CLAIMS

~~*What is claimed is:*~~

1. A method of baking a photoresist layer on a substrate, the method comprising:

receiving the substrate in a process chamber, the substrate comprising the photoresist layer thereon, wherein the photoresist layer comprises a metal-containing photoresist material;

flowing a reactive gas species from a gas source, through a gas delivery line, into the process chamber, and exposing the substrate to the reactive gas species in the process chamber; and

baking the photoresist layer while the substrate is exposed to the reactive gas species.

2. The method of claim 1, wherein the photoresist layer comprises an extreme ultraviolet (EUV) photoresist material.

3. The method of claim 2, wherein the reactive gas species comprises a gas selected from the group consisting of: water, hydrogen, oxygen, ozone, hydrogen peroxide, carbon monoxide, carbon dioxide, ammonia, nitrous oxide, nitric oxide, an alcohol, acetyl acetone, formic acid, oxalyl chloride, pyridine, a carboxylic acid, an amine, and combinations thereof.

4. The method of claim 3, wherein the reactive gas species comprises the water.

5. The method of claim 3, wherein the reactive gas species comprises the hydrogen.

6. The method of claim 3, wherein the reactive gas species comprises the oxygen.

7. The method of claim 3, wherein the reactive gas species comprises the ozone.

8. The method of claim 3, wherein the reactive gas species comprises the hydrogen peroxide.

9. The method of claim 3, wherein the reactive gas species comprises the carbon monoxide.

10. The method of claim 3, wherein the reactive gas species comprises the carbon dioxide.

11. The method of claim 3, wherein the reactive gas species comprises the ammonia.

12. The method of claim 11, wherein baking the photoresist layer occurs after the photoresist layer has been exposed to EUV radiation to pattern the photoresist layer, and wherein one of the following conditions is satisfied:

(i) the process chamber is maintained at atmospheric pressure while baking the photoresist layer, and the ammonia is provided at a concentration between about 0.001-5% (by volume), or

(ii) the process chamber is maintained at sub-atmospheric pressure while baking the photoresist layer, and the ammonia is provided at a partial pressure between about 1-100 mTorr.

13. The method of claim 3, wherein the reactive gas species comprises the nitrous oxide and/or the nitric oxide.

14. The method of claim 3, wherein the reactive gas species comprises the alcohol.

15. The method of claim 3, wherein the reactive gas species comprises the acetyl acetone.

16. The method of claim 3, wherein the reactive gas species comprises the formic acid.

17. The method of claim 3, wherein the reactive gas species comprises the oxalyl chloride.

18. The method of claim 3, wherein the reactive gas species comprises the carboxylic acid.

19. The method of claim 3, wherein the reactive gas species comprises the amine.

20. The method of claim 19, wherein the amine comprises methaylamine, dimethylamine, and/or trimethylamine.

21. The method of claim 19, wherein the amine comprises ethylamine, diethylamine, and/or triethylamine.

22. The method of any of claims ~~2~~1-21, wherein the reactive gas species is oxidative.

23. The method of any of claims ~~2-22~~1-21, wherein the reactive gas species is polar.

24. The method of any of claims ~~2-23~~1-21, wherein exposing the substrate to the reactive gas species promotes cross-linking within the photoresist layer.

25. The method of any of claims ~~2-24~~1-21, wherein exposing the substrate to the reactive gas species increases a stability of the photoresist layer.

26. The method of any of claims ~~2-25~~1-21, wherein exposing the substrate to the reactive gas species promotes removal of low molecular weight species in the photoresist layer.

27. The method of claim 26, wherein the low molecular weight species comprise zero, one, or two metal atoms per molecule.

28. The method of any of claims ~~2-27~~1-21, wherein exposing the substrate to the reactive gas species oxidizes a metal hydride species in the photoresist layer to a metal hydroxide species.

29. The method of any of claims ~~2-28~~1-21, further comprising applying vacuum to the process chamber while baking the photoresist layer.

30. The method of any of claims ~~2-29~~1-21, further comprising controlling a concentration of water in the process chamber such that it remains within a target water concentration range while baking the photoresist layer.

31. The method of any of claims ~~2-30~~1-21, further comprising controlling a concentration of oxygen in the process chamber such that it remains within a target oxygen concentration range while baking the photoresist layer.

32. The method of any of claims ~~2-31~~1-21, wherein the process chamber is maintained at or below atmospheric pressure while baking the photoresist layer.

33. The method of claim 32, wherein the process chamber is maintained below atmospheric pressure while baking the photoresist layer.

34. The method of any of claims ~~2-33~~1-21, further comprising increasing a temperature of a substrate support on which the substrate is positioned while baking the photoresist layer.

35. The method of any of claims ~~2-34~~1-21, further comprising decreasing a temperature of a substrate support on which the substrate is positioned while baking the photoresist layer.

36. The method of any of claims ~~2-35~~1-21, further comprising controlling a flow of the reactive species into the process chamber to achieve a target degree of crosslinking.

37. The method of any of claims ~~2-36~~1-21, wherein baking the photoresist layer comprises heating the substrate on a hot plate.

38. The method of any of claims ~~2-37~~1-21, wherein baking the photoresist layer comprises exposing the substrate to infrared radiation and/or ultraviolet radiation.

39. The method of any of claims ~~2-38~~1-21, wherein baking the photoresist layer comprises heating the substrate from above.

40. The method of any of claims ~~2-39~~1-21, wherein baking the photoresist layer comprises heating the substrate from below.

41. The method of any of claims ~~2-40~~1-21, wherein the photoresist layer has been applied to the substrate but not yet patterned, and the baking is a post-application bake (PAB).

42. The method of any of claims ~~2-41~~1-21, wherein the photoresist layer has been applied to the substrate and patterned by partial exposure to EUV radiation resulting in exposed and unexposed portions of the photoresist layer, and the baking is a post-exposure bake (PEB).

43. The method of claim 42, wherein the reactive gas species comprises polar and oxidative molecules.

44. The method of claim 43, wherein the reactive gas species comprises hydrogen peroxide.

45. An apparatus for baking a photoresist layer on a substrate, the apparatus comprising:

a process chamber;

an inlet for introducing a reactive gas species to the process chamber;

an outlet for removing materials from the process chamber;

a substrate support in the process chamber;

a heater configured to heat the substrate through conduction, convection, and/or radiation; and

a controller having at least one processor, wherein the at least one processor is configured to control the apparatus to cause any of the methods of claims ~~1-44~~1-21.