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[54] APPARATUS FOR
VACUUM-EVAPORATION OF METALS
UNDER THE ACTION OF AN ELECTRIC
ARC

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[58] Field of Search 219/123, 121 EM,
219/121 EB

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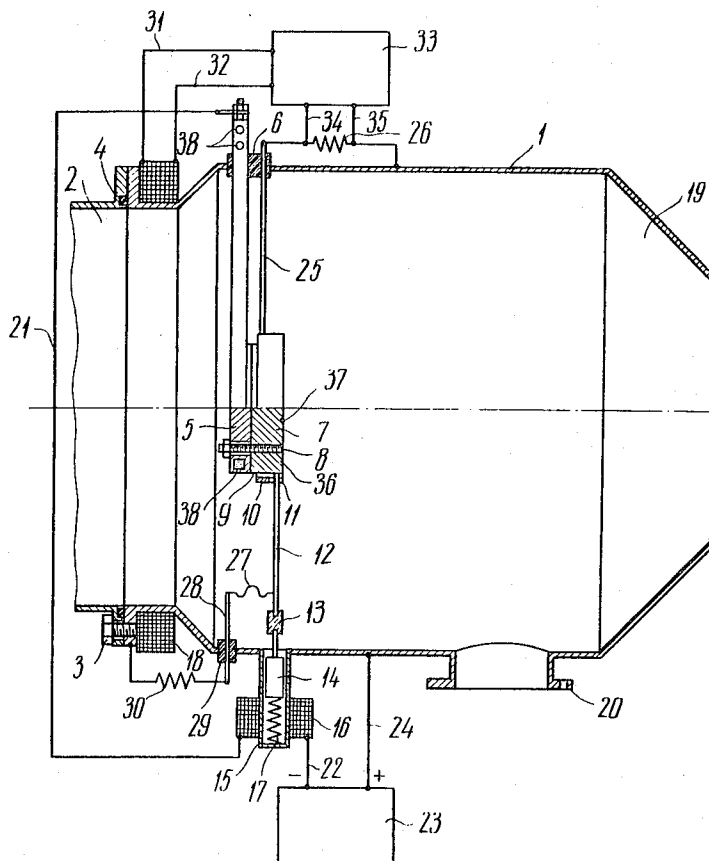
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ABSTRACT

A method for vacuum-evaporation of metals under the action of an electric arc and using a magnetic field is characterized by the fact that for retaining a cathode spot of an electric arc, a constant magnetic field is substituted by a pulsed magnetic field whose intensity reaches a maximum when the cathode spot is shifted to a non-evaporable cathode surface. This enables the travel of the cathode spot of electric arc to be unaffected by the inhomogeneity of the magnetic field and by any possible lack of perpendicularity of its lines of force to the surface being evaporated. A device for carrying out the method employs a sensor to take up the effect of electric arc, which is so arranged as to straddle the non-evaporable cathode surface and takes up the effect of electric arc only when the cathode spot is found on the non-evaporable cathode surface; the device is simple in design, smaller in size, and features a simplified-construction of an electromagnet that needs less power to be operated as compared to the prior-art devices used for vacuum-evaporation of metals under the effect of an electric arc.

