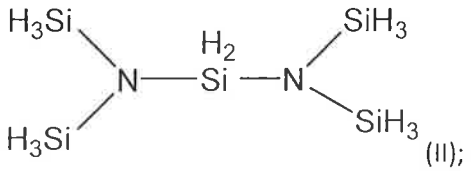
CLAIMS

1. A method for depositing a plurality of silicon-containing layers comprising a silicon oxide layer and a silicon nitride layer on at least one surface of a substrate, the method comprising:

providing the at least one surface of the substrate in a reaction chamber;

introducing into the reaction chamber a silicon precursor having the structure of Formula II:



(II);

introducing into the reaction chamber a source selected from an oxygen-containing source and a nitrogen-containing source; and

depositing via a vapor deposition process the multilayer stack on the at least one surface of the substrate wherein the vapor deposition process is selected from a group consisting of chemical vapor deposition (CVD), plasma enhanced chemical vapor deposition (PECVD), cyclic chemical vapor deposition (CCVD), plasma enhanced cyclic chemical vapor deposition (PECCVD), atomic layer deposition (ALD), and plasma enhanced atomic layer deposition (PEALD); preferably plasma enhanced chemical vapor deposition (PECVD);

wherein the at least one silicon oxide layer comprises one or more of the following properties selected from a density of about 1.9 grams per cubic centimeter (g/cm^3 or g/cc) or greater; a hydrogen content of 4 $x10^{22}$ atoms/cm^3 or less; a stress ranging from about -300 MPa to -100 MPa, a dielectric constant of 4.5 or lower, a leakage current of 10^{-9} A/cm^2 or lower at a film breakdown field of 8 MV/cm or higher; and combinations thereof; and

wherein the at least one silicon nitride layer described herein comprises one or more of the following properties: a density of about 2.2g/cm^3 or greater; a hydrogen content of about $4x10^{22}$ atoms/cm^3 or lower, a stress ranging from about 50 MPa to about 300 MPa; a stress change of 300 MPa or less after at least one thermal treatment

ranging from about 700 to about 1,000°C, a wet etch rate of 10 nm/min or greater in hot H_3PO_4, and combinations thereof.

2. The method of claim 1 wherein the silicon oxide layer comprises at least one or more of the following properties: a density of about 2.2 / cm^3 or greater, a stress ranging from about -300 to about -100 MPa, a stress shift of 50 MPa or less after up to 800°C thermal treatment, and combinations thereof.

3. The method of claim 1 wherein the silicon nitride layer comprises at least one or more of the following properties: a density of about 2.3 g/ cm^3 or greater, a stress ranging from about 50 to about 300 MPa, a stress shift of 300 MPa or less after up to 800°C thermal treatment, and combinations thereof.

4. The method of claim 1 wherein the silicon oxide layer has a deposition rate ranging from about 50 nm/min to about 500 nm/min.

5. The method of claim 1 wherein the oxygen-containing source is selected from the group consisting of water(H_2O), oxygen (O_2), oxygen plasma, ozone (O_3), NO, N_2O, carbon monoxide (CO), carbon dioxide (CO_2), N_2O plasma, carbon monoxide (CO) plasma, carbon dioxide (CO_2) plasma, and combinations thereof.

6. The method of claim 1 wherein the nitrogen-containing source is selected from the group consisting of ammonia, hydrazine, monoalkylhydrazine, dialkylhydrazine, nitrogen, nitrogen plasma, nitrogen/hydrogen, nitrogen/helium, nitrogen/argon plasma, ammonia plasma, ammonia/helium plasma, ammonia/argon plasma, ammonia/nitrogen plasma, NF_3, NF_3 plasma, and mixtures thereof.

7. The method of claim 1 wherein the temperature of the depositing step ranges from about 425°C to about 600°C.

8. The method of claim 1 wherein the deposition process is plasma enhanced chemical vapor deposition (PECVD) or PECCVD.

9. The method of claim 1 wherein the silicon precursor comprises trisilylamine.

10. The method of claim 1 wherein the silicon-containing layer is subjected to a thermal annealing at temperature up to 1000°C.

11. The method of claim 1 wherein the silicon oxide layer comprises substantially zero shrinkage or a shrinkage of about 3% or less or 2% or less or 1 % or less and about 50 MPa stress change after thermal treatment up to 800°C.

12. The method of claim 1 wherein the silicon oxide layer comprises substantially zero wet etch rate in hot H_3PO_4.

13. The methof of claim 1 wherein the silicon nitride layer comprises a growth rate of 50 nm/min or higher.

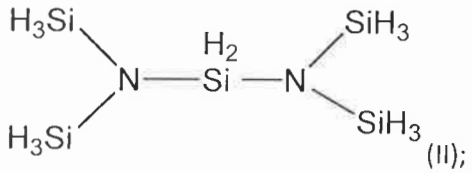
14. The method of claim 1 wherein the silicon nitride layer comprises a minimal shrinkage and less than 300 MPa stress change after thermal treatment up to 800 °C.

