

CLAIMS

What is claimed is:

1. A method of processing a substrate, comprising:
5 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
10 is increased.
2. The method of claim 1, wherein the treatment results in increased cross-linking in the photoresist.
- 15 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 (N₂), helium, neon, argon, xenon, and
20 combinations thereof.
5. The method of claim 4, wherein the ambient gas chemistry is substantially free of reactive gases.
- 25 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 (H₂), oxygen (O₂), ozone, hydrogen peroxide, carbon monoxide,
30 carbon dioxide, carbonyl sulfide, sulfur dioxide, chlorine (Cl₂), 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).

5 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.

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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
15 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.

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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
25 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.

30 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.

5 18. The method of claim 17, wherein the radicals are generated from a gas species selected from the group consisting of water, hydrogen (H₂), oxygen (O₂), ozone, hydrogen peroxide, carbon monoxide, carbon dioxide, carbonyl sulfide, sulfur dioxide, chlorine (Cl₂), ammonia, nitrous oxide, nitric oxide, methane, an alcohol, acetyl acetone, formic acid, oxalyl chloride, pyridine, a carboxylic acid, an amine, and combinations thereof.

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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
15 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
20 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.

25 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;
30 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.

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