2 Claims, 4 Drawing Figures



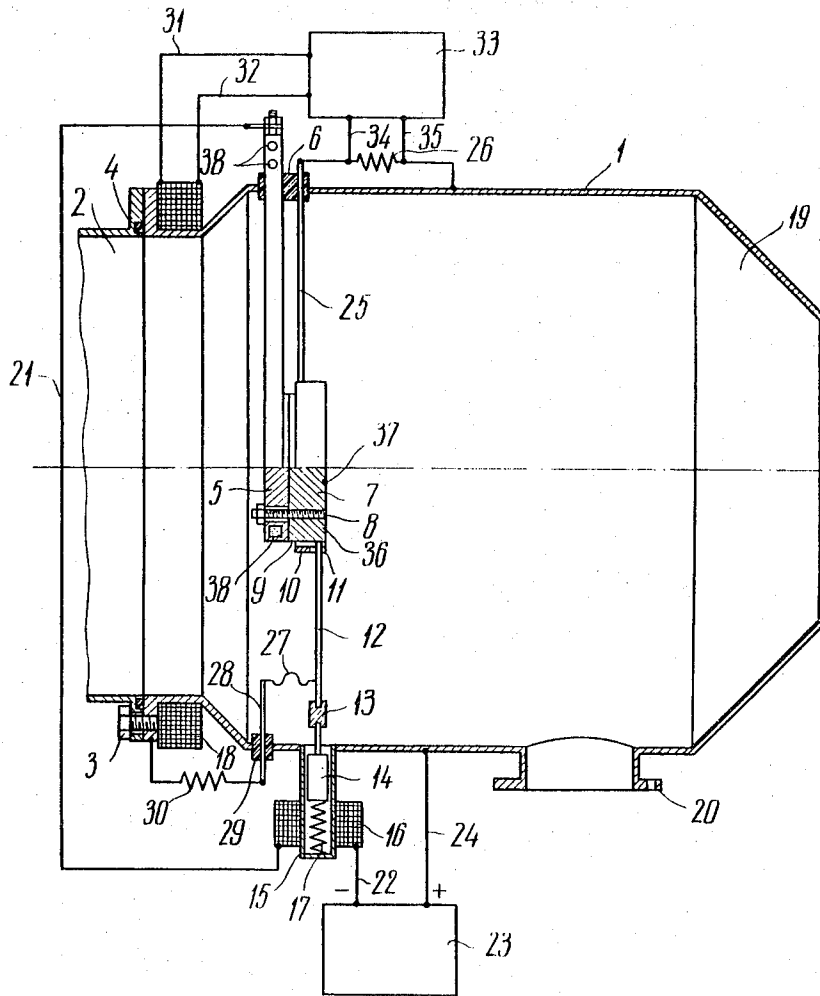
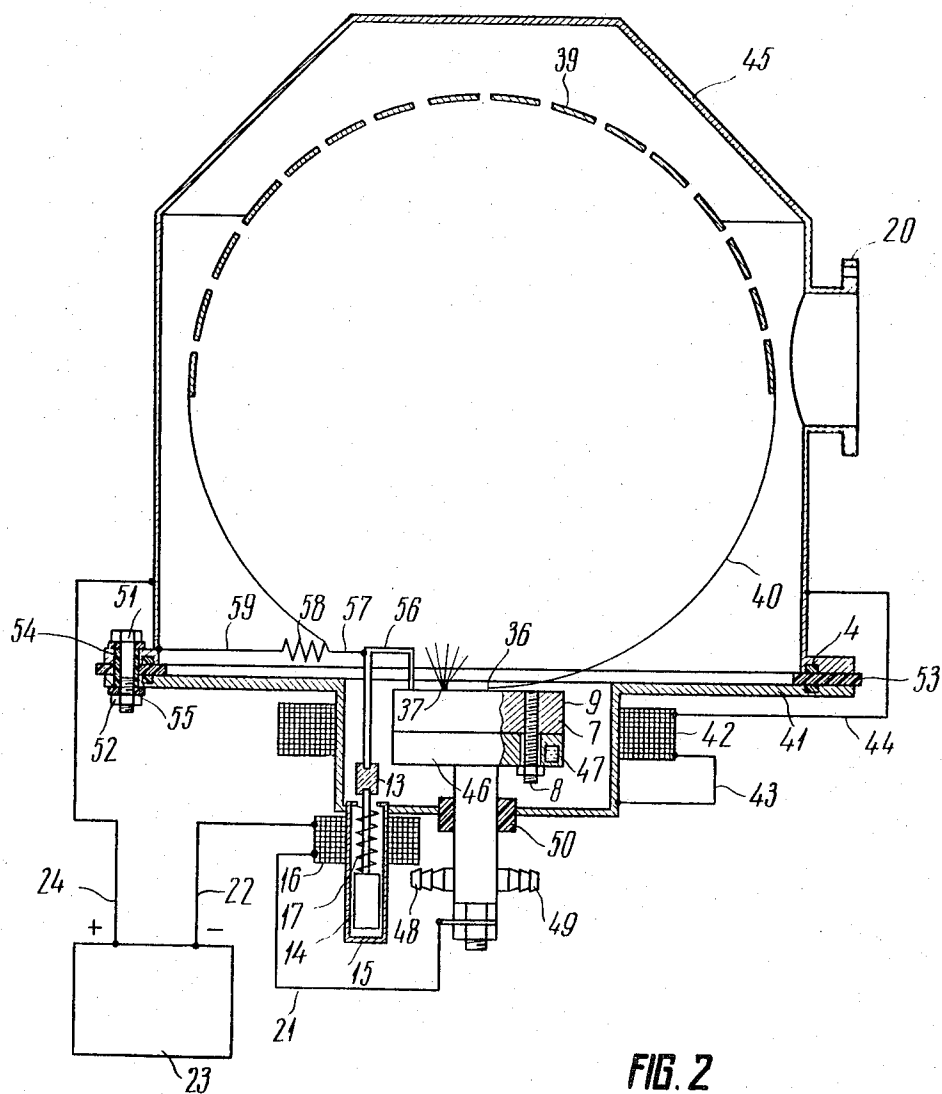


