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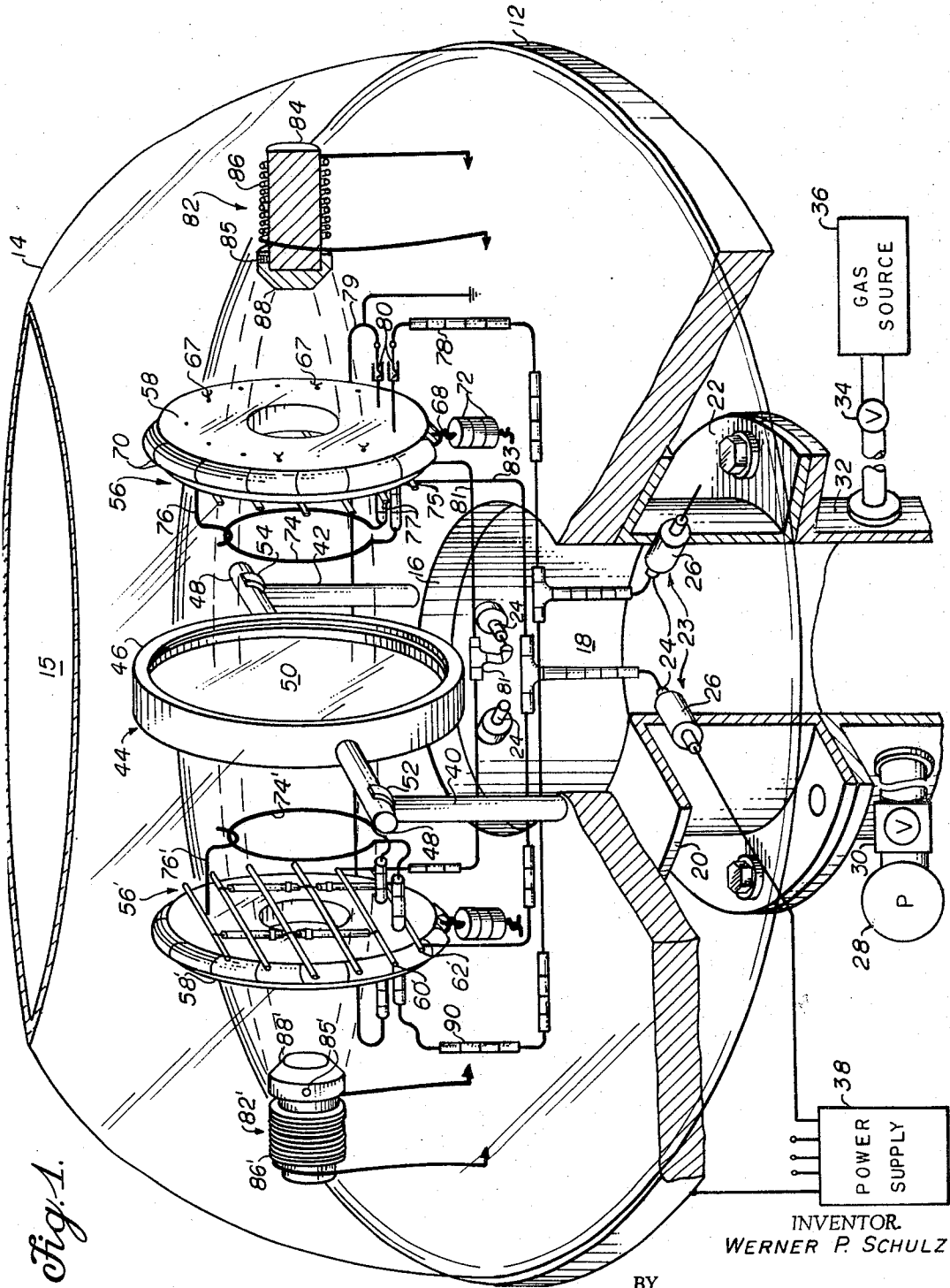
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3,293,168

