

CLAIMS

What is claimed is:

1. A method of forming a semiconductor device having copper metallization comprising:
 - providing a patterned wafer having a diffusion barrier for copper;
 - depositing a copperless seed layer on the diffusion barrier effective for direct electrochemical deposition of gapfill copper, the seed layer being formed by a conformal deposition process and by a nonconformal deposition process; and
 - electroplating copper gapfill onto the seed layer.
2. The method of claim 1, wherein the diffusion barrier comprises tantalum nitride.
3. The method of claim 1, wherein the diffusion barrier comprises tungsten nitride, tungsten carbon nitride, tantalum carbon nitride, titanium nitride, or titanium silicon nitride.
4. The method of claim 1, wherein the seed layer comprises an oxidation resistant metal selected from the group consisting of rhenium, osmium, iridium, cobalt, nickel, platinum, and palladium.
5. The method of claim 1, wherein the seed layer comprises ruthenium.
6. The method of claim 1, wherein the seed layer is substantially pure ruthenium.
7. The method of claim 1, wherein the seed layer is ruthenium and the diffusion barrier comprises tantalum nitride.

8. The method of claim 1, wherein the conformal deposition process comprises atomic layer deposition.

9. The method of claim 1, wherein the conformal deposition process comprises chemical vapor deposition.

10. The method of claim 1, wherein the nonconformal deposition process comprises physical vapor deposition.

11. The method of claim 1, wherein the non-conformal deposition process comprises metal evaporation or sputtering.

12. The method of claim 1, wherein the conformal deposition process is accomplished by atomic layer deposition and the nonconformal deposition process is accomplished by chemical vapor deposition.

13. The method of claim 1, wherein the conformal deposition process is accomplished by atomic layer deposition and the nonconformal deposition process is accomplished by physical vapor deposition.

14. The method of claim 1, wherein the nonconformal deposition process produces a thicker deposit over the field areas than in the patterned features.

15. The method of claim 1, wherein the nonconformal deposition process produces a deposit having an electrical resistance suitable for electrochemical plating gapfill copper.

16. A method of manufacturing a semiconductor device having copper metallization, the method comprising:
providing a patterned semiconductor device wafer;

using atomic layer deposition to deposit a tantalum nitride diffusion barrier for copper;

depositing a ruthenium seed layer by atomic layer deposition to form a conformal portion of the seed layer and chemical vapor deposition to form a nonconformal portion of the seed layer so that the seed layer is effective for direct electrochemical deposition of gapfill copper; and

electroplating a copper gapfill layer onto the ruthenium seed layer.

17. The method of claim 16, wherein the atomic layer deposition and chemical vapor deposition exclude oxygen compounds or oxygen.

18. The method of claim 16, further comprising treating the barrier layer surface in a hydrogen containing plasma before deposition of the ruthenium seed layer.

19. The method of claim 16, wherein the atomic layer deposition excludes oxygen compounds or oxygen and is performed before the chemical vapor deposition.

20. A seed layer for electrochemical plating of copper metallization in a semiconductor device structure comprising a conformal deposit of a portion of the seed layer and a nonconformal deposit of a portion of the seed layer.

21. The seed layer of claim 20, wherein the seed layer comprises ruthenium.

22. The seed layer of claim 20, wherein the seed layer is deposited on a diffusion barrier for copper.

23. The seed layer of claim 20, wherein the seed layer is deposited on a barrier layer comprising tantalum nitride.

24. The seed layer of claim 20, wherein the seed layer is deposited on a barrier layer comprising tantalum, tungsten nitride, tungsten carbon nitride, tantalum nitride, tantalum carbon nitride, titanium nitride, titanium silicon nitride, or combinations thereof.

25. The seed layer of claim 20, wherein the conformal deposit is formed by atomic layer deposition.

26. The seed layer of claim 20, wherein the nonconformal deposit is formed by chemical vapor deposition.

27. The seed layer of claim 20, wherein the nonconformal deposit is formed by physical vapor deposition.

28. The seed layer of claim 20, wherein the nonconformal deposit is formed by metal evaporation or sputtering.

29. The seed layer of claim 20, wherein the conformal deposit is formed by atomic layer deposition and the nonconformal deposit is formed by chemical vapor deposition.

30. The seed layer of claim 20, wherein the conformal deposit is formed by atomic layer deposition and the nonconformal deposit is formed by physical vapor deposition.

31. The seed layer of claim 20, wherein the conformal deposit is formed by atomic layer deposition or chemical vapor deposition and the nonconformal deposit is formed by chemical vapor deposition or physical vapor deposition.

