219-121. SR
11-25-75 XR 3,922,214

United States Patent [19]

Van Cakenberghe

[11] **3,922,214**

[45] **Nov. 25, 1975**

[54] **DEVICE FOR MANUFACTURING THIN LAYERS OF MINERAL SUBSTANCES**

[75] Inventor: **Jean L. Van Cakenberghe**, Beersel, Belgium

[73] Assignee: **Compagnie Industrielle des Telecommunications Cit-Alcatel**, Paris, France

[22] Filed: **Mar. 27, 1974**

[21] Appl. No.: **455,097**

[30] **Foreign Application Priority Data**

Mar. 27, 1973 Belgium 129306

[52] **U.S. Cl.** ..... **204/298;** 204/192; 219/76; 219/121 P; 427/34

[51] **Int. Cl.²** **C23C 15/00**

[58] **Field of Search** 204/192, 298

[56] **References Cited**

UNITED STATES PATENTS

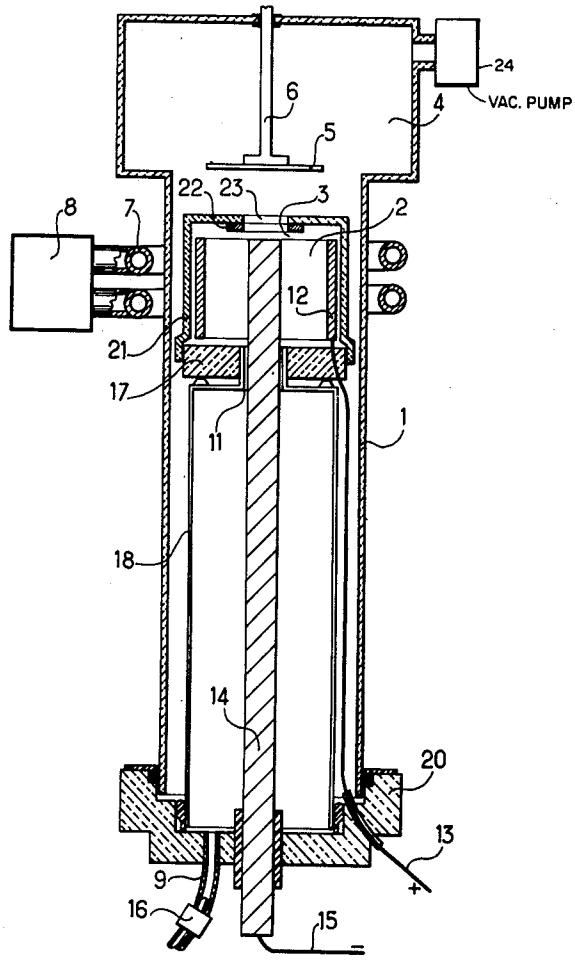
3,408,283	10/1968	Chopra et al.	204/298
3,625,848	12/1971	Snaper	204/192
3,801,355	4/1974	Van Cakenberghe	204/164

