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DATA SHEET LS Electrolysis Free Micropump

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Osmotex' has launched the first version of an electroosmotic micropump with integrated electrodes capable of pumping a wide range of ionic solutions while suppressing electrolytic reactions of the liquid pumped. This is possible as the pump can operate below the electrolysis voltage of the liquid, and care must be taken to stay below this level for the selected liquid.

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Ordering Information

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General

Osmotex' electroosmotic (EO) pumps have the following advantages:

- Very compact disc-shaped design, typical dimensions Ø15mm, thickness 2-4mm
- Do not create gas bubbles in flow path given a certain counter pressure (some versions)
- Reduced influence of electrochemistry
- Low power
- Silent
- Low cost, suitable for volume applications

Osmotex develops advanced EO pumps with strongly reduced influence of electrochemistry and bubble formation, when used in the correct way. Electrochemical reactions should still be considered when considering new liquids.

While Osmotex' standard products cover a wide range of power, flow rates, liquids and other conditions, Osmotex can also develop customized solutions when needed.

Standard pumps are delivered un-calibrated. Like for other EO pumps, the flow – pressure – voltage characteristics depends on the liquid used. Osmotex also offers robust solutions with flow-sensor feedback control.

Typical Performance LS Electrolysis Free Micropump

Operating voltage: 0 – 5 V, depending on aqueous solution (for alcohols, up to 20V)
Pressure: up to ca 0.75 PSI
Flow rates: up to ca 80 µl / min
Power consumption: 0.5 - 10 mW

Flow direction: towards negative electrode.

"Electrolysis – Free" Operation

Osmotex LS Electrolysis free pump is unique in its ability to pump a range of ionic solutions without electrolytic reactions and gas evolution being obstructive. This comes at the expense that the flow must be reversed frequently, typically every 20 to 180 seconds. When a uni-directional flow is desired (as in most applications), a flow-rectifier must therefore be applied (Please see below about solution offered by Osmotex).

The electrolysis-suppressing mechanism eliminates the need of open reservoirs for gas – venting as well as the presence of gas bubbles in the liquid flow. It also makes it possible to handle liquids normally not possible for EO pumps with integrated electrodes (Standard EO pumps would create electrolysis, whilst ACEO and ICEO pumps are limited to lower concentrations and also normally gives orders of magnitude lower pressures).

Package and Measures

Shape: Circular disc
Diameter: 14 mm
Thickness: 1.8 mm

Despite different characteristics, all Osmotex micropumps are embedded in the same type compact plastic package. These "Pump Cores" (figure 2) do not include fluidic and electric connectors, but can be interfaced with various lab-chips, connectors and other equipment.

Osmotex also offers an evaluation package with fluidic and electric connectors (see Appendix).

Figure 1: **Osmotex micropump "Core". The liquid flow generated is perpendicular to the clover-shaped area in the disc center.**

Geometry and Interfacing with Connectors

In the following is included information necessary to design fluidic and electrical connectors. The clover shaped area in the centre must be available for liquid flow, while the area around can be used for sealing. For example, a flat rubber gasket with diameter large enough to encircle the clover can be pressed against the Pump Core.

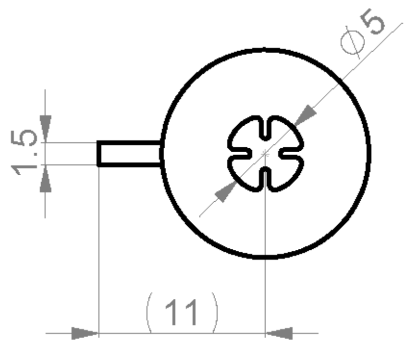

Figure 2: Top/bottom view.

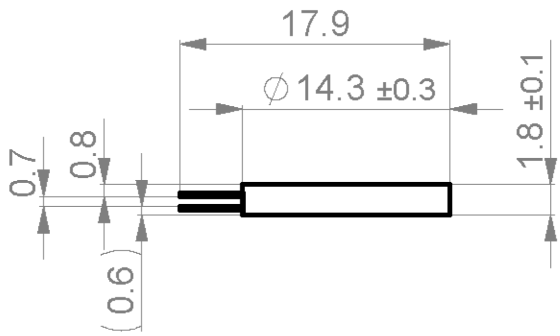

Figure 3: Side view.

Other Diameters

The standard version has electrode diameter 6mm (open flow diameter 5 mm as shown on figure). Osmotex also offer versions with diameters 4 and 8 mm, with maximum flow rates approximately half and double that of the standard version, respectively.

