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(54) **DEVICE FOR MOVING LIQUIDS AND/OR GASES**

VORRICHTUNG ZUM BEWEGEN VON FLÜSSIGKEITEN UND/ODER GASEN

DISPOSITIF DE DEPLACEMENT DE LIQUIDES ET / OU DE GAZ

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Description

[0001] The present invention relates to a device for moving liquids and/or gases as well as the use of this device as valve and/or pump.

[0002] Devices for moving liquids and/or gases in the sense of the present invention are those capable of setting liquids and/or gases into motion. Movement means both pump movements and suction movements, but also any other kind of movement of liquids and/or gases. In the sense of the present invention, there are also included, for example, any kinds of currents of liquids and/or gases, including circular and vortex-like ones. Devices in the sense of the present invention for moving liquids and/or gases are particularly pumps and/or valves, more preferably particularly devices in a construction size allowing their use in microsystem technology, medical technology, biomedicine, pharmacy or other areas. In the sense of the present invention, this includes particularly micropumps and/or microvalves as devices for moving liquids and/or gases of any kind, including tissue liquids.

[0003] Possible fields of application of devices in the sense of the present invention are particularly microsystem technology and medical technology. There are considerations to dispose micropumps and/or microvalves also in the human body. This requires the corresponding systems to have only a low operational voltage and also to be compatible with the surrounding human tissue.

[0004] From DE 103 13 158 A1, there is known a micropump with a membrane-like actuator having pump chambers comprising internal contours corresponding at least essentially to the deflection line of a membrane-like actuator. By deforming the membrane-like actuator, the volume of the pump chambers may thus at least essentially be reduced to zero, wherein the allowable counter-pressure of a fluid to be transported may thus be advantageously and comparatively high without impacting the function of the pump. Thus, a piezoelectric bending converter is suggested as actuator. What is disadvantageous in the micropump disclosed in DE 103 13 158 A1 is that the provided piezoelectric bending converter requires relatively high operational voltages, so that its use particularly in the human body is not possible.

[0005] DE 101 64 474 A1 also discloses a micropump, wherein a membrane is moved by connection members. The connection members are designed stamp-shaped. Here, the membrane also consists of a piezoelectrically operated bending converter.

[0006] From DE 197 24 240 A1, there is known a transport pump, which has at least two chambers with variable volume, adjusted via volume adjusting means, arranged essentially one after the other in the transport direction. The volume adjusting means are particularly formed by piezoelements or piezoelement stacks and/or electromagnetic lifting elements or overpressure and/or underpressure generating means. A polymer film may be provided as overpressure and/or underpressure generation means.

[0007] From US 2004/0108479 A1, there is finally known a microvalve in which a channel may be closed by an actuator designed in a film-like way. The actuator comes directly into contact with the liquid flowing through the microvalve. The actuator consists of a porous membrane which may be provided, on one side, with a layer of conductive polymer and is coated with a metal layer on the other side of the film. In order to allow the closure of the valve, the medium flowing through the microvalve has to comprise conducting salt ions, which is why the field of application of the microvalve disclosed in US 2004/0108479 A1 is disadvantageously very limited.

[0008] It is the object of the present invention to provide a device not having the disadvantages known from prior art and particularly solving the task to provide a species-compatible device operating with low operational voltages without the need to add particularly conducting salt ions to the media to be moved.

[0009] According to the invention, this object is achieved by a device for moving liquids and/or gases including a housing with at least one chamber having a first chamber wall including at least partially at least one actuator including at least one first moveable membrane and at least one layer of at least one conductive polymer arranged on the side facing the interior of the chamber; and having a second chamber wall including at least partially at least one movement element including at least one second moveable membrane and at least one metallic layer arranged on the side facing the interior of the chamber, wherein the chamber is at least partially filled with a conducting electrolyte.

[0010] The large advantage of the inventive device is that movement of the actuator is initiated by providing the same with voltage without the need to add conducting salts to the medium to be moved. This is because they are received in the chamber included in the inventive device and are thus separate from the medium to be moved. Liquids and/or gases in the sense of the present invention also include liquid melts and other transportable media, irrespective of their state of aggregation. The inventive device further has the large advantage that, due to the provision of electrically conductive polymers, it may be operated with a very low operational voltage, preferably with an operational voltage in a range from about 2 volts to about -2 volts, more preferably in a range from about 1.5 volts to about -1.5 volts. In this way, the inventive device is also suitable for the use as, for example, micropump or microvalve in human tissue. In addition, the inventive device may be implemented extremely small-sized, because the corresponding membranes and layers guarantee the function of the inventive device with very low thicknesses. The thicknesses are usually in the nanometer range.

[0011] The housing of the inventive device may be made of any suitable material, particularly of glass materials, particularly borosilicate glass and/or other quartz glasses, but also of plastics, such as polymethyl methacrylate, but also of silicon and/or SU8 photoresist resins,

particularly in the implementation as microvalve, micro-pump or other species-compatible devices usable in microsystem or medical technology. SU8 photoresist resins are modified epoxy resins produced by cationic polymerization, as they are disclosed, for example, in US 4,882,245 and are available from the company Microchem Corp., Newton, Massachusetts, USA. The chamber walls preferably form at least part of the housing wall at the same time, so that the actuator and the movement element have sufficient room for movement. However, there may also accordingly be provided recesses in the housing in the area of the chamber, which allow the movement of the actuator and the movement element. The recesses may be essentially adapted to the bending contour of the actuator and the movement element, wherein dead volumes can readily be tolerated. The amount of movement, particularly the curvature, of the actuator and the movement element may be controlled by the strength and the direction of the applied operational voltage. Specifically, the operational voltage may also be given in a pulsed form and/or in the form of triangular or rectangular voltages, wherein feed rates of up to about 100 V/s may be provided, so that a uniform, reversible movement of the actuator and the movement element is achieved. The movement element serves to equalize pressure in the chamber by deflection.

[0012] It is not required that the whole first and second chamber walls have to be formed of the actuator and the movement element, it is also possible that only parts thereof may be formed of the one or more actuators or movement elements arranged separately, wherein these may have any geometric dimensions, particularly also in the form of a stripe, but also circular etc. In a preferred embodiment of the present invention, the actuator and the movement element are arranged opposite to each other. This allows an extremely effective pressure equalization in the case of movement of the actuator and the corresponding parallel movement of the movement element, so that the volume of the chamber contents essentially does not change. The membranes of the actuator and the movement element may be such that they change their shape by stretching, when there is movement, wherein any change of shape should be reversible, though.