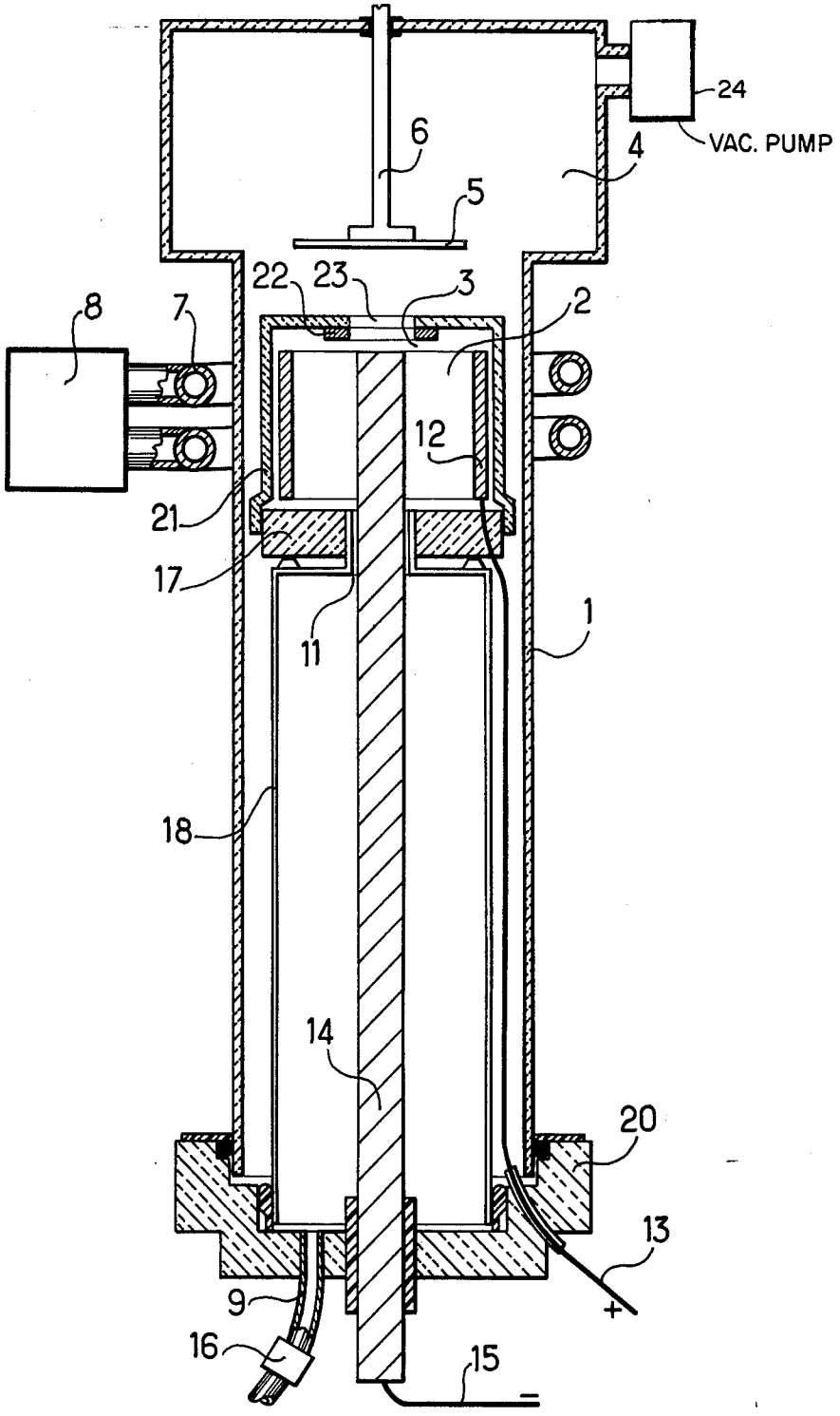
Primary Examiner—Oscar R. Vertiz
Assistant Examiner—Wayne A. Langel
Attorney, Agent, or Firm—Sughrue, Rothwell, Mion, Zinn & Macpeak

[57] **ABSTRACT**

Improvement to devices enabling thin layers of conductive substances to be deposited on a substrate arranged in a container maintained under a very low pressure. A cavity, contained in the vacuum container, and bearing the substance to be deposited, is maintained at a sufficiently high pressure for an arc operation discharge to be primed therein. Electromagnetic energising means sets up a plasma in this cavity. An opening formed in the cavity is arranged facing the substrate.

8 Claims, 1 Drawing Figure




24
VAC. PUMP
6
4
5
22
23
3
2
8
7
12
21
17
11
1
18
14
20
13
+
9
16
15
=

DEVICE FOR MANUFACTURING THIN LAYERS OF MINERAL SUBSTANCES

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The present invention concerns an improvement to devices enabling thin layers of mineral substances to be deposited on the surface of a substrate arranged in a vacuum container.

2. Description Of The Prior Art

More particularly, a device consisting of a container maintained under vacuum, in which an enclosure formed with an opening is inserted, is known; the substrate is arranged in the vacuum container opposite the opening of the enclosure. That enclosure which will subsequently be referred to as the the "cavity," is supplied with gas injected at a predetermined pressure. The cavity is lined on the inside with the substance to be deposited. A high freqency exitation means generates an electromagnetic field inside the said cavity.

It is therefore apparent that in such a device, the internal walls of the said cavity play a multiple part: on the one hand, they define the volume in which the plasma is formed; on the other hand, they form a thermal shield enabling the exchange of energy which takes place between the plasma and the wall of the cavity to be improved; lastly, these walls may act as a source of substance to be deposited on the substrate. It is a particular advantage to line the internal surface of the cavity with the substance to be deposited on the substrate. Indeed, not only is a source of substance to be deposited easy to implement, thus made available, but also, ideal protection of that substance against any contamination is provided.

The device thus produced was able to be used to great advantage for the depositing of thin layers of piezoelectric substances, semi-conductors substances having a high dielectric constant and refractory substances having a very high melting point. It enabled the producing of very good quality layers with a depositing speed which was not possible with means known up till then.

The present application concerns an improvement to the device described above enabling the producing, in very favourable conditions, of the deposit of layers and more particularly the deposit of layers of metals or conductive substances.

