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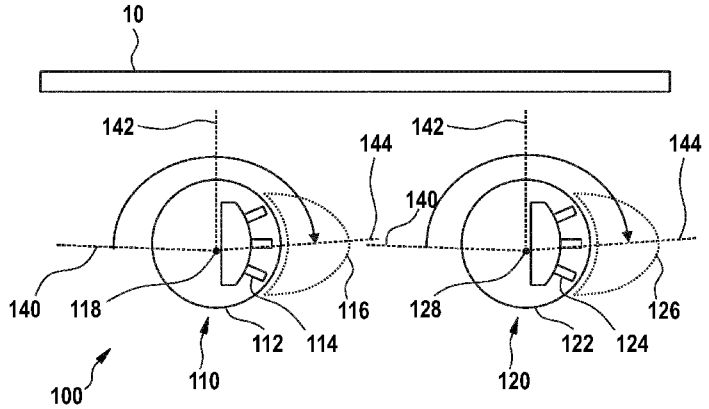


Fig. 2A

(57) Abstract: The present disclosure relates to a method for material deposition on a substrate, including moving a substrate (10) into a processing zone in a vacuum chamber having an array of at least three sputter cathodes (110, 120), wherein each of the at least three sputter cathodes (110, 120) provides a plasma zone (116, 126) in which a deposition material is supplied during operation of the at least three sputter cathodes (110, 120), and rotating the plasma zone (116, 126) only once around a respective rotational axis (118, 128) from a first rotational position (140, 140) to a second rotational position (144, 144), wherein each plasma zone (116, 126) is directed away from the processing zone in the first rotational position (140, 140), and wherein each plasma zone (116, 126) moves over the processing zone during rotating from the first rotational position (140, 140) to the second rotational position (144, 144).

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METHOD FOR MATERIAL DEPOSITION ON A SUBSTRATE, CONTROLLER FOR CONTROLLING A MATERIAL DEPOSITION PROCESS, AND APPARATUS FOR LAYER DEPOSITION ON A SUBSTRATE

FIELD

[0001] Embodiments of the present disclosure relate to a method for material deposition on a substrate, a controller for controlling a material deposition process, and an apparatus for layer deposition on a substrate. Embodiments of the present disclosure particularly relate to sputter processes for material deposition on a substrate, a controller for controlling a sputter process, and a sputter apparatus.

BACKGROUND

[0002] Several methods are known for depositing a material on a substrate. For instance, substrates may be coated by a physical vapor deposition (PVD) process, a chemical vapor deposition (CVD) process, or a plasma enhanced chemical vapor deposition (PECVD) process, etc. The process can be performed in a process apparatus or processing chamber in which the substrate to be coated is located. A deposition material is provided in the apparatus. A plurality of materials such as metals, also including oxides, nitrides or carbides thereof, may be used for deposition on a substrate. Coated materials may be used in several applications and in several technical fields. For instance, substrates for displays can be coated by a physical vapor deposition (PVD) process such as a sputtering process, e.g., to form thin film transistors (TFTs) on the substrate.

[0003] With development of new display technologies and a tendency towards larger display sizes, there is an ongoing demand for layers or film used in displays that provide an improved performance, e.g., with respect to electrical characteristics and/or optical characteristics. For example, layers or layer systems having a high purity are beneficial. Further, uniformity of the deposited layers, such as uniform thickness and uniform material component distribution, is beneficial. This particularly applies to thin layers, which can, for example, be used to form thin film transistors (TFTs). In view of the above, it is beneficial

to deposit layers with improved purity and/or uniformity. Further, a process time for deposition of the layers should be minimized in order to increase a throughput of an apparatus for layer deposition.

[0004] In view of the above, new methods for material deposition on a substrate, controllers for controlling a material deposition process, and apparatuses for layer deposition on a substrate that overcome at least some of the problems in the art are beneficial.

SUMMARY

[0005] In light of the above, a method for material deposition on a substrate, a controller for controlling a material deposition process, and an apparatus for layer deposition on a substrate are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0006] According to an aspect of the present disclosure, a method for material deposition on a substrate is provided. The method includes: moving a substrate into a processing zone in a vacuum chamber having an array of at least three sputter cathodes, wherein each of the at least three sputter cathodes provides a plasma zone in which a deposition material is supplied during operation of the at least three sputter cathodes; and rotating each plasma zone only once around a respective rotational axis from a first rotational position to a second rotational position, wherein each plasma zone is directed away from the processing zone in the first rotational position, and wherein each plasma zone moves over the processing zone during rotating from the first rotational position to the second rotational position.

[0007] According to another aspect, a controller for controlling a material deposition process is provided. The controller is configured to perform the method for material deposition on a substrate according to the embodiments described herein.

[0008] According to still another aspect, an apparatus for layer deposition on a substrate is provided. The apparatus includes a vacuum chamber having a processing zone for

processing of a substrate, an array of at least three sputter cathodes, wherein each of the at least three sputter cathodes provides a plasma zone in which a deposition material is supplied during operation of the at least three sputter cathodes, and a controller configured for rotating each plasma zone only once around a respective rotational axis from a first rotational position to a second rotational position, wherein each plasma zone is directed away from the processing zone in the first rotational position, and wherein the controller is configured for moving each plasma zone over the processing zone by rotating of each plasma zone from the first rotational position to the second rotational position.

[0009] Embodiments are also directed at apparatuses for carrying out the disclosed methods and include apparatus parts for performing each described method aspect. These method aspects may be performed by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, embodiments according to the disclosure are also directed at methods for operating the described apparatus. It includes method aspects for carrying out every function of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

FIG. 1 shows a schematic view of sputter cathodes having tubular rotatable cathodes used in a method for material deposition on a substrate according to embodiments described herein;

FIGs. 2A and 2B show schematic views of sputter cathodes having tubular rotatable cathodes illustrating the method for material deposition on a substrate according to embodiments described herein;

FIG. 3 shows a schematic view of a sputter cathode having a planer rotatable cathode illustrating the method for material deposition on a substrate according to further embodiments described herein;

FIG. 4 shows a schematic top view of an apparatus for layer deposition on a substrate with the sputter cathodes facing away from the processing zone according to embodiments described herein; and

FIG. 5 shows a schematic top view of an apparatus for layer deposition on a substrate with the sputter cathodes moving across the processing zone according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0011] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0012] With the development of new display technologies and a tendency towards larger display sizes, there is an ongoing demand for layers or layer systems having an improved purity. This particularly applies to thin layers or thin films, which can, for example, be used to form thin film transistors (TFTs). Further, there is a demand for layers or layer systems having improved uniformity. As an example, layers or layer systems having a uniform thickness are beneficial. Moreover, a process time for deposition of the layers or

layer systems should be minimized in order to increase a throughput of an apparatus for layer deposition.

[0013] According to the present disclosure, a plasma zone of a sputter cathode moves or sweeps once over a processing zone in which a substrate is located. A material to be deposited on the substrate to form a layer can be provided in the plasma zone. Moving or sweeping only once over the processing zone improves uniformity of the layer deposited on the substrate. As an example, thickness uniformity of the deposited layer can be improved. Further, purity of the deposited layer can be improved, since impurities (e.g., oxidized particles) that might be present on the sputter cathode, e.g., a sputter target, can be removed from the sputter cathode or sputter target before the plasma zone is directed towards the substrate. Moreover, a process time can be minimized and a throughput of a deposition apparatus can be increased. According to some embodiments, the layers of the present disclosure can also be referred to as “films” or “ultra-thin films”.

