

Method for manufacturing magnetron coated substrates and magnetron sputter source.

The present invention relates to a method for manufacturing magnetron coated substrates and a magnetron source.

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Definitions

The structure of a magnetron source is schematically illustrated in Fig. 1. It has a target 3 with a sputter surface 3_s , from which target material is sputtered off and reactively or not reactively deposited on the substrate 4. On the reverse side 3_R of the target a magnet arrangement 5 is provided. It has at least one pair of circumferential magnetic loops 7_a and 7_b , which, facing the reverse side 3_R of the target, have surfaces of inverse magnetic polarity. The magnetic loops 7_a and 7_b respectively are each forming closed loops, wherein "closed" absolutely also includes magnets, that are arranged at a distance from one another, as long as by both magnetic loops generate closed loops of the magnetron magnet field H at the sputter surface 3_s of the target 3. With regard to the generation of the circumferential tunnel-shaped magnetron magnet field both magnetic loops 7_a and 7_b form a pair of interacting magnetic loop pair 7_{ab} . The magnetron magnet field H is, as shown schematically, crossed by an electric field E generated between an anode and the target 3 interconnected as the cathode. Due to the magnetron magnet field H and the electric field E , the known electron trap effect occurs in the area of the tunnel-shaped magnetron magnet field H , which at that point leads to an increased plasma density and an increased sputter effect. The result is, in the area of the magnetron magnet field, a circumferential erosion trench in the sputter surface 3_s that increases in depth with the increased duration of the operation. We call a closed loop of magnets of whatever shape, which presents one of the two magnetic polarities to the reverse side 3_R of the

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target, a magnetic loop. According to Fig. 1 two of such magnetic loops 7_a and 7_b are present.

Two such adjacent magnetic loops form a pair of magnetic loops according to 7_{ab} of Fig. 1, if they generate a circumferential loop of the tunnel-shaped magnetron magnet field H. The magnet arrangement 5 can contain one or more
5 circumferential magnetic loops plus separately positioned additional magnets for forming the magnetron magnet field loops. The electric field E between the anode (not shown) and the target cathode can be generated using DC, pulsed DC, superimposed DC and AC as well as AC up to the high frequency range. As
10 mentioned before, the coating process may be performed with the one or the several target materials, or after their reaction with a reactive gas admitted into the process space between the sputter surface 3_s and the substrate 4. On one and the same target 3 with areas of different materials, several materials can be sputtered into the process space simultaneously, directly for coating or after
15 reaction with a reactive gas within the process space.

In order to extend the life time of the target 3 and/or to keep the sputter rate (amount of sputtered off material per time unit), for example, constant despite the forming of the erosion trench or trenches and thus the coating rate (amount of material deposited on the substrate 4 per time unit) it is known and common to
20 move at least parts of the magnet arrangement 5, and in particular the one or the several provided pairs of magnetic loops along the reverse side of the target, be it by cyclic linear movements or rotational movements or pendulum movements. With that the magnetron magnet field H is moved along the sputter surface, in order to generate preferably no significant local erosion trenches.

25 We call a magnetron source a single-circuit source, if it has only one pair of magnetic loops. We call a magnetron source a two or multi circuit source, if the magnet arrangement has two or more pairs of magnetic loops. It is to be observed that two pairs of magnetic loops can definitely be formed using three magnetic loops.

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The present invention now presumes a method for generating magnetron coated substrates, in which - along the reverse side of the target facing away from the substrate - a magnet arrangement is provided, by means of which at least one closed loop of a tunnel-shaped magnetic field is generated along the sputter surface of the target.

Especially in the use of large surface targets, the achievement and maintenance of a desired layer thickness distribution and, in particular, a uniform layer thickness distribution is notoriously problematic. With regard to this one of the problems is that due to target erosion the coating circumstances are dynamic, i.e. that they change in the course of the lifetime and the utilisation period respectively of the target. If during the life time of an observed target a lot of substrates are coated, the mentioned dynamic will - depending on the coating time of the individual substrates - possibly only have a small effect, whereas, if the layer thickness distribution is considered across the entire life time of the target, as if only one individual substrate would be coated, a significant change is often observed in the distribution of the layer thickness.

Definition

We define as the coating time a period of time under consideration up to the lifetime of the target, independent of the number of individual substrates that are coated using the same target in the period of time under consideration.

Rotating single-circuit magnetron sources with heart or meander shaped magnetic loop structures cover the largest part of the applications in the field of magnetron sputtering. Adjustable single-circuit magnetron sources for the optimization of the distribution of the sputter rate over the coating time are, for example, described in US 5 188 717. Static two-circuit magnetron sources are, for example, known from WO 98/03696 or US 5 997 697. Two-circuit magnetron sources with switching mechanism for switching from sputtering by one of the pairs of magnetic loops to sputtering at a second are described in WO 01/63643.

