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5. Flow Control

1. Check Valves
2. Fixed-Geometry Valves
3. Actuation Principles
4. Active Micro-Valves
5. Fluerics

5. Flow Control

1. Check Valves
2. Fixed-Geometry Valves
3. Actuation Principles
4. Active Micro-Valves
5. Fluerics

5.1. Definition „Passive Valve“

Definition:

- Flow rectifier
- Controlled by hydrodynamic pressure ($p_1 – p_2$)
  - Built up by flow itself
  - Interplay with geometrical structure

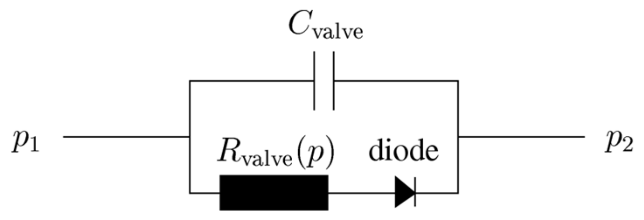
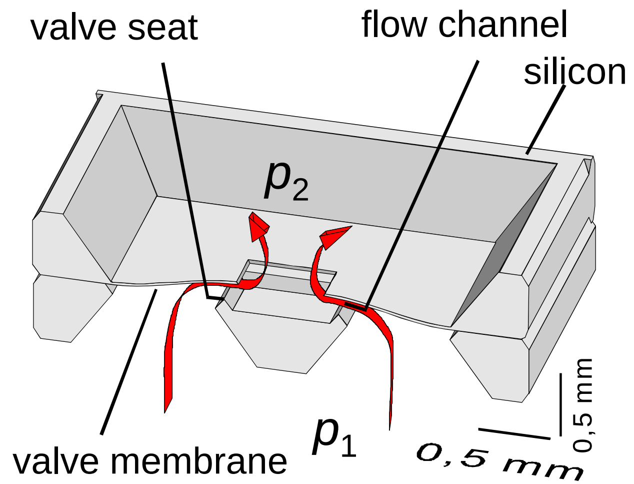


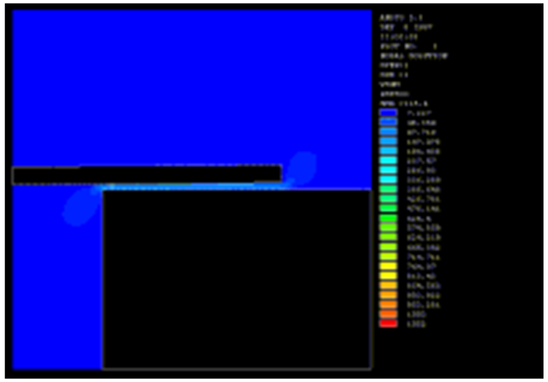
Fig. 5.1. The electric circuit equivalent of a passive valve is a resistance $R_{\text{valve}}(p)$ and a diode in parallel to a fluidic capacitance C_{valve}

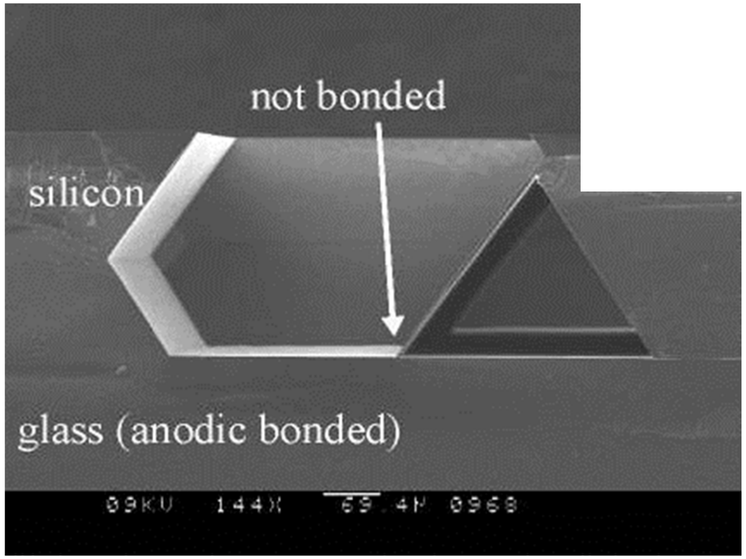
Characteristics:

- Flow rate / leakage
- Hydrodynamic “actuation” force
  $F = p\,A$
- Hydraulic capacitance
- Resonance curve



5.1. Types of Passive Valves





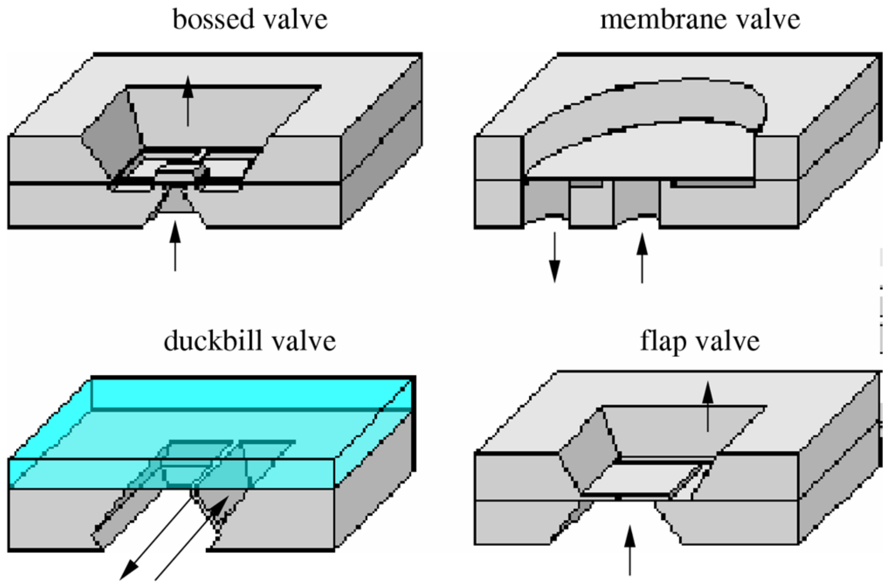


Fig. 5.2. Types of passive valves. Each type possesses a distinct working surface resulting in different hydraulic pressures for switching the valve

Note:

Different effective areas A
for force $F = p\,A$
generated by pressure Δp

5.1. Check Valves

1. Membrane Valves
2. Flap Valves
3. Bivalvular Valves
4. Leakage

5.1.1. Membrane Valves

Components:

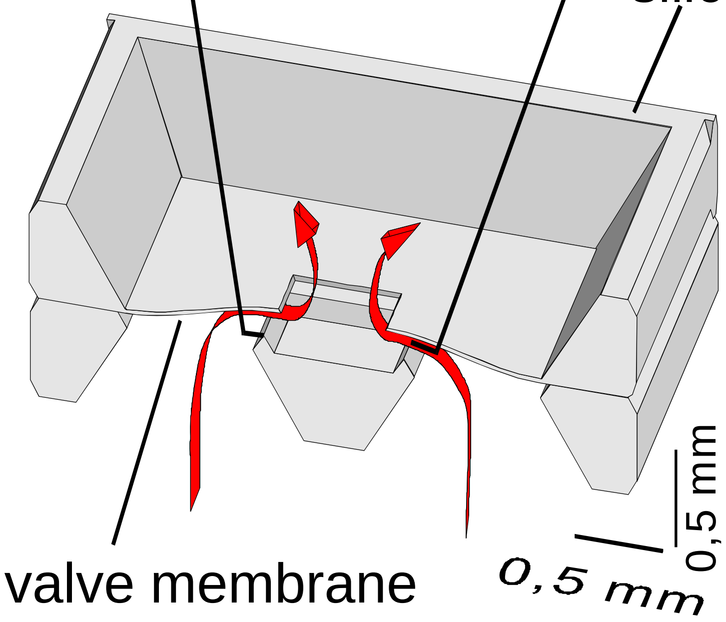
- Peripherally fixed membrane
- Central hole

Advantages:

- High force due to large effective area for pressure

Drawbacks:

- Large size
- Large capacitance
- Large dead volume



5.1.1. Theoretical Background

Calculation of flow for gases

- Main impact factor
  - Smallest cross section A_{min}
- $h < A/U$ ➔ $A_{min} = h \cdot s$
- $h > A/U$ ➔ $A_{min} = A$

