CLAIMS

1. A method comprising:

a) providing a substrate in a semiconductor process chamber, the substrate having a top surface and at least one gap feature with a gap entry width where the at least one gap feature intersects the top surface;

b) performing a deposition process to deposit a carbon film layer on the substrate and on exposed surfaces of the at least one gap feature, wherein the deposition process is performed at least until the deposited carbon film layer causes the gap entry width to be reduced;

c) performing an anisotropic etch process on the substrate with a dominant anisotropic axis substantially perpendicular to the substrate at least until the gap entry width increases from the gap entry width at the conclusion of (b);

d) performing X additional cycles of (b) and (c), wherein X is a positive integer; and

e) performing an ashing process to remove localized build-up of carbon film on the top surface of the substrate adjacent to the at least one gap feature produced as a result of (b) through (d).

2. The method of claim 1, further comprising:

f) performing Y additional cycles of (a) through (e), wherein Y is a positive integer.

3. The method of claim 2, wherein:

the at least one gap feature has a gap feature depth of ZÅ, and

Y is between $\frac{Z}{75\text{Å}}$ and $\frac{Z}{40\text{Å}}$.

4. The method of claim 2, wherein:

X is between about 1 and 100, and

Y is between about 2 and 1000.

5. The method of claim 2, wherein:

X is between about 2 and 20, and

Y is between about 10 to 100.

6. The method of claim 1, wherein:

the at least one gap feature has a depth-to-width aspect ratio of up to about 12:1, and

the gap entry width is between about 30nm and about 140nm.

7. The method of claim 1, wherein the deposition process is a plasma-enhanced chemical vapor deposition (PECVD) process.

8. The method of claim 7, wherein the PECVD process uses a C_xH_y precursor.

9. The method of claim 8, wherein the C_xH_y precursor is C_2H_2.

10. The method of claim 1, wherein the anisotropic etch process is a plasma etch process with a high ion sputtering regime as compared with the ashing process.

11. The method of claim 10, wherein the anisotropic etch process uses an etch chemistry that includes H_2 and Ar.

12. The method of claim 1, wherein the ashing process is performed under conditions that cause the ashing process to preferentially remove the localized build-up of carbon film on the top surface of the substrate adjacent to the at least one gap feature produced as a result of (b) through (d).

13. The method of claim 1, wherein (a) through (e) are performed in a single chamber without performing an intervening vacuum break.

14. The method of claim 1, wherein:

the deposition process:

lasts from between about 0.5s to about 30s,

is performed under pressure conditions of between about 0.025 Torr to about 8 Torr,

is performed at a temperature of between about 400 to about 500°C,

includes providing C_XH_Y gas to a reaction area above the substrate at a flow rate of between about 100 sccm to about 9500 sccm,

includes providing H_2 gas to the reaction area at a flow rate of between about 100 sccm to about 9500 sccm,

includes supplying high-frequency radio-frequency power of between about 100W to about 3000W, and

includes supplying low-frequency radio-frequency power of between about 200W to about 5000W;

the anisotropic etch process:

lasts from between about 0.5s to about 30s,

is performed under pressure conditions of between about 0.025 Torr to about 1 Torr,

is performed at a temperature of between about 400 to about 500°C,

includes providing H_2 gas to the reaction area at a flow rate of between about 100 sccm to about 2000 sccm,

includes supplying high-frequency radio-frequency power of between about 100W to about 1500W, and

includes supplying low-frequency radio-frequency power of between about 200W to about 5000W; and

the ashing process:

lasts from between about 0.5s to about 30s,

is performed under pressure conditions of between about 4 Torr to about 8 Torr,

is performed at a temperature of between about 400 to about 500°C,

includes providing H_2 gas to the reaction area at a flow rate of between about 5000 sccm to about 9500 sccm, and

includes supplying high-frequency radio-frequency power of between about 1500W to about 3000W, wherein the flow rate of C_XH_Y during the anisotropic etch process and the ashing process is at or about 0 sccm.

15. The method of claim 14, wherein at least one of the deposition process, the anisotropic etching process, and the ashing process further includes one or more operations selected from the group consisting of:

supplying He gas to the reaction area at a flow rate of up to about 9500 sccm,

supplying N_2 gas to the reaction area at a flow rate of up to about 9500 sccm, and

supplying Ar gas to the reaction area at a flow rate of up to about 9500 sccm.

16. The method of claim 14, wherein the ashing process further includes supplying low-frequency radio-frequency power of up to about 5000W.

