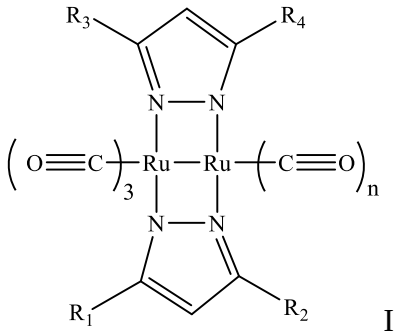
Claims

What is claimed is

1. An ALD or ALD-like process depositing a ruthenium-containing layer on a substrate comprising:

(i) exposing a surface of the substrate to a precursor comprising one or more ruthenium compound of~~, represented by~~ Formula I:



I

wherein

R_1, R_2, R_3 and R_4 are each independently selected from the group of a substituted or unsubstituted C_1 to C_{20} linear or branched ~~or cyclic~~ alkyl and a substituted or unsubstituted C_1 to C_{20} linear or branched ~~or cyclic~~ halogenated alkyl;

n = 2 or 3; and

the precursor is ~~preferably~~ substantially free of water, metal ions or metals, and organic impurities,,

(ii) thereafter exposing the surface of the substrate to one or more co-reactant;

wherein

the process is conducted at a temperature in the range of approximately 200 °C and below approximately 300 °C, and

the ruthenium-containing layer has an as-deposited resistivity of below about 40 µOhm·cm.

2. The ~~precursor~~ process of claim 1, wherein R_1, R_2, R_3 and R_4 in Formula Iare each independently one of -CH_3, -CH_2CH_3, -$CH_2CH_2CH_3$, -$CH(CH3)_2$, -$CH_2CH(CH_3)_2$, -$C(CH_3)_3$, -CF_3, -CF_2CF_3, -$CF_2CF_2CF_3$, -$CF(CF_3)_2$, -$C(CF_3)_3$.

~~**3.** The precursor of claim 1, wherein at least one of R_1, R_2, R_3 and R_4 is a substituted or unsubstituted C_1 to C_8 perfluorinated alkyl.~~

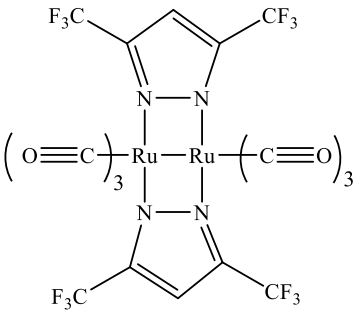
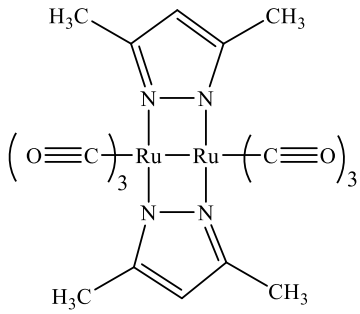
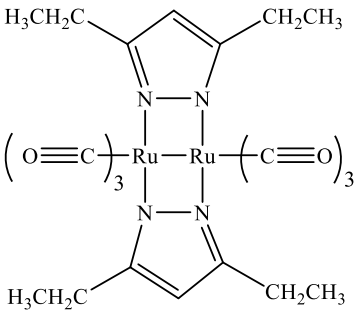
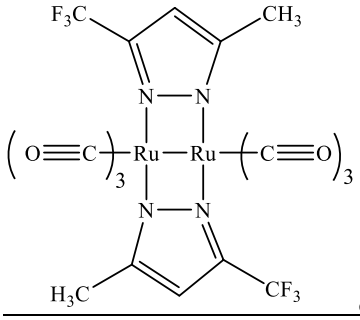
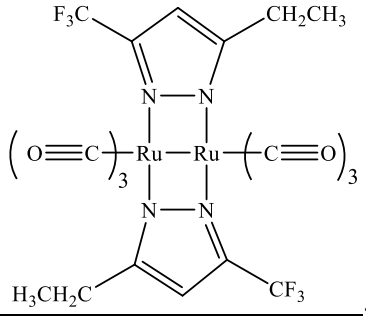
~~**4.** The precursor of claim 1, wherein n = 2.~~

~~**5.** The precursor of claim 1, wherein n = 3.~~

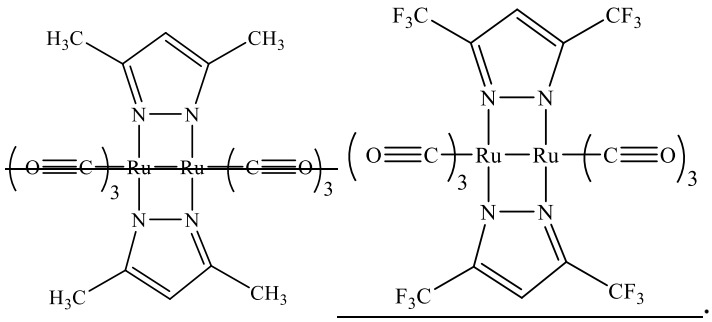
~~**6.** The precursor of claim 1, wherein each of R_1, R_2, R_3 and R_4 is the same group.~~

