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(54) Title: RADIO FREQUENCY (RF) - SPUTTER DEPOSITION SOURCE, DEPOSITION APPARATUS AND METHOD OF OPERATING THEREOF

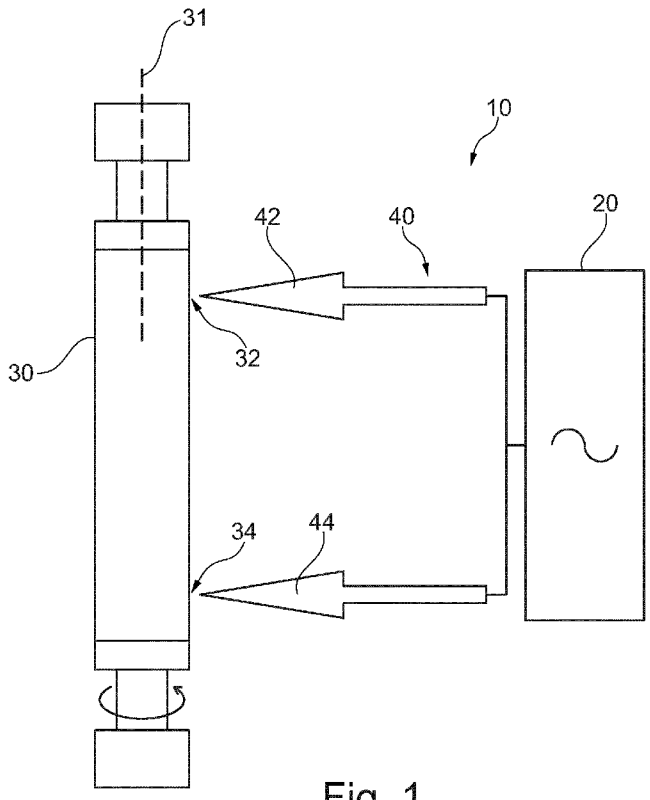


Fig. 1

(57) Abstract: A deposition source (10) for sputter deposition is provided. The deposition source includes at least one rotatable cathode (30), an RF power arrangement (20), and a power delivery assembly (40) connecting the RF power arrangement with the rotatable cathode, the power delivery assembly comprising a first power connector (42) and a second power connector (44) for simultaneously providing the rotatable cathode with RF energy from the RF power arrangement at two spaced-apart positions (32, 34).

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RADIO FREQUENCY (RF) – SPUTTER DEPOSITION SOURCE, DEPOSITION APPARATUS AND METHOD OF OPERATING THEREOF

TECHNICAL FIELD

[0001] Embodiments of the present invention relate to a deposition source for sputter deposition, a sputtering apparatus, and methods of operating thereof. Embodiments specifically relate to a sputter deposition source for radio frequency (RF) sputtering utilizing a rotatable cathode, an RF sputtering apparatus for sputter deposition in a vacuum chamber, and a method of supplying RF power from an RF power apparatus to a rotatable cathode.

BACKGROUND

[0002] PVD processes, particularly sputtering processes, gain increasing attention in some technical fields, e.g. display manufacturing. A good deposition rate can be obtained with sufficient layer characteristics by various sputtering techniques. Sputtering, particularly magnetron sputtering, is a technique for coating substrates such as glass or plastic substrates with metallic or non-metallic layers. Accordingly, a stream of coating material is generated by sputtering a target through the use of a plasma. Material is released from the target surface as a result of collisions with high-energy particles from the plasma, wherein plasma parameters such as pressure, power, gas, magnetic field etc. are controlled. The material released from the target travels from the target toward one or more substrates to be coated and adheres thereto. A wide variety of materials, including metals, semiconductors and dielectric materials can be sputtered to desired specifications. Magnetron sputtering has found acceptance in a variety of applications including semiconductor processing, optical coatings, food packaging, magnetic recording, and protective wear coatings.

[0003] Known sputtering devices include a power arrangement with a power supply for generating and supplying electric energy, a power delivery assembly for depositing said energy in a gas for igniting and maintaining the plasma, magnetic elements for controlling the motion of the plasma ions, and at least one cathode including a target for providing the coating material through sputtering by the plasma. Sputtering is accomplished with a wide variety of devices having differing electrical, magnetic, and mechanical configurations. The known configurations include power arrangements providing direct current (DC) or alternating current (AC) for producing the plasma, wherein AC electromagnetic fields that are applied to a gas regularly provide for higher plasma rates than DC electromagnetic fields. In a radio frequency (RF) sputtering apparatus, the plasma is striked and maintained by applying an RF electric field. Accordingly, also non-conductive materials may be sputtered. Comparing DC sputtering with middle frequency (MF) sputtering and DC sputtering, DC sputtering provides the highest deposition rate whereas RF sputtering provides the lowest deposition rate.

[0004] Sputtering devices with both static targets such as flat plate targets and rotating targets such as rotating cylindrical targets may be used. Regularly, sputtering devices with rotating targets are adapted for operation with direct current or low- to medium frequency alternating current only, but do not operate using RF emissions. As a result, such devices are only suitable for the deposition of conductive layers. In recent years, efforts have been made to combine the advantages of rotatable targets and RF sputtering.

SUMMARY

[0005] In light of the above, according to the independent claims, a deposition source for sputter deposition, an apparatus for sputter deposition in a vacuum chamber and a method of operating a deposition source are provided. Further aspects, advantages, and features of the present invention are apparent from the dependent claims, the description, and the accompanying drawings.

[0006] According to embodiments described herein, a sputter deposition source for sputter deposition is provided. The source includes an RF power arrangement for supplying RF

power; at least one rotatable cathode including a target for releasing the coating material during sputtering; and a power delivery assembly connecting the RF power arrangement with the rotatable cathode, accordingly feeding the rotatable cathode with RF energy from the RF power arrangement. The power delivery assembly includes a first power connector for providing the rotatable cathode with RF energy from the RF power arrangement and a second power connector for simultaneously providing the rotatable cathode with RF energy from the RF power arrangement, whereas the first power connector is arranged spaced-apart from the second power connector. As a result, the rotatable cathode may be fed with RF energy at at least one of a first position and a second position spaced-apart from the first position, and particularly at both the first position and the second position at the same time.

[0007] According to embodiments, a sputter apparatus for sputter deposition in a vacuum chamber is provided. The apparatus includes a sputter deposition source for sputter deposition in the vacuum chamber. The sputter deposition source includes a rotatable cathode that is arranged inside the vacuum chamber, the cathode comprising a target providing the material to be deposited; an RF power arrangement for supplying RF power that is arranged outside the vacuum chamber; and a first power connector and a second power connector for providing the rotatable cathode with RF energy from the RF power arrangement at two-spaced apart positions, wherein at least one of the first power connector and the second power connector includes a vacuum feed-through for transmitting the RF energy from the RF power arrangement into the vacuum chamber.

[0008] According to a further embodiment, a method of operating a deposition source for sputter deposition is provided. The method includes feeding a rotatable cathode with RF energy at a first position and at a second position spaced-apart from the first position. The method may be performed with a deposition source for sputter deposition or with a sputter apparatus in accordance with embodiments described herein. In one embodiment, at least one electric property of an electrical connection supplying RF energy to at least one of the first position and the second position is adjusted before or during sputtering.

BRIEF DESCRIPTION OF THE DRAWINGS

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

[0011] FIG. 1 shows a schematic view of a deposition source for sputter deposition according to embodiments described herein;

[0012] FIG. 2 shows a schematic view of a deposition source for sputter deposition according to embodiments described herein;

[0013] FIG. 3 shows a schematic side view of a deposition source for sputter deposition according to embodiments described herein;

[0014] FIG. 4 shows a schematic perspective view of the embodiment of FIG. 3;

[0015] FIG. 5 shows a schematic view of a deposition source for sputter deposition according to embodiments described herein;

[0016] FIG. 6 shows a schematic view of a sputtering apparatus according to embodiments described herein;

[0017] FIG. 7 shows a flowchart of a method of operating a deposition source for sputter deposition according to embodiments described herein;

[0018] FIG. 8 shows a flowchart of a method of operating a deposition source for sputter deposition according to embodiments described herein.

