Claims

1. A process for forming a hardmask on a substrate, comprising:

introducing the substrate to a processing volume of a plasma-enhanced chemical vapor deposition (PECVD) chamber, the substrate positioned on a substrate support, the substrate support comprising an electrostatic chuck;

depositing a first carbon-containing layer having a thickness of about 100 Å or less on the substrate while electrostatically chucking the substrate to the substrate support, wherein depositing the first carbon-containing layer comprises:

flowing a process gas into the processing volume within the PECVD chamber, the process gas comprising a carbon-containing gas; and

striking a plasma with the process gas by applying a first RF bias power to the electrostatic chuck to deposit the first carbon-containing layer, the first RF bias power being about 200 W to about 500 W; and

forming the hardmask by depositing a second carbon-containing layer on the first carbon-containing layer while electrostatically chucking the substrate to the substrate support, the second carbon-containing layer having a thickness of about 200 Å or more, wherein depositing the second carbon-containing layer comprises:

flowing the process gas into the processing volume within the PECVD chamber; and

applying a second RF bias power to the electrostatic chuck to deposit the second carbon-containing layer, the second RF bias power being about 1,000 W to about 10,000 W.

2. The process of claim 1, wherein the carbon-containing gas comprises or is formed from a carbon-containing compound, and wherein the carbon-containing compound is a substituted or unsubstituted C_1-C_{40} hydrocarbon, a substituted or unsubstituted C_6-C_{20} aromatic hydrocarbon, a C_1-C_{40} halogenated hydrocarbon, or a combination thereof.

3. The process of claim 2, wherein the carbon-containing compound comprises an alkyne.

4. The process of claim 3, wherein the carbon-containing compound comprises acetylene.

5. The process of claim 2, wherein the process gas further comprises a non-reactive gas.

6. The process of claim 5, wherein the carbon-containing compound comprises acetylene and the non-reactive gas comprises helium.

7. The process of claim 1, wherein the first carbon-containing layer, the second carbon-containing layer, or both, is deposited while the substrate is maintained at a temperature from about −40° C. to about 40° C.

8. The process of claim 1, wherein the first carbon-containing layer, the second carbon-containing layer, or both, comprises about 60% or more sp^3-hybridized atoms as determined by Raman spectroscopy.

9. The process of claim 1, wherein: the first carbon-containing layer is deposited while the processing volume is maintained at a first pressure; and the second carbon-containing layer is deposited while the processing volume is maintained at a second pressure, the first pressure being greater than the second pressure.

10. The process of claim 9, wherein the first pressure is about 20 mTorr or more, and the second pressure is about 10 mTorr or less.

11. A process for forming a hardmask on a substrate, comprising:

positioning the substrate within a processing volume of a plasma-enhanced chemical vapor deposition (PECVD) chamber, the substrate on an electrostatic chuck;

depositing a first carbon-containing layer having a thickness of about 100 Å or less on the substrate while electrostatically chucking the substrate, wherein depositing the first carbon-containing layer comprises:

flowing a process gas into the processing volume within the PECVD chamber, the process gas comprising a carbon-containing gas, wherein the carbon-containing gas comprises a carbon-containing compound or the carbon-containing gas is formed from a carbon-containing compound, and wherein the carbon-containing compound is a substituted or unsubstituted C_1-C_{40} hydrocarbon, a substituted or unsubstituted C_6-C_{20} aromatic hydrocarbon, a C_1-C_{40} halogenated hydrocarbon, or a combination thereof;

operating the processing volume at a first pressure of about 20 mTorr or more; and

striking a plasma with the process gas by applying a first RF bias power to the electrostatic chuck to deposit the first carbon-containing layer, the first RF bias power being about 200 W to about 500 W; and

forming the hardmask by depositing a second carbon-containing layer on the first carbon-containing layer while electrostatically chucking the substrate, the second carbon-containing layer having a thickness of about 200 Å or more, wherein depositing the second carbon-containing layer comprises:

flowing the process gas into the processing volume within the PECVD chamber;

operating the processing volume at a second pressure of about 0.5 mTorr to about 10 mTorr; and

applying a second RF bias power to the electrostatic chuck to deposit the second carbon-containing layer, the second RF bias power being about 1,000 W to about 10,000 W.

12. The process of claim 11, wherein the carbon-containing compound comprises an alkyne.

13. The process of claim 11, wherein the process gas further comprises one or more non-reactive gases.

14. The process of claim 11, wherein the first carbon-containing layer, the second carbon-containing layer, or both, is deposited while the substrate is maintained at a temperature from about 40° C. to about 10° C.

15. The process of claim 11, wherein the first carbon-containing layer, the second carbon-containing layer, or both, comprises about 60% or more sp^3-hybridized atoms as determined by Raman spectroscopy.

16. A process for forming a hardmask on a substrate, comprising:

positioning the substrate within a processing volume of a plasma-enhanced chemical vapor deposition (PECVD) chamber, the substrate on an electrostatic chuck;

depositing a first carbon-containing layer having a thickness of about 100 Å or less on the substrate while electrostatically chucking the substrate, wherein depositing the first carbon-containing layer comprises:

flowing a process gas into the processing volume within the PECVD chamber, the process gas comprising a carbon-containing gas and a non-reactive gas, wherein the carbon-containing gas comprises or is formed from a carbon-containing compound, the carbon-containing compound comprising a C_1-C_{20} substituted or unsubstituted hydrocarbon, and wherein the non-reactive gas comprises He, Ne, Ar, or combinations thereof;

operating the processing volume at a pressure of about 20 mTorr or more; and

striking a plasma with the process gas by applying a first RF bias power to the electrostatic chuck to deposit the first carbon-containing layer, the first RF bias power being about 200 W to about 500 W; and

forming the hardmask by depositing a second carbon-containing layer on the first carbon-containing layer while electrostatically chucking the substrate, the second carbon-containing layer having a thickness of about 200 Å or more, wherein depositing the second carbon-containing layer comprises:

flowing the process gas into the processing volume within the PECVD chamber;

operating the processing volume at a pressure of about 0.5 mTorr to about 10 mTorr; and

applying a second RF bias power to the electrostatic chuck to deposit the second carbon-containing layer, the second RF bias power being about 1,000 W to about 10,000 W,

wherein the first carbon-containing layer, the second carbon-containing layer, or both, is deposited while the substrate is maintained at a temperature from about -40° C.

17. The process of claim 16, wherein the first carbon-containing layer, the second carbon-containing layer, or both, is deposited while the substrate is maintained at a temperature from about −40° C. to about 10° C.

18. The process of claim 16, the first carbon-containing layer, the second carbon-containing layer, or both, comprises about 60% or more sp^3-hybridized atoms as determined by Raman spectroscopy.

19. The process of claim 16, wherein the carbon-containing compound is an alkyne, and the non-reactive gas comprises He.