

ARC DEPOSITION APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

5 The present invention relates to arc deposition apparatus and methods of use thereof for thin film coating of substrates, and in particular to improved direct cathodic arc deposition apparatus and methods for increasing operational time and efficiency of the apparatus in use.

10 Examples of arc processes include general DC arc and AC arc deposition (for example, see "Comparison of DC and AC arc thin film deposition techniques", Schuelke, *et al.*, Surface Coatings and Technology, 120-121 (1999) 226-232), and filtered cathode vacuum arc (FCVA) deposition (such as described in WO-A-96/26531).

15 Arc deposition processes generally include applying an electric field between a cathode target and an anode, both of which are located within an evacuated chamber. Free electrons flow from the cathode to the anode, creating a plasma vapour of positively charged target ions and negatively charged electrons in the chamber, the ions moving
20 along a line of sight away from the target. A substrate to be coated is placed within the chamber in the line of site of the target and therefore is coated by the ions.

Known problems associated with arc deposition processes techniques include control of the arc spot on the surface of the target, where the arc moves in an unpredictable manner
25 and may move off the edge of the target. Several techniques have been employed to control the movement of the arc, including the use of a magnet close to the target to confine the arc. The magnets used in such processes typically have an annular south polar portion and a central, round north polar portion bounded by the south polar portion. This magnet forms a toroidal magnetic field which contains the arc. In practice, the arc tends to
30 move around the north polar portion within the magnetic field, such that the toroidal magnetic field acts as a race.

A problem associated with using such magnets is that by controlling the arc to move

within the magnetic field of the magnet, the target erodes unevenly along the arc path. As the uneven erosion occurs, the magnetic field at the more eroded path on the target increases, forming localized hot spots and increasing emission of unwanted macroparticles.

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It is an object of at least one of the embodiments of the present invention to overcome or ameliorate at least one of the problems associated with the prior art.

10 SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided an arc deposition apparatus comprising:

15 a target positionable in communication with an interior of an evacuable chamber, and adapted for electrical communication with an electrical power source for providing an arc on an emission surface of the target; and

means for providing a magnetic field adjacent the target for controlling the arc, wherein the magnetic field means is movable relative to the target to move the arc on the emission surface in a predetermined manner.

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Advantageously, by moving either the magnetic field means or the target relative to one another, while controlling, or moving the arc in a predetermined manner, it is possible to improve target utilization. By improving target utilization, operational times of the apparatus can be increased, downtime as a percentage of overall operation time can be
25 decreased, and consumable costs per coated substrate can be reduced.

Preferably, the target is tubular having a bore defining a central axis and the magnetic field means is a magnet rotatable within the bore about the axis, such that the arc is movable about the emission surface in a predetermined manner.

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Preferably, the magnet comprises a support; at least two elongate south polar members on the support, the south polar portions having parallel main portions spaced equidistantly from a central magnet axis, and which are joined to each other at at least one of their

respective adjacent ends; and at least one elongate north polar member on the support, the north polar portion being parallel to the main portions and spaced apart therefrom.

Preferably, the south polar members are joined to each other at at least one of their respective adjacent ends by a south polar end cap. Alternatively, the south polar members are joined to each other at at least one of their respective adjacent ends by respective south polar end portions which are radially inwardly directed such that they meet at the axis.

There are preferably three said south polar portions and three said north polar portions, wherein the respective main portions of the three south polar portions are equidistant to each other about the axis and wherein the respective end portions of the south polar portions are joined at the magnet axis, the magnet being configured such that respective said north polar portions alternate with respective south polar main portions about the magnet axis.

Preferably, the magnet is rotatably positionable in the bore such that the magnet axis is common to the target axis, and the target is positionable in an upright position in a central location within the chamber. The target and the magnet are preferably from 0.1m to 2m in length and target diameter is from 0.04 to 0.2m.

Advantageously, by using a cylindrical target with a magnet rotating therein, it is possible to emit ions radially from the target in up to 360°, depending on the amount of rotation of the magnet. This has the affect of increasing the areas within the chamber where substrate can be placed in line of sight of the target emissions.

Alternatively, the target is planar. In this arrangement, the apparatus may comprise means for moving the target laterally with respect to the magnetic field means. Also preferably, the emission surface may be rounded or rectangular. Also in this arrangement, the magnetic field means is preferably a magnet comprising a looped south polar portion on a plane parallel to a target plane, and a north polar portion on the plane, the north polar portion bounded by and not in contact with the south polar portion. Preferably, the south polar portion is an oval-shaped elongate loop and the north polar portion is an elongate bar. Also preferably, an elongate length of the south polar portion is at least 80% of a longitudinal length of the target, and has an elongate length of from 0.05m to 2m and a

width from 0.05m to 0.5m. The target may be from 0.05m to 2m in length and 0.1m to 0.5m in width.

Advantageously, by using a planar target, the number of potential materials for use as the target is increased, as it is normally it is easier to form a planar target, compared to forming a hollow cylindrical target.

In an alternative arrangement, the south polar portion is a circular loop and the north polar portion is circular, the diameter of the south polar portion being substantially less than a longitudinal length of the target. The south polar portion preferably has a diameter in the range of 0.05m to 0.1m.

Means for moving the target on a target plane parallel to the magnet plane are also preferably provided and the target preferably supported by a heat extractable target support means. In such an arrangement, the target support means comprises a support plate substantially in contact with one surface of the target, the support plate comprising channels therethrough for passage of coolant fluid for heat extraction.

The apparatus preferably also comprises an adjusting device for adjusting the position of the magnetic field means with respect to the target.

In one arrangement, the apparatus comprises a housing hermetically attachable to a port on a wall of the chamber, the housing containing the target and the magnetic field means.

The target and the magnetic field means may be positionable within the chamber or centrally within the chamber.

The target is preferably selected from, though not limited to any one of carbon, titanium, chromium, nickel, aluminium, copper and a suitable alloy thereof.

The apparatus is preferably adapted for use in one of the processes of DC arc deposition, AC arc deposition, cathode vacuum arc (CVA) deposition and filtered cathode vacuum arc (FCVA) deposition.

The magnet may be either one of a permanent magnet and an electromagnet.

According to another aspect of the invention there is provided an arc deposition system
5 comprising:

an evacuable chamber; and

an arc deposition apparatus according to the first aspect of the invention in
communication with an interior of the chamber; and

an electrical power source in electrical communication with the target as a cathode

10 and a sidewall of the chamber as an anode.

Preferably, the chamber comprises a lid having a lid port therein, and wherein the arc
deposition apparatus is configured according to the first aspect of the invention, the
apparatus depending at least in part through the lid port, such that at least a substantial
15 portion of the target and magnet are locatable within the chamber.

Preferably, the lid is round and the lid port is centrally located on the lid.

