What is claimed is:

1. A method of forming a semiconductor film, the method comprising:

form a metal layer on a substrate surface by exposing the substrate surface to a metal precursor and a reactant, the metal layer having a reactive surface; and

form a protective capping layer on the metal layer by exposing the metal layer to a second metal precursor and a second precursor, the second precursor comprising a functional group and a carbon chain having from 2 to 20 carbon atoms, the functional group selected from the group consisting of a primary amine, a thiol, a phosphine, an alcohol, and a selenol.

2. The method of claim 1, wherein the reactant comprises one or more of ammonia (NH_3), water (H_2O), hydrogen sulfide (H_2S), phosphine (PH_3), ozone (O_3), hydrogen peroxide (H_2O_2), nitrous oxide (N_2O), and hydrogen selenide (H_2Se).

3. The method of claim 1, wherein the metal precursor and the second metal precursor independently comprise a metal and a reactive species.

4. The method of claim 3, wherein the metal is a transition metal.

5. The method of claim 3, wherein the metal is selected from one or more of titanium (Ti), silicon (Si), molybdenum (Mo), hafnium (Hf), zirconium (Zr), aluminum (Al), antimony (Sb), boron (B), gallium (Ga), germanium (Ge), indium (In), niobium (Nb), rhenium (Re), tantalum (Ta), tin (Sn), tungsten (W), and zinc (Zn), and wherein the reactive species is selected from the group consisting of halide, alkyl, arene, cyclopentadienyl, alkyne, diene, diketonate, amido, imido, alkoxo, oxo, carbonyl, amidinate, guanidinate, and formamidinate.

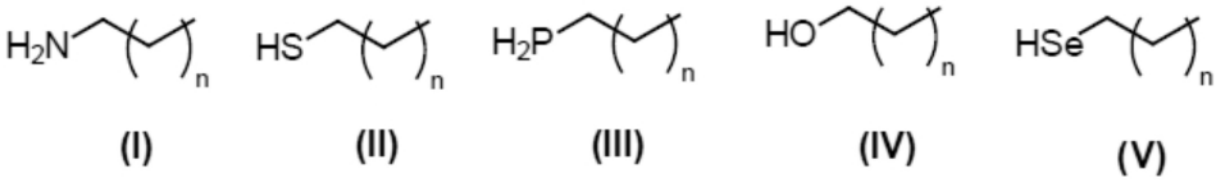
6. The method of claim 2, wherein the metal precursor and the second metal precursor independently comprise one or more of, aluminum chloride, aluminum bromide, aluminum iodide, boron trichloride, boron tribromide, gallium trichloride, germanium tetrachloride, antimony trichloride, antimony pentachloride, indium trichloride, silicon tetrachloride, silicon tetrabromide, silicon tetraiodide,

hexachlorodisilane, titanium tetrachloride, titanium tetrabromide, titanium tetraiodide, zirconium tetrachloride, hafnium tetrachloride, niobium pentachloride, niobium pentabromide, tantalum pentachloride, tantalum pentabromide, molybdenum pentachloride, tungsten hexachloride, rhenium pentachloride, zinc chloride, tin chloride, trimethyl aluminum, tetrakis(dimethylamido)titanium, tetrakis(dimethylamido)zirconium, tetrakis(dimethylamido)hafnium, (t-butylimido)tris(diethylamino)niobium, (t-butylimido)tris(diethylamino)tantalum, pentakis(dimethylamido)tantalum, bis(ethylbenzene)molybdenum, molybdenum hexacarbonyl, tungsten hexacarbonyl, and diethylzinc.

7. The method of claim 1, wherein the metal layer comprises one or more of a metal nitride, a metal oxide, a metal sulfide, a metal phosphide, and a metal selenide.

8. The method of claim 1, wherein the protective capping layer has a thickness in a range of from 0.5 nm to 5 nm.

9. The method of claim 1, wherein the second metal precursor comprises one or more of a compound selected from



(I) (II) (III) (IV) (V)

wherein n is an integer in a range of from 1 to 20.