[0014] FIG. 1 shows a schematic view of a deposition arrangement 100 having sputter cathodes used in a method for material deposition on a substrate 10 according to embodiments described herein.

[0015] The deposition arrangement 100 includes an array of at least three sputter cathodes. Each sputter cathode of the array of at least three sputter cathodes provides a plasma zone. As an example, the array of at least three sputter cathodes includes a first sputter cathode 110 providing a first plasma zone 116, a second sputter cathode 120 providing a second plasma zone 126 and a third sputter cathode 130 providing a third plasma zone 136. Each plasma zone can rotate around a respective rotational axis from a first rotational position to a second rotational position. For instance, the first plasma zone 116 can rotate around a first rotational axis 118 from a first rotational position to a second rotational position or vice versa. The second plasma zone 126 can rotate around a second rotational axis 128 from the first rotational position to the second rotational position or vice versa. The third plasma zone 136 can rotate around a third rotational axis 138 from the first rotational position to the second rotational position or vice versa. During the rotation, the plasma zones move or sweep only once over the processing zone in which the substrate 10 is located. As an example, the deposition material provided in the plasma zones is

deposited on the substrate 10 while the plasma zones move across the processing zone during rotating from the first rotational position to the second rotational position.

[0016] In some implementations, the rotation of the processing zones can be a rotation in a clockwise direction or an anticlockwise direction. As an example, the rotation from the first rotational position to the second rotational position can be a rotation in the clockwise direction and the rotation from the second rotational position to the first rotational position can be a rotation in the anticlockwise direction. In other examples, the rotation from the first rotational position to the second rotational position can be a rotation in the anticlockwise direction and the rotation from the second rotational position to the first rotational position can be a rotation in the clockwise direction.

[0017] In some implementations, the rotational axes of the plasma zones can be substantially parallel to a surface of the substrate 10 on which the deposition material is to be deposited. The term "substantially parallel" relates to a substantially parallel orientation of the rotational axes and the surface of the substrate, wherein a deviation of a few degrees, e.g. up to 10° or even up to 15°, from an exact parallel orientation is still considered as "substantially parallel".

[0018] The term "processing zone" as used throughout the specification can be understood as an area or zone in which the substrate 10 can be positioned to deposit a deposition material thereon to form, e.g., a layer for a thin film transistor. The processing zone can be located to face the array of the at least three sputter cathodes. During a sputter deposition process, the plasma zones, e.g., the first plasma zone 116, the second plasma zone 126 and the third plasma zone 136 move or sweep across the processing zone to deposit the deposition material on the substrate 10. The processing zone can be an area or region, which is provided and/or arranged for the deposition (the intended deposition) of the deposition material on the substrate 10.

[0019] Although three sputter cathodes are shown in the example of FIG. 1, the present disclosure is not limited thereto. According to some embodiments, which can be combined with other embodiments described herein, the array of at least three sputter cathodes includes 6 sputter cathodes or more, 10 sputter cathodes or more, such as 12 sputter cathodes or more. Each sputter cathode of the array can provide a respective plasma zone.

According to embodiments described herein, an array of sputter cathodes is provided, which is configured for large area substrate deposition, particularly wherein the array and the substrate are essentially stationary with respect to each other.

[0020] As an example, the substrate is static during deposition of the deposition material. According to embodiments described herein a static deposition process can be provided, e.g., for TFT processing. It should be noted that "static deposition processes", which differ from dynamic deposition processes do not exclude any movement of the substrate as would be appreciated by a skilled person. A static deposition process can include, for example, at least one of the following: a static substrate position during deposition; an oscillating substrate position during deposition; an average substrate position that is essentially constant during deposition; a dithering substrate position during deposition; a wobbling substrate position during deposition; a deposition process for which the cathodes are provided in one vacuum chamber, i.e. a predetermined set of cathodes is provided in the vacuum chamber; a substrate position wherein the vacuum chamber has a sealed atmosphere with respect to neighboring chambers, e.g. by closing valve units separating the vacuum chamber from an adjacent chamber during deposition of the layer; or a combination thereof. A static deposition process can be understood as a deposition process with a static position, a deposition process with an essentially static position, or a deposition process with a partially static position of the substrate. In view of this, a static deposition process, in which the substrate position can in some cases not be fully without any movement during deposition, can still be distinguished from a dynamic deposition process

[0021] According to some embodiments, which can be combined with other embodiments described herein, the sputter cathodes can be connected to a DC power supply such that sputtering can be conducted as DC sputtering. According to some embodiments, which can be combined with other embodiments described herein, the sputter cathodes can be connected to an AC power supply such that the rotatable cathodes can be biased in an alternating manner, e.g. for MF (middle frequency) sputtering, RF (radio frequency) sputtering or the like.

[0022] The sputter cathodes can, for example, each be a rotatable cathode. The rotatable cathode can be rotatable around a rotational axis, which can coincide with, or be identical

to, the rotational axis around which the respective plasma zone is rotated. In some implementations, the first sputter cathode 110 is a first rotatable cathode 112 (or first rotatable target), the second sputter cathode 120 is a second rotatable cathode 122 (or second rotatable target), and the third sputter cathode 130 is a third rotatable cathode 132 (or third rotatable target). The first rotatable cathode 112 can be rotatable around the first rotational axis 118, the second rotatable cathode 122 can be rotatable around the second rotational axis 128, and the third rotatable cathode 132 can be rotatable around the third rotational axis 138. The rotatable cathodes or rotatable targets can be connected to respective rotating shafts or connecting elements connecting the shaft and the rotatable cathodes or rotatable targets. In some implementations, the sputter cathodes can be tubular sputter cathodes.

[0023] According to some embodiments, which can be combined with other embodiments described herein, each sputter cathode of the array of at least three sputter cathodes includes a magnet assembly. As an example, the first sputter cathode 110 has a first magnet assembly 114, the second sputter cathode 120 has a second magnet assembly 124, and the third sputter cathode 130 has a third magnet assembly 134. The magnet assembly can be provided in the respective rotatable cathode. The sputter cathode having the rotatable cathode and the magnet assembly can provide for magnetron sputtering for depositing of the layers.

[0024] As used herein, "magnetron sputtering" refers to sputtering performed using a magnetron, i.e. a magnet assembly, that is, a unit capable of generating a magnetic field. Such a magnet assembly can consist of one or more permanent magnets. These permanent magnets can be arranged behind the target material of a target, e.g. within the rotatable cathode or rotatable target in a manner such that the free electrons are trapped within the generated magnetic field generated below a surface of the rotatable cathode or rotatable target. The permanent magnets being arranged behind the target material of the target is understood as an arrangement where the target material is provided between the permanent magnets and the processing zone or the substrate when the plasma zones are directed towards the processing zone or substrate 10. In other words, the processing zone or the substrate 10 is not directly exposed to the permanent magnets when the plasma zones are

directed towards the processing zone or substrate 10 but the target is interposed therebetween.

[0025] The sputter cathodes can, for example, each include a target of the material to be deposited on the substrate. The material of the target can include a material selected from the group consisting of: aluminum, silicon, tantalum, molybdenum, niobium, titanium, copper, silver, zinc, MoW, ITO,IZO and IGZO.

