

Dec. 28, 1937.

H. KOTT

2,103,623

ELECTRON DISCHARGE DEVICE FOR ELECTRONICALLY BOMBARDING MATERIALS

Filed Sept. 20, 1935

2 Sheets-Sheet 1

Fig. 1.

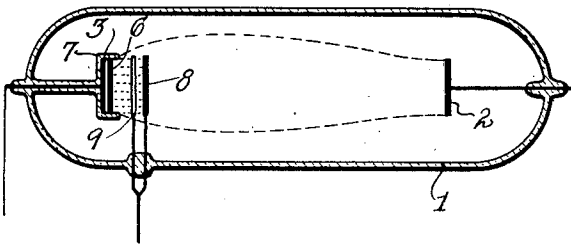


Fig. 2.

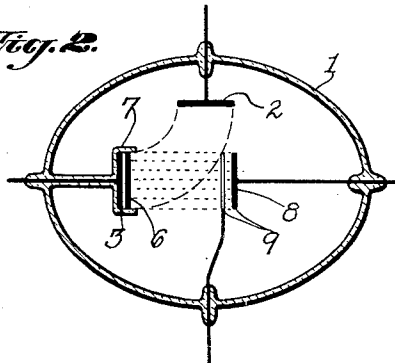


Fig. 3.

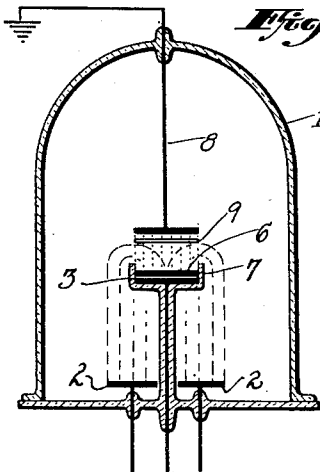


Fig. 4.

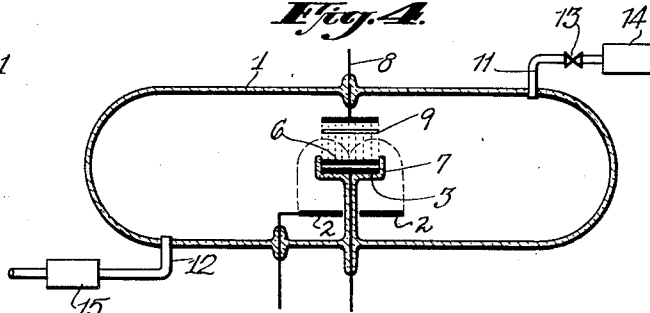


Fig. 5.

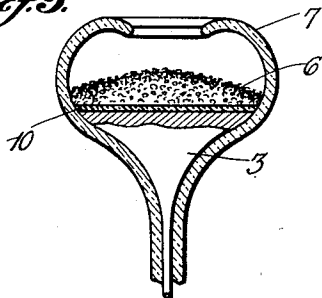


Fig. 6.

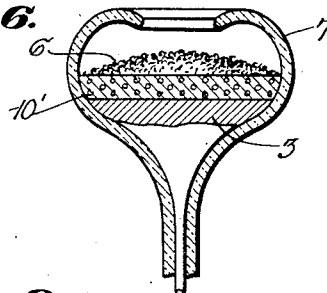


Fig. 8.

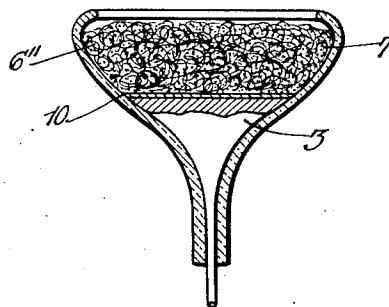
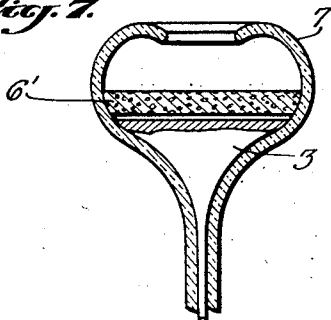


Fig. 7.



