

CLAIMS

What is claimed is:

1. A method for opening an amorphous carbon layer mask below a hardmask, comprising performing one or more cycles in a plasma processing chamber, wherein
5 each cycle comprises:
 - an amorphous carbon layer mask opening phase, comprising;
 - flowing an opening gas into a plasma processing chamber, wherein the opening gas comprises an oxygen containing component;
 - creating a plasma from the opening gas in the plasma processing
10 chamber, wherein the plasma etches features in the amorphous carbon layer mask; and
 - stopping the flow of the opening gas into the plasma processing chamber; and
 - a cleaning phase, comprising:
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 - flowing a cleaning gas into the plasma processing chamber, wherein the cleaning gas comprises a hydrogen containing component, a carbon containing component, and a halogen containing component;
 - creating a plasma from the cleaning gas in the plasma processing chamber; and
 - 20 stopping the flow of the cleaning gas into the plasma processing chamber.
2. The method, as recited in claim 1, wherein the hydrogen containing component, the carbon containing component, and the halogen containing component consist essentially of at least one hydrofluorocarbon.
- 25 3. The method, as recited in claim 2, wherein the at least one hydrofluorocarbon is one or more of CHF_3 , CH_2F_2 , and CH_3F .
4. The method, as recited in claim 1, wherein the amorphous carbon layer mask opening phase forms redeposited hardmask on the features in the amorphous carbon layer mask and wherein the cleaning phase removes the redeposited hardmask and
30 deposits a carbon containing layer on sidewalls of the features in the amorphous carbon layer mask.

5. The method, as recited in claim 4, wherein the hardmask comprises silicon or metal, wherein the redeposited hardmask comprises silicon or metal.
6. The method, as recited in claim 4, wherein the hardmask comprises at least one of SiON, SiO₂, SiN, Si, metal, doped carbon, or doped Si, wherein the redeposited hardmask comprises silicon or metal.
7. The method, as recited in claim 1, wherein the cleaning phase further comprises providing a bias with an amplitude of greater than 500 volts.
8. The method, as recited in claim 7, wherein the bias is pulsed and has a duty cycle between about 3% to about 99%.
9. The method, as recited in claim 7, wherein the amorphous carbon layer mask opening phase further comprises providing a pulsed bias with an amplitude of less than 1500 volts.
10. The method, as recited in claim 1, further comprising maintaining the amorphous carbon layer mask at a temperature of at least 20°C during the amorphous carbon layer mask opening phase and during the cleaning phase.
11. The method, as recited in claim 1, wherein the opening gas comprises oxygen and COS, or SO₂.
12. The method, as recited in claim 1, wherein the cleaning phase further comprises providing a pulsed bias with an amplitude of greater than 1000 volts.
13. The method, as recited in claim 12, wherein the pulsed bias has a duty cycle between about 20% to about 80%.
14. The method, as recited in claim 12, wherein the amorphous carbon layer mask opening phase further comprises providing a pulsed bias with an amplitude of less than 1000 volts.
15. The method, as recited in claim 1, further comprising maintaining the amorphous carbon layer mask at a temperature of at least 25°C during the amorphous carbon layer mask opening phase and during the cleaning phase.
16. The method, as recited in claim 1, wherein the opening gas is halogen free and wherein the cleaning gas is oxygen free.
17. The method, as recited in claim 1, wherein the opening the amorphous carbon layer mask opens features with a CD of less than about 300 nm.