15. The method of claim 1 wherein the number of stacked silicon-containing films comprises alternating silicon oxide and silicon nitride wherein the number of layer of silicon oxide layers ranges from about 48 to about 128 layers and the number of silicon nitride layers is from about 48 to about 128 layers; each silicon oxide layer has identical thickness and each silicon nitride layer has identical thickness.

16. A method for forming an apparatus comprising a plurality of silicon-containing layers wherein the silicon-containing layers are selected from a silicon oxide layer and a silicon nitride layer on at least a surface of a semi-conductor substrate, the method comprising:

providing the at least one surface of a semiconductor substrate;

introducing into the reaction chamber a silicon precursor having the structure of Formula II:



(II);

introducing into the reaction chamber a nitrogen-containing source;

depositing via a vapor deposition process the silicon nitride layer;

introducing at least one silicon-containing precursor selected from the group consisting of silane, disilane, tetraethoxysilane (TEOS), triethoxysilane (TES), tetramethoxysilane, trimethoxysilane, di-tert-butoxysilane (DTBOS), di-tert-pentoxysilane

(DTPOS), diethylsilane, triethylsilane, diethoxymethylsilane, dimethoxymethylsilane, di(tertiary)butoxymethylsilane, methyltriacetatoxysilane, dimethylacetatoxysilane, dimethyldiacetoxysilane, dimethyldimethoxysilane, dimethyldiethoxysilane, methyltriethoxysilane, neohexyltriethoxysilane, neopentyltrimethoxysilane, diacetoxymethylsilane, phenyldimethoxysilane, phenyldiethoxysilane, phenyltriethoxysilane, phenyltrimethoxysilane, phenylmethyldimethoxysilane, 1,3,5,7-tetramethyltetracyclosiloxane, octamethyltetracyclosiloxane, 1,1,3,3-tetramethyldisiloxane, 1-neohexyl-1,3,5,7-tetramethylcyclotetrasiloxane, hexamethyldisiloxane, 1,3-dimethyl-1-acetoxy-3-ethoxydislioxane, 1,2-diemthyl-1,2-diacetoxy-1,2-diethoxydisilane, 1,3-dimethyl-1,3-diethoxydisiloxane, 1,3-dimethyl-1,3-diacetoxydisilxane, 1,2-dimethyl,1,1,2,2-tetraacetoxydisilane, 1,2-dimethyl-1,1,2,2-tetraethoxydisilane, 1,3-dimethyl-1-acetoxy-3-ethoxydisiloxane, 1,2-dimethyl-1-acetoxy-2-ethoxydisilane, methylacetoxy(tertiary)butoxysilane, methylsilane, dimethylsilane, trimethylsilane, tetramethylsilane, hexamethyldisilane, tetramethyldisilane, and dimethyldisilane, hexamethyldisiloxane (HMDSO), octamethylcyclotetrasiloxane (OMCTS) and tetramethylcyclotetrasiloxane (TMCTS)), bis(triethoxysilyl)methane, bis(triethoxysilyl)ethane, bis(trimethoxysilyl)methane, bis(trimethoxysilyl)ethane, bis(diethoxymethylsilyl)methane, bis(diethoxymethylsilyl)ethane, bis(methyldiethoxysilyl)methane, (diethoxymethylsilyl)(diethoxysilyl)methane and combinations thereof,

introducing into the reaction chamber an oxygen-containing source; and

depositing via a vapor deposition process the silicon oxide layer.

17. The method of claim 16 wherein the silicon oxide comprises at least one or more of the following properties: a density of about 2.2 / cm^3 or greater, a stress ranging from about -300 to about -100 MPa, a stress shift of 50 MPa or less after up to 800 °C thermal treatment, and combinations thereof.

18. The method of claim 16 wherein the silicon nitride comprises at least one or more of the following properties: a density of about 2.3 g/ cm^3 or greater, a stress ranging from about 50 to about 300 MPa, a stress shift of 300 MPa or less after up to 800 °C thermal treatment, and combinations thereof.

19. The method of claim 16 wherein the silicon oxide layer has a deposition rate ranging from about 50 nm/min to about 500 nm/min.

20. The method of claim 16 wherein the oxygen-containing source is selected from the group consisting of water(H_2O), oxygen (O_2), oxygen plasma, ozone (O_3), NO, N_2O, carbon monoxide (CO), carbon dioxide (CO_2), N_2O plasma, carbon monoxide (CO) plasma, carbon dioxide (CO_2) plasma, and combinations thereof.