[0026] In some implementations, the deposition material is present in a solid phase in a target, e.g. a rotatable target. By bombarding the rotatable cathode or rotatable target with energetic particles, atoms of the target material, i.e. the deposition material, are ejected from the rotatable cathode or rotatable target and are supplied into the plasma zone. According to some embodiments, the deposition material can include a material selected from the group consisting of aluminum, silicon, tantalum, molybdenum, niobium, titanium and copper. In a reactive sputtering process, one or more process gases can be supplied to the plasma zone, e.g., at least one of oxygen and nitrogen. Reactive sputtering processes are deposition processes during which a material is sputtered under a process atmosphere. As an example, the process atmosphere can include the one or more process gases such as at least one of oxygen and nitrogen in order to deposit a material or layer containing an oxide or nitride of the deposition material.

[0027] The deposition material is provided in the plasma zone. As an example, the magnet assemblies of the sputter cathodes can be utilized to confine the plasma for improved sputtering conditions. In some implementations, the plasma zone can be understood as the sputtering plasma or a sputtering plasma region provided by the sputter cathode. The plasma confinement can also be utilized for adjusting a participle distribution of the material to be deposited on the substrate. In some embodiments, the plasma zone corresponds to a zone that includes the atoms of the target material (the deposition material) that are ejected or released from the target. The plasma zone can be confined by magnet assemblies, i.e. magnetrons, wherein the ions and electrons of processing gases and/or deposition material are confined in the proximity of the magnetrons or magnet assembly. At least some of the atoms ejected or released from the target are deposited on the substrate to form the layer.

[0028] In some implementations, the plasma zone extends in a circumferential direction of a respective sputter cathode, e.g., the rotatable cathode or rotatable target. As an example, the plasma zone does not extend over a full circumference of the rotatable cathode or rotatable target in the circumferential direction. According to some embodiments, the plasma zone extends over less than a third, and specifically less than a fourth of the full circumference of the rotatable cathode or rotatable target. Based on a rotational position of the plasma zone it can either face the processing zone or it faces away from (is not directed to) the processing zone (e.g., in the first rotational position).

[0029] The plasma zone can assume different rotational positions with respect to the processing zone and/or the rotational axis of said plasma zone. As an example, the first plasma zone 116 can assume different rotational positions with respect to the first rotational axis 118. The second plasma zone 126 can assume different rotational positions with respect to the second rotational axis 128. The third plasma zone 136 can assume different rotational positions with respect to the third rotational axis 138. According to some embodiments, each plasma zone can have rotational positions where the plasma zone is facing towards the processing zone where the substrate 10 is located, as it is shown in the example of FIG. 1. In other words, the plasma zone is facing towards the substrate 10 so that the deposition material is deposited on the substrate 10 to form a layer. The plasma zone can have other rotational positions where the plasma zone is facing away from the processing zone. In other words, the plasma zone is directed away from the substrate 10 so that no deposition material is deposited on the substrate 10 (e.g., the first rotational position and optionally the second rotational position).

[0030] According to some embodiments, which can be combined with other embodiments described herein, the plasma zones can be rotated once around the rotational axes by rotating the magnet assemblies of the sputter cathodes around the respective rotational axes. The rotational axes of the plasma zones and the rotational axes of the magnet assemblies can coincide or can be identical. As an example, the first plasma zone 116 can be rotated around the first rotational axis 118 by rotating the first magnet assembly 114 of the first sputter cathode 110 around the first rotational axis 118. The second plasma zone 126 can be rotated around the second rotational axis 128 by rotating the second magnet assembly 124 of the second sputter cathode 120 around the second rotational axis

128. The third plasma zone 136 can be rotated around the third rotational axis 138 by rotating the third magnet assembly 134 of the third sputter cathode 130 around the third rotational axis 138. The deposition arrangement can include a drive or motor for rotating the magnet assemblies around the respective rotational axes. The drive or motor can be included in the sputter cathode or an end block associated in the sputter cathode. According to some implementations, the end block may be considered a portion of the sputter cathode.

[0031] FIG. 2A shows a schematic view of the deposition arrangement 100 of FIG.1 illustrating the method for material deposition on the substrate 10. In the example of FIG. 2A, the plasma zone is rotated once by less than 360 degrees. FIG. 2B shows a schematic view of the deposition arrangement 100 of FIG.1 illustrating the method for material deposition on the substrate 10 according to further embodiments. In the example of FIG. 2B, the plasma zone is rotated once by about 360 degrees. In other words, in FIG. 2B the plasma zone performs a full rotation or rotation cycle around the rotational axis, i.e., a rotation by about 360 degrees. To provide a better overview, the examples of FIGs. 2A and 2B only illustrate two sputter cathodes of the array of at least three sputter cathodes.

[0032] In the method according to the present disclosure, the substrate 10 is moved into the processing zone in a vacuum chamber (not shown) having the array of at least three sputter cathodes. The at least three sputter cathodes provide the plasma zones at which the deposition material is supplied during operation of the at least three sputter cathodes. The plasma zones are rotated only once around the respective rotational axes from a first rotational position 140 to a second rotational position 144, or vice versa. As an example, the first plasma zone 116 is rotated only once around the first rotational axis 118 from the first rotational position 140 to the second rotational position 144, or vice versa. The second plasma zone 126 is rotated only once around the second rotational axis 128 from the first rotational position 140 to the second rotational position 144, or vice versa. Rotating of the plasma zones only once around the respective rotational axes can include a rotating of magnet assemblies around the rotational axes, as it is described with reference to FIG. 1.

[0033] The deposition material provided by the plasma zones is deposited on the substrate 10 while the plasma zones move or sweep over the processing zone during rotating from the first rotational position 140 to the second rotational position 144.

[0034] The plasma zones are rotated only once around the rotational axes for deposition of the layer on the substrate 10. In other words, only one rotation around the rotational axis is performed and in only one direction. As an example, the rotation can be a rotation in a clockwise direction or an anticlockwise direction. According to some embodiments, which can be combined with other embodiments described herein, the method can include a moving of the substrate 10 out of the processing zone when the plasma zones have moved once over the processing zone, and moving another substrate into the processing zone. The above described method for material deposition can be repeated for the other substrate to form another layer on said other substrate.

[0035] Moving or sweeping of the plasma zones only once across the processing zone can improve purity and/or uniformity of the layer deposited on the substrate. As an example, purity of the deposited layer can be improved, since impurities (e.g., oxidized particles) that might be present on a target of the at least three sputter cathodes are removed from the target before the plasma zone is directed towards the substrate for deposition. For example, if the first rotational position corresponds to the rotational position before material deposition is conducted, the following aspects may be provided. Impurities are removed from the target while the plasma zones are directed away from the processing zone in the first rotational position. Thin layers can be deposited on the substrate by moving the plasma zones only once over the substrate positioned in the processing zone from the first rotational position to the second rotational position. Further, uniformity, e.g., a thickness uniformity, of the deposited layers can be improved when the second rotational position is a rotational position where the plasma zones are directed away from the processing zone. Moreover, a process time can be minimized and a throughput of an apparatus for layer deposition can be increased.

[0036] In the described examples of the present disclosure the plasma zones and optionally the magnet assemblies of the sputter cathodes have substantially the same orientations (e.g., rotational positions) in a two-dimensional plane perpendicular to the rotational axes. As an example, the first rotational positions and the second rotational positions of all plasma zones are substantially the same or substantially identical. The term "substantially the same" or "substantially identical" relates to an orientation or positioning of the plasma zones with respect to each other and/or the rotational axes, wherein a

deviation of a few degrees, e.g. up to 10° or even up to 15°, from an exact identical orientation is still considered as "substantially the same orientation" or "substantially identical orientation".