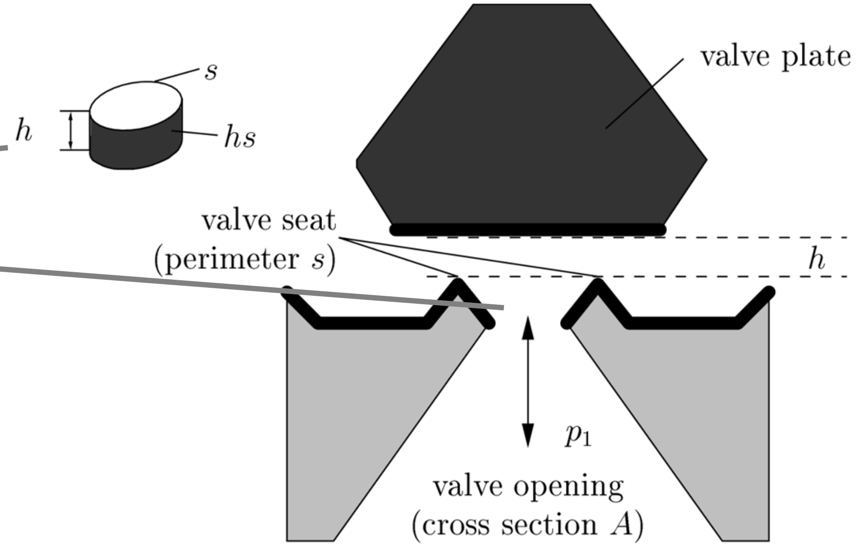


Fig. 5.34. Schematic of a valve opening. The flow through the opening is determined by the minimum cross-section A_{min}. Depending on whether the ratio between the surface of the valve opening A and the perimeter of the valve seat s is smaller or greater than the gap h, A_{min} is given by A or the product hs

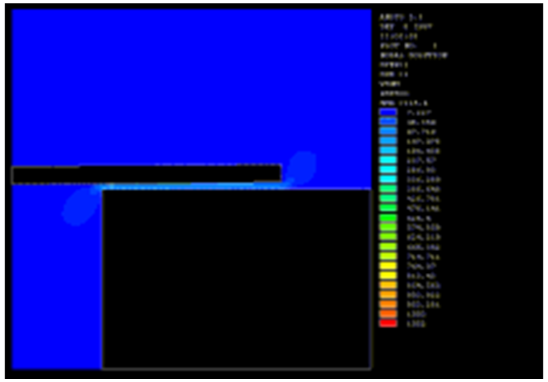
<u>Expansion flow through nozzle</u>

$$\dot{m} = \mu_M \cdot A_{\min} \cdot \psi_{A,2} \cdot \sqrt{2 \cdot \frac{p_1}{v_1}}$$

5.1.1. Membrane Valves – Flow Rate

Gap opening; pressure-dependent

$s \sim \Delta p$

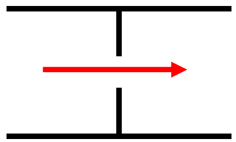


Flow through narrow gap
(laminar friction / viscosity prevails)

$$I_V = \frac{1}{12}\frac{sh^3(\Delta p)\Delta p}{\eta b} = \frac{1}{3}\frac{a_4 h^3(\Delta p)\Delta p}{\eta a_5}$$

→ $I_V \sim \Delta p^4$

Flow through short constriction (e.g.: $b < s$)
(conversion of potential to kinetic energy prevails)



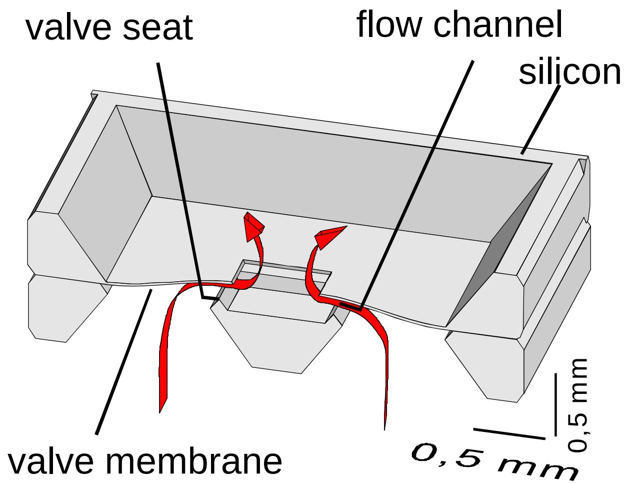
$$I_V = \phi_{\text{outlet}} s h(\Delta p)\sqrt{\frac{2\Delta p}{\varrho}} = \phi_{\text{outlet}} 4 a_4 h(\Delta p)\sqrt{\frac{2\Delta p}{\varrho}}$$

→ $I_V \sim \Delta p^{3/2}$

5.1.1. Flow Rate

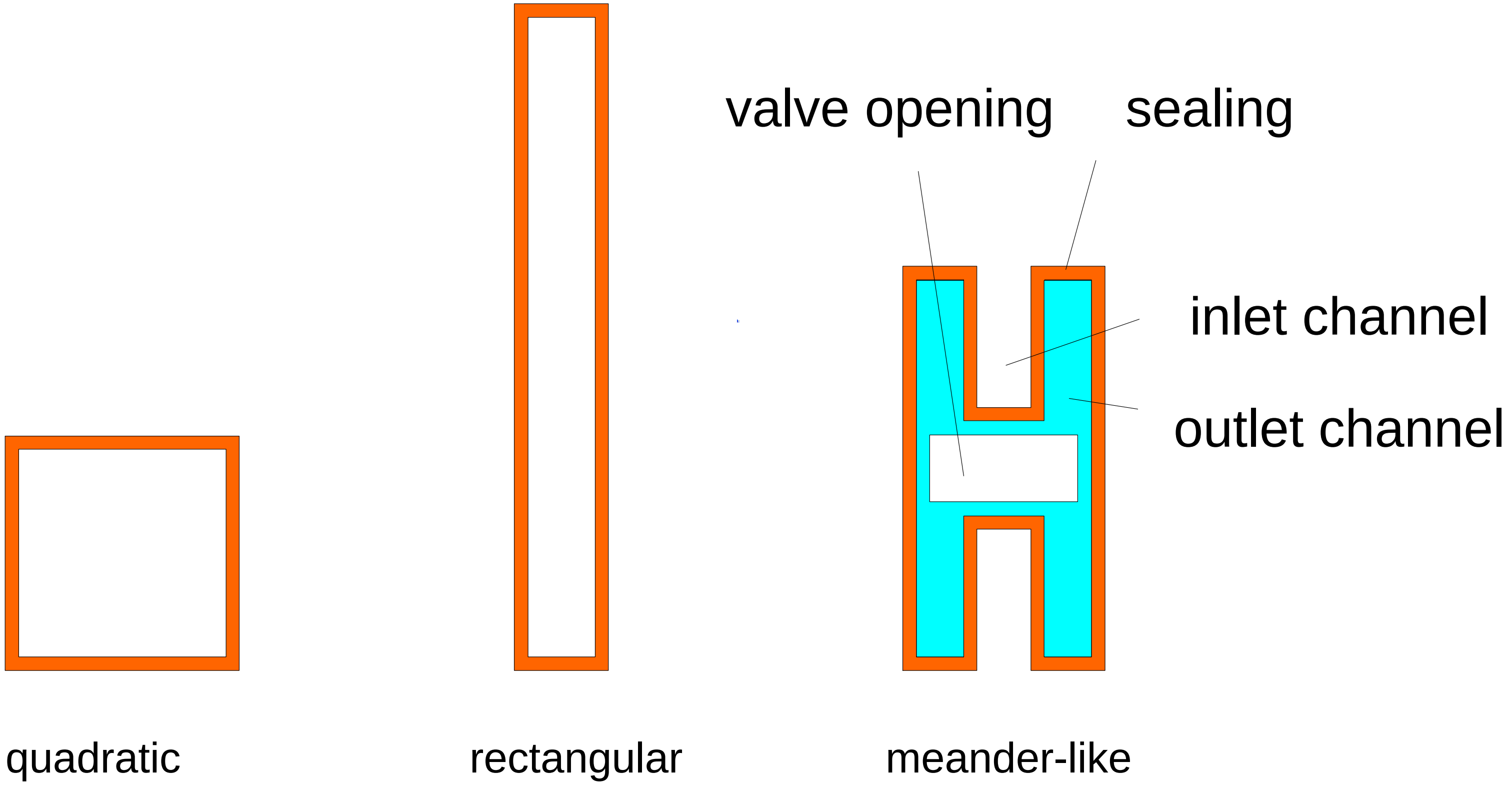
$$I(p) \propto h(F)s \propto k_{\mathrm{elast}} F s \propto k_{\mathrm{elast}} \Delta p A s$$

- Gap height h
- Circumference s
- Pressure surface A
- Elastic module k_{elast}



5.1.1. Theoretical Background

Enhancement of flow ($A_{min} = U \cdot s$)



