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Van Cakenberghe

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[54] **DEVICE FOR PLASMA DEPOSITING OF THIN LAYERS ONTO SUBSTRATES**

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[52] **U.S. Cl.** **118/49.1;** 219/383; 313/231.3

[51] **Int. Cl.** **C23c 13/12**

[58] **Field of Search** ..... 118/48–49.5; 117/106–107.2, 93.1 R, 93.1 GD, 93.1 PF; 219/383, 10.49, 121 P; 313/231.3; 315/111.5

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[57] **ABSTRACT**

Improved device for depositing under vacuum thin layers onto substrates comprising a vacuum container and a cylindrical hollow body lined on its inside with the substance to be deposited. A high-frequency electromagnetic field is concentrated inside said hollow body by two conductive cylinders connected to a high-frequency exciting means, promoting a plasma inside said hollow body in presence of an injected gas at a predetermined low pressure.

7 Claims, 3 Drawing Figures

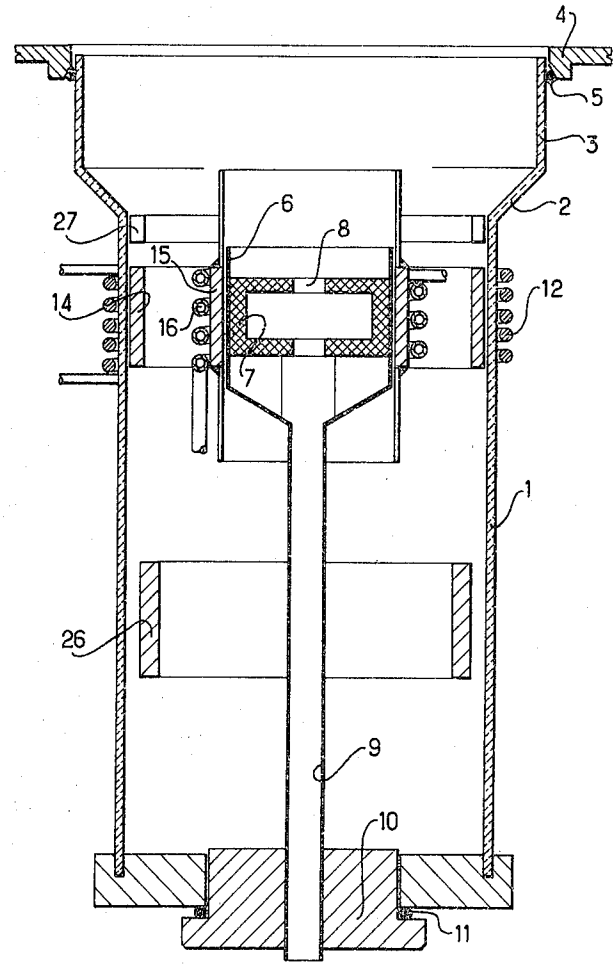

FIG.1

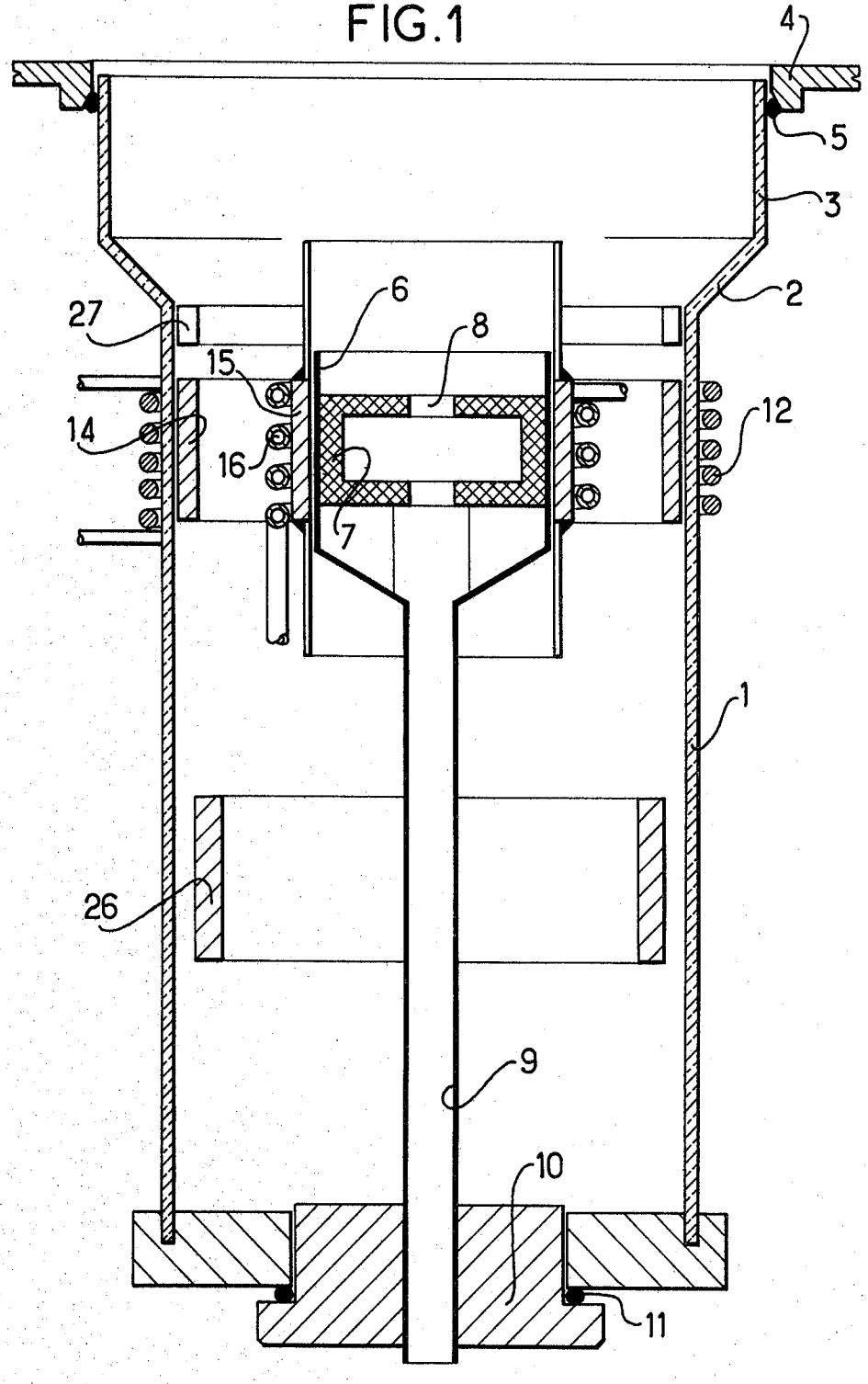

FIG. 2

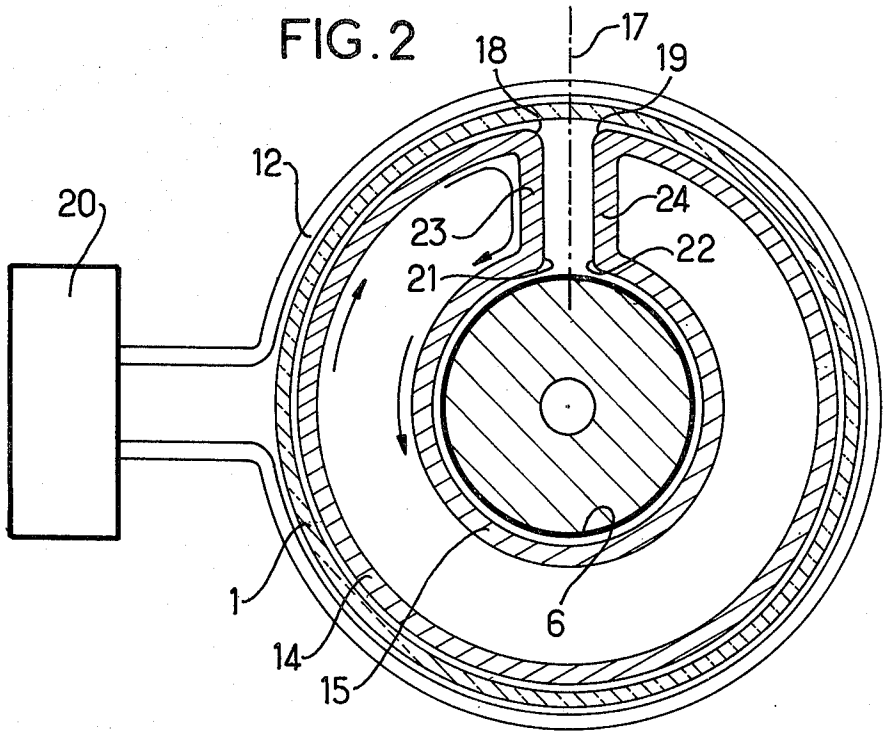
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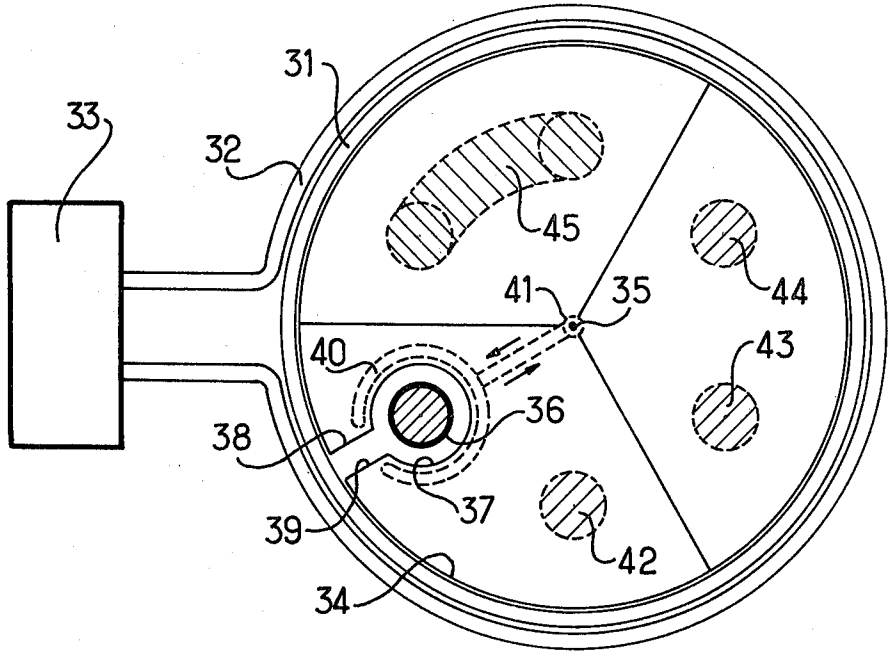
FIG. 3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DEVICE FOR PLASMA DEPOSITING OF THIN LAYERS ONTO SUBSTRATES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention concerns an improvement to devices for depositing thin layers under vacuum.