Sealing

The micropump can be interfaced with fluidic connectors using a gasket, for example made of a rubber such as NBR, FKM or (for less deformation) EPDM. It is important that the rubber does not block the gas venting holes and that the gass is allowed to pass to the atmosphere.

Geometry – Future Version with Integrated Electrical Connectors

Osmotex plans to launch a version of the micropump with electric connectors on the top face of the disc shaped Pump Core. This will provide a more compact design without leads sticking out from the periphery. The exact measures of the product might differ from the provisional measures presented in this section.

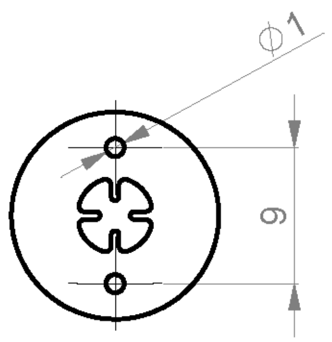

Figure 4: Top view, integrated connectors (provisional measures).

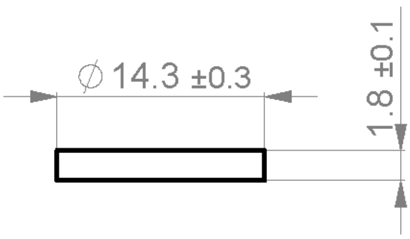

Figure 5: Side view, integrated connectors (provisional measures).

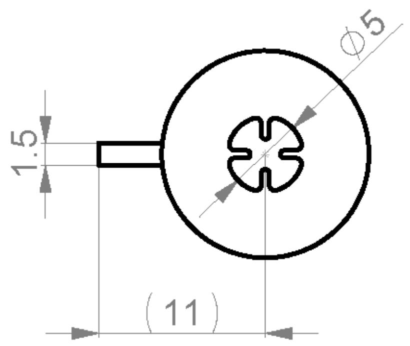

Figure 6: Bottom view, integrated connectors (provisional measures).

Application notes

Filling and Flushing

The pump can be primed by using a syringe while taking care not to inject air to the pump or applying excessive pressure.

To obtain stable flow, there should be a constant water level in the inlet reservoir.

NB Electroosmotic pumps cannot suck air and are not self priming.

Liquids

DI water and a range of ionic solutions and alcohols can be pumped. Possible electrochemical reactions should be taken into account when selecting a fluid.

Flow direction: towards positive electrode.

"Electrolysis Free" Operation – Regeneration Modes

Osmotex Electrolysis free Micropump has palladium electrodes to avoid catalytic bubble formation. Hydrogen will under many circumstances act as the main positive current carrier, and the storage capability of palladium eliminates the formation of hydrogen bubbles at the cathode. The pump should always be operated with (very) low frequency AC voltage in order to avoid emptying or overfilling either hydrogen storing electrode. Further, the current should never be so high as to result in surface filling (over saturating the electrode surface with hydrogen, leading to damage). A dual polarity square pulse signal with variable duty-cycle can be used. In order to stay within these safe conditions, the current should be electronically monitored and voltage amplitude and direction adjusted as necessary (e.g. change direction of voltage before one electrode is over filled or emptied). A less sophisticated control system might be used (e.g. applying pulses of equal amplitude and duration but opposite sign), however the pump lifetime and performance will be reduced.

Max charge storage capacity of each electrode: ca 8 Coulomb (2.2 mAh).

Critical current for surface filling of hydrogen storing electrode: ca 40 mA.
Recommended max current: 10 mA.

To increase the hydrogen filling: use ethanol or methanol as working fluid and apply 5 to 10V. The resulting electrolysis will create more hydrogen ions which are stored in the cathode.

For aqueous solutions the pump should be operated at a low enough voltage to avoid undesired anodic reactions. It is therefore recommended to apply a voltage below 2.0 V for pumping DI water (to avoid O_2 formation) and below 1.3 V for NaCl solution to avoid the formation of chlorinated compounds. Higher voltages could cause gas bubbles blocking the channel, or create compounds detrimental to the application or micropump. Low voltage AC operation leads to concentration polarization, with resulting fast declining flow over several seconds. Therefore, the pulse length should normally be between 10 seconds to 2 minutes for aqueous solutions. For symmetric Pump Cores this results in zero net flow. Osmotex' valve system and electronic control system can be used to rectify the flow, resulting in a uni-directional flow. Typical flowrates are up to several µl/min for aqueous solutions (0.5 to 2.5 V), and up to several tens of µl/min for alcohols (up to 20 V).