[0013] Preferably, the conductive polymer is selected from a group including polypyrroles, polythiophenes, polyanilines, polyphenylenes, polyparaphenylenes and/or polyvinylenes and derivatives thereof. Polypyrrole and poly-(3,4-ethylene-dioxy-thiophene) are particularly preferred. The conductive polymers may also be present in the form of copolymers, block copolymers or random block copolymers. In particular, the layer of conductive polymer may also consist of mixtures of several conductive polymers and may be structured not only with a single layer, but also with several layers, for example by successive electrochemical depositions.

[0014] Preferably, the layer of conductive polymer has a thickness in the range of about 10 nm to about 150 μm .

This layer may simply be electrochemically deposited directly onto the membrane by polymerization of monomers provided in the chamber. Preferably, it may be provided that, between the layer of conductive polymer and the membrane, there, is arranged at least one further metallic layer which may, for example, be formed of platinum, gold, silver, chromium, titanium and/or stainless steel or alloys thereof. By the provision of this at least one further layer, the adhesion of the layer of conductive polymers on the membrane may be improved.

[0015] In a preferred embodiment of the inventive device, the at least one metallic layer of the movement element is formed of metal, for example selected from a group including platinum, gold, silver, chromium, titanium and/or stainless steel or alloys thereof. This metallic layer, as well as the further metallic intermediate layer of the actuator, may be obtained by sputtering and/or vapor deposition of the corresponding metals on the first and/or the second membrane. Preferably, the metallic layer of the movement element has a thickness in a range from about 1 nm to about 250 nm, more preferably in a range from about 5 nm to about 100 nm. The metallic intermediate layer of the actuator may have a corresponding thickness. If several layers are provided on the actuator and/or movement element, these may also be formed of different metals and/or alloys.

[0016] The first and/or second movable membrane is preferably formed of a single-layer or multi-layer film, made of polymers selected from a group including polyimides, polyamides, polyurethanes, polytetrafluoroethylenes, polydimethylsiloxanes, polymethyl methacrylates, polyester, polyvinyl chlorides, polyethylenes, polyethylene terephthalates, parylenes and/or silicone rubber. Parylenes in the sense of the present invention are thermoplastic polymers with phenylene groups linked via ethylene groups in 1,4-position, for example poly-(p-xylylene). The thickness of the first and/or second membrane is preferably in a range from about 0.1 μm to about 100 μm , more preferably in a range from about 0.1 μm to about 20 μm . Preferably, the first and/or second membrane has a modulus of elasticity in a range from about 4 MPa to about 10,000 MPa, measured in accordance with EN ISO 527. Due to the selection of materials for the first and/or second membrane with relatively low values for the modulus of elasticity, an extremely long life of the inventive device is guaranteed. The film may be made of copolymers, block copolymers and random block copolymers and particularly also of mixtures of the mentioned polymers and may, in addition, have added substances commonly contained in films, such as softening agents, fillers etc. The first and/or second membrane is preferably impermeable. This advantageously prevents conducting electrolyte from the chamber of the inventive device to exit and to result in a contamination of the moved medium.

[0017] Preferably, the conducting electrolyte includes a conducting electrolyte solution selected from a group including water, polar aprotic solvents and/or ionic liq-

uids. Particularly preferred polar aprotic solvents are propylene carbonate, dichloromethane and/or acetonitrile. The polar aprotic solvents with a maximum boiling point are particularly preferred. For application in the human body, water is particularly provided as electrolyte solvent. Preferably, ionic liquids are used, because they have the large advantage to have virtually no vapor pressure. This may also allow to omit the addition of solvents, depending on the application. Furthermore, they advantageously do not perform any nucleophile attack at the polymer backbone both of the layer of the conductive polymer and of the material of the first and/or second membrane, as with polar aprotic solvents, as it may, for example, occur by the hydroxide ion of the water. In addition, ionic liquids generally have a very wide electrochemical window, so that the danger of electrochemical decomposition is significantly minimized. Possible ionic liquids in the sense of the present invention are butyl-3-methyl-imidazolium tetrafluoroborate, but also further related imidazolium derivatives or corresponding pyridinium, pyrrolidinium derivatives, phosphonium, ammonium and sulphonium derivatives. The conducting electrolyte is formed of the electrolyte solvent and the conducting salt, but it may also contain further useful additives, depending on the application, if necessary. Particularly, the conducting electrolyte includes a conducting salt selected from a group including fluorides, chlorides, bromides, iodides, perfluorides, perchlorates, perbromates, periodides, sulphates, sulphonates, borates, tetrafluoroborates, phosphates, hexafluorophosphates, hydroxides, cyanides, nitrates, chromates, tosylates, salts of trifluoromethane sulfonic acid, polyalkyl sulphate, polyalkyl sulphonates, polydodecyl benzyl sulphonates and/or polystyrene sulphonates. Tetrabutylammonium hexafluorophosphate and lithium perchlorate are especially preferred. The conducting salts are present in the electrolyte solution in a quantity sufficient to guarantee the function of the inventive device. Preferably, the system conducting salt/electrolyte solvent is selected such that the conducting salts are completely solved in the electrolyte solvent.

[0018] In a preferred embodiment, the first and/or second membrane is fixed to the housing of the inventive device. Particularly when the first and/or second chamber wall is formed completely by the actuator and/or the movement element, the membrane may correspondingly be mounted in subareas of the actuator and/or movement element on the housing of the inventive device. It may also be provided that the metallic layer and/or the layer of conductive polymer is applied over the whole side of the membrane facing the interior of the chamber, either on the full area or only on parts of the area or in traces, similarly to a power trace on a board, particularly to generate a safe connection to a voltage source arranged outside the chamber housing.

[0019] Furthermore, it may advantageously be provided that a reference electrode is inserted in the chamber, for example a silver/silver chloride electrode (Ag/AgCl), so that the inventive device may precisely be provided

with a particular operational voltage. Advantageously, the chamber of the inventive device comprises at least one opening.

[0020] Through this opening, the conducting electrolyte may, for example, be exchanged, or there may be inserted a reference electrode, and subsequently the opening may be closed again.

[0021] In a preferred embodiment, the actuator is connected as working electrode, whereas the movement element is connected as counter-electrode. When an operational voltage is provided, the actuator and the movement element perform a parallel movement. Whether the actuator moves in the direction towards the chamber interior or away therefrom and the movement element performs a corresponding movement, depends on the provided voltage and the chemical structure of the actuator and potentially also of the movement element.

[0022] In a particularly preferred embodiment, the inventive device further includes a channel arranged directly adjacent to the actuator and conducting liquid and/or gas, generally conducting a medium. The actuator is in direct contact with the medium flowing through the channel, so that the channel may preferably be closed by the actuator. The channel may also be closed multiple times by arranging several chamber housings with several actuators one after the other, and/or a directional movement of a liquid may be generated by corresponding control and regulation of the individual actuators.

