Claims

1. A microwave plasma reactor for manufacturing a synthetic diamond material via chemical vapour deposition, the microwave plasma reactor comprising:

a plasma chamber;

a substrate holder disposed in the plasma chamber for supporting a substrate on which the synthetic diamond material is to be deposited in use;

a microwave coupling configuration for feeding microwaves from a microwave generator into the plasma chamber; and

a gas flow system for feeding process gases into the plasma chamber and removing them therefrom,

wherein the microwave coupling configuration for feeding microwaves from the microwave generator into the plasma chamber comprises:

an annular dielectric window formed in one or several sections;

a coaxial waveguide having a central inner conductor and an outer conductor for feeding microwaves to the annular dielectric window; and

a waveguide plate comprising a plurality of apertures disposed in an annular configuration with a plurality of arms extending between the apertures, each aperture forming a waveguide for coupling microwaves towards the plasma chamber.

2. A microwave plasma reactor according to claim 1, wherein the waveguide plate comprises an odd number of apertures

3. A microwave plasma reactor according to claim 2, wherein the waveguide plate comprises a prime number of apertures

4. A microwave plasma reactor according to claim 3, wherein the waveguide plate comprises 3, 5, or 7 apertures.

5. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate is positioned adjacent the annular dielectric window.

6. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate is positioned between the coaxial waveguide and the annular dielectric window.

7. A microwave plasma reactor according to any preceding claim, wherein the annular dielectric window is positioned between the coaxial waveguide and the waveguide plate.

8. A microwave plasma reactor according to any preceding claim, wherein the annular dielectric window comprises two opposing surfaces through which microwaves are coupled into the plasma chamber and seals are provided on said two opposing surfaces.

9. A microwave plasma reactor according to any preceding claim, wherein the plurality of arms define one or more channels for supplying coolant and/or process gas.

10. A microwave plasma reactor according to claim 9, wherein the one or more channels comprise at least one channel configured to supply process gas to one or more injection ports arranged opposite the substrate holder for injecting process gas towards the substrate holder.

11. A microwave plasma reactor according to any preceding claim, wherein the plurality of apertures are configured to couple microwaves towards the plasma chamber in a direction parallel to a central axis of the plasma chamber.

12. A microwave plasma reactor according to any preceding claim, wherein the plurality of apertures are configured to have a periodic rotational symmetry.

13. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate comprises an outer peripheral portion which is disposed between the outer conductor of the coaxial waveguide and an outer wall of the plasma chamber.

14. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate comprises a central portion which extends across the plasma chamber and is supported by the plurality of arms extending between the apertures.

15. A microwave plasma reactor according to claim 14, wherein the central portion of the waveguide plate extends across the plasma chamber at an end opposite to an end at which the substrate holder is disposed.

16. A microwave plasma reactor according to claim 14 or 15, wherein the inner conductor forms a floating conductor supported by the central portion of the waveguide plate.

17. A microwave plasma reactor according to any one of claims 14 to 16, wherein the central portion of the waveguide plate supports a conductive surface disposed opposite the substrate holder.

18. A microwave plasma reactor according to claim 17, wherein the conductive surface is located within the plasma chamber over a high electric field anti-node region which would exist in a corresponding plasma chamber which did not comprise the conductive surface.

19. A microwave plasma reactor according to claim 17 or 18, wherein the conductive surface is cone-shaped.

20. A microwave plasma reactor according to claim 19, wherein the cone-shaped conductive surface comprises a rounded tip.

21. A microwave plasma reactor according to claim 19 or 20, wherein the cone-shaped conductive surface forms an annular recess in the plasma chamber and the annular dielectric window is disposed in said recess.

22. A microwave plasma reactor according to any preceding claim, wherein a plurality of mode cancelling blocks are disposed on an inner wall of the plasma

chamber, the mode cancelling blocks being spaced apart so as to be symmetrically related to the aperture configuration.

23. A microwave plasma reactor according to any preceding claim, wherein a ratio of an annular gap provided by the apertures in the waveguide plate to that of a diameter of the plasma chamber is in the range 1/10 to 1/50, 1/20 to 1/40, 1/25 to 1/35, or is approximately 1/30.

24. A method of manufacturing synthetic diamond material using a chemical vapour deposition process, the method comprising:

providing a microwave plasma reactor according to any preceding claim;

locating a substrate over the substrate holder;

feeding microwaves into the plasma chamber;

feeding process gases into the plasma chamber; and

forming a layer of synthetic diamond material on the substrate.