Electrode Run-In

During the initial half-cycle, hydrogen will be generated and stored in the negative electrode (cathode). It is recommended to pre-fill with up to 80% of the total capacity, and then move an amount of charge corresponding to 60% of the total charge in subsequent half-cycles of a low frequency square pulse signal. This leaves a margin of 20% from over-filling an electrode.

Osmotex electronic control unit OPC-20 handles the flow reversals automatically, and can simultaneously control a valve system assuring uni-directional flow in synchronization (se below).

Precaution

The pump should not be run at higher voltages than 15 V (20V for low conductivity liquids such as ethanol, methanol) and should never be allowed to run dry, as this could lead to breakdown of the electrodes and porous pump structure.

Customized Solutions

Osmotex can engage in application specific development for producers of end user equipment. Our broad expertise in electrokinetics and microfluidics makes us ready to meet most challenges, whether the need is a simple pump with package, a robust design with flow rate feedback control, or the integration of several pumps on a chip.

Appendix

Auxiliary Equipment

Evaluation Package

Osmotex can deliver the LS Electrolysis free Pump embedded in an open reservoir evaluation package with standard fluidic and electrical connectors.

Figure 7: Closed evaluation package with fluidic and electric connectors (right) and its parts including the “Pump Core” (left). The fluidic connector has inner diameter 1.7 mm and outer 2.5 mm.

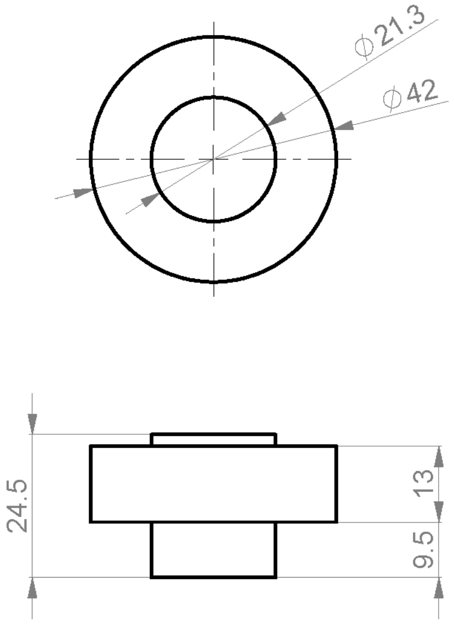

Figure 8: Osmotex' closed connector would fit into a cylinder as shown (top and side views).

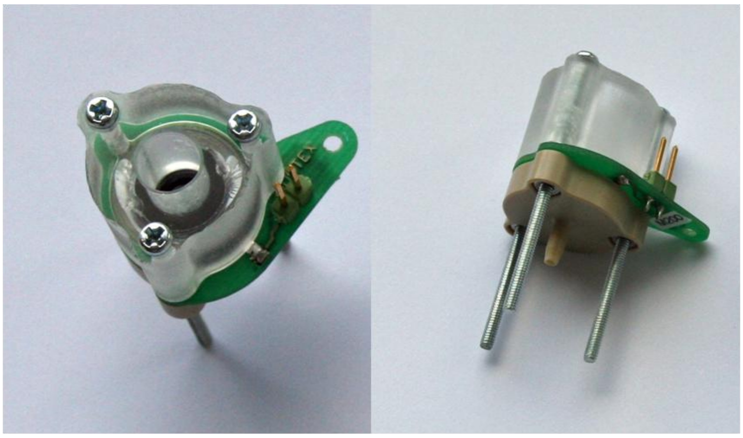

Figure 9: Evaluation package with fluidic and electric connectors and open inlet reservoir. The fluidic connector has inner diameter 1.7 mm and outer 2.5 mm.