Preferably at least one substrate to be coated by the arc deposition apparatus is
20 positionable within the chamber between the target and a sidewall of the chamber.

Preferably, the system further comprises at least one secondary anode in the chamber and
in electrical communication with the electrical power source, located such that the
substrate is positionable between the sidewall and the secondary anode.

25 If secondary anodes are not used, there is a limitation on the amount of substrate possible
to place in the chamber for coating, since by overcrowding the chamber with substrate, it
will block the path from the cathode (target) to the anode (chamber wall), and the arc will
die. Therefore, space must be provided between substrates to ensure the path for electron
30 flow is made available. Advantageously, by using secondary anodes, it is possible to
provide more substrates within the chamber, since it then does not matter that the electron
path to the chamber wall (as primary anode) is blocked.

Preferably, the chamber comprises a sidewall and a port on the sidewall, and the housing is releasably hermetically attachable to the port.

5 Preferably, the chamber comprises a plurality of the ports and the system comprises a plurality of the apparatus, each apparatus being releasably hermetically attachable to a respective one of the ports.

10 Preferably, the system comprises at least a first and a second said arc deposition apparatus wherein the first arc deposition apparatus has a first target of a substance selected from the group of carbon, titanium, chromium, nickel, aluminium, copper, or an alloy thereof, and the second arc deposition apparatus has a second target of a substance selected from the group of carbon, titanium, chromium, nickel, aluminium, copper, or an alloy thereof, wherein the substance of the second target is different to the substance of the first target.

15 Advantageously, by using two or more apparatus in communication with the chamber, it is possible to coat substrates with more than one target material, either by layering the substrate with alternate layers of different material, or by coating the substrate with a homogenous layer of more than one material.

20 The system may also comprise at least one substrate support for supporting the substrate within the chamber, and the at least one substrate support may be movable, or rotatable within the chamber.

25 According to a third aspect of the present invention there is provided an arc deposition method for coating a substrate comprising the steps of:

positioning a target and a substrate to be coated in communication with an interior of an evacuable chamber;

evacuating the chamber to a predetermined pressure;

30 providing an electrical power source to the target to produce an arc on an emission surface of the target, the arc ionizing the target at the emission surface;

providing a magnetic field adjacent the target for controlling the arc on the emission surface; and

moving the magnetic field relative to the target to move the arc on the emission

surface in a predetermined manner.

Preferably, the target is tubular having a bore defining a central axis and the magnetic field is provided by a magnet which is rotated within the bore about the axis, such that the arc
5 moves about the tubular target in a predetermined manner. In this arrangement, the magnet is continually rotated in one rotation direction for a predetermined number of rotations, such that target is emitted from the emission surface about 360° of the target.

The target may also be planar, as discussed above.

10 Preferably, the predetermined pressure is about 1 μ Torr. The method may also include the step, after the step of evacuating the chamber, of introducing a gas to increase the chamber pressure in the range of 1mTorr to 20mTorr. Preferably, the gas is one of oxygen and nitrogen, and is introduced to increase the chamber pressure to about 3mTorr.

15 Preferably, after a predetermined time, the movement of the magnetic field and the provision of the electrical power source is stopped, the pressure in the chamber raised to atmospheric pressure, and the axial position of the magnet is adjusted with respect to the target, prior to repeating the steps. Alternatively, after a predetermined time, prior to
20 repeating the steps of the method, the movement of the target and the provision of the electrical power source is stopped, the pressure in the chamber raised to atmospheric pressure, and the position of the magnet is adjusted with respect to the target and on the magnet plane in a direction normal to the lateral movement of the target.

25 Preferably, the method comprises providing a secondary magnetic field about a portion of the chamber, the secondary magnetic field having a reversed polarity to the magnet such that the secondary magnetic field is adjacent and substantially parallel to the emission surface.

30 Preferably, at least one secondary anode in the chamber and in electrical communication with the electrical power source, located such that the substrate is positionable between the sidewall and the secondary anode.

The method may be adapted for use in one of the processes of DC arc deposition, AC arc deposition, cathode vacuum arc (CVA) deposition and filtered cathode vacuum arc (FCVA) deposition.

- 5 Preferably, the electrical power source is provided by a direct current (DC) device and provides a current in the range of 60 to 300A, and more preferably, the current is about 150A. Alternatively, the electrical power source is provided by an alternating current (AC) device.
- 10 The magnet preferably has a field strength of about 1000G ($3.4 \times 10^{-7} \text{Cs}^{-1}$).

According to another aspect of the present invention there is provided a magnet for use with an arc deposition apparatus, the magnet comprising:

a support;

- 15 at least two elongate south polar members on the support, the south polar portions having parallel main portions spaced equidistantly from a central magnet axis, and which are joined to each other at at least one of their respective adjacent ends; and
at least one elongate north polar member on the support, the north polar portion being parallel to the main portions and spaced apart therefrom.

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The magnet is preferably adapted for use in one of the processes of DC arc deposition, AC arc deposition, cathode vacuum arc (CVA) deposition and filtered cathode vacuum arc (FCVA) deposition.

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BRIEF DESCRIPTION OF THE DRAWINGS

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Preferred embodiments of the invention will now be described, by way of example only and where like reference numerals denote like parts, with reference to the accompanying drawings in which:

Figure 1A is a top schematic view of a chamber employing arc deposition apparatus according to one example of the present invention;

Figure 1B is a front sectioned elevation of the chamber illustrated in Figure 1A, taken on line 1B-1B;

5 Figure 2 is a front elevation of the arc deposition apparatus illustrated in Figure 1;

Figure 3 is sectioned view of the arc deposition apparatus of Figure 2;

Figure 4 is a sectioned view of the arc deposition apparatus of Figure 2, taken on line 3-3;

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Figure 5 is a perspective view of an arc deposition apparatus according to a second example of the invention;

Figure 6 is an exploded perspective view of the arc deposition apparatus illustrated in

15 Figure 5;

Figures 7A to 7C are various views of the arc deposition apparatus illustrated in Figure 5;

Figure 7D is a detail view of Figure 7C taken on line 7D;

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Figure 8 is a sectioned top view of the arc deposition apparatus illustrated in Figure 7C, taken on line 8-8;

Figure 9 is a perspective view of a component of the arc deposition apparatus illustrated in

25 Figure 5;

Figure 10 is an exploded view of the component illustrated in Figure 9;

Figures 11A and 11B are various elevations of the component illustrated in Figure 9;

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Figure 11C is a sectioned top view of the component illustrated in Figure 11B, taken on line 11C-11C;

Figures 12A and 12B are side elevations of a magnet for use with the arc deposition apparatus illustrated in Figure 5;

Figure 13 is a perspective view of a third example of an arc deposition apparatus according to the present invention;

Figure 14 is a side elevation of the arc deposition apparatus illustrated in Figure 13;

Figure 15 is a sectioned view of the arc deposition apparatus illustrated in Figure 14, taken on line 15-15;

Figure 16 is a detailed sectioned side elevation of the arc deposition apparatus illustrated in Figure 13;

Figure 17 is a perspective view of a subchamber component for use with the arc deposition apparatus illustrated in Figure 13;

Figure 18 is a top view of the component illustrated in Figure 17;

Figure 19 is a sectioned view of the component illustrated in Figure 18, taken on line 19-19;

Figure 20 is a sectioned view of the component illustrated in Figure 18, taken on line 20-20;

Figures 21 and 22 are a perspective views of components for use with the arc deposition apparatus illustrated in Figure 13; and

Figure 23 is a perspective view of a magnet for use with the arc deposition apparatus illustrated in Figure 13.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

5 The preferred embodiments of the invention will be best illustrated by referring to three examples which employ the invention's main principles.