25. A method according to any one of claim 24, wherein the microwave plasma reactor is inverted whereby a base of the plasma chamber supporting the substrate forms an upper wall of the plasma chamber relative to earth.

Claims

1. A microwave plasma reactor for manufacturing a synthetic diamond material via chemical vapour deposition, the microwave plasma reactor comprising:

a plasma chamber;

a substrate holder disposed in the plasma chamber for supporting a substrate on which the synthetic diamond material is to be deposited in use;

a microwave coupling configuration for feeding microwaves from a microwave generator into the plasma chamber; and

a gas flow system for feeding process gases into the plasma chamber and removing them therefrom,

wherein the microwave coupling configuration for feeding microwaves from the microwave generator into the plasma chamber comprises:

an annular dielectric window formed in one or several sections;

a coaxial waveguide having a central inner conductor and an outer conductor for feeding microwaves to the annular dielectric window; and

a waveguide plate comprising a plurality of apertures disposed in an annular configuration with a plurality of arms extending between the apertures, each aperture forming a waveguide for coupling microwaves towards the plasma chamber,

wherein the plurality of arms define one or more channels for supplying coolant and/or process gas,

wherein the one or more channels comprise at least one channel configured to supply process gas to one or more injection ports arranged opposite the substrate holder for injecting process gas towards the substrate holder,

wherein the waveguide plate comprises a central portion which extends across the plasma chamber and is supported by the plurality of arms extending between the apertures, and

wherein the central inner conductor of the coaxial waveguide forms a floating conductor supported by the central portion of the waveguide plate.

2. A microwave plasma reactor according to claim 1, wherein the waveguide plate comprises an odd number of apertures

3. A microwave plasma reactor according to claim 2, wherein the waveguide plate comprises a prime number of apertures

4. A microwave plasma reactor according to claim 3, wherein the waveguide plate comprises 3, 5, or 7 apertures.

5. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate is positioned adjacent the annular dielectric window.

6. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate is positioned between the coaxial waveguide and the annular dielectric window.

7. A microwave plasma reactor according to any preceding claim, wherein the annular dielectric window is positioned between the coaxial waveguide and the waveguide plate.

8. A microwave plasma reactor according to any preceding claim, wherein the annular dielectric window comprises two opposing surfaces through which microwaves are coupled into the plasma chamber and seals are provided on said two opposing surfaces.

9. A microwave plasma reactor according to any preceding claim, wherein the one or more channels comprise at least one channel configured to supply coolant.

10. A microwave plasma reactor according to any preceding claim, wherein the plurality of apertures are configured to couple microwaves towards the plasma chamber in a direction parallel to a central axis of the plasma chamber.

11. A microwave plasma reactor according to any preceding claim, wherein the plurality of apertures are configured to have a periodic rotational symmetry.

12. A microwave plasma reactor according to any preceding claim, wherein each aperture is arcuate in shape.

13. A microwave plasma reactor according to any preceding claim, wherein the waveguide plate comprises an outer peripheral portion which is disposed between the outer conductor of the coaxial waveguide and an outer wall of the plasma chamber.

14. A microwave plasma reactor according to any preceding claim, wherein the central portion of the waveguide plate supports a conductive surface disposed opposite the substrate holder.

15. A microwave plasma reactor according to claim 14, wherein the conductive surface is cone-shaped.

16. A microwave plasma reactor according to claim 15, wherein the cone-shaped conductive surface comprises a rounded tip.

17. A microwave plasma reactor according to any preceding claim, wherein a plurality of mode cancelling blocks are disposed on an inner wall of the plasma chamber, the mode cancelling blocks being spaced apart so as to be symmetrically related to the aperture configuration.

18. A microwave plasma reactor according to any preceding claim, wherein a ratio of an annular gap provided by the apertures in the waveguide plate to that of a diameter of the plasma chamber is in the range 1/10 to 1/50, 1/20 to 1/40, 1/25 to 1/35, or is 1/30.

19. A method of manufacturing synthetic diamond material using a chemical vapour deposition process, the method comprising:

providing a microwave plasma reactor according to any preceding claim;

locating a substrate over the substrate holder;

feeding microwaves into the plasma chamber;

feeding process gases into the plasma chamber; and

forming a layer of synthetic diamond material on the substrate.

20. A method according to claim 19, wherein the microwave plasma reactor is inverted whereby a base of the plasma chamber supporting the substrate forms an upper wall of the plasma chamber relative to earth.