[0023] Furthermore, the present invention relates to the use of the inventive device as valve and/or pump, particularly as microvalve and/or micropump. Possible fields of application are medical technology and microsystem technology, particularly with respect to biological, biomedical and/or pharmaceutical fields of application. Possible fields of application are also biological systems, body liquids and lab-on-chip devices, drug delivery systems, dispensers, sample dispensers, inkjet printers, micro-dosing systems of all kinds, etc.

[0024] These and further advantages of the present invention will be explained in more detail with respect to the following figures, in which:

- Fig. 1 shows an inventive device in side view;
- Figs. 2a to 2c show disk-shaped members for producing the housing of the device of Fig. 1;
- Fig. 3 shows a top view of the device of Fig. 1;
- Fig. 4 shows a sectional view in a section plane 13 of the device of Fig. 1 in idle position;
- Fig. 5 shows a sectional view in a section plane 13 of the device of Fig. 1 in deflected position;
- Fig. 6 shows an alternative embodiment of the device in an idle state and in a deflected state; and

Fig. 7 shows a further embodiment of the inventive device as micropump.

[0025] First it is to be noted that the present invention is not limited to the feature combinations indicated in the individual figures, but that the features given in the description including the description of the figures may be combined with each other for further embodiments.

[0026] Fig. 1 shows a side view of an inventive device designated with the reference numeral 10 in its entirety. It comprises a housing 12 with a chamber 14, wherein, in the view of Fig. 1, the chamber 14 is completely covered by an actuator 24. In the interior of the housing 12, a bore 20 is provided for an opening 22. The actuator 24 includes a membrane with a metallic intermediate layer partially designed as power trace 45 to allow driving the actuator 24.

[0027] Figs. 2a to 2c explain the structure of the device of Fig. 1 in more detail. It consists of two disk-shaped members 16.1 and 16.3 forming the two exterior sides of the housing. The central part of the housing is formed of a disk-shaped member 16.2. The members 16.1, 16.2 and 16.3 comprise a bore 18.1, 18.2 and 18.3, wherein the member 16.2 additionally comprises a slot 20 for an opening 22. The disk-shaped members 16.1, 16.2 and 16.3 forming the housing 12 may be made of any suitable material, particularly of borosilicate glass and/or quartz glass, but also of an SU8 photoresist resin or silicon. By providing the bores 18.1 and 18.3 in the external disk-shaped members 16.1 and 16.3 of the housing 12 of the inventive device 10, the chamber walls of the chamber 14 are in direct contact with the surroundings of the housing 12, as it is particularly illustrated by Fig. 3. The disk-shaped structure of the housing 12 of the disk-shaped members 16.1, 16.2 and 16.3 is readily apparent from Fig. 3, wherein the chamber 14 is indicated by a dashed line in the top view shown in Fig. 3. The chamber 14 comprises chamber walls 15.1 and 15.2, which are thus simultaneously part of the exterior sides of the housing 12.

[0028] Fig. 4 shows the inventive device 10 in section corresponding to a sectional plane 13 of Fig. 1, wherein the disk-shaped structure of the housing 12 was not taken into account for simplicity. However, it is to be understood that the housing 12 may not only be structured in a disk-shaped way in the sense of Figs. 1 to 3, but may be formed in any way corresponding to the task of the present invention, for example also of massive, particularly integral members. The device 10 is shown in an operational state A, which represents the idle position thereof. Device 10 comprises an actuator 24 and a movement element 30. The actuator 24 consists of a membrane 26 mounted to the housing 12. In the area of the chamber interior 36, this membrane 26 is first provided with a metallic intermediate layer 46, on which a layer of conductive polymer 28 is disposed. The movement element 30 comprises a membrane 32 mounted to the housing 12, which is provided with a metallic layer 34 at least

in the area of the chamber interior 36. The chamber interior 36 contains a conducting salt and/or conducting electrolyte 38, including an electrolyte solvent and/or at least one ionic liquid, possibly with the addition of an electrolyte solvent and/or conducting salt. The chamber interior 36 is thus preferably completely filled with the conducting electrolyte 38. The chamber walls 15.1 and 15.2 are thus formed by the membranes 26 and 32, which are at the same time parts of the housing walls of the housing 12. In the operational state A of Fig. 4, no voltage is applied to the actuator 24. The membranes 26 and/or 32 with metallic layers 34 and 46, respectively, or only the metallic layers 34 and/or 46 may form power traces (not shown) extending on the housing wall to allow driving.

[0029] Fig. 5 shows the device of Fig. 4 in an operational state B, in which the actuator 24 is provided with an operational voltage. When the actuator 24 is provided with a voltage, the actuator 24 moves into the chamber interior 36 in the direction of arrow 42.1, whereas, as a reaction, the movement element 30 moves away from the chamber interior 36 in the direction of arrow 42.2. What is not shown in Figs. 4 and 5 are the possible connections of current-carrying lines to the actuator 24, but they may be effected in any known manner. If an operational voltage is applied to the device of Figs. 4 and 5, for example in the form of a triangular voltage or rectangular voltage, a pulsed movement of the actuator 24 and correspondingly of the movement element 30 may occur, wherein pressure equalization is not necessary due to the parallel movements of the actuator 24 and the movement element 30. The first and the second membrane 26 and 32 of the actuator 24 and the movement element 30 are preferably formed of identical materials and preferably also have the same physical-chemical parameters, particularly also more or less identical modulus of elasticity.

[0030] Fig. 6 now shows an alternative embodiment of the inventive device 10, wherein, unlike the embodiment shown in Figs. 4 and 5, an idle state A is shown with an operational state C for purposes of explanation in a single illustration. A further difference is that, in the chamber interior 36, a reference electrode 40 is arranged, for example in the form of a silver/silver chloride electrode, to allow a maximally precise adjustment of the operational voltage. Furthermore, unlike the embodiment of device 10 shown in Figs. 4 and 5, an implementation is indicated here that allows movement of the actuator 24 with a membrane 26 and the movement element 30 in an opposite direction with respect to the one of Fig. 5, namely one in the direction of arrows 44.1 and 44.2. Finally, the metallic layer 34 of the movement element 30 is disposed on the membrane 32 not only in the area of the chamber, but the membrane 32 is rather provided continuously with the metallic layer 34, wherein it may, however, also extend only on part of the area, particularly in the area of the housing 12. This allows a simplification of providing the second actuator 30 with an operational voltage. Correspondingly, the membrane 26 of the first actuator 24

comprises a metallic intermediate layer 46, which, like the metallic layer 34 of the movement element 30, is disposed on the membrane 26 not only in the area of the chamber, but is present on the whole side of the membrane 26 facing the chamber and/or the housing 12. This also allows a simple operational voltage supply to the actuator 24.

