

THE CLAIMS

What is claimed is:

1. A method of forming a ruthenium-containing film in a vapor deposition process, comprising depositing ruthenium with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species.
2. The method of claim 1 wherein the ruthenium nucleation step is uniform and rapid relative to ruthenium nucleation in the absence of the assistive metal species.
3. The method of claim 1, wherein the assistive metal species comprises at least one metal selected from the group consisting of strontium, calcium, barium, magnesium, titanium, aluminum, zirconium, tantalum, niobium, vanadium, iron and hafnium.
4. The method of claim 1, wherein the assistive metal species comprises at least one species selected from the group consisting of strontium oxide, strontium carbonate, calcium oxide, calcium carbonate, magnesium oxide, magnesium carbonate, barium oxide, barium carbonate, titanium dioxide, aluminum, zirconium oxide, hafnium oxide, tantalum oxide, and niobium oxide.
5. The method of claim 1, wherein the ruthenium-containing film is formed in a process for manufacturing a micro-electronic device or precursor structure therefor.
6. The method of claim 1, wherein the ruthenium is deposited on strontium-containing material.
7. The method of claim 6, wherein the strontium-containing material comprises strontium oxide and/or strontium carbonate.
8. The method of claim 1, wherein the assistive metal species is deposited on a non-metallic substrate.

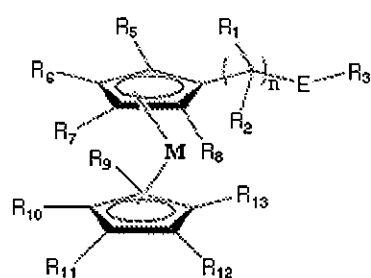
9. The method of claim 8, wherein the non-metallic substrate comprises silicon and/or silicon oxide.
10. The method of claim 8, wherein the assistive metal species is deposited by a vapor deposition process selected from the group consisting of chemical vapor deposition and atomic layer deposition.
11. The method of claim 1, wherein the assistive metal species comprises a dicyclopentadienyl strontium precursor.
12. The method of claim 1, wherein ruthenium is deposited on a strontium-containing film formed by atomic layer deposition from a vapor of a dicyclopentadienyl strontium precursor.
13. The method of claim 1, wherein ruthenium is deposited with the assistive metal, from a precursor paper comprising ruthenium and the assistive metal species.
14. The method of claim 13, wherein the assistive metal comprises strontium.
15. The method of claim 13, wherein the assistive metal species comprises a dicyclopentadienyl strontium compound.
16. The method of claim 15, wherein the dicyclopentadienyl strontium compound comprises $\text{Sr}(\text{}^n\text{PrMe}_4\text{Cp})_2$ wherein ${}^n\text{Pr}$ is n-propyl, Me is methyl and Cp is cyclopentadienyl.
17. The method of claim 1, wherein ruthenium and the assistive metal species are deposited from a precursor vapor of a precursor composition comprising strontium and ruthenium metal precursors dissolved in a solvent medium.
18. The method of claim 17, wherein the ruthenium and strontium precursors are both dicyclopentadienyl compounds.
19. The method of claim 17, wherein the ruthenium precursor comprises a dicyclopentadienyl ruthenium compound including on at least one of constituent cyclopentadienyl rings thereof a pendant Lewis base functional group that coordinates to the strontium metal center of the strontium precursor.

20. The method of claim 19, wherein the pendant Lewis base functional group comprises a functionality selected from the group consisting of amines, polyamines, ethers, and polyethers.
21. The method of claim 17, wherein the solvent medium includes a hydrocarbon solvent.
22. A precursor composition comprising a ruthenium precursor and an assistive metal species precursor, in a solvent medium, wherein one of the ruthenium and assistive metal species precursors includes a pendant functionality that coordinates with the central metal atom of the other precursor, so that ruthenium and the assistive metal species co-deposit with one another.
23. The precursor composition of claim 22, wherein the assistive metal species precursor comprises a dicyclopentadienyl strontium compound.
24. The precursor composition of claim 23, wherein the ruthenium precursor comprises a dicyclopentadienyl ruthenium compound.
25. The precursor composition of claim 24, wherein the strontium and ruthenium compounds are present in the composition in a weight ratio that is in a range of from 0.8 to 1.25.
26. The precursor composition of claim 24, wherein the solvent medium comprises a hydrocarbon solvent.
27. A composition comprising bis (n-propyl tetramethyl cyclopentadienyl) strontium and ethylmethyl amino ethyl cyclopentadienyl ruthenium dicyclopentadiene.
28. A composition comprising a dicyclopentadienyl strontium compound, a dicyclopentadienyl ruthenium compound, and a solvent medium, wherein the dicyclopentadienyl ruthenium compound includes a Lewis base functional group on at least one of its cyclopentadienyl rings that coordinates with the strontium metal center of the dicyclopentadienyl strontium compound.
29. The method of claim 4, wherein ozone, water or an alcohol is present and forms an oxide of the assistive metal, and ruthenium-containing material is deposited on the oxide of the assistive metal.