FIG. 1



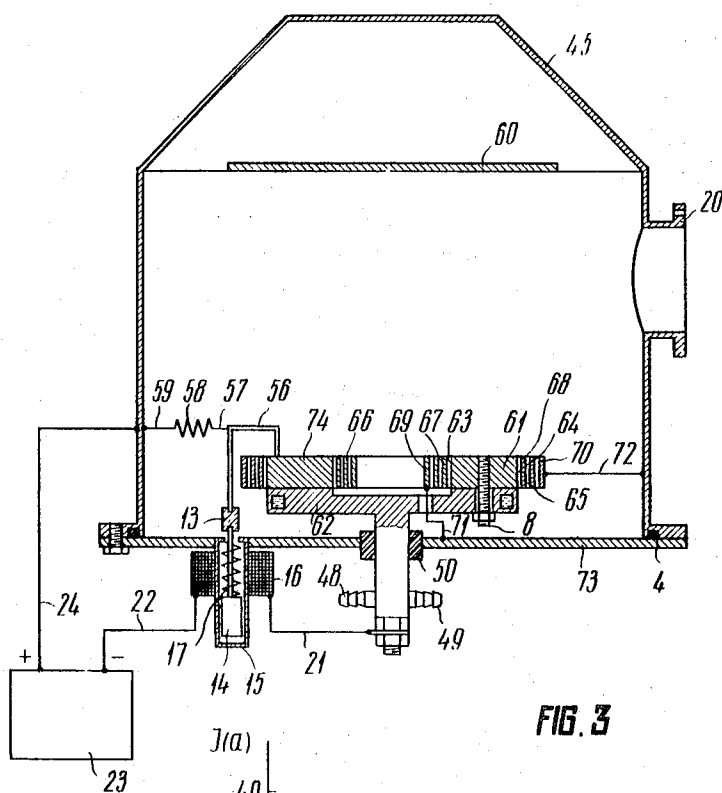


FIG. 3

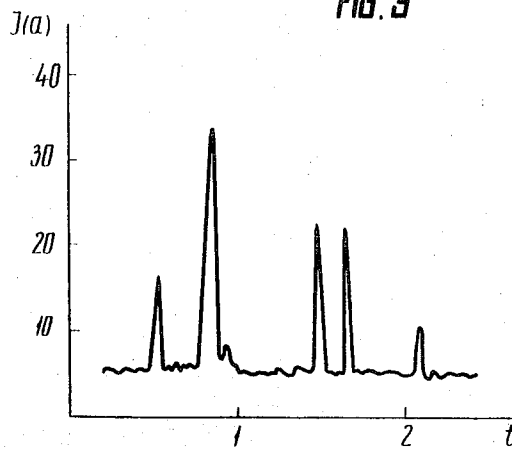


FIG. 4

APPARATUS FOR VACUUM-EVAPORATION OF METALS UNDER THE ACTION OF AN ELECTRIC ARC

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods of and devices for vacuum-evaporation of metals, and has particular reference to methods of vacuum-evaporation of metals by means of an electric arc and to devices for carrying said methods into effect.

Vacuum-evaporation of metals, in particular, under the effect of an electric arc, is used for applying metallic coatings or films to metal and dielectrics, as well as in sorption pumps.

2. Description of Prior Art

Widely known in the art is a method of arc-evaporation of metals under vacuum, wherein an electric arc is struck across a cathode made of the metal to be evaporated and an anode to evaporate the cathode metal. To provide metal evaporation from the required cathode surface (hereinafter referred to as "evaporable" cathode surface), a cathode spot of the electric arc is retained on said surface with the help of a time-constant magnetic field whose lines of force are perpendicular to the evaporable cathode surface and make up an acute angle with that cathode surface whose evaporation is undesirable (this surface will hereinafter be referred to as "non-evaporable" cathode surface).