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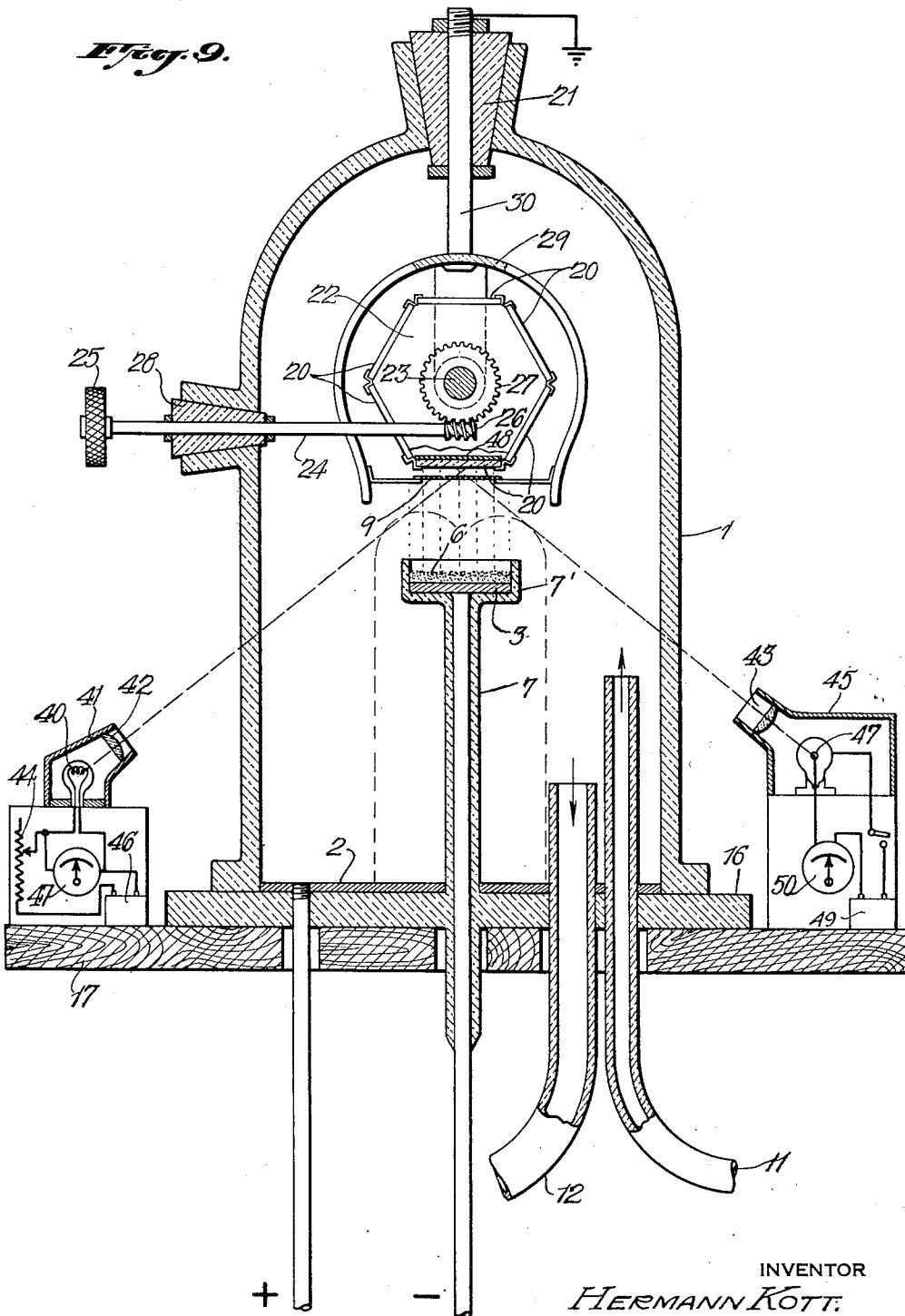
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2 Sheets-Sheet 2

Fig. 9.



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ELECTRON DISCHARGE DEVICE FOR ELECTRONICALLY BOMBARDING MATERIALS

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mesne assignments, to Ion Corporation, Short
Hills, N. J., a corporation of New Jersey

Application September 20, 1933, Serial No. 690,174

6 Claims. (Cl. 250—27.5)

This invention relates to the art of electron discharge devices and more particularly to the art of utilizing the electron flow in said devices in the bombarding of materials to effect there-
5 by a physical or chemical change in the said material and further relates to the selective projection of the constituents of the thus bombarded materials to and upon suitable and desired targets.

10 One of the objects of the present invention is to provide an improved electron discharge device.

Another object of the present invention is to provide a new method for electronically bomb-
15 arding materials.

Another object of the present invention is to provide a new method for effecting physical and chemical changes in materials.

20 Still another object of this invention is to provide an improved method for projecting materials upon the surface of other materials, targets and the like.

A further object of the present invention is to improve and facilitate the manufacture of photo-
25 sensitive electrodes and to improve the electrode product thereby.

Other objects and advantages will be apparent as the invention is more fully disclosed.

Broadly and briefly stated, the present in-
30 vention resides in the discovery that by enclosing the electron emitting cathode of an electron discharge device within what may be termed a crater type insulator with the electron emitting face of the cathode disposed adjacent the bot-
35 tom of the crater recess of said insulator and by disposing the material it is desired to bombard within the crater recess in what may be termed relatively close spaced relationship to the cathode face but electrically insulated therefrom,
40 the electrons flowing from the cathode face to the anode of the electron discharge device may be caused to collide with and bombard the said material. The kinetic energy of impact of the
45 electrons may be utilized to effect a physical or chemical change in the said material and when and if desired a selective projection of one or more of the constituents of said material may be obtained through the crater opening of the in-
50 sulator to and upon a desired target enclosed within the envelop with the cathode and anode.

