Claims:

1. A method of forming a silicon nitride material on a substrate in a reaction chamber, comprising:

periodically exposing the substrate to a vapor phase flow of a silicon-containing reactant wherein the silicon containing reactant is adsorbed onto the surface of the substrate;

exposing the substrate to a vapor phase flow of a first nitrogen-containing reactant wherein the nitrogen-containing reactant is adsorbed onto the surface of the substrate;

exposing the substrate to a vapor phase flow of a second nitrogen-containing reactant that is different from the first nitrogen-containing reactant, wherein the first nitrogen-containing reactant is carbon-free and the second nitrogen-containing reactant contains carbon; and

periodically igniting a plasma in the reaction chamber when vapor phase nitrogen-containing reactant is present in the reaction chamber and the vapor phase flow of the silicon-containing reactant has ceased.

2. The method of claim 1, wherein the silicon containing reactant is trisilylamine (TSA).

3. The method of claim 1, wherein the first nitrogen-containing reactant is ammonia, hydrazine, or hydroxylamine.

4. The method of claim 1, wherein the second nitrogen-containing reactant is C_{1-10} alkyl amine.

5. The method of claim 4, wherein the second nitrogen-containing reactant is tert-butyl amine.

6. The method of claim 4, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:1 and 10:1.

7. The method of claim 6, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:1 and 4:1.

8. The method of claim 4, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:10 and 1:1.

9. The method of claim 8, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:4 and 1:1.

10. The method of claim 1, wherein the substrate includes a germanium-tellurium-antimony alloy.

11. The method of claim 1, wherein the substrate includes a metal surface on which the silicon nitride material is formed.

12. The method of claim 1, wherein the substrate includes an oxide surface on which the silicon nitride material is formed.

13. The method of claim 1, wherein the pressure in the reaction chamber is cycled such that it is higher during the vapor phase flow of the silicon-containing reactant.

14. The method of claim 13, wherein the pressure in the reaction chamber is cycled between a first pressure and a second pressure, the first pressure being between about 5 and 50 Torr and the second pressure between about 1 and 5 Torr.

15. The method of claim 1, wherein the substrate is continuously exposed to the vapor phase flow of the first nitrogen-containing reactant throughout the method.

16. The method of claim 1, wherein the substrate is periodically exposed to the vapor phase flow of the first nitrogen-containing reactant.

What is claimed is:

1. An apparatus for depositing a silicon nitride film on a semiconductor substrate, the apparatus comprising:

(a) a reaction chamber;

(b) a plama source;

(c) a reactant inlet; and

(d) a controller comprising instructions for:

periodically flowing a vapor phase flow of a halogen-free silicon-containing reactant;

flowing a vapor phase flow of a first nitrogen-containing reactant wherein the nitrogen-containing reactant; and

periodically igniting a plasma in the reaction chamber when vapor phase nitrogen-containing reactant is present in the reaction chamber and the vapor phase flow of the halogen-free silicon-containing reactant has ceased.

2. The apparatus of claim 1, wherein the halogen-free silicon containing reactant is trisilylamine (TSA).

3. The apparatus of claim 1 or 2, wherein the first nitrogen-containing reactant is carbon-free.

4. The apparatus of claim 1 or 2, wherein the first nitrogen-containing reactant is an amine.

5. The apparatus of any of the above claims, wherein the first nitrogen-containing reactant is carbon-free.

6. The apparatus of claim 5, wherein the controller further comprises instructions for flowing a vapor phase flow of a second nitrogen-containing reactant that contains carbon.

7. The apparatus of claim 6, wherein the second nitrogen-containing reactant is C_{1-10} alkyl amine.

8. The apparatus of claim 6 or 7, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:1 and 10:1.

9. The apparatus of claim 6 or 7, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:1 and 4:1.

10. The apparatus of claim 6 or 7, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:10 and 1:1.

11. The apparatus of claim 6 or 7, wherein the volumetric flow ratio of the first nitrogen-containing reactant to the second nitrogen-containing reactant is between about 1:4 and 1:1.

12. The apparatus of any of the above claims, wherein the plasma is a RF plasma having a power between about 0.15 W/cm^2 and 0.5 W/cm^2.

13. The apparatus of any of the above claims, wherein the plasma is a RF plasma having a power between about 1 W/cm^2 and 3 W/cm^2.

14. The apparatus of any of the above claims, wherein the plasma source is a HF-only RF plasma source.

15. The apparatus of any of the above claims, wherein the controller further comprises instructions for maintain asubstrate temperature of no more than about 400°C.

16. The apparatus of any of the above claims, wherein the substrate temperature is maintained at no more than about 375°C.

17. The apparatus of any of the above claims, wherein the substrate temperature is maintained at no more than about 350°C.

18. The apparatus of any of the above claims, wherein the substrate temperature is maintained at no more than about 325°C.

19. The apparatus ofany of claims 1-3, wherein the stress of the silicon nitride material is between about -4 GPa and -2 GPa.

20. An apparatus for depositing a silicon nitride film on a semiconductor substrate, the apparatus comprising:

(a) a reaction chamber;

(b) a source of activation energy to form the silicon nitride film;

(c) a reactant inlet; and

(d) a controller comprising instructions for:

flowing first and second nitrogen-containing reactants into the reaction chamber during a deposition cycle;

periodically flowing a halogen-free silicon-containing reactant into the reaction chamber during the deposition cycle;

periodically igniting a plasma in the reaction chamber when the flow of the silicon-containing reactant has ceased and while the first and second nitrogen-containing reactants are present in the vapor phase in the reaction chamber.

21. The apparatus of claim 20, wherein the source of activation energy is one or more of a plasma generator, induction coils and a microwave source.

22. The apparatus of claim 20 or 21, wherein the halogen-free silicon containing reactant is trisilylamine (TSA).