APPARATUS FOR COATING SUBSTRATES BY CATHODE SPUTTERING

Filed May 22, 1964

2 Sheets-Sheet 1



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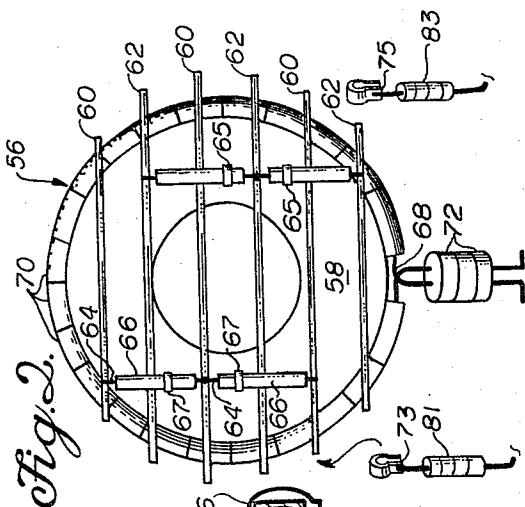
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2 Sheets-Sheet 2



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APPARATUS FOR COATING SUBSTRATES
BY CATHODE SPUTTERING

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The present invention relates generally to the coating of substrate surfaces and, in particular, to methods and apparatus for sputtering a preselected coating material in or onto the surface of an object, such as for example a waveguide window, formed of electrically non-conducting material.

There are various devices presently available for depositing a coating of material upon an object's surface. Such devices utilize various types of magnetic or electric structures to effect, in general, an electron bombardment and/or thermal vaporization of the coating material to deposit upon the object. However, the extent of penetration and/or the density of the coating deposited upon a substrate with such devices has proved inadequate when utilized in waveguide window construction, wherein it is desirable that the window withstand the very high energy levels which are associated with, for example, transmission therethrough of the energy utilized for driving the beam of a 20 billion electrotron volt accelerator. That is, waveguide windows, as heretofore coated by known apparatus and methods, are not capable of performing their required function at such high energy microwave transmission levels.

The present invention overcomes the foregoing shortcomings by providing a method and apparatus for coating an electrically nonconductive substrate with a recombined film of a desired and preselected material, e.g., a metal or metallic compound having a relatively low secondary emission coefficient, wherein the coating is effected by sputtering the ions of the coating material at high velocity to impinge upon the substrate and thereby realize deeper penetration and more constant density of coating. Furthermore, the especially adapted mechanism of the invention allows both sides of the window, or object, to be coated simultaneously, thereby circumventing the occurrence of any deleterious effects on a previously coated side when subsequently coating of the opposite side. This invention is herein particularly described utilizing a coating material of titanium ions which are accelerated against a substrate of Al_2O_3 , to form a layer of Al_2O_2TiO , which exhibits the desired, lower coefficient of secondary emission essential for optimum operation of the window in high energy applications. The invention has been extensively utilized in sputtering a resultant nonconductive layer of material of relatively low, secondary emission coefficient upon a nonconductive surface, and therefore generally utilizes materials or precursors thereof, e.g., titanium metal which provide a coating such as titanium suboxide, which have an extremely low secondary emission coefficient. However, the method and apparatus of the invention could be used to deposit an electrically conductive layer of metal, such as copper, gold, silver, etc., upon a nonconductive surface or to cause reactions of such metals or compounds thereof with various substrate surfaces to produce a wide variety of coated surfaces.

Accordingly, it is an object of the present invention to provide methods and apparatus which are capable of sputtering a wide variety of coating materials upon an electrically nonconducting substance such as ceramics, glass, quartz, and the like.

It is another object of the present invention to provide methods and apparatus for applying an interatomic bonded layer of recombined metallic particles to a nonconducting

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surface thereby providing an optimum radio-frequency dielectric material for use in constructing high energy, waveguide vacuum windows.

Another object of the present invention is to provide methods and apparatus for coating an object utilizing a simple, alternating current circuit.

Yet another object of the present invention is to provide a simple and inexpensive method and apparatus which is capable of depositing a more uniform interatomic bonded layer of a desired material, with relatively deeper penetration upon a preselected surface, in a relatively short period of time.

Still a further object of the present invention is to provide methods and apparatus for sputtering metallic ions upon a surface within an inert gas atmosphere to form thereon an interatomic bonded layer of a material having a relatively low coefficient of secondary emission.

Yet another object of the present invention is to provide methods and apparatus for sputtering metallic ions against a preselected material surface wherein the ions are focused and accelerated by means of an alternating electro-magnetic field.