Example 1

10 Referring to Figures 1 to 4 and in particular to Figure 1, a first example of an embodiment of the invention is an arc deposition apparatus in the form of a columnar DC (direct current) arc apparatus 50, for emission of ions in a preferably stainless steel, evacuable and hermetically sealable chamber 52 having a base 54, a sidewall 56 extending upwardly from the base, and a lid 58. The DC arc apparatus 50 is made available for use in the chamber 52 by depending through an aperture 60 in the lid 58. Insulation and sealing
15 means in the form of an o-ring 62 provides both electrical insulation and hermetic sealing between the DC arc apparatus 50 and the lid 58. The chamber 52 further comprises an outlet 64 for evacuating the chamber and an inlet 66 for introducing a gas, if required. The chamber in this embodiment is about 1m in diameter, however in alternative embodiments may be of larger or smaller diameters.

20 As will be understood in relation to the use of this embodiment as described below, it is preferred that the DC arc apparatus 50 depends in a vertical orientation, though in alternative embodiments, it may be desirable for the DC arc apparatus 50 to depend at any angle, or to be made available for use in the chamber 52 in a horizontal orientation by
25 passing through an aperture in the sidewall 56.

Referring to Figure 3, the DC arc apparatus 50 comprises an apparatus support 70 which is sealingly seated in the lid's aperture 60, and from which depends a target in the form of a hollow cylindrical cathode 71. The cathode 71 is made from material that is required for
30 the arc deposition process, but is typically one of copper, titanium, or aluminium, or a suitable alloy thereof. Other materials such as chromium or nickel may be used, however in practice the choice of material is limited to those which are able to be formed, molded or machined into a hollow cylinder. The cathode 71 is about 1m in axial length, though

alternatively may be chosen from the range of 0.1 to 2m. The cathode 71 has a diameter of about 0.06m and a wall thickness of typically 0.01m, but may have a diameter in the range of about 0.04m to 0.2m and a wall thickness in the range of about 0.01m to 0.02m. The cathode 71 in this example is attachable at one of its ends 72 to the support 70 by a collar 73, though in alternative arrangements may be threadedly engaged to the support 70. An advantage in using the collar 73 over a threaded arrangement is that less machining of the cathode is required. The apparatus support 70 includes a main portion 74 and a flange 76 about the main portion 74. The flange 76 bears the majority of the weight of the DC arc apparatus 50 on the lid 58. As will be understood, the cathode 71 is arranged to "float" within the chamber - that is, the cathode is not grounded.

The DC arc apparatus 50 also includes a rotatable shaft 78 which supports a magnet 80 for rotation about the shaft's axis 82. A rotational device 83 for rotating the shaft 78 is contained within the apparatus support 70.

The magnet 80 comprises a central iron core 84 upon the shaft 78, having a low friction fit thereupon. The friction fit has a low enough friction co-efficient to allow axial adjustment of the magnet 80 on the shaft 78, but also sufficient friction such that rotation of the shaft 78 about its axis permits rotation of the magnet 80 therewith. The core 84 supports south and north polar portions 86 and 88 of the magnet 80 with spacers 90. The south polar portions 86 comprise three elongate parallel main portions 86a which are equispaced both from the axis 82 and from each other. The main portions 86a are joined together at one end 86b by an end cap portion 86c and at their other end 86d by end cap portion 86e. In this embodiment, as illustrated in Figures 2 and 3, the end portions 86c and 86e are disc-like. The magnet 80 also includes three distinct elongate parallel north polar portions 88, each being equispaced from the axis 82 and equispaced from each other. The north polar portions 88 are arranged between the main portions 86a of the south polar portions 86 such that they alternate with but do not contact the main portions 86a. The arrangement of the south and north polar portions 86 and 88 provides three elongate toroidal magnetic fields along the length of the magnet 80. This effect provides elongate magnetically bounded looped "tunnels" about each of the north polar portions 88 and over an emission surface 89 of the cathode 71. The desirable lateral field strength of the magnet at the emission surface 89 is in the range of 50G-300G (preferably about 100G). This is achievable by

the magnet having a field strength of about 1000G. Given the dimensions of the magnet 80 with respect to the cathode 71, the longitudinal length of the tunnels is approximately 80 % the length of the cathode, allowing more control of the arc on the cathode surface, in that the arc is less likely to move off either end 72 or 91 of the cathode. In alternative
5 embodiments, the tunnel lengths may be from 50% to 95% of the cathode length.

In an alternative arrangement, the end portions are spoke-like and radially directed, being joined together at one end at the axis 82, and being radially directed from the axis to their respective ends 86b and 86d of the main portions 86a. The spoke-like end portions of this
10 alternative arrangement need not be normal to the axis 82, but can be radially directed at another angle from the axis, for example from 20° to 89°.

An end cap 92 is attachable to the other end 91 of the cathode 71 by a cap collar 96. An adjustment screw 98 is threadedly received in the end cap 92 to manually adjust the axial
15 position of the magnet 80 with respect to the cathode 71. The magnet also rotatably bears upon an end 100 of the screw 98. A resilient biasing means is provided in the form of a helical spring 102 inbetween an abutment flange 104 fixedly mounted to the shaft 78, and an end 104 of the magnet 80. The biasing means biases the magnet 80 toward the end cap 92 and upon the screw end 100.

As illustrated in Figure 1, an electrical power source 105 of DC is provided between the cathode 71, and the sidewall 56, acting as an anode. In use in the present example, the current of the DC source is about 150 A, but may be in the range of 60-300 A. Depending
20 on the resistance of the cathode 71, the voltage is typically 25 V. Applying DC to the cathode 71 has the undesirable affect of overheating it. Coolant inlet and outlet ports 106 are therefore provided for flow-through of coolant between the magnet 80 and the cathode 71. For this reason, the magnet is usually coated in an epoxy paint to prevent corrosion. The coolant is typically water, but may be any suitable fluid which can be used to transfer
25 heat from the cathode.