Because of the limited coverage of large target surfaces, e.g. of 1200 cm², it is often very difficult to achieve a desired uniform distribution of the sputter rate as well as of the coating rate and eventually of the layer thickness on the substrate over the period of the coating process by means of rotating single-circuit magnetron sources. For that purpose meander or heart shaped structures of the pair of magnetic loops are often employed, which, however, on large target surfaces have the disadvantage that they either have several turning points or coat wide areas of the targets insufficiently. Narrow radii of the pairs of magnetic loops in particular, in the case of increased speeds, like the rpm of the magnetic system, lead to high eddy-current losses. On the one hand, these have to be compensated for by the engine power and on the other hand lead to a weakening of the magnetron magnet field.

Static two-circuit magnetron sources, as described in WO 98/03696 or US 5 997 697, have the disadvantage that static erosion profiles are impressed into the sputter surface. As initially mentioned, it becomes especially evident that with increasing sputtering of the target the sputter rate changes as well as the coating rate and thus also the layer thickness distribution on the substrate. Therefore a mechanism is required on principle, which enables the adjustment primarily of the sputter rate distribution on the target and over the course of its lifetime. This is often solved in such way that groups of magnets of the magnet arrangement are moved laterally, i.e. along the reverse side of the target 3_R, as known for instance from WO 02/47110. The disadvantage of this is that another drive has to be superposed over the rotating system with the pairs of magnetic loops, for which the power supply has to be realised, e.g. via electrical collector rings. Balance errors are created by the moving of the aforementioned groups of magnets, which have to be compensated for by appropriate measurements. Rotating two-circuit magnetron sources with a switching mechanism for the selective activation of the one or the other pairs of magnetic loops, as described in WO 01/63643, result in a high load for the electromechanical drives.

It is a task of this invention to propose a method of the initially mentioned type and a magnetron source respectively, for which and on which respectively the sputter rate distribution along the sputter surface can be adjusted in situ during the sputter operation - the coating time - and whereby the disadvantages of known methods or magnetron sources that use the respective approaches can be avoided. With
5 regard to this, the method of the initially mentioned type is characterised by the fact that the distance of a part of the magnet arrangement from the reverse side of the target is changed in order to set the sputter rate distribution.

A good realization of this method results furthermore from the fact that at least a
10 part of the magnet arrangement is moved along the reverse side of the target. This results in a distribution of the sputter effect of the tunnel-shaped magnetron magnet field along the sputter surface.

A further good realization of the method according to the invention is, that a part of a circumferential magnetic loop is changed in distance. This results in a change of the
15 sputter intensity in the area of the magnetron magnet field co-generated with the loop.

A further good realisation exists in the fact that the distance of a whole magnetic loop is changed, if necessary in combination with the change of a part of the magnetic loop concerned and another one.

20 A further good realisation is created, if necessary in combination with the aforementioned realisations, by changing the distance of a pair of magnetic loops, especially indicated, if the magnetron source is a two or multi-circuit source. In that case the corresponding distances can also be changed at more than one of the pairs of magnetic loops.

25 If the adjustment according to the invention of the aforementioned distance is to be realized for magnetron sources, for which the magnet arrangement is rotated along the back surface of the target and if a homogenous layer thickness distribution during the coating time up to the target life time is to be achieved, then a good

realisation is created by increasing - with increasing coating time - the distance of a part of the magnet arrangement, which is closer to the target edge than a further part of the magnet arrangement, and/or by decreasing the distance of the further part.

- 5 In all the aforementioned realizations it is furthermore a good idea to keep the sputter output constant. A further good idea is - with a sputter output that is kept constant - to record the discharge voltage between an anode and the target, to compare it with a target value and to adjust the distance of the part as a function of the result of the comparison. Furthermore it is also a good idea to divide the target
10 into zones of different materials and to set the relationship of the sputter rates of the two materials by the aforementioned adjustment of the distance.

A magnetron source according to the invention has a target with a sputter surface and a magnet arrangement along the reverse side of the target facing away from the sputter surface. With regard to this, the aforementioned task is solved by the fact that
15 the distance of a part of the magnet arrangement to the back surface of the target is adjustable by means of a controlled lift drive.

It is a good concept of the magnetron source according to the invention, that at least one part of the magnet arrangement is operatively connected with a movement drive, by means of which the part is moved along the back surface of the target.

- 20 It is another good concept, which can easily be combined with the aforementioned one, if a part of a magnetic loop is operatively connected with the controlled lift drive. Another good idea for the concept of the magnetron source according to the invention, if necessary in combination with the aforementioned one, is, to adjust a whole magnetic loop using the aforementioned controlled lift drive. This concept as
25 well can be combined with the aforementioned one, if necessary, just like the other good concept, to operatively connect a pair of magnetic loops with the controlled drive. Another good concept is to provide an outer pair of magnetic loops and an inner pair of magnetic loops at the source and with regard to the back surface of the target,

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and to design at least one of the pairs of loops eccentrically with respect to an axis of rotation and to operatively connect it with a rotation drive acting on the axis of rotation.