A further object of the present invention is to provide methods and apparatus for sputtering a layer of material having a low coefficient of secondary emission upon the surfaces of waveguide windows of various shapes, such as for example, planar, conical, cylindrical and concave-convex.

Other objects and advantages will be apparent in the following description considered together with the accompanying drawings, in which:

FIGURE 1 is a perspective, partial schematic view of one embodiment of the invention, exemplifying the construction thereof as utilized in the method of the invention.

FIGURE 2 is an enlarged view showing in greater detail the construction of the anode-cathode electrode array of the apparatus shown in FIG. 1.

FIGURE 3 is a schematic, cross-sectional view of an alternative embodiment of the present invention designed to coat waveguide windows of concave-convex configuration.

FIGURE 4 is an exploded, partial schematic of a second alternative embodiment of the present invention, designed to coat on an object of conical configuration.

FIGURE 5 is a schematic cross-section view of a third alternative embodiment of the present invention, designed to coat an object of cylindrical configuration.

FIGURES 6 and 7 are cross-sectional views of alternative embodiments of the field generating, magnetic poles applicable for use with the present invention.

Briefly, apparatus exemplifying the construction and mechanism of the invention comprises means defining an enclosed volume containing a controlled inert gas atmosphere, such as argon, in which there is disposed of a filament formed of the desired coating material and located between a target or object to be coated and a gaseous-discharge electrode array. The electrode array comprises in bisymmetrical array an alternate series of cathode and anode electrodes which are likewise formed of the desired coating material and constructed to define a form or series of bars, rings, or like geometrical configurations, depending upon the general configuration of the object to be coated. The filament and the electrode array are connected to respective alternating current sources and the filament is heated to produce by sublimation a cloud of slow-moving atomic or molecular particles of the material of which it is formed. Energization of the electrode means with an alternating current source within the argon gas atmosphere creates a controlled gaseous discharge of ions of the material, which without further provisions generally would be accelerated randomly in all directions away from the electrode array. To aid in controlling and directing

the ion flow an electromagnetic field focusing means is coaxially disposed behind the electrode means on the side thereof opposite the object to be coated, wherein the magnetic field generated by the focusing means acts to direct the accelerated ions towards the filament. The accelerated ions strike the cloud of particles about the filament and the entire mass is electromagnetically guided at high velocity to impinge uniformly upon a surface of the target. The electromagnetic focusing means likewise is connected to an alternating current source, and in the preferred embodiment of the invention operates in a push-pull manner to coat both sides of the object simultaneously. That is, the polarity of the magnetic field reverses periodically, to alternately direct the cloud of ions generated at either side of the object towards the respective surface. Magnetic field intensities of from 10 to a few hundred gauss are used.

More particularly, referring to FIG. 1, there is shown apparatus for coating a selected substrate with a material in accordance with the present invention. The coating operation is conducted in an inert gas atmosphere, for example, an argon gas atmosphere disposed in a suitable vacuum enclosure. A suitable enclosure, e.g., comprises a circular base plate 12 and an inverted glass bell 14 disposed thereon, in vacuum-tight relation with the upper surface thereof, thereby defining within bell 14 and plate 12 an evacuable volume 15. Base plate 12 has an opening 16 formed therein to provide for the attachment of port means providing access to the volume 15 not only for evacuating same but also for introducing conductors carrying alternating current voltages and for the introduction of argon gas to the evacuated volume 15 without subsequent loss of the vacuum. Such port means can take the form of a tubular member 18 having flanges 20 and 22 integral therewith at either end thereof. Flange 20 of member 18 is secured as by means of bolts to the lower surface of plate 12 in vacuum-tight relation therewith, such that the passageway in tubular member 18 is thus hermetically secured to plate 12 in register with opening 16. A plurality of terminal means 23 are provided in the form of a spaced series of radially extending, electrically conductive terminal rods 24 disposed through a like series of holes in the wall of tubular member 18. Rods 24 are secured in vacuum-tight electrically insulated relation within the holes in member 18 by means of cylindrical insulators 26 disposed about the rods and pressed or sealed into the holes. It is to be understood that tubular member 18 could be an integral extension of plate 12 rather than a separate flanged member. Likewise terminal means 23 could be hermetically mounted through the outermost periphery of the base plate 12 to provide means for introducing electrical power into the volume 15. Terminal means 23 can be any suitably insulated, vacuum-tight electrical connections, e.g., kovar-type electrical connections.