In one preferred method of use of this embodiment of the invention, substrates 107 to be coated are placed about the centre of the chamber, preferably adjacent the chamber
30 sidewall 56. The lid 58 with DC arc apparatus 50 depending centrally therefrom, is

positioned to hermetically close the chamber 52. The chamber 52 is then evacuated via outlet 64 to a chamber pressure of about $1\mu\text{Torr}$ before introducing a gas via the inlet 66 to increase the pressure in the chamber 52 to about 3mTorr though in alternative embodiments may be in the range of 1 to 20mTorr . It should be noted that the location of the inlet 66 is not important.

The choice of gas introduced to the chamber 52 depends on the type of coating desired. Examples of introduced gases include nitrogen or oxygen. As will be apparent, introducing nitrogen will result in metal nitride coatings on the substrate, while introducing oxygen will result in metal oxide coatings, where the metal component of the nitride or oxide depends on the material used for the cathode 71.

Once the desired chamber pressure is reached, the shaft 78 is rotated by the rotational device 83, the rotation of the shaft in turn rotating the magnet 80 within the cathode 71. This causes the magnetic field tunnels to follow the rotation of the magnet 80, such that they move around the surface 89 of the stationary cathode 71. While the rotational speed of the magnet within the cathode 71 is not important, in this embodiment it is about 10 rpm. The magnet is fully rotated within the target for a predetermined number of rotations. The number of rotations required will depend on the thickness of cathode material desired to be coated on the substrates.

The DC source 105 is actuated to provide electrons to the cathode 71. This in turn creates a negative electrical charge build up on the surface of the cathode 71. Once a predetermined charge is reached, an arc may then form on the surface of the cathode, as charge is passed from the cathode to the chamber sidewall 56, acting as the anode. To aid in arc formation, a striker (not shown) is typically used. Strikers are known in the art, and so will not be discussed in any detail in relation to this example.

The magnetic field tunnels contain the movement of the arc therein. In theory there may be one, two or three arcs moving on the surface of the cathode, each within a respective magnetic field tunnel. In practice however, a single arc is formed where the striker strikes the cathode 71, and moves on the cathode surface 89 around an adjacent one of the north polar portions 88 and within its respective magnetic field tunnel.

The point of the arc on the emission surface 89 forms a localized hotspot from which the cathode 71 is more intensely ionized or vaporised. Negatively charge electrons are then drawn to the anode, or chamber sidewall 56. Most positively charged ions are thrown
5 from the cathode, but return to the negatively charged cathode, due to the ions' positive electrical charge. Some ions however, escape the charge of the cathode 71 and travel in a line-of-sight away from the cathode 71. Since the substrates are positioned in this line-of-sight, certain ions coat the substrate.

10 Due to the presence of the gas in the chamber, electrons fleeing the cathode impact and ionize the gas molecules. Types of coatings achievable are described above.

As discussed above, the magnet rotates during the coating process. Therefore, as the arc moves on the cathode surface 89 within the moving magnetic field path, cathode and gas
15 ions are emitted, or fired away from the cathode in a sweeping manner and a radial, or angular, direction with respect to the cathode 71. The DC arc apparatus 50 and method therefore has two distinct advantages over the prior art. Firstly, since the apparatus and method allow for predetermined, controlled movement of the arc about target, emission of ions of the cathode is substantially even about the cathode. If the magnetic field did not
20 move relative to the cathode 71, an eroded trench would eventually form along the path of the arc, thus wastefully underutilizing the cathode 71. Also, the local heat along the path of the arc would be greater than elsewhere on the cathode, resulting in an increased production of unwanted macroparticles. Further, due to the up to 360° moving angular emission of ions from the central location of the cathode 71 in the chamber 52, it is
25 possible to coat more substrate surfaces compared with emissions radiating from a fixed cathode and magnet from a side location with respect to a chamber.

As discussed above, the longitudinal length of each magnetic field tunnel is about 80% of the longitudinal length of the cathode 71. In practice, during use of the DC arc apparatus
30 50, two eroded ringed trenches form on the cathode about its axis where the arc passes over a point passed on a previous pass of the arc. This ringed trench is adjacent to the longitudinal ends 108 of the north polar portion 88. For this reason, the adjustment screw 98 is provided. After a predetermined number of coating procedures, the screw is

manually turned to change the axial position of the magnet relative to the cathode, to prevent, at least in part, the formation of the eroded ring trenches and thus further increase the life of the cathode.

- 5 If too many substrates are placed in the chamber 52 such that the path between the cathode 71 and the sidewall (anode) 56 is substantially blocked, the arc may stop during the arc sweep, thus resulting in a breakdown of the plasma, or emission of cathode ions. To overcome this problem, and in turn to allow for an increase in the volume of substrate able to be coated, secondary anodes in the form of vertical metal rods 109, preferably stainless steel, are provided in the chamber 52 between the cathode 71 and the substrates 107 to provide an electrical path. Six rods 109 are typically used, however more or less rods may be used depending on how many are required. The rods 109 are in electrical communication with the sidewall 56 and/or the DC source 105 and are narrow enough so as not to block unnecessarily the ion emission from the cathode 71. Of course, like the chamber sidewall 56, it is unavoidable that the rods 109 will be coated by emitted ions since they are in the path of the ion emission.

In this example, the substrates are placed on rotatable carousels in the form of rotatable plates 111 upon which substrates are placed such that all sides of the substrates are exposable to the ion emission. The plates are positioned about the centre of the chamber 52 and are rotatable during the coating process. In the example illustrated in Figure 1A, there are four substrates 107 and four plates 111. As will be apparent, it is possible to use more or less plates to coat more or less substrates. Alternatively, the carousels 111 may be upwardly cylindrical and have the substrates placed about thereon. Having cylindrical carousels further increases the number of substrates that may be coated during an arc deposition coating procedure.

A linear argon ion beam may also be employed in the chamber to clean the substrates prior to coating.

There are many types of substrate 107 which may be coated in the procedure. For example, tool punches or anvils may be coated with titanium nitride, to provide a hard coating over a relatively soft interior (eg steel). In such an embodiment, the procedure is

performed at a chamber temperature of about 500°C, though may be between about 400-600°C, resulting in a coating stress of about 1-2GPa and a hardness of about 2500kgmm⁻², where the heat in the chamber is provided by the plasma. In comparison, standard stress of titanium nitride coatings provided by prior art methods is about 2-3GPa. This

5 significantly reduced resultant stress compared to stress achievable by known methods is achievable because the preferred operating pressure of 3mTorr is less than is used in known methods (~20mTorr) and therefore the temperature of the ionized particles can be less. This lower pressure has not been usable before now, because it is difficult to achieve and maintain the lower pressure and at lower pressure it is more difficult to control the arc.
10 The improvements proposed by the present invention allow this lower pressure to be used practically.

