

CLAIMS

1. A method of reflowing photoresist, the method comprising:
receiving a substrate in a reaction chamber, the substrate having photoresist patterned
5 thereon, wherein the reaction chamber comprises a grid structure dividing the interior of
the reaction chamber into an upper sub-chamber proximate a plasma generator and a
lower sub-chamber proximate a substrate holder;
flowing a first plasma generating gas into the upper sub-chamber;
generating a first plasma in the upper sub-chamber from the first plasma generating gas,
10 the first plasma having a first electron density, and generating a second plasma in the
lower sub-chamber, wherein the second plasma is an ion-ion plasma that has a second
electron density at least about 10 times lower than the first electron density;
exposing the substrate to the second plasma to smooth the photoresist;
flowing a second plasma generating gas into the upper sub-chamber;
15 generating a third plasma in the upper sub-chamber from the second plasma generating
gas, the third plasma having a third electron density, and generating a fourth plasma in
the lower sub-chamber, wherein the fourth plasma is an ion-ion plasma that has a fourth
electron density at least about 10 times lower than the third electron density; and
exposing the substrate to the fourth plasma,
20 wherein before exposing the substrate to the second plasma the photoresist has an initial
line width roughness, wherein after exposing the substrate to the fourth plasma the
photoresist has a final line width roughness, and wherein the final line width roughness
is about 75% or less of the initial line width roughness.

2. The method of claim 1,

wherein exposing the substrate to the fourth plasma removes photoresist in a foot region of the photoresist.

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3. The method of claim 1, wherein the first plasma generating gas comprises at least one gas selected from the group consisting of: H₂, Ar, HBr, and combinations thereof.

4. The method of claim 3, wherein the first plasma generating gas further comprises

10 N₂ and/or HeSTG.

5. The method of claim 3, wherein the first plasma generating gas comprises H₂.

6. The method of claim 1, wherein the second plasma generating gas comprises at least

15 one gas selected from the group consisting of Ar, HBr, and a combination thereof.

7. The method of claim 6, wherein the second plasma generating gas comprises Ar.

8. The method of claim 7, wherein the first plasma generating gas comprises H₂.

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9. The method of claim 1, wherein exposing the substrate to the second plasma both (i) smooths the photoresist, and (ii) removes the photoresist in a foot region of the photoresist.

10. The method of claim 9, wherein the first plasma generating gas comprises H₂, N₂, and HeSTG.
- 5 11. The method of claim 1, wherein the photoresist comprises extreme ultraviolet photoresist.
12. The method of claim 1, further comprising applying a bias voltage to the substrate while the substrate is exposed to the fourth plasma, wherein the bias voltage is about
10 200V or less.
13. The method of claim 12, wherein the bias voltage is greater than about 30V.
14. The method of claim 1, wherein before exposing the substrate to the second plasma
15 the photoresist has an initial height, wherein after exposing the substrate to the fourth plasma the photoresist has a final height, and wherein the final height is at least about 50% of the initial height.
15. The method of claim 1, wherein the final line width roughness is about 65% or less
20 of the initial line width roughness.

16. The method of claim 1, wherein the first plasma has a first electron temperature of about 2 eV or more, and wherein the second plasma has a second effective electron temperature of about 1 eV or less.
- 5 17. The method of claim 1, wherein the second electron density is about $5 \times 10^9 \text{ cm}^{-3}$ or less.
18. The method of claim 1, wherein a ratio of negative ions:positive ions in the second plasma is between about 0.5-1.
- 10 19. The method of claim 1, wherein the first plasma is an inductively coupled plasma generated at a power between about 300-1000 Watts per substrate.
20. The method of claim 19, wherein a bias applied to the substrate is between about 50-
15 200 V.
21. The method of claim 1, wherein after smoothing the photoresist, the substrate has a line width roughness of about 3.0 nm or below.
- 20 22. The method of claim 1,
wherein the first plasma generating gas and the second plasma generating gas have different compositions.

23. The method of claim 22, wherein the first plasma generating gas comprises H₂, and wherein the second plasma generating gas does not comprise H₂.