The volume 15 within bell 14 is evacuated by means of a suitable vacuum pump 28 which is communicably coupled thereto via a valve system 30, shown schematically, and associated vacuum plumbing as herein exemplified by a portion of the flanged pipe 32. The lower end of flanged pipe 32 is sealed off, and if desired, extends downwardly to provide a base upon which the device stands. An argon gas atmosphere is provided within bell 14 via associated vacuum lines which couple to pipe 32 as shown schematically, and which include a suitable valve system 34, the gas being delivered from an argon gas source 36. Although argon gas is herein utilized in conjunction with the invention, it is to be understood that any of the inert gases, such as for example, xenon, krypton and neon, may be utilized. A multiple outlet, alternating current, power supply 38 is provided, the outlets of which are connected to the coating apparatus within volume 15 via respective terminal means 23, i.e., terminal rods 24, as is further described hereinafter.

Rigidly secured in perpendicular relation to the base plate 12 and at diametrically opposed positions, i.e., transversely relative to generally central opening 16, are forked window supports 40 and 42, formed of a non-conducting, high temperature material, such as for example, ceramic. The supports 40, 42 are of sufficient length to suitably suspend a window assembly 44 a substantial distance above the surface of plate 12. Such window assembly 44 comprises more particularly a hollow annular support band 46 and diametrically opposed, radially extending, cooling tubes 48 secured thereto. A waveguide vacuum window 50 formed of suitable material such as quartz, ceramic, glass, etc., herein comprising the object to be coated, is integrally secured within the band 46 by rings concentrically brazed within the band 46 and against the window periphery on either side thereof. Since the manner of constructing and supporting waveguide windows of the foregoing materials is well known in the art no further explanation is deemed necessary herein. Yokes 52 and 54 are rigidly secured as with screws to the upper end of supports 40, 42 respectively, the size of the yokes and the spacing between the supports 40, 42 being such to allow the midportion of each of tubes 48 to mate with its respective yoke, to thus suspend window 50 substantially above the opening 16 of plate 12.

Although the device of present invention is described herein as utilized in coating a waveguide window of the configuration hereinbefore described, it is to be understood that the apparatus of the invention may be utilized as a means for coating a desired material upon an electrically nonconductive substrate of various other shapes for use in other desired applications.

Consider now the electrode structure and circuitry as exemplified in FIG. 1 and in particular the gaseous discharge electrode array of previous mention, depicted by numeral 56, and shown in greater detail in FIG. 2. Electrode array 56 includes a planar circular array support 58 formed of an electrically nonconductive, high temperature material such as ceramic or quartz, and supported a predetermined distance from window 50 in coaxial alignment therewith. A spaced parallel series of straight wires of varying length are disposed across the face of the annular support 58 on the side thereof facing the window 50. Such a spaced series of wires defines, more particularly, an alternately arranged plurality of intermeshing anode and cathode electrodes 60 and 62 respectively, wherein the wires are formed of or are coated with the material which is to be deposited upon the window 50. Pairs of the plurality of anode electrodes 60 are electrically connected together by means of suitable wires 64 extending therebetween. Wires 64 in turn are sheathed by suitable lengths of tubing 66 formed of a high temperature, nonconducting material such as for example, ceramic or quartz. The electrically connected anodes 60, wires 64 and surrounding tubing 66 are secured to the ceramic support by suitable means such as wires 67 which are bound around tubing 66. The ends of the wires 67 are passed through holes in the support 58 and are twisted together behind the support to secure the anode electrodes thereto. The cathode electrodes 62 are electrically interconnected and secured to the support 58 in a manner similar to that described in conjunction with the anode electrodes 60, i.e., the cathode electrodes 62 are arranged in alternate relation to anode electrodes 60 across the face of support 58 and secured thereto by means of wires 65. As may be seen from FIG. 2 the length of the alternate series of anode and cathode electrodes 60, 62, are chosen and arranged to give the electrode array 56 a substantially circular configuration with an overall diameter substantially matching the diameter of window 50. The electrode array 56 is supported in coaxial alignment with window 50 by any demountable mounting means, and may for example, be so mounted by means of a loop 68 formed of suitable wire and sheathed along its entire length by a multiplicity of short

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hollow tubes 70 formed of a high temperature nonconducting material. The inside diameter of loop 68—tubes 70 are chosen to allow the combination to be snugly fitted circumjacent the outer circumference of support 58. The ends of the wire loop 68 are extended together downwardly and are sheathed along their length by ceramic tubes 72, wherein such extended ends and tubes 72 form in essence a column upon which the loop 68 and support 58 are secured. The tips of the extended wires are welded or otherwise secured to the upper surface of base plate 12.