It is another good idea, to provide a control, by means of which the distance of a part of the magnet arrangement - a part that is positioned further towards the edge of the target than another part of the magnet arrangement - is increased and/or by which the distance of the other part is decreased during the coating time.

Hereafter the invention is explained in greater detail by means of examples and with the aid of figures.

These show:

- 10 Fig. 2a a diagram of a perspective view of a first embodiment of the method according to the invention and a magnetron source according the invention respectively,
- Fig. 2b furthermore a diagram of a side view onto the arrangement shown in Fig. 2a,
- 15 Fig. 2c furthermore a diagram of two variations of the magnet arrangements, e.g. on an arrangement according to Figure 2a, for the formation of the magnetron field,
- Fig. 3 in a presentation analogous to that of Figure 2a a further embodiment of the invention,
- 20 Fig. 4 in a view analogous to that of Figure 2b, a further embodiment of the invention in a diagram,
- Fig. 5 in a presentation analogous to that of Figure 4, a further embodiment of the invention,

- Fig. 6 furthermore in a presentation analogous to that of Figures 4 and 5 respectively a further embodiment of the invention,
- Fig. 7 furthermore in a presentation analogous to that according to Figures 4 to 6 yet another embodiment of the invention,
- 5 Fig. 8 in a presentation analogous to that of Figures 4 to 7 a further magnetic loop arrangement, on which arrangements as described by means of the figures 2 and 3 are realized,
- Fig. 9 furthermore in the mentioned presentation a further embodiment of the invention,
- 10 Fig. 10 in a diagram a form of realization of a sputter source according to the invention, conceptualised in principal according to the embodiment variation of Figure 9,
- Fig. 11 a top view of a magnet arrangement employed according the invention,
- 15 Fig. 12 the graph (a) of an erosion profile at a circular target on the arrangement according to Figure 10, for a concentric pair of magnetic loops and an eccentric one, and the graph (b) for an eccentric arrangement of both pairs of magnetic loops without adjustment of the magnetic lift;
- 20 Fig. 13 layer thickness distribution graphs (a,b) for differently set lifts,
- Fig. 14 in a diagram an erosion profile on a circular disc shaped target for the discussion of an erosion profile to be aimed for,
- Fig. 15 in a presentation analogous to that of Figure 10, an arrangement according to the invention in an embodiment in principal according to Figure 7,
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- Fig. 16 the standardized layer thickness distribution on a substrate with sputter output as parameter,
- Fig. 17 in a diagram a signal flow/function block chart of an embodiment for the electrical guidance of the magnetron source according to the invention,
- Fig. 18 for example, simplified in a top view, the magnet arrangement at a single-circuit magnetron source according to the invention,
- Fig. 19 the layer thickness distribution resulting from the magnet arrangement according to Figure 18 in function of the distance adjustment.

Figure 2a illustrates a first embodiment of the method according to the invention and the magnetron source according to the invention respectively in schematised perspective view; Fig. 2b, also schematised, illustrates the side view of the arrangement illustrated in Fig. 2a. On the substrate side (substrate not shown) target 3 has a sputter surface 3_s and, facing away from the substrate, a reverse side 3_R . In the area of the back surface 3_R there is a magnet arrangement 5, which generates at least one, according to the Figures 2 one, closed loop of a tunnel-shaped magnetic field H on the sputter surface 3_s , the magnetron magnet field H, which is quite familiar to an expert. Figures 2 show a common single-circuit magnetron source. For this the magnet arrangement 5 has a first, mainly closed circumferential magnetic loop 7a as well as a second 7b, which is located inside the one mentioned first. At least one of the two magnetic loops 7a, 7b is at least to the greatest extent possible constructed by means of permanent magnets 9, for instance according to the Figures 2, the outer magnetic loop 7a. One magnetic polarity - for instance N - of the aforementioned, for example, outer magnetic loop 7a is located opposite the back surface of the target 3R. In any case, the second magnetic loop 7b is located opposite the back surface of the target 3R with the

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second magnetic polarity, for instance S. As is easily seen from Fig. 2c, the realization of the pair of magnetic loops 7_{ab} is such that along the back surface of the target 3_R a circumferential zone of the one magnetic polarity is created as well as - with regard to this - an inside or outside circumferential second zone of the second magnetic polarity. For this purpose permanent magnets 9 are provided on both loops, on the side that is facing away from the back surface of the target 3_R , this is a ferromagnetic connection 10. Alternately there are in each case, if necessary section by section, viewed along the magnetic loops, permanent magnets 9a are present on one of the loops, for example the outer one, and the second magnetic polarity - facing the back surface of the target 3_R - on the other loop, e.g. the inner one 7_b , is formed by a ferromagnetic yoke 12.

Viewed along the pair 7, the constellations according to Fig. 2c can alternate, just as, in view of the realisation with yoke 12, the arrangement of the permanent magnets.

