(12) UK Patent Application (19) GB (11) 2 147 916 A

(43) Application published 22 May 1985

(21) Application No 8421845

(22) Date of filing 29 Aug 1984

(30) Priority data
(31) 3331406 (32) 31 Aug 1983 (33) DE

(71) Applicant
Leybold-Heraeus GmbH (FR Germany),
Bonner Strasse 504, D-5000 Cologne 51, Federal Republic of Germany

(72) Inventors
Klaus Roll
Heinz Schuller
Gerd Deppisch

(74) Agent and/or Address for Service
Stevens Hewlett & Perkins,
5 Quality Court, Chancery Lane, London WC2A 1HZ

(51) INT CL[4]
C23C 14/34

(52) Domestic classification
C7F 1V2 2P 6F2

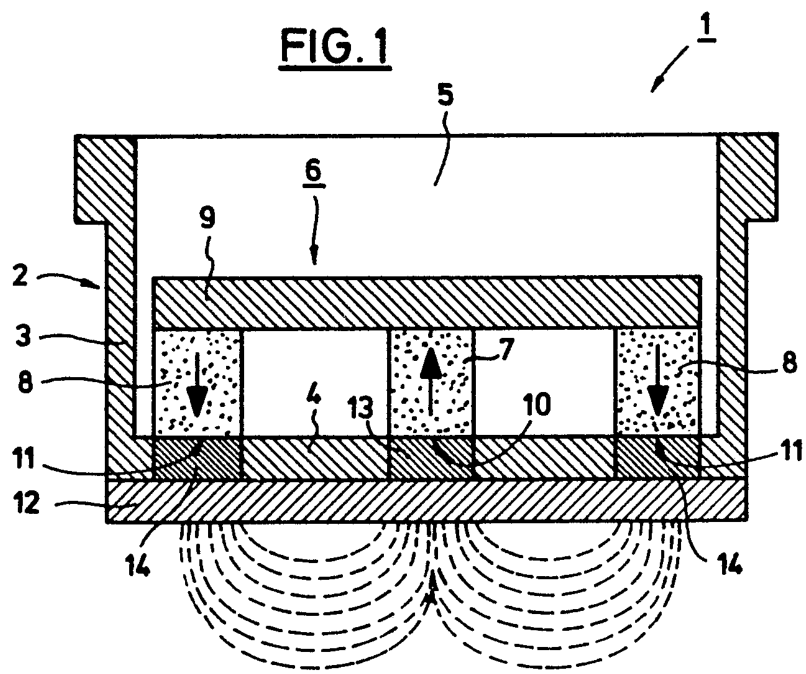
(56) Documents cited
GB A 2090872

(58) Field of search
C7F

(54) Cathodic evaporation of ferromagnetic targets

(57) In a cathode arrangement for cathodic evaporation installations, a magnet system 6 is arranged behind a target plate 12. The field lines emerging therefrom form a closed magnetic tunnel (magnetron cathode) in front of the target plate. The target plate is a detachable part of a trough-like hollow body 3, which surrounds the magnet system 6. To enable ferromagnetic target plates 12 to be atomized ferromagnetic parts 13 extend the pole zone of the magnet system directly to the rear face of the ferromagnetic target plate 12 without the formation of an air gap. The parts 13 may be strip-like intermediate elements which are welded to the bottom of the hollow body 3 and bridge the gap between the pole faces 10, 11 and the target plate 12 or the target plate may itself form the bottom of the hollow body (not shown). By using the stated arrangements, a thicker ferromagnetic target plate can also be brought more readily into the zone of magnetic saturation.