32. The seed layer of claim 20, wherein the nonconformal deposit is thicker over the field areas than in patterned features of the semiconductor device.

33. The seed layer of claim 20, wherein the nonconformal deposit has an electrical resistance sufficiently low for electrochemical plating gapfill copper.
34. A semiconductor device made using the method of claim 1.
35. A semiconductor device made using the method of claim 16.
36. A semiconductor device made using the seed layer of claim 20.

CLAIMS

1. A method of manufacturing a semiconductor device having copper metallization, the method comprising:
providing a patterned semiconductor device wafer;
using atomic layer deposition to deposit a tantalum nitride diffusion barrier for copper;
depositing a ruthenium seed layer by atomic layer deposition to form a conformal portion of the seed layer and chemical vapor deposition to form a nonconformal portion of the seed layer so that the seed layer is effective for direct electrochemical deposition of gapfill copper, wherein the atomic layer deposition excludes oxygen compounds or oxygen and is performed before the chemical vapor deposition; and
electroplating a copper gapfill layer onto the ruthenium seed layer.
2. The method of claim 1, wherein the atomic layer deposition and chemical vapor deposition exclude oxygen compounds or oxygen.
3. The method of claim 1, wherein the chemical vapor deposition includes oxygen compounds or oxygen.
4. The method of claim 1, wherein the atomic layer deposition uses a precursor ruthenium compound selected from the group consisting of bis(cyclopentadienyl) ruthenium (II), bis(ethyl cyclopentadienyl) ruthenium (II), bis(isopropyl cyclopentadienyl) ruthenium (II), bis(methyl cyclopentadienyl) ruthenium (II), bis(ethyl cyclopentadienyl) ruthenium (II)+hydrogen radicals, and (2,4-dimethylpentadienyl)(ethylcyclopentadienyl) ruthenium; and the chemical vapor deposition includes oxygen compounds or oxygen and uses a precursor ruthenium compound selected from the group consisting of ruthenium acetylacetonate (II), tris(tetramethylheptanedionato) ruthenium (III), tricarbonyl cyclopentadienyl ruthenium (I), bis(ethyl cyclopentadienyl) ruthenium (II)+oxygen, and dodecacarbonyl triruthenium (0).
5. The method of claim 1, wherein the atomic layer deposition uses a precursor ruthenium compound selected from the group consisting of bis(cyclopentadienyl) ruthenium (II), bis(ethyl cyclopentadienyl) ruthenium (II), bis(isopropyl cyclopentadienyl) ruthenium (II), bis(methyl cyclopentadienyl) ruthenium (II), bis(ethyl cyclopentadienyl) ruthenium (II)+hydrogen radicals, and (2,4-dimethylpentadienyl)(ethylcyclopentadienyl) ruthenium.
6. The method of claim 1, wherein the chemical vapor deposition includes oxygen compounds or oxygen and uses a precursor ruthenium compound selected from the group consisting of ruthenium acetylacetonate (II), tris(tetramethylheptanedionato) ruthenium (III), tricarbonyl cyclopentadienyl ruthenium (I), bis(ethyl cyclopentadienyl) ruthenium (II)+oxygen, and dodecacarbonyl triruthenium (0).

7. A method of forming a semiconductor device having copper metallization comprising:
providing a patterned wafer having a diffusion barrier for copper;

depositing a copperless seed layer on the diffusion barrier effective for direct electrochemical deposition of gapfill copper, the seed layer being formed by a conformal chemical vapor deposition that excludes oxygen compounds or oxygen or an atomic layer deposition process that excludes oxygen compounds or oxygen and by a nonconformal chemical vapor deposition process; and

electroplating copper gapfill onto the seed layer.
8. The method of claim 7, wherein the diffusion barrier comprises tantalum nitride.
9. The method of claim 7, wherein the seed layer comprises ruthenium.
10. The method of claim 7, wherein the seed layer is substantially pure ruthenium.
11. The method of claim 7, wherein the seed layer is ruthenium and the diffusion barrier comprises tantalum nitride.
12. The method of claim 7, wherein the conformal deposition process is atomic layer deposition.
13. The method of claim 7, wherein the conformal deposition process is chemical vapor deposition.
14. The method of claim 7, wherein the nonconformal deposition process is chemical vapor deposition.
15. The method of claim 7, wherein the conformal deposition process is accomplished by atomic layer deposition and the nonconformal deposition process is accomplished by chemical vapor deposition.
16. The method of claim 7, wherein the nonconformal deposition process produces a thicker deposit over the field areas than in the patterned features.
17. The method of claim 7, wherein the nonconformal deposition process produces a deposit having an electrical resistance suitable for electrochemical plating gapfill copper.