US 20110189027A1

(19) **United States**

(12) **Patent Application Publication**

Hansen et al.

(10) **Pub. No.: US 2011/0189027 A1**

(43) **Pub. Date: Aug. 4, 2011**

(54) **PUMP POWERED BY A POLYMER TRANSDUCER**

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(21) Appl. No.: **12/990,300**

(22) PCT Filed: **Apr. 30, 2009**

(86) PCT No.: **PCT/DK2009/000098**

§ 371 (c)(1), (2), (4) Date: **Apr. 26, 2011**

(30) **Foreign Application Priority Data**

Apr. 30, 2008 (DK) .... PA 2008 00619

Publication Classification

(51) **Int. Cl.**

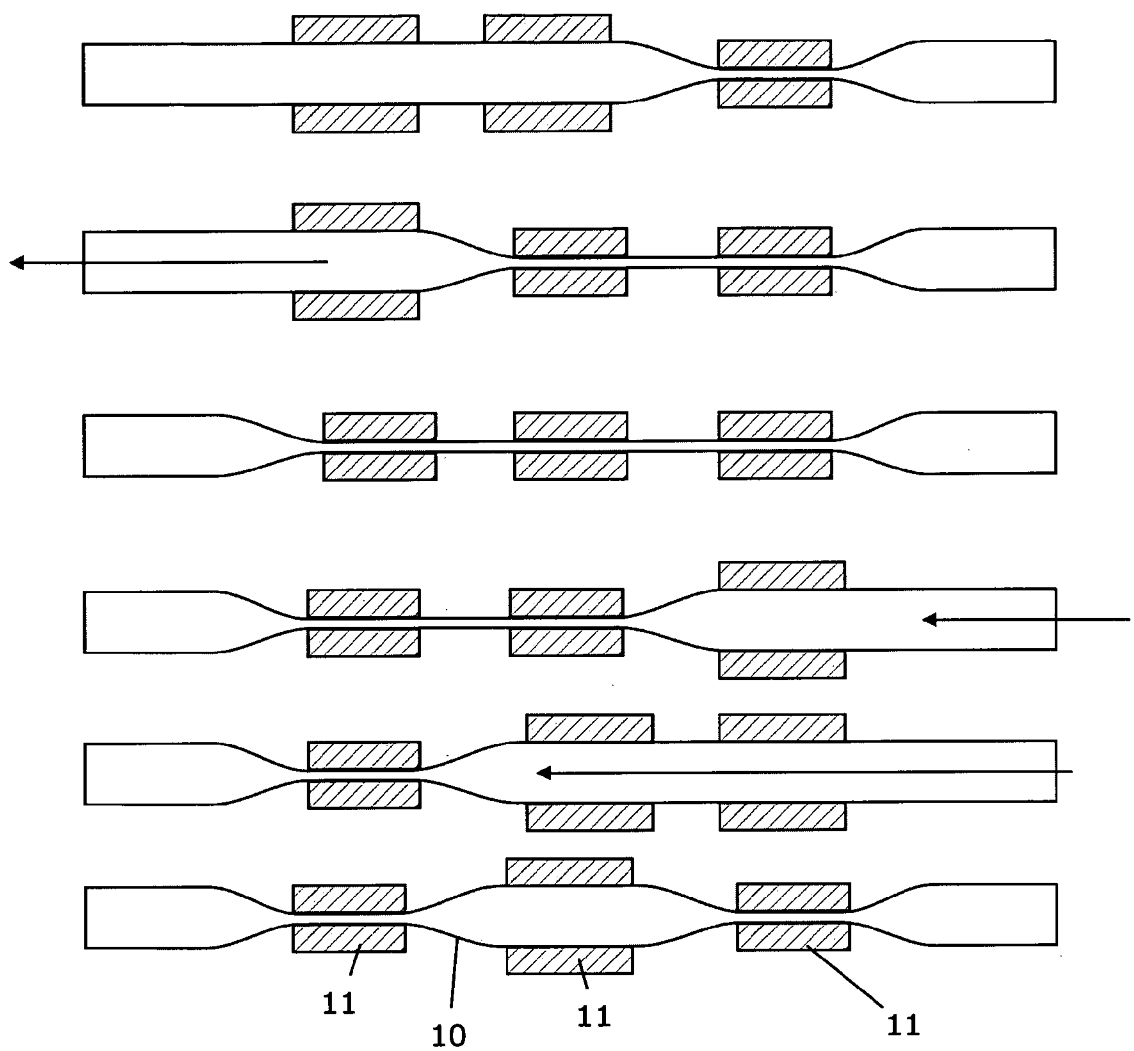
F04B 49/06 (2006.01)

F04B 43/00 (2006.01)

(52) **U.S. Cl.** **417/45**; 417/412

(57) **ABSTRACT**

The invention provides a pump with a transducer comprising a laminate with a film of a dielectric polymer material arranged between first and second layers of an electrically conductive material so that it is deflectable in response to an electrical field applied between the layers, wherein the laminate is arranged to cause a pumping action upon deflection of the film. The invention further provides a control system for a pump.