Before further disclosing the present invention reference should be made to the accompanying drawings wherein—

55 Figs. 1 to 4 inclusive are schematic diagrams of

an electron discharge device modified in accordance with the present invention;

Figs. 5 to 8 inclusive illustrate modifications permissible in one of the elements comprising the electron device of Figs. 1 to 4 inclusive; and
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Fig. 9 illustrates a practical adaptation of the elements of Figs. 1 to 4 inclusive in the adaptation of the present invention in one specific embodiment.

Referring to the drawings, Figs. 1, 2, 3, and 4
10 schematically illustrate the basic elements comprising an electron discharge device adapted for the purposes of the present invention.

In Fig. 1 the electron discharge device illustrated includes the customary elements heretofore employed; namely, an enclosing envelop 1, an anode 2 and an electron emitting cathode 3. In accordance with the present invention I enclose cathode 3 in what may be termed a crater insulator 7 and position the electron emitting face 3' of said cathode adjacent the bottom of the crater recess of the said insulator 7. Further in accordance with the present invention I position within the crater recess of insulator 7 material 6 which it is desired to bombard by the electrons emanating from the cathode 3. Further in accordance with the present invention I provide within the envelop 1 a target 8 adjacent the crater opening of insulator 7 to and upon which the material 6 may be at least in part projected and further provide screen or grille element 9 interposed between the said target and the said insulator 7 which serves to delineate upon the face of the said target a desired pattern or design of projected material.
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As a specific embodiment of the present invention I will disclose the same as it has been applied in an electron discharge device of the gaseous conduction type utilizing a cathode known in the art as a cold electron emitting cathode and a gaseous filling comprised of at least one of the so-called inert gases. It is not to be construed, however, that the present invention is limited by reason of the election of this specific embodiment as one skilled in the art will readily recognize the adaptability of the present invention in devices of the so-called evacuated type and in devices utilizing a metal vapor atmosphere or a gaseous atmosphere comprised of a combination of inert gas and metal vapor.
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Referring to Fig. 1 and in accordance with the specific embodiment of the present invention, I comprise cathode 3 of a metal plate or disk having a composition adapted to serve as an electron emitter in a cold electrical discharge and
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comprise the gaseous filling of one or more of the gases such as hydrogen, nitrogen, argon, neon, helium and the like under reduced pressure.

In the normal operation of such a gaseous conduction discharge device of the present specific embodiment illustrated in Fig. 1, when an electric potential in excess of the breakdown voltage is impressed across the electrodes 2 and 3 a flow of electrons takes place from the surface of cathode 3 disposed adjacent the bottom of the crater recess of insulator 7. These electrons pass through the crater recess and thence to anode 2. In passing through the crater recess these electrons collide with and bombard material 6 which is disposed in the recess.

Concurrently with disintegration of the elemental material 6, the discrete particles of the material are projected from the crater recess in a directional path substantially coincident to the path of electrical discharge from the cathode to the anode out of the crater recess and the velocity of projection appears to be directly dependent upon the voltage of the electrical discharge. The exact explanation of this phenomena is not at this time clearly apparent. It may be due primarily to the electrical charges accumulating upon the discrete particles within the cathode discharge area; or it may be due to the excess of energy from the kinetic energy of impact over that which is required to effect the disintegration; or it may be due to the induced electrical field of the direct current discharge in the device, or it may be a combination of these three factors or to other factors not at this time apparent.

When material 6 is comprised of an elemental substance such as gold, silver, and other metals or metalloids, I have found that by a proper regulation of the kinetic impact of electrons or of the positive ions of the electrical discharge, as for example by the application of a voltage above a certain minimum which differs with each such elemental substance, the said elemental substance may be broken up into extremely small particles and said particles projected outwardly from the cathode face a considerable distance and that the thus projected particles may be collected as an adherent film upon the face of a target disposed in the path of projection of said particles.

When material 6 is comprised of an alloy or of an intermetallic compound or of an admixture of elements or intermetallic compounds I have found that by a proper regulation and control of the kinetic energy of impact of the electrons upon the material 6 that I may effect either a selective projection of one or more of the constituents of material 6 from the crater recess or I may effect a projection of all of the constituents of the material as may be desired.

Where material 6 is comprised of a chemical compound such as an oxide, sulphide, chloride and the like compounds I have found that the energy of impact of the electrons with the material 6 may be utilized to effect a decomposition of the compound to obtain either a selective projection of the elemental constituents thereof or a selective removal of an undesirable constituent therefrom either by projection or if the constituent is gaseous in its elemental state by evacuation.