A tendency of the cathode spot to move in a magnetic field from an obtuse angle towards an acute angle made up by the cathode surface and the direction of the lines of magnetic force is used to return the cathode spot onto the evaporable cathode surface in case of its spontaneous shifting onto the non-evaporable cathode surface.

The afore-discussed method is employed in widely used devices which includes a vacuum chamber accommodating a cone- or spherical-shaped cathode and an anode, both being made of the metal being evaporated and connected to a D.C. voltage source; permanent magnets located outside the vacuum chamber establish a constant homogeneous magnetic field at the cathode surface so as to retain the cathode spot on the evaporable cathode surface. An acute angle made up by the lines of magnetic force and the non-evaporable cathode surface is provided due to the abovesaid shape of the cathode.

Upon creating a required degree of rarefaction within the vacuum chamber, an electric arc is struck across the cathode and the anode by momentarily contacting the cathode by a movable electrode. The arc burns in the vapours of the metal being evaporated while randomly moving over the cathode surface.

When the cathode spot of the electric arc, while randomly wandering over the cathode surface, gets onto its non-evaporable area, the magnetic field causes the cathode spot to return onto the evaporable cathode surface.

A disadvantage inherent in said method of arc-evaporation of metals under vacuum resides in the presence of a magnetic field while the cathode spot of the electric arc is found on the evaporable cathode surface.

In this case, strict and rigorous requirements are to be met by the homogeneity of the magnetic field at the evaporable cathode surface and by the perpendicularity

of the lines of magnetic force to said surface, since if the field is inhomogeneous the cathode spot is shifted towards its higher-intensity area, and when the lines of magnetic force are out-of-perpendicularity with the evaporable cathode surface, the cathode spot travels from an obtuse angle towards an acute angle with the result that the metal of the cathode evaporates unevenly and thus loses its true shape which disturbs the stability of arcing and leads to incomplete utilization of the material of the cathode.

Disadvantages inherent in the known prior-art device stem for the aforesaid phenomena in the method of arc-evaporation of metals and reside in sophisticated construction and large size of the magnets used to establish a homogeneous magnetic field so that in high-capacity plants the size and power consumption of the magnet exceeds reasonable limits; consequently, such prior art plants have not found wide commercial application.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for vacuum-evaporation of metals under the effect of an electric arc, which method makes it possible to dispense with the use of a constant magnetic field to retain the cathode spot on the evaporable cathode surface and to eliminate the effect of the magnetic field inhomogeneity on the travel of the cathode spot over the evaporable cathode surface.

The herein proposed method for vacuum-evaporation of metals under the effect of an electric arc enables a uniform cathode evaporation with its shape remaining unaffected.

It is another object of the present invention to provide a device that would be simpler in design and be capable of carrying into effect the method for vacuum-evaporation of metals under the effect of an electric arc, as well as would employ a smaller-sized electromagnet that needs less power to be operated.

Said objects are attained due to the fact that in a method for vacuum-evaporation of metals under the effect of an electric arc, wherein the metal per se to be evaporated serves as a cathode, and a cathode spot is retained on preset evaporable cathode surface by means of a magnetic field whose lines of force form an acute angle with the non-evaporable cathode surface, according to the invention a pulsed magnetic field is established whose intensity reaches a maximum when the cathode spot is found on the non-evaporable cathode surface.

It is most expedient that the magnetic field be established only when the cathode spot drifts and gets onto the non-evaporable cathode surface.

In conformity with the method of the invention, in a device for carrying into effect the method of evaporating metals as set forth hereinabove, which is essentially a vacuum chamber accommodating a cathode made of the metal to be evaporated and an anode between which an electric arc is struck to evaporate metal from the evaporable cathode surface, and the cathode spot is retained on the evaporable cathode surface, by means of an electromagnet that establishes a magnetic field whose lines of force make up an acute angle with the non-evaporable cathode surface, according to the invention provision is made for a sensor to sense and take up the effect of the electric arc, said sensor being so arranged with respect to the cathode as to take up the effect of the electric arc only when the cathode spot

drifts to and is found on the non-evaporable cathode surface.