Alternating current electrical power is coupled to the array 56, and in particular to the end of an anode and cathode electrode 60 and 62 respectively, by means of slip-on connectors 73 and 75, which fit tightly about the end of their respective electrode in electrically conducting relation therewith. The connectors 73 and 75 are connected in turn to sheathed lead-in wires 81 and 83 respectively which extend therefrom to connect to individual terminal rods 24.

It is understood that although the anode and cathode electrodes are herein numbered 60 and 62 respectively for purpose of description, this is the case during only one-half of the cycle of the alternating current source coupled thereto. In the subsequent, opposite, half cycle of the alternating current source, electrodes 60 will act as the cathode electrodes and electrodes 62 as the anode electrodes.

A filament 74 of substantially circular loop shape is disposed in coaxial alignment between the window 50 and the electrode array 56, and is supported with predetermined spacing therebetween by means of a suitable length of filament support wire 76 which extends from the upper portion of electrode array support 58 towards window 50. The ends of filament 74 are sheathed by tubes 77 of electrically nonconductive, high temperature material, and extend into holes in the lower portion of the support 58 to protrude from the opposite side thereof. Sheathed current conducting leads 78 and 79 are demountably secured to the protruding ends of the filament 74 such as is satisfactorily provided herein by means of clips 80, which are wrapped in an insulating material (not shown) such as for example, glass cloth or loom. Current conducting lead 78 is connected at its opposite end to one of the rods 24 of terminal means 23 in tubular member 18.

Consider now the electromagnetic focusing means of previous mention, which comprises essentially an electromagnet 82 formed of a suitable slug of laminated metal 84 about which is wound an insulated winding 86. Winding 86 is made of anodized aluminum wire to allow operation of the magnet at high temperatures, i.e., 300° C. without insulation breakdown. A magnet pole 88 having substantially a truncated cone shape is demountably secured to the end of the slug 84 which faces window 50, by suitable means such as for example, a bolt or set screw 85. The electromagnet is disposed in coaxial alignment with the electrode array 56, filament 74, and window 50 and is held in position behind electrode array 56 by any suitable mounting means, such as for example, a steel strap or bracket (not shown) which is secured at one end to slug 84 and which extends downwardly therefrom to secure at the other end thereof to the upper surface of base plate 12.

As shown in FIG. 1 the preferred apparatus configuration as utilized in coating waveguide windows employs an additional filament 74', electrode array 56' and electromagnetic focusing means 82', which are arranged and spaced in a coaxial alignment with window 50, but on the opposite side thereof from the coating elements hereinbefore described. The electrode array 56' is secured to the face of an annular support 58' which in turn is secured to the base plate 12 as previously described in conjunction with electrode array support 58. The filament 74' is secured to support 58', likewise as hereto-

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fore described. The sheathed lead 79 extends from one end of the filament 74 and is demountably secured to one end of the filament 74' as for example, by means of an alligator clip or slip-on connector (no shown) and from thence to ground. The remaining end of filament 74' is connected to lead 78 of filament 74 by means of a suitable sheathed lead 90. Filaments 74, 74' are thus connected to a power source in electrical parallel.

A coil 86' of the electromagnet 82' is electrically connected in series with the coil 86 of electromagnet 82. One end of the serially connected coils 86, 86' is grounded to base plate 12 and the other end of the coils is connected to the rod 24 of a respective terminal means 23. Energizing the electromagnets, 82, 82' generates therebetween a magnetic field of generally circular cross section having a diameter of at least the diameter of window 50.

One of the outlets of supply 38 is connected to plate 12 and acts as a ground, and each of the remaining 4 outlets is connected to respective rods 24 of the 4 terminal means 23.