DETAILED DESCRIPTION

[0019] Reference will now be made in detail to the various embodiments of the invention, 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 invention and is not meant as a limitation of the invention. 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.

[0020] FIG. 1 shows a deposition source 10 for sputter deposition, including: a rotatable cathode 30; an RF power arrangement 20; and a power delivery assembly 40. The power delivery assembly 40 connects the RF power arrangement 20 with the rotatable cathode 30 and includes a first power connector 42 and a second power connector 44 for simultaneously providing the rotatable cathode 30 with RF energy from the RF power arrangement 20 at two spaced-apart positions, e.g. first position 32 and second position 34.

In embodiments described herein, the cathode has a first axial end and a second axial end opposing the first axial end, wherein the first power connector is installed at the first axial end and the second power connector is installed at the second axial end. According to embodiments, the RF power arrangement may include a matchbox, whereas one or more electric properties of an electric connection between the matchbox and at least one of the first and the second power connectors may be made adjustable.

[0021] The RF power arrangement 20 is adapted for supplying alternating current that oscillates at radio frequencies. Whereas the term "AC power" generally refers to alternating currents, the term "RF power" as used herein particularly refers to currents oscillating at an oscillation rate in a frequency range of 1 MHz to 300 GHz, 2 MHz to 1 GHz, and particularly to AC power having a frequency of 13.56 MHz, 27.12 MHz or another multiple of 13.56 MHz. The term "MF" (middle frequency) may refer to an AC power with a frequency in the range of 1 kHz to 1 MHz. Whereas MF sputtering devices

regularly involve metal doping to deposit non-metallic materials, RF sputtering devices may be used to deposit both metallic and non-metallic materials on a substrate. However, for RF sputtering, it is more difficult to generate the RF power and to feed the RF power to the cathode that rotates during sputtering.

[0022] According to some embodiments, the RF power arrangement 20 may include an RF power generator for generating RF power. However, when RF power is used, it is desirable to maintain a constant and preferably optimal load on the power supply in order to operate efficiently. An impedance matching network, particularly a matchbox, may be used for ensuring a consistent load on the power supply and for adapting the internal resistance of the power supply to the load impedance of the operating cathode. Accordingly, in embodiments described herein, the RF power arrangement 20 may include an RF power generator in combination with a matchbox. The power generator may be connected to the power delivery assembly via the matchbox for ensuring impedance matching. In further embodiments, the RF power arrangement 20 may include solely a matchbox adapted for receiving RF power from an external RF power source, e.g. the external RF power source itself may not be a part of the RF power arrangement 20. According to embodiments which can be combined with other embodiments described herein, the matchbox provides for load matching when being connected to an external RF power source with given electric properties. In order to provide for an optimal impedance matching, the matchbox could include adjustable capacitors for balancing purposes.

[0023] According to some implementations, the sputter deposition source 10 includes a rotatable cathode 30 including a target of metallic and/or non-metallic material to be released from the target by sputtering and to be deposited on the substrate to be coated. The rotatable cathode 30 may have a cylindrical form and be rotatable about a rotation axis 31. As compared to a stationary planar target, a rotatable target provides the advantage that the target material is reliably utilized around the whole circumference of the target during sputtering, and there are no edge portions of the target in a lateral direction of the target, where less sputtering may occur on the target surface. Thus, by utilizing rotatable cathodes, material costs can be reduced and the target can be used for a longer time period, before a

target exchange becomes necessary. Target utilization for planar RF cathodes is regularly below 30%; much better values can be achieved for RF rotary cathodes.

[0024] In some implementations, the rotatable cathode 30 is connected to a cathode support by a rotating shaft, the cathode support having a rotational drive for rotating the rotatable cathode 30 at a given rotational speed. In some implementations, the rotatable cathode 30 could be configured to rotate with a speed in the range of 1 to 50 rounds per minute, 5 to 30 rounds per minute or 15 to 25 rounds per minute. Typically, the rotatable cathode 30 could be configured to rotate with a speed of about 20 rounds per minute.

[0025] According to some embodiments, the sputter deposition source can also include a magnetron. A magnetron is a magnet assembly, typically provided by permanent magnets, in order to confine the plasma during sputter deposition. Typically, these magnets are arranged within the rotatable cathode.

[0026] In some implementations, the target of the rotatable cathode 30 includes at least one nonconductive material. For example, the target may include or be made of at least one of SiO_2, Al_2O_3, LiPO, SiC, LiCoO, ITO, IZO or other target materials.

[0027] In some embodiments, which could be combined with other embodiments described herein, the target of the rotatable cathode 30 includes at least one conductive or semiconductive material. For example, the target may include or be made of ITO or LiCoO, whereas the layer properties of the deposited layer may further be improved by operating the cathode in an RF/DC-mode. In particular, in RF/DC-mode a rotatable cathode may be connected to an RF-power supply and a DC-power supply. Accordingly, by providing a deposition source which is provided with RF energy and DC energy, the sputtering deposition rate of the deposition source can be increased. In particular, layer properties obtainable by DC sputtering may be combined with a deposition rate obtainable by DC sputtering.

[0028] In some embodiments, the target, particularly the target tube, includes or is made of at least one of Ag, Cu, titan and Au. Particularly, the rotatable cathode 30 is at least

partially coated with at least one of the above stated conductive materials. As a depth of penetration of RF currents in conductors may be low (skin-effect) and, thus, the current flows along the surface of the conductor, a good conductivity at the surface is achieved by the coating. For example, the rotatable cathode 30 can include a support made of stainless steel which is coated with Ag, Cu or Au. Accordingly, aspects like costs and material strength can also be considered.

[0029] The RF power arrangement 20 is connected to the rotatable cathode 30 via the power delivery assembly 40, wherein the power delivery assembly 40 is adapted for transmitting the RF power to the rotatable cathode 30 for energizing the rotatable cathode with RF electric current at the two spaced-apart positions, e.g. first position 32 and second position 34. As a result, an appropriate RF electric field can be applied to a gas located between the rotatable cathode 30 and an opposedly charged anode such that the gas is ionized and a plasma is maintained between the rotatable cathode 30 and the anode. The RF power assembly 40 has the first power connector 42 for feeding the rotatable cathode 30 with RF current at the first position 32, and it has the second power connector 44 for feeding the rotatable cathode 30 with RF current at the second position 34.

[0030] Sputtering apparatuses do not reliably and homogeneously utilize the target material, even if the target is provided on a rotatable cathode, when the rotatable cathode is fed with RF energy at a single feeding position only. This is because the RF electric field emanating from cathode regions near the single feeding position may be stronger than the RF electric field emanating from cathode regions located distant from the feeding position, so that stronger sputtering may occur near the feeding position. In particular, rotatable cathodes which are provided with electric power via one cathode support that is arranged at a proximal end of the cathode are subjected to weaker sputtering in target areas at a distal end of the cathode distant from the cathode support. This effect leads to asymmetric target utilization, a lack of layer uniformity and to a potential increase of material costs in sputter deposition sources with a single power connector.

[0031] In contrast thereto, according to embodiments disclosed herein, the rotatable cathode 30 is fed with RF energy at least the two spaced-apart positions, e.g. first position

32 and second position 34, so that the RF electric field emanating from the rotatable cathode 30 takes a more homogenous form along the extension of the rotatable cathode 30. Thus, the target material utilization does not decrease with distance from a single feeding position, but may remain essentially constant between the first position 32 and the second position 34. In some embodiments, the deposition source could include more than two power connectors for simultaneously providing the rotatable cathode with RF energy from the RF power arrangement at more than two spaced-apart positions. For example, the rotatable cathode is fed with RF energy via three or four power connectors at three or four spaced-apart positions in embodiments.

[0032] According to some embodiments, which could be combined with other embodiments described herein, the first power connector 42 and the second power connector 44 are arranged in such a way that the rotatable cathode 30 can simultaneously be fed with RF energy at the first position 32 and at the second position 34, the distance between the first position 32 and the second position 34 being more than 5 cm, more than 50 cm and in particular 1 m or more.