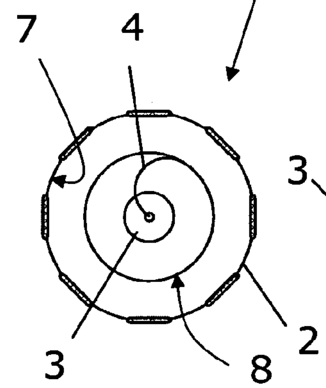


Fig. 1a

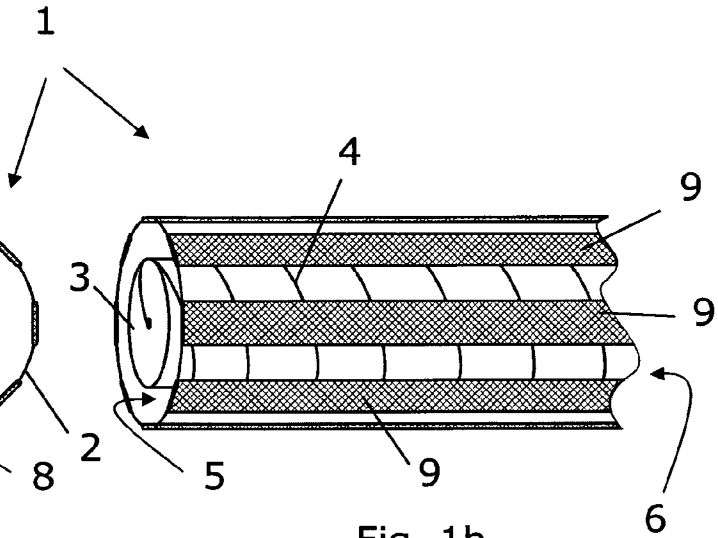


Fig. 1b

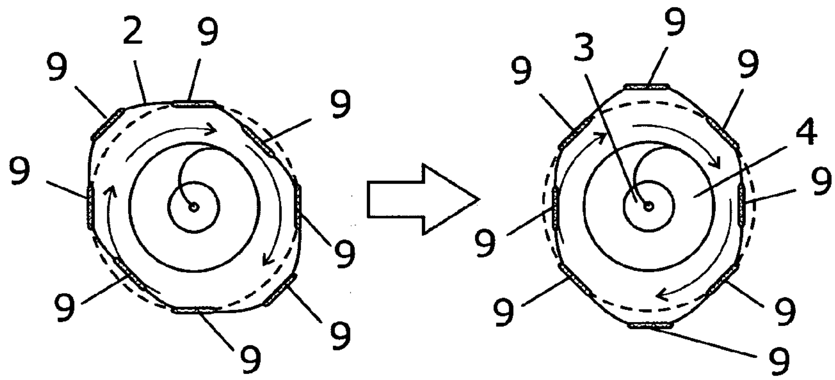


Fig. 1c

Fig. 1d

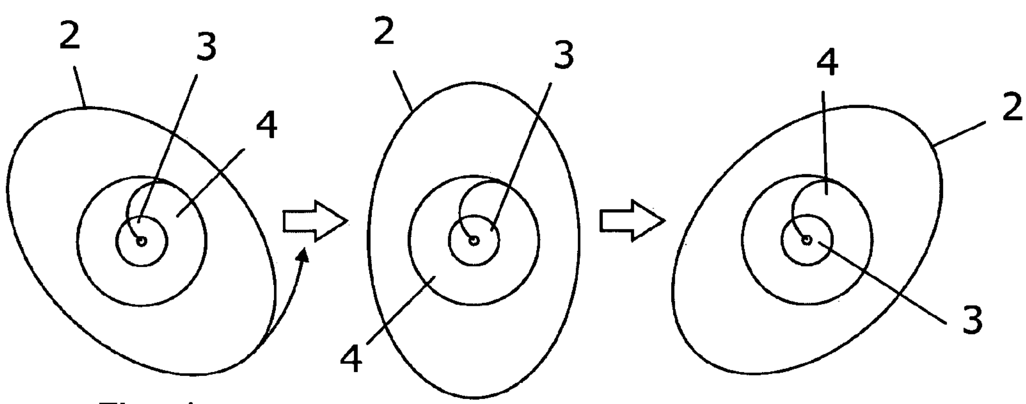


Fig. 1e

Fig. 1f

Fig. 1g

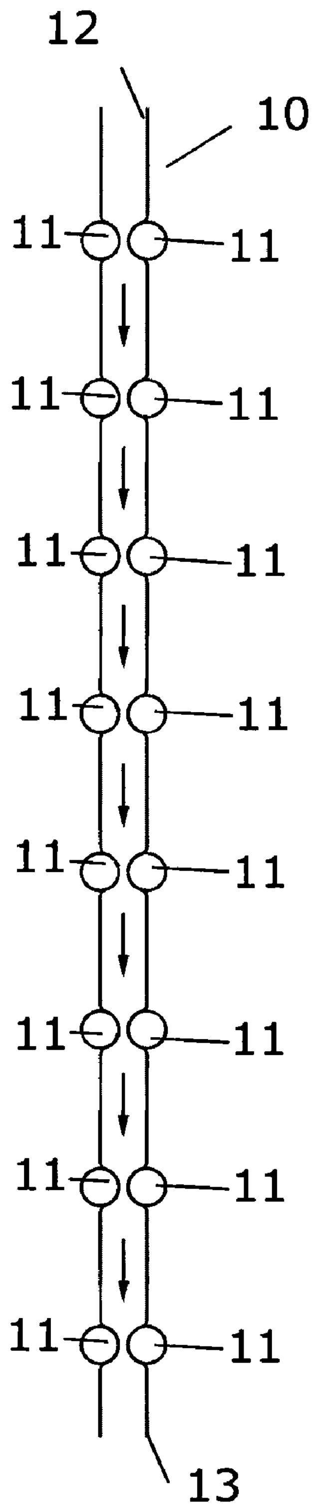


Fig. 2

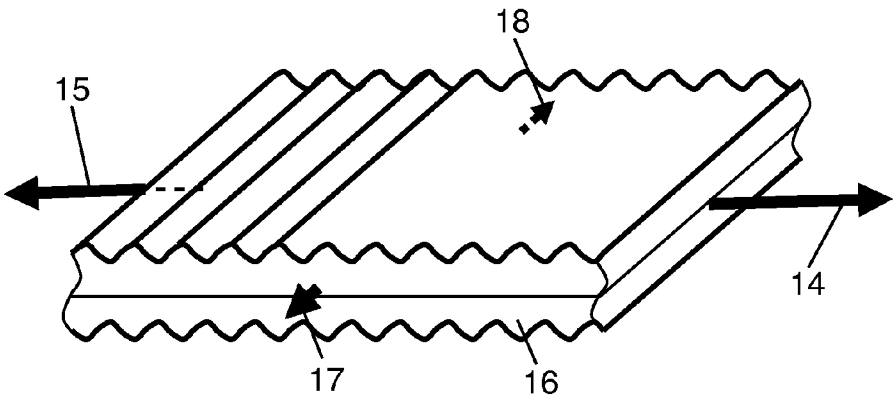


Fig. 3

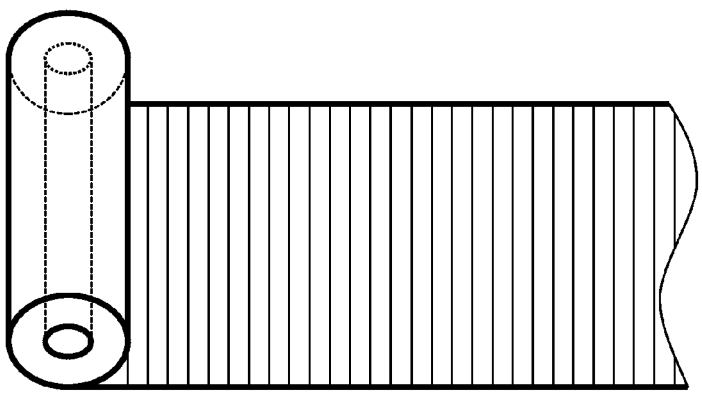


Fig. 4

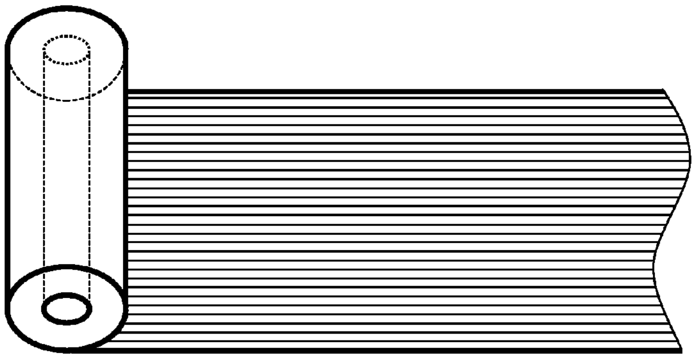


Fig. 5

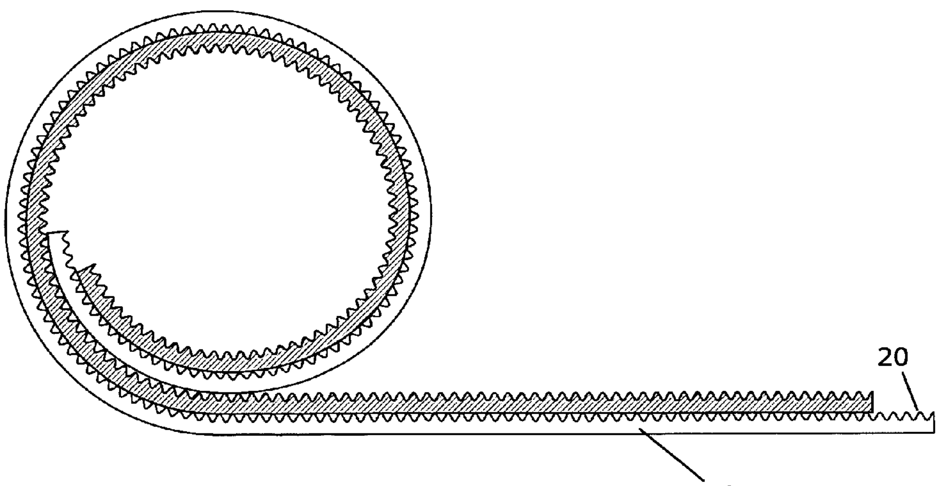


Fig. 6

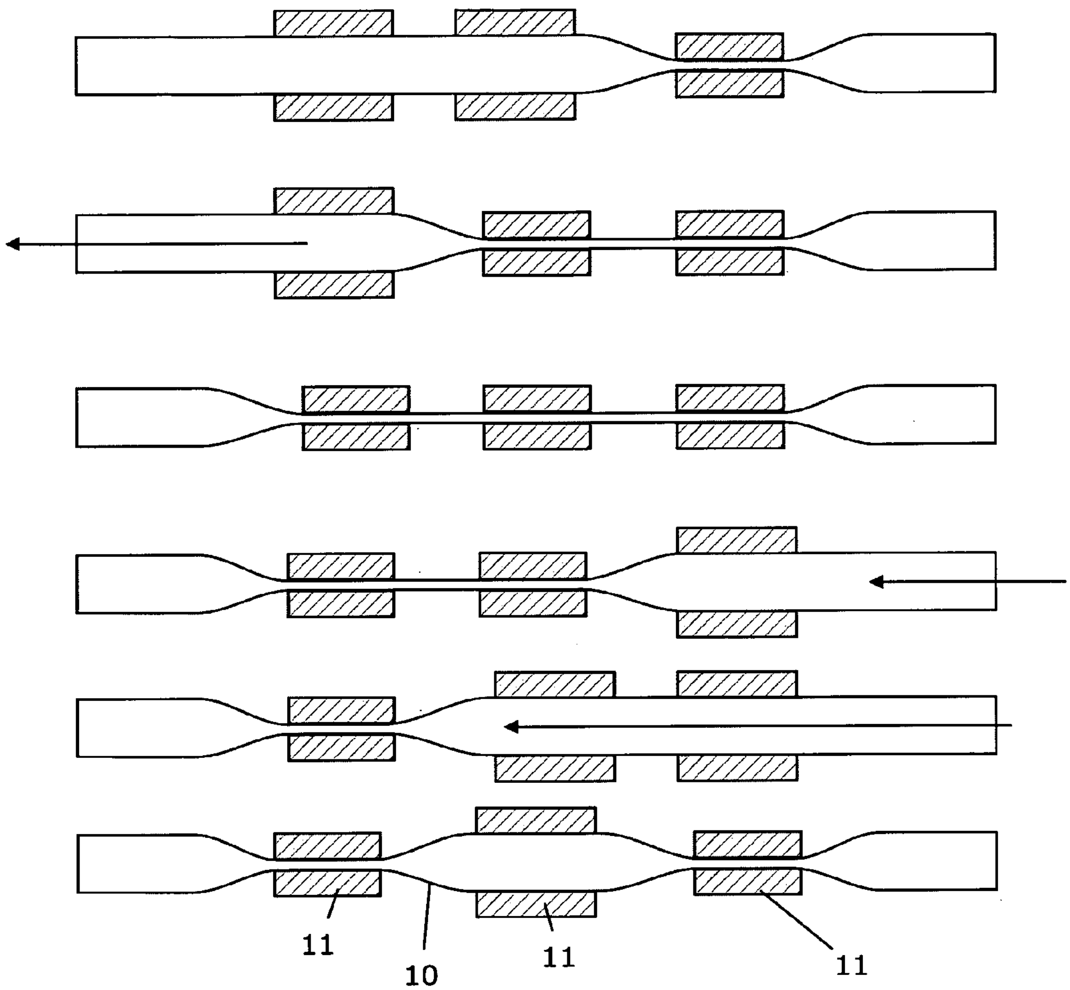


Fig. 7

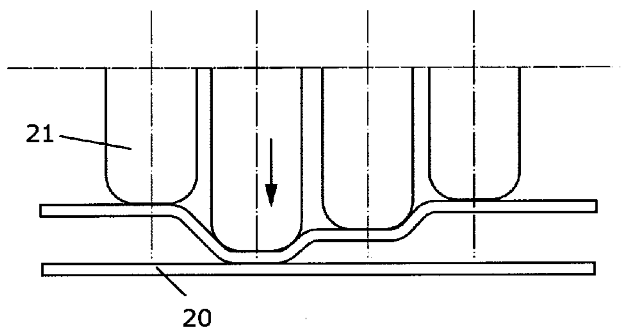


Fig. 8a

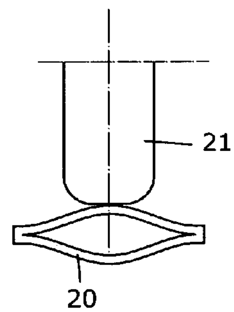