21. The method of claim 16 wherein the nitrogen-containing source is selected from the group consisting of ammonia, hydrazine, monoalkylhydrazine, dialkylhydrazine, nitrogen, nitrogen plasma, nitrogen/hydrogen, nitrogen/helium, nitrogen/argon plasma, ammonia plasma, ammonia/helium plasma, ammonia/argon plasma, ammonia/nitrogen plasma, NF_3, NF_3 plasma, and mixtures thereof.

22. The method of claim 16 wherein the temperature of the depositing step ranges from about 425°C to about 600°C.

23. The method of claim 16 wherein the deposition process is plasma enhanced chemical vapor deposition (PECVD) or PECCVD.

24. The method of claim 16 wherein the silicon precursor comprises trisilylamine.

25. The method of claim 16 wherein the silicon-containing layer is subjected to a thermal annealing at temperature up to 1000°C.

26. The method of claim 16 wherein the silicon oxide layer comprises substantially zero shrinkage or a shrinkage of about 3% or less or 2% or less or 1 % or less and about 50 MPa stress change after thermal treatment up to 800°C.

27. The method of claim 16 wherein the silicon oxide layer comprises substantially zero wet etch rate in hot H_3PO_4.

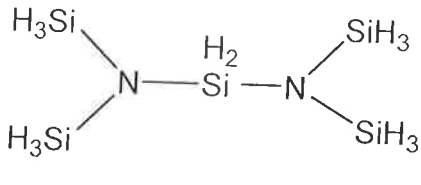
28. The method of claim 16 wherein the silicon nitride layer comprises a growth rate of 50 nm/min or higher.

29. The method of claim 16 wherein the silicon nitride layer comprises a minimal shrinkage and less than 300 MPa stress change after thermal treatment up to 800 °C.

30. The method of claim 16 wherein the number of stacked silicon-containing films comprises alternating silicon oxide and silicon nitride wherein the number of layer of silicon oxide layers ranges from about 48 to about 128 layers and the number

of silicon nitride layers is from about 48 to about 128 layers; each silicon oxide layer has identical thickness and each silicon nitride layer has identical thickness.

31. A composition for a depositing a plurality of silicon-containing films comprising a silicon-containing precursor having the structure of Formula II



(II),

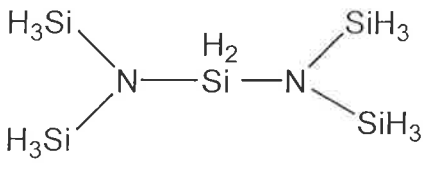
wherein the silicon-containing precursor is substantially free of one or more impurities selected from the group consisting of a halide.

32. The composition of Claim 31 wherein the composition further comprises at least one member selected from the group consisting of an oxygen containing source and a nitrogen containing source.

33. A method for forming a plurality of silicon-containing layers wherein the silicon-containing layers are selected from a silicon oxide layer and a silicon nitride layer on at least a surface of a semi-conductor substrate, the method comprising:

providing the at least one surface of a semiconductor substrate;

introducing a silicon-containing precursor having the structure of Formula II:

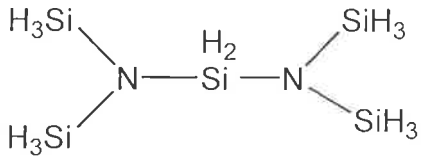


(II);

introducing into the reaction chamber a nitrogen-containing source;

depositing via a vapor deposition process the silicon nitride layer;

introducing a silicon-containing precursor having the structure of Formula II:


(II);

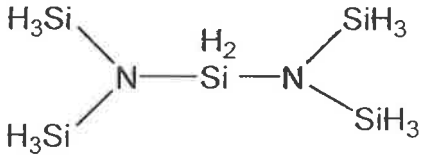
introducing into the reaction chamber an oxygen-containing source; and

depositing via a vapor deposition process the silicon oxide layer; wherein the method is repeated to provide a multilayer stock of alternating silicon nitride and silicon oxide layers.

34. A method for forming a plurality of silicon-containing layers wherein the silicon-containing layers are selected from a silicon oxide layer and a silicon nitride layer on at least a surface of a semi-conductor substrate, the method comprising:

providing the at least one surface of a semiconductor substrate;

introducing a silicon-containing precursor having the structure of Formula II:


(II);

introducing into the reaction chamber a nitrogen-containing source;

depositing via a vapor deposition process the silicon nitride layer;

introducing at least one silicon-containing precursor comprising tetraethyl orthosilicate;

introducing into the reaction chamber an oxygen-containing source; and

depositing via a vapor deposition process the silicon oxide layer; wherein the method is repeated to provide a multilayer stock of alternating silicon nitride and silicon oxide layers.