[0031] Fig. 7 now shows the implementation of the invention in the form of a micropump, wherein here it comprises, for example, a total of three chambers 50, 52 and 54. The micropump is designated with the reference numeral 48 in its entirety. The first chamber 50 comprises an actuator 56 with a layer of a conductive polymer 68.1 and a metallic intermediate layer 72.1 and a movement element 62 consisting of a metallic layer 70.1 disposed in the area of the chamber interior. The second chamber comprises a first actuator 58 and correspondingly a movement element 64, wherein the actuator 58 comprises a layer of a conductive polymer 68.2 and a metallic intermediate layer 72.1, whereas the movement element 64 comprises a metallic layer 70.2. The third chamber 54 comprises an actuator 60 and correspondingly a movement element 66, wherein the actuator 60 comprises a layer of a conductive polymer 68.3 and a metallic intermediate layer 72.3, and the movement element 66 comprises a metallic layer 70.3. All actuators 56, 58 and 60 and all movement elements 62, 64 and 66 comprise a common membrane 69 and 67, respectively, so that they may also be referred to as actuator membrane 69 and movement element membrane 67. The individual chambers 50, 52 and 54 are separated from each other and/or formed by housing parts 88.1 to 88.4.

[0032] Furthermore, the micropump 48 comprises pump housing parts 86.1, 86.2 and 86.3, which are arranged in connection with the housing parts 88.1 to 88.4 such that a channel 78 is formed. The channel 78 comprises recesses 82.1 to 82.4. Between the pump housing parts 68.1 to 68.3, an inlet 74 and an outlet 76 are formed. In the state of the micropump 48 shown in Fig. 7, the channel 78 is closed, which is made possible by a special design of the channel 78 by providing projections 80.1 and 80.2 in the channel wall at the inlet 74 and projections 80.3 and 80.4 at the outlet 78, which are sealingly fitted against the first actuators 56 and 60.

[0033] If now an operational voltage of the micropump 48 is applied, the actuator 56 of chamber 50 moves in the direction of arrow 84.1, the actuator 58 of chamber 52 moves in the direction of arrow 84.2, and the actuator 60 of chamber 54 moves in the direction of arrow 84.3 into the chamber interior. Correspondingly, the movement element 62 of the first chamber 50, the movement element 64 of the second chamber 52 and the movement element 66 of the third chamber 54 move away from the chamber interior in the direction of arrows 84.1, 84.2 and 84.3. By the movement of the actuators 56 and 60 and for achieving a pressure equalization of the movement elements 62 and 66, the channel 78 is opened, and a medium flowing therethrough, for example gas or liquid,

may flow in the direction of the outlet 76 via the inlet 74. If, specifically, a pulsed operational voltage of the micropump 48 is applied and the driving of the individual chambers 50, 52 and 54 is done separately and independently of each other, a directional movement of medium flowing into the channel 78 via the inlet 74 may occur in the direction of the outlet 76. The medium is thus drawn in through the inlet 74 and passed out of the channel 78 via the outlet 76 by the actuators 56, 58 and 60.

[0034] When the channel 74 is opened and the channel 76 is closed at the same time, the movement of the actuator 58 allows to draw in the medium, and by closing the channel 74 and opening the channel 76, by moving the actuator 58 back, the medium may subsequently be expelled via the channel 76. The transport direction of the medium is determined by the order in which the actuators 56, 58 and 60 are driven. The transport amount may be varied by the driving times and the applied voltage.

[0035] Due to the micropump 48 of Fig. 7, but also the device 10 of Figs. 1 to 6, it is not necessary to add a conducting electrolyte to the medium to be moved, thus considerably extending the field of application as compared to the devices known from prior art. Depending on the choice of the conducting electrolyte and the membrane material as well as the conductive polymer, disadvantageously occurring electrochemical processes, such as nucleophile attacks of hydroxide ions against polymers, hydrolyses or overoxidations, may be avoided. In addition, the devices 10 or the micropump 48 may readily be operated with low operational voltages below ± 2 Volt, so that battery operation is possible. The actuators of a micropump may be driven separately in the present sense, so that the transport means may also be varied. The micropump may also comprise several inlet and outlet valves as well as pump chambers in a different arrangement.

[0036] The invention will be explained in more detail based on the following example:

Flat glass plates with a length of 2.8 cm, a width of 2.5 cm and a thickness of 3 mm are produced of borosilicate glass, in which a hole with a diameter of 1 cm was centrally bored. A slot 20 with a width of 1.5 mm was introduced into the central glass plate, which subsequently forms the opening 22 of the device 10. These three glass plates were bonded with an epoxy resin glue for forming the housing 12.

Subsequently, the opening of the bores 18.1 and 18.3 of Figs. 2a and 2c was covered externally with a film of polyethylene terephthalate sputtered with platinum. The film was sputtered not only in the area of the chamber, but over the whole area facing the housing and the chamber interior. The thickness of the platinum layer was about 60 nm to about 80 nm, the thickness of the film was about 12 μ m.

For coating one of the two membrane films sputtered with platinum with a conductive polymer, the formed chamber was filled with a monomer-containing electrolyte solution via the opening 22. 0.1 M pyrrole in propylene carbonate with tetrabutylammonium hexafluorophosphate (0.1 M) and/or lithium perchlorate (0.1 M) as conducting electrolyte was used as monomer, wherein the polymerization was done potentiostatically at 850 mV. In a further embodiment, 3,4-ethylene dioxythiophene in propylene carbonate with tetrabutylammonium hexafluorophosphate, alternatively in lithium perchlorate, 0.1 M each, was used as monomer, wherein here the polymerization was done potentiostatically at about 1,000 mV. For the potentiostatic polymerization, the plastic membrane sputtered with platinum which was to be coated was connected as working electrode, the opposite membrane was connected as counter-electrode. In addition, a silver wire coated with silver chloride was introduced into the chamber interior via the opening 22 as reference electrode.

After the coating with polypyrrole and/or poly(3-4-ethylene dioxythiophene) was completed, the chamber was emptied, rinsed and filled with monomer-free electrolyte solution.

Propylene carbonate with tetrabutylammonium hexafluorophosphate or lithium perchlorate, 0.1 M each, served as electrolyte. After the filling with monomer-free electrolyte solution, a silver wire coated with silver chloride was again introduced via the opening 22 as reference electrode, and the opening was tightly closed.

