Flow control

Which flow control solutions can Micronit offer to make your device work wonders?

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Senior R&D Scientist

Throughout the years, at Micronit we have developed a toolbox of flow control solutions that can be tailored for a wide range of applications. This application note will provide you with insights into how these flow control elements can be used.

Microfluidic flow control is a vital functionality in complex labs-on-chips. By making use of the right elements, you can be sure that all the necessary steps of your assay will take place in the correct order and at the exact time. Microfluidic flow control is essential in automated workflows and in autonomous labs-on-chips that work according to the 'sample in, answer out' principle. In this article, we will focus on the possibilities in polymer, as this is particularly relevant for disposable Point-of-Care products.

To select the right flow control elements, the first distinction that has to be made is if we have to deal with an actively driven flow control approach or if a more passive approach is in order. See also our 'Expert insight' on this topic.

Active flow control

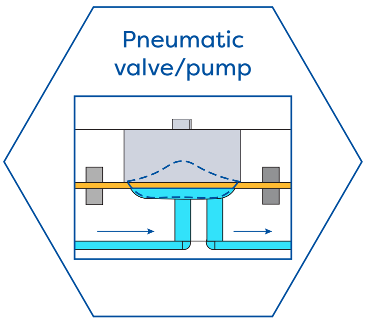
Active flow means that the flow is driven by external forces. Active flow control typically makes use of a flexible membrane in the architecture of the valve and pump elements that are integrated in the microfluidic chip. This flexible membrane causes a channel to close, and there are different ways to achieve this.

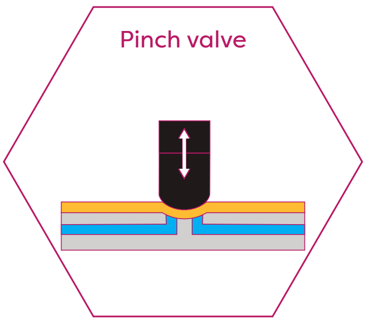
Our three most frequently used elements in this segment are:

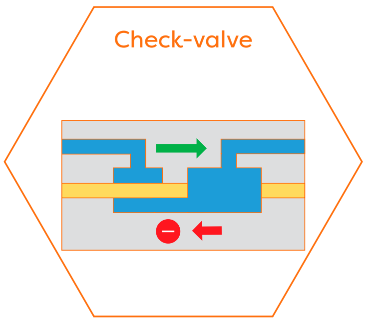
1 Pneumatic valve/pump

2 Pinch valve

3 Check-valve



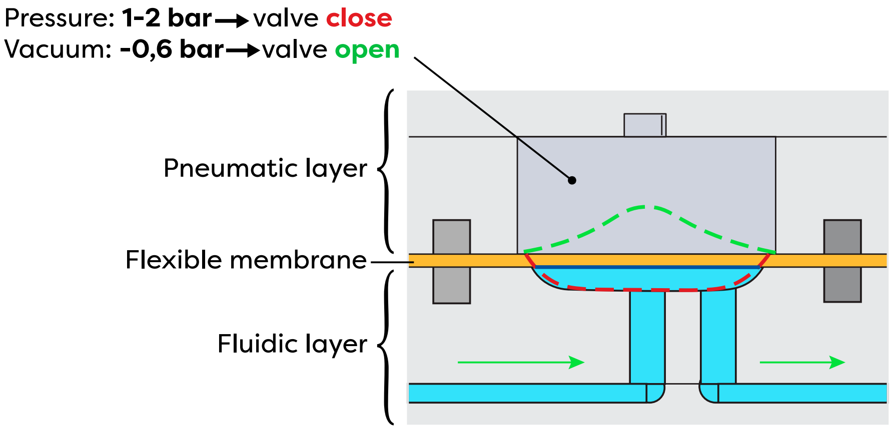


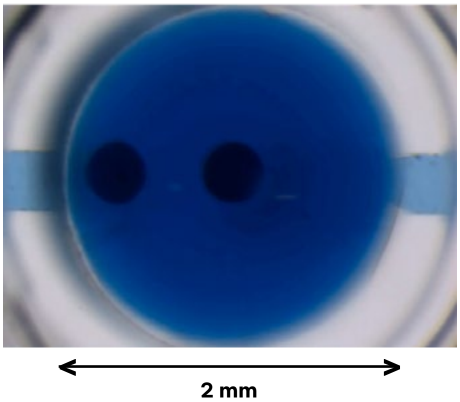


Let's zoom in on each of these solutions.

