CLAIMS

What is claimed is:

1. A method comprising:

exposing a semiconductor substrate in a chamber to a process gas comprising a hydrocarbon precursor gas and helium gas, substantially without any other inert gas; and

depositing on the substrate an ashable hard mask (AHM) film by a plasma enhanced chemical vapor deposition (PECVD) process, wherein the PECVD process comprises:

maintaining the chamber pressure at less than 500 mTorr;

igniting a plasma generated by a dual radio frequency (RF) plasma source including a high frequency (HF) component and a low frequency (LF) component.

2. The method of claim 1, wherein the chamber pressure is between about 3 and 30 mTorr.

3. The method of claim 1, wherein the HF power is at least about 50W.

4. The method of claim 1, wherein the HF power is between about 50W and 2500W.

5. The method of claim 1, wherein the HF power has a frequency between about 2MHz and about 100MHz.

6. The method of claim 1, wherein the HF power has a frequency of about 60 MHz.

7. The method of claim 1, wherein the LF power has a frequency between about 100kHz and about 2.4MHz.

8. The method of claim 1, wherein the LF power has a frequency of about 400 KHz.

9. The method of claim 1, wherein the LF power is less than 10000W.

10. The method of claim 1, wherein the LF power is 0W.

11. The method of claim 1, wherein the LF power is between 50 and 500W.

12. The method of claim 1, wherein the LF power is between 50 and 250W.

13. The method of claim 1, wherein the LF power is between 250 and 500W.

14. The method of any of claims 1-3 or 6-9, wherein the HF power is between about 50 and 150W, and the LF power is between about 50 and 500W.

15. The method of any of claims 1-13, wherein a direct current bias is applied to an electrostatic chuck that the semiconductor substrate rests upon during the PECVD process, and the potential of the DC bias may be between 100V to 10000V.

16. The method of claim 15, wherein the direct current bias has a duty cycle between about 10% and about 90%, and a repetition rate between about 100Hz and 10kHz.

17. The method of any of claims 1-13, wherein a deposition rate of the AHM is at least 350 Å/min.

18. The method of any of claims 1-13, wherein the chamber includes an electrostatic chuck that the semiconductor substrate rests upon during the PECVD process, and the electrostatic chuck temperature is between -20°C and 175°C.

19. The method of claim 18, wherein the electrostatic chuck temperature is between 80°C and 125°C.

20. The method of any of claims 1-13, further comprising annealing the AHM at a temperature of at least 500°C.

21. The method of any of claims 1-13 wherein the hydrocarbon precursor gas comprises compounds having a molecular weight of at most about 50g/mol.

22. The method of any of claims 1-13, wherein the hydrocarbon precursor gas comprises compounds having a C:H ratio of at least 0.5.

23. The method of any of claims 1-13, wherein the hydrocarbon precursor gas comprises acetylene (C_2H_2).

24. The method of any of claims 1-13, wherein the modulus of the AHM film is at least about 120 GPa.

25. The method of any of claims 1-13, wherein the hardness of the AHM film is at least about 12 GPa.

26. The method of any of claims 1-13, wherein the sp^3 content of the AHM film is at least about 67%.

27. The method of any of claims 1-13, wherein the density of the AHM film is at least about 1.8 g/cm^3.

28. The method of any of claims 1-13, wherein the thickness of the AHM film is at least about 0.1 μm.

29. The method of any of claims 1-13, further comprising patterning the deposited AHM film and etching the patterned AHM film to define features of the AHM film in the substrate.

30. The method of claim 29, further comprising etching layers in the substrate underlying the AHM film.

31. The method of any of claims 1-13, further comprising, before depositing the AHM film, depositing on the substrate an interfacial layer by a PECVD process, wherein depositing the interfacial layer comprises:

igniting a plasma generated by the dual RF plasma source, wherein the HF component and the LF are at a lower power than during deposition of the AHM film.

32. The method of any of claims 1-13, further comprising treating the AHM to ash no more than 10 nm of the AHM to remove a crust layer.

33. The method of any of claims 1-13, further comprising treating the AHM to densify a crust layer by bombarding the AHM with a process gas that does not include a hydrocarbon precursor.

34. The method of any of claims 1-13, further comprising removing hydrocarbon precursor from the process chamber prior to lowering the power of the HF component and/or the LF component.

35. The method of any of claims 1-13, further comprising cleaning the chamber using a discard-able wafer as a cover for an electrostatic chuck.

36. The method of any of claims 1-13, further comprising depositing a layer of SiO_2 on any plasma facing components within the process chamber.