Fig. 8b

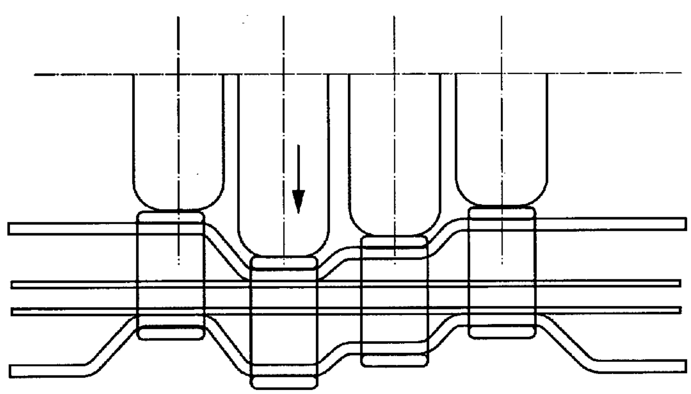


Fig. 8c

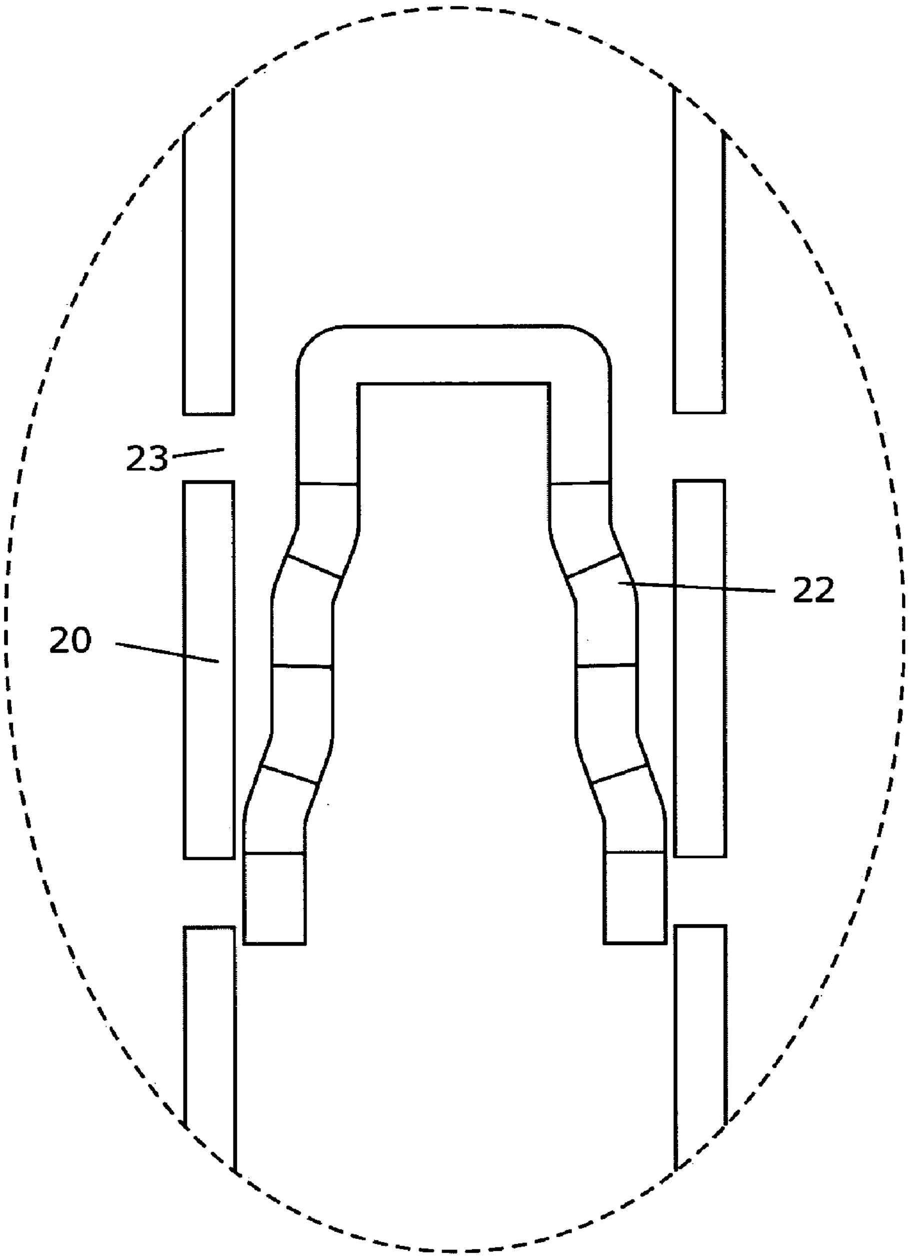


Fig. 9

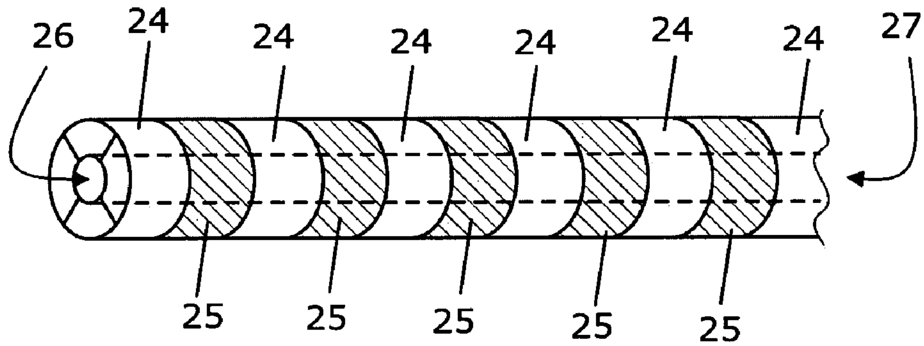


Fig. 10

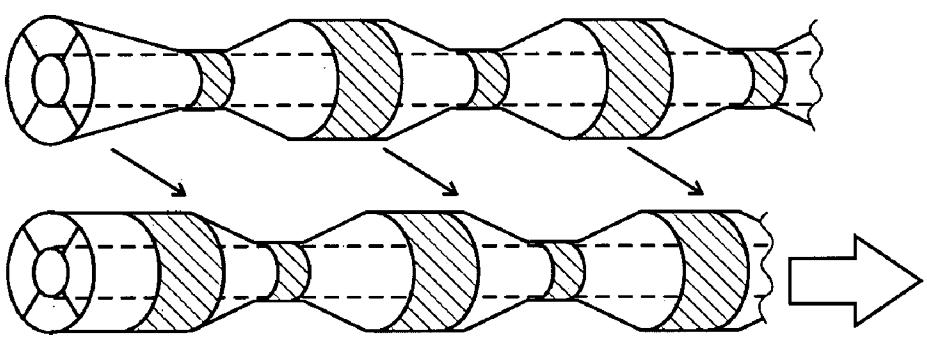


Fig. 11

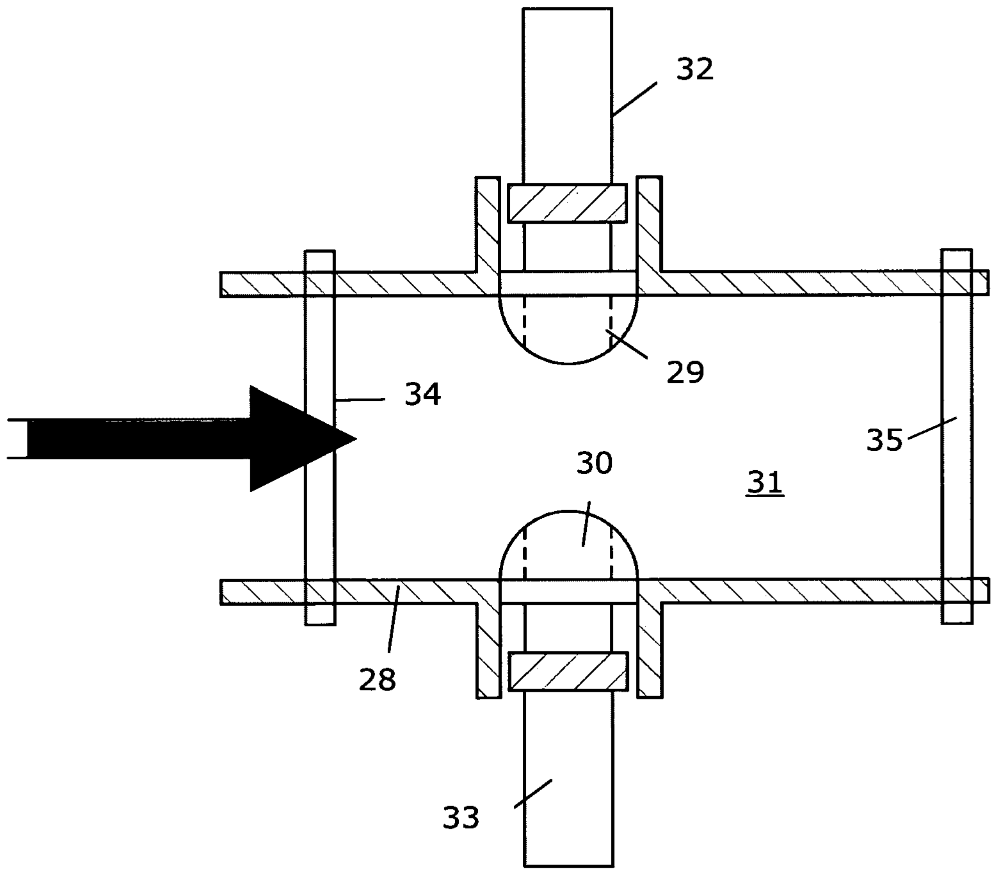


Fig. 12

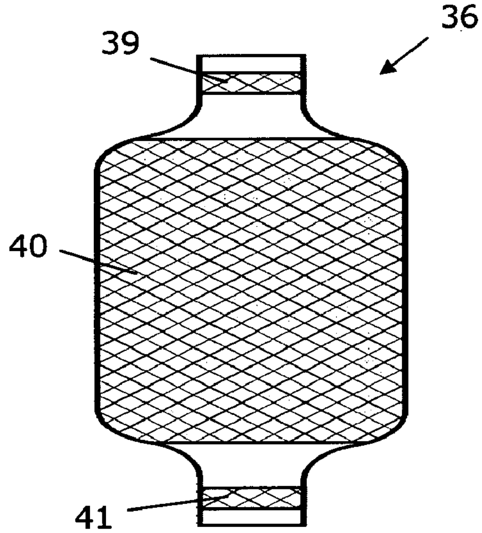


Fig. 13a

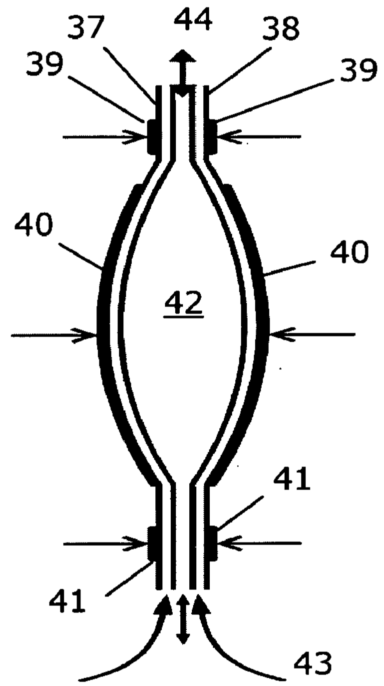


Fig. 13b

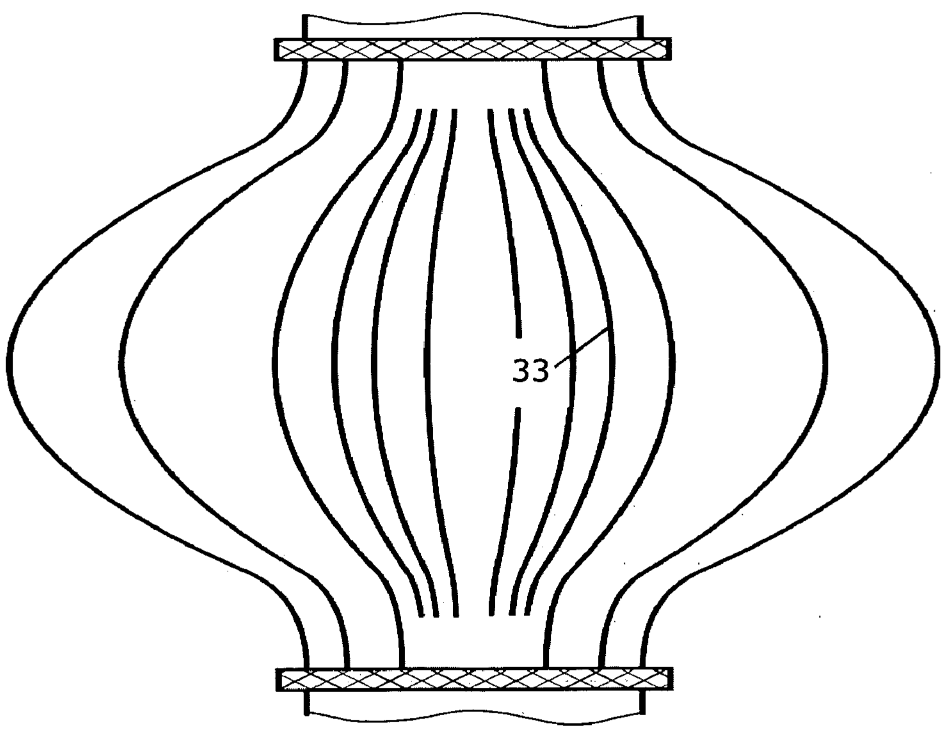


Fig. 13c

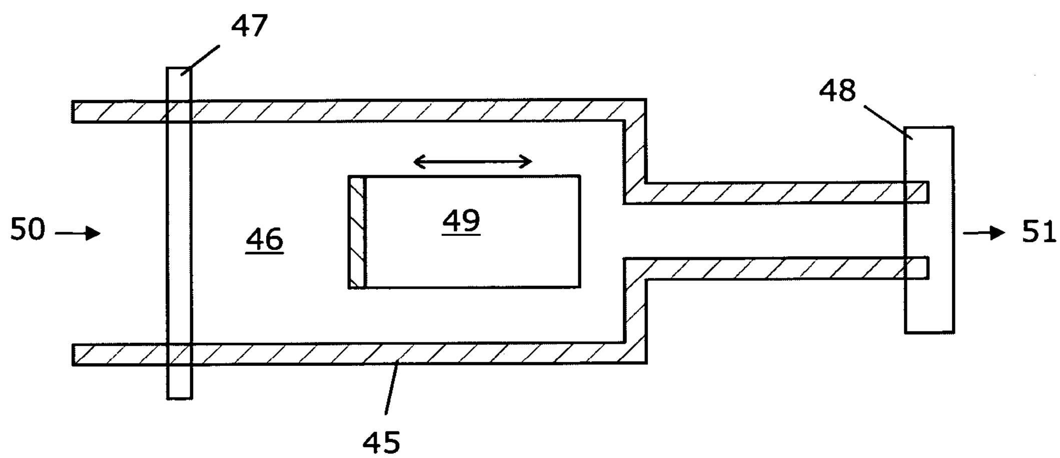
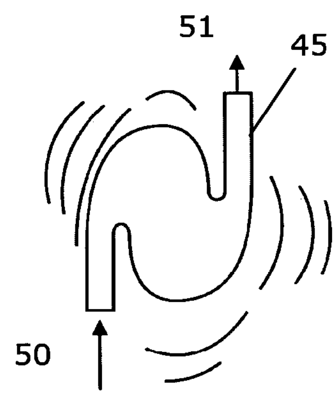


Fig. 14



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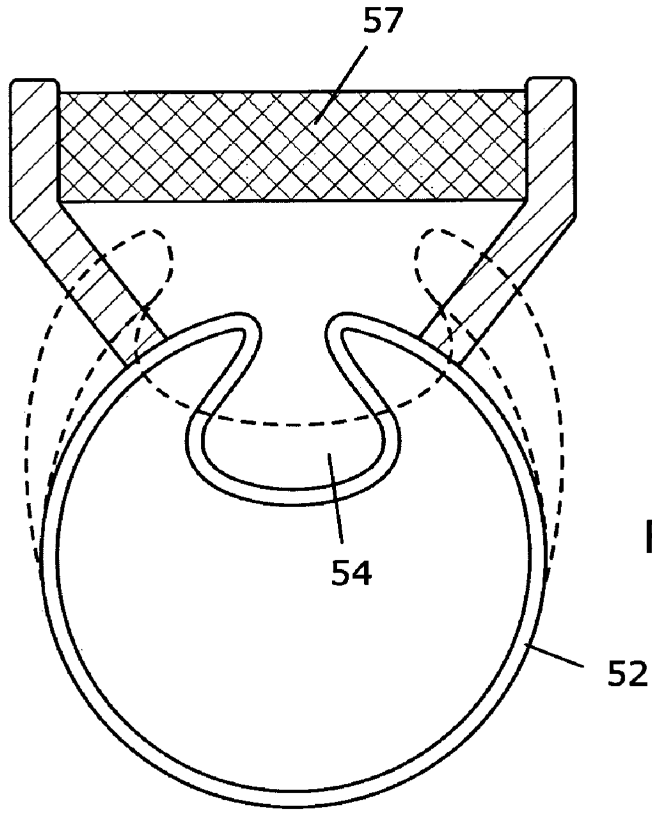

