Claims

1. A method of processing a substrate, comprising:

flowing a deposition gas comprising a hydrocarbon compound and a nitrogen dopant compound into a processing volume of a process chamber having a substrate positioned on an electrostatic chuck, wherein the nitrogen dopant compound comprises ammonia, hydrazine, methylhydrazine, dimethlyhydrazine, t-butylhydrazine, phenylhydrazine, azoisobutane, ethylazide, pyridine, or any combination thereof; and

generating a plasma above the substrate by applying a first RF bias to the electrostatic chuck to deposit a nitrogen-doped diamond-like carbon film on the substrate, wherein:

the nitrogen-doped diamond-like carbon film comprises 0.05 atomic percent to 7 atomic percent of nitrogen, and

the nitrogen-doped diamond-like carbon film has a density of greater than 1.5 g/cc and a compressive stress of--20 MPa to less than -600 MPa.

2. The method of claim 1, wherein the nitrogen-doped diamond-like carbon film has a compressive stress of -250 MPa to -400 MPa.

3. The method of claim 1, wherein the nitrogen-doped diamond-like carbon film has an elastic modulus of greater than 60 GPa to 200 GPa.

4. The method of claim 1, wherein the nitrogen-doped diamond-like carbon film has a density of 1.55 g/cc to less than 2 g/cc.

5. The method of claim 1, wherein the nitrogen dopant compound is flowed into the processing volume at a rate of 10 sccm to 1,000 sccm.

6. The method of claim 1, wherein the processing volume is maintained at a pressure of 0.5 mTorr to 10 Torr when generating the plasma and depositing the nitrogen-doped diamond-like carbon film on the substrate.

7. The method of claim 6, wherein the processing volume is maintained at a pressure of 5 mTorr to 100 mTorr, and wherein the substrate is maintained at a temperature of 0°C to 50°C.

8. The method of claim 1, wherein the nitrogen-doped diamond-like carbon film comprises 0.1 atomic percent to 5 atomic percent of nitrogen.

9. The method of claim 1, wherein the nitrogen-doped diamond-like carbon film comprises 50 atomic percent to 90 atomic percent of sp^3 hybridized carbon atoms, and wherein the nitrogen-doped diamond-like carbon film comprises 1 atomic percent to 6 atomic percent of nitrogen.

10. The method of claim 1, wherein the hydrocarbon compound comprises ethyne, propene, methane, butene, 1,3-dimethyladamantane, bicyclo[2.2.1]hepta-2,5-diene, adamantine, norbornene, or any combination thereof.

11. The method of claim 1, wherein the deposition gas further comprises helium, argon, xenon, neon, hydrogen (H_2), or any combination thereof.

12. The method of claim 1, wherein generating the plasma at the substrate further comprises applying a second RF bias to the electrostatic chuck.

13. The method of claim 12, wherein the electrostatic chuck has a chucking electrode and an RF electrode separate from the chucking electrode, and wherein the first RF bias is applied to the RF electrode and the second RF bias is applied to the chucking electrode.

14. The method of claim 12, wherein the first RF bias is provided at a power of 10 watts to 3,000 watts at a frequency of 350 KHz to 100 MHz, and wherein the second RF bias is provided at a power of 10 watts to 3,000 watts at a frequency of 350 KHz to 100 MHz.

15. A method of processing a substrate, comprising:

flowing a deposition gas comprising a hydrocarbon compound and a nitrogen dopant compound into a processing volume of a process chamber having a substrate positioned on an electrostatic chuck, wherein:

the nitrogen dopant compound comprises ammonia, hydrazine, methylhydrazine, dimethlyhydrazine, t-butylhydrazine, phenylhydrazine, azoisobutane, ethylazide, pyridine, or any combination thereof,

the electrostatic chuck has a chucking electrode and an RF electrode separate from the chucking electrode, and

the processing volume is maintained at a pressure of 0.5 mTorr to 10 Torr; and

generating a plasma above the substrate by applying a first RF bias to the RF electrode and a second RF bias to the chucking electrode to deposit a nitrogen-doped diamond-like carbon film on the substrate, wherein the nitrogen-doped diamond-like carbon film comprises 0.1 atomic percent to 6 atomic percent of nitrogen and 50 atomic percent to 90 atomic percent of sp^3 hybridized carbon atoms, and has a density of greater than 1.5 g/cc and a compressive stress of -20 MPa to less than -600 MPa.

16. The method of claim 15, wherein the nitrogen-doped diamond-like carbon film comprises 55 atomic percent to 75 atomic percent of sp^3 hybridized carbon atoms, and wherein the nitrogen-doped diamond-like carbon film comprises 1 atomic percent to 6 atomic percent of nitrogen.

17. The method of claim 15, wherein the nitrogen-doped diamond-like carbon film has a density of 1.55 g/cc to less than 2 g/cc, a compressive stress of -250 MPa to -400 MPa, and an elastic modulus of greater than 60 GPa to 200 GPa.

18. A method of processing a substrate, comprising:

flowing a deposition gas comprising a hydrocarbon compound and a nitrogen dopant compound into a processing volume of a process chamber having a substrate

positioned on an electrostatic chuck, wherein the electrostatic chuck has a chucking electrode and an RF electrode separate from the chucking electrode, and wherein the processing volume is maintained at a pressure of 0.5 mTorr to 10 Torr;

generating a plasma above the substrate by applying a first RF bias to the RF electrode and a second RF bias to the chucking electrode to deposit a nitrogen-doped diamond-like carbon film on the substrate, wherein the nitrogen-doped diamond-like carbon film comprises 0.05 atomic percent to 6 atomic percent of nitrogen, and has a density of greater than 1.5 g/cc and a compressive stress of -20 MPa to less than -600 MPa;

forming a patterned photoresist layer over the nitrogen-doped diamond-like carbon film;

etching the nitrogen-doped diamond-like carbon film in a pattern corresponding with the patterned photoresist layer; and

etching the pattern into the substrate.

19. The method of claim 18, wherein the nitrogen-doped diamond-like carbon film comprises 0.1 atomic percent to 5 atomic percent of nitrogen.

20. The method of claim 18, wherein the nitrogen dopant compound comprises ammonia, hydrazine, methylhydrazine, dimethlyhydrazine, t-butylhydrazine, phenylhydrazine, azoisobutane, ethylazide, pyridine, or any combination thereof.