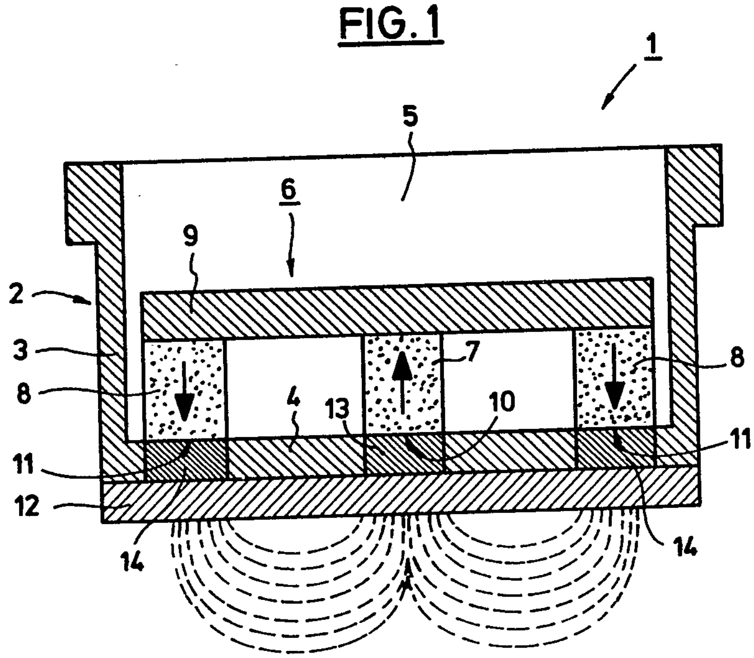
FIG. 1



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 147 916 A

FIG. 1



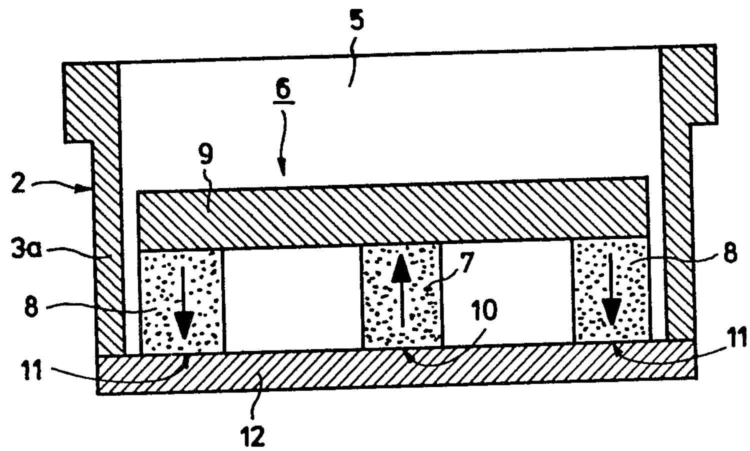
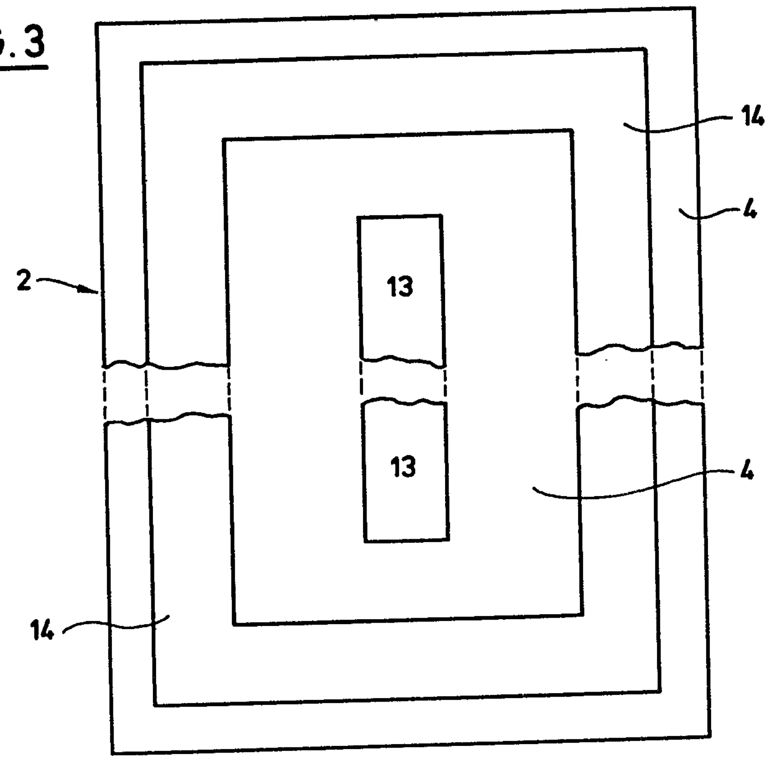


