- the indium(III)-containing film being a layer of, but not limited to, InGaAs, In_xO_y (x=0.5 to 1.5, y=0.5 to 1.5), InSnO (ITO), InGaZnO (IGZO), InN, InP, InAs, InSb, In_2S_3, or $In(OH)_3$;
- the indium(III)-containing film being a pure indium (In(0)) layer;
- the Indium-containing film containing a second element selected from P, N, S, Ga, As, B, Ta, Hf, Nb, Mg, Al, Sr, Y, Ba, Ca, As, Sb, Bi, Sn, Pb, Co, Zn, one or more lanthanides, or combinations thereof;
- the vapor deposition process being a ALD process, a CVD process or a combination thereof;
- the vapor deposition process being a PEALD process or a spatial ALD process;
- further comprising the step of exposing the substrate to a co-reactant;
- the co-reactant being selected from O_3, O_2, H_2O, NO, N_2O, NO_2, H_2O_2, O radicals and combinations thereof;
- the co-reactant being O_3 or O_2;
- the co-reactant being selected from NH_3, NO, N_2O, hydrazines, N_2 plasma, N_2/H_2 plasma, NH_3 plasma, amines and combinations thereof;
- the co-reactant being NH_3;
- the co-reactant being N_2 plasma;
- the co-reactant being treated by a plasma;
- the substrate being a powder;
- the powder comprising one or more of NMC (Lithium Nickel Manganese Cobalt Oxide), LCO (Lithium Cobalt Oxide), LFP (Lithium Iron Phosphate), and other battery cathode materials;
- the deposition pressure being held between about 10^{-3} Torr and about 100 Torr;
- the deposition pressure being held between about 10^{-2} Torr and 100 Torr;
- the deposition temperature being held between about 100°C and about 600°C;
- the deposition temperature being held between about 150°C and about 500°C; and
- the deposition reactor wall being heated from approximately 50°C to approximately 600°C.

[0018a] In one aspect, there is provided a method for forming an indium(III)-containing film on a substrate, the method comprising the steps of exposing the substrate to a vapor of a film forming composition that contains an indium(III)-containing precursor; and depositing at least part of the indium(III)-containing precursor onto the substrate to form the indium(III)-containing film on the substrate through a vapor deposition process, wherein the indium(III)-containing precursor is selected from:

[(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---CH---N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N---C(H) ---N(*iPr*))InCl]$_2$(μ-Cl)$_2$,

[(Et)N---C(*n*Bu)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---C(Me)---N(*i*Pr)]In(III)Cl_2, or

[(*i*Pr)N---C(*n*Bu)---N(*i*Pr)]In(III)Cl_2.

[0019] Also disclosed is a method for forming an indium(III)-containing film on a substrate, the method comprising the steps of:

forming a chemisorbed and/or physisorbed film, on the surface of the substrate, of an indium(III)-containing precursor having the formula:

(a) [(R^1)N---C(R^3)---N(R^2)]InX_2,

[(R^1)N---C(R^3)---N(R^2)]$_2$InX, or

selected from a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl groups; R^1, R^2, R^3, R^4 and R^5 may also be $–SiR^6R^7R^8$ where R^6, R^7, R^8 are each independently selected from a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl group. Groups R^1, R^2, R^3 and R^5 may also be selected from fluorinated linear or aromatic groups (e.g., CF_3, *m*-$(CF_3)_2$-C_6H_3, etc.). Group R^4 may also be selected from halogens, such as F,

and

(e) $[N((SiR^1R^2R^3)R^4)]InX_2$

wherein X is chosen from chlorine, bromine and iodine, preferably chlorine; R^1, R^2, and R^3 are each independently selected from hydrogen or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl groups, R^4 is hydrogen or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl group or a $–SiR^5R^6R^7$ group wherein R^5, R^6, and R^7 are each independently selected from hydrogen or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl group.

The disclosed methods may include one or more of the following aspects:

- further comprising the step of chemically reacting the chemisorbed and/or physisorbed film comprising the indium(III)-containing precursor with a co-reactant;
- the co-reactant reacting with the indium(III)-containing precursor in the chemisorbed and/or physisorbed film producing a reaction product that forms the indium(III)-containing film on the surface of the substrate;
- the co-reactant being selected from O_3, O_2, H_2O, NO, N_2O, NO_2, H_2O_2, O radicals and combinations thereof; and
- the co-reactant being selected from NH_3, NO, N_2O, hydrazines, N_2 plasma, N_2/H_2 plasma, NH_3 plasma, amines and combinations thereof.

