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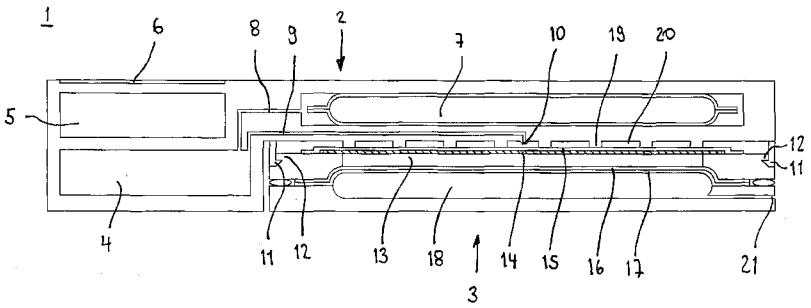
(54) Title: SWELLABLE SUBSTANCE ACTUATOR WITH AN ELECTRICALLY DRIVEN FLUIDIC TRANSPORTATION DEVICE

Fig. 1



(57) Abstract: A system (1) for generating a volume work which can be driven by a swellable substance, preferably for delivering a medicinal active compound, which comprises: a swellable substance chamber (13) filled with the swellable substance, a swelling agent reservoir (7) which can accommodate a swelling agent for swelling the swellable substance, and a fluidic transportation device (4) which can feed the swelling agent to the swellable substance from the swelling agent reservoir (7). The fluidic transportation device can be directly or indirectly electrically driven. A swelling agent dispenser (2) for feeding a swelling agent from the swelling agent reservoir (7) to a swellable substance cartridge (3) which can be connected to the swelling agent dispenser (2). Finally, a swellable substance cartridge (3) for performing a volume work, driven by a swellable substance, wherein the swellable substance cartridge (3) comprises the swellable substance chamber (13) filled with the swellable substance.

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Swellable substance actuator with an electrically driven fluidic transportation device

Description

Field of the invention

The invention relates to a system for generating a volume work which can be driven by a swellable substance, preferably for delivering a medicinal active compound. The invention moreover relates to a swelling agent dispenser to which a swellable substance cartridge can be connected, and a swellable substance cartridge.

Background of the invention

Numerous fluidic actuators with which in particular small amounts of liquid can be controlled and moved have been developed in recent years. Such actuators are used in the most diverse fields. They are to be found in the industrial environment equally as in the consumer goods market. The same actuator is often suitable for different uses in various fields. However, the framework conditions of the particular use often require an actuator which is particularly optimized with respect to certain criteria. Development in the technical field of fluidic actuators is therefore extremely dynamic.

Portable medicament dosing systems for ambulant therapy are one field of use for fluidic actuators. Depending on the therapeutic aim, other technical and economical framework conditions are to be met. In the past, the main task was to provide at all a system with a fluidic actuator for certain therapeutic aims. Recently, the focal point of development activities has been shifting towards optimizing the systems, e.g. towards making them smaller and lighter, so that they impede the patient as little as possible in carrying out his daily work. The miniaturization necessary for this sometimes requires leaps in technology based on novel actuator concepts.

Such actuator concepts can entirely consist of well-known components, such as e.g. springs (see e.g. the products Micronifusor from BD, Franklin Lakes, NJ 0741 7, USA and V-Go from Valeritas, Bridgewater, NJ 08807, USA and the laid-open specification WO 2005/018705 and the patent specification US 7,530,968). Other set-ups are e.g. the use of the change in volume of a battery when current is drained (see e.g. the product PatchPump from SteadyMed, Tel-Aviv 69719, Israel and the laid-open specification US 2009/093772), controlled emptying of a reservoir under pressure (see e.g. the laid-open specifications WO 2009/1 58655, US 2006/206054 and US 2006/150748), electroactive polymers (see the laid-open specification EP 1 834 091), volume and plunger of parts of plastic (see the laid-open specification WO 2007/074363) and the use of shape memory alloys (see the patent specification US 7,144,384).

A scientific overview of micropumps is given by e.g. Tsai et al. "Review of MEMS-based drug delivery and dosing systems", published in Sensors and Actuators A, 134 (2007) p. 555-564. Various actuator principles and technical possibilities of realization are described there. A typical MEMS micropump is combined with an insulin reservoir in the patent specification US 7,005,078.

A further class of actuators which are suitable for constructing an infusion system are swellable substance actuators, e.g. with a hydrogel as the swellable substance. Such actuators are described inter alia in the laid-open specification DE 103 00 896, in the paper by A. Richter et al., "Adjustable Low Dynamic Pumps Based on Hydrogels", published in Macromol. Symp. 2004, p. 377-384 and in the laid-open specification US 2010/030156. Swellable substance actuators in the context of the present invention also include osmotic pumps, e.g. that described by T. Deem et al. in "Osmotic dispense pump for operation at different temperatures and pressures", published in Sensors and Actuators A-Physical 136 (2007), no. 2, p. 742-748, ISSN/ISBN 0924-4247 and that described by M. Ehwald et al. in "A long-term stable and adjustable osmotic pump for small volume flow based on principles of phloem loading",

published in Biotechnology and Bioengineering 94 (2006) , no. 1, p. 37-42, ISSN/ISBN 0006-3592. The latter pump can be switched on and off.

Portable insulin pumps are obtainable from various manufacturers. The best known manufacturers are Roche Diagnostics, 68305 Mannheim, Germany and Medtronic, 40670 Meerbusch, Germany. Some known portable pumps can be very heavy and are therefore typically attached to the trousers. Insulet, Bedford, MA 01730, USA offer a very lightweight system which can be stuck directly on to the skin. The following table gives the parameters of three selected insulin pumps available on the market:

Manufac-turer	Reservoir capacity in millilitres	Weight in grams	Weight per volume of active compound in grams per millilitre	Volume in millilitres	Volume per millilitre of active compound
Roche	3.15 ml	110 g	35 g/ml	97 ml	31
Medtronic	1.76 ml	100 g	57 g/ml	76 ml	43
Insulet	2 ml	34 g	17 g/ml	43 ml	22

Table 1. Parameters of three insulin pumps currently available on the market.

Object on which the invention is based

The invention is based on the object of providing a system for generating a volume work which is improved with respect to the prior art. The invention is furthermore based on the object of providing an improved swelling agent dispenser and a swellable substance cartridge.

Solution according to the invention

The object on which the invention is based is achieved by a system for generating a volume work which can be driven by a swellable substance (also called "swellable substance actuator") which comprises a swellable substance chamber filled with a swellable substance, a swelling agent reservoir which can accommodate a swelling agent for swelling the swellable substance, and a fluidic transportation device (also called "fluidic actuator") which can feed the swelling agent to the swellable substance from the swelling agent reservoir, wherein the fluidic transportation device can be directly or indirectly electrically driven.

In connection with the present invention, "directly or indirectly electrically" means that according to the invention the fluidic transportation device does not necessarily have to be driven directly by electrical effects (for example electrical or magnetic induction) or by an electric motor, but that other drive possibilities which are triggered by an electrical current or an electrical voltage are also possible, e.g. a transportation of the fluid by means of an electric heating (for example in the bubble-jet process), with the aid of a piezoelectric effect, by means of an electroacoustic effect and so on.