Fig. 16

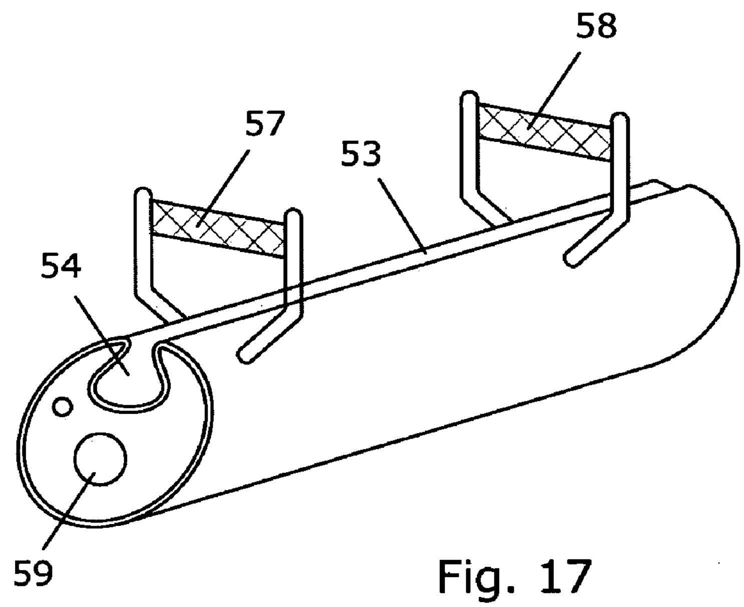

Fig. 17

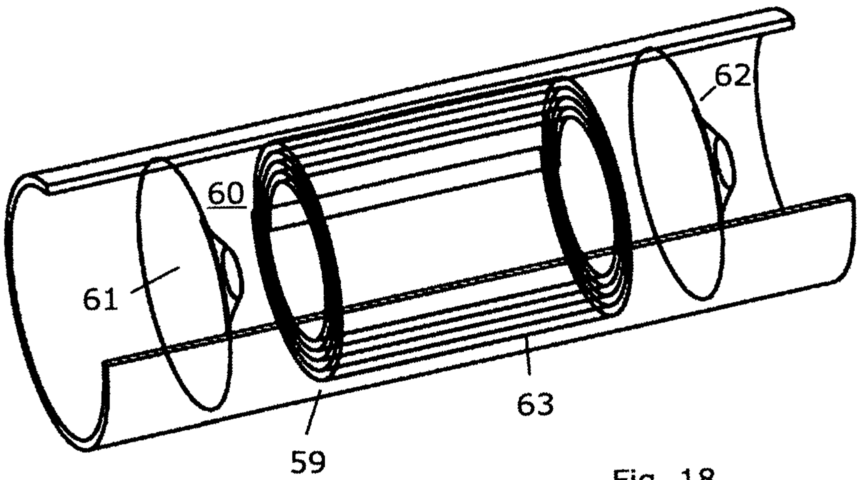

Fig. 18

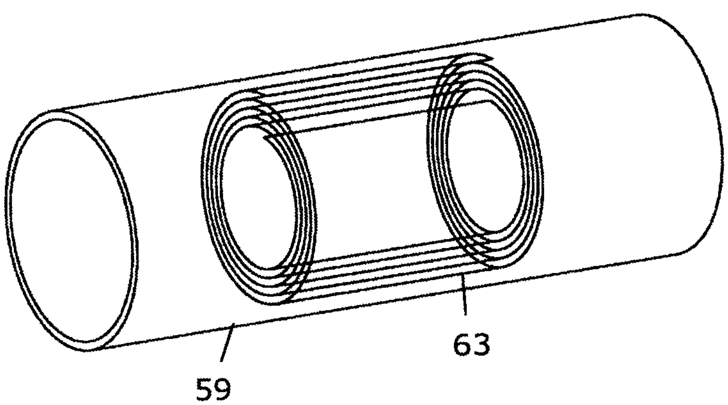

Fig. 19

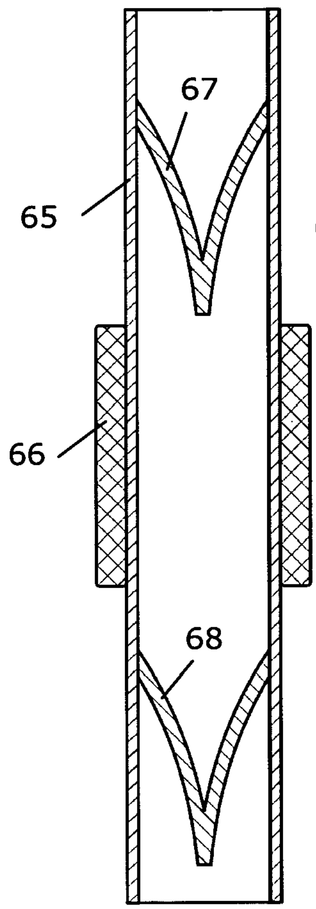

Fig. 20

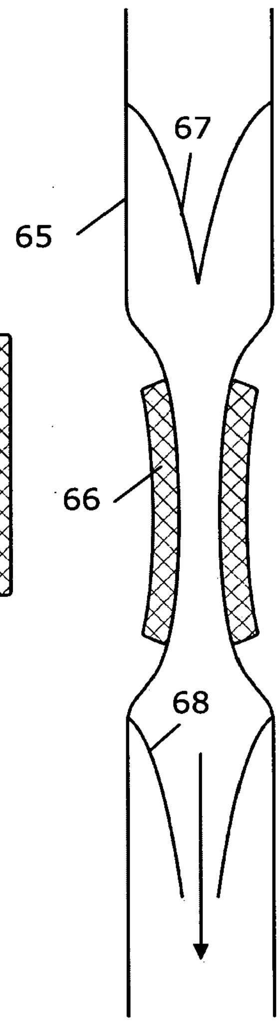

Fig. 21

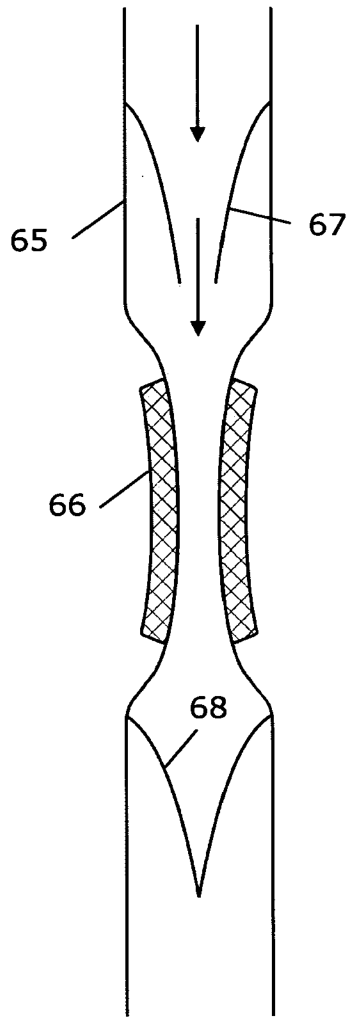

Fig. 22

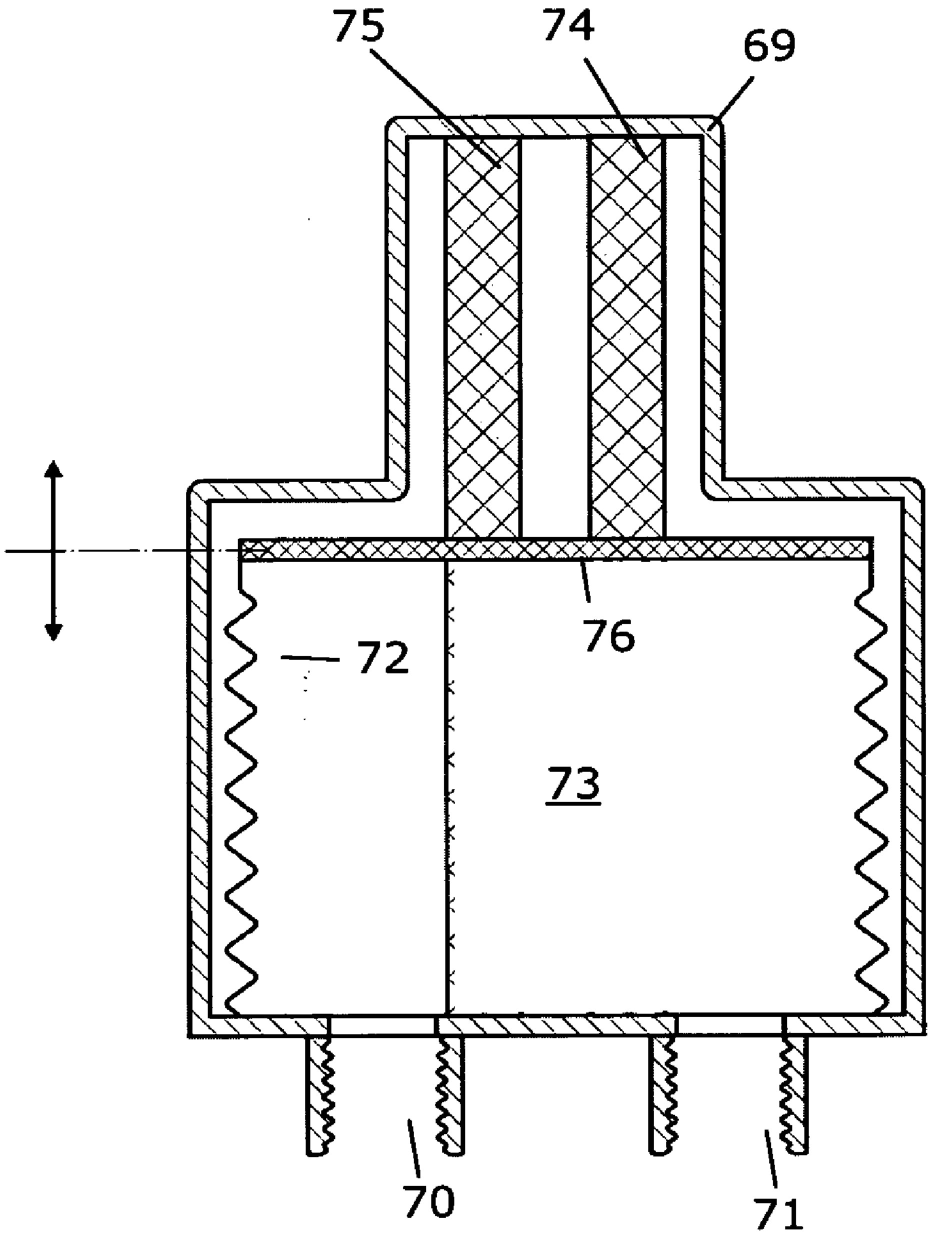

Fig. 23

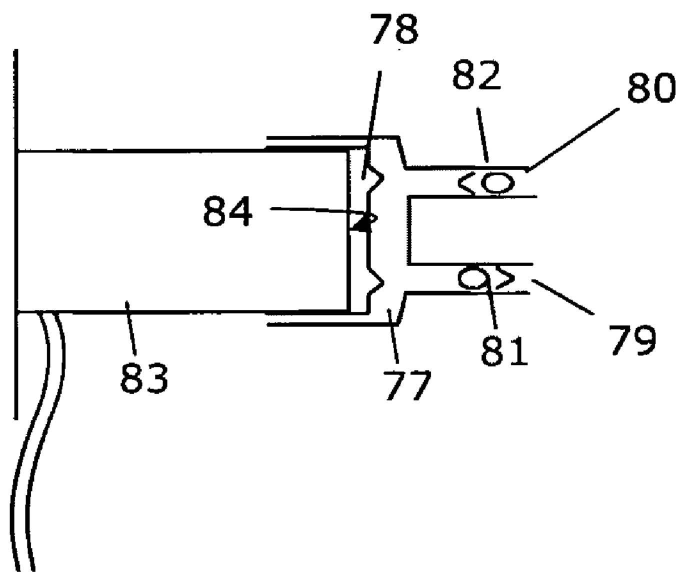

Fig. 24

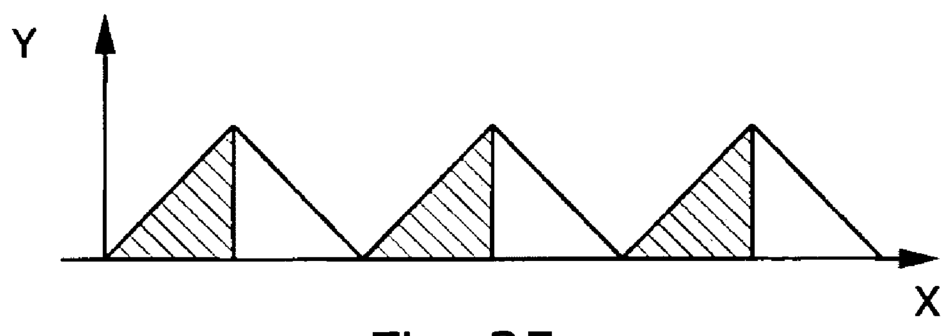

Fig. 25

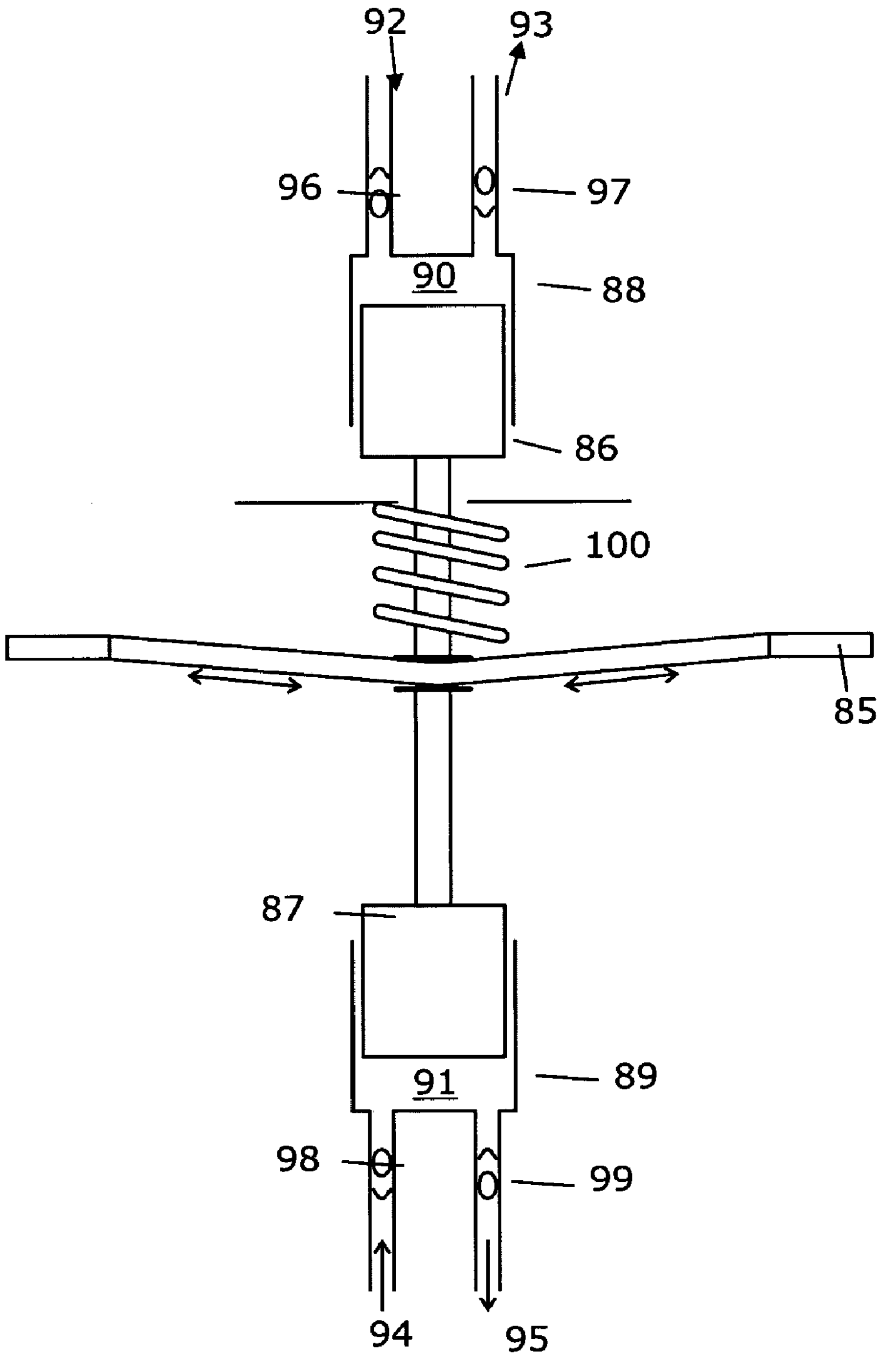

Fig. 26

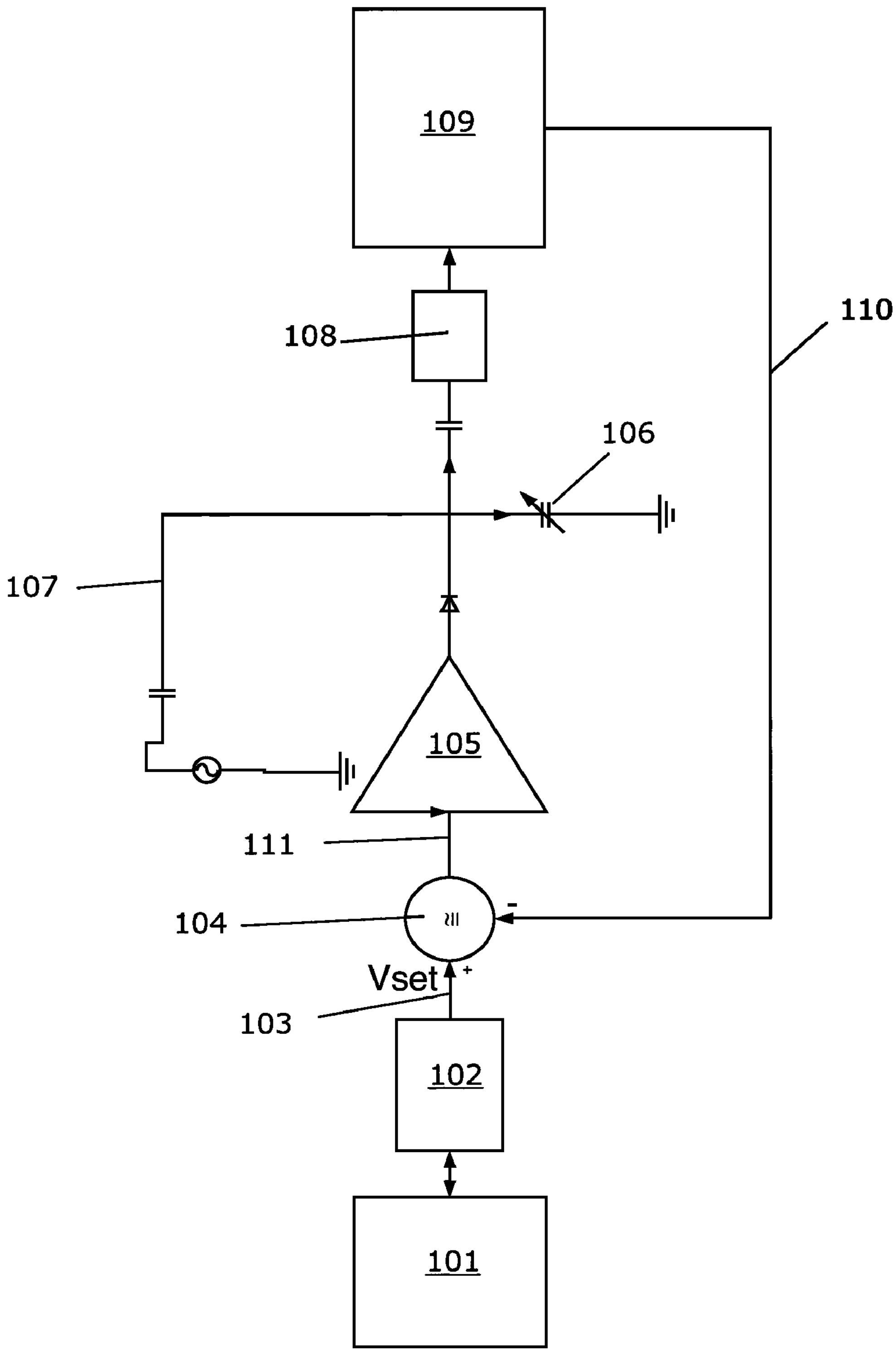

Fig. 27

PUMP POWERED BY A POLYMER TRANSDUCER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is entitled to the benefit of and incorporates by reference essential subject matter disclosed in International Patent Application No. PCT/DK2009/000098 filed on Apr. 30, 2009 and Danish Patent Application No. PA 2008 00619 filed on Apr. 30, 2008.

TECHNICAL FIELD

[0002] The present invention relates to a fluid pump for displacing a fluid medium from an inlet of the pump to an exit of the pump, the pump comprising a housing forming a path between the inlet and the exit, and a transducer arranged to cause a pumping action to move fluid through the path.

BACKGROUND OF THE INVENTION

[0003] Displacement pumps are used in many kinds of medical and non-medical appliances for pumping and optionally compressing a fluid medium. For example, pumps have been used to deliver all kinds of fluid, saline etc to treatment areas etc, pumps have been used for transporting blood from dialyses machines etc, and outside the medical sphere, pumps play an important role in numerous mechanical installations for transporting fluid, for mixing fluid and not least for compressing fluid, e.g. in combination with refrigeration systems.

[0004] In a traditional positive displacement pump, a piston is reciprocating in a cylinder, and by opening and closing inlet and outlet valves, alternately, a fluid is pumped and optionally compressed by the piston. The piston and cylinder are made from relatively inflexible metal materials, and to provide a good efficiency and long life of the piston pump, the piston and cylinder must be made with fine tolerances. Typically, a large portion of the manufacturing costs of such pumps are spent on the mechanical interaction between the piston, cylinder and other moving parts. One problem with the traditional piston pumps is that they may produce excessive noise, in particular if the reciprocating movement is generated by an eccentric element on a rotary drive shaft.

SUMMARY OF THE INVENTION

[0005] It is an object of the invention to provide a positive displacement pump in which the pumping activity is provided in an alternative way, and thus to provide a potentially more robust and cost efficient pump. It is a further object to provide a potentially more silent pump. Accordingly, the invention provides a pump wherein the transducer comprises a laminate with a film of a dielectric polymer material arranged between first and second layers of an electrically conductive material so that it is deflectable in response to an electrical field applied between the layers, wherein the laminate is arranged to cause the pumping action upon deflection of the film.

[0006] Since the pumping action is caused by deflection of a polymer material, the noise and the need for fine tolerances may be reduced considerably.

[0007] By a pumping action is meant that a fluid is moved from the inlet to the exit by the action. Typically the action involves the process of changing cyclically the volume of a chamber provided with check valves or similar valves which ensures a uni-directional flow of the fluid from the inlet to the exit through the chamber.

[0008] By transducer is hereby meant an element which is capable of converting electrical energy to mechanical energy and reciprocally of converting mechanical energy to electrical energy. This enables the use of the transducer as an actuator which works to move a fluid through the path when provided with an electrical field between the first and second layers of electrically conductive material, and/or the use of the transducer as a sensor which provides a change of an electrical characteristic, e.g. capacitance between the layers of electrically conductive material, upon a change in the flow conditions in the path. Accordingly, the transducer may provide two-way communication with a control system whereby the control system operates the transducer to work as an actuator for moving fluid through the path, and the transducer provides information to the control system for enabling e.g. a close loop control based on flow resistance or other characteristics measurable by deflection of the film of the transducer.

[0009] The housing may be provided in any kind of material, e.g. in a hard polymeric material, in metal such as brass or aluminium, or even in a soft polymeric material such as silicone etc. The pump may also include micro channels and may e.g. comprise a silicon wafer etc.

[0010] By deflect is herein meant to bend or to deform under influence of a pressure. In case of the film, the deflection is triggered by the pressure from the conductive layers under a force of attraction or repulsion from an electrical field applied between the conductive layers.

[0011] By laminate is here meant a product made by two or more layers of material. As an example, the laminate may comprise a material with dielectric properties—in the following for simplicity referred to as a dielectric material. The dielectric material may be a non conductive polymer or elastomer material. The electrically conductive material may form an electrode pattern on each side of the polymer or elastomer. The at least two kinds of material are bonded e.g. adhesively, by sintering, or simply arranged in contact with each other.

[0012] The dielectric material could be any material that can sustain an electric field without conducting an electric current, such as a material having a relative permittivity, $\in$, which is larger than or equal to 2. It could be a polymer, e.g. an elastomer, such as a silicone elastomer, such as a weak adhesive silicone or in general a material which has elastomer like characteristics with respect to elastic deformation. For example, Elastosil RT 625, Elastosil RT 622, Elastosil RT 601 all three from Wacker-Chemie could be used as a dielectric material.

[0013] In the present context the term 'dielectric material' should be interpreted in particular but not exclusively to mean a material having a relative permittivity, $\in_r$, which is larger than or equal to 2.

[0014] In the case that a dielectric material which is not an elastomer is used, it should be noted that the dielectric material should have elastomer-like properties, e.g. in terms of elasticity. Thus, the dielectric material should be deformable to such an extent that the composite is capable of deflecting and thereby pushing and/or pulling due to deformations of the dielectric material.