2. Description of the Prior Art

A device enabling the obtaining of high depositing speed for chemical compounds and consuming relatively low energy is known. Such a device comprise essentially, inside a vacuum chamber, a hollow body lined on the inside with the substance to be deposited. That hollow body is fed from its bottom part by a gas pipe keeping the hollow body at a predetermined pressure. At its upper part, the hollow body is drilled with an outlet opening arranged facing the substrate to be coated. An electromagnetic field is induced inside the hollow body by means of an induction coil placed on the outside of the vacuum chamber surroungind quite closely the said cavity. If the coil is connected to a high-frequency voltage source, a plasma leading to the forming of an arc causing, in its turn, a great rise in temperature inside the cavity leading to a progressive volatilization of the inner wall of that hollow body, is formed inside the hollow body, in contact with the gas injected into that hollow body. The distilled material escapes through the outlet opening placed facing the substrate and is deposited on the latter. Such a device may be used for the depositing of chemical compounds and for the depositing of simple substances. In the latter case, the gas used is a neutral gas.

In such a device, the walls of the hollow body constitute a heat shield.

However, in the case of prolonged operation, the wall of the vacuum chamber placed in the vicinity of the hollow body has a tendency to heat up and may suffer damage. Moreover, even if the energy output is improved in relation to that of previously known devices, nevertheless, only a part of the electromagnetic flux set up ty the induction circuit enters the hollow body.

Moreover, in certain industrial applications, it is necessary to increase the diameter of the chamber and of the induction coil; the result of this is an increase in the gap between the induction coil and the hollow body, causing an increase in the losses of electromagnetic energy and a decrease in the output.

SUMMARY OF THE INVENTION

The aim of the invention is therefore to give the device described hereinabove a more industrial character, making it possible to proceed with deposits with a very high intensity of plasma while maintaining a greater output than that of known devices.

The object of the invention is therefore a device making it possible to deposit this layers under vacuum onto a substrate, comprising:

a chamber kept under vacuum, limited by an insulating wall one part of which is cylindrical;

a cylindrical hollow body arranged axially in the cylindrical part of the chamber, lined on its inside with the substance to be deposited and connected to a source of gas arriving in the hollow body at a predetermined pressure;

an induction coil placed on the outside of the chamber, arranged round the cylindrical part of the chamber, in the vicinity of the latter, at the height of the hollow body and connected to a high-frequency voltage source;

means for concentrating the electromagnetic field inside the hollow body;

cooling means;

characterized in that the main means for concentrating the electromagnetic field inside the hollow body is formed by two concentric conductive cylinders electrically connected together, constituting the secondary winding of an impedance transformer whose primary winding is formed by the induction coil.