~~**7.** The precursor of claim 1, wherein each of R_1 and R_4 or R_2 and R_3 are the same group.~~

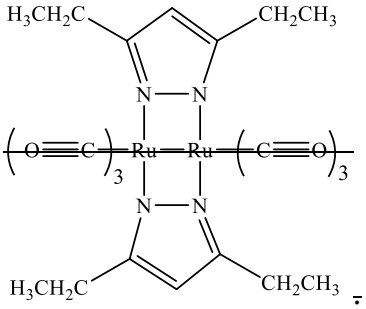
~~8~~3. The ~~precursor~~ process of claim 1, wherein the precursor comprises one or more compound of Formula I selected from the group of~~having the structure~~:





and


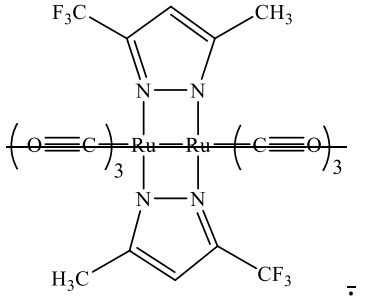
~~9~~4. The ~~precursor~~ process of claim 1, wherein the precursor comprises a compound of Formula I having the structure:



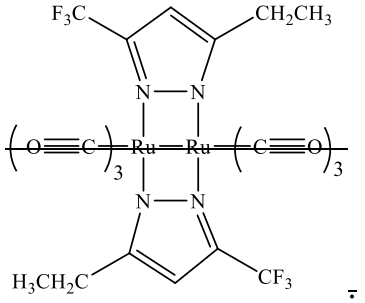
~~10.~~ ~~The precursor of claim 1, having the structure:~~



~~11.~~ ~~The precursor of claim 1, having the structure:~~



~~12.~~ ~~The precursor of claim 1, having the structure:~~



~~13.~~ ~~An ALD or ALD-like process comprising the step of depositing a ruthenium-containing layer derived from a precursor of any of claims 1 to 12 on a surface of a substrate.~~

~~14~~5. The process of claim ~~13~~ 1, wherein the surface comprises at least one of Al_2O_3, ZrO_2, HfO_2, SiO_2, WN, WCN, TiN, Cu, Co, Mo, W and combinations thereof.

~~15.~~ ~~The process of claim 13, wherein the ALD or ALD-like process is conducted at a temperature below approximately 300 °C.~~

~~16~~6. The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted at a temperature below approximately 275 °C.

~~17~~7. The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted at a temperature below approximately 250 °C.

~~18~~8. The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted at a temperature in the range of approximately ~~200~~ 225 °C and approximately ~~300~~ 295 °C.

~~19~~9. The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted at a temperature in the range of approximately 235 °C and approximately 300 °C.

~~**20.** The process of claim 13, further comprising the use of a co-reactant.~~

~~21~~10. The process of claim ~~13~~ 1, wherein the one or more co-reactant comprises ~~further comprising the use of~~ an oxygen-free co-reactant.

~~22~~11. The process of claim ~~13~~ 1, wherein the one or more co-reactant comprises ~~further comprising the use of~~ an oxygen-containing co-reactant.

~~23~~12. The process of claim ~~13~~ 1, wherein the one or more co-reactant comprises ~~further comprising the use of~~ H_2 ~~as a co-reactant~~.

~~24~~13. The process of claim ~~13~~ 1, wherein the one or more co-reactant comprises ~~further comprising the use of~~ one or more ozone, elemental oxygen and molecular oxygen/O_2 hydrogen peroxide and nitrious oxide~~as a co-reactant~~.

~~**25.** The process of claim 13, wherein the ALD or ALD-like process is conducted at a pressure between approximately 0.01 and approximately 20 Torr.~~

~~26~~14. The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted at a pressure between approximately 1 and approximately 15 Torr.

