CLAIMS

~~*What is claimed is:*~~

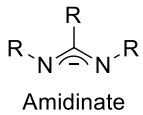
1. A method of forming a molybdenum-containing layer on a semiconductor substrate, the method comprising:

(a) introducing a molybdenum-containing precursor into a process chamber housing the semiconductor substrate, wherein the molybdenum-containing precursor is Mo_2L_n, wherein each L is independently selected from the group consisting of an amidate, an amidinate and a guanidinate ligands, wherein n is 2-5, and wherein the molybdenum-containing precursor comprises a multiple molybdenum-molybdenum bond; and

(b) reacting the molybdenum-containing precursor to form a molybdenum-containing layer on the semiconductor substrate.

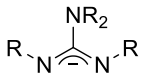
2. The method of claim 1, wherein the molybdenum-containing layer is molybdenum metal.

3. The method of claim 1, wherein the molybdenum-containing precursor is Mo_2L_n, wherein each L is independently an amidinate or a guanidinate ligand, n is 2-5, wherein the amidinate ligand is:



Amidinate

wherein each R is independently selected from the group consisting of of H, alkyl, fluoroalkyl, alkylsilyl, alkylamino, and alkoxy substituents, and wherein the the guanidinidate ligand is:



Guanidinate

wherein each R is independently selected from the group consisting of of H, alkyl, fluoroalkyl, alkylsilyl, alkylamino, and alkoxy substituents.

4. The method of claim 1, wherein the molybdenum-containing precursor is Mo_2L_3 or Mo_2L_4, wherein L is the amidinate.

5. The method of claim 1, wherein the molybdenum-containing precursor is Mo_2L_3 or Mo_2L_4, wherein L is a guanidinate.

6. The method of claim 1, wherein (b) comprises reacting the molybdenum-containing precursor with hydrogen (H_2).

7. The method of claim 1, wherein (b) comprises reacting the molybdenum-containing precursor with at least one reactant selected from the group consisting of hydrogen (H_2), ammonia (NH_3), diborane (B_2H_6), water, H_2S, a thiol, an alcohol, an amine, hydrazine, silane (SiH_4) and disilane (Si_2H_6) to form a layer of molybdenum metal.

8. The method of claim 7, wherein the molybdenum metal is deposited by thermal ALD or PEALD.

9. The method of claim 1, wherein the molybdenum-containing layer is deposited conformally onto a substrate having a recessed feature.

~~10. A method of forming a molybdenum metal layer on a semiconductor substrate, the method comprising:~~

~~(a) introducing a molybdenum-containing precursor into a process chamber housing the semiconductor substrate, wherein the precursor is a compound that includes:~~

~~molybdenum;~~

~~at least one halogen that forms a bond with molybdenum, and~~

~~at least one organic ligand that includes an element selected from the group consisting of N, O, and S, that forms a bond with molybdenum; and~~

~~(b) reacting the molybdenum-containing precursor with at least one reactant to form molybdenum metal on the semiconductor substrate.~~

~~11. The method of claim 10, wherein (b) comprises reacting the molybdenum-containing precursor with at least one reactant selected from the group consisting of hydrogen (H_2), ammonia (NH_3), diborane (B_2H_6), water, H_2S, a thiol, an alcohol, an amine, hydrazine, silane (SiH_4) and disilane (Si_2H_6) to form a layer of molybdenum metal.~~

~~12. The method of claim 11, wherein (b) comprises reacting the molybdenum-containing precursor with hydrogen (H_2) with or without plasma.~~

~~13. The method of claim 10, wherein the reaction in (b) is conducted only on a surface of the substrate.~~

~~14. The method of claim 10, wherein the reaction in (b) is conducted on a surface of the semiconductor substrate, and wherein the method comprises adsorbing the molybdenum-containing precursor onto the substrate and removing an unadsorbed molybdenum-containing precursor from the process chamber, prior to the reaction; reacting the adsorbed molybdenum-containing precursor with a reactant selected from the group consisting of water, an alcohol, H_2S, and a thiol, and, after the reaction, treating the surface of the semiconductor substrate with hydrogen (H_2) with or without plasma to form the layer of molybdenum metal.~~

~~15. The method of claim 10, wherein the precursor is $Mo(X)_m(L)_n$, wherein~~

~~each X is a halide independently selected from the group consisting of F, Cl, Br, and I; and~~

~~each L is an organic ligand independently selected from the group consisting of amidinates, amines, amidates, iminopyrrolidinates, diazadienes, beta-imino amides, alpha-imino alkoxides, beta-amino alkoxides, beta-diketiminates, beta-ketoiminates,~~

~~beta-diketonates, thioethers, thiolates, dithiolates, dithiolenes, and pyrazolates, and wherein m is 1-4, and n is from 1-3.~~

~~16. A method of forming a molybdenum metal layer on a semiconductor substrate, the method comprising:~~

~~(a) introducing a molybdenum-containing precursor into a process chamber housing the semiconductor substrate, wherein the precursor is a compound that includes:~~