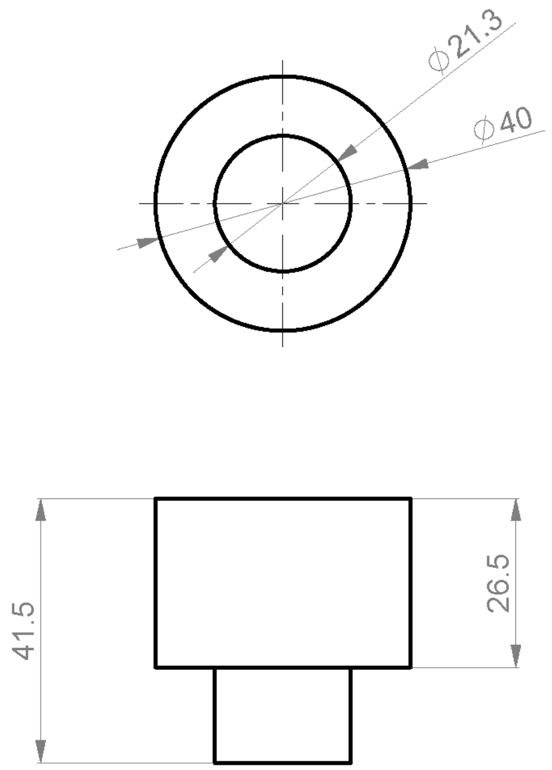

Figure 10: Osmotex' open reservoir connector would fit into a cylinder as shown (top and side views).

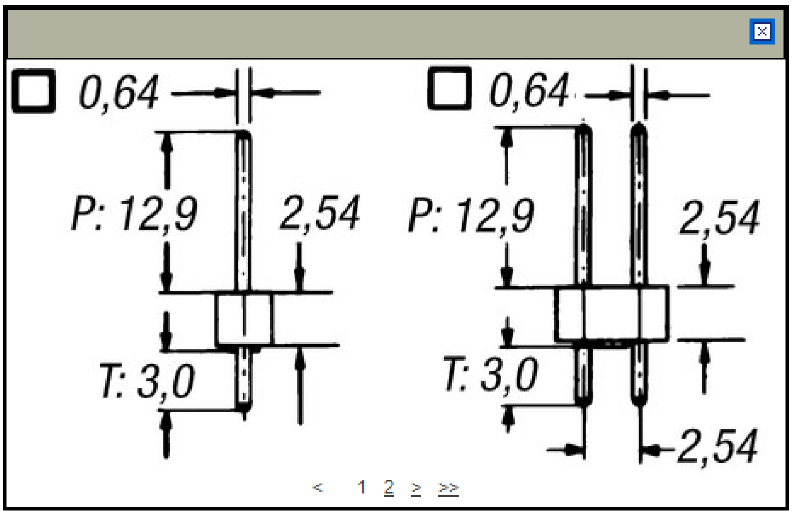

Figure 11: Electrical contact at connectors.

Electronic Control Unit

Osmotex OPC-20 electronic controller can be used for the following purposes:

- Programmable power supply for micropump operation (USB interface to PC)
- Controlling the reversal rate for bubble-free operation
- Automatic control of the valve rectifier system
- Flow feedback control (with flow sensor) for high precision flow

Flow Sensor Feedback Control System

Osmotex offers a solution with flow sensor for high accuracy pumping, see data section.

Valve Flow Rectifier

As the bubble-free micropump needs flow reversals at certain intervals, Osmotex developed a flow rectifier giving a uni-directional flow to the application. On figure 12, the right-pointing arrows indicate the directed flow, while the smaller double arrows show the pumping back- and forth. It might be further adapted to an indirect pumping system which is not dependent on limited reservoirs. Although the use of small passive valves was demonstrated to work well for several hours, passive valves are only considered to be reliable enough with future high pressure versions of the Pump Core. At the moment, standard electromechanical valves are used. Being bi-stable, the valves are only actuated at the moment of switching, resulting in low power consumption (at the level of the pump's) and less mechanical wear. The valves are controlled in synchronization with the pump by Osmotex electronic control unit.

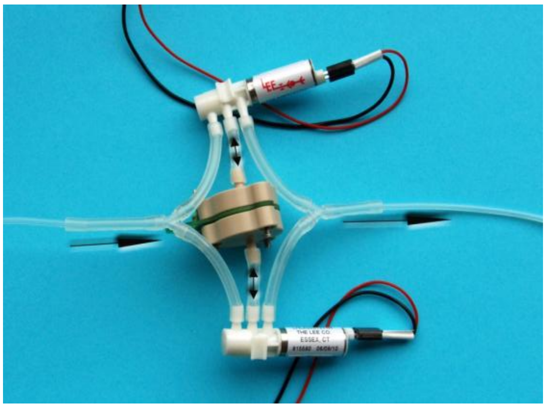

Figure 12: Flow-rectifying valve system.

High Precision Flow-Feedback System

Osmotex offers a flow-sensor feedback control system is based on Sensirion flow sensors.