5.1.1. Construction Principles

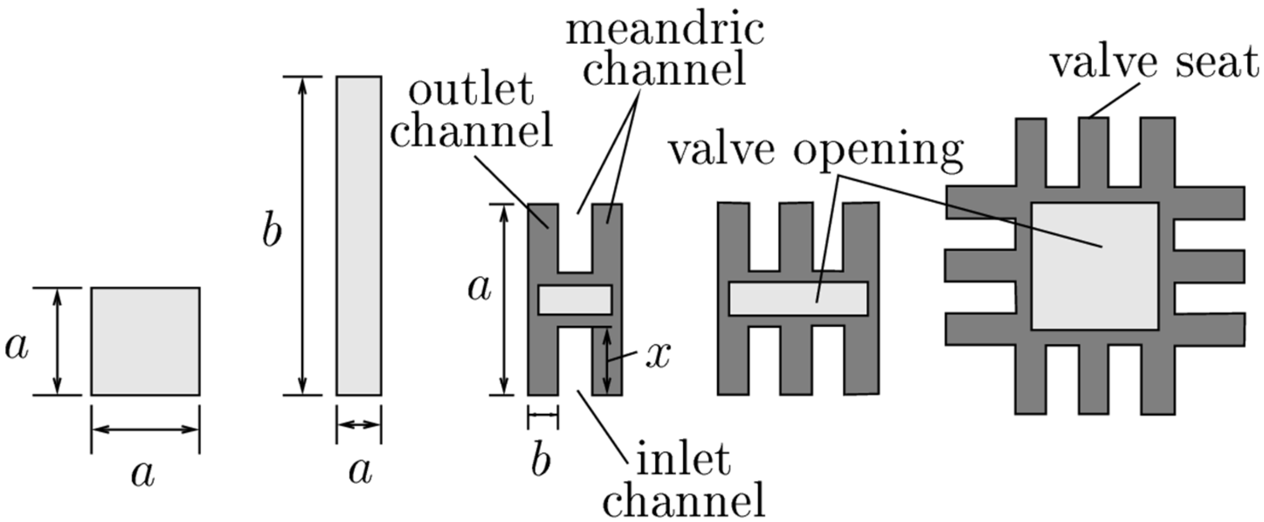
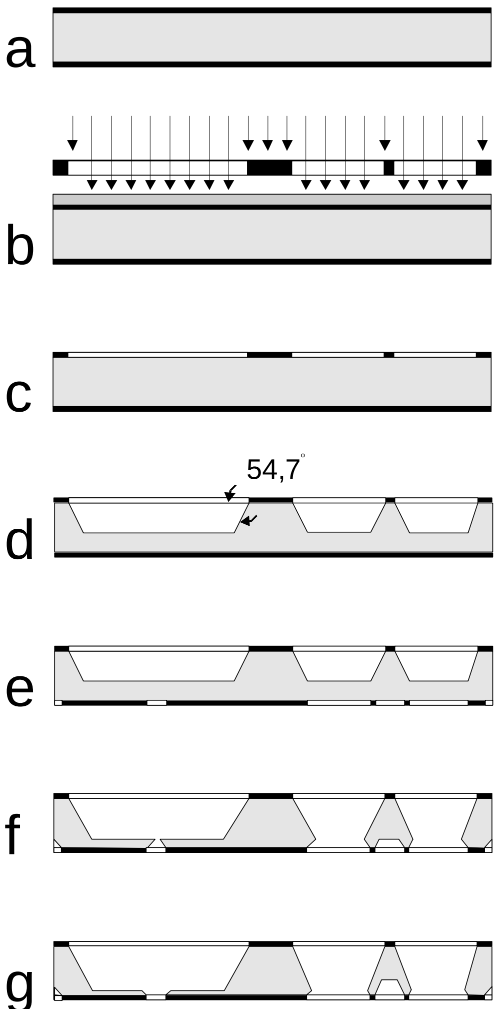
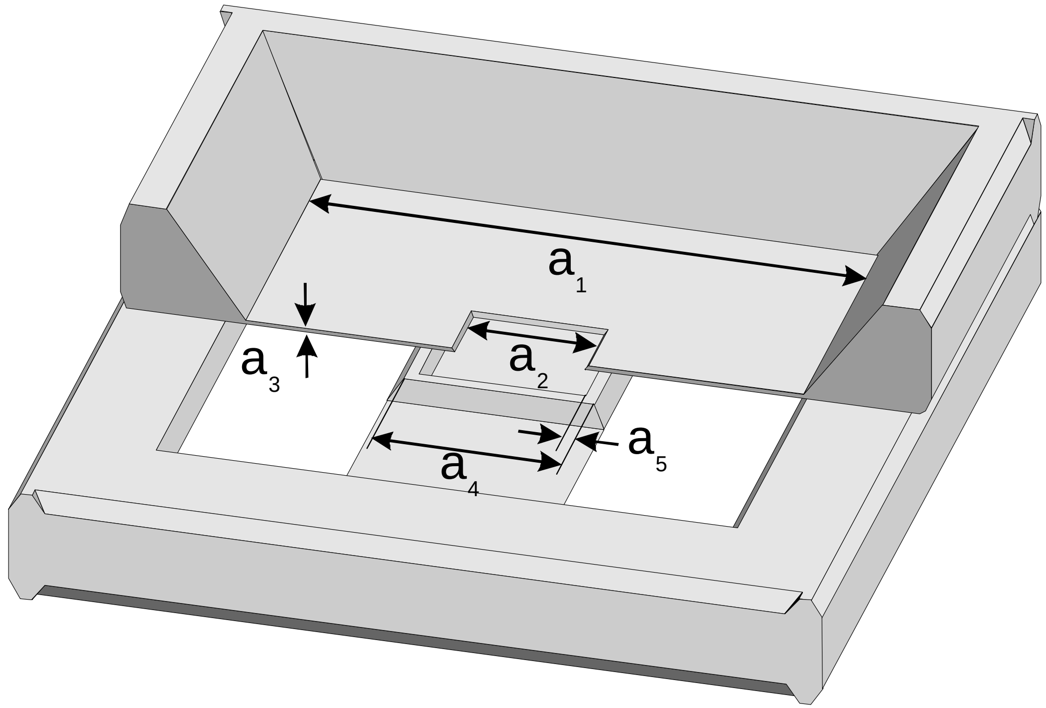


Fig. 5.35. Various seat geometries for enhancing the flow cross-section hs while maintaining the pneumatic surface. The product hs is $4ah$ for the quadratic and $2abh$ for the rectangular valve seat. For the three on the right, a fraction of the gas has to pass the meander-like channels below the valve plate before reaching the rectangular valve opening

5.1.1. Membrane Valves - Fabrication





5.1.1. Membrane Valves

<u>Components:</u>

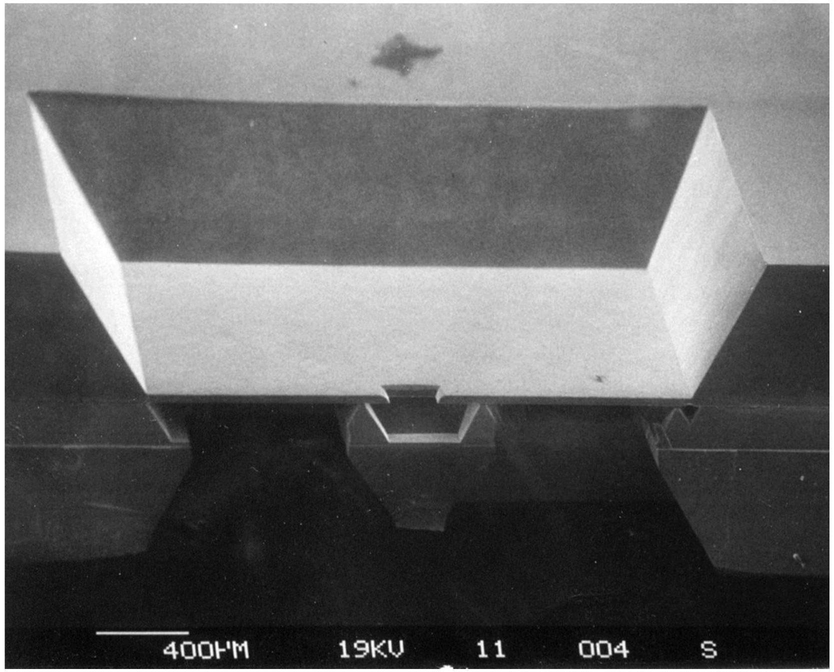
- Peripherally fixed membrane
- Central hole

