by these abbreviations (e.g., S refers to sulfur, Si refers to silicon, H refers to hydrogen, etc.).

As used herein, the abbreviation "NAND" refers to a "Negated AND" or "Not AND" gate; the abbreviation "2D" refers to 2 dimensional gate structures on a planar substrate; the abbreviation "3D" refers to 3 dimensional or vertical gate structures, wherein the gate structures are stacked in the vertical direction; and the abbreviation "DRAM" refers to Dynamic Random-Access Memory.

Please note that the Si-containing films, such as SiN and SiO, are listed throughout the specification and claims without reference to their proper stoichoimetry. The silicon-containing layers may include pure silicon (Si) layers, such as crystalline Si, polysilicon (polySi or polycrystalline Si), or amorphous silicon; silicon nitride (Si_kN_l) layers; or silicon oxide (Si_nO_m) layers; or mixtures thereof, wherein k, l, m, and n, inclusively range from 1 to 6. Preferably, silicon nitride is Si_kN_l, where k and l each range from 0.5 to 1.5. More preferably silicon nitride is Si_1N_1. Preferably silicon oxide is Si_nO_m, where n ranges from 0.5 to 1.5 and m ranges from 1.5 to 3.5. More preferably, silicon oxide is SiO_2 or SiO_3. The silicon-containing layer could also be a silicon oxide based dielectric material such as organic based or silicon oxide based low-k dielectric materials such as the Black Diamond II or III material by Applied Materials, Inc. The silicon-containing layers may also include dopants, such as B, C, P, As and/or Ge.

Summary

Disclosed are methods for etching silicon-containing films. An etching gas is introduced into a plasma reaction chamber containing a silicon-containing film on a substrate. The etching gas is trans-1,1,1,4,4,4-hexafluoro-2-butene; cis-1,1,1,4,4,4-hexafluoro-2-butene; hexafluoroisobutene; hexafluorocyclobutane (trans-1,1,2,2,3,4); pentafluorocyclobutane (1,1,2,2,3-); tetrafluorocyclobutane (1,1,2,2-); or hexafluorocyclobutane (cis-1,1,2,2,3,4). An inert gas is introduced into the plasma reaction chamber. Plasma is activated to produce an activated etching gas capable of selectively etching the silicon-containing film from the substrate.

In one aspect, there is provided a method of depositing an etch-resistant polymer layer, the method comprising plasma activating a fluorocarbon molecule to form the etch-resistant polymer layer, the fluorocarbon molecule selected from the group consisting of trans-1,1,1,4,4,4-hexafluoro-2-butene; cis-1,1,1,4,4,4-hexafluoro-2-butene; hexafluoroisobutene; hexafluorocyclobutane (trans-1,1,2,2,3,4); pentafluorocyclobutane (1,1,2,2,3-); tetrafluorocyclobutane (1,1,2,2-); and hexafluorocyclobutane (cis-1,1,2,2,3,4).

In another aspect, there is provided a method of producing a pattern etch structure, the method comprising plasma activating a fluorocarbon molecule to form an etch-resistant polymer layer on a sidewall of the pattern etch structure, the fluorocarbon molecule selected from the group consisting of trans-1,1,1,4,4,4-hexafluoro-2-butene; cis-1,1,1,4,4,4-hexafluoro-2-butene; hexafluoroisobutene; hexafluorocyclobutane (trans-1,1,2,2,3,4); pentafluorocyclobutane (1,1,2,2,3-); tetrafluorocyclobutane (1,1,2,2-); and hexafluorocyclobutane (cis-1,1,2,2,3,4).

The disclosed methods may include one or more of the following embodiments:

- the etching gas being trans-1,1,1,4,4,4-hexafluoro-2-butene;
- the etching gas being cis-1,1,1,4,4,4-hexafluoro-2-butene;

CLAIMS:

1. A method of depositing an etch-resistant polymer layer, the method comprising plasma activating a fluorocarbon molecule to form the etch-resistant polymer layer, the fluorocarbon molecule selected from the group consisting of trans-1,1,1,4,4,4-hexafluoro-2-butene; cis-1,1,1,4,4,4-hexafluoro-2-butene; hexafluoroisobutene; hexafluorocyclobutane (trans-1,1,2,2,3,4); pentafluorocyclobutane (1,1,2,2,3-); tetrafluorocyclobutane (1,1,2,2-); and hexafluorocyclobutane (cis-1,1,2,2,3,4).

2. The method of claim 1, wherein the fluorocarbon molecule is trans-1,1,1,4,4,4-hexafluoro-2-butene or cis-1,1,1,4,4,4-hexafluoro-2-butene.

3. The method of claim 1, the method further comprising no addition of oxygen.

4. The method of claim 1, wherein the etch-resistant polymer layer forms a protection layer on sidewalls of a pattern etch structure.

5. The method of claim 4, wherein the pattern etch structure has an aspect ratio ranging from 2.5:1 to 100:1.

6. The method of claim 5, wherein the pattern etch structure has an aspect ratio ranging from 10:1 to 100:1.

7. The method of claim 4, wherein the etch-resistant polymer layer prevents ions and radicals from etching the sidewalls.

8. The method of claim 7, wherein the etch-resistant polymer layer results in a pattern etch structure having a vertical profile that is straight with no bowing.

9. A method of producing a pattern etch structure, the method comprising plasma activating a fluorocarbon molecule to form an etch-resistant polymer layer on a sidewall of the pattern etch structure, the fluorocarbon molecule selected from the group consisting of trans-1,1,1,4,4,4-hexafluoro-2-butene; cis-1,1,1,4,4,4-hexafluoro-2-butene; hexafluoroisobutene; hexafluorocyclobutane (trans-1,1,2,2,3,4); pentafluorocyclobutane (1,1,2,2,3-); tetrafluorocyclobutane (1,1,2,2-); and hexafluorocyclobutane (cis-1,1,2,2,3,4).

10. The method of claim 9, wherein the fluorocarbon molecule is trans-1,1,1,4,4,4-hexafluoro-2-butene or cis-1,1,1,4,4,4-hexafluoro-2-butene.

11. The method of claim 9, the method further comprising no addition of oxygen.

12. The method of claim 9, wherein the pattern etch structure has an aspect ratio ranging from 2.5:1 to 100:1.

13. The method of claim 12, wherein the pattern etch structure has an aspect ratio ranging from 10:1 to 100:1.

14. The method of claim 9, the method further comprising the etch-resistant polymer layer preventing ions and radicals from etching the sidewalls.

15. The method of claim 14, the pattern etch structure produced having a vertical profile that is straight with no bowing.