[0033] A good symmetric feeding of the cathode is possible for embodiments in which the first power connector 42 and the second power connector 44 are arranged essentially symmetrically with respect to a sectional plane centrally intersecting the rotatable cathode 30. Such an embodiment is schematically shown in Fig. 1. The rotatable cathode 30 has the form of a cylinder with the first power connector 42 being connected for RF power feeding to the first position 32 in an upper half of the cylinder. Further, the rotatable cathode 30 may have second power connector 44 being connected for RF power feeding to the second position 34 in a lower half of the cylinder. According to embodiments which can be combined with other embodiments described herein, a first distance between the sectional plane that centrally intersects the rotatable cathode 30 and the first power connector 42 and a second distance between said sectional plane and the second power connector 44 may be essentially identical. The term “essentially” as used herein may mean that the first distance and the second distance differ by less than 20%, and particularly by less than 5%. Such a symmetrical arrangement of the first power connector 42 and of the second power connector 44 with respect to the rotational cathode 30 results in a reasonably homogenous

and uniform utilization of the target material and allows for an extension of the replacement cycle of the target.

[0034] In some implementations, the rotatable cathode has a cylindrical form with a first axial end and a second axial end opposing the first axial end. Such a cylindrical rotatable cathode 30 may advantageously be fed with RF energy at or near the first axial end as well as at or near the second axial end. For example, a first distance between the first position 32 and the first axial end of the rotatable cathode 30 may be less than a tenth of the complete dimension of the rotatable cathode 30 in an axial direction, and a second distance between the second position 34 and the second axial end of the rotatable cathode 30 may also be less than a tenth of the complete dimension of the rotatable cathode 30 in the axial direction.

[0035] In some embodiments, at least one of first power connector 42 and the second power connector 44 includes a coupling device that mechanically and electrically contacts a conducting portion of the rotatable cathode 30 for RF power feeding. For example, at least one of the first power connector 42 and the second power connector 44 could include at least one brush for conducting RF current between the stationary power delivery assembly 40 and the rotatable cathode 30, the brush being in sliding electrical contact with the conducting portion of the rotatable cathode 30.

[0036] According to some embodiments, at least one of the first power connector and the second power connector provides for an RF energy transfer to the rotatable cathode by capacitive or inductive coupling.

[0037] FIG. 2 shows a schematic view of a deposition source 100 for sputter deposition according to another embodiment described herein.

[0038] As is shown in FIG. 2, according to some embodiments, the RF power arrangement 20 includes an RF power generator 22 in combination with a matchbox 21, the matchbox 21 providing for an optimal impedance matching. Namely, the matchbox guarantees that the output impedance of the RF power generator 22 matches with the load

impedance of the electrical arrangement that is connected to an output terminal 25 of the matchbox 21.

[0039] In some embodiments, the deposition source 100 shown in FIG. 2 is used as a part of a sputtering apparatus, the sputtering apparatus including a vacuum chamber for performing sputtering within the vacuum chamber. A wall portion 151 of the vacuum chamber is shown in FIG. 2. The RF power arrangement 20 may be arranged outside the vacuum chamber, and the rotatable cathode 30 is arranged inside the vacuum chamber. A power delivery assembly 140 is provided for connecting the matchbox 21 and the rotatable cathode 30, the power delivery assembly 140 including at least one vacuum feed-through 152 for transmitting the RF power through the wall portion 151 of the vacuum chamber.

[0040] Similarly to the embodiment shown in FIG. 1, the rotatable cathode 30 shown in FIG. 2 has a cylindrical form and is rotatable around the rotation axis 31. The rotatable cathode 30 has a first axial end 132, wherein the first power connector 142 is installed at the first axial end 132, and it has a second axial end 134 opposing the first axial end 132, wherein the second power connector 144 is installed at the second axial end 134. As a result, the rotatable cathode 30 can be simultaneously supplied with RF energy from the first axial end 132 via the first power connector 142 and from the second axial end via the second power connector 144. This arrangement leads to a good and reasonably symmetrical utilization of the target material also in the regions of the outer edges of the target.

[0041] In some embodiments, the rotatable cathode 30 is supported by a cathode support 136 on at least one of the first axial end 132 and the second axial end 134. Typically, at least one cathode support 136 can also include a device for rotating the rotatable cathode 30. For example, the device for rotating can include an actuator, a drive belt, a drivetrain, or a motor configured for rotating the rotatable cathode 30. In some embodiments, at least one of the first power connector 142 and the second power connector 144 is at least partially integrated in the cathode support 136.

[0042] In some embodiments, the power delivery assembly 140 includes a first electric connection 146 electrically connecting the matchbox 21 and the first power connector 142, and a second electric connection 148 electrically connecting the matchbox 21 and the second power connector 144. In some implementations, the first electric connection 146 and the second electric connection 148 are provided between the output terminal 25 of the matchbox 21 and an electric contact such as a sheet-metal contact 149 of the first power connector 142 and the second power connector 144, respectively. In some implementations, at least one of the first electric connection 146 and the second electric connection 148 are provided as a cable, as a sheet metal conductor and/or as a conducting rod. For a good symmetric feeding of the rotatable cathode 30 via the first power connector 142 and the second power connector 144 it may be beneficial that a first electric property of the first electric connection 146 and a second electric property of the second electric connection 148 differ by less than 10%, particularly by less than 2%. Particularly, the first electric property of the first electric connection 146 and the second electric property of the second electric connection 148 are identical.

[0043] According to some embodiments, which could be combined with other embodiments described herein, the first electric property and the second electric property refer to a first impedance of the first electric connection 146 and to a second impedance of the second electric connection 148, respectively. According to some embodiments, which could be combined with other embodiments described herein, the first electric property and the second electric property refer to a first electric resistance of the first electric connection 146 and to a second electric resistance of the second electric connection 148, respectively. According to some embodiments, the first electric connection 146 and the second electric connection 148 are made of the same material, have the same length, cross section and overall shape, so that all of their electrical properties are essentially identical. The term "essentially identical" as used herein has the meaning that the respective electric properties of the first electric connection and the second electric connection differ by less than 2%. According to implementations, the arrangement formed by the first electric connection 146 and the first power connector 142 connected therewith is essentially a mirror image of the arrangement formed by the second electric connection 148 and the second power connector 144 connected therewith with the same electric properties.

[0044] Corresponding electrical properties of the first electric connection 146 and the second electric connection 148 lead to a more constant and uniform removal of target material from the first axial end 132 through to the second axial end 134 of the rotatable cathode 30 during sputtering. Therefore, in at least some embodiments, the matchbox 21 is located essentially in the middle between the first power connector 142 and the second power connector 144, with the spatial length of the first electric connection 146 and the spatial length of the second electric connection 148 being identical.

[0045] FIG. 3 shows a schematic side view of a deposition source 200 for sputter deposition according to yet another embodiment described herein; and FIG. 4 shows a schematic perspective view of this embodiment. This embodiment is similar to the embodiment described above with reference to FIG. 2. Thus, the description given above also applies to the embodiment of FIGS. 3 and 4.

[0046] As exemplarily shown in FIGS. 3 and 4, according to some embodiments, the deposition source 200 includes an adjusting device 226 for adjusting a first electrical property of a first electric connection 246 connecting the output terminal 25 of the matchbox 21 with the first power connector 142. Further, the adjusting device 226 may be configured for adjusting a second electrical property of a second electric connection 248 connecting the output terminal 25 with the second power connector 144. In some implementations, the first electrical property refers to a first impedance of the first electric connection 246, and the second electrical property refers to a second impedance of the second electric connection 248.

[0047] In some implementations, the first electrical property refers to a first electrical resistance of the first electric connection 246, and the second electrical property refers to a second electrical resistance of the second electric connection 248. An adjustment of the electrical resistance regularly goes along with an adjustment of the impedance and vice versa.

[0048] According to embodiments, the adjusting device can be used for making the first impedance equal with the second impedance before commencing with a sputtering operation, in order to preset for an equal utilization of the target at both axial ends of the rotatable cathode 30. In some implementations, such an equalization of the first impedance and the second impedance may by arranged for by varying the spatial length of the first electrical connection 246 to become equal with the spatial length of the second electrical connection 248, or by varying the spatial length of the second electrical connection 248 to become equal with the spatial length of the first electrical connection 246. This is because the electric resistance and the impedance of an elongate conductor between both ends of the conductor increase with its spatial length.