According to the figures 2, in particular Fig. 2b, and according to the embodiment example illustrated here, the distance $d_{b1}(t)$ of a part 7_{b1} of one of the magnetic loops of the pair 7 is changed under control with respect to the back surface of the target 3_R by means of a drive 14 controlled at a control input S_{14} . In Fig. 2b, d_a denotes the distance of the magnetic pole surface of the one magnetic loop 7_a from the back surface of the target 3_R , the distance d_b that of the second magnetic loop 7_b and d_{b1} the controlled adjustable distance of the part 7_{b1} on at least one of the both loops, e.g. at the inner one. The effect of the magnetron magnet field H formed by the pair 7_{ab} is changed under control. Of course, it is quite possible change the distance - at the considered magnetic loop - of both parts relatively to each other and both parts with reference to the back surface of the target 3_R in a controlled manner, i.e. for instance and in view of Fig. 2a, to lift part 7_b and to simultaneously lower the remaining part of the magnetic loop under consideration. Important is, that, viewed along the pair of magnetic loops 7_{ab} , the distances of the magnetic pole surfaces with reference to the back

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surface of the target are changed in time by controlled distance changes at the magnetic loops.

As shown in Fig. 2a, it is, for example, a good idea - in a section under consideration along the pair 7_{ab} at both magnetic loops - to change equally or
5 unequally long parts, 7_{a1} , 7_{b1} , with reference to the distance of the back surface of the target 3R in a controlled manner; in the same direction equally or unequally, or in inverse direction equally or unequally.

In a representation analogous to that of Fig. 2a, Fig. 3 shows another good embodiment of the invention. As clearly evident, the distance $d_a(t)$ between the
10 whole pole surface and the target at one of the magnetic loops, e.g. the outer magnetic loop 7_a , is set on the pair 7_{ab} using the drive 14 in a controlled manner with regard to time and thus in turn the effect of the tunnel-shaped magnetic field H that had been generated. Here, too, the distances of both of the whole magnetic loops $7a$ and $7b$ can, if necessary, be set in a controlled manner; in the same
15 direction equally, in the same direction unequally, in the respective inverse direction equally or unequally.

The embodiment according to Fig. 3 again shows a single-circuit magnetron source.

Fig. 4 shows a further good embodiment of the invention - in a view analogous to
20 the presentation of Fig. 2b. It has, in a general way, an uneven number - as shown here three - magnetic loops 7_a to 7_c , which together form two pairs of loops 7_{ab} , 7_{bc} of the magnet arrangement 5. The polarity of the magnetic loop $7b$ in the middle is inverse to that of the two adjacent ones. These form the two circumferential loops of the tunnel-shaped magnetron magnet field H_1 , H_2 shown
25 in this example of an embodiment. Analogous to the embodiments of Fig. 2, in the embodiment according to Fig. 4 the distance $d_{b1}(t)$ of at least of one part 7_{b1} of the magnetic loop $7b$ in the middle is changed by means of a controlled drive (not shown), whereas the part or the remaining parts of the magnetic loop $7b$ that is

under consideration are kept at a constant distance with respect to the back surface 3R of the target 3.

Fig. 5 shows, in a presentation analogous to Fig. 4, a further good embodiment - analogous to that shown in Fig. 3 - in which the whole central magnetic loop 7, as shown by $d_b(t)$, is changed by means of a controlled drive (not shown) with respect to the back surface 3R of the target 3.

When proceeding according to Fig. 4 and 5, mainly both magnetron magnet fields H_1 and H_2 are affected by specifically adjusting the distance $d_b(t)$ and $d_{b1}(t)$ respectively.

According to the embodiment according to Fig. 6, as is now easily understandable, a part 7_{a1} of the outer magnetic loop 7a is moved by means of a (not shown) controlled drive with respect to the drive's distance $d_{a1}(t)$, whereas the remaining part of the magnetic loop 7a is kept at a constant distance, just as the loops 7b, 7c.

In the likewise good embodiment according to Fig. 7, the distance $d_a(t)$ of the whole outer magnetic loop 7a is changed by means of a controlled drive (not shown) and relatively to the back surface of the target 3 R .

The embodiments according to figures 4 to 7 are two-circuit magnetron sources. By providing appropriately controlled drives, all individual embodiments described by means of the figures 2 to 7 may be employed at a magnetron source in combination if necessary.

Whereas the adjacent magnetron magnet fields H are adjusted in mutual dependency by the distance adjustment in the embodiments according to the figures 4 to 7, i.e. at two-circuit magnetron sources, namely that, generally speaking, upon weakening of the one field the other is strengthened and vice versa, this is less pronounced in the case of the good embodiments illustrated in the following. In the likewise good embodiment according to Fig. 8, four - generally an even number -

magnetic loops lying within one another are provided, 7a to 7d. From the innermost or outermost magnetic loop, progressing perpendicular thereto, two successive magnetic loops are each involved in the forming of a pair of magnetic loops, as illustrated in Fig. 8 by 7_{ab} , 7_{cd} , which form a magnetron magnet field, H1 and H2 respectively. At both pairs 7_{ab} , 7_{cd} , the embodiments described by means of the figures 2 and 3 can each be realized, at one of the pairs or at both. Additionally, however, in a further good embodiment of the invention and as shown in Fig. 9, the distance $d_{cd}(t)$ of a whole pair of loops - according to Fig. 9 that of the inner one 7_{cd} - can be set according to the invention by means of a controlled drive (not shown). It is also possible and a good idea, to design the distance of both provided pairs of magnetic loops with appropriate drives that can be adjusted in a controlled manner, and to adjust these distances unidirectionally equally, unidirectionally unequally, in opposite directions equally or in opposite directions unequally, if necessary in any specific combination.

