CLAIMS

What is claimed is:

1. A method of preparing an amorphous carbon hard mask, the method comprising:

(i) depositing amorphous carbon material on a substrate in a plasma deposition chamber at a deposition temperature;

(ii) exposing the amorphous carbon material to an inert gas plasma at an elevated treatment temperature greater than the deposition temperature in the plasma deposition chamber; and

(iii) repeating operations (i) and (ii) to achieve a desired thickness for an amorphous carbon hard mask.

2. The method of claim 1, wherein the inert gas plasma includes ions and/or radicals of helium, neon, argon, krypton, or xenon.

3. The method of claim 1, wherein the elevated treatment temperature is greater than the deposition temperature by a percentage increase between about 10% and about 550% from the deposition temperature.

4. The method of claim 1, wherein the amorphous carbon material has a hydrogen content of at least about 20 atomic % prior to exposure to the inert gas plasma and the elevated treatment temperature.

5. The method of claim 4, wherein exposing the amorphous carbon material to the inert gas plasma and the elevated treatment temperature reduces the hydrogen content by at least about 5 atomic %.

6. The method of claim 1, wherein exposing the amorphous carbon material to the inert gas plasma and the elevated treatment temperature increases an etch resistance of the amorphous carbon hard mask.

7. The method of any one of claims 1-6, wherein exposing the amorphous carbon material to the inert gas plasma and the elevated treatment temperature reduces sp3 carbon bonding in the amorphous carbon material.

8. The method of any one of claims 1-6, wherein exposing the amorphous carbon

material to the inert gas plasma and the elevated treatment temperature maintains a hardness within ± 20% of an original hardness of the amorphous carbon material and maintains a Young's modulus within ± 20% of an original Young's modulus of the amorphous carbon material.

9. The method of any one of claims 1-6, wherein a hardness of the amorphous carbon hard mask is between about 10 GPa and about 20 GPa and a Young's modulus of the amorphous carbon hard mask is between about 120 GPa and about 180 GPa.

10. The method of any one of claims 1-6, wherein the amorphous carbon hard mask has a hydrogen content equal to or less than about 20 atomic %.

11. The method of any one of claims 1-6, wherein the amorphous carbon hard mask is doped with an inert gas at a dopant concentration of at least about 0.1 atomic %.

12. The method of any one of claims 1-6, further comprising:

(iv) patterning the amorphous carbon material to form the amorphous carbon hard mask; and

(v) etching one or more underlayers positioned below the amorphous carbon hard mask using a plasma-based etchant.

13. The method of claim 12, wherein the one or more underlayers includes alternating layers of oxide and nitride or alternating layers of oxide and polysilicon.

14. An amorphous carbon hard mask comprising:

a hydrogen content equal to or less than about 20 atomic %;

an amount of sp3 carbon bonding equal to or less than about 25%;

a Young's modulus between about 120 GPa and about 180 GPa; and

a hardness between about 10 GPa and about 20 GPa.

15. The amorphous carbon hard mask of claim 14, further comprising:

an inert gas species, wherein a dopant concentration of the inert gas species is

at least about 0.1 atomic %.

16. The amorphous carbon hard mask of claim 15, wherein the inert gas species includes argon.

17. The amorphous carbon hard mask of any one of claims 14-16, wherein the amorphous carbon hard mask is formed by:

(i) depositing an amorphous carbon material on a substrate in a plasma deposition chamber at a deposition temperature;

(ii) exposing the amorphous carbon material to an inert gas plasma at an elevated treatment temperature greater than the deposition temperature in the plasma deposition chamber; and

(iii) repeating operations (i) and (ii) to achieve a desired thickness.

18. The amorphous carbon hard mask of claim 17, wherein the elevated treatment temperature is greater than the deposition temperature by a percentage increase between about 10% and about 550% from the deposition temperature.

19. A plasma deposition apparatus comprising:

a processing chamber;

a substrate support for supporting a substrate in the processing chamber, wherein the substrate support is configured to be heated and biased; and

a controller configured with instructions to perform the following operations:

(i) deposit an amorphous carbon material on the substrate in the processing chamber at a deposition temperature;

(ii) expose the amorphous carbon material to an inert gas plasma at an elevated treatment temperature greater than the deposition temperature in the processing chamber; and

(iii) repeat operations (i) and (ii) to achieve a desired thickness for an amorphous carbon hard mask.

20. The apparatus of claim 19, wherein the elevated treatment temperature is greater than the deposition temperature by a percentage increase between about 10% and about 550% from the deposition temperature.