[0015] The film and the electrically conductive layers may have a relatively uniform thickness, e.g. with a largest thickness which is less than 110 percent of an average thickness of the film, and a smallest thickness which is at least 90 percent of an average thickness of the film. Correspondingly, the first electrically conductive layer may have a largest thickness which is less than 110 percent of an average thickness of the first electrically conductive layer, and a smallest thickness which is at least 90 percent of an average thickness of the first electrically conductive layer. In absolute terms, the electrically conductive layer may have a thickness in the range of 0.01 μm to 0.1 μm, such as in the range of 0.02 μm to 0.09 μm, such as in the range of 0.05 μm to 0.07 μm. Thus, the electrically conductive layer is preferably applied to the film in a very thin layer. This facilitates good performance and facilitates that the electrically conductive layer can follow the corrugated pattern of the surface of the film upon deflection.

[0016] The film may have a thickness between 10 μm and 200 μm, such as between 20 μm and 150 μm, such as between 30 μm and 100 μm, such as between 40 μm and 80 μm. In this context, the thickness of the film is defined as the shortest distance from a point on one surface of the film to an intermediate point located halfway between a crest and a trough on a corrugated surface of the film.

[0017] The electrically conductive layer may have a resistivity which is less than $10^{-2}\Omega\cdot$cm such as less than $10^{-4}\Omega\cdot$cm. By providing an electrically conductive layer having a very low resistivity the total resistance of the electrically conductive layer will not become excessive, even if a very long electrically conductive layer is used. Thereby, the response time for conversion between mechanical and electrical energy can be maintained at an acceptable level while allowing a large surface area of the composite, and thereby obtaining a large actuation force in the pump. In the prior art, it has not been possible to provide corrugated electrically conductive layers with sufficiently low electrical resistance, mainly because it was necessary to select the material for the prior art electrically conductive layer with due consideration to other properties of the material in order to provide the compliance. By the present invention it is therefore made possible to provide compliant electrically conductive layers from a material with a very low resistivity. This allows a large actuation force to be obtained while an acceptable response time of the transducer is maintained.

[0018] The electrically conductive layer may preferably be made from a metal or an electrically conductive alloy, e.g. from a metal selected from a group consisting of silver, gold and nickel. Alternatively other suitable metals or electrically conductive alloys may be chosen. Since metals and electrically conductive alloys normally have a very low resistivity, the advantages mentioned above are obtained by making the electrically conductive layer from metal or from any kind of electrically conductive material, e.g. with a modulus of elasticity which is higher than that of the dielectric material—i.e. the electrically conductive layer may have a higher stiffness in the elastic range than the dielectric material.

[0019] The dielectric material may have a resistivity which is larger than $10^{10}\Omega\cdot$cm. Preferably, the resistivity of the dielectric material is much higher than the resistivity of the electrically conductive layer, preferably at least 10^{14}-10^{18} times higher.

[0020] To facilitate increased compliance of the transducer in one direction, to facilitate an improved reaction time and therefore an improved performance and controllability of the pump, or potentially to provide an increased lifetime of the transducer, the surface pattern may comprise corrugations which render the length of the electrically conductive layer in a lengthwise direction longer than the length of the composite as such in the lengthwise direction. The corrugated shape of the electrically conductive layer thereby facilitates that the composite can be stretched in the lengthwise direction without having to stretch the electrically conductive layer in that direction, but merely by evening out the corrugated shape of the electrically conductive layer. According to the invention, the corrugated shape of the electrically conductive layer may be a replica of the surface pattern of the film.

[0021] The corrugated pattern may comprise waves forming crests and troughs extending in one common direction, the waves defining an anisotropic characteristic facilitating movement in a direction which is perpendicular to the common direction. According to this embodiment, the crests and troughs resemble standing waves with essentially parallel wave fronts. However, the waves are not necessarily sinusoidal, but could have any suitable shape as long as crests and troughs are defined. According to this embodiment a crest (or a trough) will define substantially linear contour-lines, i.e. lines along a portion of the corrugation with equal height relative to the composite in general. This at least substantially linear line will be at least substantially parallel to similar contour lines formed by other crest and troughs, and the directions of the at least substantially linear lines define the common direction. The common direction defined in this manner has the consequence that anisotropy occurs, and that movement of the composite in a direction perpendicular to the common direction is facilitated, i.e. the composite, or at least an electrically conductive layer arranged on the corrugated surface, is compliant in a direction perpendicular to the common direction.

[0022] The variations of the raised and depressed surface portions may be relatively macroscopic and easily detected by the naked eye of a human being, and they may be the result of a deliberate act by the manufacturer. The periodic variations may include marks or imprints caused by one or more joints formed on a roller used for manufacturing the film. Alternatively or additionally, the periodic variations may occur on a substantially microscopic scale. In this case, the periodic variations may be of the order of magnitude of manufacturing tolerances of the tool, such as a roller, used during manufacture of the film. Even if it is intended and attempted to provide a perfect roller, having a perfect pattern, there will in practice always be small variations in the pattern defined by the roller due to manufacturing tolerances. Regardless of how small such variations are, they will cause periodical variations to occur on a film being produced by repeatedly using the roller. In this way the film may have two kinds of periodic variations, a first being the imprinted surface pattern of structures such as corrugations being shaped perpendicular to the film, this could be called the sub-pattern of variations, and further due to the repeated imprinting of the same roller or a negative plate for imprinting, a super-pattern arises of repeated sub-patterns.