[0037] In other embodiments, the plasma zones of the sputter cathodes can have different orientations. At least some of the plasma zones and optionally the magnet assemblies of the sputter cathodes can have different orientations (e.g., rotational positions) in the two-dimensional plane perpendicular to the rotational axes. As an example, the first rotational positions and/or the second rotational positions of at least some of the plasma zones can be different. In some implementations, the first rotational positions and/or the second rotational positions can be different, e.g., can have different angles with respect to the rotational axis of the respective plasma zones. As an example, an angle of the first rotational position of the first plasma zone 116 with respect to the first rotational axis 118 (or normal 142) can be different from an angle of the first rotational position of the second plasma zone 126 with respect to the second rotational axis 128 (or normal 142). Likewise, an angle of the second rotational position of the first plasma zone 116 with respect to the first rotational axis 118 (or normal 142) can be different from an angle of the second rotational position of the second plasma zone 126 with respect to the second rotational axis 128 (or normal 142).

[0038] In some implementations, the plasma zones of the outer sputter cathodes of the array can have rotational positions different from the rotational positions of the plasma zones of the inner sputter cathodes of the array. Using such different rotational positions for the plasma zones of the outer sputter cathodes and the plasma zones of the inner sputter cathodes may further improve uniformity, such as thickness uniformity, of the deposited layers.

[0039] According to some embodiments, which can be combined with other embodiments described herein, the method includes a determining (or selecting) of a rotational speed of the plasma zones based upon a predetermined layer thickness. As an example, the rotational speed of the plasma zones can be selected to allow for a formation of a layer with a predetermined layer thickness. The slower the rotational speed, the longer the plasma zones will face towards the processing zone and the thicker (e.g., up to 100nm) the layer deposited on the substrate will be. The higher the rotational speed, the shorter the

plasma zones will face towards the processing zone and the thinner (e.g., less than 10nm) the layer deposited on the substrate will be.

[0040] In some embodiments, rotating the plasma zones around the rotational axes includes rotating the magnet assemblies around the respective rotational axes. As an example, the first magnet assembly 114 of the first sputter cathode 110 can be rotated around the first rotational axis 118, and the second magnet assembly 124 of the second sputter cathode 120 can be rotated around the second rotational axis 128. The rotational speed of the plasma zones can be adjusted by adjusting a rotational speed of the respective magnet assemblies of the sputter cathodes.

[0041] According to some embodiments, which can be combined with other embodiments described herein, an angle between the first rotational position 140 and the second rotational position 144 with respect to the respective rotational axis is in a range of 180 to 360 degrees. The angle is indicated with the arrows in FIGs. 2A and 2B. In FIG. 2A the arrow is connecting the dashed lines indicating the first rotational position 140 and the second rotational position 144. For example, the angle between the first rotational position 140 and the second rotational position 144 with respect to the respective rotational axis can be about 180 degrees or can be about 360 degrees. However, the present disclosure is not limited thereto. Any suitable angle can be chosen which allows the plasma zones to face away from the processing zone at the first rotational position and optionally the second rotational position, and to face towards the processing zone in at least some rotational positions between the first rotational position 140 and the second rotational position 144.

[0042] The angle in the example of FIG. 2A is illustrated as an absolute angle between the first rotational position 140 and the second rotational position 144. However, the angle can also be defined as an angle with respect to a normal 142. The normal 142 can be normal or perpendicular to a surface of the substrate 10 and can cross the rotational axis of the respective plasma zone and/or magnet assembly of a sputter cathode. The angle between the first rotational position 140 and the second rotational position 144 can then be defined as plus/minus an angle with respect to the normal 142. As an example, the angle can be plus/minus 90 degrees (corresponding to an absolute or total angle of 180 degrees) or plus/minus 180 degrees (corresponding to an absolute or total angle of 360 degrees) with respect to the normal 142.

[0043] According to some embodiments, which can be combined with other embodiments described herein, the plasma zones of the three or more sputter cathodes are rotated synchronously from the first rotational position 140 to the second rotational position 144 or vice versa. In other words, the plasma zones of the three or more sputter cathodes can have the same rotational positions or orientations during the movement from the first rotational position 140 to the second rotational position 144 or vice versa.

[0044] In other implementations, the plasma zones of the three or more sputter cathodes can be rotated asynchronously. As an example, adjacent plasma zones of the three or more sputter cathodes can be rotated in opposite rotational directions during at least 50% of the movement between the first rotational position and the second rotational position.

[0045] According to some embodiments, which can be combined with other embodiments described herein, the rotational axes of the plasma zones are vertically oriented. Likewise, the rotational axes of the magnet assemblies can be vertically oriented. "Vertically" is understood as "substantially vertically" particularly when referring to the orientation of the rotational axes of the plasma zones and/or the magnet assemblies, to allow for a deviation from the vertical direction of 20° or below, e.g. of 10° or below. This deviation can be provided for example because the sputter cathode or the rotatable cathode can be positioned with some deviation from the vertical orientation. Yet, the orientation of the respective rotational axis is considered vertical, which is considered different from the horizontal orientation. The term "vertically" can be understood as being parallel to the force of gravity.

[0046] In some embodiments, the substrate is in a vertical orientation. The term "vertical direction" or "vertical orientation" is understood to distinguish over "horizontal direction" or "horizontal orientation". That is, the "vertical direction" or "vertical orientation" relates to a substantially vertical orientation of, for example, the substrate, wherein a deviation of a few degrees, e.g. up to 10° or even up to 15°, from an exact vertical direction or vertical orientation is still considered as a "vertical direction" or a "vertical orientation". The vertical direction can be substantially parallel to the force of gravity.

[0047] The term "substrate" as used herein shall particularly embrace inflexible substrates, e.g., a wafer, slices of transparent crystal such as sapphire or the like, or a glass

plate. However, the present disclosure is not limited thereto and the term "substrate" may also embrace flexible substrates such as a web or a foil.

[0048] The embodiments described herein can be utilized for evaporation on large area substrates, e.g. display manufacturing. For instance, a large area substrate or carrier can be GEN 4.5, which corresponds to about 0.67 m² substrates (0.73x0.92m), GEN 5, which corresponds to about 1.4 m² substrates (1.1 m x 1.3 m), GEN 7.5, which corresponds to about 4.29 m² substrates (1.95 m x 2.2 m), GEN 8.5, which corresponds to about 5.7m² substrates (2.2 m x 2.5 m), or even GEN 10, which corresponds to about 8.7 m² substrates (2.85 m × 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented.

[0049] FIG. 3 shows a schematic view of a sputter cathode having a planer rotatable cathode 510 illustrating the method for material deposition on a substrate 10 according to further embodiments described herein. The embodiment of FIG. 3 is similar to the embodiments described above with reference to FIGs. 1, 2A and 2B, and the description given with respect to said FIGs. 1, 2A and 2B also applies to the embodiment of FIG. 3. To provide a better overview, FIG. 3 illustrates only one sputter cathode of the array of at least three sputter cathodes.

[0050] In the example of FIG. 3, the sputter cathode is a planar cathode 510 providing a plasma zone 516. The plasma zone 516 can be rotated around a rotational axis 530. As an example, the planar cathode 510 can be rotated around the rotational axis 530, and also the plasma zone 516 is rotated. The planar cathode 510 and correspondingly the plasma zone 516 can be rotated to move or sweep once across the processing zone to expose the substrate 10 to the plasma zone 516 and the deposition material.