~~molybdenum;~~

~~at least one sulfur-containing ligand that forms molybdenum-sulfur bond with molybdenum, wherein the compound does not include molybdenum-carbon bonds; and~~

~~(b) reacting the molybdenum-containing precursor to form molybdenum metal on the semiconductor substrate.~~

~~17. The method of claim 16, wherein in the precursor molybdenum forms only molybdenum-sulfur bonds.~~

~~18. The method of claim 16, wherein the at least one sulfur-containing ligand is selected from the group consisting of 18, 19, 20, 21, 22, 23, 24, 25, wherein each R is independently selected from the group consisting of H, alkyl, fluoroalkyl, alkylamino, alkylsilyl, and alkoxy.~~

~~19. The method of claim 16, wherein (b) comprises reacting the molybdenum-containing precursor with a reactant selected from the group consisting of hydrogen (H_2), ammonia (NH_3), diborane (B_2H_6), water, H_2S, a thiol, an alcohol, an amine, silane (SiH_4), disilane (Si_2H_6), and hydrazine, to form a layer of molybdenum metal.~~

~~20. The method of claim 16, wherein the reaction in (b) is conducted on a surface of the semiconductor substrate, and wherein the method comprises adsorbing the molybdenum-containing precursor onto the substrate and removing an unadsorbed molybdenum-containing precursor from the process chamber, prior to the reaction, reacting the adsorbed molybdenum-containing precursor with a reactant selected from the group consisting of water, an alcohol, H_2S, and a thiol, and, after the reaction,~~

~~treating the surface of the semiconductor substrate with hydrogen (H_2) with or without plasma to form the layer of molybdenum metal..~~

~~21. A precursor for deposition of molybdenum-containing films, wherein the precursor is a compound that includes:~~

~~molybdenum;~~

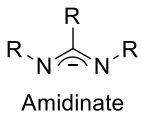
~~at least one halogen that forms a bond with molybdenum, and~~

~~at least one organic ligand that includes an element selected from the group consisting of N, O, and S, that forms a bond with molybdenum, with a proviso that the compound is not a molybdenum complex concurrently containing both an imide and a guanidinate organic ligands.~~

~~22. The precursor of claim 21, wherein the organic ligand is a bidentate ligand.~~

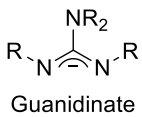
~~23. The precursor of claim 21, wherein the precursor does not contain molybdenum – carbon bonds.~~

~~24~~10. A precursor for deposition of molybdenum-containing films, wherein the precursor is Mo_2L_n, wherein each L is independently an amidinate or a guanidinate ligand, n is 2-5, and wherein the precursor comprises a multiple molybdenum-molybdenum bond, wherein the amidinate ligand is:



Amidinate

wherein each R is independently selected from the group consisting of of H, alkyl, fluoroalkyl, alkylsilyl, alkylamino, and alkoxy substituents, and wherein the the guanidinidate ligand is:



Guanidinate

wherein each R is independently selected from the group consisting of of H, alkyl, fluoroalkyl, alkylsilyl, alkylamino, and alkoxy substituents.

~~25~~11. A system for processing a semiconductor substrate, the system comprising:

(a) a processing chamber, having a substrate holder and one or more inlets for introduction of reactants to the processing chamber; and

(b) a system controller comprising program instructions for:

(i) causing an introduction of a molybdenum-containing precursor to the processing chamber, wherein the molybdenum-containing precursor is Mo_2L_n, wherein each L is independently selected from the group consisting of an amidate, an amidinate and a guanidinate ligands, wherein n is 2-5, and wherein the molybdenum-containing precursor comprises a multiple molybdenum-molybdenum bond; and

(ii) causing the molybdenum-containing precursor to react and form a molybdenum containing layer on the semiconductor substrate.

~~26. A system for processing a semiconductor substrate, the system comprising:~~

~~(a) a processing chamber, having a substrate holder and one or more inlets for introduction of reactants to the processing chamber; and~~

~~(b) a system controller comprising program instructions for:~~

~~(i) causing an introduction of a molybdenum-containing precursor to the processing chamber, wherein the molybdenum-containing precursor is a compound that includes:~~

~~molybdenum;~~

~~at least one halogen that forms a bond with molybdenum, and~~

~~at least one organic ligand that includes an element selected from the group consisting of N, O, and S, that forms a bond with molybdenum; and~~

~~(ii) causing the molybdenum-containing precursor to react and form a molybdenum containing layer on the semiconductor substrate.~~

~~27. A system for processing a semiconductor substrate, the system comprising:~~

~~(a) a processing chamber, having a substrate holder and one or more inlets for introduction of reactants to the processing chamber; and~~

~~(b) a system controller comprising program instructions for:~~

~~(i) causing an introduction of a molybdenum-containing precursor to the processing chamber, wherein the molybdenum-containing precursor is a compound that includes:~~

~~molybdenum;~~

~~at least one sulfur-containing ligand that forms molybdenum-sulfur bond with molybdenum, wherein the compound does not include molybdenum-carbon bonds; and~~

~~(ii) causing the molybdenum-containing precursor to react and form a molybdenum-containing layer on the semiconductor substrate.~~