Up to now - in the embodiments according to the figures 2 to 9, the provided magnet arrangements with the magnetic loops, aside from the distance adjustment according to the invention, were considered to be stationary with respect to the back surface of the target 3R. In all embodiments it is a good concept - in addition to the realization of the distance adjustment according to the invention - to move at least parts of the magnet arrangement 5 along the back surface of the target 3R by means of a corresponding (not shown) drive. Thus it is a good concept, to move the pair 7_{ab} cyclically along the back surface of the target 3R according to Fig. 2a, as illustrated schematically by the movement trajectory B_{ab} . The same is true for the embodiment according Fig. 3. Thereby it may also be a good concept to move - for the single-circuit magnetron sources according to Fig. 2 and 3 under consideration - the both magnetic loops forming the pair relatively to one another on different movement trajectories along the back surface 3_R .

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For the embodiment according to the figures 4 to 7, i.e. in the realization of a two-circuit magnetron source with magnetic loop triplet, good concepts result from

- moving of all provided magnetic loops equally along the back surface 3_R .
- 5 • moving the central magnetic loop with respect to both the adjacent magnetic loops;
- moving one or both of the outermost and innermost magnetic loops of the triplet equally or unequally with respect to the central magnetic loop of the triplet.
- 10 In the embodiments according to the figures 8 and 9 respectively it is a good concept
 - to move all provided pairs of magnetic loops equally along the back surface of the target 3_R , or
 - to move one pair of magnetic loops relatively to the other.
- 15 Depending on the choice of concept, to either form the magnetron magnet field by the magnetic loops or to move the magnetron magnet field along the sputter surface 3_s of the target 3, the mentioned movement possibilities are employed in combination and corresponding controlled drives are provided.

20 The magnetic loops introduced by means of the Figure 2 to 9 can be arranged circumferentially in a circular, oval, elliptical or even approximately rectangular manner, viewed in a top view of the sputter surface 3_s , or can be heart or kidney or meander shaped.

Fig. 10 shows a diagram of a good realization of a source 20 according to the invention, principally according to Fig. 9. It has a target 23 with a sputter surface 23_s and a back surface 23_R . The outer pair of magnetic loops 7_{ab} according to Fig. 9 is

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mounted on an outer support 25 via a ferromagnetic yoke 10. By means of a rotation drive 27, only illustrated schematically, the outer support 25 is brought into rotation around the axis A_{25} . By means of another rotation drive 29 with respect to the only schematically illustrated source housing, an inner support 35 is brought into rotation, in the shown example around the axis A_{35} , which here coincides with the axis of rotation A_{25} . The inner support 35 has a back panel 33 made of ferromagnetic material, facing the target 23, and supports the magnetic loops 7_c , and 7_d , which together form the pair 7_{cd} . With respect to the axis of rotation A_{25} the pair of magnetic loops 7_{ab} is concentrically mounted at the outer support 25, whereas the pair of magnetic loops 7_{cd} is mounted at the inner support 33 eccentrically with respect to the axis of rotation A_{35} . By means of a schematically illustrated controllable lift drive 37 the inner support 35 is adjusted with respect to the distance $d_{cd}(t)$ to the back surface 23_R of the target 23. The rotation speeds ω_{35} and ω_{25} and rotation directions respectively of the outer and inner support 25, 35 can be chosen to be equal or different. A good concept results, however, if, as illustrated in the top view of the magnet arrangement in Fig. 11, the pair of magnetic loops 7_{ab} is realized at the outer support 25 eccentrically and, as shown, e.g. circular, and if the pair of magnetic loops 7_{cd} at the inner support 35 rotating around the axis A_{35} is realized likewise eccentrically. In Fig. 12 the progression (a) at a circular target 23 with diameter 400 mm shows the erosion profile for a concentric arrangement of one of the two pairs of magnetic loops, according to Fig. 10, for example, of the outer one 7_{ab} and for the eccentric arrangement of the other pair of magnetic loops, according to Fig. 10 of the pair 7_{cd} . The course (b) shows the erosion profile if both, inner and outer pairs 7_{ab} and 7_{cd} , according to Fig. 11 are realized eccentrically with respect to the coinciding rotation axes A_{25} , A_{35} . It turns out that in the arrangement according to Fig. 11 no significantly diminished eroded area occurs in the intermediate area between the inner pair of magnetic loops 7_{cd} and the outer one 7_{ab} . Through the optimized eccentricity of the pairs of magnetic loops under consideration, an optimal erosions profile overlap can be achieved. In a design according to Fig. 11 it is inevitable that the rotation drives 27 and 29 according to Fig.

