CLAIMS

~~*What is claimed is:*~~

1. A method of processing a substrate, comprising:

providing the substrate in a process chamber, wherein the substrate is a semiconductor substrate comprising a substrate layer and photoresist positioned over the substrate layer, and wherein the photoresist comprises metal; and

performing a treatment on the photoresist to modify material properties of the photoresist such that etch selectivity in a subsequent post-exposure dry development process is increased.

2. The method of claim 1, wherein the treatment results in increased cross-linking in the photoresist.

3. The method of claim 1, wherein the treatment involves a thermal process with control of temperature, pressure, ambient gas chemistry, gas flow/ratio, and moisture.

4. The method of claim 3, wherein the ambient gas chemistry comprises an inert gas selected from the group consisting of nitrogen (N_2), helium, neon, argon, xenon, and combinations thereof.

5. The method of claim 4, wherein the ambient gas chemistry is substantially free of reactive gases.

6. The method of claim 3, wherein the ambient gas chemistry comprises a reactive gas species.

7. The method of claim 6, wherein the reactive gas species is selected from the group consisting of water, hydrogen (H_2), oxygen (O_2), ozone, hydrogen peroxide, carbon monoxide, carbon dioxide, carbonyl sulfide, sulfur dioxide, chlorine (Cl_2), ammonia, nitrous oxide, nitric oxide, methane, an alcohol, acetyl acetone, formic acid, oxalyl chloride, pyridine, a carboxylic acid, an amine, and combinations thereof.

8. The method of any of claims 1 to 7, wherein the photoresist has been applied to the substrate layer but not yet exposed to patterning radiation, and the treatment is a post-application bake (PAB).

9. The method of claim 8, wherein the treatment increases an exposure radiation sensitivity of the photoresist to thereby achieve a lower dose to size while the substrate is exposed to the patterning radiation, and to achieve a lower line edge roughness after the substrate is exposed to the patterning radiation, as compared to a higher dose to size and a higher line edge roughness that would be achieved without the treatment.

10. The method of claim 8, wherein the treatment is conducted at a temperature between about 90 to 250˚C or 90 to 190˚C.

11. The method of any of claims 1 to 7, wherein the photoresist has been patterned by partial exposure to patterning radiation resulting in exposed and unexposed portions of the photoresist, and the treatment is a post-exposure bake (PEB).

12. The method of claim 11, wherein the treatment is conducted at a temperature between about 170 to 250˚C or higher.

13. The method of claim 12, wherein a composition of both the unexposed and exposed portions of the photoresist is changed by the treatment to (i) increase an etch rate in a dry development etch gas, (ii) increase a difference in the composition between the unexposed and exposed portions of the photoresist, and/or (iii) increase a difference in one or more material properties between the unexposed and exposed portions of the photoresist.

14. The method of any of claims 1 to 7, wherein a temperature of the substrate is ramped while performing the treatment on the photoresist.

15. The method of any of claims 1 to 7, wherein the pressure during the treatment is controlled between about 0.1-760 Torr.

16. The method of claim 15, wherein the pressure during the treatment is controlled between about 0.1-10 Torr.

17. The method of claim 1, wherein the treatment involves exposing the photoresist to a remote plasma that generates radicals that react with the photoresist to modify one or more material properties of the photoresist.

18. The method of claim 17, wherein the radicals are generated from a gas species selected from the group consisting of water, hydrogen (H_2), oxygen (O_2), ozone, hydrogen peroxide, carbon monoxide, carbon dioxide, carbonyl sulfide, sulfur dioxide, chlorine (Cl_2), ammonia, nitrous oxide, nitric oxide, methane, an alcohol, acetyl acetone, formic acid, oxalyl chloride, pyridine, a carboxylic acid, an amine, and combinations thereof.

19. The method of any of claims 1 to 7, wherein the treatment is a thermal treatment performed using a first set of processing conditions and a second set of processing conditions, wherein the first and second sets of processing conditions vary with respect to at least one of ambient gases or mixtures, temperatures, and/or pressures to thereby modulate material properties of the photoresist and to tune etch selectivity of the photoresist.

20. The method of any of claims 1 to 7, wherein the photoresist is an EUV sensitive film.

21. The method of any of claims 1 to 7, wherein the treatment precedes exposing the photoresist to EUV lithography.

22. The method of any of claims 1 to 7, wherein the treatment occurs after exposing the photoresist to EUV lithography.

23. The method of claim 21, wherein the treatment is performed a second time after exposing the photoresist to EUV lithography.

24. An apparatus for processing a substrate, the apparatus comprising:

a process chamber comprising a substrate support;

a process gas source connected with the process chamber and associated gas flow-control hardware;

substrate thermal control apparatus;

substrate handling hardware connected with the process chamber; and

a controller having a processor, wherein the processor is at least operatively connected with the gas flow-control hardware, the substrate thermal control apparatus, and the substrate handling hardware, wherein the controller is configured to cause any one or more of the methods of claims 1-7 ~~or otherwise described herein~~.