It is further contemplated that the energy of impact of the electrons is adapted to be utilized in accordance with the teachings of the present invention to produce other effects and results not herein specifically described through modifications of the elements or constituents comprising material 6 and through varying and re-

combining the factors involved as they are herein disclosed to adapt the present invention to special uses in special arts and special devices.

In the practice of the present invention the feature of positioning the material 6 which it is desired to bombard within the crater recess of insulator 7 adjacent to but electrically insulated from the electron emitting face of the cathode 3 in such a manner as will place the material in position to be electronically bombarded is adapted to several modifications. While I have found that solid materials may be subjected to bombardment in accordance with the teachings of the present invention it is preferable that the surface area of the material be large relative to its mass. It is also preferable to dispose material 6 within the crater recess so that the electrons in passing from the cathode to the anode are forced to pass through the material rather than around the material. I therefore preferably convert material 6 into relatively small sized particles such as a powder and place the powder loosely within the crater recess adjacent to and electrically insulated from the cathode 3. Alternatively however I may agglomerate the powder particles into a porous or semi-porous mass before positioning the material within the crater recess. Alternatively also I may form a porous mass of another material having a relatively high resistivity to disintegration or disassociation under electron bombardment and impregnate this mass in any convenient manner with the material which it is desired to bombard. Alternatively also I may comprise material 6 of relatively small diameter wires, threads and the like bunched or bundled together to form what is commonly known as a "wool" which may be packed into the crater recess; or the "wool" may be comprised of material having a relatively high resistance to disintegration or disassociation under electron bombardment impregnated in any convenient manner with the specific material which is desired to be bombarded.

Other methods and means for positioning material 6 within the crater recess in accordance with the present invention may be devised.

In Figs. 5 to 8 I have illustrated four specific types of materials 6 suitable for the purposes of the present invention. In Fig. 5 material 6 is indicated as a powder product loosely placed in the crater recess of insulator 7 and resting upon the electron emitting surface of cathode 3. The electron emitting surface of cathode 3 is provided with an electron permeable insulating coating 10 to electrically insulate material 6 from the cathode 3.

In Fig. 6 I have provided a porous compacted dielectric insulator 10' which may be positioned directly upon the face of the cathode as indicated and material 6 deposited thereon as a loose powder. Alternatively insulator 10' may be impregnated with the material to be bombarded and positioned as indicated in Fig. 7. As a second alternative material 6 may be comprised of a compacted porous mass as indicated in Fig. 7 or as a "wool" packing as indicated in Fig. 8.

In Fig. 7 the powdered material 6 has been agglomerated under pressure into a porous target 6' which may be disposed within the crater recess of insulator 7 to rest directly upon the face of cathode 3 but electrically insulated therefrom as in Fig. 5 or it may be positioned in relatively close spaced relationship to the said cathode face as indicated in Fig. 7. Alternatively a porous target of other materials such as

tungsten powder which have a relatively higher resistance to disintegration under bombardment than material 6 may be formed and impregnated in any convenient manner with material 6 such as by dipping the target in fluid or molten material 6, dusting, spraying or admixing therewith before compacting.

In Fig. 8 is illustrated the adaptation of a "wool" packing 6' comprised of elongated fibers, wires, filaments and the like of either material to be bombarded or comprised of material more difficultly effected by electron bombardment than material 6 sought to be bombarded which "wool" has been impregnated in any convenient manner with material 6. Cathode 3 may be provided with an electron permeable dielectric insulating coating 10 as in Fig. 5 or may be provided with a compacted insulator 10' as in Fig. 6.

In the device schematically illustrated in Fig. 1 the two electrodes (cathode and anode) may be varied widely as to specific composition and as to size, shape or configuration without departing essentially from the nature and scope of the present invention.

I have found that the anode preferably should be of relatively large surface area and may be comprised for example of a metal or alloy which as in the case of tungsten and molybdenum may be readily degasified by heat-treatment in hydrogen, or which, as in the case of aluminum and its alloys form highly stable compounds with gases so that relatively high electron velocities are required to effect their decomposition. Aluminum and aluminum alloys are particularly serviceable as anode material for the reason that they may be readily formed and shaped to desired size, shape and configuration and further for the reason that gaseous compounds of aluminum and particularly the thin film of metal oxides surfacing said alloys are difficultly decomposed by electron bombardment. Certain iron and steel alloys, particularly those containing metals adapting the alloy to be resistant to corrosion or oxidation, such as aluminum, silicon, chromium, nickel, zirconium and titanium may be used however under certain conditions and so also may other base metals such as copper, iron and steel be used alone or when surfaced with metals such as chromium, nickel and the like.