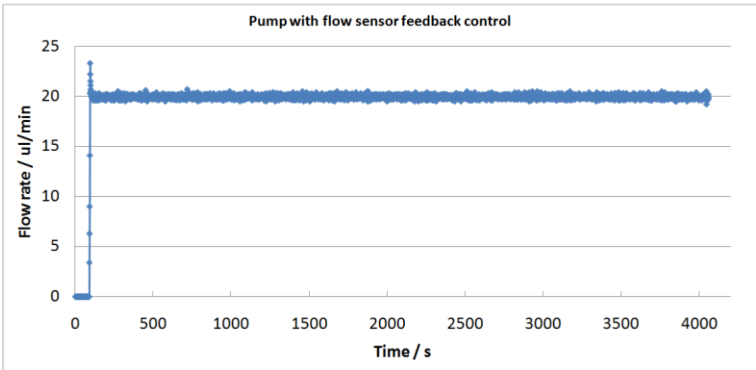

Figure 13: Flow sensor and high – precision flow with feedback loop.

Example Data (DI water and buffers)

The following liquid media have been tested:

- DI water
- Aqueous sugar based life science solutions (mannitol) which are typically used for cell and cell components studies in the life sciences (e.g. drug delivery to immobilized cells, the sugar in the supplied solution maintains the osmotic cell membrane pressure). Typical mannitol concentrations are 280 mM mannitol or diluted if required or tolerable by the application.
- Ionic aqueous buffer solutions PBS and TBE.
- The pumps were also successfully tested with 50 mM NaCl aqueous solution.

For applications without significant counter-pressure (“zero psi”), a stable and safe regime at 1-2 V operating voltage is preferred (less risk of gas evolution, longer electrode lifetime). To obtain higher pump pressures for certain applications, the pump may be run at higher driving voltages, e.g. 5 V. The next figures show performance for various liquids and voltages.

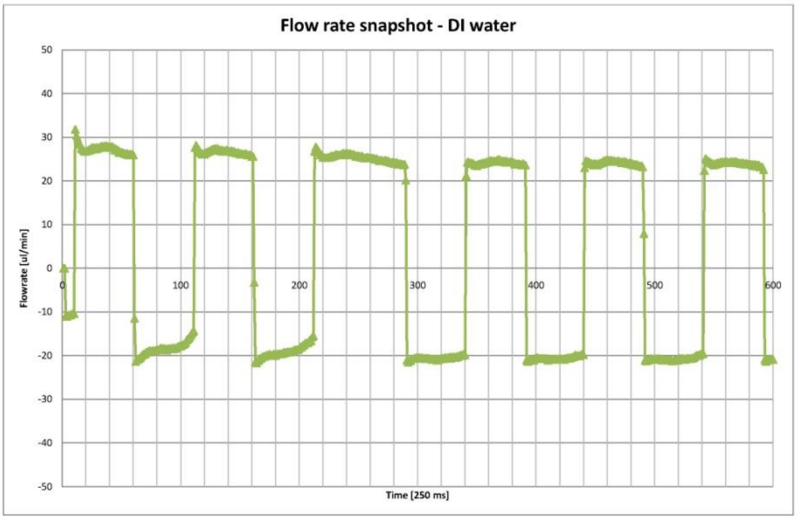

Figure 14: Pumping of DI water without flow rectification, using low frequency AC. Voltage: 5 V peak.

