(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 January 2019 (24.01.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/015783 A1

(51) International Patent Classification:
H01L 21/677 (2006.01)

(21) International Application Number:
PCT/EP2017/068514

(22) International Filing Date:
21 July 2017 (21.07.2017)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **APPLIED MATERIALS, INC.** [US/US]; 3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventor; and

(71) Applicant *(for US only)*: **EHMANN, Christian Wolfgang** [DE/DE]; Moserstraße 4, 64285 Darmstadt (DE).

(74) Agent: **ZIMMERMANN & PARTNER PATENTANWÄLTE MBB**; Josephspitalstr. 15, 80331 München (DE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title:** MAGNETIC LEVITATION SYSTEM, CARRIER FOR A MAGNETIC LEVITATION SYSTEM, AND METHOD OF OPERATING A MAGNETIC LEVITATION SYSTEM

(57) **Abstract:** A magnetic levitation system is provided. The magnetic levitation system includes a base structure (110), a carrier (120) that is movable relative to the base structure (110), and at least one active magnetic bearing (112) configured to contactlessly hold the carrier (120) at the base structure (110). The carrier (120) includes a first carrier part (121) configured to magnetically interact with the base structure (110) and a second carrier part (122) configured to carry an object (10), wherein the first carrier part (121) and the second carrier part (122) are connected to each other via a flexible connection (125). Further, a carrier for a magnetic levitation system as well as a method of operating a magnetic levitation system are described.

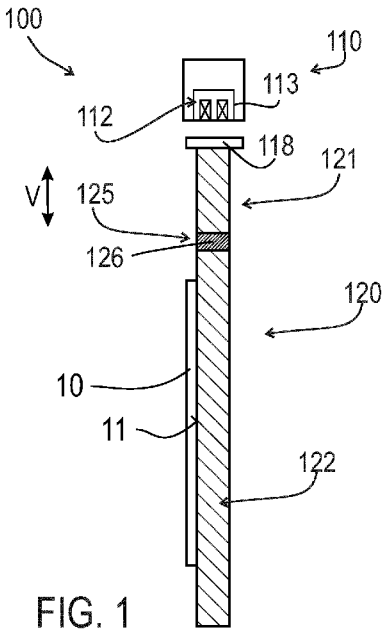


FIG. 1

WO 2019/015783 A1

MAGNETIC LEVITATION SYSTEM, CARRIER FOR A MAGNETIC LEVITATION SYSTEM, AND METHOD OF OPERATING A MAGNETIC LEVITATION SYSTEM

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to a magnetic levitation system configured to contactlessly hold, position and/or transport a carrier. Further embodiments relate to a carrier for a magnetic levitation system as well as to methods of operating a magnetic levitation system. More specifically, a magnetic levitation system is described that is configured to contactlessly transport a carrier through a vacuum system, wherein the carrier may carry an object such as a substrate, particularly in an essentially vertical orientation.

BACKGROUND

[0002] Magnetic levitation systems can be utilized for the contactless transport of carriers relative to a base structure, e.g. under sub-atmospheric pressure. An object such as a substrate that is carried by the carrier can be transported from a first position in a vacuum system, i.e. a loading position, to a second position in a vacuum system, e.g. a deposition position. Magnetic levitation systems may allow for a contactless and therefore frictionless transport of carriers and may reduce the generation of small particles in a vacuum processing system.

[0003] Magnetic levitation systems typically include one or more actively controlled magnetic bearings configured to hold the carrier at the base structure at a predetermined distance via magnetic forces. An active control of the carrier position may be problematic when the carrier vibrates at one of the natural frequencies of the carrier. In particular, under specific conditions, the active control by the active magnetic bearings of a magnetic levitation system may amplify natural vibrations of the carrier, which may lead to a resonance excitation of the carrier.

[0004] Complex control algorithms of the active magnetic bearings may be used for reducing carrier vibrations. Reducing or avoiding oscillations of the carrier of a magnetic levitation system may however be challenging, particularly because the oscillatory behavior of the carrier may depend on the size, the shape and the material of the carrier as well as of the object that is carried by the carrier. Oscillations of the carrier may negatively affect the transport stability and the positioning accuracy of the carrier.

[0005] Accordingly, it would be beneficial to improve the transport and positioning accuracy of a carrier of a magnetic levitation system. Further, it would be beneficial to provide a carrier for a magnetic levitation system adapted to be accurately and exactly transported and held at the base structure of the magnetic levitation system.

SUMMARY

[0006] In light of the above, a magnetic levitation system, a carrier for a magnetic levitation system, as well as a method of operating a magnetic levitation system are provided.

[0007] According to an aspect of the present disclosure, a magnetic levitation system is provided. The magnetic levitation system includes a base structure, a carrier that is movable relative to the base structure, and at least one active magnetic bearing configured to contactlessly hold the carrier at the base structure, wherein the carrier includes a first carrier part configured to interact with the base structure and a second carrier part configured to carry an object, wherein the first carrier part and the second carrier part are connected to each other via a flexible connection.

[0008] According to a further aspect of the present disclosure, a carrier for a magnetic levitation system is provided. The carrier includes a first carrier part configured to interact with a base structure of the magnetic levitation system which is configured to contactlessly hold, position and/or transport the carrier, and a second carrier part configured to carry an object, wherein the first carrier part and the second carrier part are connected to each other via a flexible connection.

[0009] According to a further aspect of the present disclosure, a vacuum system is provided. The vacuum system includes a vacuum chamber, a deposition source arranged in

the vacuum chamber, and a magnetic levitation system according to any of the embodiments described herein. The magnetic levitation system is configured to contactlessly transport a carrier which carries an object to be coated into a deposition area of the vacuum chamber.

[0010] According to a further aspect described herein, a method of operating a magnetic levitation system is provided. The method includes providing a carrier including a first carrier part and a second carrier part connected to each other via a flexible connection, arranging an object to be carried on the second carrier part, and contactlessly holding the carrier at a base structure with at least one active magnetic bearing, wherein the first carrier part magnetically interacts with the base structure.

[0011] Further aspects, advantages and features of the present disclosure are apparent from the description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] 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 present 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. Typical embodiments are depicted in the drawings and are detailed in the description which follows.

[0013] FIG. 1 is a schematic sectional view of a magnetic levitation system according to embodiments described herein;

[0014] FIG. 2 is a schematic sectional view of a magnetic levitation system according to embodiments described herein;

[0015] FIG. 3 is a schematic sectional view of a magnetic levitation system according to embodiments described herein;

[0016] FIG. 4 is a schematic sectional view of a magnetic levitation system according to embodiments described herein;

[0017] FIG. 5A is a schematic front view of a carrier for a magnetic levitation system according to embodiments described herein;

[0018] FIG. 5B is a schematic perspective view of an upper part of the carrier of FIG. 5A;

[0019] FIG. 6 is a schematic sectional view of an upper part of a carrier for a magnetic levitation system according to embodiments described herein; and

[0020] FIG. 7 is a flow diagram illustrating a method of operating a magnetic levitation system according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0021] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in the figures. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations.

[0022] Within the following description of the drawings, the same reference numbers refer to the same or to similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment applies to a corresponding part or aspect in another embodiment as well.

[0023] FIG. 1 is a schematic sectional view of a magnetic levitation system 100 according to embodiments described herein. The magnetic levitation system 100 includes a base structure 110 and a carrier 120 that is contactlessly held at the base structure 110 and that is movable relative to the base structure 110. The base structure 110 may include one or more stationary tracks or rails, wherein actively controlled magnetic units of the magnetic levitation system may be provided at the tracks or rails.

[0024] In the embodiment depicted in FIG. 1, the base structure 110 includes a top rail that is arranged above the carrier 120, wherein the carrier 120 is held below the top rail.

Alternatively or additionally, the base structure 110 may include a bottom rail arranged below the carrier, wherein the carrier is held above the bottom rail. Alternatively or additionally, the base structure 110 may include at least one side rail arranged at one side or at two opposite sides of the carrier 120.