<u>Advantages:</u>

- High force due to large effective area for pressure

<u>Drawbacks:</u>

- Large size
- Large capacitance
- Large dead volume

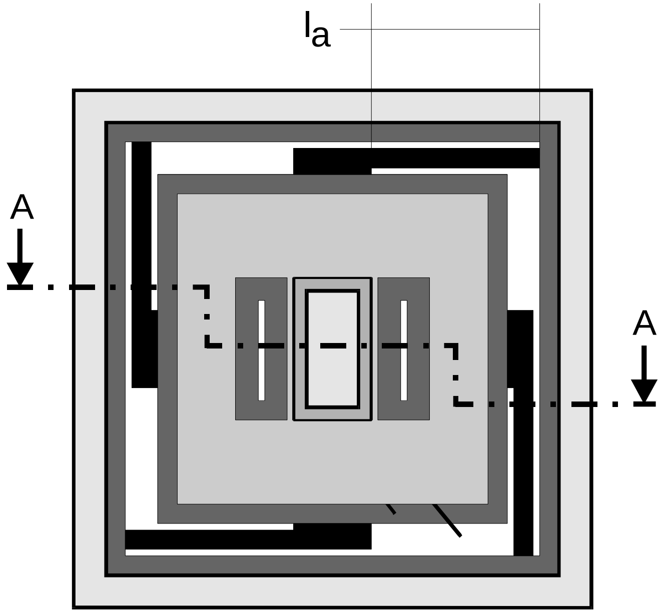


5.1.1. Theoretical Background

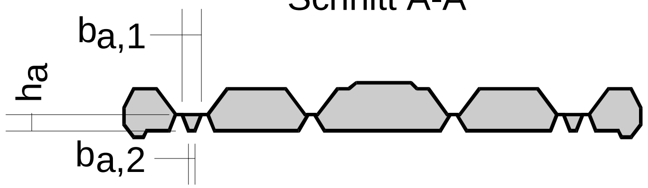
Structural mechanics

Restoring force by elastic support of valve plate

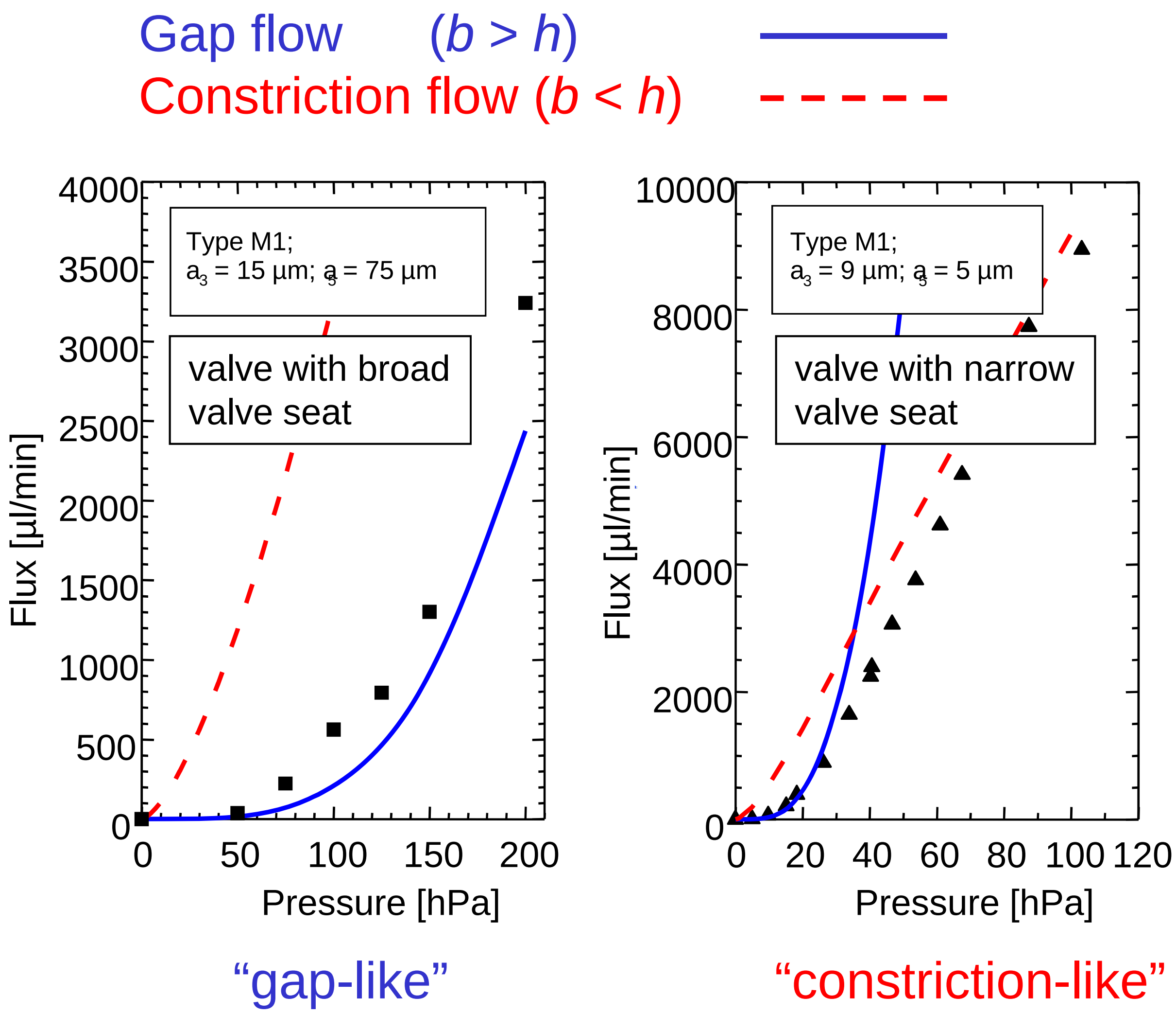
$$F_{el1} = \frac{4}{3} \cdot \frac{E}{\left(1-\nu^2\right)} \cdot \frac{\left(b_{a,1}^2 + 4 \cdot b_{a,1} \cdot b_{a,2} + b_{a,2}^2\right) \cdot h_a^3}{\left(b_{a,1} + b_{a,2}\right) \cdot l_a^3} \cdot z_{Vp}$$



Schnitt A-A



5.1.1. Membrane Valves



5.1.1. Hydraulic Capacitance

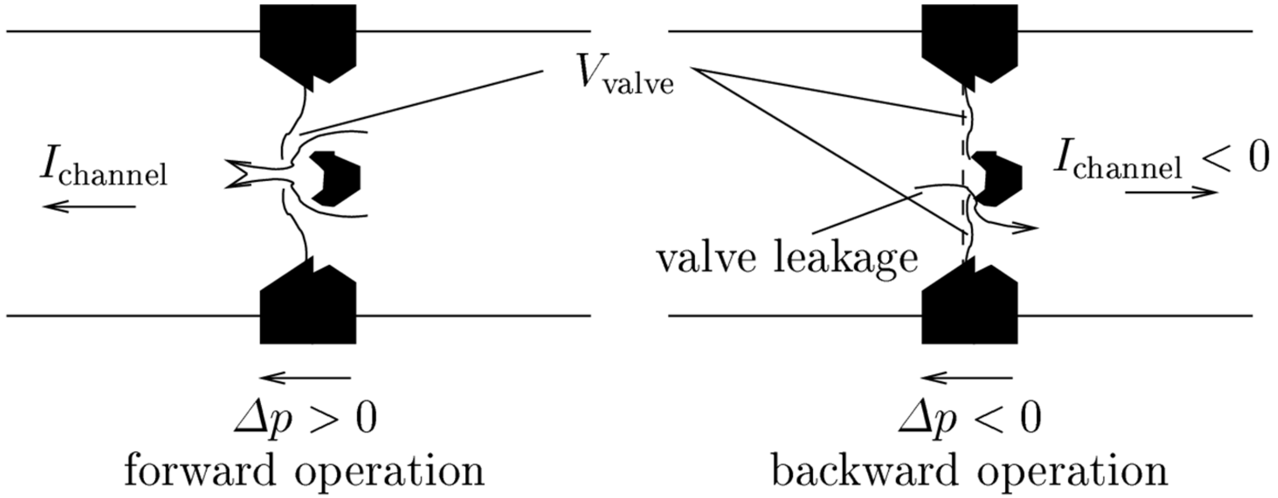


Fig. 5.4. Hydraulic capacitance C_{hd} of a membrane valve in forward and backward operation

$$\varrho \frac{\mathrm{d}V_{valve}}{\mathrm{d}t} = C_{hd} \frac{\mathrm{d}p}{\mathrm{d}t}$$

$$I_{channel} = I_{valve} + \frac{\mathrm{d}V_{valve}}{\mathrm{d}t} = I_{valve} + \frac{C_{hd}}{\rho} \frac{\mathrm{d}p}{\mathrm{d}t}$$

5.1. Check Valves

1. Membrane Valves
2. Flap Valves
3. Bivalvular Valves
4. Leakage

5.1.2. Flap Valves

<u>Components:</u>

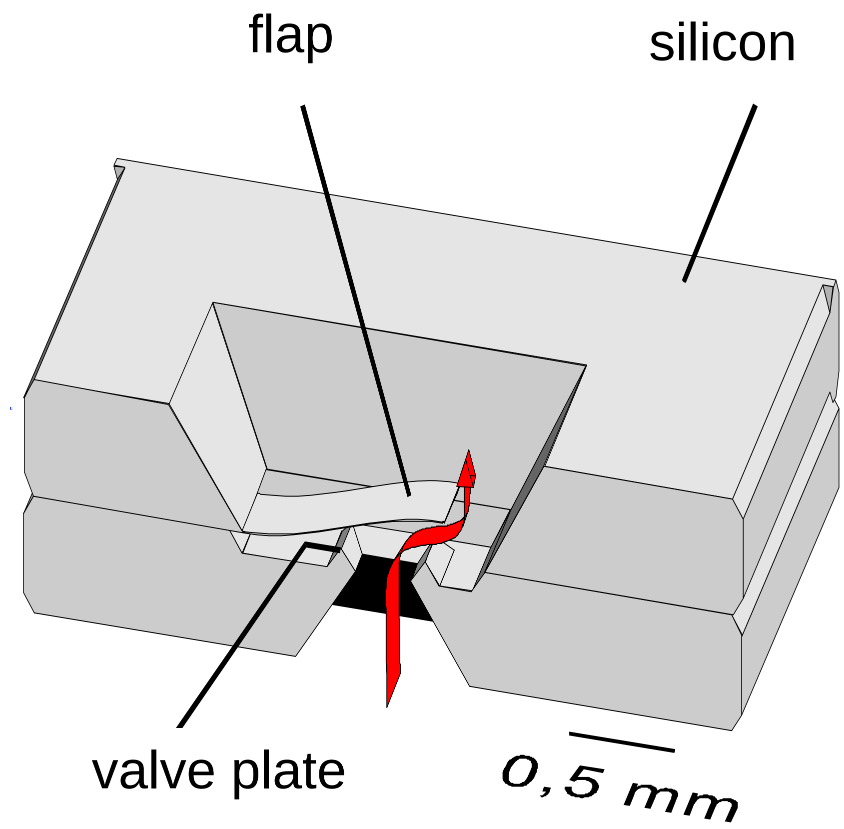
- Unilaterally fixed flap
- Opening underneath end of flap