10 are operated at same rotational speeds. By means of the lift, which is set by the drive 37 in a controlled manner, and thus through the change of the distance $d_{cd}(t)$, a still more uniform erosion and sputter distribution can be realised, as is to be shown, and thus an optimal desired layer thickness distribution can be achieved on
5 the substrate, or the target utilization can be optimized by an erosion of the target surface that is as uniform as possible.

The layer thickness distribution achieved with different lift values, and respectively in view of Fig. 10 of the distance $d_{cd}(t)$, is shown in Fig. 13 on a circular substrate with a diameter of 300 mm by means of the surface resistance of an on-sputtered
10 copper layer. Accordingly a high resistance value corresponds to a thin layer and vice versa. A double eccentric arrangement according to Fig. 11 was used for the magnet arrangement. The result according to progression (a), for which the copper layer is significantly thinner within the central area of the substrate than in the peripheral area, the lift of the inner pair 7_{cd} was set corresponding to the distance
15 $d_{cd}(t)$ according to Fig. 10, which equals the distance d_a of the outer pair 7_{ab} . Then the distance $d_{cd}(t)$ (inner pair of loops!) was reduced by 0.5 mm, which led to an increase of the sputter rate in the central area of the target and thus to an increase of the coating rate on the substrate, with the result of a significantly improved layer thickness distribution on the substrate in accordance with the progression (b) of
20 Fig. 13.

When (not shown in Fig.13) the lift $d_{cd}(t)$ was reduced by a further 0.5 mm, the result was an extremely uniform layer thickness distribution on the substrate, due to the fact that the sputter rate during the last coating phase was increased again in the centre of the target, thus further increasing the central area of the substrate of the
25 resulting layer thickness, plus further reduced surface resistant of the copper layer in the central area of the substrate in accordance with Fig. 13.

Fig. 13 shows, how by controlling the time of the distance at parts of the magnet arrangement generating the magnetic field on the one hand, the progression of the sputter rate and thus of the coating rate and thus the layer thickness distribution on

the substrate resulting after a predetermined period of time, can finely be set. In order to obtain the results according to Fig. 13, the discharge voltage at the magnetron sputter source was not influenced and the supplied electrical discharge output was kept constant.

- 5 For the time-dependent control of the distance $d_{cd}(t)$ in the arrangement according to Fig. 10 with two eccentric pairs of magnetic loop 7_{ab} and 7_{cd} according to Fig. 11, the following considerations can be helpful, if the most homogeneous layer thickness distribution possible is to be achieved on the substrate; for an expert this will open up analogous ideas concerning differently conceived magnetron sources
- 10 according to the invention and distributions to be achieved: For the time being, the erosion profile to be targeted for optimized layer thickness distribution on a circular disc shaped target on the substrate shall be discussed on the basis of Fig. 14. Without precise distance control, the arrangement according to Fig. 10 and the magnet arrangement according to Fig. 11 result in an erosion rate ER that is
- 15 higher at the outer area, which is rather desirable for the edge effect correction. However, in this outer area the formation of a significant erosion trench results in an increasingly high sputter rate, so that over a period of time the relative erosion intensity has to be reduced in the outer area of the target. This is necessary, in order to achieve a homogeneous layer thickness distribution on the substrate over
- 20 time. The reduction of the erosion intensity in the outer area is to be considered in relation to the erosion intensity in the central area of the target. Therefore, either the erosion intensity in the outer area of the target can be reduced or the erosion intensity in the central area of the target can be increased. In the explanations concerning Fig. 13 the latter method was described.
- 25 Thus - with view on Fig. 14 - the relative sputter intensity and sputter rate respectively in the outer area of the target has to be reduced from a higher value ER1 at the start to a lower value ER2 at the end of the coating period. The value of the distance reduction at $d_{cd}(t)$ the inner support and the distance increase at the outer support respectively can be roughly estimated in advance as follows:

For the time being, the erosion depth difference between the outer and inner erosion trench is measured at the end of a given coating time, e.g. the target life time. This takes place at predetermined fixed distances of the outer and the inner supports 25 and 35 respectively, in accordance with Fig. 10. Once the
5 erosion depth difference is determined, e.g. a 7 mm higher erosion depth in the edge area of the target, then the sputter intensity in the outer area of the target is relatively reduced by a relative lift change of 7 mm during the same coating time, i.e. a distance increase of the outer support 35 by 7 mm and a distance decrease of the inner support 25 by 7 mm respectively is aimed for during the
10 coating time. In this, the lift change can be performed only at the outer support or only at the inner support or in combination at the inner and outer support in opposite directions.

