

CLAIMS

1. A plasma applicator, comprising:
a plasma discharge tube in which plasma can be generated, the plasma discharge tube having a process gas inlet for allowing a plasma process gas to enter the plasma discharge tube, the plasma discharge tube having a longitudinal axis;
a microwave cavity at least partially surrounding a portion of the plasma discharge tube;
and
a coupling iris at which microwave energy can be coupled to the microwave cavity such that the microwave energy can generate a plasma in the portion of the plasma discharge tube;
wherein
the microwave cavity has three orthogonal dimensions including a length, a width and a height, at least two of the orthogonal dimensions being selected such that the microwave energy in the microwave cavity propagates in a transverse electric (TE) mode.
2. The plasma applicator of claim 1, wherein primary electric fields generated from the microwave energy combine with an evanescent electric field generated from the coupling iris, such that a combined electric field in the microwave cavity is substantially uniform along the longitudinal axis of the plasma discharge tube.
3. The plasma applicator of claim 1, wherein the microwave energy has a power of approximately 1kW.
4. The plasma applicator of claim 1, wherein a source of the microwave energy comprises a solid state generator.
5. The plasma applicator of claim 1, wherein a source of the microwave energy comprises a magnetron.
6. The plasma applicator of claim 1, wherein the plasma discharge tube is made of a material including at least one of quartz, sapphire, ceramic, aluminum nitride and boron nitride.

7. The plasma applicator of claim 1, wherein the process gas comprises at least one of oxygen, nitrogen, hydrogen, fluorinated gas, forming gas, NF_3 , NH_3 , C_2F_4 , and C_2F_6 .
8. The plasma applicator of claim 1, further comprising a plurality of radial microwave chokes disposed over an exterior of the plasma discharge tube and disposed at ends of the microwave cavity for substantially containing the microwave energy in the microwave cavity, positions of the microwave chokes being such that microwave energy propagating in the TE mode and the transverse electric magnetic (TEM) mode is attenuated.
9. The plasma applicator of claim 8, wherein the plurality of radial microwave chokes comprise a first inner choke and a first outer choke located at a first end of the microwave cavity and a second inner choke and a second outer choke located at a second end of the microwave cavity, a first space between the first inner choke and the first outer choke and a second space between the second inner choke and the second outer choke being selected to provide attenuation of the microwave energy propagating in the TE mode and the TEM mode.
10. The plasma applicator of claim 9, wherein at least one of the first and second spaces is approximately 0.38 inch.
11. The plasma applicator of claim 9, wherein the first and second spaces are substantially equal.
12. A plasma applicator, comprising:
a plasma discharge tube in which plasma can be generated, the plasma discharge tube having a process gas inlet for allowing a plasma process gas to enter the plasma discharge tube, the plasma discharge tube having a longitudinal axis;
a microwave cavity at least partially surrounding a portion of the plasma discharge tube;
and
a coupling iris at which microwave energy can be coupled to the microwave cavity such that the microwave energy can generate a plasma in the portion of the plasma discharge tube;
wherein

primary electric fields generated from the microwave energy combine with an evanescent electric field generated from the coupling iris, such that a combined electric field in the microwave cavity is substantially uniform along the longitudinal axis of the plasma discharge tube.

13. The plasma applicator of claim 12, wherein the microwave cavity has three orthogonal dimensions including a length, a width and a height, at least two of the orthogonal dimensions being selected such that the microwave energy in the microwave cavity propagates in a transverse electric (TE) mode.

14. The plasma applicator of claim 12, further comprising a plurality of radial microwave chokes disposed over an exterior of the plasma discharge tube and disposed at ends of the microwave cavity for substantially containing the microwave energy in the microwave cavity, positions of the microwave chokes being such that microwave energy propagating in the TE mode and the transverse electric magnetic (TEM) mode is attenuated.

15. The plasma applicator of claim 14, wherein the plurality of radial microwave chokes comprise a first inner choke and a first outer choke located at a first end of the microwave cavity and a second inner choke and a second outer choke located at a second end of the microwave cavity, a first space between the first inner choke and the first outer choke and a second space between the second inner choke and the second outer choke being selected to provide attenuation of the microwave energy propagating in the TE mode and the TEM mode.

16. The plasma applicator of claim 15, wherein at least one of the first and second spaces is approximately 0.38 inch.

17. The plasma applicator of claim 15, wherein the first and second spaces are substantially equal.

18. The plasma applicator of claim 12, wherein the microwave energy has a power of approximately 1kW.

19. The plasma applicator of claim 12, wherein a source of the microwave energy comprises a solid state generator.
20. The plasma applicator of claim 12, wherein a source of the microwave energy comprises a magnetron.
21. The plasma applicator of claim 12, wherein the plasma discharge tube is made of a material including at least one of quartz, sapphire, ceramic, aluminum nitride and boron nitride.
22. The plasma applicator of claim 12, wherein the process gas comprises at least one of oxygen, nitrogen, hydrogen, fluorinated gas, forming gas, NF_3 , NH_3 , C_2F_4 , and C_2F_6 .
23. A plasma applicator, comprising:
a plasma discharge tube in which plasma can be generated, the plasma discharge tube having a process gas inlet for allowing a plasma process gas to enter the plasma discharge tube, the plasma discharge tube having a longitudinal axis;
a microwave cavity at least partially surrounding a portion of the plasma discharge tube;
a coupling iris at which microwave energy can be coupled to the microwave cavity such that the microwave energy can generate a plasma in the portion of the plasma discharge tube; and
a plurality of radial microwave chokes disposed over an exterior of the plasma discharge tube and disposed at ends of the microwave cavity for substantially containing the microwave energy in the microwave cavity, positions of the microwave chokes being such that microwave energy propagating in a transverse electric (TE) mode and a transverse electric magnetic (TEM) mode is attenuated.
24. The plasma applicator of claim 23, wherein the plurality of radial microwave chokes comprise a first inner choke and a first outer choke located at a first end of the microwave cavity and a second inner choke and a second outer choke located at a second end of the microwave cavity, a first space between the first inner choke and the first outer choke and a second space between the second inner choke and the second outer choke being selected to provide attenuation

of the microwave energy propagating in the TE mode and the TEM mode.

25. The plasma applicator of claim 24, wherein at least one of the first and second spaces is approximately 0.38 inch.

26. The plasma applicator of claim 24, wherein the first and second spaces are substantially equal.

27. The plasma applicator of claim 23, wherein the microwave cavity has three orthogonal dimensions including a length, a width and a height, at least two of the orthogonal dimensions being selected such that the microwave energy in the microwave cavity propagates in a transverse electric (TE) mode.

28. The plasma applicator of claim 23, wherein primary electric fields generated from the microwave energy combine with an evanescent electric field generated from the coupling iris, such that a combined electric field in the microwave cavity is substantially uniform along the longitudinal axis of the plasma discharge tube.

29. The plasma applicator of claim 23, wherein the microwave energy has a power of approximately 1kW.

30. The plasma applicator of claim 23, wherein a source of the microwave energy comprises a solid state generator.

31. The plasma applicator of claim 23, wherein a source of the microwave energy comprises a magnetron.

32. The plasma applicator of claim 23, wherein the plasma discharge tube is made of a material including at least one of quartz, sapphire, ceramic, aluminum nitride and boron nitride.

33. The plasma applicator of claim 23, wherein the process gas comprises at least one of

oxygen, nitrogen, hydrogen, fluorinated gas, forming gas, NF_3 , NH_3 , C_2F_4 , and C_2F_6 .