The anodes 60' and cathodes 62' of electrode array 56' are connected in electrical parallel with the anode and cathode electrodes 60, 62 respectively of electrode array 56. The anode electrodes 60' are connected to the sheathed lead-in wire 81 of anode electrodes 60 and thence to a terminal rod 24 of a respective terminal means 23. The cathode electrodes 62' are connected to the sheathed lead-in wire 83 of cathode electrodes 62 and thence to a terminal rod 24 of another terminal means 23 as shown in FIG. 1. As previously mentioned, when in operation the anode and cathode electrodes of both the arrays 56, 56' alternate positions during alternate half-cycles of the alternating current source.

It is to be understood that in order to preserve the quality of coating deposited on window 50 all exposed metallic surfaces within the volume 15 should be made of the material to be deposited on the window 50, or if made of another material, should be covered or sheathed by a nonconducting material such as for example, ceramic, quartz, glass cloth or like material capable of withstanding the rather high temperatures generated by the apparatus. Alligator clips 80, for example, are preferably covered with a flexible, nonconducting material such as glass cloth. As herein disclosed titanium is utilized as the coating material for the window 50. Accordingly, the filament and electrode arrays as well as all support wiring and current conducting leads are satisfactorily formed of titanium metal.

Although the apparatus of the invention as shown in FIG. 1 is utilized in coating a planar surface, it is to be understood that the concepts of the invention may be employed to coat objects or windows having a variety of geometrical shapes. For example, referring to FIG. 3 there is shown in partial schematic, the cross section of a concave-convex waveguide window 90 placed in position within an alternative embodiment of the present invention. Here, as in FIG. 1, the invention comprises essentially a first and a second filament 92 and 92' of substantially circular loop shape, designed to lie along the outside and inside curvature respectively of the concave-convex window 90 as schematically shown in the FIGURE 3. Electrode arrays 94, 94' are disposed at either side of the concave-convex window 90 behind the filaments 92, 92' respectively, such arrays comprising in particular alternately spaced anode and cathode electrodes 96, 96' and 98, 98' respectively. The anode and cathode electrodes are formed of wires the lengths of which are varied to give the electrode arrays 94, 94' a generally circular as well as a concave-convex configuration, which matches the curvature of the surfaces of window 90. Electromagnets 82, 82' similar to those utilized in FIG. 1 are coaxially aligned with an axis passing through the center of the circumference of window 90, wherein electromagnet 82 has a magnet pole 100 of a diameter substantially equal to the diameter of the electrode array 94, wherein the surface

thereof facing the window 90 has a concave curvature matching the convex curvature of the facing surface of the window. Electromagnet 82' has a magnet pole 100' demountably secured thereto as heretofore described, wherein the surface thereof facing the window 90 has a convex curvature matching the concave curvature of the facing surface of the window. The concave-convex magnet poles 100, 100' generate a magnetic focusing field of diverging configuration, thereby providing field lines along the cross section of window 90 which pass through the walls thereof in substantially a perpendicular relation thereto. However, it is to be understood that although the particular electromagnet pole configuration shown in FIG. 3 generates an optimum magnetic field configuration and is thus preferred, such concave-convex poles 100, 100' could have flat disc-shaped configurations and be secured in perpendicular coaxial relation to the electromagnets 82, 82', wherein the field lines generated would form a generally coaxially extending envelope which would pass through the walls of the concave-convex window in other than a perpendicular relation.

The electromagnets 82, 82' of FIG. 3 are serially connected to one outlet of a multiple outlet alternating current power supply (not shown), and the filaments 92, 92' are connected in parallel to another outlet of the alternating current power supply. The cathodes 98, 98' are connected together to a third outlet of the alternating current power supply, while the anodes 96, 96' are connected together to still another outlet of the supply, thus providing a parallel electrical connection therefor.

Referring now to FIG. 4 there is shown in exploded relation a second alternative embodiment of the present invention particularly designed for use in coating a waveguide window 102, or like object, having a substantially conical shape. The conical waveguide window 102 is disposed in coaxial alignment with a series of electrodes as hereinbefore described in conjunction with FIGS. 1 and 3. More particularly, beginning at the conical window 102 and progressing outwardly, there are disposed in spaced relation therefrom at either side thereof, filaments 104, 104', electrode arrays 106, 106' and electromagnetic focusing means comprising electromagnets 82, 82' respectively. As may be seen, the spacing and positioning of the various electrodes and filaments is generally the same as heretofore described wherein, however, the configuration thereof is particularly tailored for coating a conical waveguide window or object of like shape.