[0025] The magnetic levitation system 100 includes at least one active magnetic bearing 112 configured to contactlessly hold the carrier 120 at the base structure 110. A plurality of active magnetic bearings may be provided. The at least one active magnetic bearing 112 may be configured to generate a magnetic force acting between the base structure 110 and the carrier 120, such that the carrier is contactlessly held at a predetermined distance from the base structure. In some embodiments, the at least one active magnetic bearing 112 is configured to generate a magnetic force acting in a first direction V (which is typically an essentially vertical direction) such that a distance between the top rail and the carrier in the first direction can be maintained essentially constant.

[0026] In some embodiments, the at least one active magnetic bearing 112 includes an actuator 113 that is arranged at the base structure 110, particularly at a top rail of the base structure 110. The actuator 113 may include a controllable magnet such as an electromagnet. The actuator 113 may be actively controllable for maintaining a predetermined distance between the base structure 110 and the carrier 120. A magnetic counterpart 118 may be arranged at the carrier 120, particularly at a head part of the carrier. The magnetic counterpart 118 of the carrier may magnetically interact with the actuator 113 of the base structure.

[0027] For example, an output parameter such as an electric current which is applied to the actuator 113 may be controlled depending on an input parameter such as a distance between the carrier and the base structure. In particular, a distance between the top rail of the base structure 110 and the carrier 120 may be measured by a distance sensor, and the magnetic field strength of the actuator 113 may be set depending on the measured distance. In particular, the magnetic field strength may be increased in the case of a distance above a predetermined threshold value, and the magnetic field strength may be decreased in the case of a distance below the threshold value. The actuator 113 may be controlled in a closed loop or feedback control.

[0028] Depending on the size, the shape, and the material of the carrier 120, so-called "eigenmodes" or natural vibrations of the carrier may impede a stable and robust control of the carrier position by the active magnetic bearings. Already very small excitation amplitudes at eigenfrequencies of the carrier may lead to large resonance vibrations of the carrier. Depending on the frequency range of the eigenfrequencies, the vibrations may be further amplified by the active magnetic bearings. Complicated control algorithms of the active magnetic bearings and/or specifically shaped carriers may be utilized to reduce natural vibrations of the carrier during magnetic levitation.

[0029] Yet, the above measures may not be sufficient or suitable to allow for an accurate contactless positioning and a stable transport of the carrier. Embodiments described herein are meant to improve the transport stability and the positioning accuracy of carriers of magnetic levitation systems.

[0030] According to embodiments described herein, the carrier 120 includes a first carrier part 121 and a second carrier part 122 which are mechanically connected to each other via a flexible connection 125. Thus, the oscillatory properties of the carrier can be modified as appropriate by using a flexible connection with a suitable flexibility, elasticity, restoring force, mass, material properties and further characteristics.

[0031] The first carrier part 121 may be configured to magnetically interact with the base structure 110. For example, the at least one active magnetic bearing 112 may act between the first carrier part 121 and the base structure 110. In particular, the magnetic counterpart 118 which magnetically interacts with the actuator 113 of the at least one active magnetic bearing 112 may be provided at the first carrier part 121. Alternatively or additionally, active magnetic units of the magnetic levitation system may be integrated in the first carrier part.

[0032] The second carrier part 122 is configured to carry the object 10. In particular, the second carrier part 122 may include a holding portion 11 where the object 10 to be carried by the carrier is held. The second carrier part 122 may further include a mounting device configured to hold the object 10 at the holding portion 11.

[0033] In particular, the first carrier part 121 may include magnetic components of the magnetic levitation system, e.g. parts of active and/or passive magnetic units, and the second carrier part 122 may be configured as a holder for holding the object 10. For example, the second carrier part 122 may include a plate component with a holding surface for holding a substrate to be coated. Accordingly, components for interacting with the base structure and components for holding the object at the carrier can be functionally and spatially separated from each other by providing a first carrier part 121 and a second carrier part 122.

[0034] The first carrier part 121 and the second carrier part 122 are connected to each other by the flexible connection 125. The flexible connection 125 modifies the oscillatory behavior of the carrier 120 and provides a damping effect with regard to natural vibrations of the carrier. The first carrier part 121 and the second carrier part 122 may oscillate relative to each other via the flexible connection 125. Vibration peaks of the carrier at resonance frequencies are attenuated, since the second carrier part 122 can move with respect to the first carrier part 121 via the flexible connection 125.

[0035] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 includes a flexible material, particularly an elastic material 126. The elasticity of the elastic material may be selected depending on the natural frequencies and the eigenmodes of the carrier that are to be damped.

[0036] In some implementations, the elastic material 126 comprises rubber, Viton and/or another elastic sealing material. In some embodiments, the elastic material 126 is an insulator material. An elastic material 126 comprising Viton is particularly suitable for vacuum applications. Said materials are elastic and provide excellent dampening properties. Accordingly, vibrations of the carrier can be effectively dampened.

[0037] In the embodiment of FIG. 1, the elastic material 126 is arranged between the first carrier part 121 and the second carrier part 122, such that the first carrier part 121 and the second carrier part 122 can move or oscillate relative to each other in the first direction V. Therein, the elastic material 126 may partially or entirely fill a gap between the first carrier part 121 and the second carrier part 122. The first direction V may correspond to the direction in which the at least one active magnetic bearing 112 controls a distance between

the carrier 120 and the base structure 110. In particular, the first direction V may be an essentially vertical direction.

[0038] In particular, in some embodiments, the flexible connection 125 is elastically deformable in the first direction V, wherein the first direction essentially corresponds to a direction in which the at least one active magnetic bearing 112 controls the distance between the base structure 110 and the carrier 120. Thus, vibrations of the carrier, which may be stimulated by the at least one active magnetic bearing 112, are dampened via the flexible connection 125 in a particularly effective way.

[0039] In some implementations, the first carrier part 121 and the second carrier part 122 may be predominantly metal components, and the elastic material 126 may be a non-metal material, particularly an isolator material. Accordingly, by connecting the first carrier part 121 and the second carrier part 122 via the elastic material, the first carrier part 121 and the second carrier part 122 may be thermally and/or electrically isolated from each other.

[0040] The flexible connection 125 may thermally and/or electrically isolate the first carrier part 121 from the second carrier part 122. In particular, the flexible connection may form an electrical isolation and/or a thermal barrier between the first carrier part 121 and the second carrier part 122. Accordingly, heat transfer from components integrated in the first carrier part 121 toward the object 10 held by the second carrier part 122 can be reduced or avoided. Further, heat transfer from the second carrier part 122 toward the first carrier part 121 can be reduced or avoided. Accordingly, delicate electronic components and/or permanent magnets that may be integrated in the first carrier part 121 can be protected from heat which may be generated, for example during the deposition of a coating material on the object 10.

[0041] In some embodiments, which may be combined with other embodiments described herein, the first carrier part 121 is a carrier head that is arranged partially or entirely above the second carrier part 122, when the carrier 120 is contactlessly held at the base structure 110. In particular, the first carrier part 121 may be contactlessly held below a top rail of the base structure, and the second carrier part 122 may be arranged below the first carrier part 121 and be mechanically connected to the first carrier part by the flexible connection 125.

[0042] The carrier 120 may extend essentially in a vertical direction, wherein the first carrier part 121 is arranged above the second carrier part 122. The second carrier part 122 may include an essentially vertically oriented holding portion 11 for holding the object 10, e.g. a substrate or a mask, in an essentially vertical orientation.

[0043] As is schematically depicted in FIG. 1, the carrier 120 may be a substrate carrier configured to hold a substrate at the holding portion 11 of the second carrier part 122 in an essentially vertical orientation. Alternatively, the carrier 120 may be configured for carrying a different object, e.g. a mask or a shield.

[0044] A "substrate carrier" as used herein relates to a carrier configured to carry a substrate along a substrate transportation path in a vacuum chamber. The substrate carrier may hold the substrate during the deposition of a coating material on the substrate. In some embodiments, the substrate may be held at the substrate carrier in a non-horizontal orientation, particularly in an essentially vertical orientation, e.g. during transport and/or deposition.