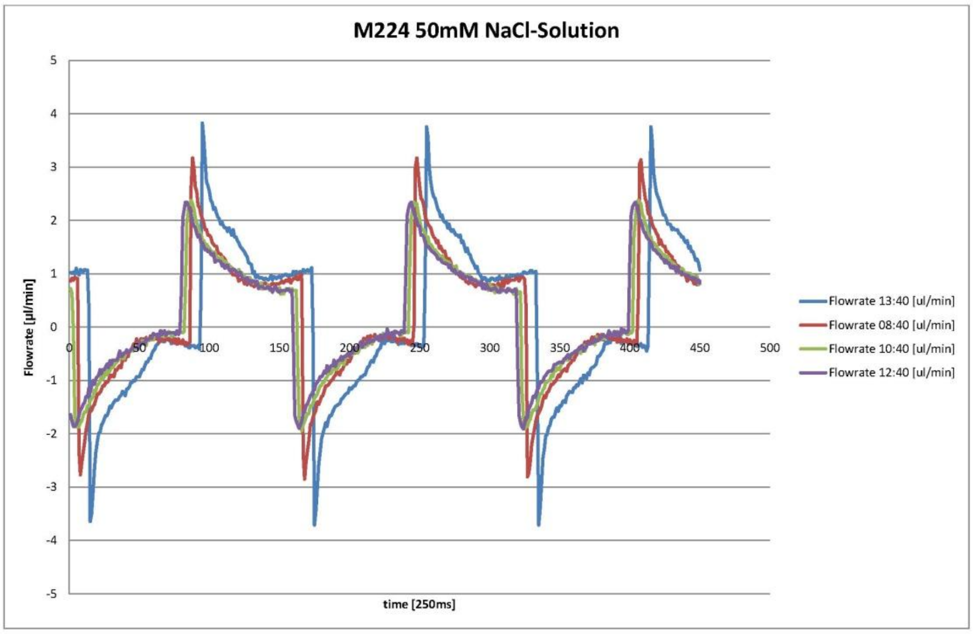

Figure 15: Pumping of 50 mM NaCl aqueous solution (4x superimposed snap-shots). Voltage: 1.1 V peak.

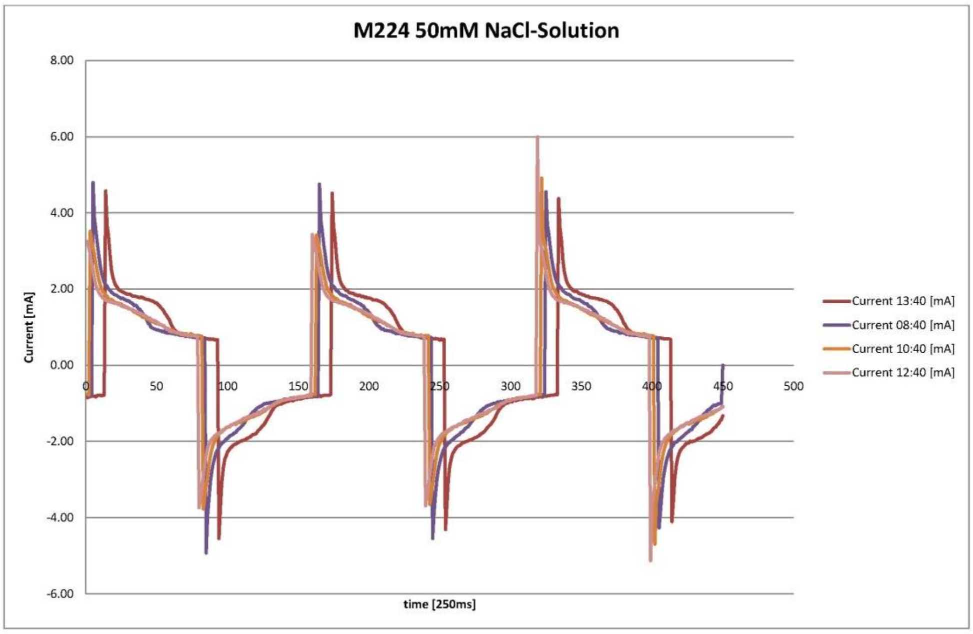

Figure 16: Electric current corresponding to flow plot in figure 2.

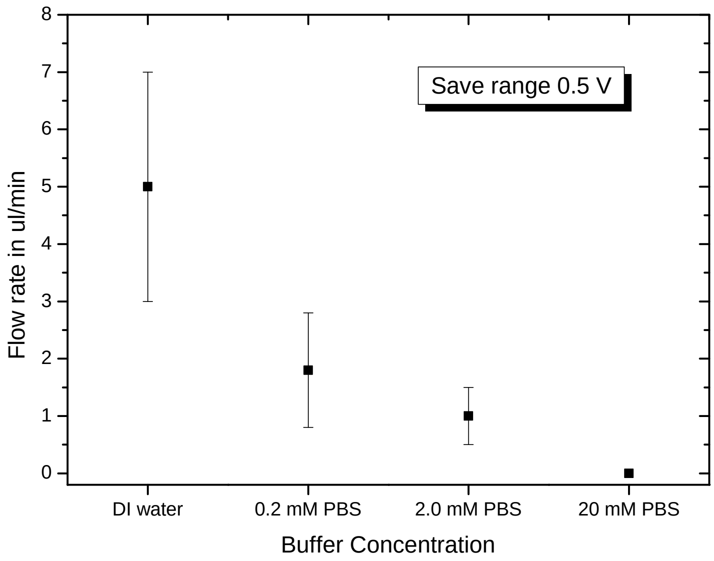

Figure 17: Flow rate versus buffer concentration at 0.5 V driving voltage for PBS buffer.