The release is moreover achieved by a swelling agent dispenser which can feed a swelling agent from a swelling agent reservoir to a swellable substance cartridge which can be connected to a swelling agent dispenser, and comprises electrical means for electrically driving a fluidic transportation device. Finally, the object is achieved by a swellable substance cartridge which comprises a swellable substance chamber filled with a swellable substance and, driven by the swellable substance, can perform a volume work.

With the invention, the swelling, that is to say the expansion of the swellable substance, can advantageously be controlled with the aid of the fluidic transportation device, and in particular by the swelling agent being dispensed by the fluidic transportation device. The actual volume work can be performed by the swelling swellable substance. The positive properties of electrically driven fluidic

transportation devices can advantageously be combined with the positive properties of swellable substance actuators by the invention. The advantages of electrically driven fluidic transportation devices can lie in particular in a small construction, a low weight, in a low energy consumption and in a very precise controllability. The advantages of swellable substance actuators can lie in particular in the fact that they can provide a high pressure and therefore a high delivery output, and that the delivery rate is independent of the delivery pressure within a comparatively wide pressure range. One advantage of swellable substance actuators can also lie in their high media compatibility compared with electrically driven fluidic transportation devices, i.e. they can transport the most diverse media without damage to the actuator, blockages or the like occurring.

By the fact that according to the invention the task of the fluidic transportation device can be limited to feeding swelling agent from the swelling agent reservoir to the swellable substance, and that it can be achieved by this means that the delivery pressure is essentially known, effects of a possible delivery pressure dependency of the fluidic transportation device can be avoided or compensated very well. Since moreover the volume work generated by the system can be performed by the swellable substance, adverse effects of a low delivery output of the fluidic transportation device can be avoided. Consequently, it can advantageously be achieved with the invention that the required volume work performed by the fluidic transportation device is lower than the volume work performed by the swellable substance.

The system according to the invention is suitable in particular for providing a device with which the volume work generated by the swellable substance is employed for delivery of an active compound, in particular a medicinal active compound, e.g. insulin. Surprisingly, an improved such device can be provided with the invention, although in addition to the volume to be delivered the volume of the swelling agent must also still be provided. In the case of typical swellable substance actuators, these two volumes are essentially the same size, so that in total for the same amount of active compound twice the volume must be provided compared with known

systems without a swellable substance actuator. However, the inventors have found that this disadvantage can be more than compensated by the fact that a smaller and more energy-saving electrically driven fluidic transportation device can be employed. The fact that due to the swellable substance actuator the pump does not have to generate a high delivery output and high delivery pressure can contribute to this in particular. Furthermore, swellable substances are also known which within certain limits require for an increase in volume only a swelling agent volume which corresponds to a fraction of the increase in volume

Preferred embodiments of the invention

Advantageous embodiments or further developments, which can be employed individually or in combination with one another, are the subject matter of the dependent claims. A preferred electrically driven fluidic transportation device is a pump which is arranged downstream of the swelling agent reservoir in the direction of flow of the swelling agent, that is to say in the direction from the swelling agent to the swellable substance, in order to deliver the swelling agent from the swelling agent reservoir to the swellable substance. A preferred pump has a fluid connection to the swelling agent reservoir on the intake side. Preferably, the pump sucks in the swelling agent from the swelling agent reservoir and releases it in a direction to the swellable substance. The pump can operate e.g. by an electromagnetic, an electrostatic, a piezoelectric or a bubble-jet method. A suitable pump is e.g. a micropump or a free jet dispenser. The person skilled in the art can find micropumps which are suitable for realizing the present invention e.g. in the review article by Tsai et al. "Review of MEMS-based drug delivery and dosing systems", published in Sensors and Actuators A, 134 (2007) p. 555-564 and in the patent specification US 7,005,078. Suitable free jet dispensers are known e.g. from Le et al. "Progress and Trends in Ink-jet Printing Technology", Journal of Imaging Science and Technology, 42 (1998), p. 49-62. The exit of a preferred free jet dispenser is a nozzle. The preferred free jet dispenser can generate on the exit side droplets of the swelling agent which can move with a high speed through a medium of significantly

lower density, e.g. air. Preferably, a fluid connection, e.g. a hose, is arranged at the exit of the pump in order to transport the swelling agent in the direction of the swellable substance.

As an alternative or in addition to the pump, the fluidic transportation device can also comprise means which can drive the swelling agent out of the swelling agent reservoir, e.g. an electrically driven plunger which can reduce the size of the swelling agent reservoir in order to drive out the swelling agent. Preferably, in this embodiment a fluid connection, e.g. a hose, is arranged on one exit of the swelling agent reservoir in order to transport the swelling agent in the direction of the swellable substance.

The preferred device according to the invention comprises control means, preferably electrical control means, in order to control the delivery rate of the electrically driven fluidic transportation device. Preferably, the delivery rate can be adjusted to essentially any desired values between no transportation and the maximum delivery rate, particularly preferably during operation of the fluidic transportation device. A suitable control means can be e.g. a time-switch, e.g. in the form of an electric timing circuit, which is connected to the fluidic transportation device in order to control the delivery rate thereof according to time and/or switch the delivery on or off according to time. Another preferred control means is an electronic control circuit which regulates the delivery rate of the fluidic transportation device or switches the delivery on or off according to one or more signals of a sensor, e.g. a (blood) sugar sensor.

The swellable substance chamber is preferably closed with a filter which the swellable substance cannot overcome in amounts which are relevant in practice, but through which swelling agent can be fed into the swellable substance chamber. With the filter, swelling substance leaving the swellable substance chamber through the flow path of the swelling agent can be avoided. The filter can be e.g. a semipermeable membrane. The filter can have only one pore or many, in which case very small pores. The filter can be hydrophilic or hydrophobic. It can also be very thick. It can have a regular structure or be unstructured. The filter can also comprise

several layers of different materials. Embodiments of the filter in which this comprises several layers of different material are also conceivable. The filter is preferably of a flat configuration.

Support means are moreover preferably provided, in order to counteract arching of the filter. Arching of the filter is intended to mean here arching outwards when viewed from the swellable substance chamber. Preferred support means are accordingly present on the outside of the swellable substance chamber. Possible support means are e.g. a part of a housing of the device or a part of the device (e.g. of the swelling agent dispenser discussed below), for example a housing surface or one or more projections or ribs.

Preferably, a flat transportation layer which can distribute the swelling agent over an area of the swellable substance is present in the flow path of the swelling agent downstream or upstream of the filter. The preferred transportation layer is a (preferably wide-mesh) filter material. In principle, materials which have both a supporting and a liquid-transporting (e.g. by means of capillary forces) property can be employed for the transportation layer. Embodiments of the invention in which the transportation layer simultaneously acts as the support means and/or as the filter are conceivable.