[0045] The substrate may be held at a holding surface of the second carrier part during the transport through a vacuum chamber, during positioning of the substrate in the vacuum chamber, e.g. with respect to a mask, and/or during the deposition of a coating material on the substrate. In particular, the substrate may be held at the second carrier part by a mounting device, e.g. including an electrostatic chuck or a magnetic chuck.

[0046] A "mask carrier" as used herein relates to a carrier configured to carry a mask for the transport of the mask along a mask transport path in a vacuum chamber. The mask carrier may carry the mask during transport, during alignment with respect to a substrate and/or during deposition on the substrate. In some embodiments, the mask may be held at the mask carrier in a non-horizontal orientation, particularly in an essentially vertical orientation during transport and/or deposition. The mask may be held at the second carrier part of the mask carrier by a mounting device, e.g. a mechanic mount such as a clamp, an electrostatic chuck or a magnetic chuck. Other types of mounting devices may be used which may be connected to or integrated in the carrier.

[0047] The second part of a mask carrier may include a plate body with an opening, wherein the mask can be held at a circumferential edge of the opening, such that the mask covers the opening. Accordingly, a coating material can be directed through the mask toward a substrate. The mask may be an edge exclusion mask or a shadow mask. An edge exclusion mask is a mask which is configured for masking one or more edge regions of the substrate, such that no material is deposited on the one or more edge regions during the coating of the substrate. A shadow mask is a mask configured for masking a plurality of features which are to be deposited on the substrate. For instance, the shadow mask can include a plurality of small openings, e.g. a grid of small openings.

[0048] An "essentially vertical orientation" as used herein may be understood as an orientation of the second carrier part 122 in which an angle between the gravity vector and a holding surface of the second carrier part is 20° or less, particularly 10° or less, more particularly 5° or less. Accordingly, a substrate or another object can be held at the holding surface in an essentially vertical orientation.

[0049] It is to be noted that the first direction V is not necessarily an essentially vertical direction. For example, in some embodiments, the first direction may be a non-vertical direction, e.g. an essentially horizontal direction. In particular, the base structure may be configured to hold, position and/or transport the carrier while the carrier is in an essentially horizontal orientation. The second carrier part may include an essentially horizontal holding surface such that an object can be held at the second carrier part in an essentially horizontal orientation. When the carrier is held in an essentially horizontal orientation at the base structure, the flexible connection may be elastically deformable in a horizontal direction and the at least one active magnetic bearing may control the distance between the base structure and the carrier in said horizontal direction.

[0050] FIG. 2 is a schematic sectional view of a magnetic levitation system 200 according to embodiments described herein. The magnetic levitation system 200 may include features of the magnetic levitation system 100 depicted in FIG. 1, such that reference can be made to the above explanations, which are not repeated here.

[0051] The magnetic levitation system 200 includes a base structure 110 including a stationary top rail configured to contactlessly hold a carrier 120 below the top rail. At least

one active magnetic bearing 112 with a controllable actuator 113 provides an attractive magnetic force between the carrier 120 and the base structure 110.

[0052] The carrier 120 includes a first carrier part 121, which may carry the magnetic components of the magnetic levitation system, and a second carrier part 122 which may be configured as a holding device for carrying an object 10. The first carrier part 121 may be configured as a carrier head arranged above the second carrier part 122. The first carrier part 121 and the second carrier part 122 are connected via a flexible connection.

[0053] The second carrier part 122 may include a holding portion 11 and a mounting device 15 configured to hold the object 10 at the holding portion. The mounting device 15 may include a mechanical mount, e.g. a clamp, and/or an electrostatic chuck or a magnetic chuck. For example, an electrostatic chuck may be integrated in a body of the second carrier part 122. The electrostatic chuck may hold the object 10 at the holding portion 11 by electrostatic forces that may be induced in a surface of the object and/or in a surface of the holding portion 11. A voltage source, e.g. a battery, for powering the electrostatic chuck may be arranged at the second carrier part 122. For example, the voltage source may be housed in an atmospheric enclosure provided at or in the second carrier part 122.

[0054] In some implementations, a magnetic counterpart 118 of the at least one active magnetic bearing 112 may be fixed to the first carrier part 121. The magnetic counterpart 118 may magnetically interact with the actuator 113 that is arranged at the base structure 110 above the carrier 120.

[0055] In some embodiments, which may be combined with other embodiments described herein, at least one further magnetic device 220 may be provided for providing a side stabilization of the carrier in a second direction S transverse to the first direction V, particularly perpendicular to the first direction V. The second direction S may correspond to an essentially horizontal direction, particularly to a thickness direction of the carrier 120. The at least one further magnetic device 220 may include at least one magnetic component fixed to the first carrier part 121.

[0056] The at least one further magnetic device 220 may be a passive magnetic stabilizing device. In particular, the at least one further magnetic device 220 may include a

first plurality of permanent magnets 218 fixed to the carrier and a second plurality of permanent magnets 219 fixed to the base structure. The magnetic forces between the first plurality of permanent magnets 218 and the second plurality of permanent magnets 219 may urge the carrier to a predetermined position in the second direction S, e.g. to a position at a predetermined distance from a side guiding rail or to a center position between two side guiding rails.

[0057] In the embodiment depicted in FIG. 2, the further magnetic device 220 provides a repulsive magnetic force between two side guiding rails on both sides of the first carrier part 121 and permanent magnets fixed to the first carrier part 121. Accordingly, the first carrier part 121 can be contactlessly held at a center position between the side guiding rails. Alternatively, as is schematically depicted in FIG. 3, a lower and/or an upper side stabilization device may be provided at one side of the carrier.

[0058] The second carrier part 122 may be held below the first carrier part 121 via the flexible connection 125. In particular, a gap 124 may be provided between the first carrier part 121 and the second carrier part 122, wherein the flexible connection may mechanically connect the first carrier part 121 and the second carrier part by bridging the gap 124 between the carrier parts. The gap 124 may extend in the first direction V, i.e. in the control direction of the at least one active magnetic bearing 112. Vibration peaks of the carrier can be attenuated, since the first and second carrier parts are elastically movable relative to each other.

[0059] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 includes a bridging component 130 that bridges the gap 124 between the first carrier part 121 and the second carrier part 122. The bridging component 130 may include a rigid material, particularly an inelastic material such as a metal. In particular, the bridging component 130 may be configured as a plate component, e.g. an adapter plate, connected to both the first carrier part 121 and the second carrier part 122.

[0060] A first elastic component 131 may act between the bridging component 130 and the first carrier part 121, and/or a second elastic component 132 may act between the bridging component 130 and the second carrier part 122. The first elastic component 131

and the second elastic component 132 may be made of an elastically deformable material, e.g. Viton.

[0061] The flexible connection 125 may allow for an elastic deformation of the carrier 120 in the first direction V. In particular, a vibration of the carrier 120 in the first direction V may lead to a shearing force acting on the first elastic component 131 and/or on the second elastic component 132. The elasticity of the elastic components may allow the bridging component 130 to slightly move with respect to the first carrier part 121 and the second carrier part 122. Vibrations peaks can be attenuated in a particularly effective way.

[0062] FIG. 3 is a schematic sectional view of a magnetic levitation system 300 according to embodiments described herein. The magnetic levitation system 300 may include features of the magnetic levitation system 100 depicted in FIG. 1 and/or of the magnetic levitation system 200 depicted in FIG. 2 , such that reference can be made to the above explanations which are not repeated here.

[0063] The magnetic levitation system 300 includes a base structure 110 including a top rail configured to contactlessly hold a carrier 120 below the top rail. At least one active magnetic bearing 112 provides an attractive magnetic force between the carrier 120 and the base structure 110, wherein the attractive magnetic force may act in the first direction V, particularly in an essentially vertical direction.