[0051] The plasma zone 516 can assume different rotational positions with respect to the processing zone and/or the rotational axis of said plasma zone. As an example, the plasma zone 516 can have at least one rotational position where the plasma zone 516 is facing towards the processing zone where the substrate 10 is located, as it is indicated with the dashed lines in FIG. 3. In other words, the plasma zone 516 is facing towards the substrate 10 so that the deposition material is deposited on the substrate 10 to form a layer. The plasma zone can have other rotational positions, such as the first rotational positions and

optionally the second rotational position, where the plasma zone 516 is facing away from the processing zone, as it is indicated with the solid lines in FIG. 3. In other words, the plasma zone 516 is directed away from the substrate 10 so that no deposition material is deposited on the substrate 10.

[0052] A magnet assembly (not shown) can be arranged behind the planar cathode 510 or planar target. As an example, the planar cathode 510 or planar target is provided between the magnet assembly and the processing zone or the substrate 10 when the plasma zone 516 is directed towards the processing zone or substrate 10.

[0053] In some implementations, the planar target can extend in a lengthwise direction and in a widthwise direction. The rotational axis 530 can be substantially parallel to the lengthwise direction, and can be substantially perpendicular to the widthwise direction. In other words, the planar cathodes or planar targets can be rotated around their lengthwise extension.

[0054] FIG. 4 shows a schematic top view of an apparatus 300 for layer deposition on a substrate with the plasma zones 2 of the at least three sputter cathodes 324 facing away from the processing zone according to embodiments described herein. FIG. 5 shows a schematic top view of the apparatus 300 with the plasma zones 2 of the at least three sputter cathodes 324 moving over the processing zone according to embodiments described herein. The apparatus 300 is configured for sputter deposition, such as, for example, reactive sputter deposition.

[0055] The apparatus includes a vacuum chamber 302 having a processing zone for processing of a substrate 10, an array of at least three sputter cathodes 324, wherein each of the at least three sputter cathodes 324 provides a plasma zone 2 in which a deposition material is supplied during operation of the at least three sputter cathodes 324, and a controller configured for rotating each plasma zone 2 only once around a rotational axis from a first rotational position to a second rotational position. Each plasma zone 2 is directed away from the processing zone in the first rotational position. The controller is configured for moving each plasma zone 2 over the processing zone by rotating of each plasma zone 2 from the first rotational position to the second rotational position. The vacuum chamber 302 can also be referred to as “processing chamber”.

[0056] In FIG. 4, the plasma zones 2 of the at least three sputter cathodes 324 are facing away from the processing zone. The plasma zone (not shown in FIG. 4), e.g., a sputtering plasma, is also confined facing away from the substrate 10 and can be directed to a shield (not shown), which can collect material to be sputtered while the plasma zones 2 are directed towards the shield. This condition of non-exposure can, for example, be maintained until the plasmas of the plasma zones 2 provided by the at least three sputter cathodes 324 are stabilized. As shown in FIG. 5, the magnet assemblies of the sputter cathodes 324 can then be rotated around their rotational axes, and also the plasma zones 2 are rotated. The magnet assemblies and correspondingly the plasma zones 2 can be rotated to move or sweep once across the processing zone to expose the substrate 10 to the plasma zone 2 and the deposition material.

[0057] Exemplarily, one vacuum chamber 302 for deposition of layers therein is shown. Further vacuum chambers 303 can be provided adjacent to the vacuum chamber 302. The vacuum chamber 302 can be separated from adjacent further vacuum chambers 303 by a valve having a valve housing 304 and a valve unit 305. After a carrier 314 with the substrate 10 thereon is, as indicated by arrow 1, inserted in the vacuum chamber 302, the valve unit 305 can be closed. The atmosphere in the vacuum chamber 302, such as a process atmosphere for a reactive sputtering process, can be individually controlled by generating a technical vacuum, for example, with vacuum pumps connected to the vacuum chamber 302, and/or by inserting one or more process gases in the processing zone in the vacuum chamber 302. The one or more process gases can include gases for creating a process atmosphere for a reactive sputtering process. Within the vacuum chamber 302, rollers 310 can be provided in order to transport the carrier 314, having the substrate 10 thereon, into and out of the vacuum chamber 302.

[0058] Within the vacuum chamber 302, the at least three sputter cathodes 324 are provided. The at least three sputter cathodes 324 can be configured as described with respect to FIGs. 1, 2A and 2B. As an example, the at least three sputter cathodes 324 can each include one or more rotatable cathodes and one or more anodes 326. For example, the one or more rotatable cathodes can have the sputter targets of the material to be deposited on the substrate 10. The one or more rotatable cathodes can have the magnet assembly therein and magnetron sputtering can be conducted for depositing the layers.

[0059] The one or more rotatable cathodes and the one or more anodes 326 can be electrically connected to a DC power supply 328. In some implementations, the one or more rotatable cathodes can be rotated simultaneously, e.g., synchronously, towards the substrate 10 for exposure thereof. Sputtering for forming the layer on the substrate 10 can be conducted as DC sputtering. The one or more cathodes are connected to the DC power supply 328 together with the one or more anodes 326 for collecting electrons during sputtering. According to yet further embodiments, which can be combined with other embodiments described herein, at least one of the one or more rotatable cathodes can have its corresponding, individual DC power supply.

[0060] FIGs. 4 and 5 show a plurality of sputter cathodes 324, wherein each sputter cathode 324 includes one rotatable cathode and one anode 326. Particularly for applications for large area deposition, an array of sputter cathodes can be provided within the vacuum chamber 302. In some examples, six or more sputter cathodes 324 are provided. As an example, 12 sputter cathodes 324 can be provided.

[0061] Pre-sputtering and/or target conditioning can be utilized in addition to the methods described herein. During pre-sputtering and/or target conditioning, the plasma zones 2 can be facing away from the processing zone as shown in FIG. 4. As an example, during pre-sputtering and/or target conditioning, the plasma zones 2 can be directed away from the processing zone. The plasma zones 2 can, for example, be directed towards a shield (not shown).

[0062] According to the present embodiments, a controller for controlling a material deposition process is provided. The controller is configured to perform the method for material deposition on a substrate according to the embodiments described herein. The controller can be included in the apparatus for layer deposition according to the embodiments described herein. According to embodiments described herein, the controller can be configured to perform the method of the present embodiments by means of computer programs, software, computer software products and the interrelated controllers, which can have a CPU, a memory, a user interface, and input and output means being in communication with the corresponding components of the apparatus for processing a large area substrate.

[0063] According to the present disclosure, plasma zones of sputter cathodes move or sweep only once over a processing zone in which a substrate is located. The plasma zones include a material to be deposited on the substrate to form a layer. Moving or sweeping once across the processing zone improves at least one of uniformity and purity of the layer deposited on the substrate. As an example, thickness uniformity of the deposited layer can be improved. Further, purity of the deposited layer can be improved, since impurities (e.g., oxidized particles) that might be present on a target of the at least three sputter cathodes are removed from the target before the plasma zone is directed towards the substrate for deposition. Moreover, a process time can be minimized and a throughput of an apparatus for layer deposition can be increased.

[0064] While the foregoing is directed to embodiments of the disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. Method for material deposition on a substrate, comprising:

moving a substrate into a processing zone in a vacuum chamber having an array of at least three sputter cathodes, wherein each of the at least three sputter cathodes provides a plasma zone in which a deposition material is supplied during operation of the at least three sputter cathodes; and

rotating each plasma zone only once around a respective rotational axis from a first rotational position to a second rotational position, wherein each plasma zone is directed away from the processing zone in the first rotational position, and wherein each plasma zone moves over the processing zone during rotating from the first rotational position to the second rotational position.