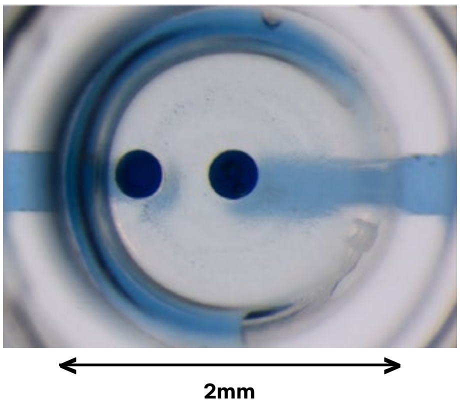
1 Membrane-based flow control: pneumatic valve/pump

In this module, the membrane is actuated by pneumatic pressure. Pressure differences cause the flexible membrane to deform, opening or closing the fluidic pathway. By placing several of these pneumatic valves in a row, a pumping system can be created. Interestingly, such a pump can drive fluids forward or backward, depending on the sequence actuation of the valves.

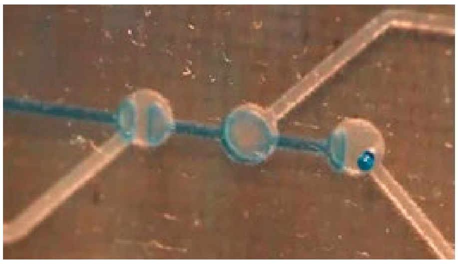




Valve opened



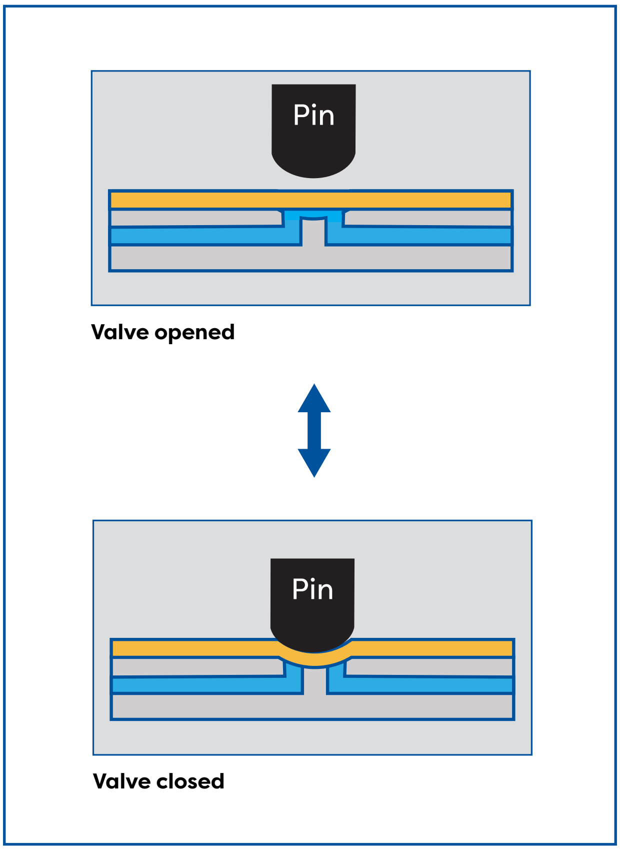
Valve closed



Pumping

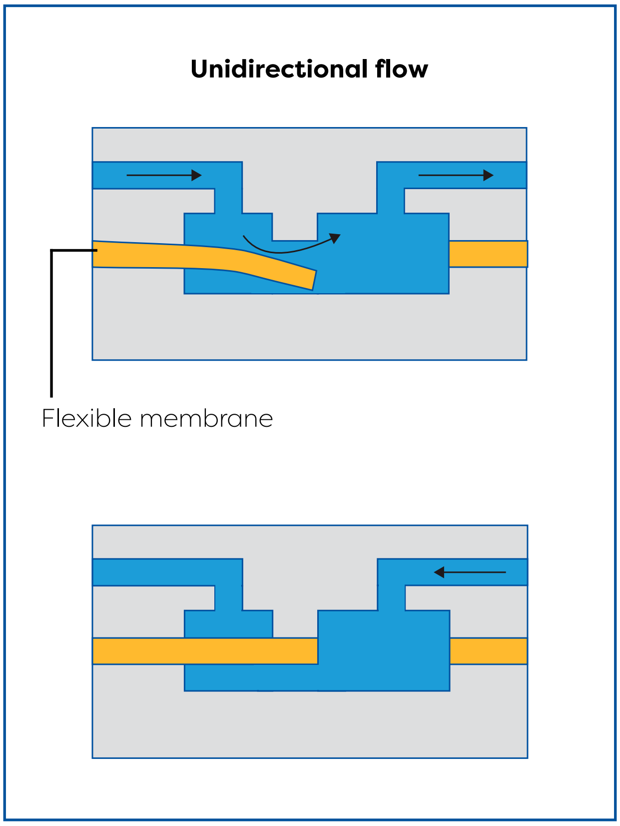
2 Membrane-based flow control: pinch valves

This type of valve works by 'pinching' the microfluidic channel until it closes. By mechanically pushing a pin against the membrane, the path of the fluid is obstructed, thus stopping the flow. As soon as the pin is withdrawn, the flow can recommence. An advantage of this type of valving is that the actuation mechanism can easily be reused from one chip to another.



3 Membrane-based flow control: check-valves

Microfluidic check-valves (or one-way valves) are the hydraulic equivalent of the electric diode, allowing fluid to flow in one direction while blocking it in the opposite direction. This functionality can be achieved by the use of a particular type of 'flap' made using the flexible membrane. A fluid can easily bend downward the membrane to open a pathway, as long as it flows in the right direction. As soon as the flow is reversed, the membrane is pushed against the edges of the fluidic pathway, now serving as a tight lid and preventing backflow.