FIG. 2

FIG. 3



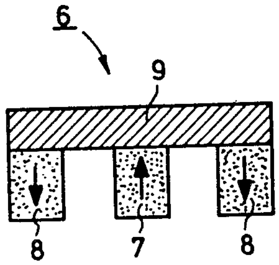


FIG. 4

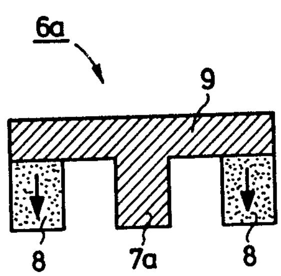


FIG. 5

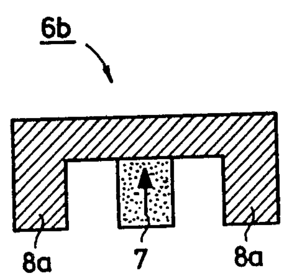


FIG. 6

SPECIFICATION

Atomizing cathode

This invention relates to a cathode arrangement for cathodic evaporation installations, comprising a target plate of ferromagnetic material and a magnet system which is located behind the target plate and comprises opposite poles which are arranged in such relative positions to the target plate that at least some of the field lines emanating from the poles pass out through the target plate and back into it, the target plate being a detachable part of a trough-like hollow body in which the magnetic system is accommodated.

A comparable cathode arrangement for non-ferromagnetic targets is known from DE–OS 30 47 113. The hollow body is made of a non-magnetic material such as copper and is in the shape of a rectangular trough with a parallelipiped cavity which is closed off by a bottom formed integrally with the trough. A target plate made of the material to be atomized is secured to the lower face of the bottom and flat against it. The pole faces extend into the immediate vicinity of the bottom of the trough, so that the magnetic field lines have to pass through the bottom of the trough—which has a thickness of several millimetres—and the target plate before they form a closed tunnel of magnetic field lines on the free surface of the target. Very special importance, however, attaches to this closed tunnel, which limits the glow discharge substantially to the zone of the target surface and therefore increases the atomization rate by a factor of 10 to 30. Cathode arrangements of this kind are also referred to as magnetron cathodes. It has been found that for a like geometry of the magnet system and with a like field strength, that part of the field lines that extends within the bottom of the trough is unusable. Thus, to compensate this effect, even in the case of target plates of non-magnetic material, a magnet system of correspondingly larger dimensions has to be used. However, the magnetic materials that might be considered for this purpose are extremely expensive. Furthermore, in the case of target plates of magnetic materials, such as have to be used, for example, in the production of magnetic recording tapes, considerably more serious problems arise.

In the case of ferromagnetic target plates, the magnetic flux is short-circuited to a considerable extent by the target material, so that a magnetic field of adequate strength cannot be built up in front of the face of the target by means of the existing arrangements. It is true that, in principle, it is possible to avoid this problem to some extent by providing external magnets in front of, or alongside the target plates, by forming faces on the target plate itself, for example by means of grooves or steps, or by heating the target plate to a level above its Curie point.

However, simply providing externally disposed magnet poles leads to deep and narrow atomization zones (erosion pits as they are called) and therefore to inefficient utilization of material. Furthermore, the magnet system itself is atomized to a relatively great extent, and this is extremely undesirable since it influences the properties of the coatings and leads to gradual "consumption" of the cathode arrangement. Grooves, slots or steps in ferromagnetic target plates likewise lead to erosion pits, which are strictly limited spatially, and therefore also to poor utilization of material. In addition, the cost of machining in the production of targets is undesirably high. The heating of the target plates to a level above the Curie point leads to heavy thermal loading of the substrates and calls for complicated cathode constructions to enable the thermal problems to be overcome.