It concerns a device in which the cavity bearing or containing the substance to be deposited is maintained at a relatively high pressure, so that the discharge operation which is established and maintained therein be an arc operation whereas the remainder of the container in which the substrate support is placed is maintained, on the contrary, at a pressure which is considerably lower as a large free path is required to be obtained for the particles leaving the opening of the cavity, so that an arc operation could neither be set up not maintained therein.

The device therefore comprises two chambers maintained at clearly different pressures: the vacuum container in which it is desirable to obtain a sufficiently low pressure for the free path of the particles leaving the opening of the cavity to be sufficient for these particles to reach the surface of the substrate without interference shocks and the chamber designated above by the name of cavity, in which the plasma is set up under the action of an electromagnetic field and in which the

pressure must be sufficiently high for the arc operation to be able to be established and maintained therein. The cavity is situated inside the vacuum container and communicates with the latter through an opening. Such an arrangement may perfectly be produced by conferring, on the one hand, on the pumps of the vacuum container a sufficient discharge for maintaining the required vacuum in the container and, on the other hand, by fitting a diaphragm to the opening of the cavity and by regulating the discharge of the gas injected at a sufficient value.

SUMMARY OF THE INVENTION

The object of the invention is therefore a device enabling the depositing, in a container maintained under vacuum, of the thin layers at the surface of at least one substrate arranged facing an opening formed in a cavity contained in the vacuum container, a gas being injected at a predetermined pressure in the said cavity in which an electromagnetic energising means sets up a plasma, characterized in that the said cavity is maintained at a sufficiently high pressure for an arc operation discharge to be primed and maintained therein and in that the enclosure containing the substrate is maintained at a pressure sufficiently low for an arc operation not to be able to be primed therein.

The maintaining of the cavity at a pressure sufficiently high for an arc operation to be able to be set up therein is an advantage in all cases, whatever the substance to be sprayed may be. Nevertheless, it becomes more particularly easy to set up when the layers to be deposited on the substrates are constituted by metals or, more generally, by a conductive material. It is then possible to insert, in fact, without any disadvantage, within the cavity, an electrode bearing at least at its surface the substance to be deposited.

The object of the invention is, then, an improved device enabling the depositing in a container maintained under vacuum of thin layers at the surface of a substrate arranged facing an opening formed in a cavity contained in the vacuum container, a gas being injected at a predetermined pressure in the said cavity, in which a means of electromagnetic energising sets up a plasma, characterized in that the substance to be deposited is inserted in the said cavity at least at the surface of an electrode which may be brought to a negative potential in relation to the internal wall of the said cavity.

In the case where the cavity is formed with a single opening, it is an advantage to confer on the cavity a shape comprising an axis of symmetry to form a circular opening in the cavity along the axis of symmetry and to arrange the electrode emitting the substance to be deposited on the substrate in the axis of symmetry of the cavity facing the opening.

To great advantage, the lateral wall of the cavity is lined on the inside with the substance to be deposited. To avoid the forming of induced currents, the lateral wall of the cavity is cut up and interrupted along a generating line parallel to the axis of symmetry of the cavity. According to the conductivity of the substance to be projected which lines the said cavity internally, it is necessary to cut the lateral wall of the cavity along a single generating line or along a certain number of generating lines.

BRIEF DESCRIPTION OF THE DRAWINGS

The single FIGURE herewith makes it possible to describe an example having no limiting character of an

embodiment of the device which is the object of the present invention. That single FIGURE is a diagrammatic cutaway view through a vertical plane of the example of embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Within the vacuum container formed by a tube **1** constituted by an insulating substance, silica or a ceramic substance, for example, a cylindrical cavity **2** communicating with a vacuum container **4** by means of an opening **3** formed in one of its transversal faces, is arranged. The internal lateral wall **12** of the cavity **2** is connected to the positive pole **13** of a direct current voltage source (not shown), which may vary by a few tens to a few hundreds of volts. An elongated electrode **14** is arranged coaxially with the opening **3**, along the axis of the cylindrical cavity. That electrode is connected to the negative pole **15** of the voltage source. That electrode **14** is constituted by the metal or conductive substance to be projected onto the substrate **5**. The latter is maintained facing the opening **3** by a suitable substrate support **6**. To avoid contamination, it is an advantage, in certain cases, to form the wall of the cavity with the same substance as the electrode **14**. Means (not shown) are contingently provided for making the electrode **14** advance axially as the latter consumes itself.

An induction coil **7** connected to a high-frequency voltage source **8**, whose frequency may be of 6 Mc/s, for example, is arranged at the level of the cavity **2**.