2. The method of claim 1, wherein the deposition material provided by the plasma zones is deposited on the substrate while the plasma zones move over the processing zone during rotation from the first rotational position to the second rotational position.

3. The method of claim 1 or 2, wherein rotating the plasma zones once around the rotational axes includes a rotating of magnet assemblies around the respective rotational axes.

4. The method of one of claim 1 to 3, further including:

moving the substrate out of the processing zone when the plasma zones have moved only once over the processing zone; and

moving another substrate into the processing zone.

5. The method of any one of claims 1 to 4, wherein an angle between the first rotational position and the second rotational position with respect to the respective rotational axis is in a range of 180 to 360 degrees.

6. The method of any one of claims 1 to 5, wherein the angle between the first rotational position and the second rotational position with respect to the respective rotational axis is about 360 degrees.

7. The method of any one of claims 1 to 6, wherein the array of at least three sputter cathodes includes 6 or more sputter cathodes or 12 or more sputter cathodes.

8. The method of claim 7, wherein the plasma zones of the at least three sputter cathodes are rotated synchronously from the first rotational position to the second rotational position.

9. The method of any one of claims 1 to 8, wherein the substrate is static during deposition of the deposition material.

10. The method of any one of claims 1 to 9, wherein the rotational axes are vertically oriented.

11. The method of any one of claims 1 to 10, wherein the substrate is in a vertical orientation.

12. The method of any one of claims 1 to 11, wherein the deposition material includes a material selected from the group consisting of: aluminum, silicon, tantalum, molybdenum, niobium, titanium and copper.

13. The method of any of claims 1 to 12, further comprising:

determining a rotational speed of the plasma zones based upon a predetermined layer thickness.

14. Controller for controlling a material deposition process, wherein the controller is configured to perform the method of any one of claims 1 to 13.

15. Apparatus for layer deposition on a substrate, including:

a vacuum chamber having a processing zone for processing of a substrate;

an array of at least three sputter cathodes, wherein each of the at least three sputter cathodes provides a plasma zone in which a deposition material is supplied during operation of the at least three sputter cathodes; and

a controller configured for rotating each plasma zone only once around a respective rotational axis from a first rotational position to a second rotational position, wherein each plasma zone is directed away from the processing zone in the first rotational position, and wherein the controller is configured for moving each plasma zone over the processing zone by rotating each plasma zone from the first rotational position to the second rotational position.