A further possible way of atomizing ferromagnetic material consists in effecting magnetic saturation of the target plates. The required magnet mass depends on the thickness and the magnetizing of the target plates as well as upon optimization of the magnetic circuit. A technically achievable magnet system necessitates the use of target plates of small thickness which, for example in the case of target material of high iron content, is less than roughly 2 to 3 mm, and in the case of target material of high nickel content, is less than approximately 5 mm. The basis for this is the consideration that the magnetic field strength at the surface of the target should be at least 400 Oe approximately.

Whereas on the one hand the principle of magnetic saturation can be regarded as constituting the simplest method of atomizing ferromagnetic materials, this step, when use is made of the known magnetron constructions, involves the use of thin ferromagnetic target plates and therefore necessitates their frequent replacement accompanied by lengthy periods during which the entire vacuum installation is inoperative, so that heavy capital outlay is not thereby encouraged.

The object of the present invention is, therefore, to effect an improvement of a cathode arrangement of the initially described kind for enabling ferromagnetic target plates of greater thickness to be used and of therefore achieving a higher atomization rate together with a greater degree of utilization than hitherto.

According to the invention, this object is achieved in that the ferromagnetic parts extend in the pole zone of the magnet system directly to the rear face of the ferromagnetic target plate without an air gap.

The invention means that no air gaps or gaps made of non-magnetic material are to be present between the pole faces and the rear face of the ferromagnetic target.

Although DE–OS 31 24 599 and US–PS 4 169 031 disclose the idea of extending magnet poles to the immediate vicinity of the rear side of the target, this does not lead to any particular advantage in the case of the non-ferromagnetic targets mentioned, since the target material behaves as an air gap.

The invention can be reduced to practice by means of two basic constructional principles:

In a first form of construction, the hollow body has a bottom on which the target plate is laid, and strips of ferromagnetic material are inserted in the bottom in the pole zone of the magnet system, these strips closing the magnetic circuit between the magnet system and the target plate, the remaining part of the bottom being made of a non-magnetic material (e.g. copper).

In a second construction, the target plate is mounted in a gas- and liquid-tight manner on a frame and, together with the frame, forms the above-mentioned hollow body, the magnet system itself extending to the rear face of the target plate.

By means of the above-mentioned arrangements, direct magnetic coupling of the magnetic flux produced by the magnet system is achieved, and the magnetic flux is passed into closed magnetic circuits which consist of the magnet system, the target plate and, optionally, magnetic parts or strips (first form of construction). The magnetic circuits are of such dimensions that the magnetic flux emerges in part from the target plate in the zone of the target. The condition permitting this is

$$\phi_L > M_s . d \qquad (1)$$

wherein:

ϕ_L is the magnetic flux per unit of length,
M_s is the saturation magnetization of the target material,
d is the thickness of the target.

For a given target material, the thickness of the target plates and the magnet system must be in accordance with equation (1). The remaining zones of the magnetic circuit must be so dimensioned that only the smallest possible part of the magnetic system drops and only slight loss of magnetic flux occur therein. In the case of the first form of construction, this is achieved by the use of high-permeability materials such as, for example, Permalloy, Mu-metal, soft iron etc. in the bottom of the trough, as well as by adequately large cross-sections and by the avoidance of gaps transverse to the magnetic flux. In the case of the second form of construction, it is achieved by direct contact of the magnet poles and the target plate. In this way, the voltage produced by the magnet system drops mainly in the zone of the target plate, so that the target can be saturated. If, at the same time, the requirement in accordance with equation (1) is met, the excess magnetic flux in front of the surface of the target causes build-up of the known magnetic tunnel which suffices to atomize the target plate at a higher rate.