A capillary stop is preferably arranged in the fluid connection for feeding the swelling agent to the swellable substance. An unintentional flow of swelling agent from the swelling agent reservoir to the swellable substance can be counteracted by means of this. Such an unintentional flow of swelling agent can arise by capillary action e.g. if the fluidic transportation device does not or does not completely close the flow path in the switched-off state or if a valve provided in the flow path does not close completely. In a preferred embodiment of the invention, the capillary stop is realized by an air-filled chamber. Preferably, an opening which can form a fluid connection with the swelling agent reservoir (usually via the fluidic transportation device) is present in a first wall of the chamber. Means for transmitting the fluid in the direction of the swelling agent are moreover provided on the chamber; particularly preferably,

for this purpose a second wall of the chamber forms a part of the filter or transportation layer. The side of the filter or transportation layer facing the swelling agent reservoir is preferably hydrophilic for this purpose. Particularly preferably, the first wall of the chamber is hydrophobic in construction. As a result, creeping of the swelling agent out of the opening on this wall can be suppressed. Geometric structures in the course of the flow between the swelling agent reservoir and swelling agent can optionally also perform the function of a capillary stop.

The preferred system comprises a swelling agent dispenser and a swellable substance cartridge. By this means, reusable components of the system can advantageously be accommodated in the swelling agent dispenser, so that the swelling agent dispenser can be reused. In this case for renewed use of the swelling agent dispenser it would merely be necessary to replace the swellable substance cartridge. The capillary stop is preferably arranged on a transition between the swelling agent dispenser and the swellable substance cartridge.

The swelling agent dispenser preferably has electrical means for driving the fluidic transportation device. These can include one or more the following components: A battery, control means for control of the fluidic transportation device (e.g. an electronic control circuit), an operating element, an electrical connection for a further electrical apparatus (e.g. for programming the control or for charging the battery), a sensor (e.g. a (blood) sugar sensor). The preferred swellable substance cartridge comprises the swellable substance chamber filled with swellable substance.

A preferred swelling agent dispenser moreover comprises the electrically drivable fluidic transportation device for transporting the swelling agent to a swelling agent release point of the swelling agent dispenser. The swelling agent dispenser furthermore preferably comprises fixing means, e.g. one or more catch hooks, in order to connect the swellable substance cartridge to the swelling agent dispenser such that the swellable substance cartridge can absorb the swelling agent released at the release point. Corresponding fixing means, e.g. one or more under-cuts into which the catch hooks can engage, are preferably provided on the swellable

substance cartridge. It is also conceivable to provide a shaft in the swelling agent dispenser, into which the swellable substance cartridge can be pushed or laid. In an alternative embodiment of the invention, the swellable substance cartridge comprises the electrically drivable fluidic transportation device for feeding the swelling agent to the swellable substance. In this case the swelling agent dispenser comprises fixing means in order to connect the swellable substance cartridge to the swelling agent dispenser such that the electrical means of the swelling agent dispenser can drive the fluidic transportation device of the swellable substance cartridge. Corresponding fixing means are preferably provided on the swellable substance cartridge.

In a preferred embodiment of the invention, the swelling agent dispenser moreover comprises the swelling agent reservoir. This can facilitate construction of the system. Alternatively, the swellable substance cartridge can also contain the swelling agent reservoir. By this means, the swelling agent can advantageously be replaceable together with the swellable substance.

A preferred system comprises an active compound chamber for accommodating an active compound, e.g. insulin. The active compound chamber is preferably present in the swellable substance cartridge. In a preferred embodiment of the invention, the system or the swellable substance cartridge provided has an active compound chamber prefilled with active compound. In an alternative embodiment, the active compound chamber provided is in the non-filled state, and means are provided which enable the user to fill the active compound chamber with active compound before use. The active compound chamber cooperates with the swellable substance chamber such that an increase in volume of the swellable substance chamber leads to a decrease in volume of the active compound chamber. Preferably, this cooperation is achieved by a flexible and/or elastic separating membrane which separates the swellable substance chamber from the active compound chamber. When the volume of the swellable substance chamber increases, the separating membrane is preferably displaced into the active compound chamber, e.g. by tucking into this, in order to reduce the volume of the active compound chamber as a result. A barrier membrane which is impermeable to water vapour can furthermore be

provided between the active compound chamber and swellable substance chamber in order to ensure the storability of the active compound. This is advantageous in particular if the swellable substance cartridge provided is prefilled with active compound. The separating and barrier membrane can form a laminate. Alternatively, the barrier function of the barrier membrane can also be fulfilled by the separating membrane.

According to the invention, a level sensor, which can be accommodated e.g. in the swelling agent dispenser or the swellable substance cartridge, is preferably provided. The level sensor can measure e.g. the volume of the swelling agent reservoir, of the swellable substance chamber or of the active compound chamber. The level measurement can be e.g. capacitive. Thus, for example, capacitive measurement of the swellable substance chamber volume by means of an electrode in the vicinity of the filter of the swellable substance chamber and a conductive separating or barrier membrane is possible.

Superabsorbers or liquid, osmotically active substances are suitable, for example, as the swellable substance. Superabsorbers are particularly well-suited as the swellable substance, because they have a very high affinity for water, but are not hygroscopic. A swelling hydrogel or a swelling polymer network which can be adjusted exactly with respect to their swelling properties can be employed e.g. as superabsorbers. A sodium chloride solution, for example, can be used as an osmotically active swellable substance. With respect to swellable substances which are known to the person skilled in the art, reference is made in particular to DE 103 00 896, the paper by A. Richter et al., "Adjustable Low Dynamic Pumps Based on Hydrogels", published in Macromol. Symp. 2004, p. 377-384, the laid-open specification US 201 0/0301 56 and the papers by Deem, T. et al., Osmotic dispense pump for operation at different temperatures and pressures", published in Sensors and Actuators A-Physical 136 (2007), no. 2, p. 742-748, ISSN/ISBN 0924-4247 and by Ehwald, M. et al., "A long-term stable and adjustable osmotic pump for small volume flow based on principles of phloem loading", published in Biotechnology and Bioengineering 94 (2006) , no. 1,

p. 37- 42, ISSN/ISBN 0006-3592. The swelling agent is usually a liquid, e.g. water, typically distilled water, e.g. doubly distilled water (Dl water).

Brief description of the figures

The invention is explained more closely in further details in the following with the aid of diagrammatic drawings.

These show:

Fig. 1: a diagram of the construction of a first embodiment example of the device according to the invention with a filled active compound chamber;

Fig. 2: a diagram of the construction of a second embodiment example of a device according to the invention with a filled active compound chamber;

Fig. 3: a diagram of the construction of the embodiment example according to Fig. 1 but with an emptied active compound chamber;

Fig. 4: a diagram of the construction of an embodiment example of the swellable substance chamber;

Fig. 5: a diagram of a test set-up to measure the swelling agent dynamics of the swellable substance chamber according to Fig. 4;

Fig. 6: the swelling dynamics of the swellable substance chamber according to Fig. 4, measured with the test set-up according to Fig. 5;

Fig. 7: the counter-pressure dependency of the swellable substance chamber according to Fig. 4; and

Fig. 8: a diagram of the construction of a third embodiment example of a device according to the invention with a filled active compound chamber.