Due to the lower operating temperature which is achieved, in other examples, certain plastics with high melting points may be metal coated for decorative or functional
15 purposes. Examples include ophthalmic applications and mobile telephones. For instance, an aesthetic reflective appearance may be provided on sunglass lenses or durability of optic lenses or mobile telephone casings may be improved in terms of hardness, scratch resistance and impact resistance. Also, in the case of mobile telephones, the interior of the plastic casing may be coated with a suitable metal to decrease the
20 electromagnetic radiation from the telephone in the direction of the user's head. This may aid in reducing the risk of brain tumors, the risk of which may be increased by mobile telephone use.

Example 2

25 Another example of the invention will now be described, with reference to Figures 5 to 12B, where like reference numerals from the previously described example refer to like parts in this example. In this example, the DC arc apparatus 50' is housed in an apparatus subchamber 110. The apparatus subchamber 110 is sealed on five sides 112, and has an
30 open port 114 for fluid communication with a complementary chamber port (not shown) on the chamber sidewall. In this embodiment, therefore, the DC arc apparatus 50' is in communication with the chamber 52 from the sidewall 56, rather than from the chamber centre. It will be apparent therefore, that in this embodiment, there is no aperture in the lid

58. Also in this embodiment, the cathode 71' and the magnet 80' are planar, lying on proximate parallel planes. The cathode 71' has a rectangular emission surface 89' and has dimensions 0.2m x 0.05m x 0.02m. However, as will be understood, the cathode 71' may be square, or of larger or smaller dimensions. For example, the cathode may be 1m x 0.2m x 0.03m. Also, the cathode may have rounded corners, or be oval or circular.

As illustrated in Figures 5, 6, 9 and 10, the cathode 71' is a component of a cathode assembly 116 slidably mounted within the subchamber 110. Fasteners 117 releasably clamp the cathode 71' in the cathode assembly 116 between first and second frame subcomponents 118 and 120, and a support plate 122. The first and second frame subcomponents 118 and 120, cathode 71', and support plate 122 are attached to and supported by a cathode frame 123. The support plate also functions as part of a cooling mechanism to transfer heat from the cathode 71' when in use. To do so, the support plate 122 is configured to be in substantial contact with a rear surface 124 of the cathode 71', and has hollow portions to facilitate fluid flow of a coolant, such as water, therethrough. An inlet 125 and an outlet 126 provide ingress and egress of the coolant through the support plate 122. The inlet 125 and outlet 126 are connected in fluid communication to the cathode frame 123, as illustrated in Figures 9 and 10.

The cathode assembly 116 is movable laterally with respect to the magnet 80' and within the subchamber 110. This is achievable by a movement means in the form of a pneumatic subassembly 129. The pneumatic subassembly 129 operates conventionally, as described below. In an alternative arrangement, the magnet 80' is laterally movable by movement means, and the cathode 71' fixed in relation thereto. In yet another alternative embodiment, both the cathode 71' and the magnet 80' are laterally movable.

The magnet 80' provides the same function to the magnet 80 of the previous embodiment. As illustrated in Figures 12A and 12B, it includes an elongate looped south polar portion 130 which bounds an elongate north polar portion 132. The south and north polar portions are fixed to an iron support plate 134 by spacers 90'. The configuration of the magnet 80' provides a tunnel-like magnetic field, as described above in relation to the previous

embodiment. The magnet 80' is fixed within the subchamber 110 and includes an adjustment screw 98' which allows adjustment of the longitudinal position of the magnet 80' with respect to the cathode 71' via a support rod 135 to which is attached the plate 134.

5 As illustrated in Figures 5 and 6, also included in the subchamber is an anode in the form of a pair of anode plates 136. The anode plates 136 are attached to the subchamber 110 by brackets 138 which are spaced to allow movement of a striker 140 therebetween such that the striker 140 can strike the cathode 71'. The purpose of the striker is described above in reference to Example 1.

10 In use, substrates to be coated are placed centrally in the chamber 52 before the chamber is evacuated and gas introduced as described with respect to the above embodiment. A DC source is provided between the cathode 71' and the anode plates 136. The striker 140 is then used to create an arc on the cathode 71'. The arc provides for emission of the cathode
15 in a line-of-sight manner, as previously described, however due to the planar structure of the cathode 71', the emission is directed generally to the centre of the chamber 52 to coat the substrates. The substrates may be placed on a rotatable carousel, as described in reference to Example 1, to ensure they are evenly coated during the DC arc process.

20 The magnetic field tunnel provided by the magnet 80' controls the path of the arc on the surface of the cathode 71', such that the arc moves within the tunnel around the north polar magnet portion 132. To prevent the formation of an eroded trench on the cathode 71', the pneumatic subassembly 129 is employed to provide reciprocating lateral, or side to side, movement of the cathode 71' to move the cathode over the magnetic field of the magnet
25 80'. This in turn moves the magnetic field tunnel and therefore the arc's track across the emission surface 89' of the cathode 71'.

The longitudinal length of the magnetic field tunnel is about 80% of the longitudinal length of the cathode 71'. During use of the DC arc apparatus 50', two lateral linear eroded
30 trenches form on the cathode along where the arc passes over a point passed on a previous pass of the arc. This line of erosion is adjacent the longitudinal ends 142 of the north polar portion 132. It is for this reason that the adjustment screw 98' is provided. After a predetermined number of coating procedures, the screw 98' is manually turned to change

the longitudinal position of the magnet 80' relative to the cathode 71', to prevent, at least in part, the formation of the linear eroded trenches and thus further increase the life of the cathode.

- 5 This example of an embodiment of the invention is adapted to operate under the same or similar chamber pressures, magnetic fields and DC applied to the cathode and anode as described above in relation to Example 1. However, given the alternative arrangements of the DC arc apparatus, more space is provided in the chamber 52, resulting in lower operating temperatures. This allows for substrates of lower melting points to be coated in
10 this latter example when compared with Example 1.

- In an alternative embodiment of Example 2, the chamber 52 has four chamber ports to which are attached a respective one of four DC arc apparatus 50'. In this alternative embodiment, the four chamber ports are equispaced about the chamber wall, and the DC
15 arc apparatus 50 arranged to direct emission toward the centre of the chamber. Advantages of this arrangement include that the substrate may be coated with more than one cathode material. For example, to provide a titanium aluminium nitride (TiAlN) coating on a substrate, nitrogen is present in the chamber, two opposed DC arc apparatus 50 use titanium cathodes 71' while another two opposed DC arc apparatus 50 use
20 aluminium cathodes 71'. The substrate is then rotated on the carousel to be coated on all sides to provide a TiAlN coat. Depending on the speed of rotation of the carousels, the substrates can be coated in different layers of emitted material (slower rotation), or have an effectively mixed coating (faster rotation).