[0019a] In yet another aspect, there is provided a A composition for deposition of a film comprising an indium(III)-containing precursor selected from:

[(Et)N⁼⁼⁼C(Me)⁼⁼⁼N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N⁼⁼⁼CH⁼⁼⁼N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N⁼⁼⁼C(H) ⁼⁼⁼N(*iPr*))InCl]$_2$(μ-Cl)$_2$,

[(Et)N⁼⁼⁼C(*n*Bu)⁼⁼⁼N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N⁼⁼⁼C(Me)⁼⁼⁼N(*i*Pr)]In(III)Cl_2, or

[(*i*Pr)N⁼⁼⁼C(*n*Bu)⁼⁼⁼N(*i*Pr)]In(III)Cl_2.

[0020] Also disclosed is a composition for deposition of a film comprising an indium(III)-containing precursor having the formula:

(a) $[(R^1)N⁼⁼⁼C(R^3)⁼⁼⁼N(R^2)]InX_2$,

$[(R^1)N⁼⁼⁼C(R^3)⁼⁼⁼N(R^2)]_2InX$, or

$[((R^1)N⁼⁼⁼C(R^3)⁼⁼⁼N(R^2))InX]_2(\mu\text{-}X)_2$,

wherein X is chosen from chlorine, bromine and iodine, preferably chlorine; R^1 and R^2 are each independently selected from a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl groups or $–SiR^4R^5R^6$ wherein R^4, R^5, R^6 are each independently selected from a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl groups; R^3 is selected from H or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl group or $–NR^7R^8$ where R^7 and R^8 are each independently selected from H or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl groups. Under certain conditions when the disclosed In(III)-containing precursors have

are each independently selected from hydrogen or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl groups, R^4 is hydrogen or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl group or a $–SiR^5R^6R^7$ group wherein R^5, R^6, and R^7 are each independently selected from hydrogen or a linear, branched or cyclic C_1 to C_9 alkyl, vinyl or aryl group.

The disclosed methods may include one or more of the following aspects:

- X being chloride;
- the indium(III)-containing precursor being selected from [(Et)N⁃⁃C(Me)⁃⁃N(*t*Bu)]In(III)Cl_2, [(*i*Pr)N⁃⁃CH⁃⁃N(*i*Pr)]In(III)Cl_2, [(Et)N⁃⁃C(Me)⁃⁃N(*t*Bu)]In(III)Cl_2 or [(*i*Pr)N⁃⁃C(*n*Bu)⁃⁃N(*i*Pr)]In(III)Cl_2;
- the indium(III)-containing precursor being [(Et)N⁃⁃C(Me)⁃⁃N(*t*Bu)]In(III)Cl_2;
- the indium(III)-containing precursor being [(*i*Pr)N⁃⁃CH⁃⁃N(*i*Pr)]In(III)Cl_2;
- the indium(III)-containing precursor being [(Et)N⁃⁃C(Me)⁃⁃N(*t*Bu)]In(III)Cl_2;
- the indium(III)-containing precursor being [(*i*Pr)N⁃⁃C(*n*Bu)⁃⁃N(*i*Pr)]In(III)Cl_2;
- the indium(III)-containing precursor having a purity ranging from approximately 93% w/w to approximately 100% w/w; and
- the indium(III)-containing precursor having a purity ranging from approximately 99% w/w to approximately 99.999% w/w.

[00020a] In yet another aspect, there is provided a method for forming an indium(III)-containing film on a substrate, the method comprising the steps of forming a chemisorbed and/or physisorbed film of an indium (III)-containing precursor, on the surface of the substrate, wherein the indium(III)-containing precursor is selected from:

[(Et)N⁃⁃C(Me)⁃⁃N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N⁃⁃CH⁃⁃N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N⁃⁃C(H) ⁃⁃N(*iPr*))InCl]$_2$(μ-Cl)$_2$,

[(Et)N⁃⁃C(*n*Bu)⁃⁃N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N⁃⁃C(Me)⁃⁃N(*i*Pr)]In(III)Cl_2, or

[(*i*Pr)N⁃⁃C(*n*Bu)⁃⁃N(*i*Pr)]In(III)Cl_2.

Notation and Nomenclature

[0021] The following detailed description and claims utilize a number of abbreviations, symbols, and terms, which are generally well known in the art. Certain abbreviations, symbols, and terms are used throughout the following description and claims, and include:

[0022] As used herein, the indefinite article “a” or “an” means one or more.

[0023] As used herein, “about” or “around” or “approximately” in the text or in a claim means ±10% of the value stated.

[0024] As used herein, “room temperature” in the text or in a claim means from approximately 20°C to approximately 25°C.

[0025] The term “ambient temperature” refers to an environment temperature approximately 20°C to approximately 25°C.