In the case of the presently known magnetic electrodes, however, only a very small part of the magnetic voltage decreases at the target plate, whereas the major part decreases at the gaps between the pole faces and the target plate and is therefore of no effect as regards the build-up of a magnetic tunnel on the surface of the target.

It is particularly advantageous to connect the ferromagnetic strips to the non-magnetic material of the trough by electron-beam welding, since this method produces only very slight mechanical stresses in the trough, and it is also possible to join together in a gas-and liquid-tight manner materials not deemed to be weldable by other processes.

The invention can also be used in the case of rotationally symmetrical cathode arrangements wherein the hollow body is designed as a circular cup, as well as in cathode arrangements of rectangular symmetry wherein the hollow body has a parallelipiped cavity as, for example, in the subject-matter of DE–OS 30 47 113.

Some embodiments of cathode arrangements according to the invention will now be described in greater detail by reference to the accompanying drawings which show only the functionally important parts of the cathode arrangements in a much simplified representation. In the drawings:–

Figure 1 is a cross-section through a cathode arrangement comprising a hollow body having a bottom on which the target plate is placed,

Figure 2 is a cross-section through a cathode arragement similar to that of Fig. 1, but wherein the bottom of the hollow body is formed by the target plate itself,

Figure 3 is an underneath view of the Fig. 1 arrangement with the target plate omitted, and

Figures 4, 5 and 6 illustrate respective forms of the magnet system.

Fig. 1 shows a cathode arrangement 1 which comprises a trough-like hollow body 2 comprising a surround 3 and a bottom 4, these two parts enclosing a substantially parallelipiped cavity 5.

The hollow body 2 is secured to a support plate, not illustrated, by way of which the cathode arrangement is connected to a vacuum chamber, likewise not illustrated. Details of an arrangement of this kind can be obtained from DE–OS 30 47 113.

Contained in the cavity 5 is a magnet system 6 which consists of a large number of permanent magnets 7 and 8. The permanent magnets 7 are arranged in a straight row and at the middle, whereas a closed series of permanent magnets 8 surrounds, and is spaced from, the permanent magnets 7. In this arrangement, the permanent magnets have a specific pole position indicated by the arrows, i.e. in the case of middle permanent magnets 7, all of the north poles are at the top for example, whereas all the south poles of the outer permanent magnets 8 are at the top

The upper pole faces of all the permanent magnets are in contact with a ferromagnetic yoke plate 9, whereas the lower pole faces 10 and 11 respectively rest on the bottom 4. A target plate 22 is connected to the bottom 4 and bears flat thereon, this being achieved, for example, by brazing.

In the zone of the pole faces 10 and 11, strips 13 and 14 of ferromagnetic material are let into the bottom 4 of the hollow body 2; these strips are of the same thickness as the bottom 4, and the lower and upper limiting faces of the strips and of the bottom respectively each lie in a common plane, i.e. they terminate flush with each other. The vertical planes of separation, visible in Fig. 1, have been joined together by electron-beam welding, so that the hollow body 2 and the strips 13 and 14 are inseparable and form a one-piece component. Thus, no air gaps at all are present between the permanent magnets 7 and 8, on the one hand, and the target plate 12 on the other. Instead, the entire space in the pole zone of the magnet system is bridged by ferromagnetic parts, i.e. the above-mentioned ferromagnetic strips.

Consequently, a closed magnetic tunnel develops along the relatively thick ferromagnetic target plate 12 in the direction of the magentic field lines, indicated by dashes, assuming that the relationship indicated above is maintained.

In Fig. 2, parts similar to those in Fig. 1 have been allotted the same reference numerals so that their description does not need to be repeated. In Fig. 2 however, the surround is not provided with a special bottom; instead it forms a frame 3a, on which the target plate 12 is directly mounted in a gas- and liquid-tight manner. Thus, the frame 3a and the target plate 12 together form a hollow body, and the magnet system 6 is extended directly to the rear face of the target plate 12. In this case, therefore, the ferromagnetic parts are formed by the permanent magnets 7 and 8 themselves or by their pole faces 10 and 11, so that the magnetic flux is enclosed in a similar way as in the arrangement of Fig. 1.