- 25 In practice, more materials can be used as the cathode 71' in this example when compared with Example 1, since it is easier to form a planar cathode than a tubular one. Therefore, it would be appropriate to use chromium or nickel in this embodiment, as well as copper, titanium, or aluminium, or a suitable alloy thereof. While both Examples 1 and 2 are designed for use with metal cathodes, tetrahedral amorphous carbon (ta-C) may also be
30 used.

In one alternative embodiment of this example, the cathode is fixed, and the magnet is laterally movable.

In another variation of this example, the chamber is adapted to allow linear movement of the substrate across the port 114. This embodiment allows inline coating of substrates having a significant length, such as glass panels for example.

5

Example 3

Another example of a preferred embodiment of the invention will now be described, with reference to Figures 13 to 23, where like reference numerals from this example refer to like parts in the previous examples. This example makes use of the invention under different operating chamber pressure conditions, such that it is used with filtered cathodic vacuum arc (FCVA) techniques, such as those described in patent WO-A-98/03988. This example is therefore configured to be operated at lower pressure than the previous examples. This example uses one FCVA apparatus 50" which is housed in an apparatus subchamber 110" supported by a frame 144 such that the subchamber 110" is not electrically grounded. The subchamber 110" includes a lid 146 having an aperture 148. A port 150 is attachable at its proximal end 152 to the lid 146 to be communication with the subchamber 110" via the aperture 148. An anode 153 is fixed on a side of the port 150. The port is generally cylindrical and is attachable at its distal end 154 to a chamber (not shown) which houses the substrate. The chamber may be a double bend tube, as described in WO-A-96/26531.

In this example, as illustrated in Figures 21 and 22, the cathode 71" is planar and has preferred dimensions of 0.15m x 0.2m x 0.02m. While preferably rectangular at its emission surface 89", it may also be square, rounded, or circular. Similarly to the previous embodiment, the cathode 71" is also secured by a frame component 156 and a support plate 122", the support plate 122" having hollow portions to allow coolant flow therein via ports 157 to remove heat from the cathode 71".

The magnet 80" is fixed within the subchamber 110" closely adjacent the support plate 122". As illustrated in Figure 23, the magnet 80" has an annular south polar portion 130" which bounds a solid circular north polar portion 132". The south and north polar portions are fixed to an iron support plate 134" by spacers 90". The configuration of the magnet

80" provides a tunnel-like magnetic field about the north polar portion 132", as described above in relation to the previous examples. The south polar portion 130" has a diameter of about 70-80 mm, providing an arc diameter on the cathode emission surface 89" of about 30-60 mm. It will be apparent that the size ratio of the magnet 80" to the emission surface 89" in this example is smaller in comparison to examples 1 and 2.

Movable means are provided to move the cathode 71" laterally and longitudinally on the plane of the emission surface 89". In this example, two movable means are provided in the form of first and second motors, 158a and 160a, and first and second rails, 158b and 160b. In alternative embodiments, the movable means may be pneumatic or hydraulic. As illustrated in Figure 16, the subchamber 110" is sized to accommodate movement of the cathode 71" both laterally and longitudinally such that a substantial proportion of the cathode 71" can be moved over the magnetic field tunnel formed by the magnet 80".

The arc is more difficult to control in this example due to the lower operating pressure. Additional features are therefore provided to aid in controlling the arc. For example, means are provided for preventing an arc forming directly between the cathode 71" and anode 153 in the form of a thin metal sheet 162, fixed between the cathode 71" and the anode 153. Without the sheet, there is a risk of a direct arc due to the close proximity of the cathode 71" and anode 153. A hole (not shown) is provided in the sheet, its position corresponding to the position of the magnet 80", to allow the arc to form on the emission surface 89".

Also provided is a secondary magnetic field means in the form of a magnetic coil 163. This is arranged to provide a second magnetic field over the cathode, such that the second magnetic field flows in an opposite direction (a reversing field) to the tunnel field. The secondary magnetic field is positioned such that a null point is formed just above the cathode emission surface 89" and over the cathode 71" where the arc is formed.

Since in use the emission from the cathode is provided in a generally upward direction, a collection means in the form of an annular bowl 164 is provided above the thin metal sheet 162 to collect macroparticles which are released from the cathode 71", but fall back towards it. In alternative embodiments where the emission is generally horizontal, the

bowl is not required. A channel 166 is provided in the bowl 164 to allow movement therethrough of a striker 140", which operates in a known manner.

The use of this example is similar to the previously described examples, however a gas is not introduced into the chamber once the chamber has been evacuated to about 1 μ Torr. This example is therefore configured for comparatively much lower operating pressures compared to the previous examples.

In an alternative embodiment of this example, the cathode is fixed and the magnet is movable in a plane parallel to the target plane. In this embodiment, the magnet is movable laterally and longitudinally to provide a magnetic field over a substantial portion of the emission surface.

In all the examples of the invention so far described the substrate is preferably biased to reduce stress in the resulting coating. Biasing is provided by applying an electric potential, or voltage, to the substrate. Whereas a higher applied voltage may be desired to further reduce coating stress, problems can occur if the applied voltage is too high, such as affecting substrate properties; eg annealing of the substrate may occur. Also, the presence of a high electrical bias in the chamber 52 may affect the arc by causing the plasma to break down. Therefore, to be able to apply a higher current to the substrate to improve the coating properties, a pulsed voltage, or pulsed bias is applied to the substrate. The potential of the pulsed bias is -2 to -3 kV, though may be up to -5kV. The bias pulse lasts 5 to 10 μ s, but may last up to 120 μ s. The pulse frequency is 1 to 3 kHz, though may be up to 10kHz. Compared with known biasing potentials of about -600V, a bias of -2 to -3kV provides significant improvements to the properties of the coating.

In relation to Examples 2 and 3, the lateral or lateral and longitudinal movement of the cathode has been described as moving by way of pneumatic means. As will be apparent, the movement may be provided by other means, such as hydraulic movement means.

In all the embodiments described, DC is supplied between the cathode and anode, however as will be apparent to the skilled addressee, each embodiment can be adapted to accept an AC source. Also, as will be apparent to the addressee, where the magnets for each

example have been described as having north polar portions bounded by south polar portions, in alternative embodiments, the polarity of the portions may be reversed. In such alternative embodiments, south polar portions are bounded by north polar portions.

- 5 While the present invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes may be made to the invention without departing from its scope as defined by the appended claims.

CLAIMS

1 A physical vapour deposition apparatus comprising:

5 a target positionable in communication with an interior of an evacuable chamber,
and adapted for electrical communication with an electrical power source for providing an
arc on an emission surface of the target; and

means for providing a magnetic field adjacent the target for controlling the arc,
wherein the magnetic field means is movable relative to the target to move the arc
on the emission surface in a predetermined manner.

10 2 The apparatus of claim 1 wherein the target is tubular having a bore defining a
central axis and the magnetic field means is a magnet rotatable within the bore about the
axis, such that the arc is movable about the emission surface in a predetermined manner.

