of claims 1-7 wherein Y is pyrrolidinyl, and R^3 is selected from the group consisting of methyl and ethyl.

12. A method for forming a metal oxide film by a vapour deposition process, the method comprising the steps of:
    a. Providing at least one substrate having functional O-H groups covering the surface,
    b. delivering to said substrate at least one compound of Formula 1 in the gaseous phase:

$$(A)_x\text{-}M\text{-}(OR^3)_{4-x}$$

wherein:

A is selected from the group consisting of $-NR^1R^2$, $-N(R^4)(CH_2)_nN(R^5R^6)$,

$-N{=}C(NR^4R^5)(NR^6R^7)$, $OCOR^1$, halo and Y;

R^1 and R^2 are independently selected from the group consisting of H and a cyclic or acyclic alkyl group having from 1 to 8 carbon atoms, with the proviso that at least one of R^1 and R^2 must be other than H;

R^4, R^5, R^6 and R^7 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms;

Y is selected from the group consisting of a 3- to 13-membered heterocyclic radical containing at least one nitrogen atom;

R^3 is a cyclic or acyclic alkyl group having from 1 to 6 carbon atoms;

M is selected from the group consisting of Si, Ge and Sn;

x is an integer from 1 to 3; and

n is an integer from 1 to 4;

with the proviso that when A is $-NR^1R^2$, R^3 is methyl, and

with the proviso that the compound of Formula 1 is not diacetoxy-di-t-butoxysilane;

c. purging the substrate with purge gas,
d. delivering to said substrate an oxygen source in the gaseous phase,
e. purging the substrate with purge gas,
f. repeating steps b) through e) until a desired thickness of metal oxide has been deposited.

13. The method of claim 7, wherein A is selected from the group consisting of acetate, tetraethylguanidinyl, dimethylethylenediaminyl, bromo, iodo, $-NR^1R^2$, and Y.

14. The method of claim 13, wherein A is $-NR^1R^2$.

15. The method of any one of claims 12-14, wherein R^1 and R^2 are independently selected from the group consisting of H and an acyclic alkyl group having from 1 to 4 carbon atoms, preferably 1 to 3 carbon atoms.

16. The method of claim 15, wherein R^1 and R^2 are independently selected acyclic alkyl groups having from 1 to 4 carbon atoms.

17. The method of claim 15, wherein R^1 and R^2 are independently selected acyclic alkyl groups having from 1 to 3 carbon atoms.

18. The method of claim 12, wherein A is Y.

19. The method of any one of claims 12, 13 or 18, wherein Y is selected from the group consisting of aziridinyl, azetidinyl, pyrrolidinyl, pyrrolyl, piperidinyl, pyridinyl, azepanyl, and azepinyl.

20. The method of claim 19, wherein Y is selected from the group consisting of aziridinyl, azetidinyl and pyrrolidinyl.

21. The method of any one of claims 7-20, wherein the oxygen source is selected from H_2O in gaseous phase, H_2O_2 in gaseous phase, O_2, O_3 and hydrazine.

22. The method of any one of claims 7-21 wherein the vapour deposition process is chemical vapour deposition or atomic layer deposition.