With respect to the cathode, this electrode is preferably one which readily emits electrons under the particular electrical discharge conditions contemplated. As the cathode is also subjected during service to positive ion bombardment from the gaseous atmosphere present (residual or otherwise) it must also be either substantially inert with respect to such gases as oxygen, nitrogen, hydrogen, chlorine, bromine, iodine and the like, or adapted to react therewith to form an adherent surface film of such compounds having such stability as will serve as a protection against further reaction. If reactive superficially with such gases, the adherent film must be of such nature as to permit the ready egress of electrons from the cathode.

For most purposes I have found that where a cold cathode is employed as is contemplated in the present specific embodiment an aluminum or aluminum alloy cathode is most suitable. Aluminum and aluminum alloys may be readily shaped to any desired size, shape and configuration and are substantially gas free, due to the fact that the gases present therein are present as aluminide compounds. These compounds

have a relatively high stability and require unusually high voltages to effect their decomposition by electron or positive ion bombardment. Moreover, aluminum and aluminum alloys form upon exposure to the atmosphere a relatively thin adherent film of oxide, which, as has heretofore been recognized in the art, is an excellent dielectric insulator, but which does not appear to inhibit materially the emission of electrons from the underlying metal surface when used as an electrode in a cold electrical discharge. The voltages required to emit electrons from an aluminum or aluminum alloy electrode moreover is relatively low as compared to other metals and may be made still lower by the incorporation therein of a proportion of suitable low potential electron emitting elements, such as the alkali metals, alkaline earth metals, magnesium and the like.

With respect to the gaseous atmosphere adapted to be employed in the present invention, various gases or combinations of gases may be used, depending primarily upon the specific material it is desired to electronically project and upon the ultimate projected coating it is desired to obtain. Where substantially pure metals are desired to be projected, the gaseous atmosphere employed must be substantially inert or non-reactive therewith. With noble metals such as gold, platinum, silver and the like the choice of a gaseous atmosphere is not difficult. With metals that are readily oxidizable, oxygen must be excluded from the gaseous atmosphere. With metals that readily form nitrides and hydrides hydrogen and nitrogen must be excluded. For the more highly reactive metals such as the alkali or alkaline earth metals, the rare earth metals, the rarer metals such as thorium, zirconium, titanium, uranium and the like, the gaseous atmosphere preferably is comprised solely of the so-called monatomic gases, argon, helium, neon, krypton and the like. In some instances a vapor pressure of mercury may be employed.

Where it is desired, however, to form deposits upon the face of element 8 which are comprised at least in part of a gaseous component such as oxygen, hydrogen or nitrogen and the like a proportion of these gases in the gaseous atmosphere of the device may be used.

Where it is desired to project compounds such as sulphides, phosphides, tellurides and the like, it is inadvisable to employ a gaseous atmosphere comprised in part of gases reducing with respect to such compounds. With more difficultly reduced compounds such as metal oxides, refractories and the like non-metallic materials the range of permissible gases to be employed is quite wide.

The present invention is substantially a "cold" process of electronically bombarding materials and is distinctive in this respect from the various methods heretofore proposed.

With respect to the gas pressures permissible in the practice of the present invention, it is apparent that this factor also is subject to wide variations without departing essentially from the nature and scope of the same, depending upon the specific gas or gas composition employed, the specific material under bombardment and deposition, the desired projection thereof, the potential applied between the electrodes and the like factors. One of the controlling factors of gas pressure is that of breakdown potential between the electrodes. By the provision of one of the so-called "trigger" devices heretofore known in the

art this controlling factor can be materially reduced and the effect thereof substantially eliminated or overcome. Under most conditions favorable results from a material projection standpoint may be obtained with all materials with gas pressures as high as one millimeter mercury, but it is to be recognized that higher and lower gas pressures than one millimeter may be employed if desired and operative to produce the result herein defined.

It is also apparent that this gas pressure or any desired gas pressure that is operative to produce the result desired may be a maintained gas pressure; that is, one that is produced by reason of a continuous stream of gas flowing through the device under reduced pressure, and in some instances and in the projection of some materials a maintained gas pressure is preferable. This is most conveniently obtained by providing gas inlet and gas outlet openings 11 and 12 respectively in envelop 1 as indicated in Fig. 4; the gas inlet opening 11 being connected through valve 13 to gas supply source 14 and the gas outlet opening 12 being connected to vacuum pump or evacuating means 15.

In the remaining schematic Figures 2, 3, and 4 I have illustrated various modifications in the relative positioning of the elements of Fig. 1.

In Fig. 2 the anode electrode 2 is positioned out of the direct line path of particle projection from cathode 3 to element 8. This arrangement permits the ready isolation of element 8 and screen 9 from the electrical field of the gaseous conduction discharge between electrodes 2 and 3 and thereby eliminates to a large degree the accumulation of electrical charges upon element 8 and screen 9 which in some instances are objectionable.