Subsequently, triangular and rectangular potentials in the range between 0 V and 1 V were applied with a feed rate of up to 1 V/sec, resulting in pulsed curvature of the first actuator 24 and the second actuator 30.

Claims

1. Device (10) for moving liquids and/or gases including a housing (12) with at least one chamber (14) having a first chamber wall (15.1) including at least partially at least one actuator (24) including at least one first movable membrane (26) and at least one layer (28) of at least one conductive polymer arranged on the side facing the chamber interior (36); and having a second chamber walls (15.2) including at least partially at least one movement element (30) including at least one second movable membrane (32) and at least one metallic layer (34) arranged on the side facing the chamber interior (36), wherein the chamber (14) is at least partially filled with a conducting electrolyte (38), and wherein the actuator (24) and the movement element (30) are moveable by applying a voltage between the conductive polymer and the metallic layer (34).
2. Device of claim 1, **characterized in that** the actuator (24) and the movement element (30) are arranged opposite each other.
3. Device of one of the preceding claims, **characterized in that** the first and/or second moveable membrane (26, 32) is formed of a film selected from a group including polyimides, polyamides, polyurethanes, polytetrafluoroethylenes, polydimethylsiloxanes, polymethyl methacrylates, polyester, polyvinyl chlorides, polyethylenes, polyethylene terephthalates, parylenes and/or silicon rubber.
4. Device of one of the preceding claims, **characterized in that** the first and/or second membrane (26, 32) is impermeable.
5. Device of one of the preceding claims, **characterized in that** the conducting electrolyte (38) includes a conducting electrolyte solution selected from a group including water, aprotic solvents and/or ionic liquids.
6. Device of one of the preceding claims, **characterized in that** the conducting electrolyte (38) includes a conducting salt selected from a group including fluorides, chlorides, bromides, iodides, perfluorides, perchlorates, perbromates, periodides, sulphates, sulphonates, borates, tetrafluoroborates, phosphates, hexafluorophosphates, hydroxides, cyanides, nitrates, chromates, tosylates, salts of trifluoromethane sulfonic acid, polyalkyl sulphates, polyalkyl sulphonates, polydodecyl benzyl sulphonates and/or polystyrene sulphonates.
7. Device of one of the preceding claims, **characterized in that** the first chamber wall (15.1) is formed by the actuator (24) and the second chamber wall (15.2) is formed by the movement element (30).
8. Device of one of the preceding claims, **characterized in that** the first and/or second membrane (26, 32) is mounted to the housing (12).
9. Device of one of the preceding claims, **characterized in that**, between the first membrane (26) and the layer (28) of conductive polymer, at least one further metallic layer (36) is disposed.
10. Device of one of the preceding claims, **characterized in that** a reference electrode (40) is arranged in the chamber (14).
11. Device of one of the preceding claims, **characterized in that** the first actuator (24) is connected as

working electrode.

12. Device of one of the preceding claims, **characterized in that** the chamber (14) comprises at least one opening (22).
13. Device of one of the preceding claims, **characterized in that** it further includes a channel (78) arranged directly adjacent to the actuator (24) and conducting liquid and/or gas.
14. Device of one of the preceding claims, **characterized in that** the channel (78) may be closed by the actuator (24).
15. Use of a device according to one of claims 1 to 14 as valve and/or pump.

Patentansprüche

1. Vorrichtung (10) zum Bewegen von Flüssigkeiten und/oder Gasen, die ein Gehäuse (12) mit zumindest einer Kammer (14) umfasst, welche eine erste Kammerwand (15.1) aufweist, die zumindest teilweise zumindest ein Betätigungsglied (24) umfasst, das zumindest eine erste bewegliche Membran (26) und zumindest eine Schicht (28) zumindest eines leitfähigen Polymers, das auf der dem Kammerinneren (36) zugewandten Seite angeordnet ist, umfasst; und welche eine zweite Kammerwand (15.2) aufweist, die zumindest teilweise zumindest ein Bewegungselement (30) umfasst, das zumindest eine zweite bewegliche Membran (32) und zumindest eine auf der dem Kammerinneren (36) zugewandten Seite angeordnete metallische Schicht (34) umfasst, wobei die Kammer (14) zumindest teilweise mit einem leitenden Elektrolyten (38) gefüllt ist und wobei das Betätigungsglied (24) und das Bewegungselement (30) bewegbar sind, indem eine Spannung zwischen das leitfähige Polymer und die metallische Schicht (34) angelegt wird.
2. Vorrichtung gemäß Anspruch 1, **dadurch gekennzeichnet, dass** das Betätigungsglied (24) und das Bewegungselement (30) einander gegenüberliegend angeordnet sind.
3. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die erste und/oder die zweite bewegliche Membran (26, 32) aus einem Film gebildet ist, der aus einer Gruppe ausgewählt ist, die Polyimide, Polyamide, Polyurethane, Polytetrafluorethylene, Polydimethylsiloxane, Polymethylmethacrylate, Polyester, Polyvinylchloride, Polyethylene, Polyethylenterephthalate, Parylene und/oder Siliziumkautschuk umfasst.

4. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die erste und/oder zweite Membran (26, 32) undurchlässig ist.
5. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der leitende Elektrolyt (38) eine leitende Elektrolytlösung umfasst, die aus einer Gruppe ausgewählt ist, die Wasser, aprotische Lösungsmittel und/oder ionische Flüssigkeiten umfasst.
6. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der leitende Elektrolyt (38) ein leitendes Salz umfasst, das aus einer Gruppe ausgewählt ist, die Fluoride, Chloride, Bromide, Iodide, Perfluoride, Perchlorate, Perbromate, Periodide, Sulfate, Sulfonate, Borate, Tetrafluorborate, Phosphate, Hexafluorophosphate, Hydroxide, Cyanide, Nitrate, Chromate, Tosylate, Salze von Trifluormethansulfonsäure, Polyalkylsulfate, Polyalkylsulfonate, Polydodecylbenzylsulfonate und/oder Polystyrensulfonate umfasst.
7. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die erste Kammerwand (15.1) durch das Betätigungsglied (24) gebildet ist und die zweite Kammerwand (15.2) durch das Bewegungselement (30) gebildet ist.
8. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die erste und/oder zweite Membran (26, 32) an dem Gehäuse (12) angebracht ist.
9. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** zwischen der ersten Membran (26) und der Schicht (28) aus leitfähigem Polymer zumindest eine weitere metallische Schicht (36) angeordnet ist.
10. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** eine Referenzelektrode (40) in der Kammer (14) angeordnet ist.
11. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das erste Betätigungsglied (24) als Arbeitselektrode angeschlossen ist.
12. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Kammer (14) zumindest eine Öffnung (22) aufweist.
13. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** sie ferner einen Kanal (78) umfasst, der direkt neben dem Betätigungsglied (24) angeordnet ist und Flüssigkeit

und/oder Gas leitet.