[0023] Manufacturing the film by repeatedly using the same shape defining element, allows the film to be manufactured in any desired length, merely by using the shape defining element a number of times which results in the desired length. Thereby the size of the composite along a length direction is not limited by the dimensions of the tools used for the manufacturing process. This is very advantageous. The film may be produced and stored on a roll, and afterwards, the film may be unrolled while the electrically conductive layer or layers are applied to the film.

[0024] Each wave in the corrugated surface may define a height being a shortest distance between a crest and neighbouring troughs. In this case, each wave may define a largest wave having a height of at most 110 percent of an average wave height, and/or each wave may define a smallest wave having a height of at least 90 percent of an average wave height. According to this embodiment, variations in the height of the waves are very small and a very uniform pattern is obtained.

[0025] According to one embodiment, an average wave height of the waves may be between ⅓ μm and 20 μm, such as between 1 μm and 15 μm, such as between 2 μm and 10 μm, such as between 4 μm and 8 μm.

[0026] Alternatively or additionally, the waves may have a wavelength defined as the shortest distance between two crests, and the ratio between an average height of the waves and an average wavelength may be between 1/30 and 2, such as between 1/20 and 1.5, such as between 1/10 and 1.

[0027] The waves may have an average wavelength in the range of 1 μm to 20 μm, such as in the range of 2 μm to 15 μm, such as in the range of 5 μm to 10 μm.

[0028] A ratio between an average height of the waves and an average thickness of the film may be between 1/50 and 1/2, such as between 1/40 and 1/3, such as between 1/30 and 1/4, such as between 1/20 and 1/5.

[0029] The second electrically conductive layer may, like the first layer, have a surface pattern, e.g. including a corrugated shape which could be provided as a replica of a surface pattern of the film. Alternatively, the second electrically conductive layer is substantially flat. If the second electrically conductive layer is flat, the composite will only have compliance on one of its two surfaces while the second electrically conductive layer tends to prevent elongation of the other surface. This provides a composite which bends when an electrical potential is applied across the two electrically conductive layers.

[0030] One way of making the laminate is by combining several composites into a multilayer composite with a laminated structure. Each composite layer may comprise:

- **[0031]** a film made of a dielectric material and having a front surface and rear surface, the front surface comprising a surface pattern of raised and depressed surface portions, and
- **[0032]** a first electrically conductive layer being deposited onto the surface pattern, the electrically conductive layer having a corrugated shape which is formed by the surface pattern of the film.

[0033] In this structure, an electrode group structure may be defined, such that every second electrically conductive layer becomes an electrode of a first group and every each intermediate electrically conductive layer becomes an electrode of a second group of electrodes. A potential difference between the electrodes of the two groups will cause deformation of the film layers located there between, and the composite is therefore electroactive. In such a layered configuration, a last layer will remain inactive. Accordingly, a multilayer composite with three layers comprises 2 active layers, a multilayer composite with 10 layers comprises 9 active layers, etc.

[0034] According to one embodiment, the raised and depressed surface portions of the surface pattern of the film of each composite layer may have a shape and/or a size which varies periodically along at least one direction of the front surface. This has already been explained above.

[0035] If the electrically conductive layers are deposited on front surfaces of the films, it may be an advantage to arrange the layers with the rear surfaces towards each other. In this way, the multilayer composite becomes less vulnerable to faults in the film. If the film in one layer has a defect which enables short circuiting of electrodes on opposite surfaces thereof, it would be very unlikely if the layer which is arranged with its rear surface against the film in question has a defect at the same location. In other words, at least one of the two films provides electrical separation of the two electrically conductive layers.

[0036] The multilayer composite can be made by arranging the composite layers in a stack and by applying an electrical potential difference between each adjacent electrically conductive layer in the stack so that the layers are biased towards each other while they are simultaneously flattened out. Due to the physical or characteristic properties of the film, the above method may bond the layers together. As an alternative or in addition, the layers may be bonded by an adhesive arranged between each layer. The adhesive should preferably be selected not to dampen the compliance of the multilayer structure. Accordingly, it may be preferred to select the same material for the film and adhesive, or at least to select an adhesive with a modulus of elasticity being less than the modulus of elasticity of the film.

[0037] The composite layers in the multilayer composite should preferably be identical to ensure a homogeneous deformation of the multilayer composite throughout all layers, when an electrical field is applied. Furthermore, it may be an advantage to provide the corrugated pattern of each layer either in such a way that wave crests of one layer are adjacent to wave crests of the adjacent layer or in such a way that wave crests of one layer are adjacent to troughs of the adjacent layer.

[0038] In one embodiment, the pump is based deformation and thus volume change of a section of the path. This could e.g. be combined with valves on opposite sides of that section of the path. As an example, check valves such as flapper valves may be arranged to provide uni-directional flow, i.e. flow in one direction through the path so that repeated volume change of the section causes a flow of fluid through the path. The section of the path may be provided in a body of an elastically deformable material, e.g. a hose of a silicone material, a bellow of a rubber material or in general of a body having a flexibly deformable wall. The transducer could be arranged to deflect the body upon deflection of the film whereby the path changes volume. The transducer could be arranged either outside the path, inside the path, or it may form part of the body of an elastically deformable material.

[0039] The transducer may be provided with at least three independent active portions which can be activated independently and each portion being arranged to enable deformation of the body at different locations along the path. In this way, a first portion being upstream the flow direction may firstly be activated to squeeze the body and close the path at an upstream first location. Subsequently, a second portion located between the other two portions could be activated while the first portion prevents backflow in the path. The deformation of the body caused by the second portion will press fluid in the path in the downstream direction. Subsequently, the last, third, portion could be activated to prevent backflow in the path while the first and second portions are released. For this purpose, a control system may be provided which is adapted to activate the portions in a predetermined sequence.

[0040] The body may have a build-in tension which presses the path towards a neutral configuration from which it can be pushed against the build-in tension towards an activated configuration by the transducer. The neutral configuration may be a configuration where the flow resistance in the path is either lower or higher than in the activated configuration.

[0041] Alternatively, or additionally, the shape of the body is held by the transducer which actively moves the body between different deformed states without any support from the body itself. As an example, the body may comprise a bag of a flexible foil material, e.g. a plastic bag. In one embodiment, the body is constituted at least partly by the laminate itself. For this purpose, the already mentioned composite layers from at least two of which the laminate is made may form a front and a rear surface of a bag which constitutes the body.

[0042] According to a preferred embodiment the laminate may have been rolled to form a coiled pattern of dielectric material and electrodes. In the following description, a transducer with a rolled laminate is referred to as a rolled transducer. In the present context the term 'coiled pattern' should be interpreted to mean that a cross section of the transducer exhibits a flat, spiral-like pattern of electrodes and dielectric material. Thus, the rolled transducer resembles a Swiss roll or part of a Swiss roll.

[0043] According to this embodiment, the transducer is preferably designed by rolling or spooling a laminate of potentially unlimited length in a thick-walled column-like self-supporting structure, the self-supporting structure being sufficiently strong to prevent buckling during normal operation of the pump.

[0044] The laminate may be rolled around an axially extending axis to form a transducer of an elongated shape extending in the axial direction.

[0045] The rolled laminate may form a tubular member. This should be understood in such a manner that the rolled laminate defines an outer surface and an inner surface facing a hollow interior cavity of the rolled laminate. Thus, the transducer in this case forms a 'tube', but the 'tube' may have any suitable shape.

[0046] In the case that the rolled transducer forms a tubular member, the rolled laminate may form a member of a substantially cylindrical or cylindrical-like shape. In the present context the term 'cylindrical-like shape' should be interpreted to mean a shape defining a longitudinal axis, and where a cross section of the member along a plane which is at least substantially perpendicular to the longitudinal axis will have a size and a shape which is at least substantially independent of the position along the longitudinal axis. Thus, according to this embodiment the cross section may have an at least substantially circular shape, thereby defining a tubular member of a substantially cylindrical shape. However, it is preferred that the cross section has a non-circular shape, such as an elliptical shape, an oval shape, a rectangular shape, or even an unsymmetrical shape. A non-circular shape is preferred because it is desired to change the cross sectional area of the transducer during operation, while maintaining an at least substantially constant circumference of the cross section. In the case that the cross section has a circular shape this is not possible, since a circular shape with a constant circumference is not able to change its area. Accordingly, a non-circular shape is preferred.

[0047] The rolled transducer may define a cross sectional area, A, being the area of the part of the cross section of the rolled transducer where the material forming the rolled transducer is positioned, and A may be within the range 10 mm^2 to 20000 mm^2, such as within the range 50 mm^2 to 2000 mm^2, such as within the range 75 mm^2 to 1500 mm^2, such as within the range 100 mm^2 to 1000 mm^2, such as within the range 200 mm^2 to 700 mm^2. Thus, A may be regarded as the size of the part of the total cross sectional area of the rolled transducer, which is 'occupied' by the transducer. In other words, A is the cross sectional area which is delimited on one side by the outer surface and on the other side by the inner surface facing the hollow cavity of the rolled structure.

[0048] The rolled laminate may define a radius of gyration, r_g, given by

$$r_g = \sqrt{\frac{I}{A}},$$

where I is the area moment of inertia of the rolled transducer, and r_g may be within the range 5 mm to 100 mm, such as within the range 10 mm to 75 mm, such as within the range 25 mm to 50 mm. The radius of gyration, r_g, reflects a distance from a centre axis running along the longitudinal axis of the tubular member which, if the entire cross section of the rolled transducer was located at that distance from the centre axis, it would result in the same moment of inertia, I.

[0049] Furthermore, the rolled laminate may define a slenderness ratio, λ, given by $\lambda=L/r_g$, where L is an axial length of the rolled laminate, and A may be smaller than 20, such as smaller than 10. Thus, the slenderness ratio, λ, reflects the ratio between the axial length of the rolled laminate and the radius defined above. Accordingly, if λ is high the axial length is large as compared to the radius, and the rolled laminate will thereby appear to be a 'slender' object. On the other hand, if λ is low the length is small as compared to the radius, and the rolled transducer will thereby appear to be a 'fat' object, hence the term 'slenderness ratio'. An object having a low slenderness ratio tends to exhibit more stiffness than an object having a high slenderness ratio. Accordingly, in a rolled laminate having a low slenderness ratio buckling during actuation is avoided, or at least reduced considerably.

[0050] The rolled laminate may define a wall thickness, t, and the ratio t/r_g may be within the range 1/1000 to 2, such as within the range 1/500-1, such as within the range 1/300-2/3. This ratio reflects how thin or thick the wall defined by the rolled laminate is as compared to the total size of the rolled laminate. If the ratio is high the wall thickness is large, and the hollow cavity defined by the rolled transducer is relatively small. On the other hand, if the ratio is low the wall thickness is small, and the hollow cavity defined by the rolled laminate is relatively large.

[0051] Alternatively or additionally, the rolled laminate may have a wall thickness, t, and may comprise a number of windings, n, being in the range of 5 to 100 windings per mm wall thickness, such as in the range 10 to 50 windings per mm wall thickness. The larger this number is, the thinner the unrolled laminate has to be. A large number of windings of a thin film allows a given actuation force to be achieved with a lower potential difference between the electrodes as compared to similar transducers having a smaller number of windings of a thicker film, i.e. having the same or a similar cross sectional area. This is a great advantage.

[0052] The mechanical and electrostatic properties of an electroactive web are used as a basis to estimate actuator force per unit area and stroke. Rolled laminates as described above are made by rolling/spooling very thin composite layers, e.g. having a thickness within the micrometers range. A typical transducer of this type can be made of laminate which is wound in thousands of windings.

[0053] When activated, direct/push transducers convert electrical energy into mechanical energy. Part of this energy is stored in the form of potential energy in the transducer material and is available again for use when the transducer is discharged. The remaining part of mechanical energy is effectively available for actuation. Complete conversion of this remaining part of the mechanical energy into actuation energy is only possible if the transducer structure is reinforced against mechanical instabilities, such as well known buckling due to axial compression. This can be done by reinforcing the cross sectional area of the transducer on one hand and then optimising the length of the transducer according to Euler's theory.

[0054] The optimisation process starts by defining the level of force required for a given pump. Then based on the actuator force per unit area, it is possible to estimate the necessary cross sectional area to reach that level of force.

[0055] Stabilisation of the transducer against any mechanical instability requires reinforcing its cross section by increasing its area moment of inertia of the cross section, I. Low values of I result in less stable structures and high values of I result in very stable structures against buckling. The design parameter for reinforcing the structure is the radius of gyration

$$r_g \left(r_g = \sqrt{\frac{I}{A}} \right)$$

which relates cross section, A, and area moment of inertia, I. Low values of r_g result in less stable transducer structures and high values of r_g result in highly stable transducer structures. After having defined optimum ranges for both area, A, and radius of gyration, r_g, it is possible to define the optimum range for the rolled transducer wall thickness, t, with respect to r_g in the form of t/r_g. Area, A, radius, r_g, and wall thickness, t, are the design parameters for reinforcing the transducer cross section for maximum stability. Low values of t/r_g result in highly stable transducer structures and high values of t/r_g result in less stable transducer structures.

[0056] Once the ranges of the cross section parameters have been determined, it is necessary to estimate the maximum length, L, of the transducer, for which buckling by axial compression does not occur for the required level of force. Slenderness ratio, λ, as defined above, is the commonly used parameter in relation with Euler's theory. Low values of λ result in highly stable transducer structures and high values of λ result in less stable transducer structures against buckling.