<u>Advantages:</u>

- Compact size
- Low capacitance
- High resonance frequency
- Moderate dead volume

<u>Drawbacks:</u>

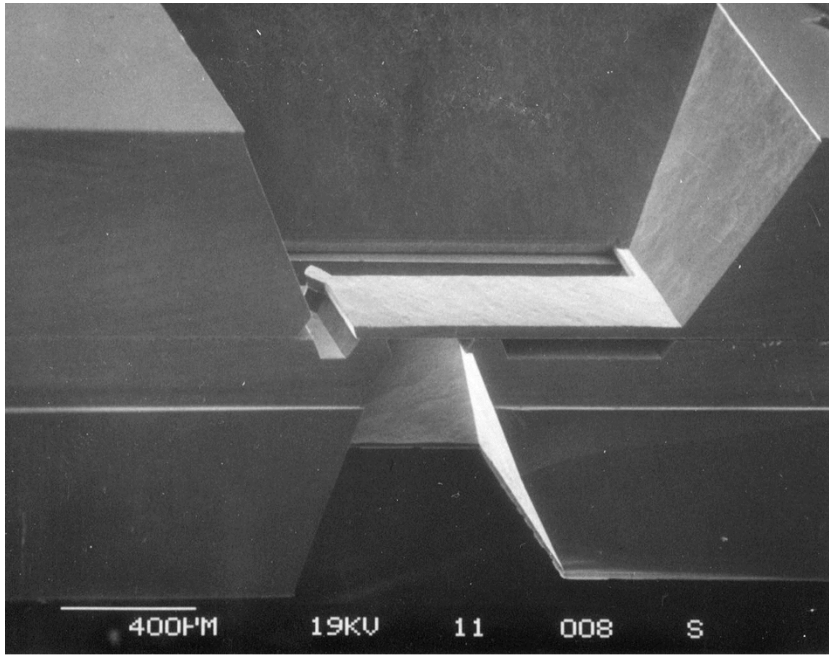
- Low actuation force
  due to low effective area



5.1.2. Flap Valves

Components:

- Unilaterally fixed flap
- Opening underneath end of flap



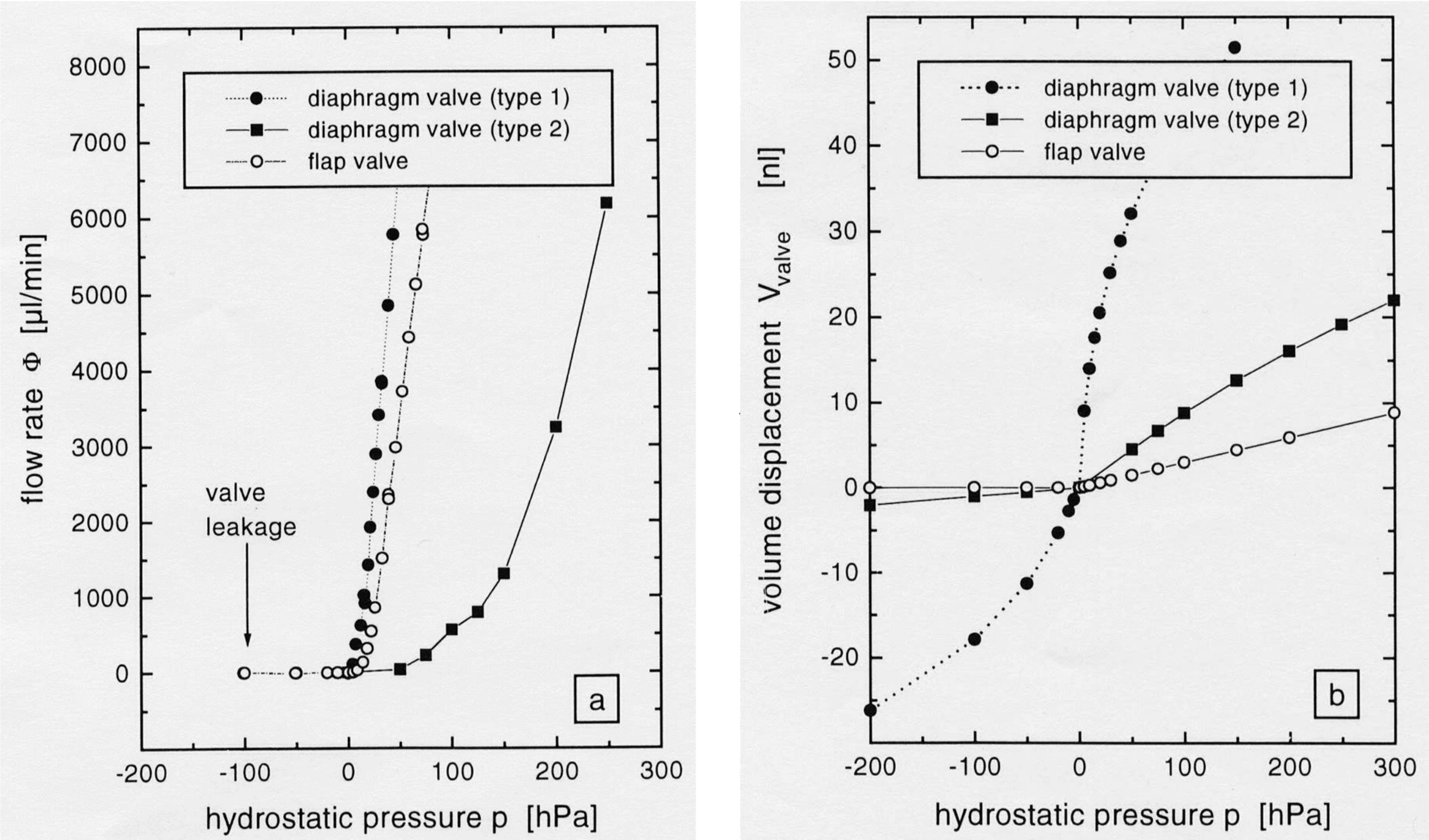
Advantages:

- Compact size
- Low capacitance
- High resonance frequency
- Moderate dead volume

Drawbacks:

- Low actuation force
  due to low effective area

5.1.1. Comparison: Flap / Membrane Valves



5.1. Check Valves

1. Membrane Valves
2. Flap Valves
3. Bivalvular Valves
4. Leakage

5.1.3. Bivalvular Valves

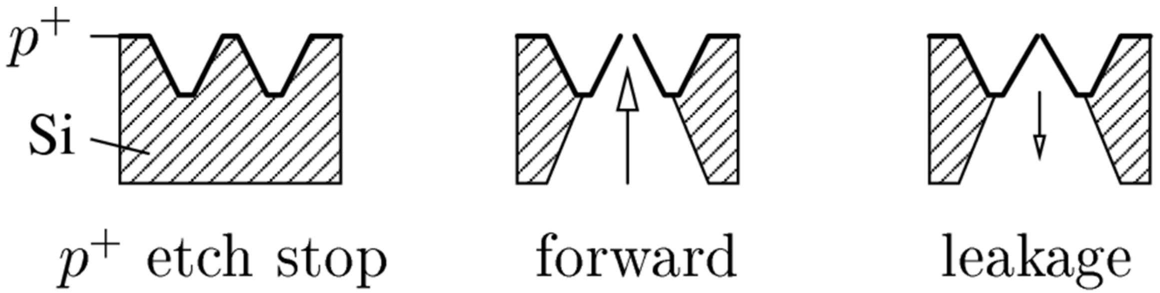


Fig. 5.9. Bivalvular valves can be designed in a one-wafer process using the p^+ etch stop method to produce the membrane. The membrane is cleared by the hydraulic pressure while the keystone effect closes the valve in reverse direction