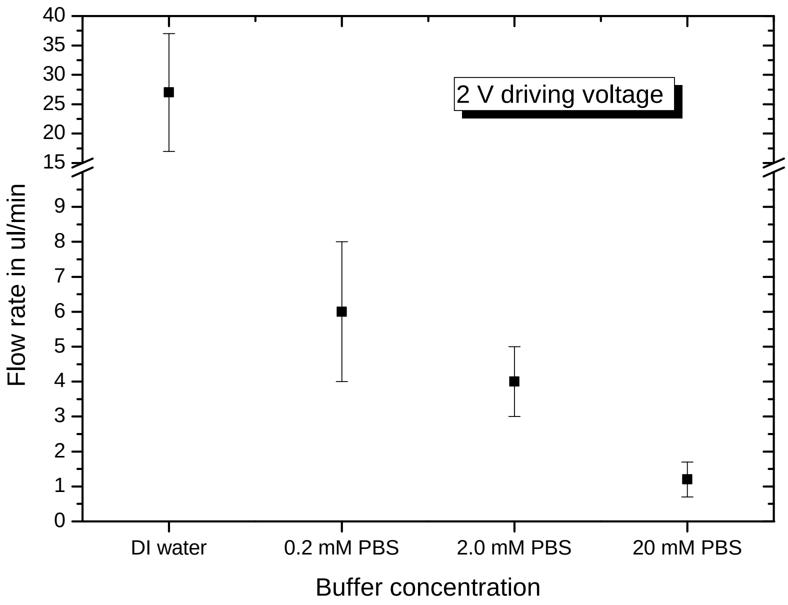

Figure 18: Flow rate versus buffer concentration at 2 V driving voltage for PBS buffer.

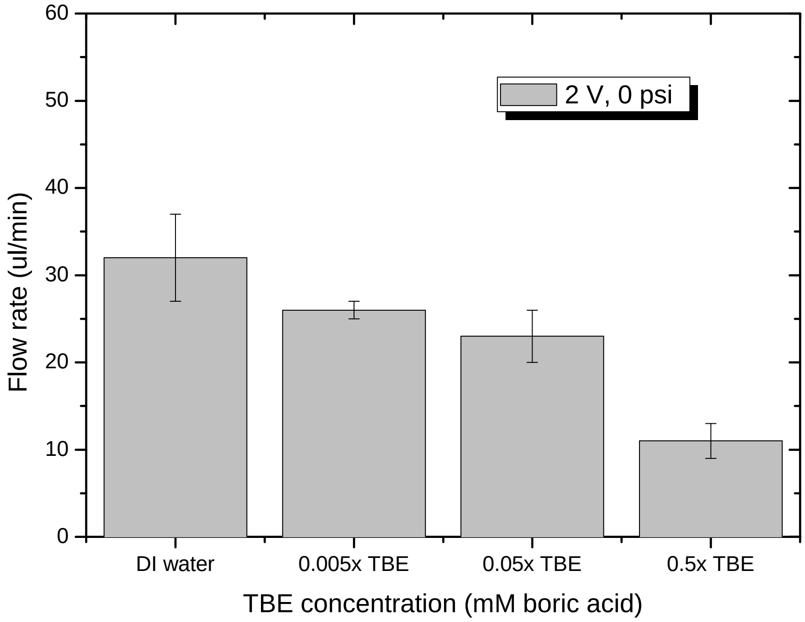

Figure 19: Flow rates for DI water and various TBE ionic buffer concentrations at 2 V square pulse cycle voltage and zero counter pressure.