[0064] The carrier 120 includes a first carrier part 121, which may carry magnetic components of the magnetic levitation system, and a second carrier part 122 which is configured as a holding device for carrying the object 10. The first carrier part 121 may be configured as a carrier head arranged above the second carrier part 122. The first carrier part 121 and the second carrier part 122 are connected via a flexible connection.

[0065] In some embodiments, which may be combined with other embodiments described herein, a third carrier part 123 may be provided which may be connected to the second carrier part via a further flexible connection 128. In some implementations, the third carrier part 123 is arranged below the second carrier part 122. The further flexible connection 128 may be configured in a way similar or identical to any of the flexible

connections described herein. Yet further carrier parts connected to the second carrier part via a respective flexible connection may be provided in other embodiments.

[0066] The third carrier part 123 may carry magnetic components of the magnetic levitation system. For example, at least one active or passive magnetic component of a side stabilization device 320 may be fixed to the third carrier part 123.

[0067] Alternatively or additionally, at least one magnetic component of a drive unit 330 configured to contactlessly transport the carrier along a carrier transport path may be fixed to the third carrier part 123. The drive unit 330 may include a linear motor.

[0068] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 includes a first bridging component 133 and a second bridging component 134. The first bridging component 133 may connect the first carrier part and the second carrier part on a first side of the carrier parts, and the second bridging component 134 may connect the first carrier part and the second carrier part on a second side of the carrier parts opposite the first side. In particular, the first bridging component 133 and the second bridging component 134 may be arranged on opposite sides of a gap 124 that is provided between the first carrier part 121 and the second carrier part 122.

[0069] First elastic components 131 may act between the first carrier part 121 and the first bridging component and/or between the first carrier part 121 and the second bridging component. Second elastic components may act between the second carrier part 122 and the first bridging component and/or between the second carrier part 122 and the second bridging component. The first elastic components 131 and the second elastic components 132 may be made of an elastically deformable material, e.g. Viton.

[0070] The first and second elastic components may be configured as strips of elastic material attached to the first and second carrier parts.

[0071] The first and second bridging components may include a rigid material, particularly an inelastic material such as a metal. In particular, the first and second bridging components can be configured as inelastic adapter plates connected to both the first carrier part 121 and the second carrier part 122, respectively. When first bridging component 133

and the second bridging component 134 are arranged on both sides of the carrier and overlap with both the first carrier part and the second carrier part in the first direction V, respectively, a bending of the carrier 120 around a horizontal bending axis can be impeded or prevented. Thus, a stable carrier can be provided which is resistant to bending, but at the same time flexible in the first direction V.

[0072] Vibrations of the carrier 120 in the first direction V may lead to a shearing strain on the first elastic components 131 and/or on the second elastic components 132. The relative movement between the first carrier part and the second carrier part due to the elastic deflection of the elastic components can attenuate vibration peaks of the carrier, and a stable carrier resistant to bending can be provided.

[0073] FIG. 4 is a schematic sectional view of a magnetic levitation system 400 according to embodiments described herein. The magnetic levitation system 400 may include features of any of the previously described magnetic levitation systems, such that reference can be made to the above explanations, which are not repeated here.

[0074] The magnetic levitation system 400 includes a carrier 120 with a first carrier part 121 and a second carrier part 122 connected to each other via a flexible connection 125 that is similar to the flexible connection of the magnetic levitation system 300 depicted in FIG. 3.

[0075] In particular, a gap 124 is provided in the first direction V between the first carrier part 121 and the second carrier part 122. Bridging components that connect the first carrier part 121 and the second carrier part 122 to each other are provided on two opposite sides of the gap 124. The bridging components may be adapter plates made of a rigid material, respectively. Elastic components may be provided between the bridging components and the carrier parts in order to provide a flexibility of the connection in the first direction V.

[0076] As is schematically depicted in FIG. 4, a first bridging component 133 may be provided on a first side of the carrier parts, and a second bridging component 134 may be provided on a second side of the carrier parts opposite the first side. First elastic components 131 may be arranged between the first carrier part 121 and the first bridging component 133 and/or between the first carrier part 121 and the second bridging

component 134. Second elastic components 132 may be arranged between the second carrier part 122 and the first bridging component 133 and/or between the second carrier part 122 and the second bridging component 134. Accordingly, the bridging components can slightly move relative to the first carrier part 121 and/or relative to the second carrier part 122 in the first direction V when the elastic components are elastically deformed by shear forces.

[0077] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 may be a clamping connection. In particular, the first carrier part 121 and the second carrier part 122 may be clamped between the first bridging component 133 and the second bridging component 134 that are arranged on opposite sides of the first and second carrier parts. By pressing the first bridging component 133 and the second bridging component 134 toward the first and second carrier parts from opposite sides, the second carrier part 122 may be held below the first carrier part 121 by the clamping force provided by the first and second bridging components.

[0078] In some implementations, connection elements may be provided for pressing the first bridging component 133 and the second bridging component 134 toward the first carrier part 121 and the second carrier part 122 from opposite sides. For example, the connection elements may include at least one of screws, bolts, pins, rods, or similar elements.

[0079] In the exemplary embodiment depicted in FIG. 4, the connection elements extend from the first bridging component 133 to the second bridging component 134 through openings that are provided in the first carrier part 121 and in the second carrier part 122. Alternatively or additionally, as is depicted in FIG. 4 in dashed lines, at least one connection element may extend through the gap 124 between the first carrier part and the second carrier part.

[0080] The first elastic components 131 and/or the second elastic components 132 may be configured as elastic rings that are penetrated by the connection elements. The first elastic components 131 may rest on opposite side surfaces of the first carrier part 121 such as to be aligned with the openings that are provided in the first carrier part. The second elastic components 132 may rest on opposite side surfaces of the second carrier part 122

such as to be aligned with the openings that are provided in the second carrier part. Alternatively, the first elastic components 131 and the second elastic components 132 may be configured as strips of elastic material that are provided on the side surfaces of the first and second carrier parts.

[0081] When the first and second bridging components are arranged on both sides of the carrier parts and overlap with both the first carrier part and the second carrier part in the first direction V, respectively, a bending of the carrier 120 around a horizontal bending axis can be prevented. Thus, a stable carrier can be provided which is resistant to bending but at the same time flexible in the first direction V.

[0082] In some embodiments, which can be combined with other embodiments described herein, a drive unit 330 configured to contactlessly move the carrier 120 along a carrier transport path may be provided. The drive unit 330 may be configured to contactlessly transport the carrier, e.g. in a third direction perpendicular to paper plane of FIG. 4. The drive unit 330 may transport the carrier by magnetic forces acting on the carrier. For example, the drive unit 330 may include a linear motor. The drive unit 330 may magnetically interact with a magnetic counterpart provided at the carrier. The magnetic counterpart may include one or more arrays of permanent magnets.

[0083] In some embodiments, the drive unit 330 may be provided at a bottom rail of the base structure 110 that is arranged below the carrier. In the embodiment of FIG. 4, a top rail of the base structure 110 includes the active magnetic bearings providing at least a part of the holding force for contactlessly holding the carrier at the base structure 110, and a bottom rail of the base structure 110 includes the drive units 330 configured to transport the carrier. In other embodiments, the positions of the drive units 330 and/or the positions of the active magnetic bearings may be swapped or otherwise changed.

[0084] FIG. 5A is a schematic front view of a carrier 520 of a magnetic levitation system according to embodiments described herein. FIG. 5B is a schematic perspective view of an upper part of the carrier 520 of FIG. 5A which also shows a partial cross-section of the carrier 520. The carrier 520 may include features of the previously described embodiments, which are not repeated here.

[0085] The carrier 520 can be contactlessly held at a base structure of any of the embodiments described herein. For example, the carrier 520 includes a magnetic counterpart 118 configured to magnetically interact with a controllable actuator of an active magnetic bearing such that the carrier 520 can be held and transported at a predetermined distance from the base structure.

[0086] The carrier 520 includes a first carrier part 121 and a second carrier part 122 which are connected to each other via a flexible connection 125. The flexible connection 125 may include elastic components made of an elastic material 126, e.g. Viton. The second carrier part 122 includes a holding portion 11 configured to carry an object such as a substrate.

