CLAIMS

1. A method of forming a substantially carbon-free metal-containing layer on a semiconductor substrate, the method comprising:

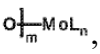
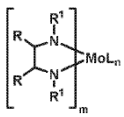
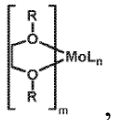
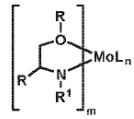
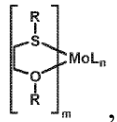
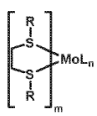
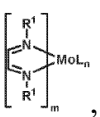
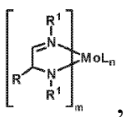
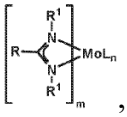
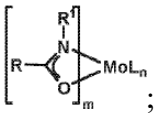
(a) introducing a metal-containing precursor into a processing chamber housing the semiconductor substrate, wherein the metal-containing precursor is a halide-free, carbonyl-free compound that comprises at least one ligand, bound to a metal comprising molybdenum, wherein the halide-free, carbonyl-free compound does not include metal-carbon bonds and metal-oxygen double bonds; and

(b) reacting the metal-containing precursor with at least one reactant in an absence of plasma to form a metal-containing layer on the semiconductor substrate, wherein the formed metal-containing layer is a substantially carbon-free molybdenum-containing layer that has a carbon content of less than 5 atomic %, wherein the layer is selected from the group consisting of Mo, MoN, MoON, MoB, MoSi layers and combinations thereof.

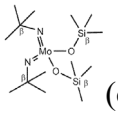
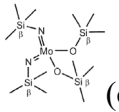
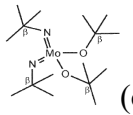
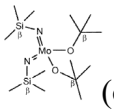
2. The method of claim 1, wherein the formed metal-containing layer has a carbon content of less than 2 atomic %.

3. The method of claim 1, wherein the metal-containing precursor does not include beta-hydrogen atoms.

4. The method of claim 1, wherein the formed metal-containing layer is selected from the group consisting of Mo, MoN, and MoON.

5. The method of claim 1, wherein the metal-containing precursor is selected from the group consisting of: , , , , , , , , , , , , and ;

wherein each R and R1 is independently selected from the group consisting of an alkyl, fluoroalkyl, and alkylsilyl, wherein L is a carbon-containing ligand that does not form metal-carbon bonds, wherein R does not include beta hydrogen bonds, n is 1-4 and m is 1-4.

6. The method of claim 1, wherein the metal-containing precursor is a compound selected from the group consisting of:  (compound 17) ,  (compound 18),  (compound 19), and  (compound 20).

7. The method of claim 1, further comprising:

(c) treating the formed metal-containing layer with a nitrogen-containing reactant and increasing nitrogen content in the metal-containing layer.

8. The method of claim 7, wherein the treated metal-containing layer is a MoN layer having a work function of greater than 4.9 eV.

9. The method of claim 7, wherein the treated metal-containing layer is a MoN layer having nitrogen content of at least 25 atomic %.

10. The method of claim 7, wherein the treated metal-containing layer is a MoN layer having a work function of greater than 5.0 eV.

11. The method of claim 7, wherein (c) comprises treating the semiconductor substrate with a plasma formed in a process gas comprising the nitrogen-containing reactant.

12. The method of claim 1, further comprising:

(c) densifying the formed metal-containing layer by treating the metal-containing layer with a plasma formed in a process gas comprising H_2.

13. The method of claim 1, wherein in (b) the reaction between the metal-containing precursor and the at least one reactant occurs on the surface of the semiconductor substrate.

14. The method of claim 13, wherein (a) comprises:

forming a layer of the metal-containing precursor on the surface of the semiconductor substrate and removing the non surface-bound metal-containing precursor from the processing chamber; and wherein (b) comprises:

introducing the at least one reactant into the processing chamber and reacting with the metal-containing precursor on the surface of the semiconductor substrate.

15. The method of claim 1, wherein the substantially carbon-free metal-containing layer is a diffusion barrier layer or a liner layer.

16. The method of claim 1, wherein the method comprises forming the substantially carbon-free metal-containing layer having a work function of greater than 5.0 eV in a pMOS device.

17. The method of claim 1, wherein forming the substantially carbon-free metal layer having a work function of greater than 5.0 eV, comprises treating the semiconductor substrate after (b) with a plasma-activated nitrogen-containing reactant, to increase nitrogen content in the metal-containing layer.

18. The method of claim 1, wherein the substantially carbon-free metal layer is formed in (b) at a temperature of less than 450 °C.

19. The method of claim 1, wherein the method comprises repeating (a) and (b), such that the method comprises between 1 – 100 cycles, wherein each cycle comprises (a) and (b).

20. The method of claim 1, wherein the at least one reactant is selected from the group consisting of H_2,NH_3, and N_2H_4.

21. The method of claim 1, wherein (b) comprises reacting the metal-containing precursor with H_2.

22. The method of claim 1, further comprising:

applying photoresist to the semiconductor substrate;

exposing the photoresist to light;

patterning the photoresist and transferring the pattern to the semiconductor substrate; and

selectively removing the photoresist from the semiconductor substrate.