A gas which enters through the nozzles **11** through the duct **9** is inserted in the cavity **2** and creates a predetermined pressure, in the order of 5×10^{-2} Torr, to 1 Torr, for example, prevail therein. That gas may be an inert gas, argon for example, or a reactive gas if the refractory metal is required to form a compound such as a carbide or a nitride, for example. The discharge of that gas is regulated by a means **16** known per se. A relatively low pressure, less than 10^{-3} Torr, is maintained in the vacuum container by means of pumps, such as vacuum pump **24** having a high discharge. The nozzles **11**, the foot **17** of the cylindrical cavity **2**, are supported by a piedestal **18** resting on the base **20** of the tubular container **1**. When the substance to be desosited is conductive, it is an advantage to replace the cylindrical cavity forming the wall **12** by an interrupted ring. That wall is also been broken up in the case where the substance to be deposited is highly conductive. In a certain number of cases, more particularly when the temperature of the plasma is very high, it is an advantage to surround the cavity **2** with a thermal screen **21** bearing against the foot **17** of the cylindrical cavity **2**. It also seemed an advantage, for limiting the rise in the temperature, to surround thermal screen **21** with a cooling jacket (not shown). When a thermal screen **21** is used, it is an advantage to protect the opening of that screen with a ring **22** constituted by the substance to be deposited with a view to avoiding any contamination of the substrate by an erosion, by the plasma, of the opening **23** formed in the thermal screen. When the induction coil **7** has a high-frequency current flowing through it, the electromagnetic field which it induces inside the cavity sets up therein, a plasma in arc operation. That plasma is sufficiently electrically conductive for a voltage of a few tens of volts applied between the electrodes **12** and **14** to set up strong current, in the order of a few amperes, or, even, a few tens of amperes.

In these conditions, the negative electrode undergoes an ionic bombardment which is very great and causes its erosion and its distillation in the cavity. Considerably high-speed depositing results therefrom.

The distilled substance is projected through the openings **3** and **23** and is deposited on the substrate **5**. In the vacuum container **4**, there prevails a pressure in the order of 10^{-3} to 10^{-5} Torr for the gas pressure in the cavity indicated above.

When the lateral wall of the cavity consists entirely of that substance to be sprayed, it may be an advantage to surround that wall defining the said cavity with a second and even a third casing having a slightly greater diameter in order to enable a more prolonged operation of the device. This set of lateral walls which fit into one another is surrounded by a heat-insulating screen. The various openings formed in the successive casings are generally placed in a staggered configuration so that the central electrode does not see the insulating screen. Nevertheless, in certain cases where the substance to be deposited is a very good conductor of electricity, the number of fragmentations of the lateral walls may be high and it becomes difficult to fulfill the above condition.

The central electrode and the thermal screen are cooled by a fluid flow in the installations where the device according to the invention operates during a very long period without interruption or to extend the method to non-refractory substances.

An improvement in the quality of the deposit has been found by super-imposing an alternating current voltage on the voltages applied to the two electrodes or by applying an alternating current voltage directly to the electrodes so that the central electrode and the internal wall of the cavity are sprayed alternately.

What is claimed is:

1. In a device for plasma deposition of a thin conductive layer onto the surface of a substrate, said device comprising a container, means forming a cavity within said container, and having a cavity opening therein, electromagnetic energizing means for setting up a plasma within said cavity for passage through said cavity opening, means for supporting said substrate within said container facing said cavity opening and spaced therefrom, means for supplying a fluid under pressure to said cavity, vacuum pump means connected to said container for maintaining a vacuum pressure within said container, the improvement comprising within said cavity, inner and outer concentrically spaced cylindrical electrodes and at least the surface of the inner cylindrical electrode carrying the conductive substance to be deposited on the surface of the substrate by plasma deposition, and means for providing a potential difference across said electrodes to effect arcing therebetween.

2. The device according to claim **1**, wherein the outer electrode is interrupted along a straight line parallel to the axis of said outer electrode.

3. The device according to claim **2**, wherein the outer electrode is entirely formed of the substance to be deposited on the substrate.

4. The device according to claim **3**, wherein both electrodes are constituted by the substance to be deposited, and wherein the outer electrode is surrounded by at least one casing adjacent thereto and formed of the same substance.

5. The device according to claim **1**, wherein at least the outer electrode surface facing said inner electrode

is formed of the same conductive substance to be plasma deposited as the surface of the inner electrode.

6. The device according to claim **1**, wherein said cavity within which the plasma set up is formed with an axis of symmetry, the cavity opening of said cavity being circular and being provided on the axis of symmetry along with said inner electrode.

7. The device according to claim **1**, wherein said inner electrode is formed entirely of said conductive substance to be deposited.

8. The device according to claim **1**, wherein the lateral walls of the cavity are surrounded by a casing.

* * * * *