[0087] As is schematically depicted in FIG. 5A and FIG. 5B, a gap 124 extending in a first direction V may be provided between the first carrier part 121 and the second carrier part 122. The flexible connection 125 provides a flexibility between the first carrier part 121 and the second carrier part 122 in the first direction V.

[0088] In some embodiments, which may be combined with other embodiments described herein, the second carrier part may be configured to carry an object with a size of 1 m^2 or more, particularly 5 m^2 or more, more particularly 10 m^2 or more. For example, the second carrier part 122 may be configured to carry a large-area substrate for display manufacturing. Accordingly, the second carrier part may provide a holding surface with an area of 1 m^2 or more, particularly 5 m^2 or more, more particularly 10 m^2 or more. Large carriers tend to have numerous critical eigenmodes. Separating the carrier into two or more parts which are connected to each other via flexible connections may considerably damp oscillations of the carrier at the natural frequencies of the carrier.

[0089] The flexible connection 125 may include a plurality of bridging components 130 respectively connected to the first carrier part 121 and the second carrier part 122, wherein the elastic material 126 is provided between the bridging components 130 and the first and second carrier parts. The bridging components 130 may be configured as plates that extend essentially parallel to the first and second carrier parts on both sides of the first and second carrier parts. Each plate may overlap with both the first carrier part 121 and with the second carrier part 122. Accordingly, a bending of the carrier around the flexible

connection 125 can be prevented, while a relative movement between the first and second carrier parts in the first direction V may be possible. In some embodiments, the flexible connection 125 includes three, five or more bridging components arranged on both sides of the first and second carrier parts. For example, the flexible connection may include three or more bridging components provided next to each other in a width direction of the carrier.

[0090] An elastic material is provided between the bridging components 130 and the first and second carrier parts, respectively. For example, a plurality of elastic rings or other elastic components may be provided between each bridging component 130 and the first carrier part 121, and a plurality of elastic rings or other elastic components may be provided between each bridging component and the second carrier part 122. One of the bridging components is omitted in FIG. 5A, in order to illustrate the plurality of elastic components which may act between the bridging components and the first and second carrier parts. Elastic components configured as elastic rings are depicted in FIG. 5B in a sectional view.

[0091] FIG. 6 is a schematic sectional view of an upper part of a carrier 620 according to embodiments described herein. The carrier 620 may include features of the previously described embodiments which are not repeated here.

[0092] The carrier 620 includes a first carrier part 121 and a second carrier part 122 which are connected to each other via a flexible connection 125. A gap 124 may be provided between the first carrier part and the second carrier part in a first direction V.

[0093] The flexible connection 125 may include a bridging component 130, which connects the first carrier part 121 and the second carrier part 122 while allowing a relative movement between the first carrier part 121 and the second carrier part 122 in the first direction V. In particular, first elastic components 131 may act between the first carrier part 121 and the bridging component 130, and second elastic components 132 may act between the second carrier part 122 and the bridging component 130. The first elastic components 131 and/or the second elastic components 132 may be configured as elastic rings 622, e.g. including an elastic material such as Viton.

[0094] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 may be a positive fit connection. In particular, the bridging component 130 may engage with a first opening of the first carrier part 121 and with a second opening of the second carrier part 122. In some implementations, the bridging component may engage with a plurality of openings of the first carrier part 121, which may be arranged side-by-side in a horizontal direction and/or above one another in a vertical direction. Further, the bridging component 130 may engage with a plurality of openings of the second carrier part 122, which may be arranged side-by-side in a horizontal direction and/or above one another in a vertical direction.

[0095] In particular, the bridging component 130 may include an essentially vertically extending plate portion and a plurality of engagement pins extending from the plate portion through the first and second openings. The second carrier part 122 cannot drop down from the first carrier part 121 because the engagement pins of the bridging component positively engage with first openings of the first carrier part and with the second openings of the second carrier part.

[0096] In some implementations, a first elastic component 131, particularly an elastic ring, is arranged in the first opening, and a second elastic component 132 is arranged in the second opening. An engagement pin of the bridging component 130 may penetrate through the first elastic component 131 in the first opening, and a further engagement pin of the bridging component 130 may penetrate through the second elastic component 132 in the second opening. When the second carrier part 122 oscillates with respect to the first carrier part 121, the elastic rings 622 are subjected to compressional and tensional forces acting in the vertical direction, such that high oscillation amplitudes of the carrier in the vertical direction are dampened by the resulting restoring forces of the elastic rings.

[0097] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 includes elastic components which are subjected to shear forces when the second carrier part and the first carrier part move relative to each other in the first direction V (see, e.g., carriers depicted in FIGS. 2, 3, 4, 5A, 5B). Such carriers may be strongly resistant to bending. In some embodiments, the flexible connection 125 includes elastic components which are subjected to compressional and tensional forces when the second carrier part and the first carrier part move relative to

each other in the first direction V (see, e.g., carriers depicted in FIGS. 1 and 6). Such carriers may be particularly durable. In some embodiments, the flexible connection may include a combination of elastic elements subjected to shear forces and elastic elements subjected to compressional and tensional forces during a relative movement between the first carrier part and the second carrier part.

[0098] A carrier according to embodiments described herein includes a first carrier part 121 configured to magnetically interact with a stationary base structure of a magnetic levitation system which is configured to contactlessly hold, position and/or transport the carrier 120, and a second carrier part 122 configured to carry an object 10. The first carrier part 121 and the second carrier part 122 are connected to each other via the flexible connection 125.

[0099] The magnetic levitation system according to any of the embodiments described herein may be used in a vacuum system. The vacuum system includes a vacuum chamber, a deposition source arranged in the vacuum chamber, and the magnetic levitation system. The magnetic levitation system may be configured to contactlessly transport a carrier carrying an object into a deposition area of the vacuum chamber. A coating material can be deposited on the object by the deposition source in the deposition area.

[00100] FIG. 7 is a flow diagram that schematically illustrates a method of operating a magnetic levitation system according to embodiments described herein.

[00101] In box 710, a carrier according to any of the embodiments described herein is provided. The carrier includes a first carrier part 121 and a second carrier part 122 which are connected to each other via a flexible connection.

[00102] In box 720, an object 10 to be carried by the carrier is arranged on the second carrier part 122.

[00103] The object 10 may be loaded on the second carrier part 122 while the carrier is arranged in a non-vertical orientation, e.g. in an essentially horizontal orientation. The carrier may then be moved to a second orientation, e.g. to an essentially vertical orientation. In the essentially vertical orientation, the carrier can be held and transported along the base structure 110 of the magnetic levitation system. For example, the carrier

may be rotated from an essentially horizontal loading position into an essentially vertical transport orientation by a vacuum swing module.

[00104] Alternatively, the object may be loaded on the second carrier part 122 while the carrier is in a non-horizontal orientation, e.g. in an essentially vertical orientation. For example, the carrier may be held at the base structure 110 during the loading of the object on the second carrier part.

[00105] In some embodiments, the object may be a substrate to be coated, particularly a large-area substrate for display manufacturing. Other objects can be carried by the carrier, e.g. a mask or a shield.

[00106] In box 730, the carrier is contactlessly held at a base structure 110 of the magnetic levitation system with at least one active magnetic bearing 112, wherein the first carrier part 121 magnetically interacts with the base structure 110. For example, the at least one active magnetic bearing 112 may provide an attractive force between a top rail of the base structure and the first carrier part 121.

[00107] In some embodiments, which may be combined with other embodiments described herein, the flexible connection 125 is flexible in a first direction V, particularly in an essentially vertical direction. In particular, the second carrier part 122 may be movable with respect to the first carrier part 121 in the first direction V via the flexible connection, e.g. through an elastic deformation of elastic components of the flexible connection. Accordingly, the oscillatory behavior of the carrier can be modified by the flexible connection, and vibration peaks of the carrier, e.g. at the resonance frequencies, can be attenuated.