14. Vorrichtung gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Kanal (18) durch das Betätigungsglied (24) geschlossen werden kann.

15. Verwendung einer Vorrichtung gemäß einem der Ansprüche 1 bis 14 als Ventil und/oder Pumpe.

Revendications

1. Dispositif (10) pour déplacer des liquides et/ou des gaz, comportant un boîtier (12) avec au moins une chambre (14) présentant une première paroi de chambre (15.1) comportant au moins partiellement au moins un actionneur (24) comportant au moins une première membrane mobile (26) et au moins une couche (28) d'au moins un polymère conducteur disposée sur le côté faisant face à l'intérieur de la chambre (36); et présentant une deuxième paroi de chambre (15.2) comportant au moins partiellement au moins un élément de déplacement (30) comportant au moins une deuxième membrane mobile (32) et au moins une couche métallique (34) disposée sur le côté faisant face à l'intérieur de la chambre (36), dans lequel la chambre (14) est au moins partiellement remplie d'un électrolyte conducteur (38), et dans lequel l'actionneur (24) et l'élément de déplacement (30) sont déplaçables par application d'une tension entre le polymère conducteur et la couche métallique (34).

2. Dispositif selon la revendication 1, **caractérisé par le fait que** l'actionneur (24) et l'élément de déplacement (30) sont disposés opposés l'un à l'autre.

3. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** la première et/ou la deuxième membrane mobile (26, 32) est formée d'un film sélectionné parmi un groupe comportant les polyimides, les polyamides, les polyuréthanes, les polytétrafluoréthylènes, les polydiméthylsiloxanes, les polyméthacrylates de méthyle, le polyester, les chlorures de polyvinyle, les polyéthylènes, les téréphtalates de polyéthylène, les parylènes et/ou le caoutchouc à base de silicium.

4. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** la première et/ou la deuxième membrane (26, 32) est imperméable.

5. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** l'électrolyte conducteur (38) comporte une solution d'électrolyte conducteur sélectionnée parmi un groupe comportant l'eau, les solvants aprotiques et/ou les liquides ioniques.

6. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** l'électrolyte conducteur (38) comporte un sel conducteur sélectionné parmi un groupe comportant les fluorures, les chlorures, les bromures, les iodures, les perfluorures, les perchlorates, les perbromates, les periodures, les sulfates, les sulfonates, les borates, les tétrafluoroborates, les phosphates, les hexafluorophosphates, les hydroxydes, les cyanures, les nitrates, les chromates, les tosylates, les sels de l'acide sulfonique de trifluorométhane, les sulfates de polyalcoyle, les sulfonates de polyalcoyle, les polysulfonates de dodécyle et benzyle et/ou les sulfonates de polystyrène.

7. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** la première paroi de chambre (15.1) est formée par l'actionneur (24) et la deuxième paroi de chambre (15.2) est formée par l'élément de déplacement (30).

8. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** la première et/ou la deuxième membrane (26, 32) est montée sur le boîtier (12).

9. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait qu'**entre la première membrane (26) et la couche (28) de polymère conducteur est disposée au moins une autre couche métallique (36).

10. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait qu'**une électrode de référence (40) est disposée dans la chambre (14).

11. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** le premier actionneur (24) est connecté comme électrode de travail.

12. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** la chambre (14) comprend au moins une ouverture (22).

13. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait qu'**il comporte par ailleurs un canal (78) disposé directement adjacent à l'actionneur (24) et conduisant du fluide et/ ou du gaz.

14. Dispositif selon l'une des revendications précédentes, **caractérisé par le fait que** le canal (78) peut être obturé par l'actionneur (24).