~~**27.** The process of claim 13, wherein the ALD or ALD-like process is conducted at a pressure between approximately 5 and approximately 15 Torr.~~

~~**28.** The process of claim 13, wherein the ALD or ALD-like process is conducted at a pressure between approximately 5 and approximately 10 Torr.~~

~~**29.** The process of claim 13, wherein the ALD or ALD-like process is conducted at a pressure of approximately 5 Torr.~~

~~**30.** The process of claim 13, wherein the ALD or ALD-like process is conducted at a pressure of approximately 10 Torr.~~

~~**31.** The process of claim 13, wherein the ALD or ALD-like process is conducted at a pressure of approximately 15 Torr.~~

~~32~~15. The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted with a precursor pulse time of approximately 1 sec to approximately 15 sec.

~~**33.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor pulse time of approximately 5 sec to approximately 10 sec.~~

~~**34.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor pulse time of approximately 10 sec.~~

~~**35.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor pulse time of approximately 15 sec.~~

~~**36.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor purge time of approximately 1 sec to approximately 20 sec.~~

~~**37.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor purge time of approximately 5 sec to approximately 15 sec.~~

~~**38.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor purge time of approximately 10 sec. to approximately 15 sec.~~

~~**39.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor purge time of approximately 10 sec.~~

~~**40.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a precursor purge time of approximately 15 sec.~~

~~**41**~~**16.** The process of claim ~~13~~ 1, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 1 sec to approximately 60 sec.

~~**42.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 10 sec to approximately 50 sec.~~

~~**43.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 20 sec to approximately 40 sec.~~

~~**44.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 30 sec to approximately 40 sec.~~

~~**45.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 30 sec.~~

~~**46.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 40 sec.~~

~~**47.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant pulse time of approximately 50 sec.~~

~~**48.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 1 sec to approximately 90 sec.~~

~~**49.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 10 sec to approximately 80 sec.~~

~~**50.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 20 sec to approximately 70 sec.~~

~~**51.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 30 sec to approximately 60 sec.~~

~~**52.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 50 sec.~~

~~**53.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 60 sec.~~

~~**54.** The process of claim 13, wherein the ALD or ALD-like process is conducted with a co-reactant purge time of approximately 70 sec.~~

~~**55**~~**17.** ~~An ALD or ALD-like deposited film comprising~~ A ruthenium-containing layer deposited by the process of claim 1, wherein the layer comprises the reaction product of a precursor of ~~any of~~ claim~~s~~ 1 ~~to 12~~ and at least one oxygen-free co-reactant.

~~**56**~~**18.** The ~~ALD- or ALD-like deposited film~~ ruthenium-containing layer of claim ~~55~~ 17, wherein the at least one oxygen-free co-reactant comprises hydrogen.

~~**57**~~**19.** The ~~ALD- or ALD-like deposited film~~ ruthenium-containing layer of claim ~~55~~ 17, wherein the at least one oxygen-free co-reactant comprises a nitrogen-containing co-reactant.

~~**58**~~**20.** The ~~ALD- or ALD-like deposited film~~ ruthenium-containing layer of claim ~~55~~ 17, wherein the at least one oxygen-free co-reactant comprises one or more of ammonia, hydrazine, an alkylhydrazine and an alkyl amine.

~~**59**~~**21.** ~~An ALD- or ALD-like deposited film comprising~~ A ruthenium-containing layer deposited by the process of claim 1, wherein the layer comprises the reaction product of ~~a~~ the precursor ~~of any of claims 1 to 12~~ and at least one oxygen-containing co-reactant.

~~**60**~~**22.** The ~~ALD- or ALD-like deposited film~~ ruthenium-containing layer of claim ~~59~~ 21, wherein the at least one oxygen-containing co-reactant comprises one or more of oxygen, hydrogen peroxide and nitrous oxide.

~~**61**~~**23.** The ~~ALD- or ALD-like deposited film~~ ruthenium-containing layer of claim ~~59~~ 21, wherein the at least one oxygen-containing co-reactant comprises one or more of ozone, elemental oxygen and molecular oxygen/O_2.

~~**62**~~**24.** The ~~ALD- or ALD-like deposited film~~ ruthenium-containing layer of claim ~~59~~ 21, wherein the at least one oxygen-containing co-reactant comprises O_2.

~~**63.** The process of claim 13, wherein the ALD or ALD-like process is conducted:~~

- ~~**(i)** at a temperature of approximately 245 °C;~~
- ~~**(ii)** at a pressure of approximately 10 Torr;~~
- ~~**(iii)** with a precursor pulse time of approximately 10 sec;~~
- ~~**(iv)** with a precursor purge time of approximately 15 sec;~~
- ~~**(v)** with a co-reactant pulse time of approximately 40 sec; and~~
- ~~**(vi)** with a co-reactant purge time of approximately 60 sec.~~

~~**64.** The process of claim 63, wherein the co-reactant is H_2.~~

~~**65.** The use of the precursor of any one of claims 1 to 12 in ALD and ALD-like processes.~~