More particularly, filament 104 is wound in tapered helical form, the dimensions thereof being slightly larger than the outer tapered surface of waveguide window 102 and conforming thereto, such that filament 104 may be disposed circumjacent about the window 102 along the length thereof. Likewise, electrode array 106, comprising an alternately arranged series of graduated rings, defining anode and cathode electrodes 108, 110 respectively, has a generally tapering conical shape of dimensions large enough to allow the array 106 to be concentrically composed about the filament 104 and the waveguide window 102. The electromagnet 82 is formed of the laminated slug of metal 84 and insulated wire winding 86 previously described in conjunction with FIGS. 1 and 3. However, to generate a focusing magnetic field of preferred configuration, that is, a configuration wherein the field lines pass in perpendicular relation through the tapered walls of the waveguide window 102, a generally conical-shaped magnet pole 112 is demountably secured to the electromagnet 82 as heretofore described. The pole 112 is formed of suitable dimensions to allow same to be concentrically disposed circumjacent about the assembled electrode array 106, filament 104, and window 102 in preselected spaced relation therefrom.

In accordance with the invention, the filament 104' and electrode array 106' (herein outlined in phantom line for reasons of simplicity) as well as electromagnet 82' are disposed in coaxial alignment on the opposite side of conical waveguide window 102. However, the elements

are particularly designed to fit concentrically within, rather than without, the conical window 102. More particularly, the filament 104' is identical in construction to filament 104, but is of lesser dimensions such that it may fit with proper spacing within window 102. Likewise electrode array 106' is identical in construction to array 106 but is of relatively smaller dimensions such that it may fit within filament 104' and be suitably spaced therefrom. A magnet pole 112' whose outer surface is shaped in the general form of a cone, is disposed circumjacent within the electrode array 106', filament 104' and window 102, and is demountably secured at the larger end thereof to the electromagnet 82'. Thus it may be seen that a magnetic field generated between the poles 112, 112' passes through the walls of the conical waveguide window 102 in essentially perpendicular relation therewith.

The manner of connecting a multiple-outlet, alternating current power supply to the various elements shown in FIG. 4 is substantially identical with the manner of connecting the apparatus shown in FIGS. 1 and 3. Likewise, the entire coating apparatus is disposed within an evacuated volume having an inert gas atmosphere, as heretofore taught. The mechanism of operation is identical to the operation of the apparatus of FIG. 1, each conical element of FIG. 4 performing its intended function as heretofore described in accordance with the invention.

Referring now to FIG. 5 there is shown in schematic a cross-sectional view of a third alternative apparatus embodiment of the present invention wherein same is particularly designed to coat an object having a generally cylindrical configuration. Briefly, an electrically non-conductive cylinder 112 having a central axis therethrough has disposed circumjacently thereabout, in spaced relation therefrom, a filament 114, an electrode array 116, and a magnet pole 118. The apparatus of the invention of FIG. 5 could be utilized with only the outer elements, if an additional magnet pole 118' is disposed coaxially within the cylinder 112 to provide the necessary focusing magnetic field through the walls of the cylinder 112. Such configuration with only outer elements would provide a coating only on the outside surface of the cylinder 112. To obtain a similar coating on the inside surface it is necessary to likewise include therewithin a suitably spaced, coaxially mounted filament 114' and an electrode array 116' of generally cylindrical configuration. As taught in the apparatus of FIGS. 1, 3 and 4 the filaments 114, 114' are connected in parallel to an alternating current supply (not shown); the alternately arranged anode electrodes 120, 120' and the cathode electrodes 122, 122' are connected together respectively in parallel across respective outlets of the alternating current power supply. The anode and cathode electrodes alternate positions during each half cycle of the power source, as previously mentioned. The coils of the electromagnets (not shown) which energize poles 118, 118' are serially connected across still another outlet of the alternating current power supply.