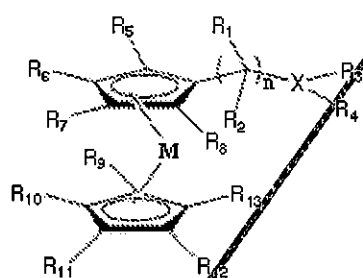
30. The method of claim 4, wherein an agent selected from the group consisting of ammonia, hydrogen, boranes, and carbon monoxide is present to facilitate deposition of assistive metal-containing material, and ruthenium-containing material is deposited on the assistive metal-containing material.

31. A precursor composition comprising a ruthenium precursor and an assistive metal species precursor, wherein one of the ruthenium and assistive metal species precursors includes a pendant functionality that coordinates with the central metal atom of the other precursor, so that ruthenium and the assistive metal species co-deposit with one another.

32. A composition comprising a ruthenium precursor and an assistive metal species precursor, wherein the composition comprises at least one precursor of the formula selected from the group consisting of:



; and



wherein:

E is O or S;

X is N;

M is ruthenium, strontium, barium or calcium; and

each of R₁ to R₁₃ can be the same as or different from one another, and each is independently selected from hydrogen, methyl, ethyl and propyl.

CLAIMS

1. A method of forming a ruthenium metal film in a vapor deposition process, comprising depositing ruthenium from a ruthenium precursor with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein the assistive metal species is deposited on a substrate in a layer having a thickness of 0.8 to 8 Å before the deposition of the ruthenium, and the assistive metal species is selected from the group consisting of one or more assistive metal species containing strontium metal, calcium, barium metal, magnesium, titanium metal, zirconium metal, niobium, vanadium, iron and hafnium metal.

2. The method of claim 1 wherein the ruthenium nucleation step is uniform and rapid relative to ruthenium nucleation in the absence of the assistive metal species.

3. The method of claim 1, wherein the assistive metal species is selected from the group consisting of assistive metal species containing strontium metal, calcium, barium metal, magnesium, titanium metal, zirconium metal, niobium, vanadium, iron and hafnium metal.

4. The method of claim 1, wherein the ruthenium metal film is formed in a process for manufacturing a micro-electronic device or precursor structure therefor.

5. The method of claim 1, wherein the assistive metal species is deposited on a non-metallic substrate.

6. The method of claim 5, wherein the non-metallic substrate comprises silicon and/or silicon oxide.

7. The method of claim 5, wherein the assistive metal species is deposited by a vapor deposition process selected from the group consisting of chemical vapor deposition and atomic layer deposition.

8. A method of forming a ruthenium metal film in a vapor deposition process, comprising depositing ruthenium with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein the assistive metal species is deposited on a substrate in a layer having a thickness of 0.8 to 8 Å before the deposition of the ruthenium, and wherein the ruthenium metal is deposited on strontium-containing material.

9. The method of claim 8, wherein the strontium-containing material comprises strontium oxide and/or strontium carbonate.

10. A method of forming a ruthenium metal film in a vapor deposition process, comprising depositing ruthenium with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein the assistive metal species is deposited on a substrate in a layer having a thickness of 0.8 to 8 Å before the deposition of the ruthenium, and wherein the assistive metal species is deposited from a precursor comprising a dicyclopentadienyl strontium precursor.

11. The method of claim 10 wherein the assistive metal species further comprises an assistive metal species selected from the group consisting of strontium, calcium, barium, magnesium, titanium, aluminum, zirconium, tantalum, niobium, vanadium, iron and hafnium.

12. A method of forming a ruthenium metal film in a vapor deposition process, comprising depositing ruthenium with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein the assistive metal species is deposited on a substrate in a layer having a thickness of 0.8 to 8 Å before the deposition of the ruthenium, and wherein ruthenium metal is deposited on a strontium-containing film formed by atomic layer deposition from a vapor of a dicyclopentadienyl strontium precursor.

13. A method of forming a ruthenium-containing film in a vapor deposition process, comprising depositing ruthenium from a ruthenium precursor with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein the assistive metal species is selected from the group consisting of one or more assistive metal species containing strontium, calcium, barium, magnesium, aluminum, zirconium, niobium, vanadium, iron and hafnium, wherein ruthenium is deposited with the assistive metal, from a precursor vapor comprising ruthenium and the assistive metal species, wherein, when the assistive metal species is a strontium amidinate or a barium amidinate, the ruthenium precursor is not a ruthenium amidinate, and wherein when the assistive metal species is dicyclopentadienyl calcium, strontium, or barium, the ruthenium precursor is a dicyclopentadienyl ruthenium precursor.