The lift change over time that is to be controlled, must be performed with high precision and depends on the targeted erosion profile progression throughout the
15 coating time, the target material, the target thickness, the specified requirements for the substrate with respect to the layer thickness distribution as well as the sputter rate. In order to monitor and control the controlled distances, one or several direct or indirect distance measurements are performed in-situ. Fig. 10 shows a diagram of a sensor arrangement 40 for this. As the outer support is not
20 lift-adjusted in this embodiment, the arrangement measures the currently set distance between the outer support 25 and the inner support 35 and thus the progression and the current value respectively of $d_{cd}(t)$. The sensor arrangement 40 can, for example, work on the basis of the principle of triangulation measurements, can be designed as a capacitive or optical sensor, as mechanical
25 sensor etc. With regard to this, it is a good idea to employ a contact-free measuring sensor arrangement, so that the magnet arrangement does not have to be electrically insulated against the target, and thus that the distances between the pole surfaces of the magnet arrangement and the back surface of the target can be chosen and set respectively at a minimum as well.

On principle, the procedure according to the invention makes it possible to adjust a desired sputter rate distribution progression over a period of time. If consequently, for example with an arrangement according to Fig. 10, the inner pair of magnetic loops 7_{cd} is guided along a first target area made of a first material, the outer pair of magnet loops 7_{ab} on the other hand along a target area made of a second material, and if the target consists of two zones made of different materials, the relative coating rate of the both materials as well can be adjusted on the substrate using the procedure in accordance with the invention.

Fig. 15 - in a presentation analogous to that of Fig. 10 - shows a diagram of an embodiment, which in principal corresponds to that shown in Fig. 7. This, too, shows a two-circuit magnetron source. Only the outer magnetic loop 7_a is adjusted in distance with respect to the two magnetic loops 7_b and 7_c located on the inside. The outer magnetic loop 7_a is mounted fixedly with respect to the source casing 31. The inner pair of magnetic loops 7_{cb} is, mounted on a rotation-driven support 35_a, eccentrically with respect to the axis of rotation A_{35a} . On the basis of the explanations concerning Fig. 10, the simplified illustrated embodiment according to Fig. 15 is easily understandable for an expert.

Fig. 16 shows - with the sputter output as parameter - the normalised layer thickness distribution on the substrate and as coating time over the lifetime of the target. The distance of the outer pair of magnetic loops 7_{ab} according to Fig. 10 is 1 mm larger than the distance of the inner pair of magnetic loops 7_{cd} . The progression (a) was measured for a sputter rate of 32 kW, (b) for 28 kW, progression (c) for 24 kW, (d) for 16 kW and finally progression (e) for 20 kW.

This shows a strong dependency of the resulting layer thickness distribution on the set sputter output. From this it follows, that it is a good concept to keep the sputter output with respect to the reverse side of the target constant, when performing the time-controlled adjustment, in accordance with the invention, of the distance of at least one part of the magnet arrangement generating the magnetron field.

Furthermore, an unequivocal dependency exists between the discharge voltage U_E and the current sputter rate distribution on the target. Experience shows, that the discharge voltage decreases with increasing target utilization, because of the increasing erosion in the outer area of the target.

5 Thus the possibility arises, to record the discharge voltage as a measured regulating value, to compare it with a target value and to keep it constant in a controlling sense by tracking the distance of the outer pair of magnetic loops.

As a result, the principal statement is that the discharge voltage for a multi circuit magnetron source is mainly determined by the sputter effect of the pair
10 of magnetic loops, that causes the highest sputter intensity on the target.

Commonly it is recorded in advance - with the sputter output as parameter - how the distance adjustment according to the invention should be conducted over time, in order to achieve the desired layer thickness distribution on the substrate within the coating time. The characteristic graphs obtained in that way are stored in
15 tables. The distance adjustment is then - in dependence from the sputter output - controlled according to the stored graphs. The regulation of the discharge voltage U_E is then carried out by adjusting the respective distance, if necessary as working point regulation.

Fig. 17 - by means of a diagram of a signal flow / function block - shows a possible
20 concept for the electrical guidance of the magnetron source according to the invention. The magnetron source 42 has a control input S_{42} for the distance adjusted over time in accordance with the invention of at least one part of the magnet arrangement generating the magnetron magnet field. The source is electrically supplied with the adjustable, constant output P by the generator 44. The
25 electrical output P that is set for the operation of the target under consideration, is fed to a table storage device 46, that stores the time-distance functions $d(t,P)$ that had been determined in advanced as being required for each of the different output settings. From the beginning of the sputter coating with the considered target, a timekeeper 48 controls the read-out of the distance value corresponding to the

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current coating time from the table storage device 46. The required distance value is set by the distance control input S_{42} at the magnetron source. Via the position sensor 40 - described, for example, on the basis of Fig. 10 - the accurate adherence to the currently required distance can be controlled. This position control circuit is not shown in Fig. 17. Furthermore, the discharge voltage U_E is measured as an actual value and compared with a stipulated target discharge voltage U_{SOLL} at a comparator circuit 50. The result of the comparison is applied as control difference Δ as an adjustment signal to the input S_{42} of the source 42 via a regulator 52 and a superposition unit 54. Thus the working point is maintained at the stipulated value from table 46 by regulating the discharge voltage.