Referring to FIGS. 6 and 7 there is shown alternative embodiments of magnet poles 124 and 126 which may be utilized in conjunction with the various apparatus shown in the FIGURES 1-5 depending upon the surface configuration of the object to be coated. For example, pole 124 is designed with a concave surface, and when demountably secured to an electromagnet 82 and in conjunction with another suitably matched magnet, provides a converging magnetic field configuration of flux lines and could thus be utilized in coating a particular area within an overall exposed surface. Magnet pole 126 utilizes a convex surface and when demountably secured to an electromagnet 82 provides, in conjunction with another, suitably matched and spaced magnet, a generally divergent magnetic field configuration extending therefrom, which preferably could be utilized in coating large surface areas of an object.

As noted in FIG. 1 all exposed metallic surfaces, such

as for example, lead-in wires, connectors and the like should be either coated with the material to be deposited upon the object, or should be formed entirely of the material. All other types of materials within the evacuated volume should be covered and shielded with an electrically nonconducting, high temperature material, such as for example, ceramic or quartz tubing, and/or woven glass loom or prevent vaporization of undesired materials.

Satisfactory design parameters for a practical embodiment of the apparatus described hereinbefore and shown in FIG. 1 are as follows: The waveguide window 50 is three inches in diameter; the filaments 74, 74' are formed of .020 diameter titanium wire and are 37 mm. in diameter; and anode and cathode electrodes 60, 60' and 62, 62' respectively are formed of titanium wire and are spaced a distance of 14 mm. apart; the filaments 74, 74' are each axially spaced a distance of 20 mm. from the facing surface of window 50 at either side thereof; electrode arrays 56, 56' are spaced an axial distance of 10 mm. from filaments 74, 74' respectively; the filament is heated by its alternating current source in the range of from 900° C. to 1100° C. and generally to 950° C. at a voltage which can be regulated from 0-20 volts alternating current; the electrode array is operated at approximately 4000 volts alternating current; the electromagnets 82, 82' operate within the range of 50 to 100 watts, and generate a focusing magnetic field of a few gauss, e.g., 20 to 25 gauss; the process is conducted within the bell 14 at a pressure within the range of from 50-100 microns; the vacuum pump 28 is a conventional mechanical vacuum pump; the vacuum valve 30 is a sliding gate valve; and the inert gas valve is the type commonly known as a Veeco valve.

While the invention has been disclosed with respect to several embodiments thereof, it will be apparent to those skilled in the art that numerous variations and modifications may be made within the spirit and scope of the invention and it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. A sputtering apparatus for coating the surface of an object with highly accelerated atoms of a preselected material comprising;

- (a) enclosure means including a housing and base plate defining therewithin an evacuable airtight volume;
- (b) inert gas source means communicably coupled to said evacuable volume within said enclosure means;
- (c) vacuum pump means communicably coupled to said evacuable volume within said enclosure means;
- (d) electrical terminal means integrally secured to said enclosure means to extend into said evacuable volume in electrically insulated relation;
- (e) support means integrally secured to the upper

surface of said plate and extending upwardly therefrom into the central region of said evacuable volume, said support means being adapted to secure and suspend said object to be coated substantially above said plate;

- (f) filament means formed of said preselected material disposed in close proximity to said object at either side thereof;
- (g) gaseous discharge electrode means including an alternate plurality of cathode and anode electrodes formed of said preselected material disposed in spaced aligned relation in close proximity to said filament means on either side thereof opposite the object to be coated;
- (h) electromagnetic field generating means including two electromagnets disposed in spaced-apart aligned relation behind said gaseous discharge electrode means on either side thereof opposite said object to be coated;
- (i) and alternating current power source means having a plurality of outputs each coupled via respective terminal means in electrical parallel to said filament means, and to said gaseous discharge electrode means, and in electrical series to said electromagnetic field generating means.

2. The sputtering apparatus in accordance with claim 1 wherein said object to be coated is a planar circular waveguide window and wherein said filament means comprises a substantially circular loop of wire; said gaseous discharge electrode means comprises alternately arranged cathode and anode electrodes formed of straight lengths of wire, the lengths of said wires being varied to form an array having a generally circular configuration with a diameter substantially the diameter of said window; and said electromagnetic field generating means further includes magnet pole means of generally truncated cone shape disposed in facing opposed relation to generate therebetween a magnetic field having a generally circular cross section and a graduated diameter substantially matching the diameters of said waveguide window and said gaseous discharge electrode means.

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