14. The method of claim 13, wherein the assistive metal comprises strontium.

15. The method of claim 13, wherein the assistive metal species comprises a dicyclopentadienyl strontium compound.

16. The method of claim 15, wherein the dicyclopentadienyl strontium compound comprises $\text{Sr}(\text{}^n\text{PrMe}_4\text{Cp})_2$ wherein ^nPr is n-propyl, Me is methyl and Cp is cyclopentadienyl.

17. The method of claim 13, wherein ruthenium and the assistive metal species are deposited from a precursor vapor of a precursor composition comprising strontium and ruthenium metal precursors dissolved in a solvent medium.

18. The method of claim 17, wherein the solvent medium includes a hydrocarbon solvent.

19. A method of forming a ruthenium-containing film in a vapor deposition process, comprising depositing ruthenium with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein ruthenium and the assistive metal species are deposited from a precursor vapor of a precursor composition comprising strontium and ruthenium metal precursors dissolved in a solvent medium and wherein the ruthenium precursor comprises a dicyclopentadienyl ruthenium compound including on at least one of constituent cyclopentadienyl rings thereof a pendant Lewis base functional group that coordinates to the strontium metal center of the strontium precursor.

20. The method of claim 19, wherein the pendant Lewis base functional group comprises a functionality selected from the group consisting of amines, polyamines, ethers, and polyethers.

21. A method of forming a ruthenium-containing film in a vapor deposition process, comprising depositing ruthenium with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species wherein ruthenium and the assistive metal species are deposited from a precursor vapor of a precursor composition comprising strontium and ruthenium metal precursors dissolved in a solvent medium, and wherein the ruthenium and strontium precursors are both dicyclopentadienyl compounds.

22. A method of forming a ruthenium-containing film in a vapor deposition process, comprising depositing ruthenium from a ruthenium precursor with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein ruthenium is deposited with the assistive metal species, from a precursor vapor comprising ruthenium and the assistive metal species and wherein the assistive metal species is selected from the group consisting of one or more assistive metal species containing calcium, barium, magnesium, aluminum, zirconium, niobium, vanadium, iron and hafnium, wherein, when the assistive metal species is a barium amidinate, the ruthenium precursor is not a ruthenium amidinate, and wherein when the assistive metal species is dicyclopentadienyl calcium or barium, the ruthenium precursor is a dicyclopentadienyl ruthenium precursor.

23. The method of claim 22, wherein the ruthenium nucleation step is uniform and rapid relative to ruthenium nucleation in the absence of the assistive metal species.

24. The method of claim 22, wherein the ruthenium-containing film is formed in a process for manufacturing a micro-electronic device or precursor structure therefor.

25. The method of claim 22, wherein the assistive metal species is deposited on a non-metallic substrate.

26. The method of claim 25, wherein the non-metallic substrate comprises silicon and/or silicon oxide.

27. A method of forming a ruthenium metal film in a vapor deposition process, comprising depositing ruthenium from a ruthenium precursor with an assistive metal species that increases the rate and extent of ruthenium nucleation in relation to deposition of ruthenium in the absence of such assistive metal species, wherein the assistive metal species is deposited on a substrate in a layer having a thickness of 0.8 to 8 Å before the deposition of the ruthenium, and the assistive metal species is selected from the group consisting of one or more assistive metal species comprising oxides, sulfides, and carbonates of strontium, calcium, barium, magnesium, titanium, aluminum, zirconium, tantalum, niobium, vanadium, iron and hafnium, wherein when the assistive metal species comprises an oxide of aluminum, hafnium, zirconium, or titanium, the ruthenium precursor does not comprise alkenyl or cycloalkenyl functionality.

28. The method of claim 27, wherein the ruthenium metal film is formed in a process for manufacturing a micro-electronic device or precursor structure therefor.

29. The method of claim 27, wherein the assistive metal species is deposited on a non-metallic substrate.

30. The method of claim 29, wherein the non-metallic substrate comprises silicon and/or silicon oxide.

31. The method of claim 29, wherein the assistive metal species is deposited by a vapor deposition process selected from the group consisting of chemical vapor deposition and atomic layer deposition.

32. The method of claim 27, wherein the assistive metal species comprises at least one species selected from the group consisting of strontium oxide, strontium carbonate, calcium oxide, calcium carbonate, magnesium oxide, magnesium carbonate, barium oxide, barium carbonate, titanium dioxide, aluminum oxide, zirconium oxide, hafnium oxide, tantalum oxide, and niobium oxide.

33. The method of claim 32, wherein ozone, water or an alcohol is present and forms an oxide of the assistive metal, and ruthenium metal film is deposited on the oxide of the assistive metal.

34. The method of claim 27, wherein an agent selected from the group consisting of ammonia, hydrogen, boranes, and carbon monoxide is present to facilitate deposition of assistive metal-containing material, and ruthenium metal film is deposited on the assistive metal-containing material.