17. The method of claim 14, wherein the C_XH_Y gas is C_2H_2.

18. The method of claim 14, wherein:

the deposition process:

lasts approximately 3s,

is performed under pressure conditions of approximately 0.5 Torr,

is performed under temperature conditions of approximately 450°C,

includes providing C_XH_Y gas to a reaction area above the substrate at a flow rate of approximately 300 sccm,

includes providing H_2 gas to the reaction area at a flow rate of approximately 200 sccm,

includes providing Ar gas to the reaction area at a flow rate of approximately 2000 sccm,

includes supplying high-frequency radio-frequency power of approximately 400W, and

includes supplying low-frequency radio-frequency power of approximately 2400W;

the anisotropic etch process:

lasts approximately 9s,

is performed under pressure conditions of approximately 0.3 Torr,

is performed under temperature conditions of approximately 450°C,

includes providing H_2 gas to the reaction area at a flow rate of approximately 400 sccm,

includes providing Ar gas to the reaction area at a flow rate of approximately 5600 sccm,

includes supplying high-frequency radio-frequency power of approximately 1000W, and

includes supplying low-frequency radio-frequency power of approximately 2000W; and

the ashing process:

lasts approximately 15s,

is performed under pressure conditions of approximately 6 Torr,

is performed under temperature conditions of approximately 450°C,

includes providing Ar gas to the reaction area at a flow rate of approximately 5000 sccm, and

includes supplying high-frequency radio-frequency power of approximately 3000W.

19. A semiconductor processing tool comprising:

a process chamber;

one or more gas inlets into the process chamber and associated flow-control hardware;

a low-frequency radio-frequency (LFRF) generator;

a high-frequency radio-frequency (HFRF) generator; and

a controller having at least one processor and a memory, wherein:

the at least one processor and the memory are communicatively connected with one another,

the at least one processor is at least operatively connected with the flow-control hardware, the HFRF generator, and the LFRF generator, and

the memory stores computer-executable instructions for controlling the at least one processor to at least control the process chamber, the flow-control hardware, the HFRF generator, and the LFRF generator to:

a) receive a substrate within the process chamber, the substrate having a top surface and at least one gap feature with a gap entry width where the at least one gap feature intersects the top surface;

b) perform a deposition process to deposit a carbon film layer on the substrate and on exposed surfaces of the at least one gap feature, wherein the

deposition process is performed at least until the deposited carbon film layer causes the gap entry width to be reduced;

c) perform an anisotropic etch process on the substrate with a dominant anisotropic axis substantially perpendicular to the substrate at least until the gap entry width increases from the gap entry width at the conclusion of (b);

d) perform X additional cycles of (b) and (c), wherein X is a positive integer; and

e) perform an ashing process to remove localized build-up of carbon film on the top surface of the substrate adjacent to the at least one gap feature produced as a result of (b) through (d).

20. The semiconductor processing tool of claim 19, wherein the computer-executable instructions further include instructions for controlling the at least one processor to at least control the flow-control hardware, the HFRF generator, and the LFRF generator to f) perform Y additional cycles of (a) through (e), wherein Y is a positive integer.

CLAIMS

What is claimed is:

1. A method comprising:

a) providing a substrate in a semiconductor process chamber, the substrate having a top surface and at least one gap feature with a gap entry width where the at least one gap feature intersects the top surface;

b) performing a deposition process to deposit a carbon film layer on the substrate and on exposed surfaces of the at least one gap feature, wherein the deposition process is performed at least until the deposited carbon film layer causes the gap entry width to be reduced;

c) performing an anisotropic etch process on the substrate with a dominant anisotropic axis substantially perpendicular to the substrate at least until the gap entry width increases from the gap entry width at the conclusion of (b);

d) performing X additional cycles of (b) and (c), wherein X is a positive integer; and

e) performing an ashing process to remove localized build-up of carbon film on the top surface of the substrate adjacent to the at least one gap feature produced as a result of (b) through (d).

2. The method of claim 1, further comprising:

f) performing Y additional cycles of (a) through (e), wherein Y is a positive integer.

3. The method of either claim 1 or claim 2, wherein:

the at least one gap feature has a gap feature depth of ZÅ, and

Y is between $\frac{Z}{75\text{Å}}$ and $\frac{Z}{40\text{Å}}$.

4. The method of either claim 1 or claim 2, wherein:

X is between about 1 and 100, and

Y is between about 2 and 1000.

5. The method of either claim 1 or claim 2, wherein:

X is between about 2 and 20, and

Y is between about 10 to 100.

6. The method of either claim 1 or claim 2, wherein:

the at least one gap feature has a depth-to-width aspect ratio of up to about 12:1, and

the gap entry width is between about 30nm and about 140nm.

7. The method of either claim 1 or claim 2, wherein the deposition process is a plasma-enhanced chemical vapor deposition (PECVD) process.

8. The method of claim 7, wherein the PECVD process uses a C_xH_y precursor.

9. The method of claim 8, wherein the C_xH_y precursor is C_2H_2.

10. The method of either claim 1 or claim 2, wherein the anisotropic etch process is a plasma etch process with a high ion sputtering regime as compared with the ashing process.

11. The method of claim 10, wherein the anisotropic etch process uses an etch chemistry that includes H_2 and Ar.

12. The method of either claim 1 or claim 2, wherein the ashing process is performed under conditions that cause the ashing process to preferentially remove the localized build-up of carbon film on the top surface of the substrate adjacent to the at least one gap feature produced as a result of (b) through (d).

13. The method of either claim 1 or claim 2, wherein (a) through (e) are performed in a single chamber without performing an intervening vacuum break.