15. Utilisation d'un dispositif selon l'une des revendications 1 à 14 comme soupape et/ ou pompe.

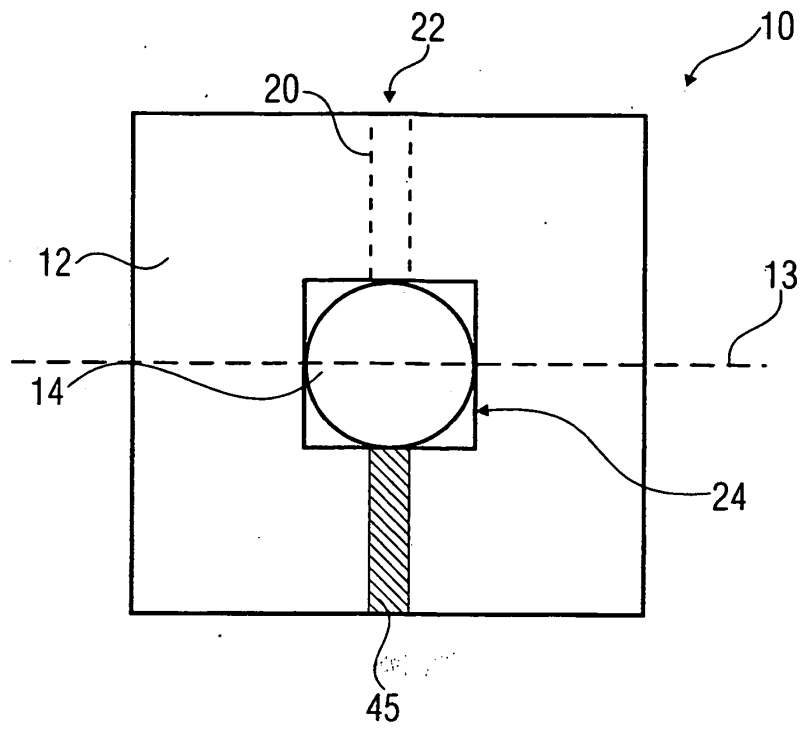


FIG 1

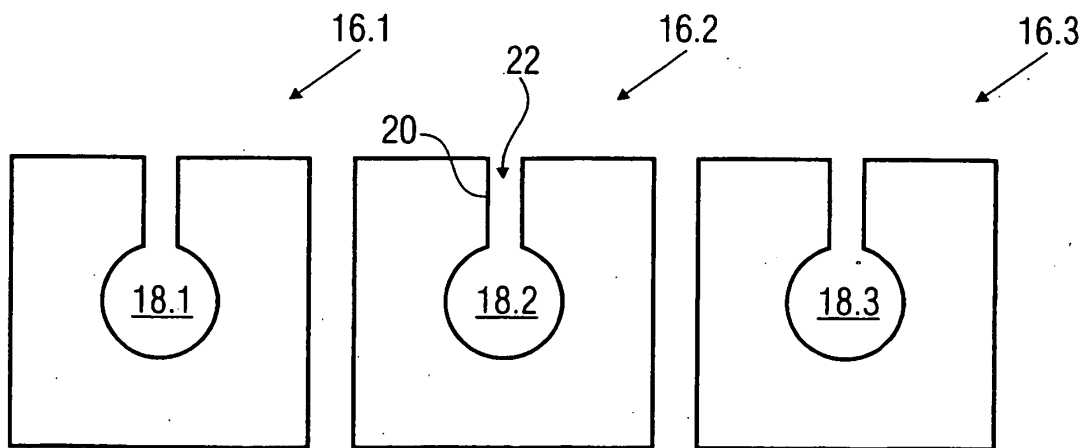


FIG 2A

FIG 2B

FIG 2C

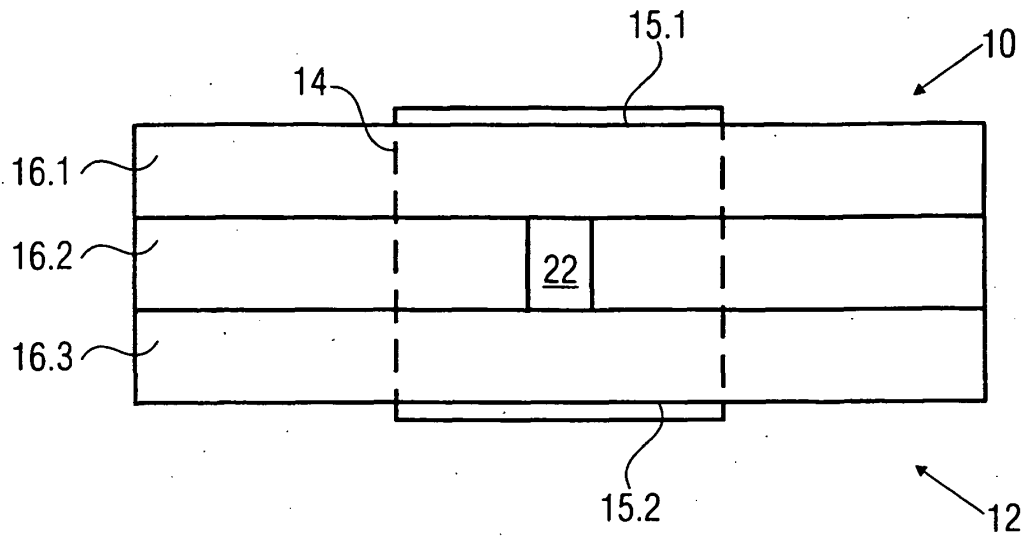


FIG 3