10. A method of forming a semiconductor film, the method comprising:

performing a first process cycle comprising exposing a substrate surface to a metal precursor and a reactant to form a metal layer on the substrate surface, the metal layer having a reactive surface; and

performing a second process cycle comprising exposing the metal layer to a second metal precursor and a second precursor to form a protective capping layer on the metal layer, the second precursor comprising a carbon chain having

from 2 to 20 carbon atoms and a functional group, the functional group selected from the group consisting of a primary amine, a thiol, a phosphine, an alcohol, and a selenol.

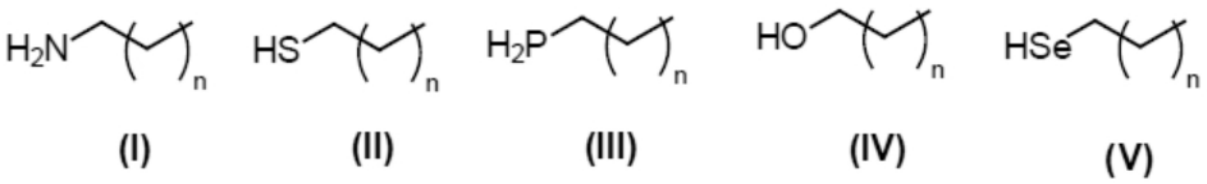
11. The method of claim 10, wherein the metal precursor and the second metal precursor independently comprise a metal and a reactive species and wherein the reactant comprises one or more of ammonia (NH_3), water (H_2O), hydrogen sulfide (H_S), phosphine (PH_3), ozone (O_3), hydrogen peroxide (H_2O_2), nitrous oxide (N_2O), and hydrogen selenide (H_2Se).

12. The method of claim 11, wherein the metal is selected from one or more of titanium (Ti), silicon (Si), molybdenum (Mo), hafnium (Hf), zirconium (Zr), aluminum (Al), antimony (Sb), boron (B), gallium (Ga), germanium (Ge), indium (In), niobium (Nb), rhenium (Re), tantalum (Ta), tin (Sn), tungsten (W), and zinc (Zn), and wherein the reactive species is selected from the group consisting of halide, alkyl, arene, cyclopentadienyl, alkyne, diene, diketonate, amido, imido, alkoxo, oxo, carbonyl, amidinate, guanidinate, and formamidinate.

13. The method of claim 11, wherein the metal precursor and the second metal precursor independently comprise one or more of aluminum chloride, aluminum bromide, aluminum iodide, boron trichloride, boron tribromide, gallium trichloride, germanium tetrachloride, antimony trichloride, antimony pentachloride, indium trichloride, silicon tetrachloride, silicon tetrabromide, silicon tetraiodide, hexachlorodisilane, titanium tetrachloride, titanium tetrabromide, titanium tetraiodide, zirconium tetrachloride, hafnium tetrachloride, niobium pentachloride, niobium pentabromide, tantalum pentachloride, tantalum pentabromide, molybdenum pentachloride, tungsten hexachloride, rhenium pentachloride, zinc chloride, tin chloride, trimethyl aluminum, tetrakis(dimethylamido)titanium, tetrakis(dimethylamido)zirconium, tetrakis(dimethylamido)hafnium, (t-butylimido)tris(diethylamino)niobium, (t-butylimido)tris(diethylamino)tantalum,

pentakis(dimethylamido)tantalum, bis(ethylbenzene)molybdenum, molybdenum hexacarbonyl, tungsten hexacarbonyl, and diethylzinc.

14. The method of claim 10, wherein the second metal precursor comprises one or more of a compound selected from



(I) (II) (III) (IV) (V)

wherein n is an integer in a range of from 1 to 20.

15. The method of claim 10, wherein the first process cycle is repeated from 2 to 100 times and the second process cycle is repeated from 2 to 10 times.