

silicon-containing layers may also include dopants, such as B, C, P, As and/or Ge.

Summary

[0021a] In one aspect, there is disclosed a method of etching an aperture in a silicon-containing substrate using a cyclic process, the method comprising:

- a. plasma etching the silicon-containing substrate with an etching fluid containing fluorine to form an etched silicon-containing substrate;
- b. producing approximately 50 % to approximately 100 % of a total number of $C_aH_bF_c$ species having a C:F ratio greater than 1:2 by plasma-treating an unsaturated hydrogen-containing polymer deposition fluid, wherein $a=1$ or 2, $b=1$ or 2, and $c=1$ to 3;
- c. depositing a polymer on the etched silicon-containing substrate from the $C_aH_bF_c$ species;
- d. repeating steps a to c.

[0022] Disclosed are methods of etching apertures in silicon-containing substrates using cyclic processes. The silicon-containing substrate is plasma etched by an etching fluid containing fluorine to form an etched silicon-containing substrate. A polymer is deposited on the etched silicon-containing substrate by plasmas of a hydrogen-containing polymer deposition fluid. The cyclic plasma etching and polymer deposition steps are repeated.

[0023] Also disclosed are methods of etching apertures in silicon-containing substrates using a cyclic process. Once again, the silicon-containing substrate is plasma etched with an etching fluid containing fluorine to form an etched silicon-containing substrate. Plasma-treating a hydrogen-containing polymer deposition fluid produces $C_aH_bF_c$ species, wherein $a=1$ or 2, $b=1$ or 2, and $c=1$ to 3, wherein approximately 50 % to approximately 100 % of the total number of species have a C:F ratio greater than 1:2. The $C_aH_bF_c$ species deposit a polymer on the etched silicon-containing substrate. The plasma etching, plasma-treating and polymer deposition steps are repeated.

[0024] Either of the disclosed methods may include one or more of the following aspects:

- the silicon-containing substrate being silicon;
- the hydrogen-containing polymer deposition fluid having the formula $C_xH_yF_z$, with $1 \leq x < 7$, $1 \leq y \leq 13$, and $1 \leq z \leq 13$;

- the hydrogen-containing polymer deposition fluid containing at least one of the following ligand selected from the group consisting of $=CH_2$, $=CF_2$, $=CFH$, $-CF_2H$, CH_2F , $>CHF$, and $>CH_2$;
- the hydrogen-containing polymer deposition fluid being trifluoroethylene;
- the hydrogen-containing polymer deposition fluid being (Z)-1,2,3,3,3-pentafluoropropene;
- the hydrogen-containing polymer deposition fluid being 1,1,2,3,3-pentafluoropropene;
- the hydrogen-containing polymer deposition fluid being 1,1,3,3,3-pentafluoropropene;
- the hydrogen-containing polymer deposition fluid being 1,2,3,3,3-pentafluoropropene;
- the hydrogen-containing polymer deposition fluid being (E)-1,2,3,3,3-pentafluoropropene;
- the hydrogen-containing polymer deposition fluid being 2,3,3,3-tetrafluoropropene;
- the hydrogen-containing polymer deposition fluid being (E)-1,3,3,3-tetrafluoropropene;
- the hydrogen-containing polymer deposition fluid being 1,1,3,3-tetrafluoropropene;

What is claimed is:

1. A method of etching an aperture in a silicon-containing substrate using a cyclic process, the method comprising:
 - a. plasma etching the silicon-containing substrate with an etching fluid containing fluorine to form an etched silicon-containing substrate;
 - b. producing approximately 50 % to approximately 100 % of a total number of $C_aH_bF_c$ species having a C:F ratio greater than 1:2 by plasma-treating an unsaturated hydrogen-containing polymer deposition fluid, wherein $a=1$ or 2, $b=1$ or 2, and $c=1$ to 3;
 - c. depositing a polymer on the etched silicon-containing substrate from the $C_aH_bF_c$ species;
 - d. repeating steps a to c.
2. The method of claim 1, wherein said hydrogen-containing polymer deposition fluid is selected from the group consisting of (Z)-1,2,3,3,3-pentafluoropropene, 1,1,2,3,3-pentafluoropropene, 1,1,3,3,3-pentafluoropropene, 1,2,3,3,3-pentafluoropropene, (E)-1,2,3,3,3-pentafluoropropene, 1,1,3,4,4,4-hexafluorobut-2-ene; 2,3,3,4,4,4-hexafluoro-1-butene; 1,1,2,3,3,4,4-heptafluorobut-1-ene, 1,1,1,2,4,4,4-heptafluoro-2-butene, and cis-1,1,2,2,3,4-hexafluorocyclobutane.
3. The method of claim 1, wherein said hydrogen-containing polymer deposition fluid is selected from the group consisting of (Z)-1,1,1,4,4,4-hexafluoro-2-butene; (E)-1,1,1,4,4,4-hexafluoro-2-butene; trans-1,1,2,2,3,4-hexafluorocyclobutane; and hexafluoroisobutene.
4. The method of claim 1, wherein the silicon-containing substrate is silicon.
5. The method of claim 1, wherein the etching fluid is selected from the group consisting of SF_6 , SF_5CF_3 , SF_4 , PF_3 , Si_2F_6 , BF_3 , CF_3I , C_2F_5I , C_3F_7I , SOF_4 , IF_5 , and COF_2 .

6. The method of claim 5, wherein the etching fluid is selected from the group consisting of SF_6 , SF_4 , PF_3 , Si_2F_6 , BF_3 , SOF_4 , and IF_5 .
7. The method of claim 1, wherein said aperture has an aspect ratio ranging from approximately 2:1 to approximately 100:1.
8. The method of claim 1, wherein said aperture has a width ranging from approximately 40 nm to approximately 2000 μm (microns or micrometers).
9. The method of claim 1, wherein the silicon etching method selectively etches silicon more than silicon oxide.
10. The method of claim 1, wherein the silicon etching method selectively etches silicon more than silicon nitride.
11. The method of claim 1, wherein the method does not utilize an inert gas.
12. The method of claim 1, wherein the method does not utilize an oxygen-containing gas.
13. The method of claim 12, wherein the oxygen-containing gas is ozone, oxygen, H_2O , N_2O , NO , and combinations thereof.
14. The method of claim 1, wherein the step of plasma etching the silicon-containing substrate selectively etches silicon more than silicon oxide.
15. The method of claim 1, wherein the step of plasma etching the silicon-containing substrate selectively etches silicon more than silicon nitride.