Fig. 18 shows the magnet arrangement 5 on a single-circuit magnetron source, with meander shaped magnetic loops 7_a and 7_b . Both magnetic loops 7_a and 7_b , i.e. the pair 7_{ab} , rotate around axis A. Fig. 19 shows the resulting layer thickness distributions for a substrate with a diameter of 300 mm, if, according to progression (a), the distance of the loop 7_b from the back surface of the target is 2 mm larger than the distance of the outer magnetic circuit 7_a and if it is reduced step-by-step by 2 mm in accordance with the progressions (b), (c), (d). From this is can be seen that even for a single-circuit source or for proceeding in accordance with the invention at a single-circuit source respectively - as shown by means of Figures 2 and particularly 3 - it is possible to control the current sputter rate and therefore - for a coating time under consideration up to the lifetime of the target - the setting and maintenance respectively of a desired layer thickness distribution on the substrate can be ensured, in particular a homogeneous, i.e. uniform distribution.

With view on the embodiment according to Fig. 10, realized according to Fig. 11, it was furthermore established that this configuration of a two-circuit magnetron source results in a reduction of the eddy current losses, when compared with the single-circuit source according to Fig. 18, which makes it possible to reduce the necessary drive output for the respective rotation drive by about 20%. In addition,

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the reduction of eddy currents reduces the resulting stray field in the perimeter of the rotating magnet arrangement and thus lowers the potential danger of the disturbance of surrounding installation components.

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Patent Claims:

1. A method for manufacturing magnetron coated substrates comprising:

- 5 • providing in a vacuum recipient a magnetron source comprising a stationary target arrangement with a sputter surface and with a backside;
 - 10 • providing along the backside of said target arrangement a magnet arrangement generating along said sputter surface at least one closed loop of tunnel-shaped magnetron magnetic field eccentrically about an axis perpendicular to said backside, by means of a loop of magnets of said magnet arrangement;
 - 15 • providing a substrate opposite to and distant from said sputter surface;
 - 20 • rotating said closed loop about said axis;
 - varying a distance of at least a part of said magnet arrangement to said backside, thereby increasing with an increasing coating time said distance of at least a part of said loop of magnets which is closer to an edge of said target arrangement relative to other parts of said magnet arrangement more remote from said edge of said target arrangement.
2. The method of claim 1, wherein varying said distance comprises varying said distance of said loop of magnets.
- 25 3. The method of claim 1, further comprising generating a further closed loop of tunnel-shaped magnetron magnetic fields.

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4. The method of claim 3, comprising generating said further closed loop of tunnel-shaped magnetron magnetic field eccentrically about a further axis perpendicular to said backside and rotating said further closed loop about said further axis.

5. The method of claim 4, wherein said axis and said further axis are the same axes.

6. The method of claim 3, comprising generating said further closed loop of tunnel-shaped magnetron magnetic field by means of a loop of magnets of said magnet arrangement, said varying comprising varying said distance of at least a part of said further loop of magnets.

7. The method of claim 1, further comprising monitoring a discharge voltage of said magnetron source, comparing said discharge voltage monitored with a desired value for said discharge voltage and performing said varying in dependency of a result of said comparing.

8. A method for manufacturing magnetron coated substrates comprising providing in a vacuum recipient a magnetron source comprising a stationary target arrangement with at least two zones of different target materials and with a sputter surface and with a backside;

- providing along said backside of said target arrangement a magnet arrangement generating along said sputter surface at least one closed loop of tunnel-shaped magnetron magnetic field eccentrically about an axis perpendicular to said backside;

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- providing a substrate opposite to and distant from said sputter surface;
- rotating said closed loop about said axis;
- controlling a ratio of said different materials deposited on said substrate by varying a distance of at least a part of said magnet arrangement to said backside;
- sputter coating said substrate.

9. A magnetron source comprising a stationary target arrangement with a sputter surface and a backside, a magnet arrangement along said backside of said target arrangement, said magnet arrangement comprising a loop of magnets eccentrically about an axis perpendicular to said backside, a drive rotating said loop of magnets about said axis and a further drive for varying a distance of at least a part of said magnet arrangement to said backside and further comprising a control unit, the output thereof being operatively connected to a control input of said further drive, said control unit controlling said further drive in such a way that the distance of at least a part of said magnet arrangement which is located closer to an edge of said target arrangement than other parts of said magnet arrangement is increased over sputtering time, relative to said distance of other parts of said magnet arrangement.

10. A magnetron source comprising a stationary target arrangement with at least two zones of different target materials and with a sputter surface and a backside, a magnet arrangement along said backside of said target

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arrangement, said magnet arrangement comprising a loop of magnets eccentrically about an axis perpendicular to said backside, a drive rotating said loop of magnets about said axis and a further drive for varying a distance of at least
5 a part of said magnet arrangement to said backside and further comprising a control unit operatively connected to a control input of said further drive and controlling a ratio of said different materials deposited on a substrate by controlling said further drive.