This enables the size and power consumption rate of the electromagnet that establishes the magnetic field, to be substantially reduced and its construction to be simplified.

Specifically, the sensor adapted to sense and take up the effect of the electric arc when the cathode spot is found on the non-evaporable cathode surface, comprises an electrode which is under the anode potential and straddles the non-evaporable cathode surface.

It is expedient to make use of a turn of the electromagnet coil establishing the magnetic field, as an electrode.

As a result of the herein-disclosed invention, there are provided a method for an arc-evaporation of metals and a device for carrying said method into effect, wherein the construction of electromagnet is substantially simplified, at the same time ensuring a uniform cathode evaporation, the stability of the electric arc remaining unaffected. Such a simplified construction of the electromagnet is attained due to the fact that the herein proposed method does not require homogeneity of the magnetic field effective on the evaporable cathode surface. In as much as the maximum magnetic field intensity that is enough to return the cathode spot onto the evaporable cathode surface is established only at the instant the cathode spot drifts and gets onto the non-evaporable cathode surface, the size of the electromagnet and amount of power consumed for creating the magnetic field are reduced by many times.

The herein-disclosed invention enables also the shape of the cathode to be simplified which makes possible, with the commensurable size of the device, an increase the stock of the evaporable cathode metal. The invention also makes possible the use of a cathode with large-area evaporable surface and provides vacuum-evaporation devices of practically unlimited production capacity.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will hereinafter be best understood by making reference to the accompanying drawings, wherein:

FIG. 1 illustrates a device for vacuum-evaporation of metals, made according to the present invention with particular reference to devices for sorption evacuation of active gases;

FIG. 2 illustrates a device for vacuum-evaporation of metal, made according to the present invention with particular reference to devices for obtaining fine films on metal and dielectric work-pieces;

FIG. 3 illustrates a modified device for evaporation of metals with particular reference to obtaining uniform metallic films on flat-shaped work-pieces; and

FIG. 4 shows an oscillogram of the current of an electromagnet that establishes a pulsed magnetic field in the device of FIG. 2.

DESCRIPTION OF PREFERRED INVENTIVE EMBODIMENTS

A device for sorption evacuation of active gases as shown in FIG. 1, is designed as follows. A pump housing 1 made of a non-magnetic material is connected to the flange of a space 2 to be evacuated by bolts 3 and is packed with a rubber seal 4. The housing 1 itself serves as a anode accommodates a cathode 7 made of

the metal being to be evaporated; the cathode is placed on a water-cooled copper bed 5 which is insulated from the housing 1 by means of an insulator 6. The cathode 7 which is expediently shaped as a disk is tightly forced against the cooled bed 5 with studs 8. A cylindrical non-evaporable surface 9 of the cathode 7 is embraced with an electrode 10 which is in fact a sensor adapted to sense and pick up the effect of an electric arc when the cathode spot is found on the non-evaporable surface 9 of the cathode 7; the electrode 10 is fixed to the cooled bed 5 through insulators (not shown) and has a recess 11 for a movable electrode 12 to strike an electric arc. The movable electrode 12 is held through an insulator 13 to an armature 14 located inside a tube 15 which is made of a non-magnetic material. A coil 16 of the electromagnet is adapted to break the gap "cathode - movable electrode" by compressing a spring 17. Located outside the housing 1 is an electromagnet 18 capable of establishing a magnetic field whose lines of force pass at an acute angle to the non-evaporable surface 9 of the cathode 7. For pre-evacuation of the space 2 being vacuumized and of a chamber 19 of a pump, as well as for evacuating inert gases that are not sorbable provision is made for a fore-pumping system, incorporating a mechanical pump and a high-vacuum evacuation system which comprises a vapour-oil diffusion pump (not shown) connected to a flange 20. The cathode 7 made of an evaporable metal, viz. titanium, is connected through a wire conductor 21 to one of the ends of the coil of the electromagnet 16, while the other end of the electromagnet 16 is connected via a wire conductor 22 to the negative pole of a power source 23. The positive pole of the power source 23 is connected to the pump housing 1 via a wire conductor 24. The electrode 10 is electrically connected to the housing 1 via a wire conductor 25 passing through the vacuum-tight insulator 6 and a resistor 26. The movable electrode 12 is connected to the pump housing 1 through a resistor 30 and by means of a flexible conductor 27 and a wire conductor 28 passing through a vacuum-tight insulator 29. The coil of the electromagnet 18 is connected via wire conductors 31 and 32 to the output of an amplifier 33 at whose input is delivered a signal taken from the resistor 26 via wire conductors 34 and 35.