Detailed description of the invention with the aid of embodiment examples

An example of a system according to the invention comprises 1.8 ml (millilitres) of an active compound solution in an active compound chamber, 2 ml of a swelling agent in a swelling agent reservoir, a micropump weighing 0.8 g (gram) with a volume of 1 ml, a battery weighing 3 g with a volume of likewise 1 ml, electrical control components with a weight of 3 g and a volume of 0.5 ml and 0.1 g of a hydrogel as the swellable substance, which is present in a swellable substance chamber (weight of the swellable substance chamber with hydrogel filling: 1 g) with a volume of approx. 1 ml. A volume of close-on 7.5 ml and a weight of close-on 12 g therefore result for the functions. If these components are integrated into a housing with a volume of 25 ml and its own weight of 12 g, a device weight per volume of active compound of 24 g ÷ 1.8 ml = 13.3 g/ml and a device volume per volume of active compound of 25 ml ÷ 1.8 ml = 14 results for the device. Significantly more favourable device weight per volume of active compound ratios and device volume per volume of active compound ratios can therefore be achieved with the invention than known from the prior art mentioned above by way of example.

Fig. 1 shows a first embodiment example of a system 1 according to the invention with a swelling agent dispenser 2 and a swellable substance cartridge 3. The swelling agent dispenser 2 is equipped with a micropump 4 which is driven by an electric motor and is electrically operated and controlled with the aid of an electronic control circuit 5. The control circuit 5 and micropump 4 are supplied with current by a battery (not shown), which can be replaced. Both embodiments with rechargeable and those with non-rechargeable batteries are conceivable. An electrical connection (not shown) or inductive means (not shown) can be provided on the swelling agent dispenser 2 for wireless or wired recharging of the battery. The control circuit 5 can be operated via a keypad 6 of the swelling agent dispenser 2, e.g. in order to

program it. Alternatively or in addition, it is also conceivable that the control circuit 5 receives wired or wireless control signals, e.g. from a sensor (not shown). The micropump 4 is connected via a channel 8 to a swelling agent reservoir 7, in which swelling agent is held in reserve. Via the channel 8, the micropump 4 can remove the swelling agent from the swelling agent reservoir 7 and deliver it via a further channel 9 to a swelling agent release point 10 of the swelling agent dispenser 2.

Fixing means 11 are moreover provided on the swelling agent dispenser 2, via which the swellable substance cartridge 3 can be connected to the swelling agent dispenser 2 by means of corresponding fixing means 12 of the swellable substance cartridge 3. The swellable substance cartridge 3 contains a swellable substance chamber 13 which is filled completely with swellable substance and is closed off with a flat transportation layer 14 and a flat filter 15 on top of this on the one side and on the other side with a separating membrane 16 and a barrier membrane 17 joined to this in a laminate-like manner. The separating/barrier membrane laminate 16, 17 separates the swellable substance chamber 13 from an active compound chamber 18, which contains an active compound to be dosed, e.g. insulin.

In the assembled state of the swellable substance cartridge 3, the filter 15 lies on bridge-like support means 19 of the swelling agent dispenser, so that air chambers 20 are formed between the bridges 19. The release point 10 of the swelling agent dispenser 2 leads into one of these air chambers 20. During operation of the micropump 4 the swelling agent is delivered to the release point 10 and passes from there on to the filter 15 of the swellable substance cartridge 3 and through the filter 15 into the transportation layer 14, where it is distributed over the surface of the transportation layer 14 and arrives at the swellable substance. This swells and displaces the separating 16 and barrier membrane 17 into the active compound chamber 18, from which active compound is consequently displaced and emerges at an active compound release point 21 of the swellable substance cartridge 3. Fig. 3 shows the same system as in Fig. 1, but with an emptied active compound chamber 18.

A system similar to the system of Figures 1 and 3 is shown in Fig. 2. However, the fixing means here are not catch means 11, 12, but a door 22, which is hinged on to the swelling agent dispenser 2 by means of a hinge 23 and exposes or covers a shaft for the swellable substance cartridge 3. It is also conceivable to provide a charging station into which the swelling agent dispenser 2 can be inserted in order to recharge the battery. Such a charging station can also serve to top up the swelling agent reservoir.

A further system similar to the systems in Figures 1 to 3 is shown in Fig. 8. Here the swelling agent reservoir 7 is integrated into the swellable substance cartridge 3. The fluidic micropump 4 removes the swelling agent from the swellable substance cartridge 3 at one point and introduces it back into the swellable substance cartridge 3 at another point. A venting hole 34 in the swellable substance cartridge 3 is also shown in Fig. 8, which ensures that the swelling agent reservoir can empty properly.

A diagram of the construction of a swellable substance chamber 13 filled with swellable substance is shown in Fig. 4. The swellable substance chamber 13 has a filter 15 in the form of a polyester net with a mesh width of e.g. 40 μιτι and an elastic separating membrane 16 of thermoplastic elastomer film, which are welded to the two flat sides of a ring 24 of polypropylene and close this off. The inside of the swellable substance chamber 13 created in this way is filled completely with superabsorber granules (produced e.g. by BASF, Evonik or Sumitomo) as the swellable substance.

In one test, doubly distilled water (DI water) as the swelling agent is fed at intervals of time of approx. one hour to the swellable substance chamber 13 shown in Fig. 4 in order to measure the swelling dynamics. The test set-up is shown in Figure 5. The swellable substance chamber 13 is mounted on the upper edge of a glass flange 25 filled with water and is fixed with clamps 26. The water is directly adjacent to the elastic membrane of the hydrogel actuator. An O-ring 27 between the edge of the glass flange 25 and the separating membrane 16 prevents the water from escaping at the sides. The water can escape only via an opening 28 in the vicinity of the base

of the glass flange 25 via a hose 29 and a valve 30, into a glass beaker 31 standing on a balance 32. The glass beaker 31 is partly filled with water and the surface of the water is covered with paraffin oil 33, in order to prevent water loss by evaporation.

The DI water is trickled with the aid of a pipette on to the filter 15 and enters through the filter 15 into the swellable substance chamber 13, where it is absorbed by the swellable substance present therein. The swellable substance swells and arches the elastic separating membrane 16. This leads to a reduction in volume in the glass flange 25. A volume of water corresponding to the reduction is displaced via the opened valve 30 into the glass beaker 31. The volume of water displaced can be concluded with the aid of the increase in weight measured by the balance 32.

The test results are shown in Figure 6, the horizontal axis indicating the course of time t in hours and the vertical axis indicating the weight m displaced in grams, while the DI water is metered to the swellable substance actuator in units of 0.2 ml, 0.5 ml and 1.0 ml. The dynamics of the absorption of water by the swellable substance here are high (swelling rate > 400 µl/hour). Thereafter, a relevant change in volume of the swellable substance chamber 13 is no longer to be detected. The adverse ratio of water displaced (vertical axis) to swelling agent fed in (values in parentheses) is due to the fact that in the test the filter 15 also arches outwards, in addition to the elastic separating membrane 16. The filter 15 is not ideally rigid and must therefore be supported. Support means 19 for the filter 15 are therefore provided in the embodiment examples of the system which are described above. They ensure that the filter 15 is adequately supported. Only if the filter 15 is adequately supported or sufficiently rigid can the active compound solution be metered with a good ratio of output volume to intake volume.

The experimentally determined counter-pressure dependency of the increase in volume of the swellable substance chamber 13 is shown in Figure 7. For this test, the same amount of liquid was fed to 5 identical swellable substance chambers 13 under different counter-pressures. After 4 hours, the volume displaced by the separating membrane 16 was measured. In the figure, the horizontal axis indicates the counter-

pressure p in bar and the vertical axis indicates the weight m in milligrams displaced by the separating membrane 16 of the swellable substance chamber under this counter-pressure. It can be clearly seen that the volume displaced does not fall below the value in load-free fall up to a counter-pressure of approx. 1 bar.