14. The method of either claim 1 or claim 2, wherein:

the deposition process:

lasts from between about 0.5s to about 30s,

is performed under pressure conditions of between about 0.025 Torr to about 8 Torr,

is performed at a temperature of between about 400 to about 500°C,

includes providing C_XH_Y gas to a reaction area above the substrate at a flow rate of between about 100 sccm to about 9500 sccm,

includes providing H_2 gas to the reaction area at a flow rate of between about 100 sccm to about 9500 sccm,

includes supplying high-frequency radio-frequency power of between about 100W to about 3000W, and

includes supplying low-frequency radio-frequency power of between about 200W to about 5000W;

the anisotropic etch process:

lasts from between about 0.5s to about 30s,

is performed under pressure conditions of between about 0.025 Torr to about 1 Torr,

is performed at a temperature of between about 400 to about 500°C,

includes providing H_2 gas to the reaction area at a flow rate of between about 100 sccm to about 2000 sccm,

includes supplying high-frequency radio-frequency power of between about 100W to about 1500W, and

includes supplying low-frequency radio-frequency power of between about 200W to about 5000W; and

the ashing process:

lasts from between about 0.5s to about 30s,

is performed under pressure conditions of between about 4 Torr to about 8 Torr,

is performed at a temperature of between about 400 to about 500°C,

includes providing H_2 gas to the reaction area at a flow rate of between about 5000 sccm to about 9500 sccm, and

includes supplying high-frequency radio-frequency power of between about 1500W to about 3000W, wherein the flow rate of C_XH_Y during the anisotropic etch process and the ashing process is at or about 0 sccm.

15. The method of claim 14, wherein at least one of the deposition process, the anisotropic etching process, and the ashing process further includes one or more operations selected from the group consisting of:

supplying He gas to the reaction area at a flow rate of up to about 9500 sccm,

supplying N_2 gas to the reaction area at a flow rate of up to about 9500 sccm, and

supplying Ar gas to the reaction area at a flow rate of up to about 9500 sccm.

16. The method of claim 14, wherein the ashing process further includes supplying low-frequency radio-frequency power of up to about 5000W.

17. The method of claim 14, wherein the C_XH_Y gas is C_2H_2.

18. The method of claim 14, wherein:

the deposition process:

lasts approximately 3s,

is performed under pressure conditions of approximately 0.5 Torr,

is performed under temperature conditions of approximately 450°C,

includes providing C_XH_Y gas to a reaction area above the substrate at a flow rate of approximately 300 sccm,

includes providing H_2 gas to the reaction area at a flow rate of approximately 200 sccm,

includes providing Ar gas to the reaction area at a flow rate of approximately 2000 sccm,

includes supplying high-frequency radio-frequency power of approximately 400W, and

includes supplying low-frequency radio-frequency power of approximately 2400W;

the anisotropic etch process:

lasts approximately 9s,

is performed under pressure conditions of approximately 0.3 Torr,

is performed under temperature conditions of approximately 450°C,

includes providing H_2 gas to the reaction area at a flow rate of approximately 400 sccm,

includes providing Ar gas to the reaction area at a flow rate of approximately 5600 sccm,

includes supplying high-frequency radio-frequency power of approximately 1000W, and

includes supplying low-frequency radio-frequency power of approximately 2000W; and

the ashing process:

lasts approximately 15s,

is performed under pressure conditions of approximately 6 Torr,

is performed under temperature conditions of approximately 450°C,

includes providing Ar gas to the reaction area at a flow rate of approximately 5000 sccm, and

includes supplying high-frequency radio-frequency power of approximately 3000W.

19. A semiconductor processing tool comprising:

a process chamber;

one or more gas inlets into the process chamber and associated flow-control hardware,

a low-frequency radio-frequency (LFRF) generator;

a high-frequency radio-frequency (HFRF) generator; and

a controller having at least one processor and a memory, wherein:

the at least one processor and the memory are communicatively connected with one another,

the at least one processor is at least operatively connected with the flow-control hardware, the HFRF generator, and the LFRF generator, and

the memory stores computer-executable instructions for controlling the at least one processor to at least control the flow-control hardware, the HFRF generator, and the LFRF generator to:

a) perform a deposition process on a substrate having a top surface and at least one gap feature with a gap entry width where the at least one gap feature intersects the top surface to deposit a carbon film layer on the substrate and on exposed surfaces of the at least one gap feature, wherein the deposition process is performed at least until the deposited carbon film layer causes the gap entry width to be reduced;

b) perform an anisotropic etch process on the substrate with a dominant anisotropic axis substantially perpendicular to the substrate at least until the gap entry width increases from the gap entry width at the conclusion of (a);

c) perform X additional cycles of (a) and (b), wherein X is a positive integer; and

d) perform an ashing process to remove localized build-up of carbon film on the top surface of the substrate adjacent to the at least one gap feature produced as a result of (a) through (c).

20. The semiconductor processing tool of claim 19, wherein the computer-executable instructions further include instructions for controlling the at least one processor to at least control the flow-control hardware, the HFRF generator, and the LFRF generator to e) perform Y additional cycles of (a) through (e), wherein Y is a positive integer.