

CLAIMS

1. A method for processing a semiconductor substrate, the method comprising:
 - (a) providing a semiconductor substrate comprising an exposed metal layer;
 - (b) forming a silicon oxide layer over and in contact with the metal layer, wherein forming the silicon oxide layer comprises reacting a silicon-containing precursor adsorbed to the metal layer with a plasma formed in a process gas comprising H_2 and an oxygen source, wherein the composition of the process gas is configured for suppressing oxidation of the metal layer; and
 - (c) contacting the semiconductor substrate having an exposed silicon oxide layer after (b) with a reducing plasma to reduce residual metal oxide underlying the silicon oxide layer to metal.
2. The method of claim 1, wherein the volume ratio of H_2 to the oxygen source in the process gas is at least 4:1.
3. The method of claim 1, wherein the oxygen source is O_2 , and wherein the volume ratio of H_2 to O_2 in the process gas is at least 9:1.
4. The method of claim 1, wherein the oxygen source is O_2 , and wherein the volume ratio of H_2 to O_2 in the process gas is at least 10:1.
5. The method of claim 1, wherein the oxygen source is O_2 , and wherein the process gas consists essentially of H_2 at a concentration of between 2-10 %, O_2 at a concentration of less than 1 %, and an inert gas.
6. The method of claim 1, wherein the oxygen source is O_2 , and wherein the process gas consists essentially of H_2 at a concentration of greater than 95 % and O_2 at a concentration of less than 5%.
7. The method of claim 1, wherein the oxygen source is selected from the group consisting of O_2 , O_3 , CO_2 and N_2O .

8. The method of claim 1, wherein the oxygen source is O₂.
9. The method of claim 1, wherein the metal is selected from the group consisting of W, Cu, Co, Ti, and Ta.
10. The method of claim 1, wherein the metal is W.
11. The method of claim 1, wherein (b) comprises:
 - (i) contacting the semiconductor substrate with the silicon-containing precursor and adsorbing the silicon-containing precursor on the layer of metal;
 - (ii) removing the unadsorbed silicon-containing precursor by purging and/or evacuating a process chamber housing the semiconductor substrate;
 - (iii) contacting the semiconductor substrate with the plasma formed in the process gas comprising H₂ and the oxygen source and forming silicon oxide from the adsorbed silicon-containing precursor;
 - (iv) purging and/or evacuating the process chamber after (iii); and
 - (v) repeating steps (i) – (iv).
12. The method of claim 1, further comprising pre-cleaning the exposed metal layer to remove metal oxide from the exposed metal layer prior to (b).
13. The method of claim 1, wherein the plasma formed in a process gas comprising H₂ and an oxygen source in (b) reduces a metal oxide on the metal layer to metal.
14. The method of claim 1, wherein the silicon oxide is formed in (b) to a thickness of less than 10 Å.
15. The method of claim 1, wherein the silicon oxide is formed in (b) to a thickness of 5 Å.
16. The method of claim 1, wherein the semiconductor substrate provided in (a) comprises a plurality of recessed features and further comprises an exposed dielectric

layer, and wherein the silicon oxide is formed both on the exposed metal layer and the exposed dielectric layer.

17. The method of claim 16, further comprising depositing a silicon carbide layer onto the silicon oxide layer.

18. The method of claim 1, further comprising:
applying photoresist to the semiconductor substrate;
exposing the photoresist to light;
patterning the photoresist and transferring a pattern to the semiconductor substrate; and
selectively removing the photoresist from the semiconductor substrate.

19. A deposition apparatus comprising:
(a) a process chamber having a substrate holder configured for holding a semiconductor substrate;
(b) a plasma generating system coupled with the process chamber; and
(c) a controller comprising program instructions for:
(i) causing formation of a silicon oxide layer over and in contact with a metal layer on the semiconductor substrate by reacting a silicon-containing precursor adsorbed to the metal layer with a plasma formed in a process gas comprising H₂ and an oxygen source, wherein the composition of the process gas is configured for suppressing oxidation of the metal layer; and
(ii) causing treatment of the formed semiconductor substrate having an exposed silicon oxide layer with a reducing plasma to reduce a residual metal oxide underlying the silicon oxide layer to metal.

20. The apparatus of claim 19, wherein the program instructions for causing (i) comprise program instructions for providing a volume ratio of H₂ to the oxygen source in the process gas of at least 4:1.

21. The apparatus of claim 19, wherein the program instructions for causing (i) comprise program instructions for providing a volume ratio of H₂ to the oxygen source in the process gas of at least 9:1.

22. The apparatus of claim 19, wherein the program instructions for causing (i) comprise program instructions for providing the process gas consisting essentially of H₂ at a concentration of between 2-10 %, O₂ at a concentration of less than 1 %, and an inert gas.
23. The apparatus of claim 19, wherein the oxygen source is selected from the group consisting of O₂, O₃, CO₂ and N₂O.
24. The apparatus of claim 19, wherein the oxygen source is O₂.
25. The apparatus of claim 19, wherein the program instructions for causing (i) comprise program instructions for causing:
- (1) contacting of the semiconductor substrate with the silicon-containing precursor and adsorption the silicon-containing precursor on the layer of metal;
 - (2) removal of the unadsorbed silicon-containing precursor by purging and/or evacuating the process chamber housing the semiconductor substrate;
 - (3) contacting of the semiconductor substrate with the plasma formed in the process gas comprising H₂ and the oxygen source and formation of silicon oxide from the adsorbed silicon-containing precursor;
 - (4) purging and/or evacuation of the process chamber after (3); and
 - (5) repeating of steps (1) – (4).
26. The apparatus of claim 19, further comprising program instructions for causing pre-cleaning of the metal layer to remove metal oxide from the metal layer prior to formation of the silicon oxide.
27. The apparatus of claim 19, wherein the program instructions for (i) comprise program instructions for causing formation of the silicon oxide to a thickness of less than 10 Å.
28. The apparatus of claim 19, further comprising program instructions for causing a deposition of a silicon carbide layer onto the silicon oxide layer such that

thickness of the deposited silicon carbide layer is greater than the thickness of the silicon oxide layer.