The combination of fluidic actuator and swellable substance described provides volume work. In this context, the volume work which the fluidic actuator has to achieve is preferably kept low. As a result, the electrical energy consumption of the fluidic actuator can advantageously also be kept low. The swellable substance actuator absorbs the volume of swelling agent provided by the fluidic actuator and generates the necessary pressure. It can be seen from Figure 7 that a volume e.g. of 0.7 ml (= 0.7 cm^3) can be displaced up to a pressure of close-on 1 bar. This corresponds to a volume work of

$$W = p\,V = 100\ \text{kPa} \cdot 0.7\ \text{cm}^3 = 0.07\ \text{J}$$

The fluidic actuator must transport the same volume V = 0.7 cm^3, however, under a significantly lower counter-pressure. For example, a flow rate of 1.5 ml ÷ 24 h = 0.0625 ml/h may be assumed. A connecting line between the fluidic actuator and hydrogel actuator could be a straight tube with an internal diameter of 0.4 mm and a length of 40 mm. With a dynamic viscosity of 10^{-3} Pas, according to the Hagen-Poiseuille a counter-pressure of

$$p = \frac{8 \cdot \eta \cdot l}{\pi \cdot R^4} q = \frac{8 \cdot 10^{-3}\ \text{Pas} \cdot 40\ \text{mm}}{\pi \cdot (0.2\ \text{mm})^4} \cdot 0.0625\ \text{ml/h} = 1.1\ \text{Pa}$$

is achieved.

The volume work which the fluidic actuator has to perform is accordingly

$$W = p\,V = 18\ \text{Pa} \cdot 0.7\ \text{cm}^3 = 8 \cdot 10^{-7}\ \text{J}$$

Compared with the fluidic actuator, the hydrogel actuator consequently performs approx. 90,000 times the volume work.

The features disclosed in the above description, the claims and the drawings can be of importance both individually and in any desired combination for realizing the invention in its various embodiments.

Claims:

1. System (1) for generating a volume work which can be driven by a swellable substance, preferably for delivering a medicinal active compound, which comprises:
a swellable substance chamber (13) filled with the swellable substance, a swelling agent reservoir (7) which can accommodate a swelling agent for swelling the swellable substance, and
a fluidic transportation device (4) which can feed the swelling agent to the swellable substance from the swelling agent reservoir (7), **characterized in that**
the fluidic transportation device (4) can be directly or indirectly electrically driven.

2. System (1) according to claim 1, **characterized in that**
the fluidic transportation device (4) is a pump which is arranged downstream of the swelling agent reservoir (7) in the direction of flow of the swelling agent in order to deliver the swelling agent to the swellable substance from the swelling agent reservoir (7).

3. System (1) according to one of the preceding claims, **characterized in that**
it comprises control means (5) in order to control the delivery rate of the fluidic transportation device (4).

4. System (1) according to one of the preceding claims, **characterized in that**
the swellable substance chamber (13) is closed with a filter (15) which the swellable substance essentially cannot overcome, but through which swelling agent can be fed into the swellable substance chamber (13).

5. System (1) according to claim 4, **characterized in that**
the system (1) moreover comprises control means in order to counteract an arching of the filter (15).

6. System (1) according to one of the preceding claims, **characterized in that** a capillary stop is arranged in a fluid connection (9) for feeding the swelling agent to the swellable substance.

7. System (1) according to one of the preceding claims, **characterized in that** the system (1) comprises a swelling agent dispenser (2) and a swellable substance cartridge (3), wherein the swelling agent dispenser has electrical means for driving the fluidic transportation device (4) and the swellable substance cartridge (3) contains the swellable substance chamber (13) filled with swellable substance.

8. System (1) according to claim 7, **characterized in that**
the swelling agent dispenser (2) moreover comprises the fluidic transportation device (4) for transporting the swelling agent to a swelling agent release point (10) of the swelling agent dispenser (2).

9. System (1) according to claim 8, **characterized in that**
the swelling agent dispenser (2) comprises fixing means (11, 12) in order to connect the swellable substance cartridge (3) to the swelling agent dispenser (2) such that the swellable substance cartridge (3) can absorb the swelling agent released at the release point (10).

10. System (1) according to claim 7, **characterized in that**
the swellable substance cartridge (3) contains the fluidic transportation device (4).

11. System (1) according to one of claims 7 to 10, **characterized in that**
the swelling agent dispenser (2) moreover contains the swelling agent reservoir (7).

12. System (1) according to one of claims 7 to 10, **characterized in that**
the swellable substance cartridge (3) contains the swelling agent reservoir (7).

13. System (1) according to one of claims 7 to 12, **characterized in that** the swellable substance cartridge (3) comprises an active compound chamber (18) which cooperates with the swellable substance chamber (13) such that an increase in volume of the swellable substance chamber (13) leads to a decrease in volume of the active compound chamber (18).

14. System (1) according to one of the preceding claims, **characterized in that** it is equipped with a level sensor.

15. Swelling agent dispenser (2) for feeding a swelling agent from a swelling agent reservoir (7) to a swellable substance cartridge (3) which can be connected to the swelling agent dispenser (2), wherein the swelling agent dispenser (2) comprises electrical means for electrical driving of a fluidic transportation device (4).

16. Swellable substance cartridge (3) for performing a volume work, driven by a swellable substance, wherein the swellable substance cartridge (3) comprises a swellable substance chamber (13) filled with the swellable substance.