[0057] Once all design parameters for the optimum working direct transducer have been determined, it is possible to estimate the total number of windings that are necessary to build the transducer based on the transducer wall thickness, t, and the number of windings per millimeter, n, for a given electroactive web with a specific thickness in the micrometer range.

[0058] The rolled transducer may comprise a centre rod arranged in such a manner that the transducer is rolled around the centre rod, the centre rod having a modulus of elasticity which is lower than a modulus of elasticity of the dielectric material. According to this embodiment the hollow cavity defined by the tubular member may be filled by the centre rod, or the centre rod may be hollow, i.e. it may have a tubular structure. The centre rod may support the rolled transducer. However, it is important that the modulus of elasticity of the centre rod is lower than the modulus of elasticity of the dielectric material in order to prevent that the centre rod inhibits the function of the transducer.

[0059] Alternatively or additionally, the rolled transducer may comprise a centre rod arranged in such a manner that the transducer is rolled around the centre rod, and the centre rod may have an outer surface abutting the rolled transducer, said outer surface having a friction which allows the rolled transducer to slide along said outer surface during actuation of the transducer. The centre rod could, in this case, e.g. be a spring. Since the rolled transducer is allowed to slide along the outer surface of the centre rod, the presence of the centre rod will not inhibit elongation of the transducer along a longitudinal direction defined by the centre rod, and the operation of the transducer will thereby not be inhibited by the presence of the centre rod due to the low friction characteristics of the centre rod.

[0060] The transducer which comprises a rolled laminate may have an area moment of inertia of the cross section which is at least 50 times an area moment of inertia of the cross section of an un-rolled transducer, such as at least 75 times, such as at least 100 times. According to the present invention, this increased area moment of inertia is preferably obtained by rolling the transducer with a sufficient number of windings to achieve the desired area moment of inertia of the rolled structure. Thus, even though the unrolled transducer is preferably very thin, and therefore must be expected to have a very low area moment of inertia, a desired area moment of inertia of the rolled transducer can be obtained simply by rolling the transducer with a sufficient number of windings. The area moment of inertia of the rolled transducer should preferably be sufficient to prevent buckling of the transducer during normal operation.

[0061] Thus, the rolled transducer may have a number of windings sufficient to achieve an area moment of inertia of the cross section of the rolled transducer which is at least 50 times an average of an area moment of inertia of the cross section of an un-rolled transducer, such as at least 75 times, such as at least 100 times.

[0062] According to one embodiment, positive and negative electrodes may be arranged on the same surface of the dielectric material in a pattern, and the transducer may be formed by rolling the dielectric material having the electrodes arranged thereon in such a manner that the rolled transducer defines layers where, in each layer, a positive electrode is arranged opposite a negative electrode with dielectric material there between. According to this embodiment the transducer may preferably be manufactured by providing a long film of dielectric material and depositing the electrodes on one surface of the film. The electrodes may, e.g., be arranged in an alternating manner along a longitudinal direction of the long film. The long film may then be rolled in such a manner that a part of the film having a positive electrode positioned thereon will be arranged adjacent to a part of the film belonging to an immediately previous winding and having a negative electrode thereon. Thereby the positive and the negative electrodes will be arranged opposite each other with a part of the dielectric film there between. Accordingly, a transducer is formed when the film is rolled.

[0063] The laminate may e.g. be rolled relative to a surface pattern of at least one of the layers so that the deformation of the film causes radial expansion of the transducer. This could be obtained with a pattern of corrugations extending parallel to an axis around which the laminate is rolled. Alternatively, the laminate could be rolled relative to a surface pattern of at least one of the layers so that the deformation of the film causes axial expansion of the transducer and thus variable distance between axially opposite end faces of the transducer. This could be obtained with a pattern of corrugations extending perpendicularly to the axis around which the laminate is rolled so that the crests and chests of the corrugations extend circumferentially around the transducer.

[0064] If the laminate is rolled to form a cylindrically shaped body portion which is hollow, then the rolled laminate may itself form at least a part of the path.

[0065] The pump may comprise at least one, and optionally a plurality of rolled transducers provided for axial elongation and arranged in a cylindrical chamber with end portions moving as pistons in the chamber. If a plurality of rolled transducers is provided in this way, they may be arranged with end faces of adjacent transducers towards each other forming a continuous row of transducers in a continuous cylindrical chamber.

[0066] The transducers may e.g. be fixed to the wall of the chamber at a location between the end portions. When the transducers are actuated, they expand axially and thus reduce volumes of spaces provided between adjacent transducers. When the transducers contract axially, the volumes of the spaces between adjacent transducers increase. Additional spaces may be provided between the end faces of each of the transducers—i.e. between an outer surface of the rolled laminate and an inner surface of the cylindrical chamber or in inner cavities within the rolled transducers. When the transducers contract or expand simultaneously, the volumes of these additional spaces increase or decrease in a reverse order relative to the spaces between the transducers. By providing a set of check valves or valves having a similar uni-directional function at each end of the spaces, a pumping action may be obtained during simultaneous actuation of all transducers in the cylinder.

[0067] In an non-rolled embodiment of the pump, the transducer comprises a plane sheet of the laminate, and the pump comprises a control system adapted to drive the transformer with a frequency corresponding to a resonance frequency of the plane laminate so that vibration of the laminate can be obtained with a relatively large amplitude of the movement with a low energy supply. One or more variable volume chambers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0068] Preferred embodiments of the invention will now be described in further details with reference to the drawing in which:

[0069] FIGS. **1** and **2** illustrate two different pump structures according to the invention;

[0070] FIG. **3** illustrates a laminate for a transducer;

[0071] FIGS. **4** and **5** illustrate rolling of the laminate for elongation and expansion, respectively;

[0072] FIG. **6** illustrates an alternative way of making a rolled transducer by stacking of two composite structures;

[0073] FIGS. **7-26** illustrate various alternative pumps; and

[0074] FIG. **27** illustrates an electrical diagram of a control system for controlling the pumps.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0075] FIG. **1** illustrates a pump **1**, comprising a housing **2** with an internally arranged fixed spindle **3** with a screw thread structure of a helix shaped fin **4** on an outer surface. The housing forms an inlet **5** for entering fluid into the pump, and an exit **6** for exit of the fluid from the pump. A path extends from the inlet to the exit between an inner surface **7** of the housing and an outer surface **8** of the spindle. The housing is made from an elastically deformable material, and transducers **9** are attached to an outer surface to cause deflection of the housing. FIGS. **1***c* and **1***d* illustrate two differently deflected states of the housing, and FIGS. **1***e*, **1***f* and **1***g* illustrate a sequence of deflections around the fixed spindle **3**. The sequential deflection around the spindle causes movement of a fluid, guided by the spindle, from the inlet **5** to the exit **6**.

[0076] Each transducer **9** is made from a laminate with a film of a dielectric polymer material arranged between first and second layers of an electrically conductive material so that it is elastically deformable in response to an electrical field applied between the layers. The laminate is rolled, stacked or folded.

[0077] FIG. **2** illustrates an alternative pump with a hose **10** which is deformable by application of a pressure, and a plurality of transducers **11** arranged around the hose to deform the pressure. A pumping effect may be provided by an activation sequence where the transducers are activated by turns to provide a flow from the inlet **12** to the exit **13**, c.f. also FIG. **7**.

[0078] The laminate is provided so that it is easier to deform in one, compliant, direction than in other directions. The laminate is further provided with an anisotropic characteristic so that it is less compliant in one specific direction than in other directions. As illustrated in FIG. **3**, this characteristic can be provided by a waved surface structure by which the laminate can be expanded in the compliant, longitudinal, direction indicated by the bold arrows **14**, **15** by elastic deformation of the polymer material **16**, while the electrically conductive material which is applied to the waved surface is straightened out rather than stretched.

[0079] By selection of a conductive material which requires a larger force to deform elastically than that required to deform the polymer material, and by application of the conductive material throughout the transverse direction indicated by the bold arrows **17**, **18**, i.e. parallel to the direction in which the crests and troughs of the waves extend, the laminate becomes anisotropic. By anisotropic is meant that the laminate is compliant in the longitudinal direction and non-compliant in the transverse direction.

[0080] The laminate structure illustrated in FIG. **3** is rolled to form a tubular actuator. The laminate may be rolled around an axis extending in parallel with the crests and troughs as shown in FIG. **4**. This provides radial expansion of the tubular actuator upon deformation of the polymer—herein referred to as "rolled for expansion". The laminate may also be rolled around an axis being perpendicular to the crests and troughs as shown in FIG. **5**. This provides axial elongation of the tubular actuator upon deformation of the polymer—herein referred to as "rolled for elongation". When the laminate is rolled, the two opposite layers of a conductive material, in the following referred to as the top and bottom layer, must be electrically separated from each other by an additional film of a non conductive material.

[0081] FIG. 6 illustrates a laminate which is rolled to form a tubular structure and which comprises a multilayer structure with at least two composites. The composites are identical and each comprises a film **19** made of a dielectric polymer material and having a front surface and a rear surface, the front surface comprising a surface pattern of raised and depressed surface portions, and a first layer **20** of an electrically conductive material being deposited onto the surface pattern. When such two composites are arranged on top of each other, a laminate with a film of a polymer material between two electrically conductive layers is formed. The second film provides isolation between the top and bottom layers. The composites may be arranged, as shown, with front surface of one composite against a rear surface of an adjacent composite. Alternatively, the composites may be arranged with rear surfaces against each other to form a laminate of two films against each other and two electrically conductive layers forming outer surfaces on opposite sides of the two films.

[0082] The transducers in FIG. **2** are each made from a laminate which is rolled for elongation. The axial end portions of the rolled laminate are subsequently joined to form a torus shape. FIG. **7** further illustrates the sequence and principle of this pump.

[0083] FIGS. **8***a* and **8***b* illustrate a pump with a tube **20** and a row of transducers **21**. The transducers are each made from a laminate which is rolled for elongation, and one of the axial end portions thereof are arranged towards the tube **20** to deform the tube **20** either by direct contact therewith or via a pressure element arranged between the axial end of the rolled laminate and the outer surface of the tube (not shown). FIGS. **8***a*-**8***c* illustrate that the pump has a structure whereby it only works against a dynamic pressure of the fluid which is pumped in the tube **20**. The static pressure difference between the lowest pressure in the tube and the pressure outside the tube can be neglected when considering the force by which the transducers **21** must act on the tube.

[0084] FIG. **9** illustrates a check-valve element **22** which is inserted in the tube **20** in FIGS. **8***a*-**8***c* or in the hose **10** in FIG. **2**.

[0085] FIG. **10** illustrates an alternative design of the pump in which sections of a passive hose **24** are arranged alternating sections of an active hose. The active hose sections comprise a laminate of the previously mentioned kind and thus constitute transducers for the pump. The laminate is rolled for elongation so that radial contraction and expansion is possible in the active sections, and by a suitable activation sequence, a fluid can be displaced through the hose **24**, **25** from the inlet **26** to the exit **27** as shown in FIG. **11**.

[0086] FIG. **12** illustrates a pump with a housing **28** and two transducers comprising displacement members **29**, **30** movable into and out of the passage **31** by use of the laminates **32**, **33** which are rolled for elongation. The pump comprises two check valves **34**, **35** arranged on opposite sides of the transducers in the flow direction—indicated by the bold arrow.

[0087] FIGS. **13***a*-**13***c* illustrate an alternative embodiment of a pump according to the invention. The pump **36** comprises a number of composites **37**, **38** each having three conductive layers **39**, **40** and **41**. A cavity **42** is formed between the two composites **37**, **38** and by repulsion or contraction of the composites away from each other or towards each other, the volume of the cavity **42** can be changed. A bias voltage may initially be provided to the conductive layers **39** whereby the upper part of the composites are biased towards each other while a liquid enters the inlet **43**. Subsequently, the bias voltage between the conductive layers **39** is removed and a bias voltage is applied to the conductive layers **41**. This closes the inlet **43** and a bias voltage can be applied to the conductive layers **40** whereby the mid sections of the composites are biased towards each other and the volume of the cavity **42** is reduced. The fluid in the cavity is therefore pumped out of the chamber through the exit **44**.

[0088] FIG. **14** illustrates a pump with a housing **45** forming a chamber **46** with a check valve **47**, **48** in opposite ends. A transducer **49** formed by a laminate which is rolled for either expansion or elongation is arranged in the chamber **46** so that the free volume in the chamber can be changed cyclically and so that a fluid is pumped through the chamber from the inlet **50** to the exit **51**. FIG. **15** illustrates the pump structure in FIG. **14** where the chamber is in a "heart" shape.

[0089] FIGS. **16**-**17** illustrate a pump with a housing **52** having a slot **53** forming a chamber **54** extending between an inlet **55** and an exit **56**. The housing is deformed by use of the transducers **57**, **58** which comprises a laminate rolled for elongation. The housing **52** further comprises a number of cavities or a through going bore which makes the housing more easily deflected. Check valves may be located in opposite ends of the chamber **54** to ensure that the flow is in one direction only.

[0090] FIG. **18** illustrates schematically a pump with a housing **59** forming a passage **60** between two check valves **61**, **62**. A spring-structure coil **63** is arranged in the passage. The coil is made from an elongated element which is constituted by a laminate rolled for elongation. During elongation or contraction of the laminate, the coil opens up and thus increases the size of the space **64** between the windings, or closes down and decreases a space between the windings, whereby a pumping action is provided in the passage. FIG. **19** illustrates the same pump without the check valves. In this case, the pumping action is provided by the geometry of the passage or the coiled laminate by which shape the fluid is pushed in a pumping direction by contraction of the rolled laminate.