The high-vacuum electric-arc sorption pump illustrated in FIG. 1, operates as follows. Upon pumping out gas from the space 2 being evacuated and from the chamber 19 by means of the fore-pumping system till a pressure of $1 \cdot 10^{-1}$ to $5 \cdot 10^{-2}$ mm Hg is reached, the movable electrode 12 is used to strike an electric arc on the non-evaporable surface 9 of the cathode 7 at a cathode spot. The arc burns across the surface 9 of the cathode 7 and the electrode 10 which are connected via the resistor 26 to the housing 1, i.e., the anode. A voltage drop effective across the resistor 26 is impressed upon the input of the amplifier 33 to whose output is connected the electromagnet 18. As a result, a current flows along the coil of the electromagnet 18 to establish a magnetic field which expels the cathode spot of the electric arc onto an evaporable surface 36 of the cathode 7. As soon as the cathode spot travels from the surface 9 to the surface 36, current ceases flowing along the resistor 26 and the magnetic field created by the electromagnet 18, disappears. While randomly travelling over the evaporable surface 36 of the cathode 7 made of titanium, the cathode spot 37 causes

metal to evaporate, whereupon the evaporated metal is deposited upon the inner walls of the housing 1 (anode). Thus, titanium deposited upon the walls of the housing 1 effects evacuation of active gases. In the course of metal evaporation process the cathode 7 grows hot; to cool down the cathode 7 a coolant is made to flow liquid along a passageway 38 made in the cooling bed 5. Upon reaching a pressure of 1.10^{-3} to 1.10^{-4} mm Hg inside the space being evacuated, the fore-pumping system is disconnected and the high-vacuum evacuation system is engaged to evacuate an active gas (viz., argon) remaining in the space 2 to be evacuated.

While performing randomwise motion over the evaporable surface 36 of the cathode 7, the cathode spot 37 of the electric arc periodically drifts and gets onto the non-evaporable surface 9, thus closing the circuit comprising the surface 9, the electrode 10, the wire conductor 25, the resistor 26 and the housing 1 thereby energizing the electromagnet 18 via the amplifier 33; as a result, the electromagnet 18 establishes a magnetic field that expels the cathode spot onto the evaporable surface 36.

Thus, the magnetic field is established only when the cathode spot is found on the non-evaporable surface 9 of the cathode 7.

FIG. 2 illustrates a device for a vacuum-deposition of fine films. Therein, the cathode 7 made of the metal being evaporated, is disk-shaped, while the work pieces 39 on which metal is to be deposited are located oppositely to the cathode on the surface of an imaginary sphere 40 tangential to the evaporable surface 36 of the cathode 7. A cover 41 is made of a non-magnetic material, whereas an electromagnet 42 establishing a magnetic field, is mounted on the cover 41 and is electrically connected through a wire conductor 43 to the cover 41 and through a wire conductor 44, thence to a housing 45 which serves as an anode. In this device the cover 41 serves as a sensor to pick up the effect of electric arc when the cathode spot is found on the non-evaporable surface 9 of the cathode 7.

The cathode 7 is fixed to a cooled bed 46 by the studs 8. The cooled bed has a passageway 47 for the coolant liquid to pass; the latter is let in and out through pipe connectors 48 and 49. The cooled bed 46 is vacuum-tightly attached to the cover 41 made of a non-magnetic material, by means of an insulator 50. The cover 41 is fixed on a housing 45 by bolts 51 and nuts 52 and is insulated therefrom with an insulating gasket 53, the rubber seals 4, an insulating bush 54 and insulating washers fitted onto the bolt 51.

A movable electrode 56 is fixed on the armature 14 through the insulator 13.

Gas-evacuation procedure occurs through the use of the systems of fore-pumping and high-vacuum evacuation (not shown in FIG. 2).