[0049] According to embodiments, which may be combined with other embodiments disclosed herein, the adjusting device 226 can be used for adjusting the first impedance or for adjusting the second impedance in the case of an asymmetric target utilization. For example, in some cases, the electric properties of the first power connector 142 and the electric properties of the first electric connection 146 may slightly differ, which could lead to an asymmetric target utilization after a first sputtering period, in spite of corresponding electric properties of the first electric connection 246 and the second electric connection 248. Thereafter, the first impedance or the second impedance may be adjusted using the adjusting device in such a way that said asymmetric target utilization or layer uniformity is compensated for or overcompensated for by continuing sputtering operation with said target.

[0050] According to the embodiment shown in FIGS. 3 and 4, the adjusting device 226 is provided by the output terminal 25 of the matchbox 21 being installed movably along a conducting rod 249, the conducting rod 249 electrically connecting the first power connector 142 and the first electric connection 146. In other words, the first electric connection 246 and the second electric connection 248 are provided by the conducting rod 249, whereas the output terminal 25 of the matchbox 21 is installed for sliding movement on said conducting rod 249. Thus, an increase of length of the first electric connection 246 goes along with a decrease of length of the second electric connection 248 and vice versa. In some embodiments, the matchbox 21 as a whole is installed for sliding movement along

the conducting rod 249, whereas the matchbox 21 is provided with a fixing device such as a clamp for fixing the output terminal 25 together with the matchbox 21 at a desired position along the length of the conducting rod 249.

[0051] As is shown in FIG. 4, according to some embodiments, which could be combined with other embodiments described herein, the first power connector 142 and the second power connector 144 are at least partially integrated in cathode supports 136 and 236, respectively, for holding and supporting the rotatable cathode 30 at both axial ends. At least one of the cathode supports 136, 236, and particularly the upper cathode support 236 being in a vertical direction, is provided with a positioning device 250 for moving the cathode support 236 with respect to the rotatable cathode from an operating position for sputtering operation to an installation position for the disassembly of the rotatable cathode and/or for the disassembly of a magnet yoke that may at least partially be arranged inside the rotatable cathode 30. In some embodiments, the cathode support 236 at least partially covers the upper axial end of the rotatable cathode 30, whereas part of the first power connector 142 and/or part of a rotating drive of the cathode support 236 axially engages with the cylindrically shaped rotatable cathode 30 in the operating position. After moving the cathode support 236 in an axial direction away from the rotatable cathode 30, the cathode support 236 no longer axially engages with the rotatable cathode 30, so that the rotatable cathode 30 may be removed for maintenance or replacement. In some embodiments, the movable cathode support is provided by a moveable sealing that seals at least one of the power connectors, e.g. first power connector 142 and second power connector 144.

[0052] FIG. 5 shows a schematic view of a deposition source 300 for sputter deposition according to another embodiment described herein. This embodiment is similar to the embodiment described above with reference to FIGS. 3 and 4. Thus, the description given above also applies to the embodiment of FIG. 5.

[0053] As is shown in FIG. 5, a first power connector 342 is installed at a first axial end 332 of the rotatable cathode 30 for providing for an RF energy transfer to the rotatable cathode by capacitive coupling at a first position, and a second power connector 344 is

installed at a second axial end 334 of the rotatable cathode 30 opposing the first axial end 332 for providing for an RF energy transfer to the rotatable cathode by capacitive coupling at a second position.

[0054] In the following description, only the first power connector 342 and the first axial end 332 of the rotatable cathode 30 will be described in detail; however, the second power connector 344 and the second axial end 334 of the rotatable cathode may have a corresponding layout in some embodiments.

[0055] According to some implementations, the first power connector 342 includes a first coupling element 382 and the first axial end 332 of the rotatable cathode 30 includes a second coupling element 384 arranged at a distance with respect to the first coupling element 382 for defining a capacitance. According to some embodiments, the capacitance is in the range of 1 to 5000 pF, in the range of 10 to 2000 pF, in the range of 100 to 1000 pF, in the range of 400 to 600 pF, or is particularly about 500 pF. Thus, the first power connector 342 allows for transport of RF power to the rotatable cathode 30 by capacitive coupling.

[0056] The first coupling element 382 and the second coupling element 384 may be arranged in such a way that said capacitance remains essentially equal when rotating the second coupling element 384 in relation to the first coupling element 382 about the rotation axis 31. As an example, the first coupling element 382 and the second coupling element 384 may be rotationally symmetrical with respect to the rotation axis 31, and they may particularly have plate elements and/or cylinder elements that oppose each other at a given distance. In some implementations, the first coupling element 382 is a first hollow cylinder element and the second coupling element 384 is a second hollow cylinder element, wherein one of the hollow cylinder elements has a smaller diameter than the other hollow cylinder element and coaxially engages with the other hollow cylinder element.

[0057] The distance between the first coupling element 382 and the second coupling element 384 may be filled with a dielectric such as a gas or air, or with a vacuum.

[0058] In embodiments, at least one of the first and the second power connectors is adapted for an RF energy transfer to the rotatable cathode by inductive coupling or via a contacting device such as a brush.

[0059] FIG. 6 shows a schematic view of a sputtering apparatus 400 according to embodiments described herein. The sputtering apparatus 400 includes a vacuum chamber 410 and a deposition source 420 in accordance with any of the embodiments described herein. In the shown embodiment, the deposition source 420 includes four rotatable cathodes 30 and four corresponding anodes 430 facing the cathodes, the rotatable cathodes 30 and the anodes 430 being arranged inside the vacuum chamber 410. More than four rotatable cathodes may be provided.

[0061] An RF power arrangement 20 for supplying RF power is arranged outside the vacuum chamber 410 and is electrically connected to the rotatable cathodes 30 and anodes 430 via respective electric connections and power connectors. According to embodiments of the sputtering apparatus which can be combined with other embodiments described herein, the housing of the vacuum chamber may be electrically connected to the RF power arrangement 20. Accordingly, the housing of the vacuum chamber may be used as a corresponding anode for the rotatable cathodes. As is shown in FIG. 6, each of the rotatable cathodes 30 is associated with a first power connector 442 and a second power connector 444 for providing the respective rotatable cathode 30 with RF energy from the RF power arrangement 20 at two spaced-apart positions. As is shown in FIG. 6, each of the rotatable cathodes 30 may be connected to a DC power supply 125 for providing the rotatable cathode with DC energy. Further, with exemplary reference to FIG. 6, according to embodiments of the sputtering apparatus which can be combined with other embodiments described herein, each power arrangement 20 for supplying RF power to the respective rotatable cathode 30 may be connected to an arc-synchronisation device 170 for synchronizing the RF power supplied to the respective cathodes.

[0062] As indicated in FIG. 6, further chambers 411 can be provided adjacent to the vacuum chamber 410. The vacuum chamber 410 can be separated from the adjacent chambers by valves having a valve housing 404 and a valve unit 405, respectively.

Accordingly, after a carrier 406 with a substrate 407 to be coated, is inserted in the vacuum chamber 410, as indicated by arrow 401, the valve units 405 can be closed. Accordingly, the atmosphere in the vacuum chambers 410 can be individually controlled by generating a technical vacuum, for example, with vacuum pumps connected to the vacuum chambers 410, and/or by inserting process gases in the deposition region of the vacuum chamber 410.

[0063] According to typical embodiments, process gases can include inert gases such as argon and/or reactive gases such as oxygen, nitrogen, hydrogen and ammonia, ozone, activated gases or the like.

[0064] Within the vacuum chamber 410, rollers 408 are provided in order to transport the carrier 406 with the substrate 407 into and out of the vacuum chamber 410. The term "substrate" as used herein shall embrace both inflexible substrates, e.g., a glass substrate, a wafer, slices of transparent crystal such as sapphire or the like, and flexible substrates, such as a web or a foil.

[0065] FIG. 6 shows the rotatable cathodes 30 with magnet assemblies or magnetrons 431 provided in the rotatable cathodes 30, wherein the magnetrons 431 may be provided within backing tubes that are equipped with the target material on an outer surface, respectively.