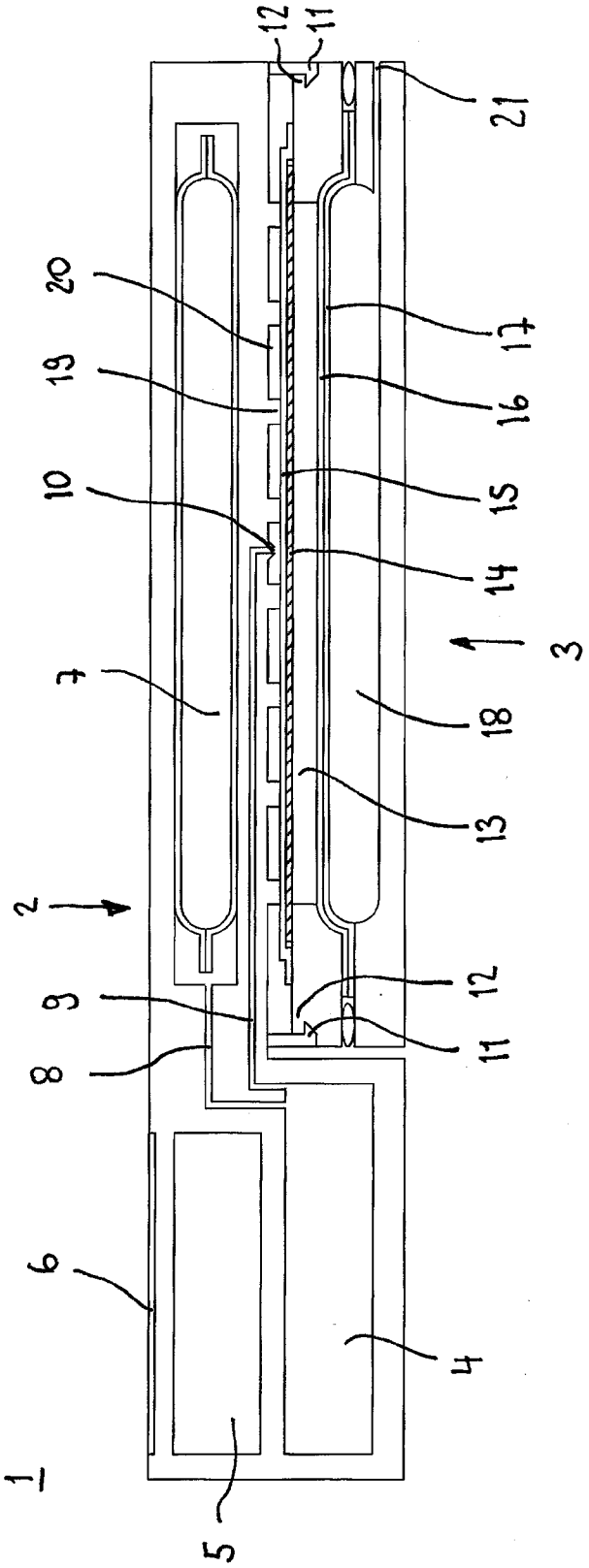


Fig. 1

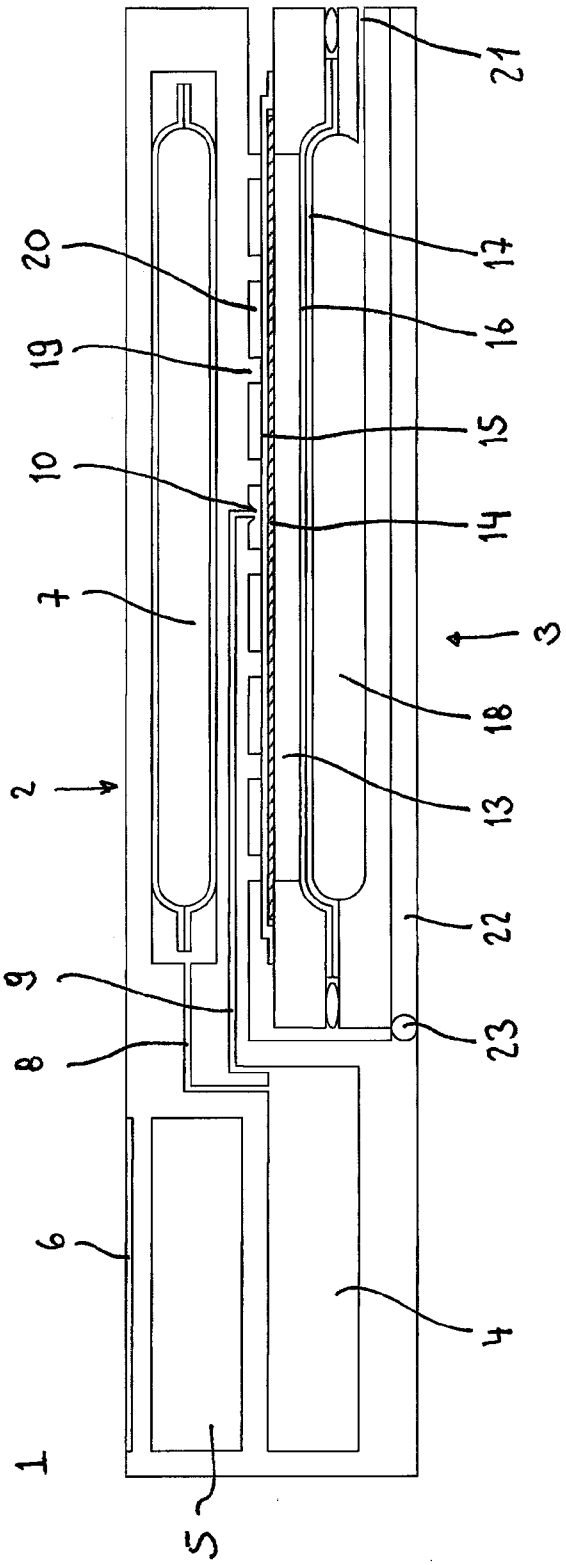


Fig. 2

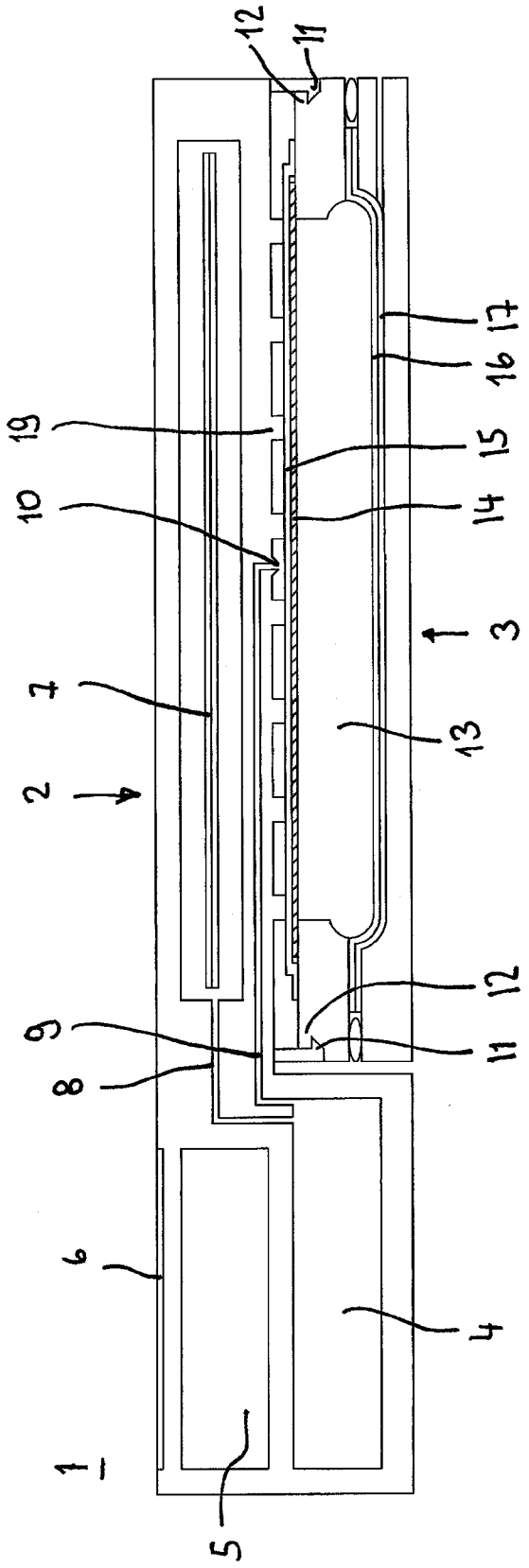