In Fig. 3 the anode electrode is positioned behind the electron emitting face 3' of the cathode 3 so that the line of projection of discrete particles from the crater insulator 7 is away from the said anode and cathode. The electron stream in this arrangement of elements may be sharply deflected in a reverse direction from the line of projection leaving the projected particles to proceed through the electric field of discharge to a receiving target 8 which may be positioned at a point substantially outside of the field. This arrangement of the elements of the electron discharge device affords the widest range of adaption in the practical application of the present invention in the arts and industries.

In each of the modifications of Figs. 1, 2, and 3 the path of projection of the discrete particles of material 6 is preferably away from the horizontal and still more preferably either vertically upward or vertically downward to avoid deflection of the projected particles from a straight line path by gravity.

Referring to the drawings, Fig. 9, the apparatus illustrated therein is substantially an adaptation of the device schematically illustrated in Figs. 3 and 4 to serve the instant objective in view. In Fig. 9 like numerals have been used to identify the schematically described elements in Figs. 3 and 4. In Fig. 9 the enclosing envelop 1 comprises a glass bell jar having the bell opening thereof adapted to form a ground joint seal with dielectric plate 16 resting upon the dielectric supporting base 17. Plate 16 and base 17 are comprised of dielectric insulating material such as glass and wood respectively. Extending upwardly through base 17 and plate 16 are anode and cathode electrodes 2 and 3 respectively, ter-

minating in anode plate 2' and cathode plate 3' respectively interiorly in envelop 1. Anode plate 2' rests upon plate 16 and is perforated to permit cathode lead 3 to pass therethrough. Cathode lead 3 is electrically insulated from the anode plate 2' by dielectric insulator 7 which extends the full length of cathode lead 3 and is shaped as indicated at 7' about the cathode plate 3' to provide a crater recess at the bottom of which lies the electron emitting face of cathode plate 3' and within which is disposed the material 6 which it is desired to electronically project. The open end of the crater insulator corresponds in contour to the shape of target plate 20 upon which it is desired to project material 6. With this arrangement of elements an electrical discharge from cathode plate 3' to anode plate 2' takes place between the upper faces of each. The discrete particles of material 6 produced by electron bombardment are projected vertically upward through the crater opening of crater insulator 7 towards target base plate 20. The electron stream bends sharply over the edges of the crater opening of crater insulator 7 and passes downwardly to anode 2. The two paths of travel are indicated in dotted and dash lines respectively.

Gas inlet and gas outlet openings 11 and 12 respectively are provided through base 17, plate 16 and anode plate 2' into enclosing envelop 1, through which a stream of inert gas, preferably argon at a pressure approximating one millimeter of mercury is maintained. Openings 11 and 12 are connected to a valved source of gas supply and to an evacuating means respectively (not shown in Fig. 9 but schematically indicated in Fig. 4) in order to accomplish this.

In electronically projecting gold upon base plate 20 in accordance with the present invention material 6 in crater insulator 7 is preferably comprised of finely disseminated gold powder or granules of the order of less than 60 mesh. Cathode 3 and anode 2 are preferably comprised of aluminum or an aluminum alloy. The finely disseminated gold material 6 is laid directly upon the electron emitting surface 3' of cathode 3 within the crater recess of insulator 7, the surface oxides of the aluminum cathode serving to electrically insulate the gold powder from the electron emitting face 3' of the cathode 3.

In the arrangement indicated in Fig. 9 a plurality of base plates 20 is shown mounted on a frame 22 keyed to shaft 23 and means are provided to rotate the frame 22 to bring each base plate successively into a position to intercept the electronically projected material from crater opening of crater insulator 7. The means shown includes a drive shaft 24 extending through the envelop 1 through a hermetic seal 28 the said shaft having on the outside end a thumb nut 25 to rotate said shaft and a driving worm gear 26 on the inner end thereof, the driving worm gear 26 meshing with driven gear 27 keyed on shaft 23. The shaft 23 and frame 22 is enclosed within and supported by housing 29 depending from bolt 30 extending through hermetic seal 21 in envelop 1. This arrangement provides for the coating of a plurality of base plates 20 at one set up of the apparatus.

To obtain any desired grid pattern of electronically deposited gold upon the surface of base plate 20, I provide a grille 9 which is interposed between the base plate 20 and the crater opening of insulator 7 in such manner as is convenient and in such relative spaced relationship with re-

spect to base plate 20 as to obtain the desired grille definition thereon. Preferably also the upper end of bolt 30 is electrically grounded to carry off negative charges accumulating upon the assembly substantially as is indicated.