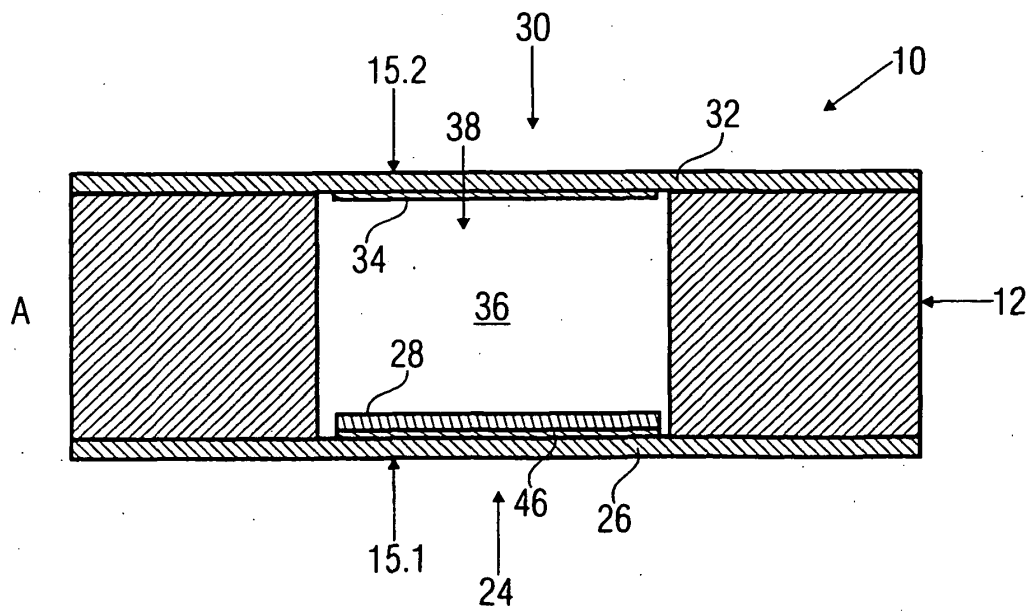


FIG 4

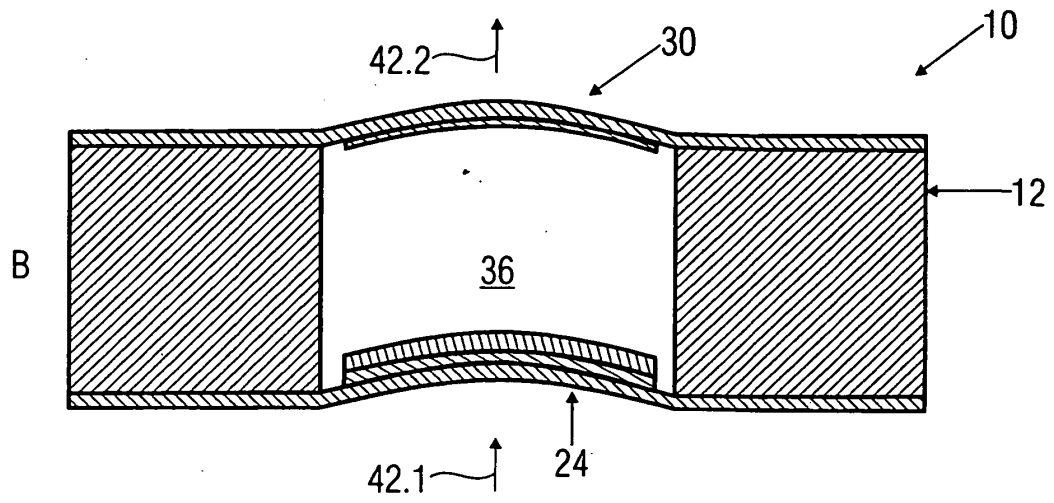


FIG 5

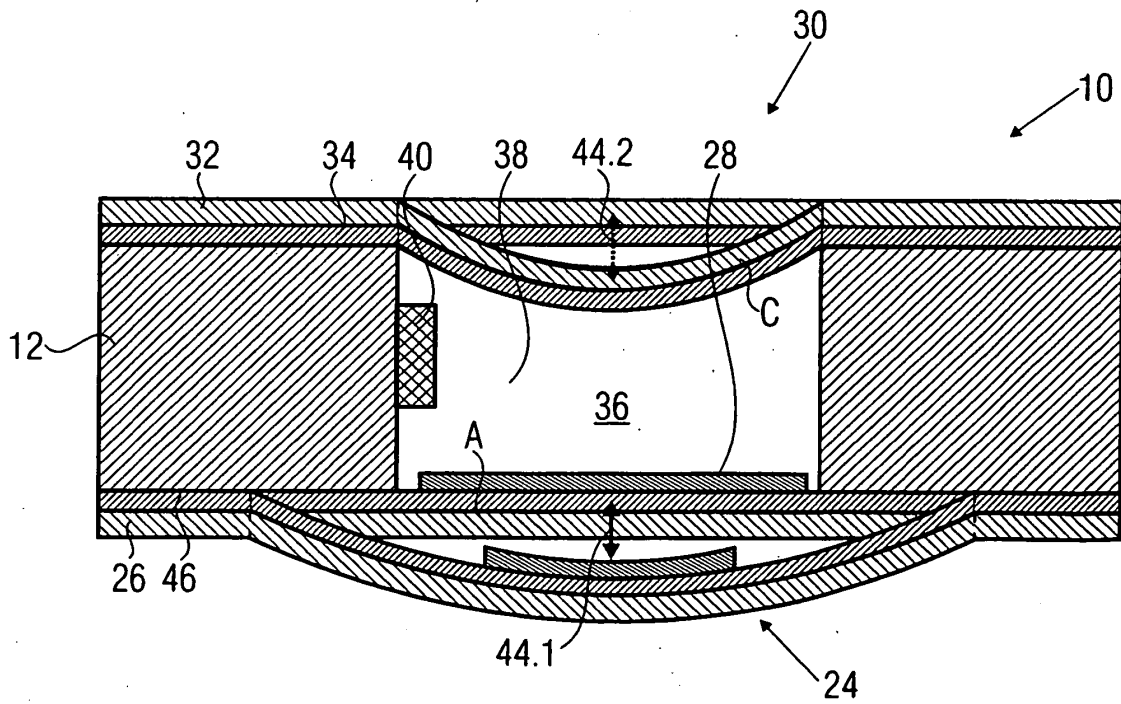


FIG 6

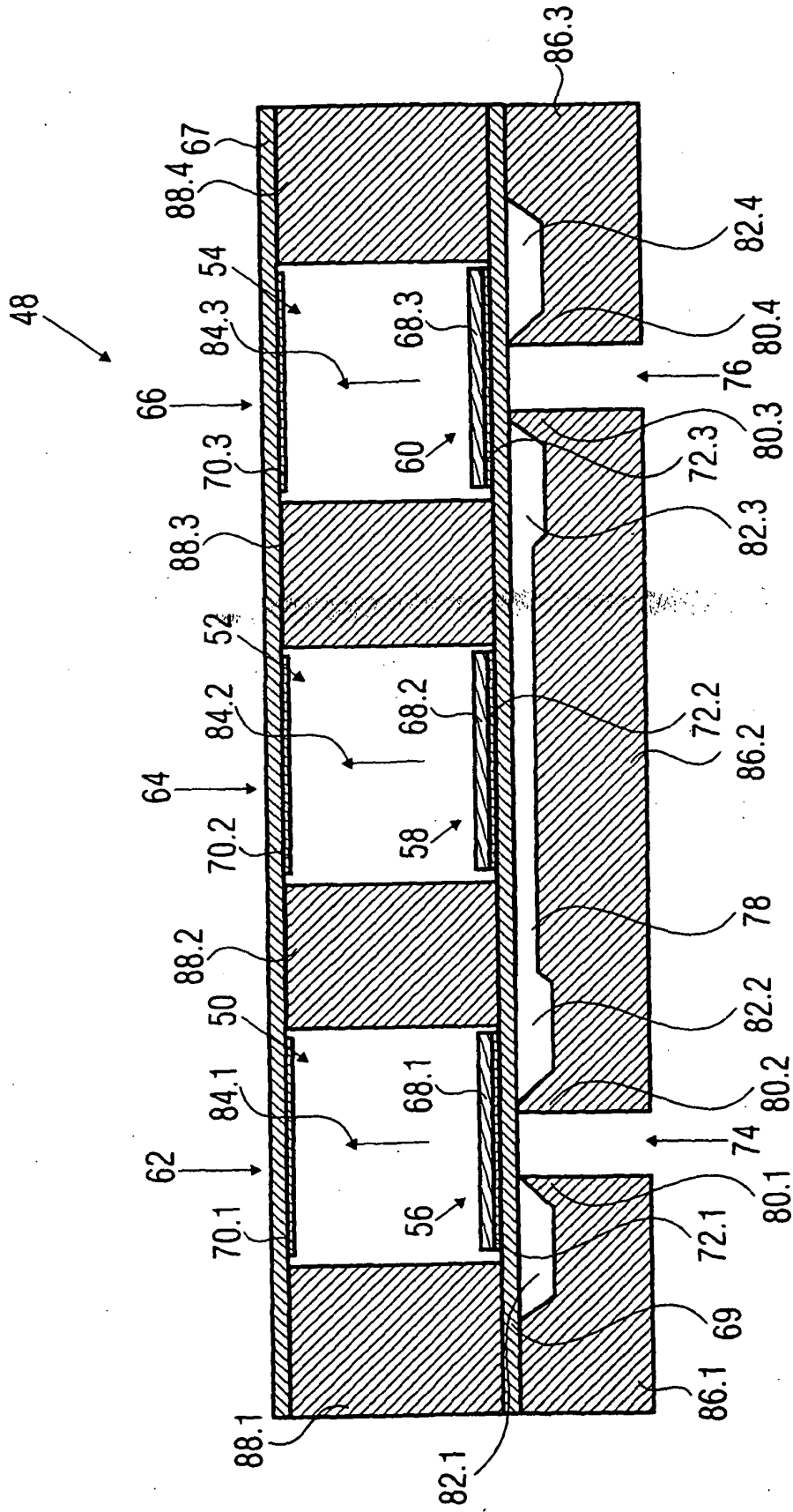


FIG 7

REFERENCES CITED IN THE DESCRIPTION

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