[0066] Details of the first power connector 442 and/or of the second power connector 444 that are associated with each of the rotatable cathodes 30 may be taken from one of the previously described embodiments or by combining any of the previously described embodiments, and they are not repeated here.

[0067] FIG. 7 shows a flowchart of a method of operating a deposition source for sputter deposition according to embodiments described herein. Any of the previously described embodiments may be taken as the deposition source to be operated in accordance with the operation method described herein.

[0068] As is shown in FIG. 7, the method includes simultaneously feeding a rotatable cathode with RF energy at a first position and at a second position spaced-apart from the

first position, as exemplarily illustrated by the first block 702. According to embodiments, the RF energy may be taken from an RF power arrangement and may be supplied to the rotatable target via a power delivery assembly including two spaced-apart power connectors. Accordingly, a plasma can be ignited for sputtering a target area of the rotating cathode. Thereupon, target material may be released from the target area and be deposited on a substrate to be coated.

[0069] FIG. 8 shows a flowchart of a method of operating a deposition source for sputter deposition according to another embodiment described herein.

[0070] As is shown in FIG. 8, the method includes adjusting a first electrical property of a first electrical connection supplying RF energy from a third position to the first position and/or adjusting a second electrical property of a second electrical connection supplying RF energy from the third position to the second position, as exemplarily illustrated by the second block 802. According to embodiments described herein, the first electrical connection connects an output terminal of a matchbox arranged at the third position with the first power connector feeding the RF energy to the rotatable cathode at the first position. Similarly, the second electrical connection connects the output terminal of the matchbox with the second power connector feeding the RF energy to the rotatable cathode at the second position. In some implementations, the first electrical property is a first impedance and/or a first electric resistance of the first electrical connection, and the second electrical property is a second impedance and/or a second electric resistance of the second electrical connection.

[0071] According to some embodiments, the first electric property and/or the second electric property are adjusted by varying the spatial length of the first electric connection and/or of the second electric connection. In particular, the ratio between the length of the first electrical connection and the length of the second electrical connection may be varied. In some embodiments, said ratio could be adjusted to become essentially or exactly 1. "Essentially" as used herein, encompasses ratio values from 0.98 to 1.02. A ratio of 1 regularly results in a symmetrical feeding of the rotating cathode and, thus, to a uniform target utilization. In other implementations, said ratio could be adjusted to become more or

less than 1, in order to compensate for an asymmetric usage of an already used target and/or in order to compensate for unequal electric properties of the first power connector and/or the second power connector.

[0072] After adjusting, as exemplarily illustrated by the second block 802 in FIG 8, the rotatable cathode is fed with RF energy via the first electric connection and the second electric connection at two spaced-apart positions for sputter operation, as exemplarily illustrated by the third block 804 in FIG 8.

[0073] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. A deposition source (10, 100, 200, 300, 420) for sputter deposition, comprising:

at least one rotatable cathode (30);

an RF power arrangement (20); and

a power delivery assembly (40, 140) connecting the RF power arrangement with the rotatable cathode, wherein the power delivery assembly comprises a first power connector (42, 142, 342, 442) and a second power connector (44, 144, 344, 444) for simultaneously providing the rotatable cathode with RF energy from the RF power arrangement at two spaced-apart positions (32, 34).

2. The deposition source of claim 1, wherein the first power connector (42, 142, 342) and the second power connector (44, 144, 344) are arranged essentially symmetrically with respect to a sectional plane centrally intersecting the rotatable cathode (30).

3. The deposition source of claim 1 or 2, wherein the rotatable cathode (30) has a cylindrical form with a first axial end (132, 332) and a second axial end (134, 334) opposing the first axial end, and wherein the first power connector (142, 342) is installed at the first axial end and the second power connector (144, 344) is installed at the second axial end.

4. The deposition source of any of claims 1 to 3, wherein at least one of the first power connector (342) and the second power connector (344) provides for an RF energy transfer to the rotatable cathode (30) by capacitive or inductive coupling.

5. The deposition source of any of claims 1 to 4, wherein the RF power arrangement comprises a matchbox (21), and wherein the power delivery assembly comprises:

a first electric connection (146, 246) connecting the matchbox and the first power connector;

and a second electric connection (148, 248) connecting the matchbox and the second power connector.

6. The deposition source of claim 5, wherein a first impedance of the first electric connection and a second impedance of the second electric connection differ by less than 10%, particularly wherein the first impedance and the second impedance are essentially identical and/or wherein a first electrical resistance of the first electric connection and a second electrical resistance of the second electric connection differ by less than 10%, particularly wherein the first electrical resistance and the second electrical resistance are essentially identical.

7. The deposition source of claim 5 or 6, comprising an adjusting device (226) for adjusting a first electrical property of the first electric connection and/or a second electrical property of the second electrical connection, particularly by varying a length of the first electric connection and/or of the second electric connection.

8. The deposition source of any of claims 5 to 7, wherein the matchbox (21) comprises an output terminal (25) that is installed moveably along at least one of the first electric connection (246) and the second electric connection (248).

9. The deposition source of any of claims 5 to 8, wherein the first electric connection and the second electric connection are provided by a conducting rod (249) connected between the first power connector (142) and the second power connector (144), the matchbox (21) being installed for movement on the conducting rod.

10. The deposition source of any of claims 1 to 9, wherein at least one of the first power connector and the second power connector includes a cathode support (236) that is

moveable with respect to the rotatable cathode (30) from an operating position for sputtering operation to an installation position for the disassembly of the rotatable cathode.

11. The deposition source of claim 10, wherein the cathode support (236) is moveable in an axial direction away from the rotatable cathode (30).

12. A sputtering apparatus (400), comprising:

a vacuum chamber (410); and

a deposition source (420) according to any of claims 1 to 11, wherein the rotatable cathode (30) is positioned inside the vacuum chamber (410),

wherein at least one of the first power connector and the second power connector includes a feed-through (152), and particularly a vacuum rotary feed-through, for transmitting the RF energy from the RF power arrangement into the vacuum chamber.

13. A method of operating a deposition source for sputter deposition, particularly of any of claims 1 to 11, the method comprising simultaneously feeding a rotatable cathode (30) with RF energy at a first position (32) and at a second position (34) spaced-apart from the first position.

14. The method of claim 13, comprising adjusting a first electrical property of a first electrical connection (246) supplying RF energy from a third position to the first position and/or adjusting a second electrical property of a second electrical connection (248) supplying RF energy from the third position to the second position.

15. The method of claim 14, wherein the first electrical property and the second electrical property are adjusted by varying the ratio between the length of the first electrical connection and the length of the second electrical connection.

