

Claims:

1. A method for processing a substrate, comprising:
forming a dielectric layer on ~~patterned features~~exposed surfaces of one or more trenches in the substrate by exposing the substrate to a gas mixture of a first precursor and a second precursor simultaneously with plasma present in a process chamber, wherein the plasma is formed by a first pulsed RF power;
exposing the dielectric layer to a plasma densification treatment using a gas mixture of nitrogen and helium in the process chamber;~~and~~ to form a treated dielectric layer;
forming a passivation layer on the treated dielectric layer in the process chamber;
and
performing a plasma etch process by exposing the treated dielectric layer and the passivation layer to a plasma formed from a gas mixture of a fluorine-containing precursor and a carrier gas, wherein the plasma is formed in the process chamber by a second pulsed RF power with a frequency of about 5 kHz to about 30 kHz, the plasma etch process etching a top portion of the one or more trenches at a faster rate than at a bottom surface of the one or more trenches.
2. The method of claim 1, wherein the forming the passivation layer further comprising:
comprises exposing the treated dielectric layer to a silicon-containing precursor ~~after exposing the dielectric layer to the first plasma treatment and prior to performing the plasma etch process~~.
3. The method of claim 2, wherein the silicon-containing precursor comprises silane.
4. The method of claim 2, wherein the treated dielectric layer is exposed to a nitrogen-containing gas while exposing to the silicon-containing gas precursor.
5. The method of claim 1, further comprising ~~purging the process chamber~~;

before and/or after the first plasma densification treatment, purging the process chamber.

6. The method of claim 1, wherein the ~~patterned features are~~ trenches ~~having~~have an aspect ratio of about 3:1 to about 10:1.

7. A method for processing a substrate, comprising:

forming a dielectric layer on ~~patterned features~~exposed surfaces of one or more trenches in the substrate by a plasma deposition process, wherein a first plasma is formed by a first pulsed RF power in a process chamber;

densifying the dielectric layer by a plasma treatment; ~~and~~ to form a treated dielectric layer;

forming a passivation layer on the treated dielectric layer and within the one or more trenches; and

etching a portion of the treated dielectric layer and the passivation layer by a plasma etch process, wherein a second plasma formed from a gas mixture of a fluorine-containing gas and a carrier gas, wherein the second plasma is formed in the process chamber by a second pulsed RF power, a top portion of the one or more trenches etched at a faster rate than at a bottom surface of the one or more trenches.

8. The method of claim 7, wherein the first and second pulsed RF power has a duty cycle in a range from about 5 % to about 30 % and a frequency in a range from about 10 kHz to about 20 kHz.

9. The method of claim 7, wherein the second pulsed RF power has a pulsing width of about 1 μsum to about 50 μsum.

~~40~~10. The method of claim 7, wherein the dielectric layer is silicon nitride.

11. The method of claim 7, wherein the plasma etch process is performed in a radical-based ambient.

12. The method of claim 7, wherein the fluorine-containing gas of the plasma etch process comprises NF_3 , F_2 , C_2F_6 , CF_4 , C_3F_8 , or SF_6 .

4413. The method of claim ~~7~~12, wherein the carrier gas of the plasma etch process comprises argon, helium, nitrogen, oxygen, or nitrous oxide.

14. The method of claim 13, wherein a ratio of the fluorine-containing gas and the carrier gas is in a range of about 1 (fluorine-containing gas):6 (carrier gas) to about 1 (fluorine-containing gas):20 (carrier gas).

4215. A method for processing a substrate, comprising:

forming a dielectric layer on patterned features of the substrate by a plasma deposition process, wherein a first plasma is formed by a first pulsed RF power in a process chamber;

densifying the dielectric layer by a plasma treatment using a gas mixture of nitrogen and helium in the process chamber to form a treated dielectric layer;

forming a first passivation layer on the treated dielectric layer;

etching the first passivation layer and a portion of the dielectric layer by a plasma etch process to form an etched dielectric layer, wherein a second plasma is formed in the process chamber by a second pulsed RF power at a frequency of about 5 kHz to about 30 kHz to etch a top surface of the patterned features at a faster etch rate than at a bottom sidewall of the patterned features; and

forming a second passivation layer on the etched dielectric layer.

4316. The method of claim ~~42~~15, wherein the plasma deposition process comprises flowing a first precursor and a second precursor into the process chamber.

17. The method of claim 16, wherein the first precursor is a nitrogen-containing precursor comprising ammonia or nitrogen, and the second precursor is a silicon-containing precursor comprising silane or trisilylamine (TSA).

18. The method of claim 15, wherein the plasma treatment uses a gas mixture of nitrogen and helium in the process chamber.

19. The method of claim 18, wherein a ratio of the nitrogen and helium in the plasma treatment is in a range of about 1 (nitrogen):3 (helium) to about 1 (nitrogen):10 (helium).

20. The method of claim 15, wherein the first and second passivation layers comprise silicon layers.

21. The method of claim 1, wherein the plasma densification treatment is performed at an RF power of about 300 W to about 1200 W.

22. The method of claim 1, wherein the plasma etch process prevents a top opening of the one or more trenches from pinching off and a conformal profile of the dielectric layer is obtained.