The secondary winding of the impedance transformer comprises two coaxial conductive cylinders having a height substantially equal to that of the hollow body, the outer cylinder being situated in the immediate vicinity of the wall of the chamber inside the latter; the two cylinders are split along a radial plane determining two lips on each of the two cylinders. The homologous lips are connected together by two portions of conductive radial planes.

The result of this is an increase in the density of the electromagnetic energy inside the hollow body.

A great proportion of the electromagnetic energy contained in the volume limited by the induction coil is therefore concentrated inside the hollow body.

The invention will be described hereinafter with reference to the accompanying drawings among which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal cutaway view of an embodiment of the device according to the invention;

FIG. 2 is a transversal cutaway view of the same embodiment;

FIG. 3 is a diagrammatic cutaway view of another embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, it will be seen that the vacuum chamber 13 comprises a cylindrical part 1 extended at its upper part by a part 2 flared upwards and by a cylinder 3 having a greater diameter than the cylindrical part 1; that cylinder 3 is connected to the plate 4 of a vacuum chamber by means of a seal 5.

The substrate or substrates and the substrate supports are placed in that vacuum chamber (not shown).

The cylindrical hollow body 6 lined on the inside with the material 7 to be deposited on substrate is arranged in a known manner in the axis of the cylindrical part 1 of the vacuum chamber 13. The upper part of the hollow body 6 comprises an opening 8 arranged facing the substrate. At its lower part, the hollow body 6 is connected to a pipe 9 which crosses through a removable stopper 10 by means of the O ring 11. The pipe 9 itself is connected to the gas source supplying the required gas at a predetermined pressure (for example, from a few hundredths to a few tenths of a torr).

At the height of the cylindrical hollow body, it will be observed that there is, on the outside of the cylindrical part of the vacuum chamber, an induction coil 12 connected to a high frequency voltage source (not shown). At the same height, on the inside of the cylindrical part of the chamber, a cylinder 14 made of a material which is a good conductor (copper for example) is arranged according to the present invention. A second concen-

tric cylinder **15**, arranged in the immediate vicinity of the hollow body **6** is cooled by a flow of water **16**.

FIG. 2 makes it easier to understand the electrical connection set up between the cylinders **14** and **15**. That figure shows diagrammatically at **20** the high-frequency voltage generator not shown in FIG. 1 which feeds the induction coil **12** and is placed on the outside of the cylindrical wall **1** of the vacuum chamber. In the vicinity of that wall, there is the conductive cylinder **14** split along a radial half-plane **17**, shown by discontinuous lines. In this way, that cylinder has two lips **18** and **19**. The cylinder **15** is split along the same radial half-plane **17** making two lips **21** and **22** appear; the homologous lips **18** and **21** on the one hand and **19** and **22** on the other hand are connected together by two portions of radial conductive planes **23** and **24**. In this way, if the induction coil sets up a field inducing, on the cylinder **14**, currents going in a clockwise direction, the cylinder **15** has currents in an anti-clockwise direction flowing through it.

A very great proportion of the electromagnetic energy appearing in the volume comprised inside the induction coil is concentrated inside the cylindrical hollow body.

The two cylinders **14** and **15** therefore actually fulfill the function of electromagnetic energy concentrators.

Moreover, these cylinders play a great part:

It is known that the material **7** lining the wall **6** of the hollow body is progressively volatilized and that the temperature of the wall **6** is high, so that it radiates in its turn. That radiations is absorbed, in the device according to the invention, by the cylinder **15** made of thick copper (4mm, for example). That quantity of heat is immediately dissipated by the cooling circuit **16** and therefore the cylindrical wall **1** of the chamber is not heated. It is now possible to make it with a material which is less refractory than quartz used up till now and it is possible to use glass, to great advantage, for making it.

The system for concentrating electromagnetic energy may, moreover, be completed as follows:

A cylinder **26** (FIG. 1) arranged below the cavity sets up, by induction, a field which tends to push the electromagnetic field back towards the cavity. A cylinder **27** (FIG. 1) fulfills the same functions above the hollow body.

Finally, the electromagnetic field is confined in the volume of the cylindrical hollow body by means of the combined action of the cylinders **14** and **15** and of the cylinders **26** and **27**.

The cylinders **14** and **15** constitute the secondary winding of a transformer whose induction coil **12** forms the primary winding and act as an impedance transformer adapted to the cavity.

For the dissipation of energy to be minimum, it is an advantage to make the slot of the cylinders **14** and **15** in the plane **17** as narrow as possible. In the device produced, the gap between the two lips **18** and **19** does not exceed a millimetre.