In electronically projecting gold, the enclosing envelop 1 is first oven baked to remove gases and water vapor that may be occluded upon the inner surface thereof and then is evacuated to a pressure at least approximating 0.2 millimeters of mercury. The envelop thereafter should be repeatedly flushed with an inert gas such as nitrogen to eliminate water vapor and oxygen therefrom. A pressure of approximately 1.0 millimeters of mercury of inert gas such as argon is then introduced and a cold electrical discharge initiated between the cathode and anode using direct current of high potential.

It is preferable to initiate a cold electrical discharge at a voltage below that at which the material 6 will be electronically projected and to maintain the same for a time interval in order to obtain a "cleaning-up" of deleterious gases remaining in the envelop by their ionization and conduction to one or the other of the two electrodes. This is particularly advantageous also in cleaning up the electrode surfaces of such gases and water vapor as are occluded thereon. During this preliminary cleaning up stage it is advantageous to maintain a flow of inert gas through the device to facilitate the sweeping away of the liberated atmospheric gases and water vapor. The potential of the electrical discharge then may be raised at regular increments to that potential resulting in electronic deposition of the material comprising material 6 upon plate 20, or to such an excess over this as will deposit the material with the degree of adherence to the surface of plate 20 as is desired. This particular potential widely varies as has heretofore been defined.

In the deposition of gold I have found that with any given physical state of gold employed as material 6 the projecting potential varies depending upon the spacing of electrode faces 2' and 3', the gas pressure and the gas composition. For example, using gold powder of approximately 90 mesh with an electrode spacing of about 7 inches, a gas pressure of about 1.0 millimeter of mercury, and a gas comprised substantially of argon, the ultimate potential that produces the most satisfactory deposition for the purposes of this specific embodiment upon plate 20 positioned approximately 2 centimeters from the cathode face 3' is of the order of 10,000 volts at about 42 milliamperes. Adherent coatings may be obtained at lower and higher voltages however. By varying any one of the factors hereinbefore identified other voltages will be necessary to obtain comparable results.

The depth of coating obtainable by the practice of the present invention may be regulated by proper control over the potential of the discharge and the time interval of application. It may also be regulated by the provision of suitable apparatus adapted to measure the same as it is being built up. This apparatus is indicated in Fig. 9 and consists in a light source 40 enclosed in a housing 41 having lens means 42 to angularly project a beam of light radiation upon the face of base plate 20 (as indicated in dash lines). Base plate 20 is provided with a backing 48 of light reflecting material such as a bright metal plate. The reflected light radiation then is collected by lens 43 and projected upon photoelectric cell 47 enclosed in,

housing 45. Circuit means including electric current supply source 46, ammeter 47 and rheostat 44 are provided to maintain the light radiation from light source 40 substantially constant. Circuit means including an electric current supply source 49 and an ammeter 50 are provided to measure the intensity of reflected radiation. When base plate 20 is free from deposited material the maximum current flow through photo-sensitive device 47 is indicated by meter 50. As the reflected light is cut off by deposited material the meter 50 will show the extent of such deposit by its deflection from the maximum reading.

As a further illustration of the practice of the present invention, I have comprised material 6 of silver sulphide in finely divided form, and have subjected the silver sulphide to electronic bombardment in a gaseous atmosphere comprised of argon at a pressure of about 1.0 millimeter utilizing a direct current potential of 1800 volts at 28 milliamperes. At this potential the sulphur content of the silver sulphide was electronically projected upon target 8 whereas the silver content thereof was left behind in the crater recess. By increasing the potential to 4000 volts at 35 milliamperes the silver then was electronically projected upon target 8.

As a further illustration platinum chloride was positioned in the crater recess of insulator 7 and subjected to electron bombardment using an electrical potential of about 1400 volts at 24 milliamperes and further employing a circulating gas atmosphere of hydrogen at about 1.0 millimeter of pressure. After a short time the platinum chloride changed color and became a finely divided powder distinguishable under the microscope as fine metal powder. Upon raising the electrical discharge potential to about 7400 volts at 35 milliamperes platinum was deposited upon target 8.

As a further illustration material 6 was comprised of black non-magnetic iron oxide Fe_2O_3 and subjected to electron bombardment in an argon atmosphere at about 1.0 millimeter of mercury pressure using 2800 volts and 21 milliamperes of current. After a time the black oxide became intense red in color and became magnetic indicating its conversion as a result of the electron bombardment into the lower magnetic oxide Fe_3O_4 . The same effect may be obtained using an atmosphere of hydrogen at the same pressure using slightly different voltages in the electrical discharge. In an air atmosphere at about 0.3 millimeter pressure the same effect may be obtained using 3500 volts and 25 milliamperes in the electrical discharge.

Bismuth oxide similarly electronically bombarded was converted from a grey powder to a green powder. Many other experiments have been made indicating the extent and scope of the physical and chemical changes obtainable in the electronic bombardment of materials by the practice of the present invention but need not be specifically described in view of the specific embodiments herein disclosed.