[0026] The term “substrate” refers to a material or materials on which a process is conducted. The substrate may refer to a wafer having a material or materials on which a process is conducted. The substrates may be any suitable wafer used in semiconductor, photovoltaic, flat panel, or LCD-TFT device manufacturing. The substrate may also have one or more layers of differing materials already deposited upon it from a previous manufacturing step. For example, the wafers may include silicon layers (e.g., crystalline,

What is claimed is:

1. A method for forming an indium(III)-containing film on a substrate, the method comprising the steps of:

exposing the substrate to a vapor of a film forming composition that contains an indium(III)-containing precursor; and

depositing at least part of the indium(III)-containing precursor onto the substrate to form the indium(III)-containing film on the substrate through a vapor deposition process, wherein the indium(III)-containing precursor is selected from:

[(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---CH---N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N---C(H) ---N(*iPr*))InCl]$_2$(μ-Cl)$_2$,

[(Et)N---C(*n*Bu)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---C(Me)---N(*i*Pr)]In(III)Cl_2, or

[(*i*Pr)N---C(*n*Bu)---N(*i*Pr)]In(III)Cl_2.

2. The method of claim 1, wherein the indium(III)-containing precursor is [(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2.

3. The method of claim 1, wherein the indium(III)-containing precursor is [(*i*Pr)N---CH ---N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N---C(H) ---N(*iPr*))InCl]$_2$(μ-Cl)$_2$.

4. The method of claim 1, wherein the indium(III)-containing precursor is [(Et)N---C(*n*Bu)---N(*t*Bu)]In(III)Cl_2.

5. The method of claim 1, wherein the indium(III)-containing precursor is [(*i*Pr)N---C(*n*Bu)---N(*i*Pr)]In(III)Cl_2.

6. The method of claim 1, wherein the indium(III)-containing film is an indium oxide film, or a binary, ternary and quaternary indium alloy film.

7. The method of claim 1, wherein the indium(III)-containing film is InGaAs, In_xO_y (x=0.5 to 1.5, y=0.5 to 1.5), InSnO (ITO), InGaZnO (IGZO), InN, InP, InAs, InSb, In_2S_3, or $In(OH)_3$.

8. The method of claim 1, wherein the vapor deposition process is an ALD or a CVD process.

9. The method of any claims from 1 to 9, further comprising the step of exposing the substrate to a co-reactant.

10. The method of claim 10, wherein the co-reactant is selected from O_3, O_2, H_2O, NO, N_2O, NO_2, H_2O_2, O radicals and combinations thereof.

11. The method of claim 10, wherein the co-reactant is selected from NH_3, NO, N_2O, hydrazines, N_2 plasma, N_2/H_2 plasma, NH_3 plasma, amines and combinations thereof.

12. A composition for deposition of a film comprising an indium(III)-containing precursor selected from:

[(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---CH---N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N---C(H) ---N(*iPr*))InCl]$_2$(μ-Cl)$_2$,

[(Et)N---C(*n*Bu)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---C(Me)---N(*i*Pr)]In(III)Cl_2, or

[(*i*Pr)N---C(*n*Bu)---N(*i*Pr)]In(III)Cl_2.

.

13. The composition of claim 12, wherein the indium(III)-containing precursor is selected from [(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2, [(*i*Pr)N---CH---N(*i*Pr)]In(III)Cl_2, [(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2, [(*i*Pr)N---C(Me)---N(*i*Pr)]In(III)Cl_2 or [(*i*Pr)N---C(*n*Bu)---N(*i*Pr)]In(III)Cl_2.

14. A method for forming an indium(III)-containing film on a substrate, the method comprising the steps of:

forming a chemisorbed and/or physisorbed film of an indium (III)-containing precursor, on the surface of the substrate, wherein the indium(III)-containing precursor is selected from:

[(Et)N---C(Me)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---CH---N(*i*Pr)]In(III)Cl_2 or [((*iPr*)N---C(H) ---N(*iPr*))InCl]$_2$(μ-Cl)$_2$,

[(Et)N---C(*n*Bu)---N(*t*Bu)]In(III)Cl_2,

[(*i*Pr)N---C(Me)---N(*i*Pr)]In(III)Cl_2, or

[(*i*Pr)N---C(*n*Bu)---N(*i*Pr)]In(III)Cl_2.

15. The method of claim 14, further comprising the step of chemically reacting the chemisorbed and/or physisorbed film comprising the indium(III)-containing precursor with a co-reactant.

16. The method of claim 15, wherein the co-reactant reacting with the indium(III)-containing precursor in the chemisorbed and/or physisorbed film produces a reaction product that forms the indium(III)-containing film on the surface of the substrate.

17. The method of any claims from 14 to 16, wherein the co-reactant is selected from O_3, O_2, H_2O, NO, N_2O, NO_2, H_2O_2, O radicals and combinations thereof.

18. The method of any claims from 14 to 16, wherein the co-reactant is selected from NH_3, NO, N_2O, hydrazines, N_2 plasma, N_2/H_2 plasma, NH_3 plasma, amines and combinations thereof.

19. The method of claim 1, wherein the indium(III)-containing precursor is [(*i*Pr)N---C(Me)---N(*i*Pr)]In(III)Cl_2.