CLAIMS

1. A method of forming a patterned hard mask, the method comprising:

exposing a semiconductor wafer to a deposition gas comprising a boron dopant gas comprising 5% to 20% diborane in H_2 on a molar basis, a carbon gas comprising one or more of methane or carbon dioxide in H_2, and 50% to 90% argon on a molar basis at a temperature less than or equal to 550° C;

igniting a pulsed microwave plasma from the deposition gas to form a boron doped ultrananocrystalline diamond film having an average roughness in a range of from 0.1 nm to 5 nm and a modulus in a range of from 250 to 400 GPa, wherein there is a gas pressure during forming the boron doped ultrananocrystalline diamond film in a range of 0.2 Torr to 2 Torr and a plasma power in a range of from 3 kW to 10 kW; and

patterning the hard mask to form the patterned hard mask.

2. The method of claim 1, wherein the dopant gas further comprises one or more of a nitrogen dopant, a sulfur dopant species and a phosphorus dopant species.

3. The method of claim 1, wherein the deposition gas comprises greater than or equal to 60% argon.

4. The method of claim 1, wherein the pulsed microwave plasma is pulsed at a duty cycle in a range of 25% to 75%.

5. The method of claim 4, wherein the pulsed microwave plasma is pulsed at a 50% duty cycle.

6. The method of claim 5, wherein the film has a modulus in a range of from 300 to 350 GPa.

7. The method of claim 6, wherein the boron doped ultrananocrystalline diamond has a thickness in the range of 300 nm to 500 nm.

8. The method of claim 7, wherein the patterned hard mask is patterned by etching and subsequently withstands a reactive plasma etching during formation of a 3D NAND device.

9. The method of claim 1, wherein the temperature is less than or equal to 500° C.

10. The method of claim 1, wherein a microwave plasma source used to generate the pulsed microwave plasma is spaced at a distance from the semiconductor wafer in a range of from 5 cm to 8 cm.

11. A method of forming a patterned hard mask, the method comprising:

forming a hard mask on a semiconductor wafer comprising:

exposing the semiconductor wafer to a deposition gas comprising a boron dopant gas comprising 5% to 20% diborane in H_2 on a molar basis, a carbon gas comprising methane and carbon dioxide in H_2, and in the range of 10% to 90% argon on a molar basis at a temperature less than or equal to 550° C; and

igniting a pulsed microwave plasma from the deposition gas to form a boron doped ultrananocrystalline diamond film having an average roughness in a range of from 0.1 nm to 5 nm and a modulus in a range of from 250 to 400 GPa, the pulsed microwave plasma having a 50% duty cycle, wherein there is a gas pressure during forming the boron doped ultrananocrystalline diamond film in a range of 0.2 Torr to 2 Torr and a plasma power in a range of from 3 kW to 10 kW; and

patterning the hard mask to form a patterned hard mask on the semiconductor wafer.

12. The method of claim 11, wherein the deposition gas comprises greater than or equal to 50% argon.

13. The method of claim 12, wherein patterning the hard mask comprises etching the hard mask.

14. The method of claim 13, wherein the temperature is less than 500° C.

15. The method of claim 13, wherein the film comprises a hard mask with a thickness in the range of 300 nm to 500 nm.

16. The method of claim 15, wherein the patterned hard mask is patterned by etching and subsequently withstands a reactive plasma etching during formation of a 3D NAND device.

17. The method of claim 11, wherein a microwave plasma source used to generate the pulsed microwave plasma is spaced at a distance from the semiconductor wafer in a range of from 5 cm to 8 cm.