Fig. 3 is an underneath view of the Fig. 1 but without the target plate 12. The bottom 4 with the inserted ferromagnetic strips 13 and 14 can be seen. The inner ferromagnetic strip 13 extends along a straight line; the outer ferromagnetic strips 14 enclose the outer ferromagnetic strip 13 in the manner of a rectangular frame. The frame may be of one-piece construction but it may also consist of plurality of strip-like parts, which are likewise interconnected in a fluid-tight manner, preferably by electron-beam welding. It will be understood that the corners of the frame of the outer strips 14 may also be rounded. The length of the cathode arrangement is virtually unlimited, this being indicated by the break lines. As regards their position, the pole faces 10 and 11 of the magnet system 6 correspond to the position of the strips 13 and 14, respectively, in Fig. 3. The position of the pole faces 10 and 11 in Fig. 2 would also correspond, in projection, with that shown in Fig. 3.

Fig. 4 shows a magnet system 6 which corresponds to that of Figs. 1 and 2.

In the magnet system 6a shown in Fig. 5, only the outer rim of the permanent magnets 8 is present, whereas the inner permanent magnet is replaced by a pole shoe 7a on the yoke plate 9.

In the magnet system 6b illustrated in Fig. 6, the relationships are precisely reversed as compared with the Fig. 5 arrangement. The inner permanent magnet 7 is present, whereas the rim of outer permanent magnets is replaced by a circumferentially closed pole shoe 8a.

It will be seen from Figs. 5 and 6 that the magnet mass can be considerably reduced, and a minimum magnet mass can be achieved in the form of construction shown in Fig. 6. The magnet system shown in Figs. 5 and 6 can nevertheless be used with advantage in the invention, since the reduction of the magnetic losses to a minimum permits the use of a correspondingly smaller magnet mass.

It will be seen that in all of the forms of construction the magnet systems can be magnetically coupled to the target plate either directly or with the help of ferromagnetic or soft magnetic transmission elements. In the forms shown in Figs. 5 and 6, it is the pole shoes 7a and 8a which extend directly to the ferromagnetic strips 13 and 14 respectively (Fig. 1) or to the target plate 12 (Fig. 2). The ferromagnetic strips 13 and 14 of Fig. 1 thus constitute extensions of the pole shoes 7a and 8a respectively.

CLAIMS

1. A cathode arrangement for cathodic evaporation installations, comprising a target plate of ferromagnetic material and a magnet system which is located behind the target plate and comprises opposite poles which are arranged in such relative position to the target plate that at least some of the field lines emanating from the poles pass out through the target plate and back into it, the target plate being a detachable part of a trough-like hollow body in which the magnet system is accommodated, and ferromagnetic parts extending the pole zone of the magnet system

directly to the rear face of the ferromagnetic target plate without an air gap.

2. A cathode arrangement according to Claim 1, wherein the hollow body comprises a bottom of non-magnetic material against which the target plate is laid, and the ferromagnetic parts comprise strips of ferromagnetic material which are inserted in the bottom to close the magnetic circuit between the pole faces of the magnet system and the target plate.

3. A cathode arrangement according to Claim 2, wherein the ferromagnetic strips are inset into the bottom and connected thereto by electron-beam welding.

4. A cathode arrangement according to Claim 1, wherein the target plate is mounted in a fluid-tight manner on a frame and together therewith forms the hollow body, and the magnet system itself bears against the rear face of the target plate whereby said target plate itself constitutes said ferromagnetic parts.

5. A method of producing a hollow body as in Claim 2, wherein the ferromagnetic strips are connected to the non-magnetic material at the bottom by electron-beam welding.

6. A cathode arrangement for cathodic evaporation installations, substantially as hereinbefore described with reference to the accompanying drawings.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1985, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.