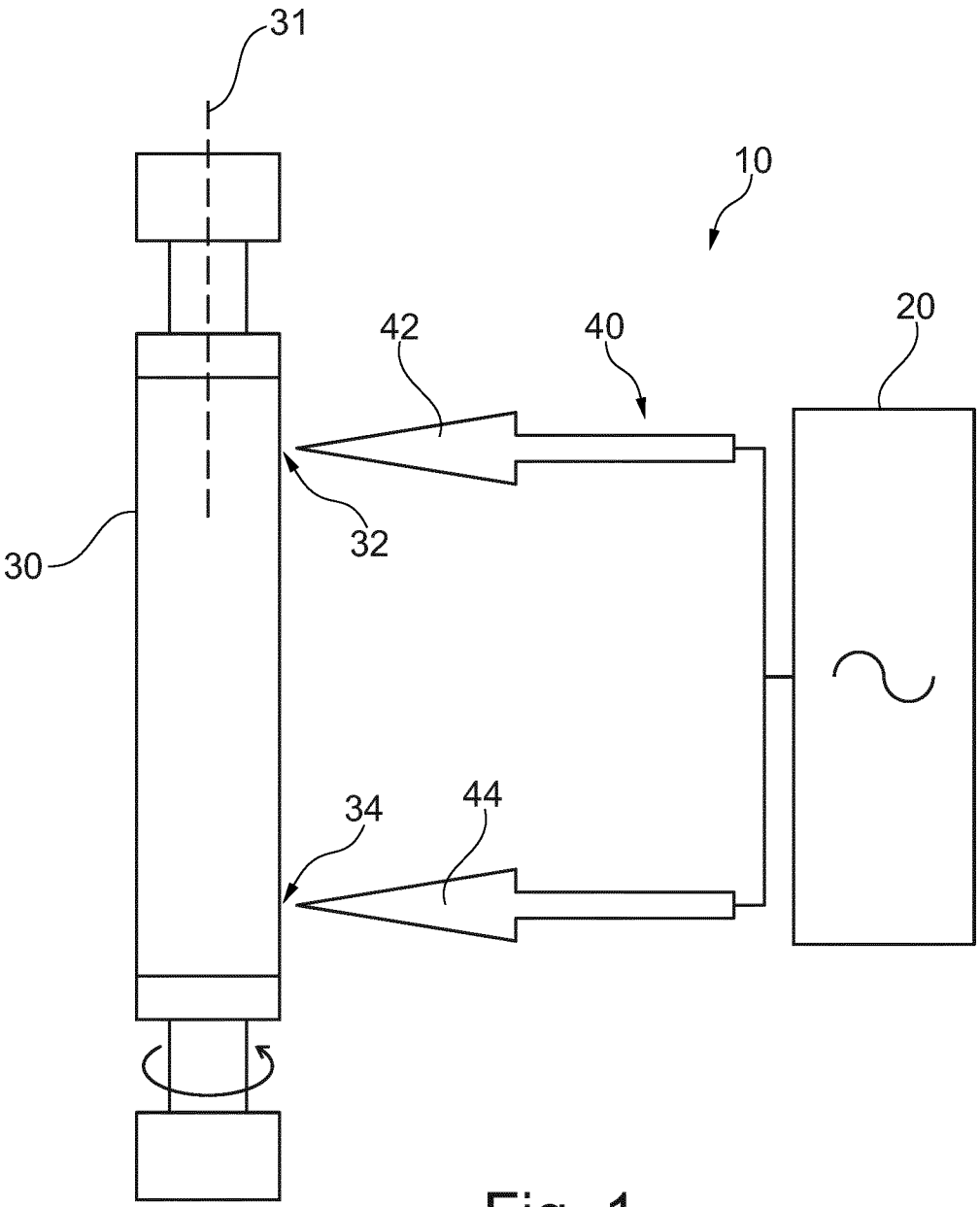


Fig. 1

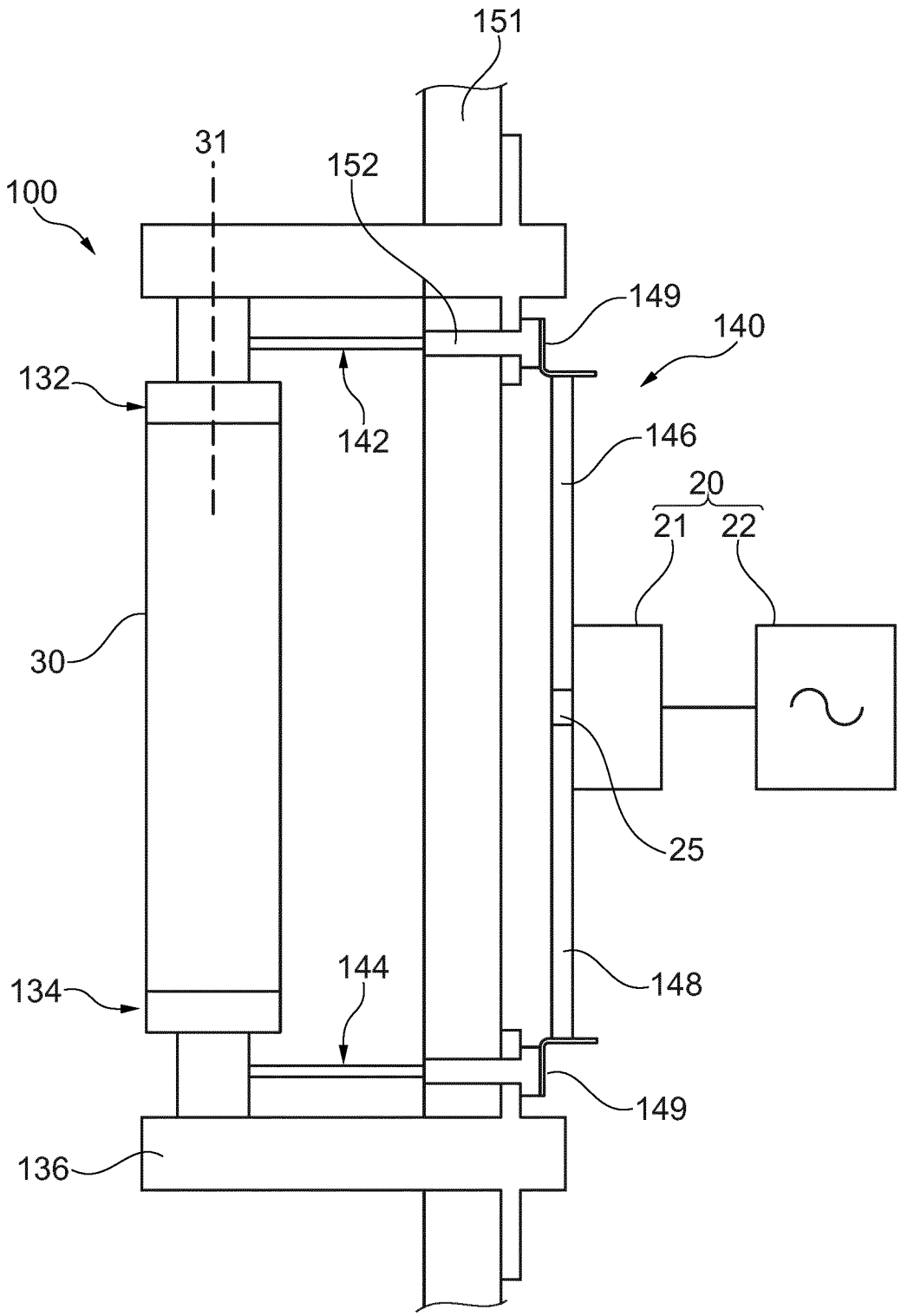

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Fig. 2

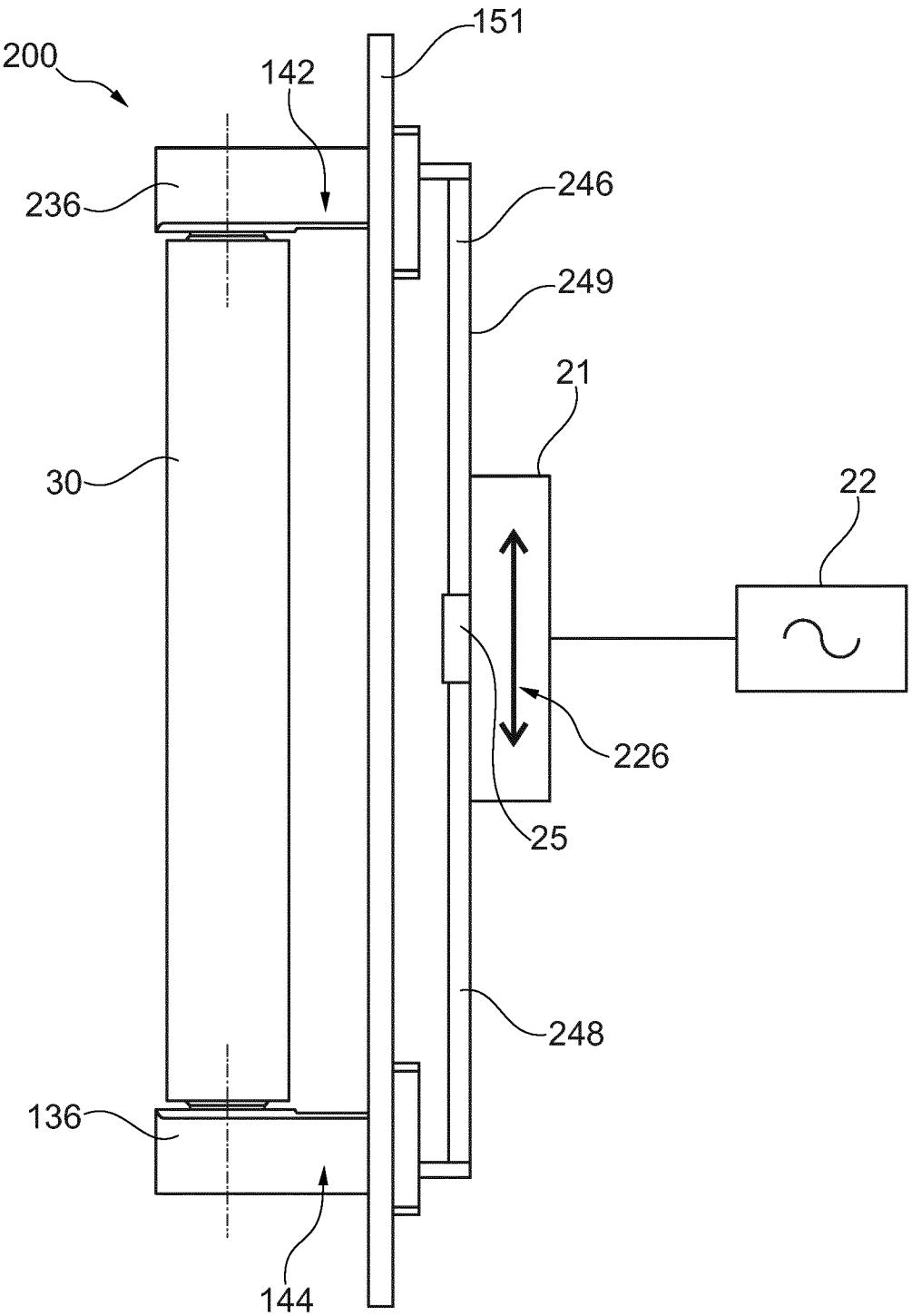


Fig. 3

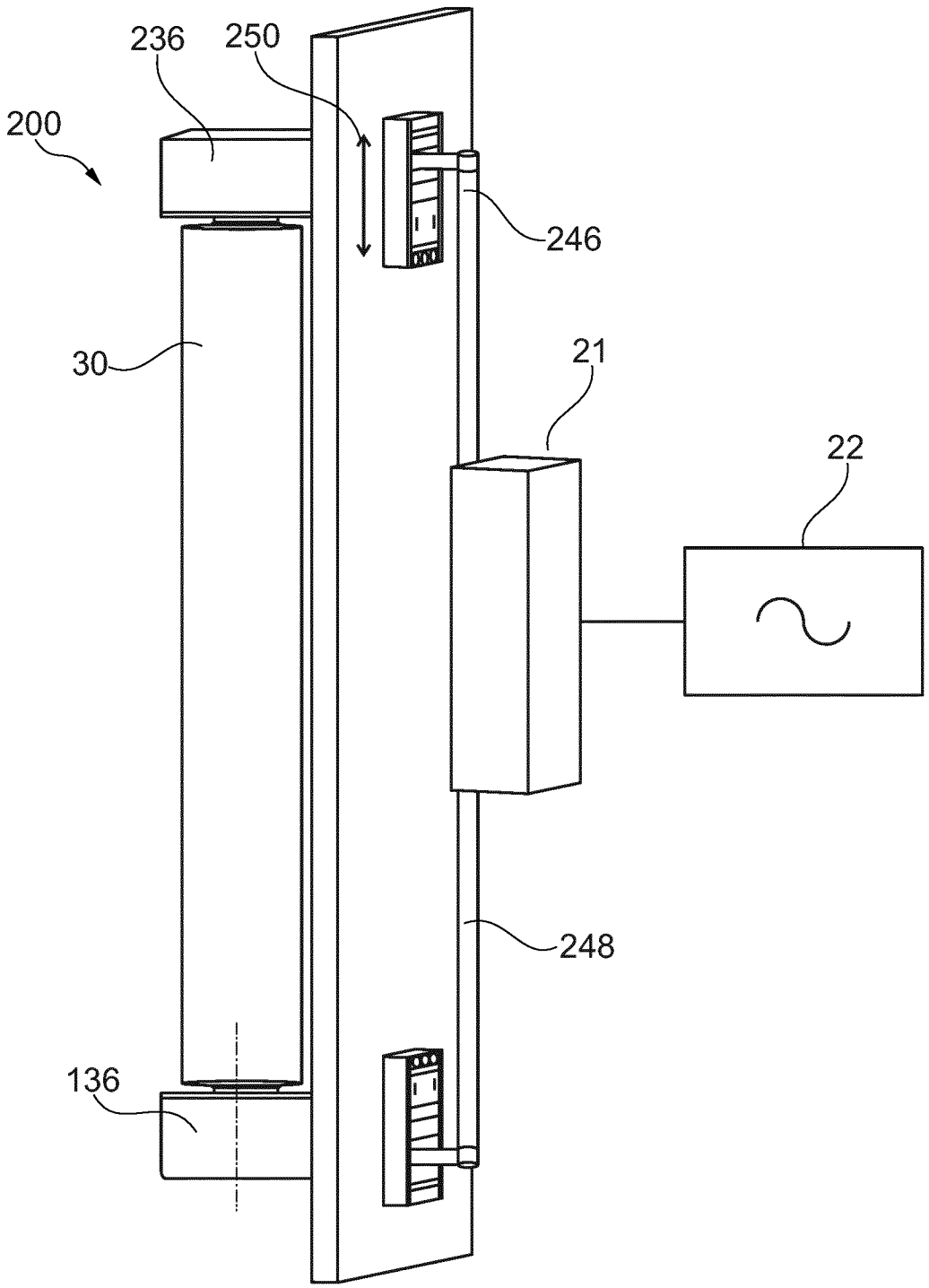


Fig. 4

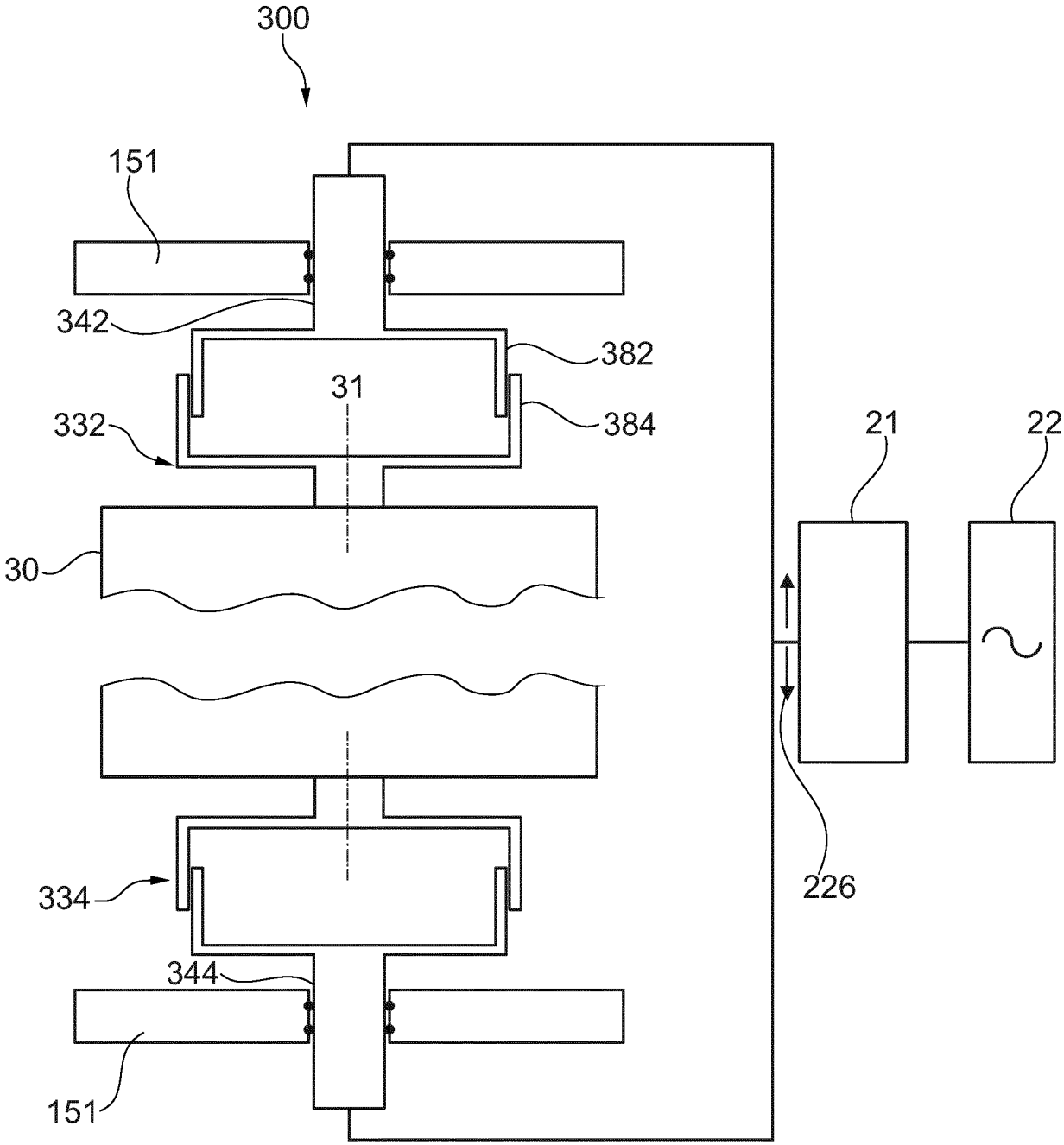


Fig. 5

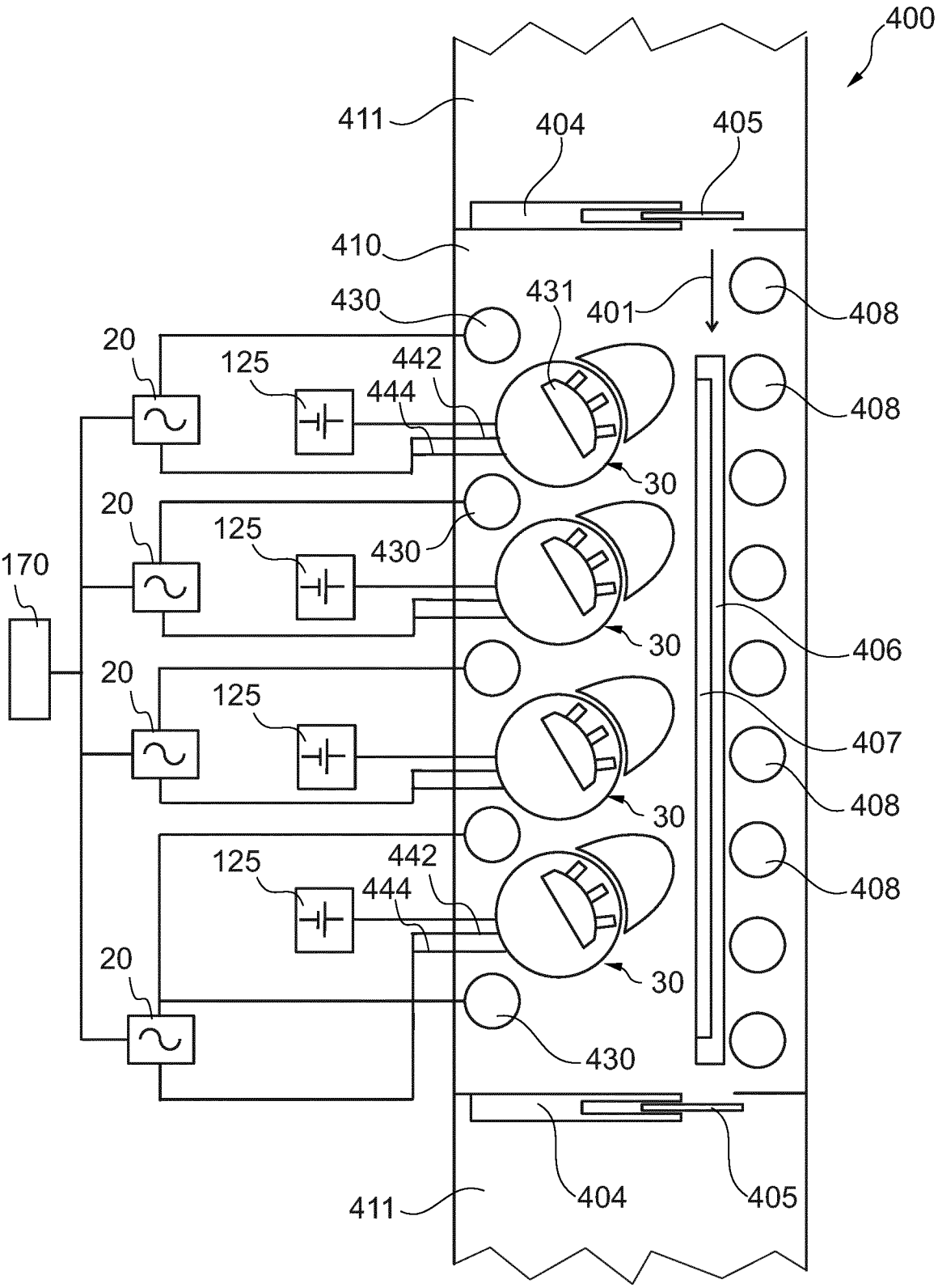

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Fig. 6

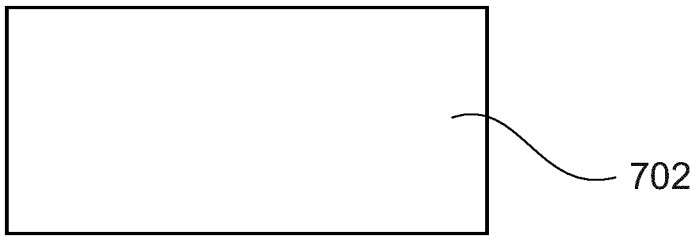


Fig. 7

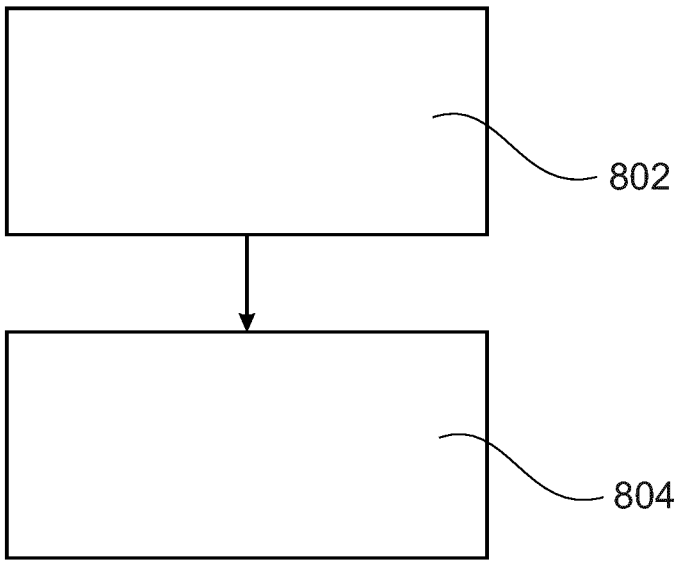


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/060228

A. CLASSIFICATION OF SUBJECT MATTER
INV. 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)
H01J C23C

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, INSPEC, 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 A	EP 2 750 162 A2 (SILEVO INC [US]) 2 July 2014 (2014-07-02) paragraph [0023] - paragraph [0032] figure 2 -----	1-7,10, 12,13 8,9,11, 14,15
X	US 2014/332375 A1 (GAWER OLAF [DE] ET AL) 13 November 2014 (2014-11-13) paragraph [0025] - paragraph [0065] figures -----	1-5,10, 12,13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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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

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"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
14 December 2015	21/12/2015

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	Aguilar, María

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2015/060228

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2750162 A2	02-07-2014	EP 2750162 A2	02-07-2014
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