Having broadly and specifically described the present invention and given specific embodiments thereof, it is apparent that many modifications may be made therein without departing from the nature and scope thereof and all such modifications are contemplated as may fall within the scope of the following claims.

What I claim is:

1. The method of electrically disintegrating

and projecting deposits of material which comprises disposing the said material adjacent the electron emitting surface of a cathode but electrically insulated therefrom, confining said material and cathode to direct any gaseous conduction discharge through the material to and from the said surface, disposing an anode rearwardly of said cathode surface, enclosing said cathode and anode from the atmosphere introducing in said enclosure a reduced pressure of ionizable gases substantially inert towards said material, establishing a gaseous conduction discharge between said cathode and anode, and impressing a voltage to said discharge adapted to effect a disintegration of said material through bombardment by positive and negative ions of said discharge and a projection of the disintegrated particles outwardly from the said cathode surface.

2. The method of electrically disintegrating and projecting deposits of material which comprises disposing the said material adjacent the electron emitting surface of a cathode but electrically insulated therefrom, confining said material and the cathode to compel any gaseous discharge to pass through the material to and from the said cathode surface, disposing an anode rearwardly of said cathode surface, introducing in said enclosure a reduced pressure of ionizable gases substantially inert towards said material, establishing a gaseous conduction discharge between said cathode and anode, impressing a voltage to said discharge adapted to effect a disintegration of said material through bombardment by positive and negative ions in said discharge and a projection of the disintegrated particles outwardly from the said cathode surface and collecting the said projected particles upon the surface of an object disposed in the path of projection of said particles but out of the path of electrical discharge.

3. The method of electrically disintegrating and projecting deposits of material which comprises disposing the said material adjacent the electron emitting surface of a cathode but electrically insulated therefrom, confining said material and said cathode to compel any discharge to pass through the material to and from said cathode surface, disposing an anode rearwardly of said cathode surface, introducing in said enclosure a reduced pressure of ionizable gases substantially inert towards said material, establishing a gaseous conduction discharge between said cathode and anode, impressing a voltage to said discharge adapted to effect a disintegration of said material through bombardment by the positive and negative ions of said discharge passing therethrough and a projection of the disintegrated particles outwardly from the said cathode surface, disposing an object desired to be coated with said material in the path of projection of said particles but out of the path of electrical discharge and electrically grounding said object to effectively neutralize the accumulating electrical charges carried by said projected particles.

4. The method of electrically disintegrating and projecting deposits of material which comprises disposing the said material adjacent the electron emitting surface of a cathode but elec-

trically insulated therefrom, confining said material and the said cathode surface to compel any electrical discharge to and from said surface to pass through the said material, disposing an anode rearwardly of said cathode surface, introducing in said enclosure a reduced pressure of ionizable gases substantially inert towards said material, establishing a gaseous conduction discharge between said cathode and anode, impressing a voltage to said discharge adapted to effect a disintegration of said material through bombardment by the positive and negative ions passing therethrough to the said cathode surface and a projection of the disintegrated particles outwardly from the said cathode surface, disposing an object desired to be coated with said material in the path of projection of said particles but out of the path of electrical discharge between said anode and said cathode, electrically grounding said object and interposing in front of said object a grille element adapted to intercept some of the said particles to produce thereby a desired pattern of deposited material on the surface of the said object.

5. The method of forming surface coatings of metals and metal mixtures which comprises disposing a gas pervious layer of said metals over the surface of an electron emitting cathode in a gaseous conduction discharge device but electrically insulated therefrom, disposing the anode of said device rearwardly of said surface, directing any gaseous conduction discharge between said anode and said cathode through the said metals, impressing an electrical potential to the said discharge adapted to produce disintegration of said material metals by positive and negative ion bombardment and projection of the disintegrated particles outwardly from said cathode surface, disposing the object to be surfaced in the path of said projection but outside of the path of electrical discharge between said anode and cathode, and electrically grounding the said object to remove accumulating electrical charges thereon.

6. The method of surfacing objects with metal and metal mixtures which comprises finely dividing said metal, disposing the same in covering relation to the electron emitting surface of a cathode in a gaseous conduction discharge device but electrically insulated therefrom, directing the gaseous conduction discharge between said surface and an anode through the said material, disposing the said anode in a position relative to said cathode surface that the said gaseous conduction discharge therebetween takes a path substantially remote from a path normal to said cathode surface, impressing an electrical potential across said cathode and anode adapted to impart to the positive and negative ions of said discharge a kinetic energy of impact adapted to effect disintegration and projection of relatively small particles of the said material outwardly from the said cathode surface in a path substantially normal to the said surface, and disposing the object to be coated in the path of said projection but out of the path of said gaseous conduction discharge.

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