Fig. 3

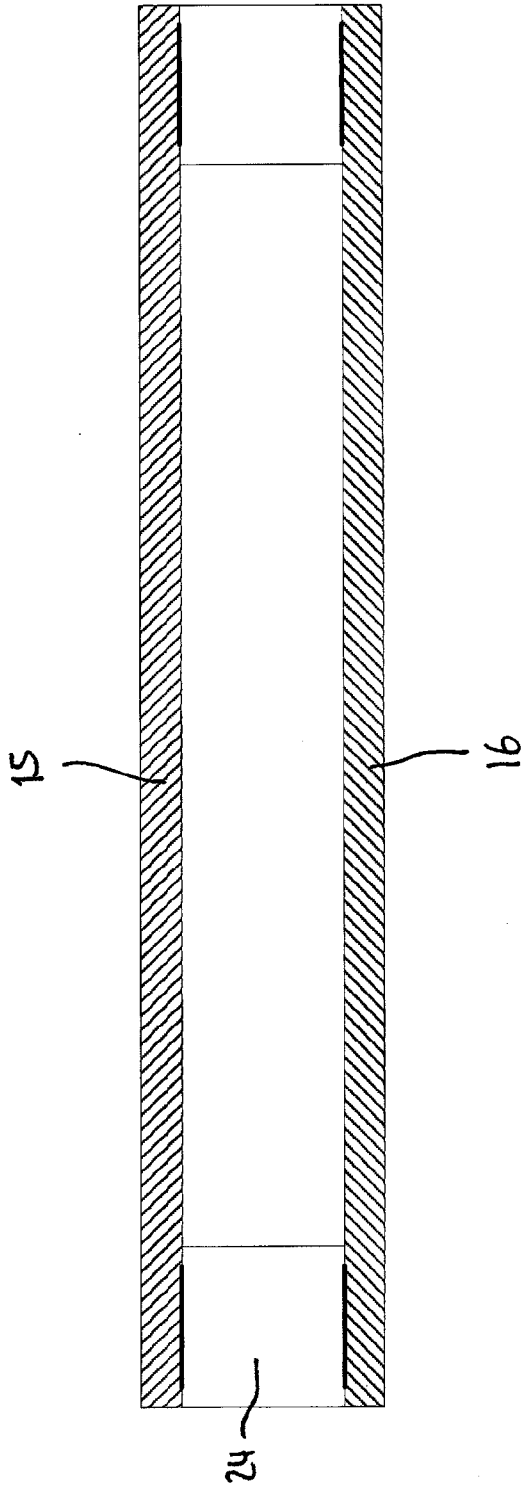


Fig. 4

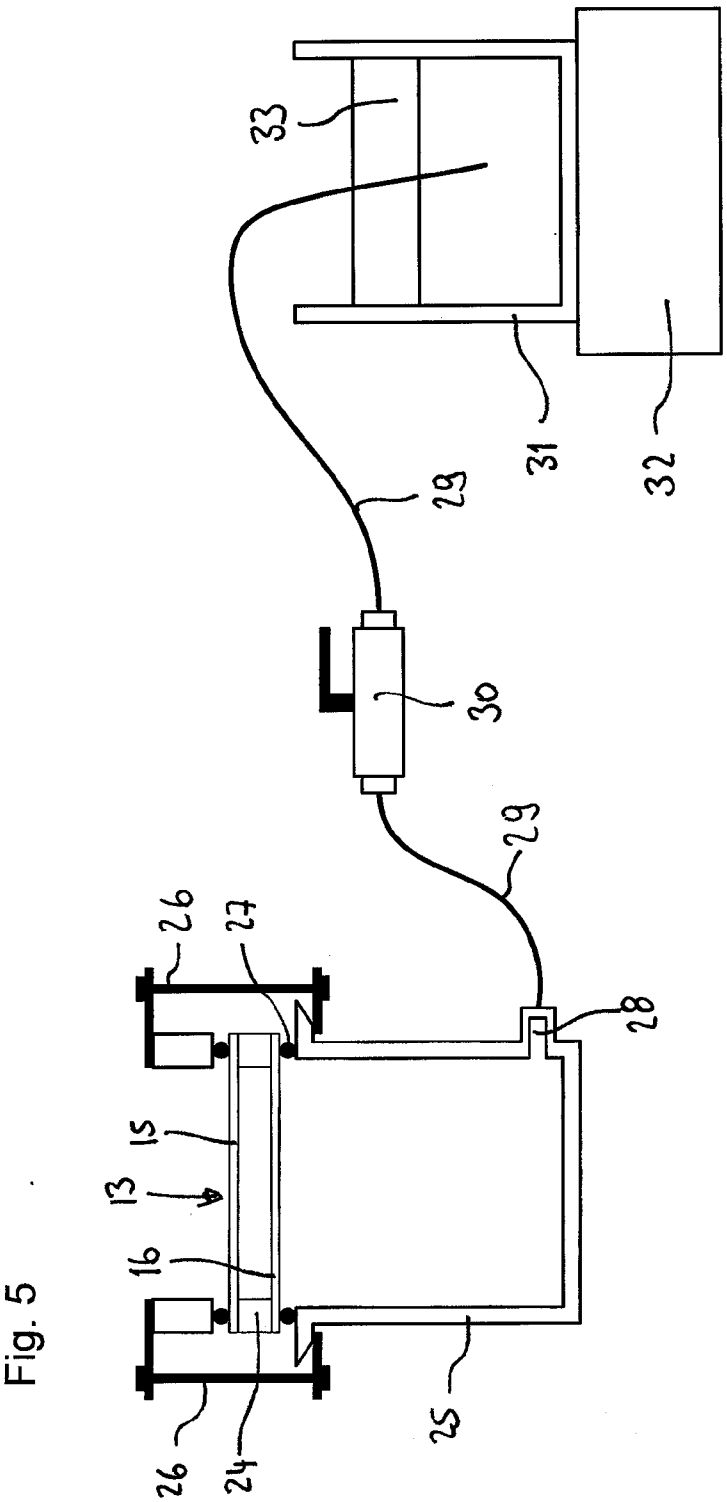
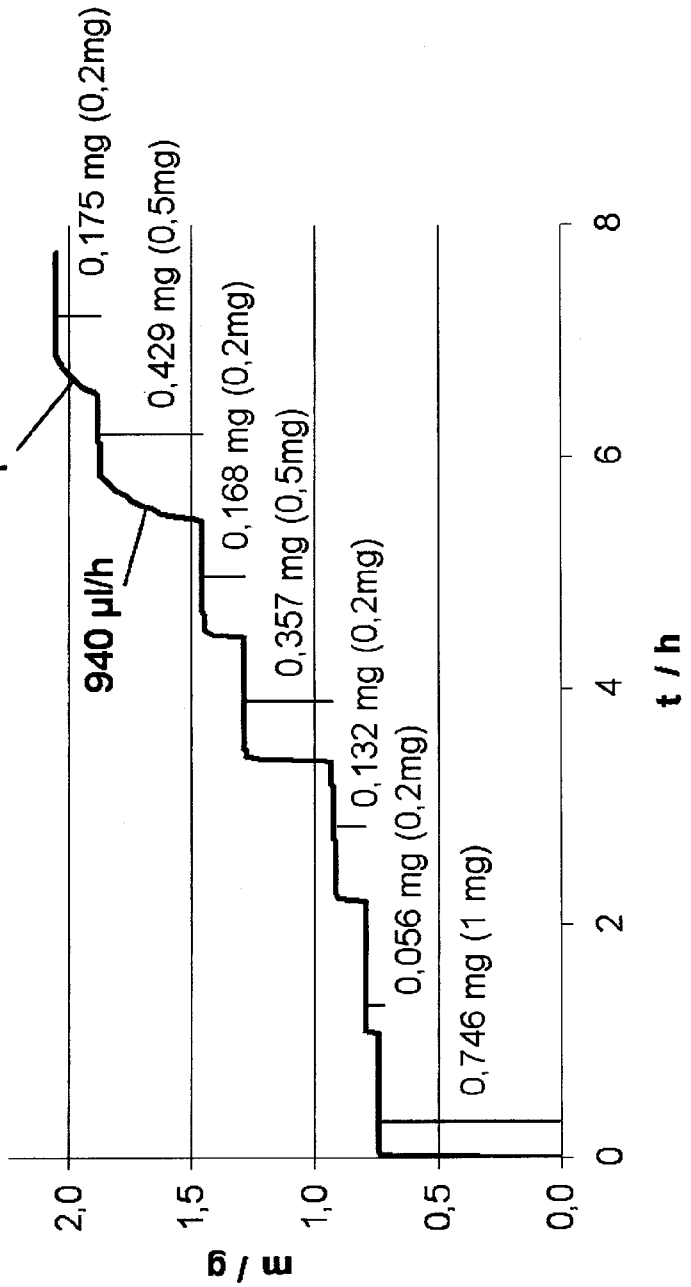