[00108] The at least one active magnetic bearing 112 may control a distance between the base structure and the carrier in the first direction V. Accordingly, an amplification of natural vibrations of the carrier by the active magnetic bearing acting in the first direction V can be reduced or avoided.

[00109] In optional box 740, the carrier may be transported through a vacuum chamber while being contactlessly held at the base structure.

[00110] In optional box 750, the carrier may be positioned in a deposition area, e.g. in front of a deposition source. A coating material may be deposited on the object 10 that is carried by the carrier. During the deposition, the carrier may be contactlessly held at the base structure. Alternatively, the carrier may be mounted to a mount during the deposition, wherein the carrier may be in mechanical contact with the mount.

[00111] The object may be a substrate, particularly a large-area substrate having a size of 0.5 m^2 or more, more particularly 1 m^2 or more, or even 5 m^2 or 10 m^2 or more. For example, the substrate may be a large-area substrate for display manufacturing.

[00112] An organic material may be deposited on the substrate. For example, an OLED device may be manufactured by depositing the organic material on the substrate.

[00113] It is to be noted that the first carrier part is not necessarily arranged above the second carrier part that is configured to carry the object. For example, in some implementations, the first carrier part may be arranged below the second carrier part or at a side of the second carrier part. In particular, the first carrier part may magnetically interact with a bottom rail of the base structure, wherein actuators of a plurality of active magnetic bearings may be arranged at the bottom rail. In the latter case, the active magnetic bearings may generate a magnetic lifting force for contactlessly holding the carrier above the bottom rail. In yet further embodiments, the second carrier part may be arranged next to the first carrier part in a horizontal direction. The amplitudes of vibrations stimulated by a horizontally acting side stabilization device may be reduced, and an amplification of natural vibrations can be avoided.

[00114] 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. A magnetic levitation system, comprising:

a base structure (110);

a carrier (120) that is movable relative to the base structure (110); and

at least one active magnetic bearing (112) configured to contactlessly hold the carrier (120) at the base structure (110),

wherein the carrier (120) comprises a first carrier part (121) configured to interact with the base structure (110) and a second carrier part (122) configured to carry an object (10), the first carrier part (121) and the second carrier part (122) being connected to each other via a flexible connection (125).

2. The magnetic levitation system of claim 1, wherein the flexible connection (125) comprises a flexible material, particularly an elastic material (126).

3. The magnetic levitation system of claim 1 or 2, wherein the first carrier part (121) is a carrier head that is arranged partially or entirely above the second carrier part (122).

4. The magnetic levitation system of any of claims 1 to 3, wherein the at least one active magnetic bearing (112) includes an actuator (113) arranged at the base structure (110) and a magnetic counterpart (118) arranged at the first carrier part (121), wherein the actuator (113) is controllable for maintaining a predetermined distance between the base structure (110) and the carrier (120).

5. The magnetic levitation system of any of claims 1 to 4, wherein the flexible connection (125) is elastically deformable in a first direction (V) corresponding to a direction in which the at least one active magnetic bearing (112) controls a distance between the base structure (110) and the carrier (120).

6. The magnetic levitation system of any of claims 1 to 5, wherein the flexible connection (125) holds the second carrier part (122) below the first carrier part (121) such that a gap (124) is provided between the first carrier part and the second carrier part.

7. The magnetic levitation system of any of claims 1 to 6, wherein the flexible connection (125) comprises a bridging component (130), a first elastic component (131) acting between the bridging component and the first carrier part (121) and a second elastic component (132) acting between the bridging component and the second carrier part (122).

8. The magnetic levitation system of any of claims 1 to 7, wherein the flexible connection (125) comprises a first bridging component (133) and a second bridging component (134), wherein the first carrier part and the second carrier part are clamped between the first bridging component (133) and the second bridging component (134).

9. The magnetic levitation system of claim 7, wherein the bridging component (130) engages with a first opening of the first carrier part (121) and with a second opening of the second carrier part (122), wherein the first elastic component (131) is arranged in the first opening and wherein the second elastic component (132) is arranged in the second opening, particularly wherein the first elastic component (131) and the second elastic component (132) are elastic rings.

10. The magnetic levitation system of any of claims 1 to 9, wherein the second carrier part (122) comprises a mounting device (15) configured to hold the object (10) at a holding portion (11) of the second carrier part (122), particularly wherein the mounting device (15) comprises an electrostatic chuck or a magnetic chuck.

11. The magnetic levitation system of any of claims 1 to 10, wherein the carrier (120) is a substrate carrier or a mask carrier configured to hold a substrate or a mask in an essentially vertical orientation.

12. A carrier (120) for a magnetic levitation system, comprising:

a first carrier part (121) configured to interact with a base structure (110) of the magnetic levitation system which is configured to contactlessly hold, position and/or transport the carrier (120); and

a second carrier part (122) configured to carry an object (10), wherein the first carrier part (121) and the second carrier part (122) are connected to each other via a flexible connection (125).

13. A method of operating a magnetic levitation system, comprising:

providing a carrier comprising a first carrier part (121) and a second carrier part (122) connected to each other via a flexible connection (125);

arranging an object (10) on the second carrier part (122); and

contactlessly holding the carrier at a base structure (110) with at least one active magnetic bearing (112), wherein the first carrier part (121) interacts with the base structure (110).

14. The method of claim 13, wherein the flexible connection (125) is flexible in a first direction (V), particularly in an essentially vertical direction, and wherein the at least one active magnetic bearing (112) controls a distance between the base structure and the carrier in the first direction (V).

15. The method of claim 13 or 14, further comprising:

transporting the carrier through a vacuum chamber while being contactlessly held at the base structure;

positioning the carrier in a deposition area; and

depositing a coating material on the object (10) that is carried by the carrier.