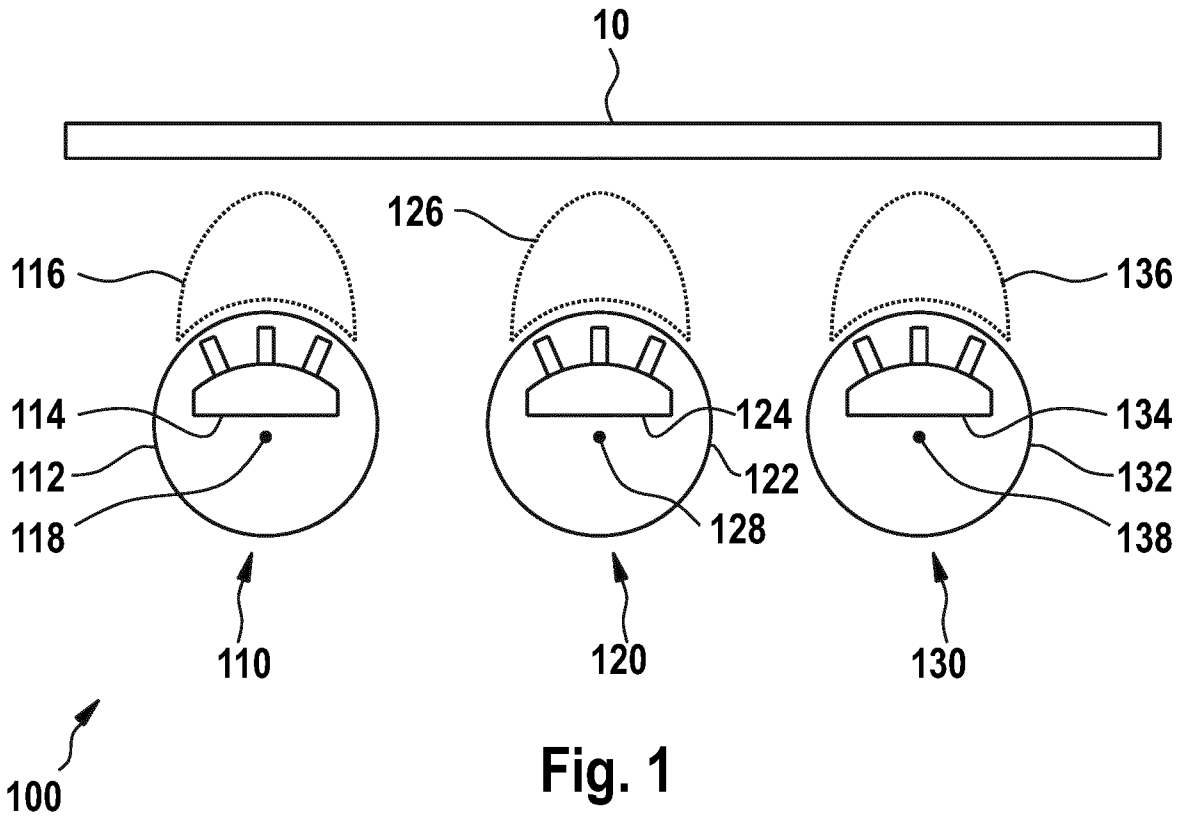

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Fig. 1

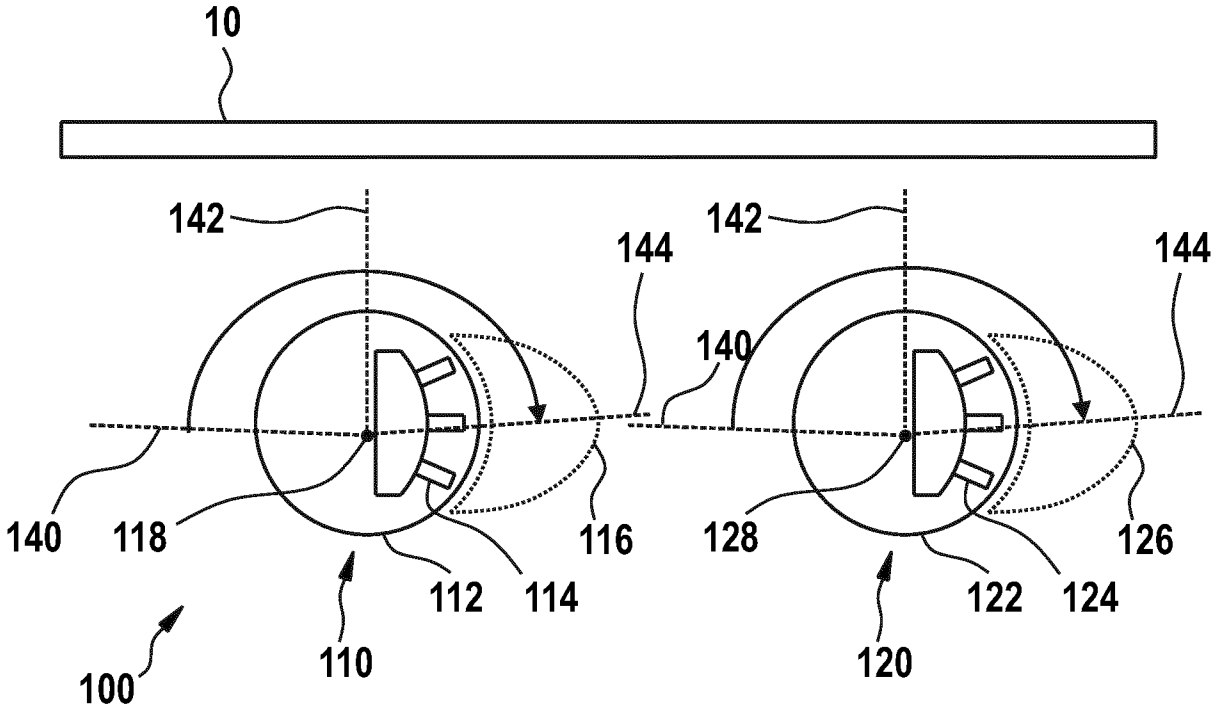

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Fig. 2A

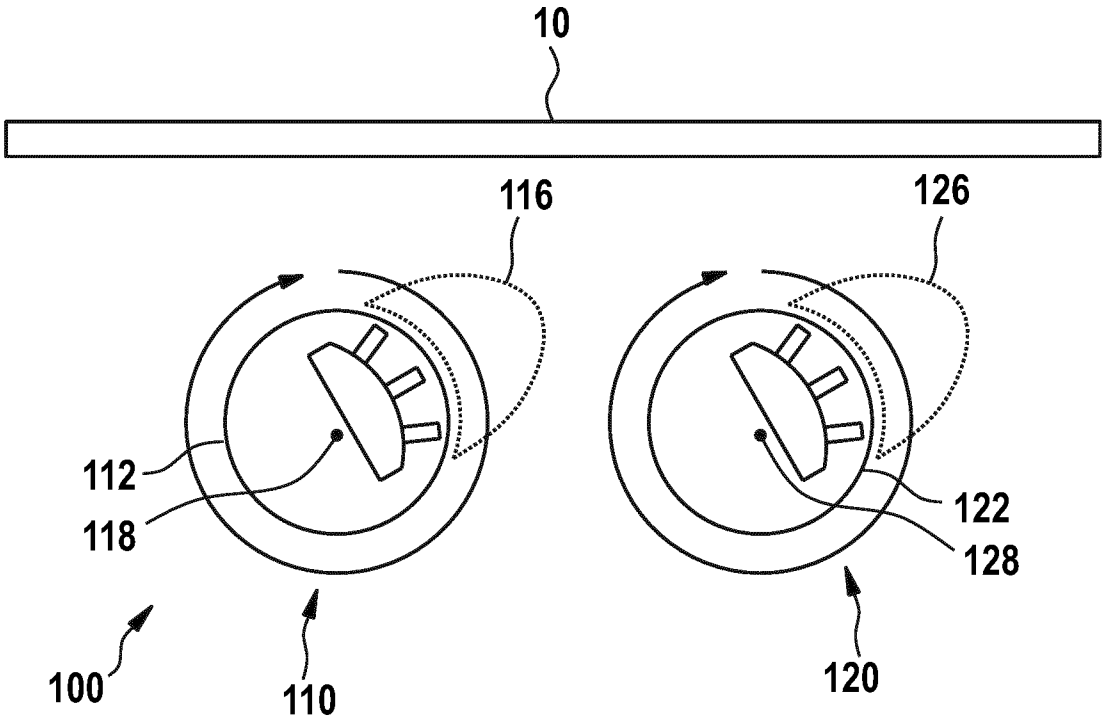


Fig. 2B

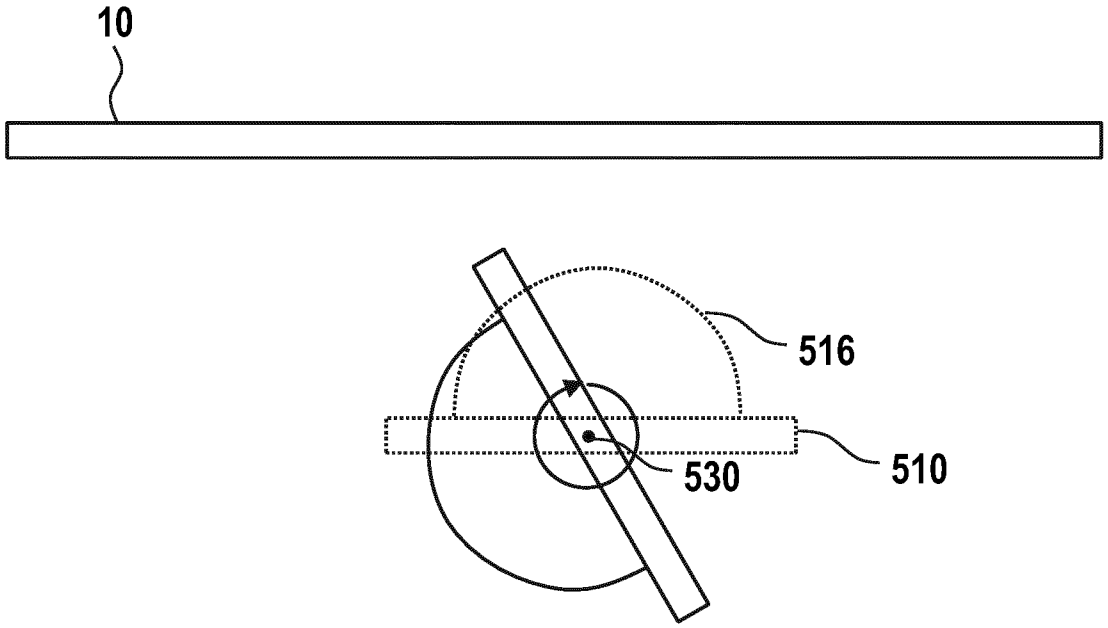


Fig. 3

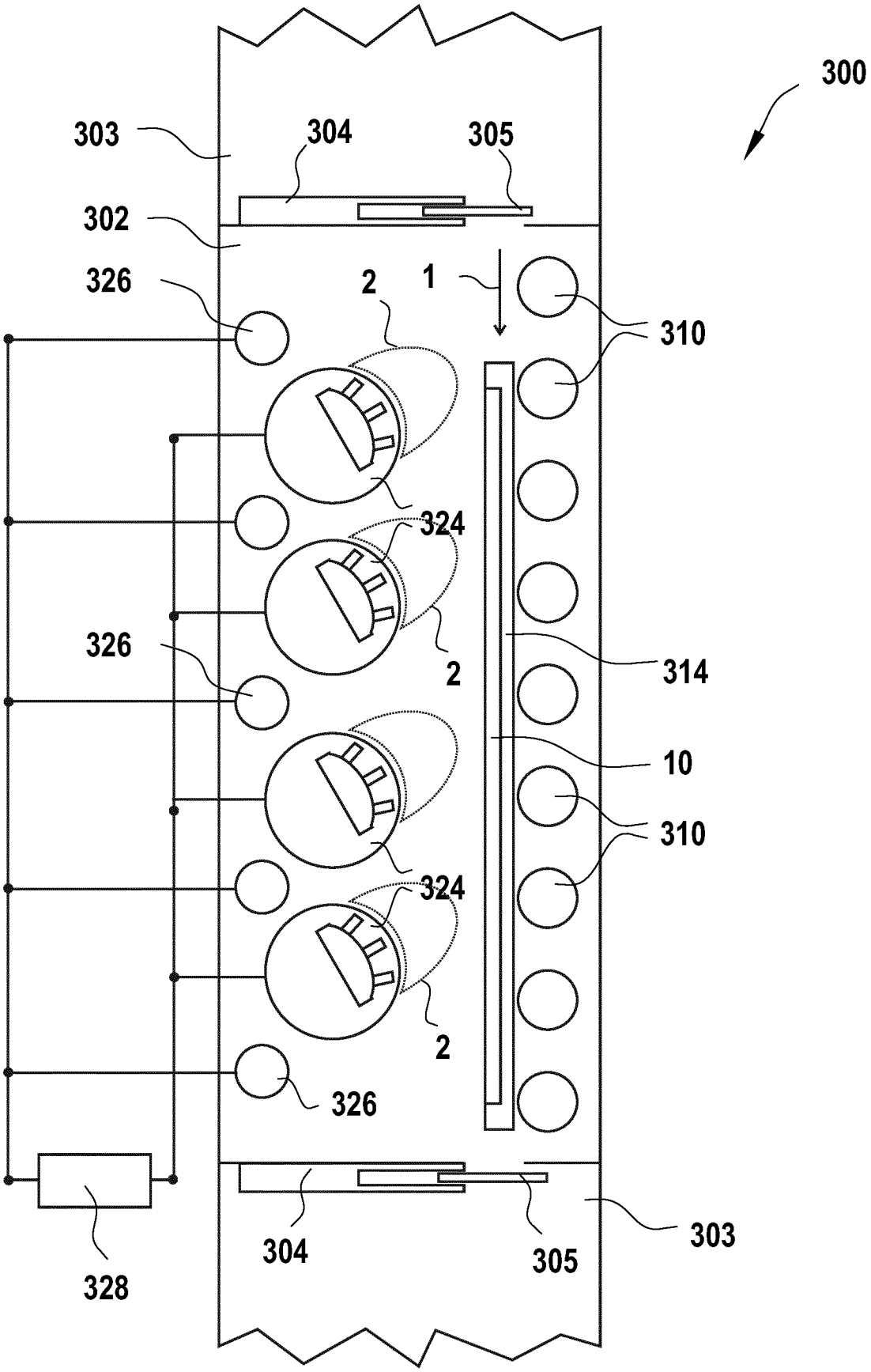

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Fig. 4

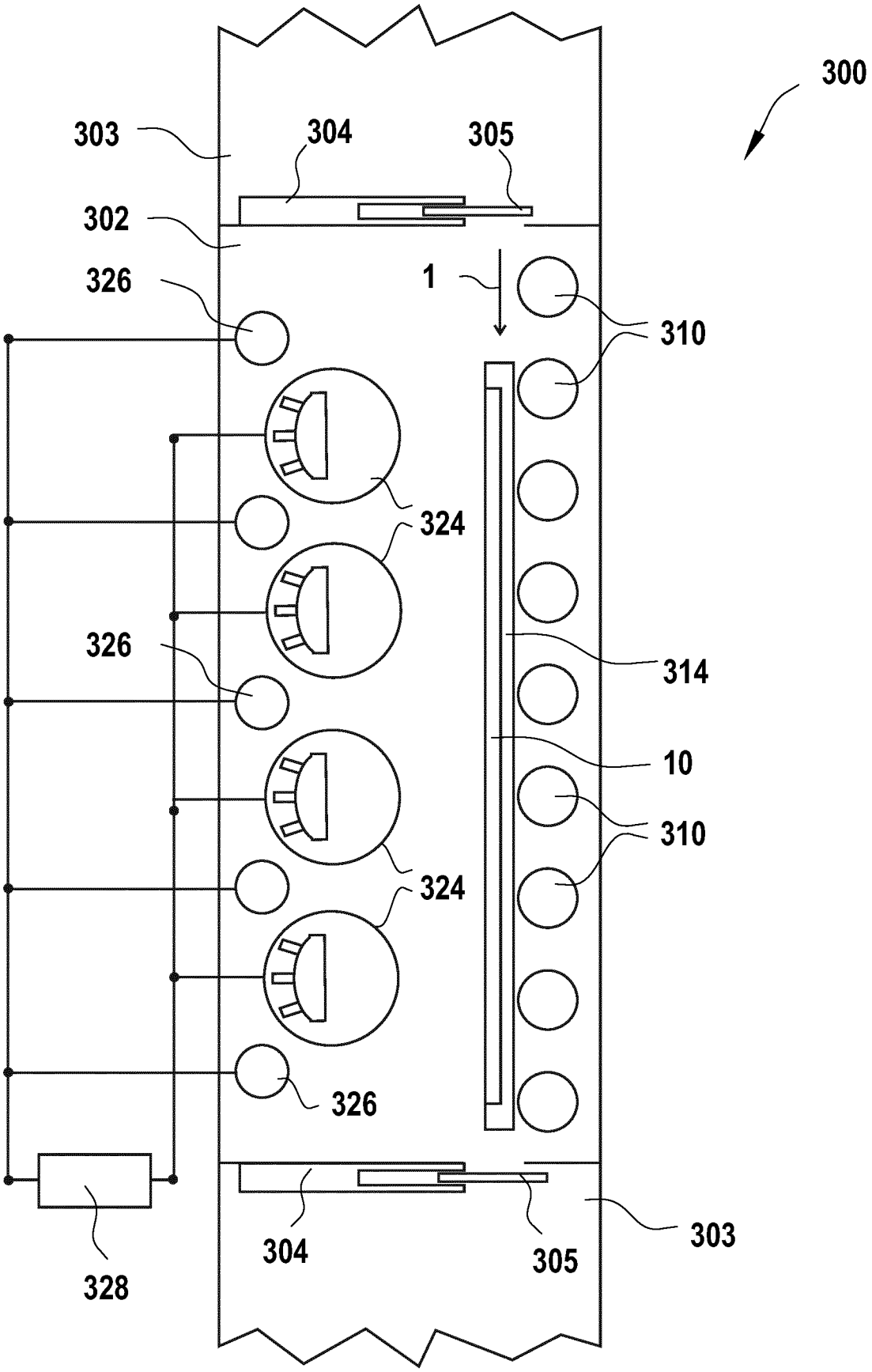

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Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/057769

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C14/56 C23C14/35 C23C14/34 H01J37/34
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C23C H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	EP 2 306 489 A1 (APPLIED MATERIALS INC [US]) 6 April 2011 (2011-04-06) paragraph [0001] paragraphs [0016], [0050] paragraph [0051] - paragraph [0056] paragraph [0034] paragraph [0065] paragraph [0012] paragraph [0055] paragraph [0049]	1,3-9, 12,14,15 2,10,11 13

Y	WO 2013/178252 A1 (APPLIED MATERIALS INC [US]; SCHEER EVELYN [DE]; HANIKA MARKUS [DE]; SC) 5 December 2013 (2013-12-05) page 12, line 1 - line 3	10,11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 June 2015	03/07/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kudelka, Stephan

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/057769

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2007/256933 A1 (YOON HYUK SANG [KR] ET AL) 8 November 2007 (2007-11-08) paragraphs [0052], [0053]; figure 6	1-15

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International application No
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