5.1. Check Valves

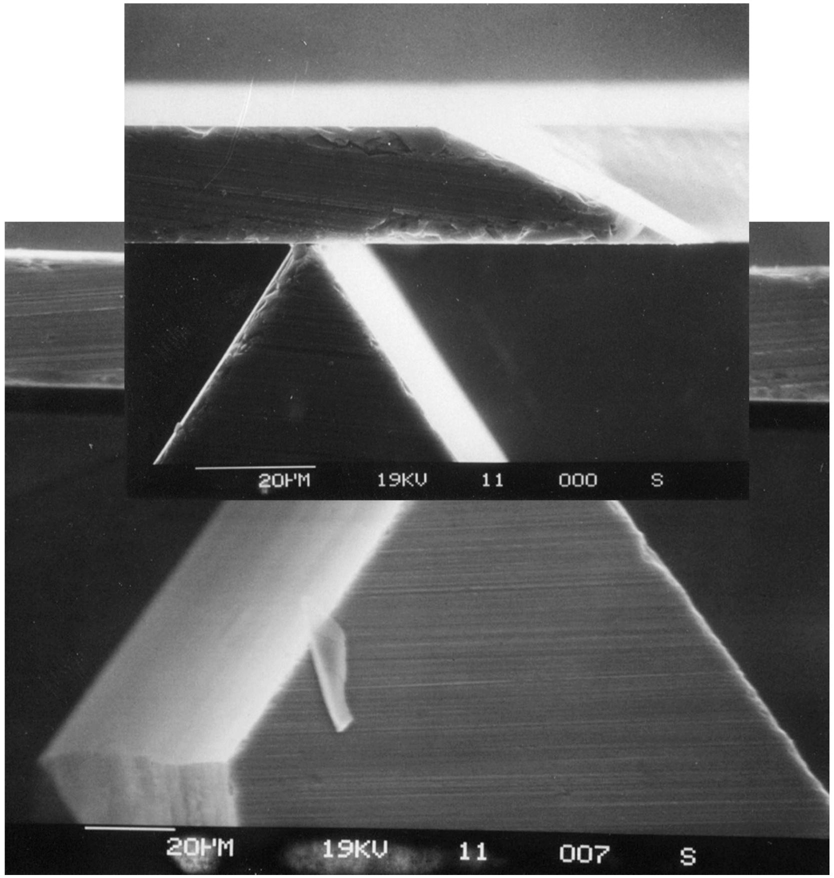
1. Membrane Valves
2. Flap Valves
3. Bivalvular Valves
4. Leakage

5.1.4. Leakage

<u>Leakage:</u>

- Causes
  - Assembly
  - Internal stress
  - Particles / contamination

- Possible solutions
  - Integrated filters
  - Combination of materials
    - Hard - soft



5. Flow Control

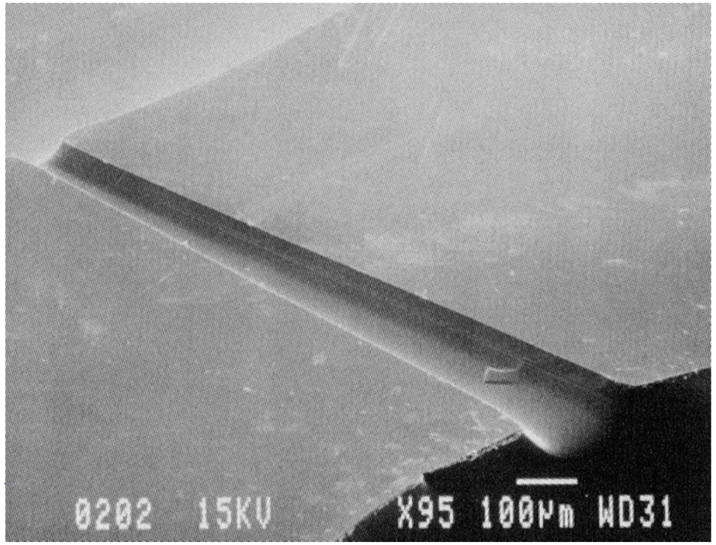
5.2. Fixed-Geometry Valves

1. Diffuser/Nozzle Valves
2. Tesla Valves
3. Hydrophobic Barriers

5.2.1. Diffuser-Nozzle Valves

<u>Components:</u>

- Conical channel



<u>Advantages:</u>

- Simple structure
- Compact size

<u>Drawbacks:</u>

- Low forward-backward ratio
- High leakage rate

A. Olson; Valveless Diffuser Micropumps; Stockholm 1998

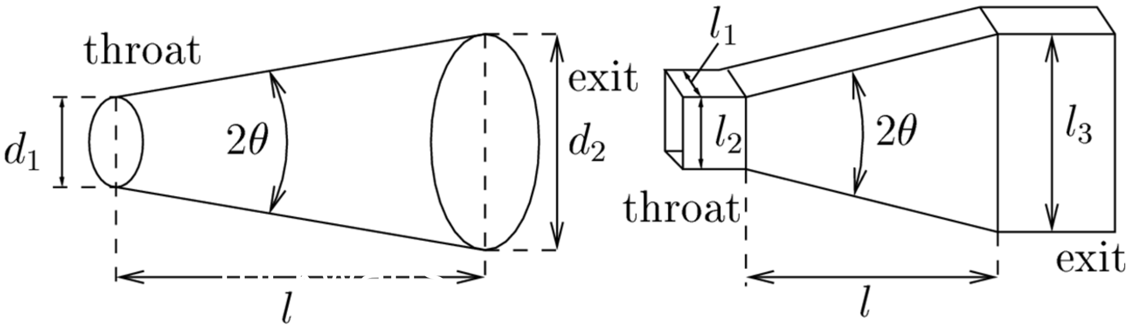
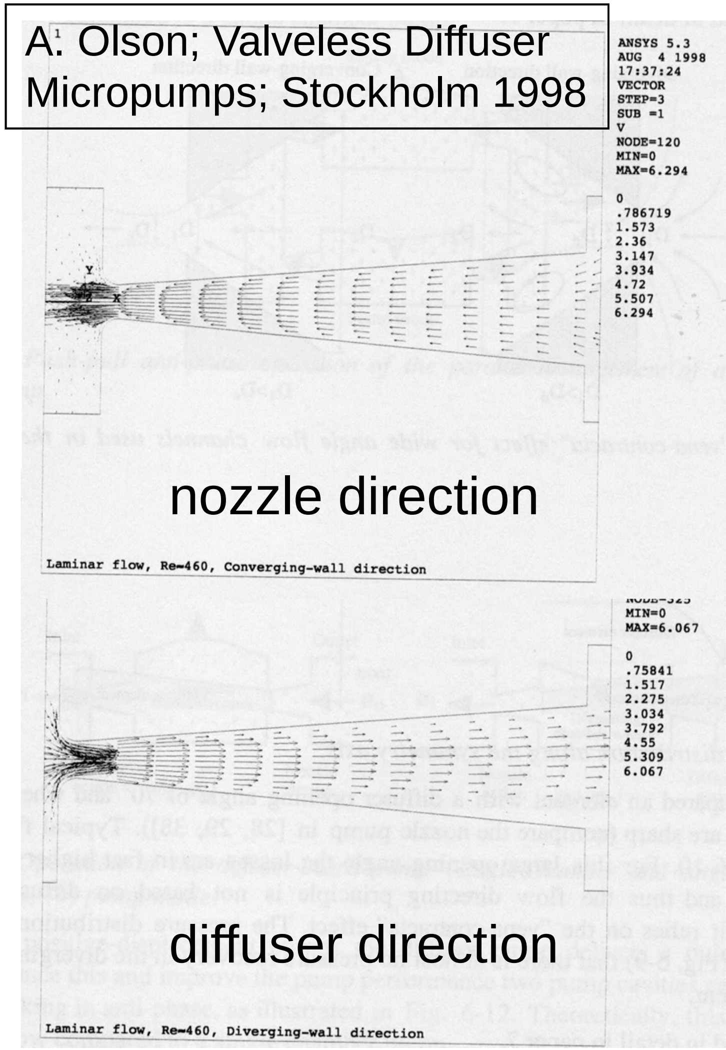


Fig. 5.11. Conical and flat pyramidal diffuser geometries

5.2.1. Diffuser-Nozzle Valves

A: Olson; Valveless Diffuser Micropumps; Stockholm 1998



nozzle direction

diffuser direction

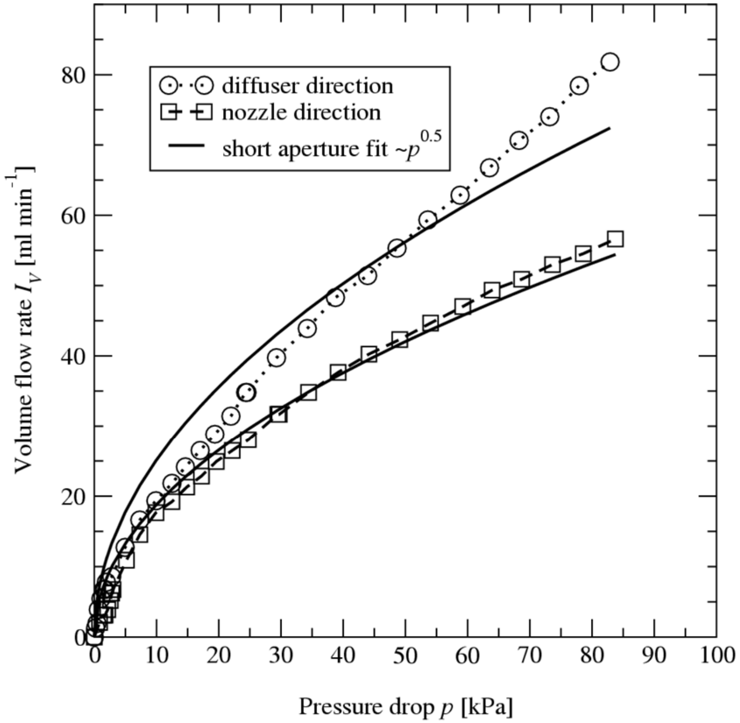


Fig. 5.13. Volume flow in diffuser and nozzle direction as a function of the pressure drop. The deviating slopes ($\propto 1/R$) reflect the direction-dependent flow resistances R. The diffuser direction exhibits a lower flow resistance (JD: Ask Roland for source, ?)