Fig. 5

Fig. 6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940 µl/h
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0,429 mg (0,5mg)
0,168 mg (0,2mg)
0,357 mg (0,5mg)
0,132 mg (0,2mg)
0,056 mg (0,2mg)
0,746 mg (1 mg)
m / g
t / h
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1,5
1,0
0,5
0,0
0
2
4
6
8

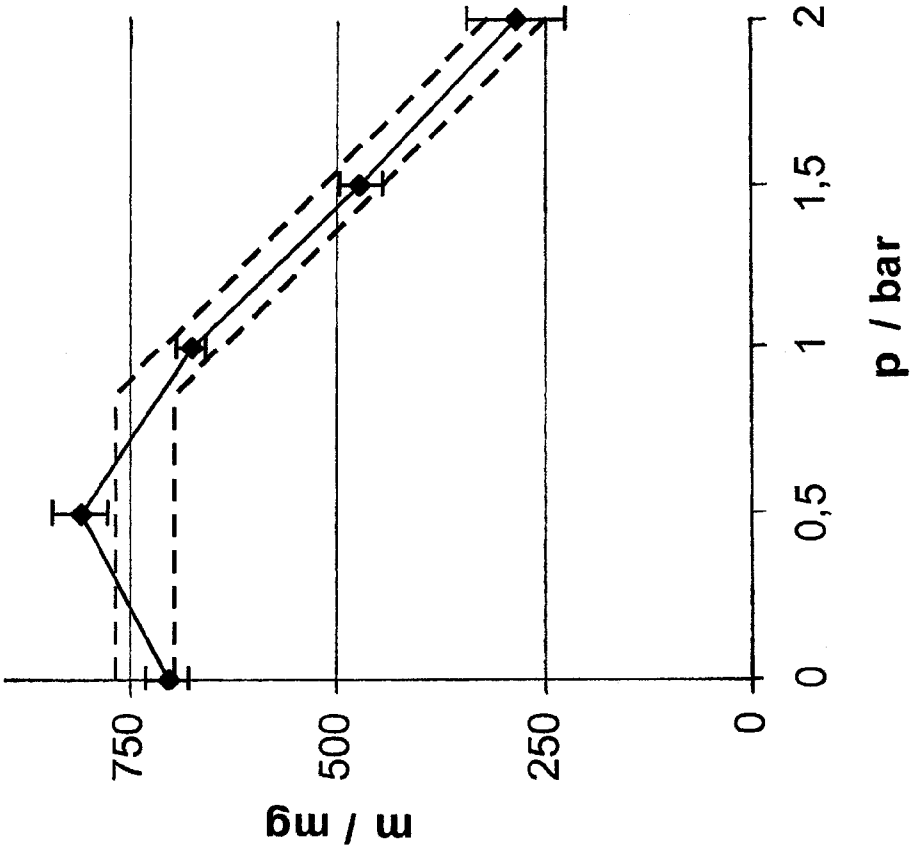

Fig. 7

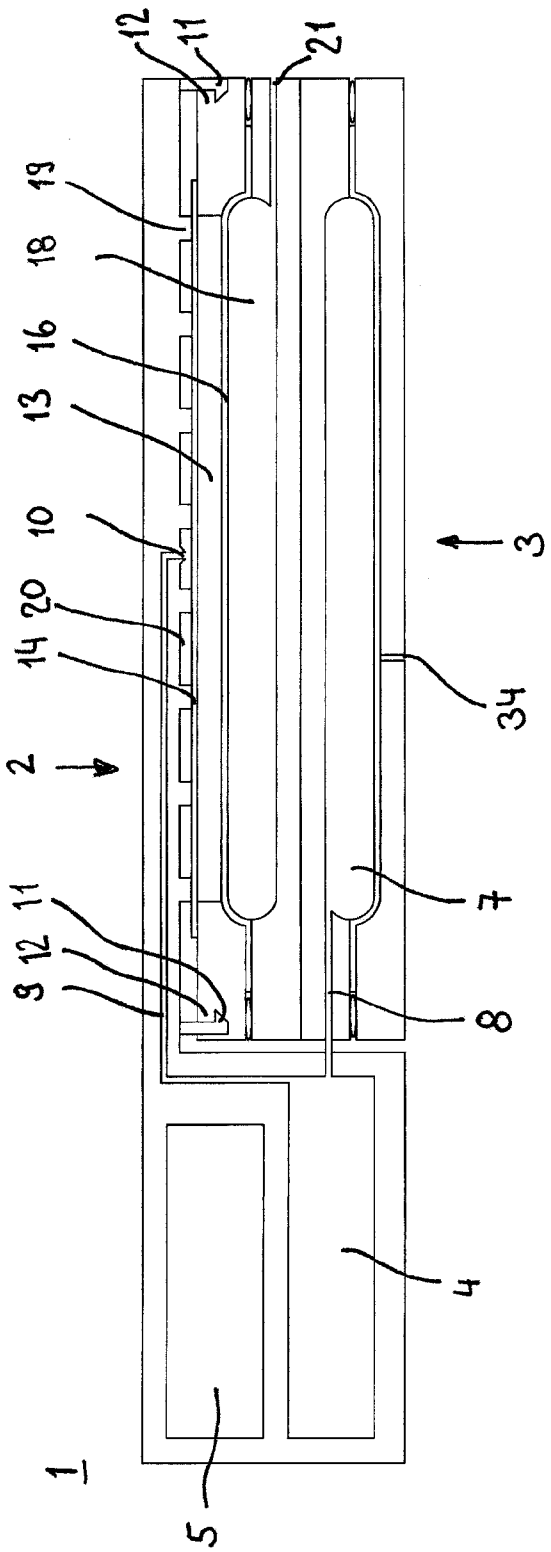

Fig. 8