Actuation setup

All of the above-mentioned valves require an actuation setup.

The pinch valve would typically require to be placed very close to the chip. Such proximity of an electromechanical architecture can provide a number of limitations:

- Thermal management can become more challenging as the chip may be exposed to unwanted heating generated by the electronics.
- Electromagnetic interferences to an on-chip sensing can occur in conditions where the pins are actuated by solenoids.

The pneumatic and check-valves can afford a more remote actuation setup. This however, could cause the complete system to be relatively more bulky.

Fabrication technologies

At Micronit, we have in-house manufacturing capabilities for all of these membrane-based valve solutions. To manufacture them, we make use of the following fabrication techniques:

- Milling
- Embossing
- Injection molding
- Lamination
- Laser ablation
- Thermal bonding

Passive flow control

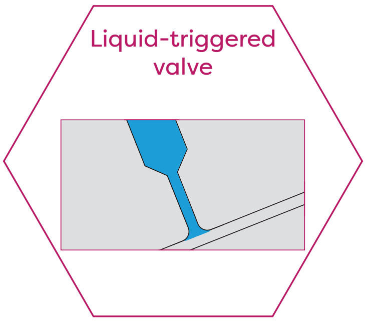
Passive flow control centers around capillary-based systems in which the flow is driven by the properties of the microfluidic channels themselves. Next to surface characteristics (wettability), the geometry of the channels is also an important factor.

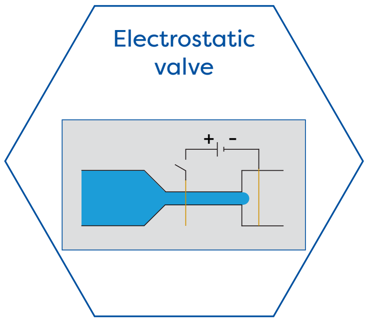
Geometrical characteristics are also of the essence when it comes to valving. Capillary stop valves (or burst valves) operate on the principle of an abrupt enlargement of the diameter of a microfluidic channel, which causes the flow to stop. Reactivating the flow can be achieved in different ways.