[0091] FIGS. **20**-**22** illustrate a pump with a housing with a tube **65**, a transducer **66** comprising a laminate rolled around the tube for expansion and contraction, and check valves **67**, **68**.

[0092] FIG. **23** illustrates a pump with a housing **69** with an inlet **70** and an exit **71** the inlet and exit are provided with a check valve which is not shown in FIG. **23**. The check valves provide uni-directional flow from the inlet to the exit. The pump comprises a bellow **72** forming a chamber **73** with variable volume. The transducers **74**, **75** are arranged to move a top wall **76** of the chamber **73** and thus cause changes to the volume of the chamber. Each transducer comprises a laminate which is rolled for elongation.

[0093] FIG. **24** illustrates a pump with a housing **77** forming a chamber **78** with an inlet **79** and an exit **80**. The inlet and exit are provided with check valves **81**, **82** providing a unidirectional flow from the inlet to the exit. The transducer **83** comprises a laminate which is rolled for expansion and moves back and forth in the chamber **78** as a piston in a cylinder and thus causes a variable volume of the chamber **78** and thus provides a pumping effect. FIG. **25** illustrates the pumping effect where the hatched areas represents filling of the chamber **78** and the non-hatched areas represent emptying of the chamber **78**. Time is along the X-axis and the position of the end face **84** of the transducer **83** is along the Y-axis.

[0094] FIG. **26** illustrates a pump with a laminate **85** forming a transducer of the pump. The laminate moves one, and possibly two pistons **86**, **87** which moves in corresponding cylinders **88**, **89** and thereby forms variable volume chambers **90**, **91**. Inlets and outlets **92**, **93**, **94**, **95** with check valves **96**, **97**, **98**, **99** provide a uni-directional flow through the chamber during the pumping activity. A spring-force structure, e.g. in the form of a helically coiled spring **100** can be arranged to adjust the characteristics of the pump.

[0095] FIG. **27** illustrates an electrical diagram of a control system for controlling operation of a pump. The control system is particularly suitable in combination with a displacement pump of the kind where the pumping is effected by deflection of a chamber with a variable volume—i.e. when the chamber is deflected in one direction, the volume increases and the chamber is filled with a fluid and when the chamber is deflected in another direction the volume decreases and the fluid is displaced out of the chamber.

[0096] The control system is based on the fact that the laminate has a capacitor structure where the capacitance is indicative of the distance between the first and second layers, and thereby indicative of a degree of deflection of the film.

[0097] By determining the capacitance of the laminate, the control system is able to determine a pressure difference over the pump, and if the pump is a displacement pump, it may also be able to determine a degree of displacement in a variable volume chamber of the pump. This feature may e.g. be utilized for dosage purposes, where the pump according to the invention can provide a relatively precise dose of a fluid by determining a degree of deflection of the film and thus a degree of compression of the variable volume chamber.

[0098] In the following description, the wording "bias voltage" describes a voltage which is applied between the first and second layers to deflect the film, and "measuring voltage" describes a voltage which is applied to determine capacitance of the laminate.

[0099] The control system according to the invention is capable of applying a known bias voltage between the layers and simultaneously to determine the capacitance of the laminate. According to a reference characteristic for the pump, the applied bias voltage should provide a theoretical deflection of the film and thus a theoretical volume change of a displacement pump. By measuring the capacitance while the bias voltage is applied, the control system is capable of deriving an actually obtained deflection of the film and thus an actually obtained displacement of a fluid out of a chamber with variably volume.

[0100] The control system comprises data storage capacity **101** in which a ratio between displacement of a fluid out of a chamber versus actuator capacitance is specified. In a most simple embodiment, the ratio is stored as discrete values. A computing device **102** communicates with the data storage **101** and determines based on a dose of fluid to be displaced by the pump, a theoretical bias voltage **103** by which the film is theoretically deflected to cause the desired volume change of the chamber. The computing device communicates the theoretical bias voltage to an error correction device **104** from which the bias source **105** receives input for setting a high voltage bias signal to the transducer **106**. The actuating device **106** comprises a laminate of the kind already described, and in the diagram, such a laminate corresponds to a capacitor.

[0101] In addition to the bias signal, the bias source **105** provides, via the connection **107**, a low voltage test signal which is applied to the laminate simultaneously with the bias signal. The filter **108** extracts the low voltage signal from the high voltage signal, and the capacitance measuring device **109** determines the actual capacitance of the transducer **106**.

[0102] The capacitance is determined while the film is deflected by the high voltage bias signal and therefore, the capacitance indicates how much the film was deflected by the bias signal. In the illustrated embodiment, the capacitance is converted into feedback signal **110**, in this case in form of a comparative bias voltage, i.e. a bias voltage which, with the reference characteristics of the pump, would have provided that deflection of the film which actually occurred and which was determined by measuring of the capacitance. The comparative bias voltage is subtracted from the determined bias voltage in the correction device **104** and the resulting corrected bias voltage **111** is received by the bias source **105**.

[0103] In general, the feedback signal **110** can be manipulated in various ways via amplifies and converters of different kind.

[0104] The capacitance measuring device may also be implemented in a regular computer system, and it may include, without being limited to, any of the following measuring principles: AC Power, AC Voltage, RMS Power, Peak detectors, Log detectors, RSSI, Impedance, Pulse Measuring circuit or Spectral Measuring circuit.

[0105] The setting voltage that provides the high voltage bias signal to the actuator is typically greater than 300 Volts and less than 10 kV. An example would be 500 to 2.5 kV. The Low voltage test signal would typically be between 1 and 10 V, an example would be 3 to 5V. The High voltage actuator control signal is typically DC to low frequency less than 1 KHz repetition rate, an example would be 50 Hz. The AC test signal is generally at a frequency rate considerably higher than the actuator, usually by a factor of 10 away from the actuator repetition rate. An actuator with a 2.5 kV signal, with a 10 Hz repetition rate, could have an AC test signal of 5V and 1 KHz repetition rate.

[0106] The data processing structure may further be adapted to use the determined deflection of the variable volume chamber to provide flow specific information. Such information may be based on information in a second data file which describes a ratio between the deflection of the variable volume chamber and a pressure drop over the pump, flow speed for a specific fluid through the pump etc.

[0107] Furthermore, the control system may be adapted to control the pump for dosing purposes. As an example, the control system may be capable of reading a user request with respect to the flow. As an example, this may be a desired pressure drop, a desired flow speed, or a desired dose of a fluid medium which is released through the pump. Based on the request, the control system applies a bias voltage to the first and second electrically conductive layers while the capacitance is measured. In this way the deflection of the variable volume chamber is determined and by use of the data in the first and second data files, the request may be fulfilled.

[0108] While the present invention has been illustrated and described with respect to a particular embodiment thereof, it should be appreciated by those of ordinary skill in the art that various modifications to this invention may be made without departing from the spirit and scope of the present.

What is claimed is:

1-43. (canceled)

44. A fluid pump for displacing a fluid medium from an inlet to an exit, the pump comprising a housing forming a path between the inlet and the exit, and a transducer comprising a laminate with a film of a dielectric polymer material arranged between first and second layers of an electrically conductive material so that it is deflectable in response to an electrical field applied between the layers, wherein the laminate is arranged to cause a pumping action upon deflection of the film.

45. The pump according to claim **44**, wherein the film has a first surface and an opposite second surface, at least the first surface comprising a surface pattern of raised and depressed surface portions

46. The fluid pump according to claim **45**, wherein the surface pattern comprises a super-pattern arises of repeated sub-patterns.

47. The pump according to claim **44**, wherein the laminate comprises a multilayer structure with at least two composites, each composite comprising:

- a film made of a dielectric polymer material and having a front surface and a rear surface, the front surface comprising a surface pattern of raised and depressed surface portions, and
- a first layer of an electrically conductive material being deposited onto the surface pattern, the electrically conductive layer having a corrugated shape which is formed by the surface pattern of the film.

48. The pump according to claim **47**, wherein the transducer is provided with at least three independent active portions, each portion being arranged to enable deformation of the body at different locations along the path.

49. The pump according to claim **44**, wherein the laminate is rolled to form an elongated transducer with axially opposite end faces and a cylindrically shaped body portion between the end faces.

50. The pump according to claim **49**, wherein the rolled laminate defines a radius of gyration, r_g, given by

$$r_g = \sqrt{\frac{I}{A}},$$

where I is the area moment of inertia of the rolled transducer, and r_g may be within the range 5 mm to 100 mm, such as within the range 10 mm to 75 mm, such as within the range 25 mm to 50 mm.

51. The pump according to claim **49**, wherein the rolled laminate may define a slenderness ratio, λ, given by $\lambda = L/r_g$, where L is an axial length of the rolled laminate, and λ may be smaller than 20, such as smaller than 10.

52. The pump according to claim **44**, wherein the first electrically conductive layer is deposited onto the surface pattern and has a shape of raised and depressed surface portions which is formed by the surface pattern.

53. The pump according to claim **44**, wherein the raised and depressed surface portions have a shape which varies periodically along at least one direction of the first surface.

54. The pump according to claim **44**, wherein the raised and depressed surface portions have a size which varies periodically along at least one direction of the first surface.

55. The pump according to claim **44**, wherein the first electrically conductive layer has a modulus of elasticity being higher than a modulus of elasticity of the film.

56. The pump according to claim **44**, wherein the film has a thickness between 90 percent and 110 percent of an average thickness of the film.

57. The pump according to claim **44**, wherein the first electrically conductive layer has a thickness which is between 90 percent and 110 percent of an average thickness of the first electrically conductive layer.

58. The pump according to claim **52**, wherein the surface pattern comprises waves forming troughs and crests extending in essentially one common direction.

59. The pump according to claim **58**, wherein each wave defines a height being a shortest distance between a crest and neighbouring troughs, an average of the heights of the waves is between ⅓ and 20 μm.

60. The pump according to claim **44**, wherein the film has an average thickness being between 10 and 200 μm.

61. The pump according to claim **44**, wherein the first electrically conductive layer has a thickness in the range of 0.01-0.1 μm.

62. The pump according to claim **52**, wherein the second surface is substantially flat.

63. The pump according to claim **47**, wherein at least two adjacent composites are arranged with the rear surfaces towards each other.

64. The pump according to claim **47**, wherein at least two adjacent composites are arranged with the front surfaces towards each other.

65. The pump according to claim **47**, wherein at least two adjacent composites are arranged with the rear surface of one composite towards the front surface of the other composite.

66. The pump according to claim **47**, wherein a section of the path is formed by a space between the composites.

67. The pump according to claim **44**, comprising at least two check valves arranged in the path to form a pumping space there between.

68. The pump according to claim **66**, wherein the valve structure is formed by additional layers of an electrically conductive material on the film of each composite.

69. The pump according to claim **68**, wherein the transducer is formed in such a manner that the laminate, in an unsupported state, fulfils Euler's criteria for stability within a normal operating range for the pump.

70. The pump according to claim **44**, wherein at least a section of the path is provided in a body of an elastically deformable material, the transducer being arranged to deflect the body upon deflection of the film whereby the path changes volume.

71. The pump according to claim **48**, further comprising a control system adapted to provide subsequent activation of one portion after another in a sequence which fulfils a pumping action whereby a fluid is pushed in the path in a flow direction.

72. The pump according to any of claim **71**, wherein the body has a build-in tension which presses the path towards a neutral configuration from which it can be pushed against the build-in tension towards an activated configuration by the transducer,

73. The pump according to claim **72**, wherein the neutral configuration provides a lower flow resistance in the path than the activated configuration.

74. The pump according to claim **72**, wherein the neutral configuration provides a higher flow resistance in the path than the activated configuration.

75. The pump according to claim **44**, wherein the transducer is arranged outside the path.

76. The pump a according to claim **44**, wherein the transducer is arranged in the path.

77. The pump according to claim **76**, wherein the transducer is arranged to cause a volumetric change of a section of the path upon deflection of the film.

78. The pump according to claim **49**, comprising at least two check valves arranged on opposite sides of the transducer and providing a uni-directional flow between the inlet and exit, at least one of the valve elements being attached to, or forms part of the end faces.

79. The pump according to claim **78**, wherein the cylindrically shaped body portion is hollow and forms part of the path.

80. The pump according to claim **78**, comprising a plurality of elongated transducers arranged with end portions of adjacent transducers towards each other in a continuous cylindrical chamber.

81. The pump according to claim **78**, wherein the laminate is rolled relative to a surface pattern of at least one of the layers so that the deflection of the film causes radial expansion of the transducer.

82. The pump according to claim **78**, wherein the laminate is rolled relative to a surface pattern of at least one of the layers so that the deflection of the film causes axial expansion of the transducer.

83. The pump according to claim **44**, comprising a below with an internal space, the transducer being arranged to deflect the below and thus to provide variable volume in the space.

84. The pump according to claim **44**, comprising a cylinder forming part of the path and being provided with two check valves arranged to cause a uni-directional flow from the inlet through the cylinder to the exit, and a piston being movable in a cylinder, wherein the transducer is arranged to move the piston relative to the cylinder.

85. The pump according to claim **84**, wherein the laminate of the transducer is a plane laminate, and wherein the pump comprises a control system adapted to drive the transformer with a frequency corresponding to a resonance frequency of the plane laminate.

86. The pump according to claim **44**, and including a control system adapted to apply a known bias voltage between the layers and simultaneously to determine a measure which is significant for a capacitance of the laminate.

87. The pump according to claim **86**, wherein the transducer is arranged to provide deflection of a variable volume chamber.

88. A control system for a pump according to claim **44**, the control system being adapted to apply a known bias voltage between the layers and simultaneously to determine a capacitance of a laminate of the pump.

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