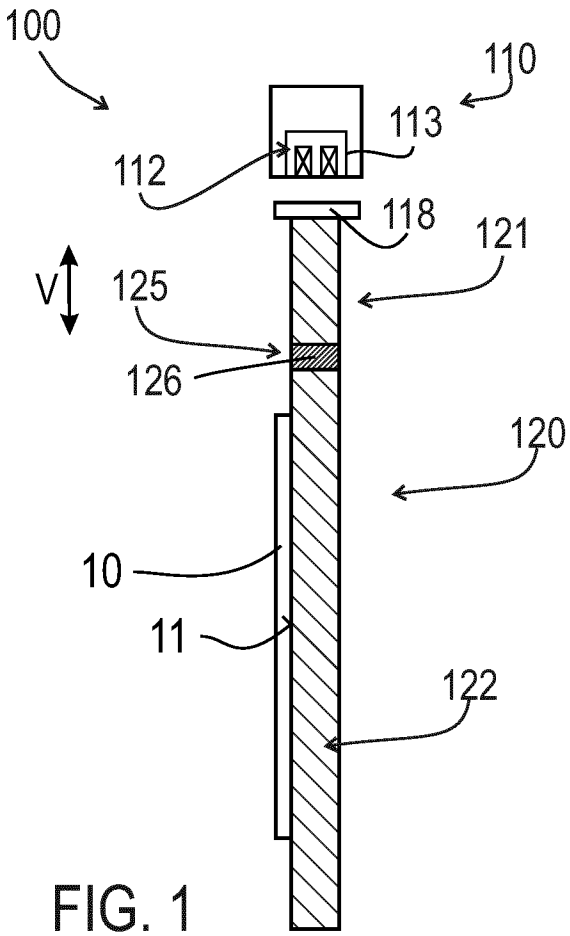

100
110
113
112
118
121
V
125
126
120
10
11
122

FIG. 1

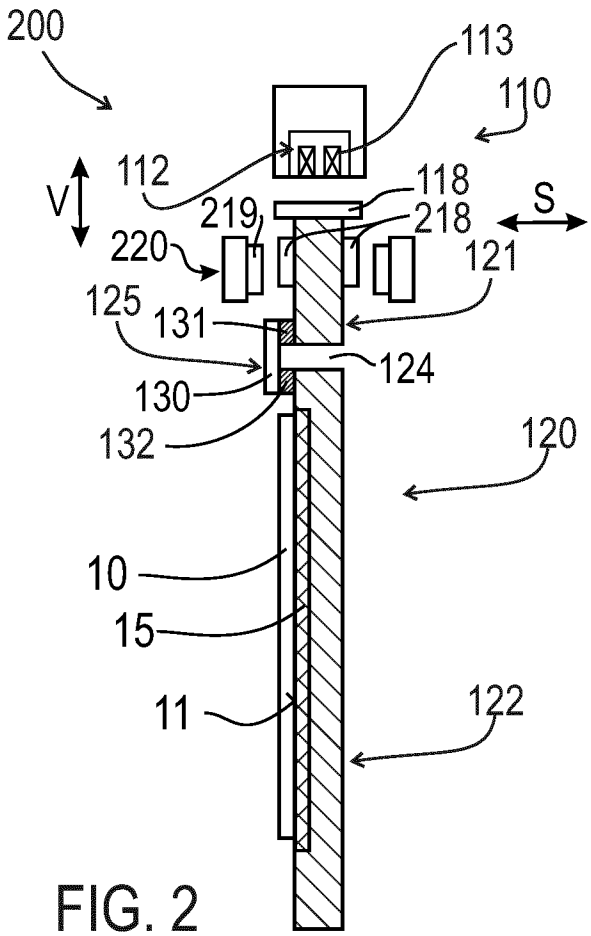

200
113
110
V
112
118
S
219
218
220
121
125
131
124
130
132
120
10
15
11
122

FIG. 2

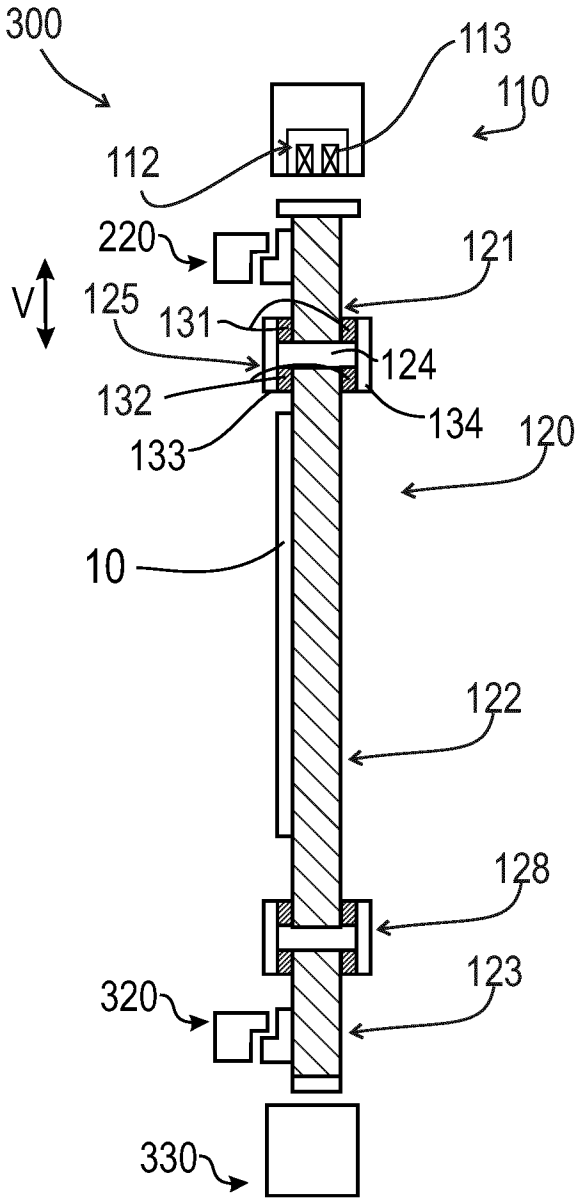

300
113
110
112
220
121
V
125
131
124
132
134
120
133
10
122
128
123
320
330

FIG. 3

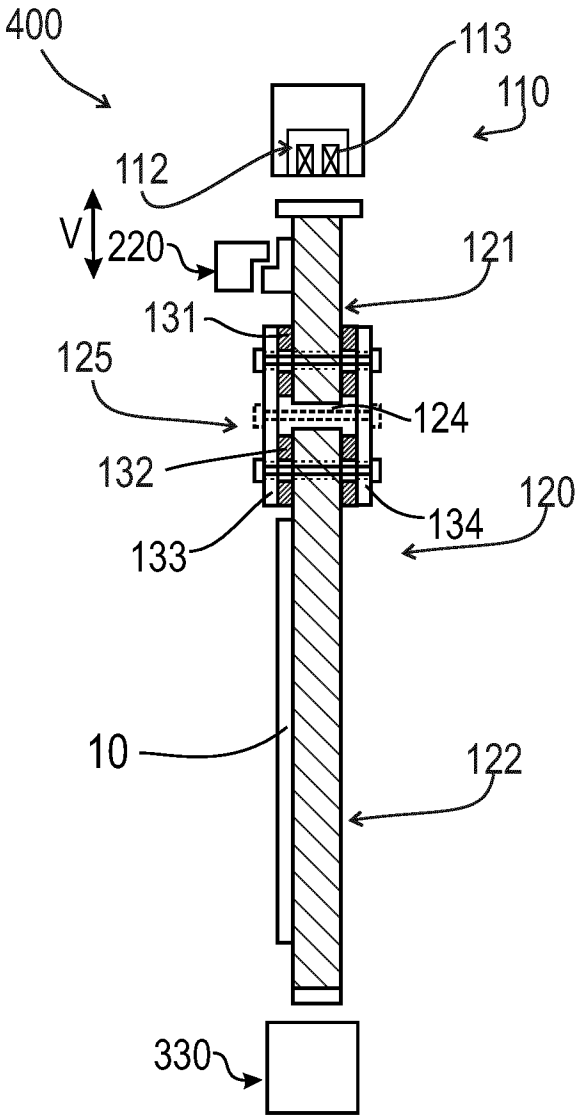

400
113
110
112
V
220
121
131
125
124
132
134
120
133
10
122
330

FIG. 4

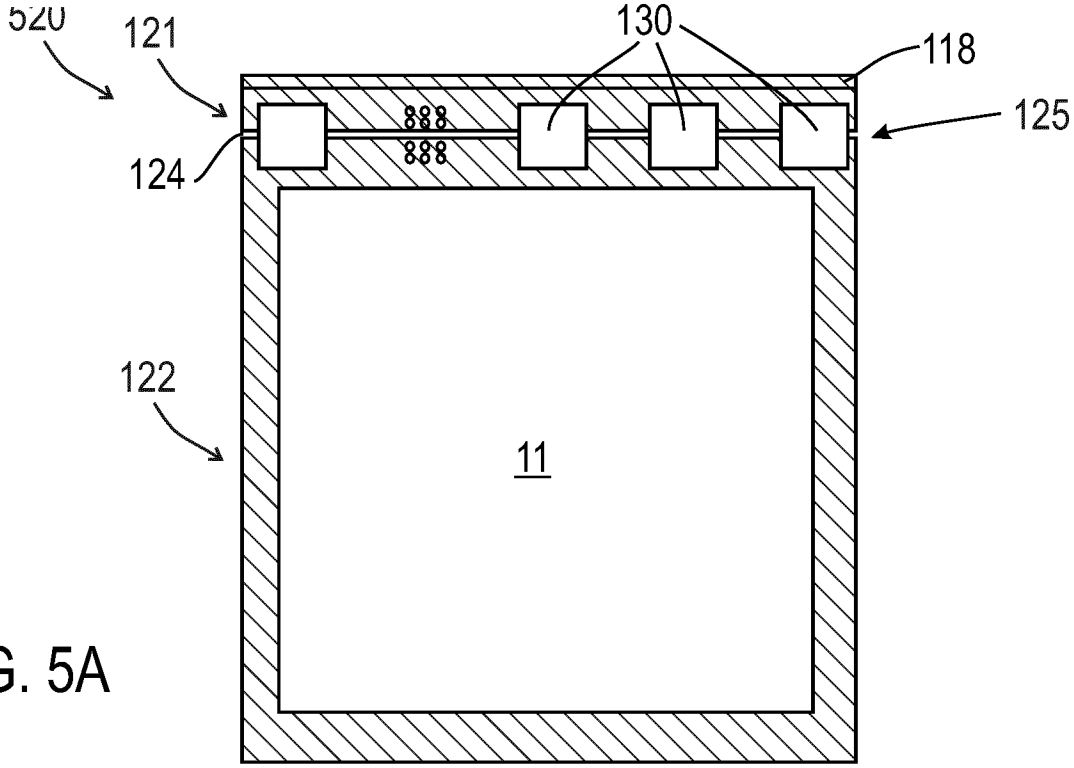

520
121
130
118
125
124
122
11

FIG. 5A

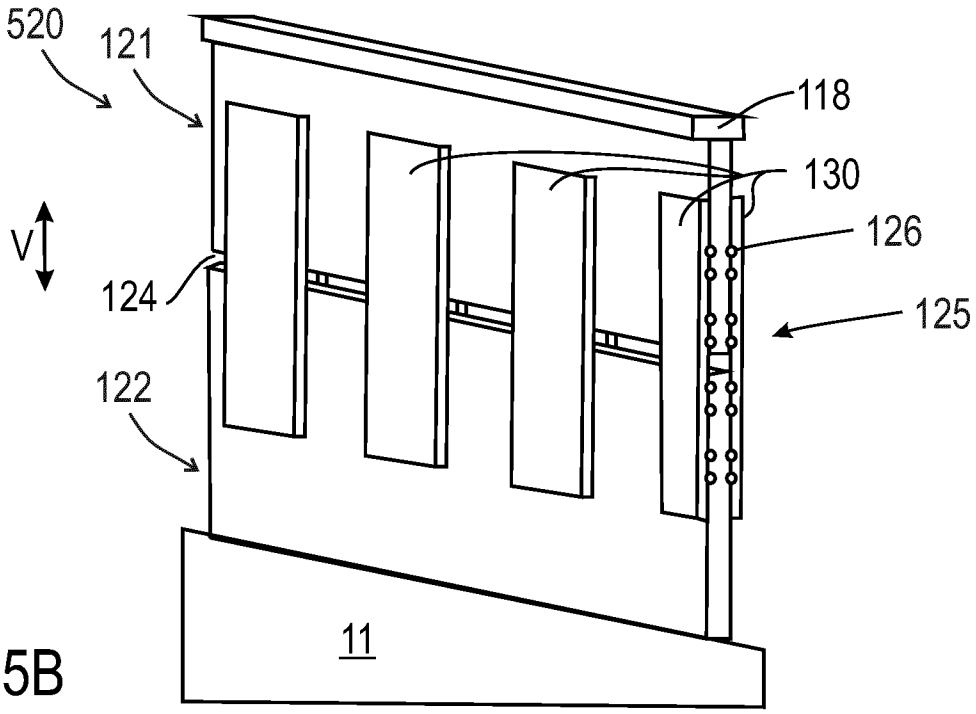

520
121
118
130
V
126
124
125
122
11

FIG. 5B

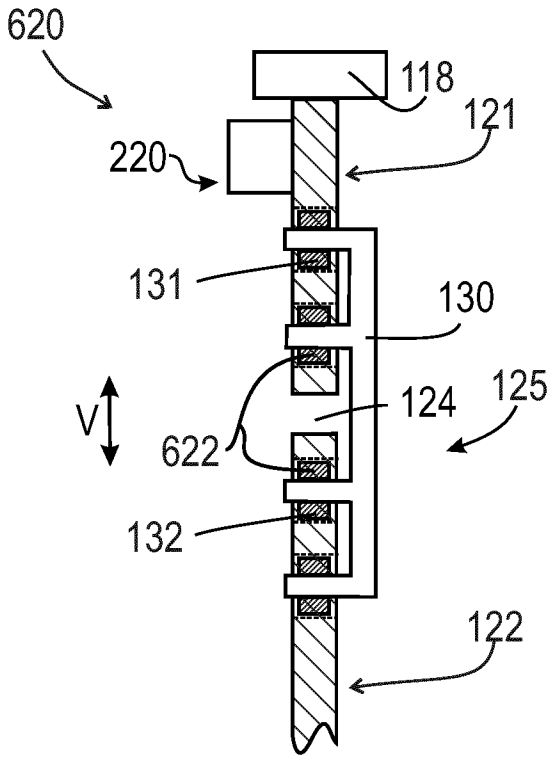


FIG. 6

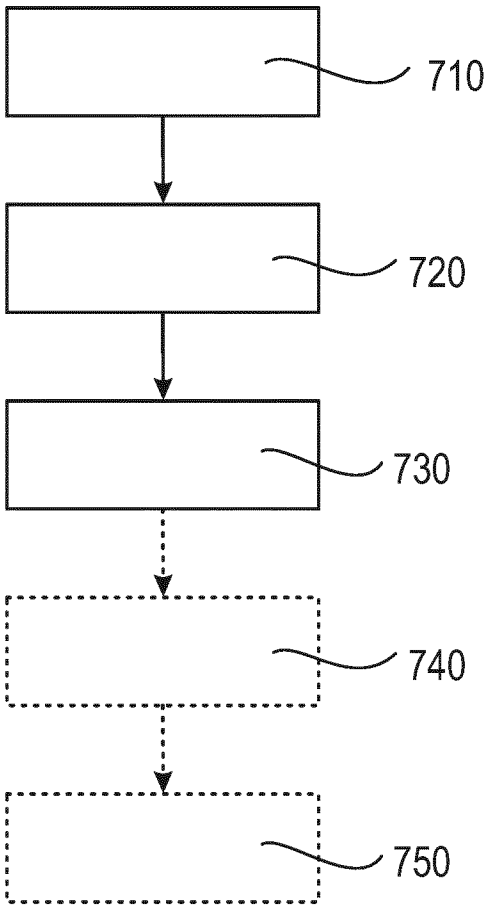


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/068514

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L21/677
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)
H01L

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	JP H11 354617 A (SUMIERE SEZ KK) 24 December 1999 (1999-12-24) abstract; figures 1-3	1,2,5, 10-14
Y	WO 2017/050350 A1 (APPLIED MATERIALS INC [US]; BRÜNING ANDRE [DE]; KELLER STEFAN [DE]; HI) 30 March 2017 (2017-03-30) abstract; figure 3B	1-15