15 3 The apparatus of claim 2 wherein magnet comprises:

a support;
at least two elongate south polar members on the support, the south polar portions
having parallel main portions spaced equidistantly from a central magnet axis, and which
are joined to each other at at least one of their respective adjacent ends; and

20 at least one elongate north polar member on the support, the north polar portion
being parallel to the main portions and spaced apart therefrom.

4 The apparatus of claim 3 wherein the at least two elongate south polar members are
joined to each other at at least one of their respective adjacent ends by a south polar end
25 cap.

5 The apparatus of claim 4 wherein the at least two elongate south polar members are
joined to each other at at least one of their respective adjacent ends by respective south
polar end portions radially inwardly directed such that they are joined at the axis.

30 6 The apparatus of any of claims 3 or 5 comprising three said south polar portions
and three said north polar portions, wherein the respective main portions of the three south
polar portions are equidistant to each other about the axis and wherein the respective end

portions of the south polar portions are joined at the magnet axis, the magnet being configured such that respective said north polar portions alternate with respective south polar main portions about the magnet axis.

5 7 The apparatus of any of claims 2 to 6 wherein the magnet is rotatably positionable in the bore such that the magnet axis is common to the target axis.

8 The apparatus of any of claims 2 to 7 wherein the target is positionable in an upright position in a central location within the chamber.

10

9 The apparatus of any of claims 2 to 8 wherein the target and the magnet are from 0.1m to 2m in length and target diameter is from 0.04m to 0.2m.

10 The apparatus of claim 1 wherein the target is planar.

15

11 The apparatus of claim 10 comprising means for moving the target laterally with respect to the magnetic field means.

12 The apparatus of claim 10 or 11 wherein the emission surface is rounded.

20

13 The apparatus of claim 10 or 11 wherein the emission surface is rectangular.

14 The apparatus of claim 10 to 13 wherein the magnetic field means is a magnet comprising a looped south polar portion on a plane parallel to a target plane, and a north polar portion on the plane, the north polar portion bounded by and not in contact with the south polar portion.

25

15 The apparatus of claim 14 wherein the south polar portion is an oval-shaped elongate loop and the north polar portion is an elongate bar.

30

16 The apparatus of claim 14 or 15 wherein an elongate length of the south polar portion is at least 80% of a longitudinal length of the target.

17 The apparatus of any of claims 14 to 16 wherein the south polar portion has an elongate length of from 0.05m to 2m and a width from 0.05m to 0.5m.

5 18 The apparatus of any of claims 10 to 17 wherein the target is from 0.05m to 2m in length and 0.1m to 0.5m in width.

10 19 The apparatus of claim 14 wherein the south polar portion is a circular loop and the north polar portion is circular, the diameter of the south polar portion being substantially less than a longitudinal length of the target.

20 20 The apparatus of claim 19 wherein the south polar portion has a diameter in the range of 0.05m to 0.1m.

15 21 The apparatus of any of claims 14 to 18 comprising means for moving the target on a target plane parallel to the magnet plane.

22 The apparatus of claim 21 wherein the moving means are configured for moving the target laterally.

20 23 The apparatus of claim 19 or 20 wherein the moving means are configured for moving the target laterally and longitudinally.

24 The apparatus of any of claims 10 to 23 wherein the target is supported by a heat extractable target support means.

25 25 The apparatus of claim 24 wherein the target support means comprises a support plate substantially in contact with one surface of the target, the support plate comprising channels therethrough for passage of coolant fluid for heat extraction.

30 26 The apparatus of any preceding claim comprising an adjusting device for adjusting the position of the magnetic field means with respect to the target.

27 The apparatus of any of claims 10 to 26 comprising a housing hermetically

attachable to a port on a wall of the chamber, the housing containing the target and the magnetic field means.

28 The apparatus of any of claims 10 to 26 wherein the target and the magnetic field
5 means are positionable within the chamber.

29 The apparatus of any preceding claim wherein the target is selected from any one of carbon, titanium, chromium, nickel, aluminium, copper and a suitable alloy thereof.

10 30 The apparatus of any preceding claim wherein the arc deposition apparatus is adapted for use in one of the processes of DC arc deposition, AC arc deposition, cathode vacuum arc (CVA) deposition and filtered cathode vacuum arc (FCVA) deposition.

31 The apparatus of any preceding claim wherein the magnetic field means is one of a
15 permanent magnet and an electromagnet.

32 A physical vapour deposition system comprising:
an evacuable chamber; and
an arc deposition apparatus according to any of the preceding claims in
20 communication with an interior of the chamber; and
an electrical power source in electrical communication with the target as a cathode and a sidewall of the chamber as an anode.

33 The system of claim 32 wherein the chamber comprises a lid having a lid port
25 therein, and wherein the arc deposition apparatus is configured according to any one of claims 1 to 8, the apparatus depending at least in part through the lid port, such that at least a substantial portion of the target and magnet are locatable within the chamber.

34 The system of claim 33 wherein the lid is round and the lid port is centrally located
30 on the lid.

35 The system of claim 33 or 34 wherein at least one substrate to be coated by the arc deposition apparatus is positionable within the chamber between the target and a sidewall

of the chamber.

36 The system of claim 35 further comprising at least one secondary anode in the
chamber and in electrical communication with the electrical power source, located such
5 that the substrate is positionable between the sidewall and the secondary anode.

37 The system of claim 32 wherein the chamber comprises a sidewall and a port on
the sidewall, and the arc deposition apparatus is configured according to claim 27, and
wherein the housing is releasably hermetically attachable to the port.

10 38 The system of claim 37 wherein the chamber comprises a plurality of the ports and
the system comprises a plurality of the apparatus, each apparatus being releasably
hermetically attachable to a respective one of the ports.

15 39 The system of claim 38 comprising at least a first and a second said arc deposition
apparatus wherein the first arc deposition apparatus has a first target of a substance
selected from the group of carbon, titanium, chromium, nickel, aluminium, copper, or an
alloy thereof, and the second arc deposition apparatus has a second target of a substance
selected from the group of carbon, titanium, chromium, nickel, aluminium, copper, or an
20 alloy thereof, wherein the substance of the second target is different to the substance of the
first target.

40 The system of any of claims 37 to 39 wherein a substrate for coating by the arc
deposition apparatus is positionable within the chamber.

25 41 The system of claim 35, 36 or 40 comprising at least one substrate support for
supporting the substrate within the chamber.

42 The system of claim 41 wherein the at least one substrate support is movable for
30 moving the substrate within the chamber.

43 The system of claim 41 wherein the at least one substrate support is rotatable for
rotating the substrate within the chamber.