Besides the advantages already listed, that device has other qualities: It is often an advantage to impart to the cylindrical wall **7** a great diameter without modifying the volume of the hollow body. But then, the gap between the wall of the chamber and the hollow body is increased and hence the losses are increased. By means of the cylinders **14** and **15**, it is possible to keep the induced power constant and to increase the diameter of the induction coil without increasing losses. The diameter of the cylinder **14** and the length of the **2** portions of radial planes **23** and **24** will be increased without modifying the diameter of the cylinder **15** or the volume of the hollow body. The required increase of the outer diameter has therefore actually been effected without reducing the density of energy inside the hollow body.

It should be observed, moreover, that in that case, the solid angle at which the material may be deposited onto the substrate from the outlet opening **8** of the cylindrical hollow body is no longer limited by the wall of the chamber and may therefore be increased. It is then possible to coat a substrate having a greater surface and to obtain at the same time a more homogenous coating.

FIG. 3 shows diagrammatically an industrial device according to the invention. An induction coil **32** fed by a high-frequency voltage source **33** is arranged around a cylindrical chamber **31** having a large diameter. A split cylinder **34** made of a conductive metal analogous to the preceding cylinder **14** may rotate on itself within the chamber about a central axis **35**. As previously, the cylindrical hollow body **36** made of a material to be sprayed is surrounded by a split cylinder **37**. As previously, the homologous lips of the slots of two cylinders **34** and **37** are connected together by portions of plane conductors **38** and **39**. The cylinder **37** is cooled by a water pipe **40**, shown in discontinuous lines, fed from an axial column **41**.

The assembly constituted by the hollow body **36**, the inner cylinder **37**, the water pipe **40**, may rotate about the axis **35** at the same time as the cylinder **34**. In this way, the opening of the cylindrical hollow body **36** is placed successively facing the substrates **42, 43, 44**, spaced regularly in a circle and lastly facing an elongated substrate **45** before which the opening of the hollow body **36** passes slowly at a constant speed, thus providing a very homogenous coating on the whole of the substrate **45**.

The effect of concentration of the electromagnetic field is obtained as previously, as the electromagnetic field prevailing between the cylinder **37** and the cylinder **34**, is negligible.

What is claimed is:

1. Device for vapor depositing a thin layer under vacuum onto a substrate, comprising:

a chamber kept under vacuum, limited by an insulating wall, one part of which is cylindrical;

means supporting at least one substrate in an upper section of said chamber;

a cylindrical hollow body arranged axially in the cylindrical part of the chamber, lined on its inside with the substance to be deposited, connected to a source of gas arriving in the hollow body at a predetermined pressure and in alignment with said at least one substrate;

an induction coil placed on the outside of the chamber, arranged round the cylindrical part of the chamber, in the vicinity of the latter, at the height of the hollow body and connected to a high-frequency voltage source whereby to generate a plasma to evaporate said substance;

means for concentrating the electromagnetic field inside the hollow body

formed by two concentric conductive cylinders (**14** and **15**) electrically connected together, constituting the secondary winding of an impedance transformer whose

primary winding is formed by the induction coil; and means to cool said cylindrical hollow body.

2. Device according to claim 1, wherein the two concentric cylinders are split by a radial half-plane (17), the homologous lips being connected together by portions of conductive radial planes (23 and 24) so that the two concentric conductive cylinders (14 and 15) constitute a single circuit.

3. Device according to claim 2, one of the concentric conductive cylinders (14) being arranged in the immediate vicinity of the wall of the cylindrical hollow body (6) and the second conductive cylinder (15) being placed in the vicinity of the wall 1 of the vacuum chamber (13).

4. Device according to claim 3, wherein the concentric conductive cylinder (14) placed in the vicinity of the cylindrical hollow body is cooled by a water pipe (16).

5. Device according to claim 4, wherein the electromagnetic field concentration means additionally comprises a conductive cylinder (26) arranged in vicinity of the wall (1) of the chamber (13), inside the latter, below the hollow body (6).

6. Device according to claim 5, wherein the concentration means additionally comprises a conductive cylinder (27) arranged in the vicinity of the wall (1) of the chamber (13) above the hollow body (6).

7. Device according to claim 1 wherein:

means support a plurality of substrates in a spaced annular array in said upper section of, and about the axis of, said chamber, a cylinder generated through said annular array passing through said hollow body; and

further means rotatably support said hollow body and concentrating means whereby said hollow body is orbited in a path in sequential alignment with said plurality of substrates to effect said depositing on each substrate.

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