Claims

1. A method comprising:

providing a substrate including a feature in a chamber;

depositing a tungsten nucleation layer in the feature by performing one or more cycles of an atomic layer deposition (ALD) process, where each cycle comprises:

flowing one or more boron-containing reducing agent doses in the chamber,

flowing one or more silicon-containing reducing agent doses in the chamber, wherein the one or more boron-containing reducing agent doses and the one or more silicon-containing reducing agent doses are sequential reactant doses, and

after flowing the one or more boron-containing reducing agent doses and one or more silicon-containing reducing agent doses in the chamber, flowing one or more tungsten-containing precursor pulses in the chamber.

2. The method of claim 1, wherein the feature is a wordline (WL) feature in a 3-D NAND structure, the 3-D NAND structure comprising vertically-oriented sidewalls, a plurality of openings in the sidewalls leading to a plurality of horizontally-oriented WL features.

3. The method of claim 1, further comprising purging the chamber between sequential reactant doses.

4. The method of claim 1, further comprising, depositing a bulk tungsten layer on the tungsten nucleation layer.

5. The method of claim 4, wherein the bulk tungsten layer is deposited by an atomic layer deposition process using hydrogen (H_2) as a reducing agent.

6. The method of claim 1, wherein each cycle begins with a boron-containing reducing agent dose.

7. The method of claim 1, wherein each cycle begins with a silicon-containing reducing agent dose.

8. A method comprising:

providing a 3-D NAND structure comprising vertically-oriented sidewalls, a plurality of openings in the sidewalls leading to a plurality of horizontally-oriented wordline (WL) features in a chamber;

depositing a tungsten nucleation layer in the WL features by performing one or more cycles of an atomic layer deposition (ALD) process, where each cycle comprises

flowing one or more boron-containing reducing agent doses in the chamber,

flowing one or more silane doses in the chamber; and

after flowing the one or more boron-containing reducing agent doses and one or more silicon-containing reducing agent doses in the chamber, flowing one or more tungsten-containing precursor pulses in the chamber.

9. The method of claim 8, wherein the one or more boron-containing reducing agent doses and the one or more silicon-containing reducing agent doses are sequential reactant doses.

10. The method of claim 9, wherein each cycle begins with the boron-containing reducing agent dose.

11. The method of claim 9, wherein each cycle begins with the silicon-containing reducing agent dose.

12. The method of claim 8, wherein the boron-containing reducing agent dose is co-flowed with the silicon-containing reducing agent dose.

13. The method of claim 8, further comprising purging the chamber between sequential reactant doses.

14. The method of claim 8, further comprising, depositing a bulk tungsten layer on the tungsten nucleation layer.

15. The method of claim 14, wherein the bulk tungsten layer is deposited by an atomic layer deposition process using hydrogen (H_2) as a reducing agent.

16. An apparatus comprising:

(a) a process chamber comprising one or more process stations, each process station comprising a substrate support configured to hold a substrate;

(b) at least one outlet for coupling to a vacuum;

(c) one or more process gas inlets coupled to one or more process gas sources; and

(d) a controller for controlling operations in the apparatus, comprising machine-readable instructions for:

flowing one or more boron-containing reducing agent doses in the process chamber,

flowing one or more silicon-containing reducing agent doses in the process chamber; and

after flowing the one or more boron-containing reducing agent doses and one or more silicon-containing reducing agent doses in the chamber, flowing one or more tungsten-containing precursor pulses in the process chamber.

17. The apparatus of claim 16, wherein the process gas sources comprises charge volumes.

18. The method of claim 1, wherein the temperature of the substrate is below 300°C.

19. The method of claim 8, wherein the temperature of the 3-D NAND structure is below 300°C.

20. The method of claim 1, wherein the tungsten nucleation layer comprises at least 99% tungsten.

21. The method of claim 1, wherein the tungsten nucleation layer is 100% tungsten.

22. The method of claim 8, wherein the tungsten nucleation layer comprises at least 99% tungsten.

23. The method of claim 8, wherein the tungsten nucleation layer is 100% tungsten.