

CLAIMS

1. A method comprising:
exposing a surface of a semiconductor substrate in a processing chamber to a halogen-containing precursor, wherein the halogen-containing precursor is delivered to the processing chamber or formed in situ within the processing chamber;
and
depositing on the surface an ashable hard mask film (AHM) by a plasma enhanced chemical vapor deposition (PECVD) process.
2. The method of claim 1, wherein said exposing comprises delivering the halogen-containing precursor to the processing chamber.
3. The method of claim 2, wherein the halogen-containing precursor comprises a straight-chain or branched-chain aliphatic moiety, an aromatic moiety, a cycloaliphatic moiety, or a multicycloaliphatic moiety, in which each moiety comprises one or more halo substitutions.
4. The method of claim 3, wherein the one or more halo substitutions is provided on an sp carbon, sp² carbon, an sp³ carbon, a branched portion, or an unbranched portion.
5. The method of claim 3, wherein the halogen-containing precursor comprises a halocarbon, a haloaliphatic, a haloalkane, a haloalkene, a haloalkyne, a haloaromatic, or a halocarbo cycle.
6. The method of claim 1, wherein said exposing further comprises delivering a process gas comprising the halogen-containing precursor and an inert gas.
7. The method of claim 1, wherein said exposing comprises forming the halogen-containing precursor in situ within the processing chamber with an organic reactant and a halogen-containing reactant.

8. The method of claim 7, wherein the organic reactant comprises a pure hydrocarbon reactant, a halocarbon reactant, a hydrocarbon reactant having a leaving group, or a heterocycle reactant.

9. The method of claim 8, wherein the pure hydrocarbon reactant comprises an alkane, an alkene, an alkyne, an aromatic, or a carbocycle.

10. The method of claim 8, wherein the halocarbon reactant comprises an alkane, an alkene, an alkyne, an aromatic, or a carbocycle comprising one or more halo substitutions.

11. The method of claim 8, wherein the hydrocarbon reactant having the leaving group comprises an alkane, an alkene, an alkyne, an aromatic, or a carbocycle comprising one or more leaving groups.

12. The method of claim 11, wherein the hydrocarbon reactant having the leaving group comprises a halosulfonyl group, a sulfonate group, a cyano group, a nitrous oxide group (N_2O), or a nitrate group ($-\text{ONO}_2$).

13. The method of claim 11, wherein the hydrocarbon reactant having the leaving group comprises an alkyl sulfonyl halide, an aryl sulfonyl halide, an alkyl triflate, an aryl triflate, an alkyl mesylate, an aryl mesylate, a cyanoalkane, a cyanoaromatic, an alkyl nitrate, or an aryl nitrate.

14. The method of claim 7, wherein the halogen-containing reactant comprises a halide, a halogen gas, a tetrahalosilane, a trihalosilane, a dihalosilane, a monohalosilane, or a Grignard reagent.

15. The method of claim 7, wherein said exposing further comprises delivering a first process gas comprising the organic reactant with a first inert gas and a second process gas comprising the halogen-containing reactant with a second inert gas.

16. The method of claim 1, wherein the halogen-containing precursor comprises a ratio of carbon atoms to halogen atoms (a C:H ratio) of at least about 1:3 and/or a ratio of halogen atoms to hydrogen atoms (an X:H ratio) of at least about 1:20.

17. The method of claim 1, wherein said exposing further comprises delivering a hydrogen (H₂) gas.

18. The method of claim 1, wherein said exposing further comprises delivering a hydrocarbon precursor with the halogen-containing precursor.

19. The method of claim 18, wherein the hydrocarbon precursor comprises an alkane, an alkene, an alkyne, an aromatic, or a carbocycle.

20. The method of claim 1, wherein said exposing further comprises delivering a metal-containing reactant and said depositing provides a metal-doped AHM.

21. The method of claim 20, wherein the metal-containing reactant comprises an organometallic reagent, a metal halide, or a metal hydride.

22. The method of claim 1, wherein said PECVD process comprises igniting a plasma comprising a low frequency (LF) component and/or a high frequency (HF) component.

23. The method of claim 1, wherein the method provides a multilayer stack comprising the AHM.

24. The method of claim 1, further comprising:
patterning the AHM, thereby providing a patterned AHM; and
etching the patterned AHM to define features of the AHM in the semiconductor substrate.

25. The method of claim 24, further comprising:
etching one or more layers in the semiconductor substrate underlying the patterned AHM; and

removing the patterned AHM.

26. An apparatus for forming an ashable hard mask (AHM), the apparatus comprising:

- a processing chamber;
- a substrate holder in the processing chamber;
- one or more gas inlets for flowing gases into the processing chamber;
- a plasma generator for generating plasmas within the processing chamber;

and

one or more controllers comprising machine-readable instructions for operating the substrate holder, the one or more gas inlets, and the plasma generator to deposit the AHM onto a semiconductor substrate, the instructions of the one or more controllers comprising instructions for:

- (a) causing operation of the one or more gas inlets to flow a halogen-containing precursor or an organic reactant with a halogen-containing reactant into the processing chamber, wherein the organic reactant and the halogen-containing reactant form the halogen-containing precursor, thereby exposing a surface of the semiconductor substrate held in the substrate holder to the halogen-containing precursor; and

- (b) causing operation of the plasma generator to generate a plasma to form the AHM on the surface.

27. The apparatus of claim 26, wherein the instructions of the one or more controllers further comprise instructions for:

- (c) prior to causing operation of the plasma generator, further causing operation of the one or more gas inlets to flow a hydrogen (H₂) gas into the processing chamber.

28. The apparatus of claim 26, wherein the instructions of the one or more controllers further comprise instructions for:

- (c) prior to causing operation of the plasma generator, further causing operation of the one or more gas inlets to flow a metal-containing reactant into the processing chamber.

29. The apparatus of claim 26, wherein the instructions of the one or more controllers further comprise instructions for:

(c) causing operation of the substrate holder at a temperature of at least about 50°C.

30. The apparatus of claim 26, wherein the plasma generator is operated to provide a plasma comprising a low frequency (LF) component and/or a high frequency (HF) component.