44 A physical vapour deposition method for coating a substrate comprising the steps of:

positioning a target and a substrate to be coated in communication with an interior

5 of an evacuable chamber;

evacuating the chamber to a predetermined pressure;

providing an electrical power source to the target to produce an arc on an emission surface of the target, the arc ionizing the target at the emission surface;

10 providing a magnetic field adjacent the target for controlling the arc on the emission surface; and

moving the magnetic field relative to the target to move the arc on the emission surface in a predetermined manner.

45 The method of claim 44 wherein the target is tubular having a bore defining a central axis and the magnetic field is provided by a magnet which is rotated within the
15 bore about the axis, such that the arc moves about the tubular target in a predetermined manner.

46 The method of claim 45 wherein the magnet is continually rotated in one rotation
20 direction for a predetermined number of rotations, such that target is emitted from the emission surface about 360° of the target.

47 The method of claim 45 or 46 wherein the magnet comprises:

a support;

25 at least two elongate south polar members on the support, the south polar portions having parallel main portions spaced equidistantly from a central magnet axis, and which are joined to each other at at least one of their respective adjacent ends; and

at least one elongate north polar member on the support, the north polar portion being parallel to the main portions and spaced apart therefrom,

30 wherein the magnetic field is toroidal and about the north polar portion.

48 The method of claim 47 wherein the at least two elongate south polar members are joined to each other at at least one of their respective adjacent ends by a south polar end

cap.

49 The method of claim 47 wherein the at least two elongate south polar members are joined to each other at at least one of their respective adjacent ends by respective south
5 polar end portions radially inwardly directed such that they are joined at the axis.

50 The method of any of claims 47 to 49 comprising three said south polar portions and three said north polar portions, wherein the respective main portions of the three south polar portions are equidistant to each other about the axis and wherein the respective end
10 portions of the south polar portions are joined at the axis, the magnet being configured such that respective said north polar portions alternate with respective south polar main portions about the magnet axis.

51 The method of any of claims 45 to 50 wherein the target and magnet are from 0.1m
15 to 2m in length and target diameter is from 0.04m to 0.2m.

52 The method of any of claims 45 to 51 wherein after a predetermined time, the movement of the magnetic field and the provision of the electrical power source is stopped, the pressure in the chamber raised to atmospheric pressure, and the axial position
20 of the magnet is adjusted with respect to the target, prior to repeating the steps.

53 The method of any of claims 45 to 52 wherein the target and the magnet are positioned within the chamber.

25 54 The method of claim 53 wherein the target and the magnet are positioned centrally within the chamber and the substrate is positioned between the target and a sidewall of the chamber, the sidewall being the anode of the electrical power source.

55 The method of claim 54 further comprising providing at least one secondary anode
30 in the chamber and in electrical communication with the electrical power source, located such that the substrate is positionable between the sidewall and the secondary anode.

56 The method of claim 44 wherein the target is planar.

57 The method of claim 56 wherein the magnetic field means is in a fixed position and the target is moved laterally on its plane with respect to the magnetic field means.

5 58 The method of claim 56 or 57 wherein the magnetic field is provided by a magnet comprising a looped south polar portion on a plane substantially parallel to a target plane, and a north polar portion on the plane, the north polar portion bounded by and not in contact with the south polar portion, the magnetic field being a toroidal and about the north polar portion.

10

59 The method of claim 58 wherein the south polar portion is an oval-shaped elongate loop and the north polar portion is an elongate bar.

60 The method of claim 58 or 59 wherein an elongate length of the south polar portion
15 is at least 80% of a longitudinal length of the target.

61 The method of claim 58 wherein the south polar portion is a circular loop and the north polar portion is circular, the diameter of the south polar portion being substantially less than a longitudinal length of the target.

20

62 The method of any of claims 56 to 61 wherein after a predetermined time, prior to repeating the steps of the method, the movement of the target and the provision of the electrical power source is stopped, the pressure in the chamber raised to atmospheric pressure, and the position of the magnet is adjusted with respect to the target and on the
25 magnet plane in a direction normal to the lateral movement of the target.

63 The method of any of claims 56 to 62 comprising a housing hermetically attachable to a port on a wall of the chamber, the housing containing the target and the magnetic field means.

30

64 The method of any of claims 56 to 63 comprising providing a secondary magnetic field about a portion of the chamber, the secondary magnetic field having a reversed polarity to the magnet such that the secondary magnetic field is adjacent and substantially

parallel to the emission surface.

65 The method of any of claims 44 to 64 wherein the predetermined pressure is about 1 μ Torr.

5

66 The method of any of claims 44 to 65 wherein after the step of evacuating the chamber, a gas is introduced to increase the chamber pressure in the range of 1mTorr to 20mTorr.

10 67 The method of claim 66 wherein the gas is introduced to increase the chamber pressure to about 3mTorr.

68 The method of claim 66 or 67 wherein the gas is one of nitrogen and oxygen.

15 69 The method of any of claims 44 to 68 adapted for use in one of the processes of DC arc deposition, AC arc deposition, cathode vacuum arc (CVA) deposition and filtered cathode vacuum arc (FCVA) deposition.

20 70 The method of any of claims 44 to 69 wherein the target is selected from any one of carbon, titanium, chromium, nickel, aluminium, and copper.

71 The method of any of claims 44 to 70 wherein the electrical power source is provided by a direct current device and provides a current in the range of 60 to 300A.

25 72 The method of claim 71 wherein the current is about 150A.

73 The method of any of claims 44 to 70 wherein the electrical power source is provided by an alternating current device.

30 74 The method of any of claims 44 to 73 wherein the magnet has a field strength of about 1000G.

75 A magnet for use with an arc deposition apparatus, the magnet comprising:

a support;

at least two elongate south polar members on the support, the south polar portions having parallel main portions spaced equidistantly from a central magnet axis, and which are joined to each other at at least one of their respective adjacent ends; and

at least one elongate north polar member on the support, the north polar portion being parallel to the main portions and spaced apart therefrom.

The magnet of claim 75 wherein the south polar members are joined to each other at at least one of their respective adjacent ends by a south polar end cap.

The magnet of claim 75 wherein the south polar members are joined to each other at at least one of their respective adjacent ends by respective south polar end portions which are radially inwardly directed such that they meet at the axis.

The magnet of any of claims 75 to 77 comprising three said south polar portions and three said north polar portions, wherein the respective main portions of the three south polar portions are equidistant to each other about the axis and wherein the respective end portions of the south polar portions are joined at the magnet axis, the magnet being configured such that respective said north polar portions alternate with respective south polar main portions about the magnet axis.

The magnet of any of claims 75 to 78 for use with the apparatus of claim 1 or 2.

An apparatus substantially as herein described with reference to the accompanying drawings.

A system substantially as herein described with reference to the accompanying drawings.

A method substantially as herein described with reference to the accompanying drawings.

A magnet substantially as herein described with reference to Figures 1A to 4 of the

accompanying drawings.