The device operates as follows. Upon reaching the degree of operating vacuum inside the space of the housing 45, lower than 1.10^{-1} mm Hg, preferably 10^{-5} to 10^{-7} mm Hg, the power source 23 is switched on to energize an electric arc. As a result, current starts flowing along the circuit comprising the wire conductor 22, the magnet coil 16, the wire conductor 21, the cooling bed 46, the cathode 7, the movable electrode 56, the wire conductor 57, the resistor 58, the wire conductor 59, the housing 45 (anode), and the wire conductor 24, thereby inducing current in the magnet coil 16 with the

result that the armature 14 gets pulled thereinto. An electric arc is thus struck across the evaporable surface 36 of the cathode 7 and the movable electrode 56.

As soon as the cathode spot 37 is shifted to the non-evaporable surface 9 of the cathode 7, current starts flowing in the circuit comprising the cathode 7, the cover 41, the wire conductor 43, the electromagnet 42, the wire conductor 44, the housing 45, the wire conductor 24, the power source 23, the wire conductor 22, the magnet coil 16, the wire conductor 21, the cooled bed 46, and the cathode 7. Magnetic field created by the electromagnet 42, expels the cathode spot 37 onto the evaporable surface 36 of the cathode 7, and current flowing along the electromagnet circuit is considerably diminished. An oscillogram of the current flowing along the electromagnet is represented in FIG. 4.

The oscillogram of the current of the electromagnet 42 is taken with the diameter of the titanium cathode 7 equal to 50 mm and a mean arc-discharge current of 55 A.

A modification of the device for evaporation of metals, as depicted in FIG. 3, serves for making uniform coatings or films on flat-shaped work pieces 60. To this end, a cathode 61 of the metal being evaporated is shaped as a flat ring and is disposed on a cooled bed 62. Non-evaporable surfaces 63 and 64 of the cathode 61 are embraced by electromagnets 65 and 66.

Turns 67 and 68 of the coils of the electromagnets 65 and 66 have a clearance with the non-evaporable surfaces 63 and 64 of the cathode 61, whereas turns 69 and 70 are connected through wire conductors 71 and 72 to the housing 45 and a cover 73. The entire cathode unit is mounted on the cover 73 of the housing 45. In the course of operation of the device the cathode spot of electric arc, while randomly travelling over an evaporable surface 74 of the cathode 61, periodically gets into the gap between the non-evaporable surface 63 or 64 and the turns 67 or 68, with the result that arc-discharge current starts flowing along the electromagnet 65 or 66, creating a magnetic field whose lines of force make up an acute angle with the non-evaporable surface 63 and 64, and the cathode spot of electric arc returns onto the evaporable surface 74 of the cathode 61.

The rest of the operating features of this modification are similar to those described above.

What we claim is:

1. A device for vacuum-evaporation of metals under the effect of an electric arc, comprising a cathode having an evaporable and a non-evaporable surface, said cathode being made of a solid metal to be evaporated by the cathode spot of said electric arc randomly moving over the evaporable surface of said cathode; an anode; means for generating said electric arc between said cathode and said anode; an electromagnet disposed so that at least one turn of said electromagnet facing the non-evaporable surface of said cathode forms a gap with said non-evaporable surface at the side of said evaporable surface of said cathode, the size of said gap being such that when said cathode spot shifts on to said non-evaporable surface said electric arc strikes at least partially between said non-evaporable surface and said turn of said electromagnet, said electromagnet being connected to said anode so that electric current flows in the turn of said electromagnet when said electric arc strikes between said non-evaporable surface and said turn, a magnetic field

being induced as a result of the flow of said electric current, said magnetic field having lines of force which form an acute angle with said non-evaporable surface and force said cathode spot to return to said evaporable surface of said cathode.

2. A device for vacuum-evaporation of metals under the effect of an electric arc, comprising a cathode having an evaporable and a non-evaporable surface, said cathode being made of a solid metal to be evaporated by the cathode spot of said electric arc randomly moving over the evaporable surface of said cathode; an anode; means for generating said electric arc between said cathode and said anode; an electrode arranged so

that when said cathode spot shifts onto the non-evaporable surface said electric arc strikes at least partially between said non-evaporable surface and said electrode; an electromagnet connected to said electrode and said anode so that at least a part of the current of said electric arc striking between said non-evaporable surface and said electrode flows in said electromagnet which is disposed so that when said current flows therein it induces a magnetic field which forces said cathode spot to return to said evaporable surface of said cathode.

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