Y	JP 2003 309164 A (MITSUBISHI HEAVY IND LTD) 31 October 2003 (2003-10-31) abstract; figures 1,2	1-15
A	JP 2012 001283 A (CANON ANELVA CORP) 5 January 2012 (2012-01-05) paragraph [0025] - paragraph [0031]; figure 1	1-15

-/--

[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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
5 April 2018	11/04/2018

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	Oberle, Thierry

1

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

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004 359436 A (ISHIKAWAJIMA HARIMA HEAVY IND) 24 December 2004 (2004-12-24) paragraph [0024] - paragraph [0028]; figures 1-3	1-15
A	JP H01 168038 A (TOSHIBA CORP) 3 July 1989 (1989-07-03) abstract; figure 1	1,12,15
A	JP 2006 019396 A (TOKYO ELECTRON LTD) 19 January 2006 (2006-01-19) abstract; figures 4,7	1,12,13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/068514

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H11354617 A	24-12-1999	NONE	
WO 2017050350 A1	30-03-2017	NONE	
JP 2003309164 A	31-10-2003	NONE	
JP 2012001283 A	05-01-2012	NONE	
JP 2004359436 A	24-12-2004	JP 4273845 B2 JP 2004359436 A	03-06-2009 24-12-2004
JP H01168038 A	03-07-1989	NONE	
JP 2006019396 A	19-01-2006	JP 4429825 B2 JP 2006019396 A	10-03-2010 19-01-2006