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wherein M is a transition metal selected from the group consisting of Cr, Mo, and W; and wherein R_1, R_2, and R_3 are each independently selected from the group consisting of methyl, ethyl, F, Cl, and Br. In certain embodiments, M is molybdenum and R_1, R_2, and R_3 are each independently selected from the group consisting of methyl and Cl. In certain embodiments, the precursor is (methylphosphonous dichloride)pentacarbonyl molybdenum.

[0012] Methods for forming metal-containing films by vapor deposition processes, such as CVD and ALD, are provided herein using organometallic precursors corresponding in structure to Formula I.

[0013] In addition, superior quality films made by the methods described immediately above are also described herein.

[0013a] In one aspect, there is provided a method for forming a molybdenum-containing film by a deposition process, the method comprising delivering at least one organometallic precursor of the formula $[CH_3(Cl)_2P]Mo(CO)_5$ to a substrate.

[0013b] In another aspect, there is provided a conformal molybdenum-containing film with an aspect ratio of at least about 20:1, wherein the film has a resistivity of no more than about 190 μΩ.cm and contains no more than about 20% of each of carbon, phosphorus, and oxygen.

[0014] Other embodiments, including particular aspects of the embodiments summarized above, will be evident from the detailed description that follows.

DETAILED DESCRIPTION OF THE INVENTION

[0015] In one embodiment, the methods disclosed herein can be used to create or grow metal-containing thin films—in particular, molybdenum-containing thin films—which display conductive properties.

I. Definitions

[0016] As used herein, "precursor" refers to an organometallic molecule, complex and/or compound which forms a thin film while passing over a substrate during a deposition process, for example, CVD or ALD.

[0017] As used herein, "vapor deposition process" refers to any type of vapor deposition technique such as CVD or ALD. In various embodiments of the invention, CVD may take the form of conventional (*i.e.*, continuous flow) CVD, liquid injection CVD, or photo-assisted CVD. CVD may also take the form of a pulsed technique, *i.e.,* pulsed CVD. In other embodiments, ALD may

take the form of conventional (*i.e.*, pulsed injection) ALD, liquid injection ALD, photo-assisted ALD, or plasma-assisted ALD. The term "vapor deposition process" further includes various vapor deposition techniques described in *Chemical Vapour Deposition: Precursors, Processes, and Applications*; Jones, A. C.; Hitchman, M. L., Eds. The Royal Society of Chemistry: Cambridge, 2009; Chapter 1, pp 1–36.

[0018] As used herein, all five carbon atoms of the carbonyls are bound to the metal center in η^5-coordination by π bonding, therefore the precursors described herein are "π complexes."

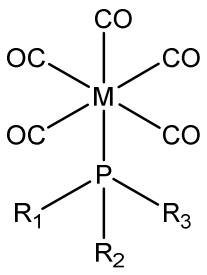
[0019] The term "alkyl" refers to a saturated hydrocarbon chain of 1 to about 8 carbon atoms in length, such as, but not limited to, methyl, ethyl, propyl and butyl. The alkyl group may be straight-chain or branched-chain. "Alkyl" is intended to embrace all structural isomeric forms of an alkyl group. For example, as used herein, propyl encompasses both *n*-propyl and *iso*-propyl; butyl encompasses *n*-butyl, *sec*-butyl, *iso*-butyl and *tert*-butyl. Further, as used herein, "Me" refers to methyl, "Et" refers to ethyl, "Pr" refers to propyl, "*i*-Pr" refers to *iso*-propyl, "Bu" refers to butyl, "*t*-Bu" refers to *tert*-butyl, "*s*-Bu" refers to *sec*-butyl, "*i*-Bu" refers to *iso*-butyl, and "Np" refers to *neo*-pentyl. It should also be noted that C_2 is intended to refer to an ethyl group, and not dimethyl.

[0020] Deposition of molybdenum metal is difficult because of stability issues, being either unstable or too stable for deposition. The organometallic complexes described in the embodiments of the invention allow for control of physical properties as well as provide for increased stability and simple high yield synthesis.

[0021] The words "comprise", "comprises", and "comprising" are to be interpreted inclusively rather than exclusively.

II. Organometallic Complexes

[0022] Organometallic precursors corresponding in structure to Formula I are useful in the methods described herein:



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