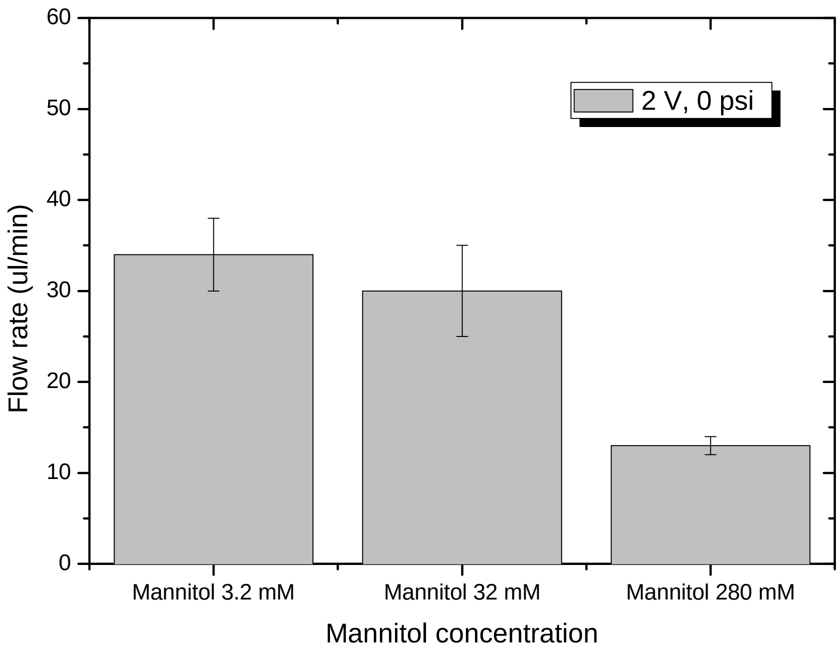

Figure 20: Flow rates for various mannitol buffer concentrations at 2 V square pulse cycle voltage and zero counter pressure.

For applications requiring the overcoming of counter pressures of 5 kPa (0.75 psi) at flow rates of 20 ul/min, a 5 V square pulse cycle for pump operation is recommended.

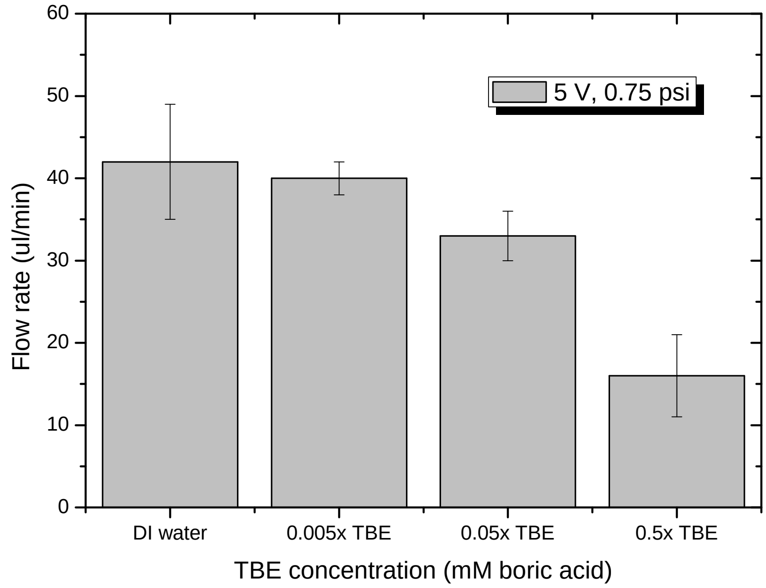

Figure 21: Flow rates for DI water and various TBE ionic buffer concentrations at 5 V square pulse cycle voltage and 0.75 psi (5 kPa) counter pressure. The concentration of 0.5x is a standard TBE buffer concentrations. In many applications, where no significant metabolic processes are taking place and no severe pH changing chemical reagents are used, diluted TBE concentrations may also be considered. Note that the driving voltage in the pressure tests (5 V) is higher than for pumping at zero counter pressure (2 V).

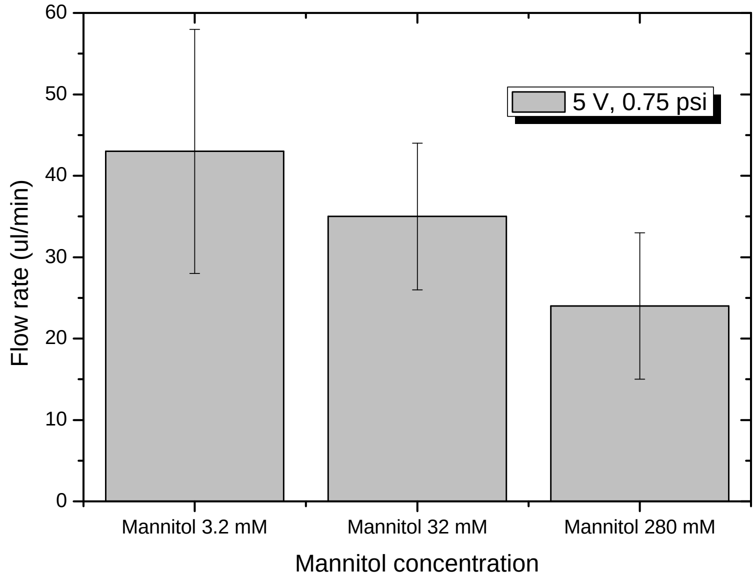

Figure 22: Flow rates for various mannitol buffer concentrations at 5 V square pulse cycle voltage and 0.75 psi (5 kPa) counter pressure. Note that the driving voltage in the pressure tests (5 V) is higher than for pumping at zero counter pressure (2 V).