Our portfolio includes the two following families of elements:

1 Liquid-triggered stop valves

2 Electrostatically triggered stop valves



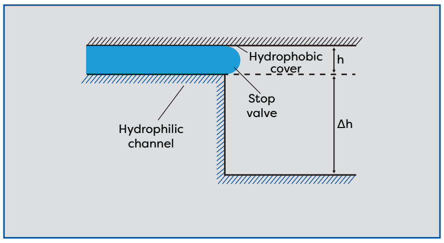


1 Capillary-based flow control: liquid-triggered stop valves

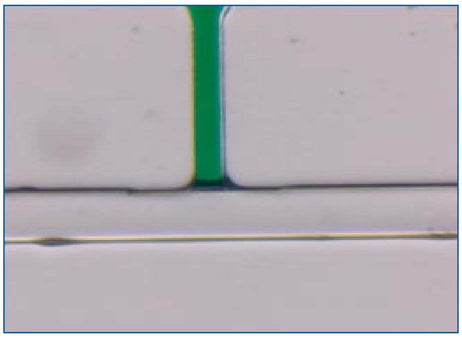
When the flow has stopped at the capillary stop valve, it can be reactivated either by another stream reaching the valve or, even, the same initial stream that follows a longer parallel path before reaching the valve again.

2 Capillary-based flow control: electrostatic valves

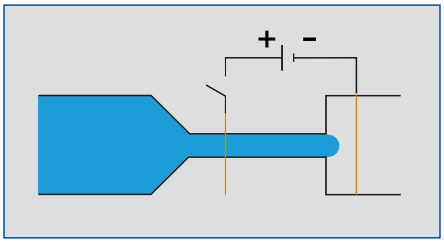
In the case of an electrostatic valve, electric voltage pulses are used as the trigger, bursting the valve and recommencing the flow. The voltage is applied between two integrated electrodes: one placed in front of and the other behind the valve.



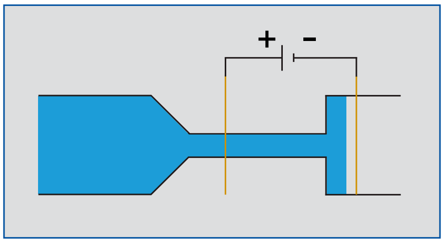
Capillary stop valve cross-section



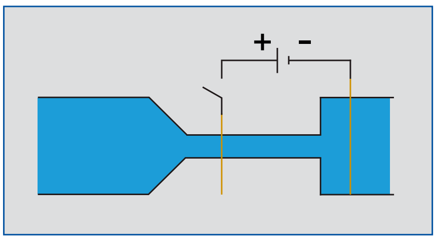
Injection molded stop valve



1. Liquid stops at stop valve



2. Electrical pulse bursts the valve



3. Flow continues downstream

Fabrication technologies

Micronit has in-house capabilities to manufacture these capillary-based valve solutions. The following techniques are typically used to manufacture them:

- Embossing
- Injection molding
- Coating
- Lithography
- Metal deposition
- Lamination

At Micronit, we have many years of experience with the above-mentioned techniques. Our established fabrication processes have delivered reliable solutions for a variety of customer applications. However, we remain open to integrate other technologies that might be better suited for your needs.

We advocate for combining the optimal fluidic design and adequate fabrication technologies from the very beginning of the project. Making the right choices at an early stage, will save you from losing time and money later on in the process.

Fabien Abeille

Senior R&D Scientist,
Flow control expert

Fabien Abeille studied Micro- and nanotechnologies and Micro- and nanoelectronics through a joint master program in Grenoble (FR), Turin (IT) and Lausanne (CH), followed by a PhD in Biotechnologies at CEA Grenoble, (FR). After his studies, Fabien held a position as a scientist at Illumina, in which he focused on microfluidics-based NGS. In 2019, Fabien joined Micronit and is now a Senior R&D scientist. Fabien is expert on flow control within Micronit's Core Technology Group.

About Micronit

Micronit offers a broad range of bonding capabilities so that the requirements for specific applications and materials can be met.

Micronit bv, founded in 1999, with development and manufacturing facilities in the Netherlands and Germany, provides innovative lab-on-a-chip and MEMS solutions using micro- and nanotechnologies. Solutions that help customers improve their products and research, contributing to the quality of life.

Micronit is ISO 9001 and ISO 13485 certified.

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