Flow through narrow constriction

$$\Phi = \mu A \sqrt{\frac{2 \Delta p}{\rho}}$$

5.2.1. Diffuser / Nozzle Valves in Silicon

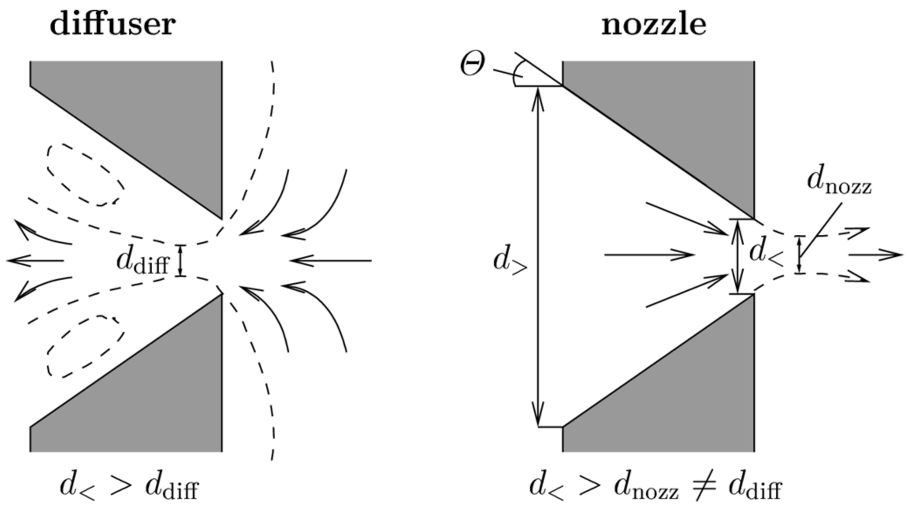


Fig. 5.12. Asymmetry of flow ($d_{\mathrm{diff}} \neq d_{\mathrm{nozz}}$) and jet contraction ($d_< > d_{\mathrm{diff}}$ and $d_< > d_{\mathrm{nozz}}$) in diffuser and nozzle direction with diameters $d_<$ and $d_>$

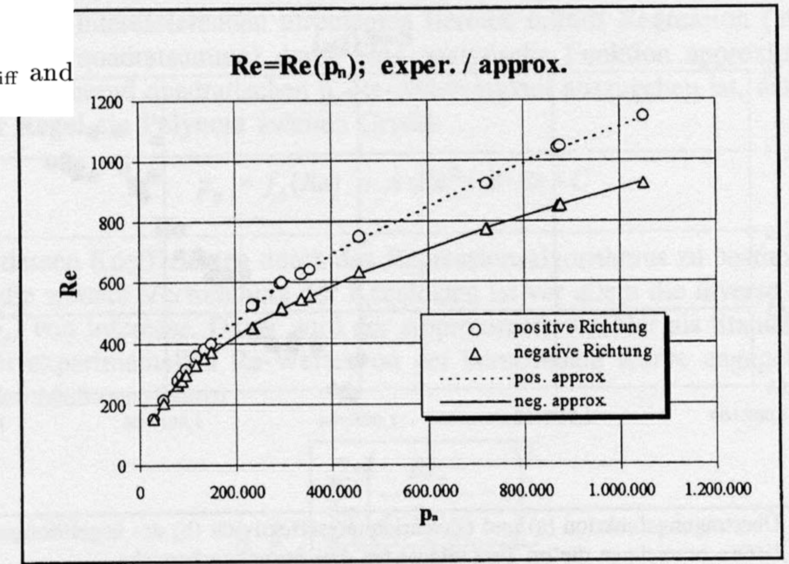


Abb. 2.12 : Vergleich der Versuchsdaten mit den Approximationsfunktionen (linearer Maßstab); konischer Modellkanal

5.2. Fixed-Geometry Valves

1. Diffuser/Nozzle Valves
2. Tesla Valves
3. Hydrophobic Barriers

5.2.2. Bypass-Valves

Components:

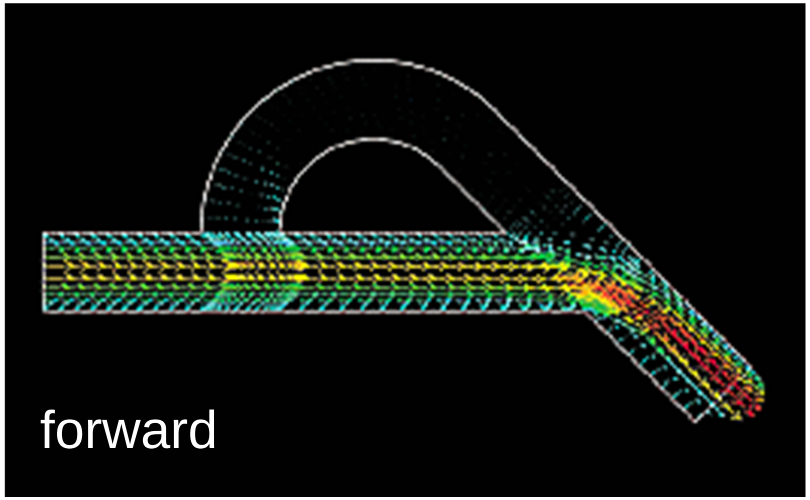
- Bypass with deviating angles

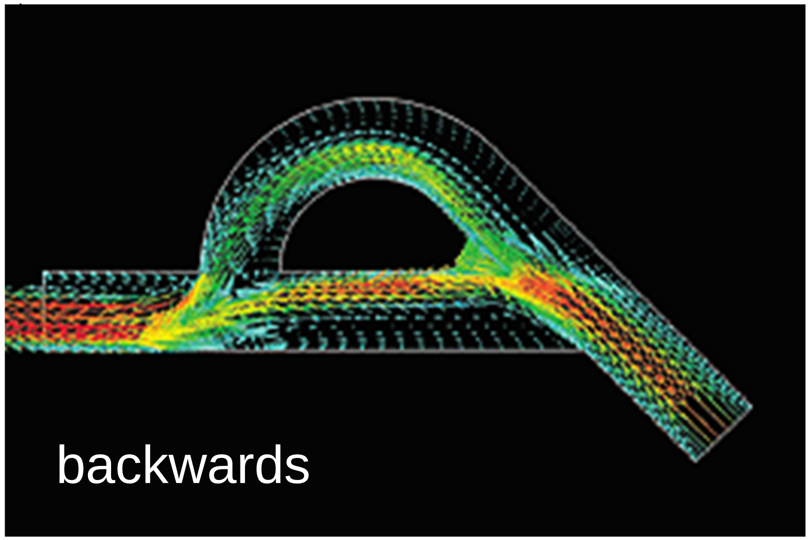
Advantages:

- Simple structure
- Compact size

Drawbacks:

- Low forward-backward ratio
- High leakage rate





5.2.2. Bypass-Valves

Components:

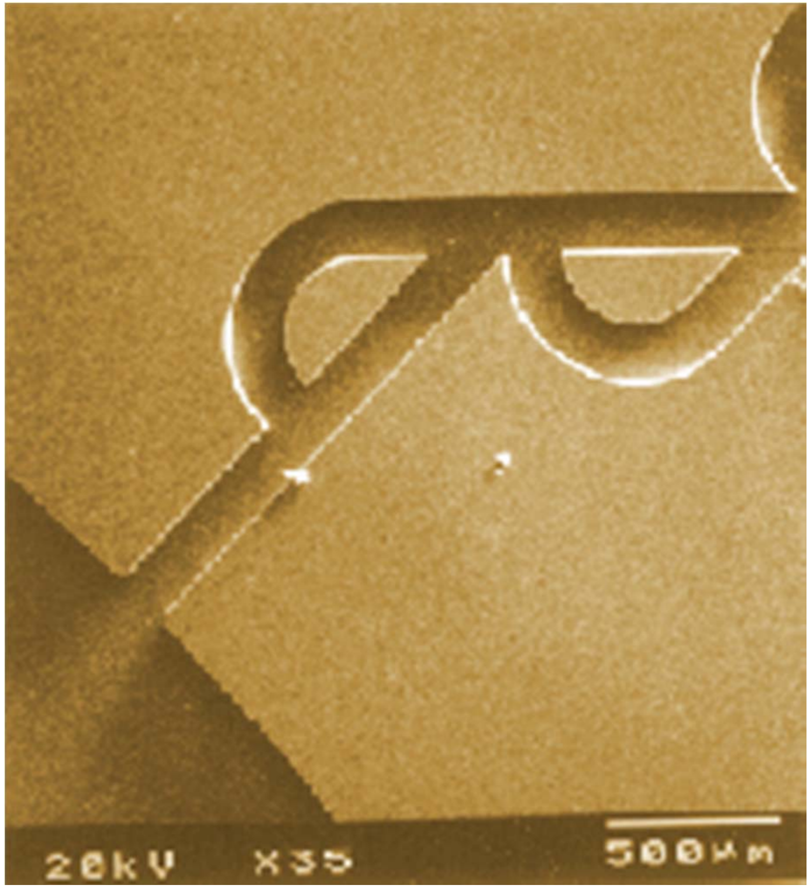
- Bypass with deviating angles

Advantages:

- Simple structure
- Compact size

Drawbacks:

- Low forward-backward ratio
- High leakage rate



5. Flow Control

5.3. Actuation Principles

1. Thermal Actuators
2. Piezoelectric Actuation
3. Electrostatic Actuation
4. Electromagnetic Actuation
5. Pneumatic Actuation
6. Hydrogel Actuators
7. Bubble-Spring Actuation

known mechanisms

5.3.7. Bubble-Spring Actuation

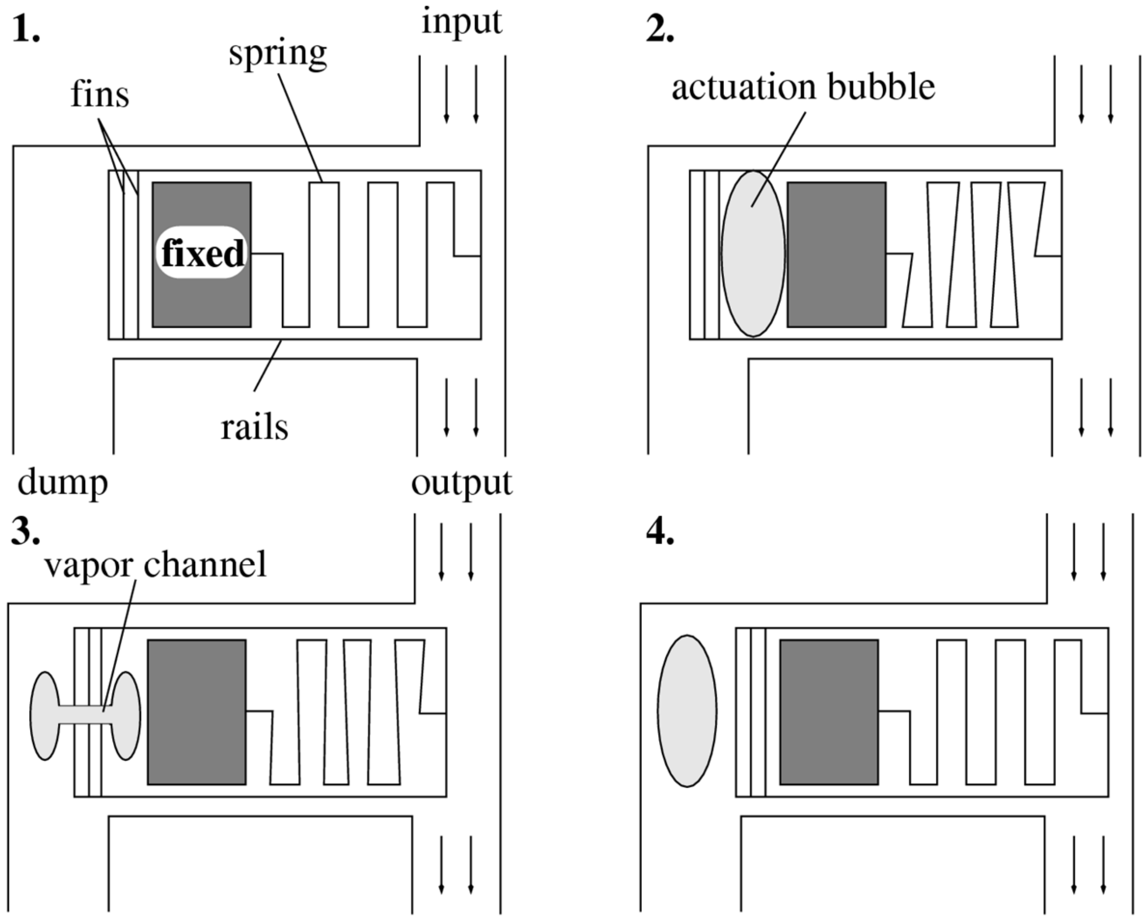
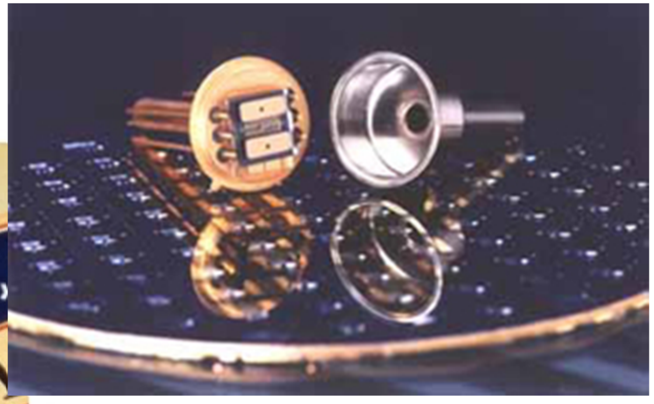


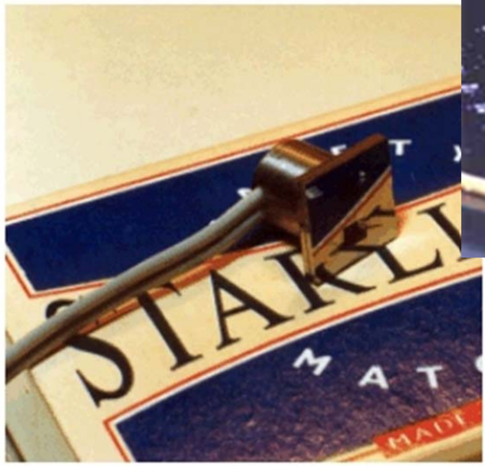
Fig. 5.27. Bubble spring and channel (BSaC) . In this bistable valve, the frame is moved by the expanding bubble against the force of the compressed spring to clear the flow channel. When a second bubble is created above the fins, the actuation bubble which so far stabilized the open-valve position is released via the vapor channel to the dump. The frame returns to its initial position

5. Flow Control

5.4. Active Microvalves

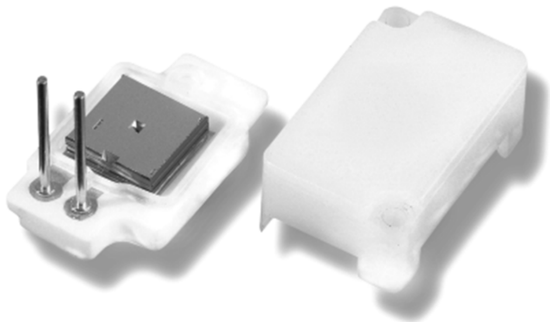


Microvalve NC 1500
Redwood Microsystems



Bi-stable magnetically actuated microvalve (dimensions 6x6x6 mm)

Microvalve
Twente MicroProducts



Microvalve MegaMic
Hoerbiger-Origa

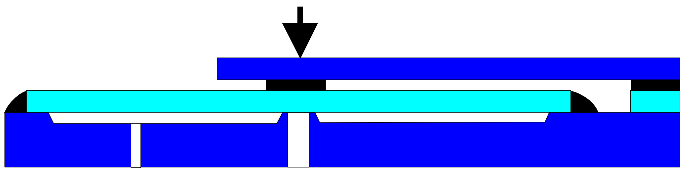
5.4. Active Microvalves

1. Definition and Concepts
2. Design Principles
3. Microvalve Actuation
4. 2-Way Microvalves
5. Microvalves for Pneumatic Systems
6. 3-Way Microvalves
7. Modeling of Flow in Microvalves

5.4.1. Definition and Nomenclature

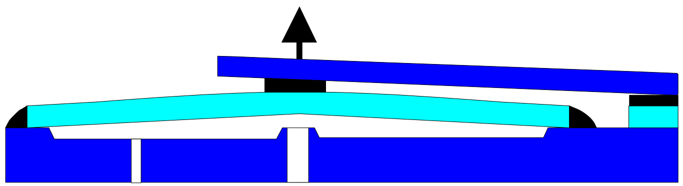
- **Valves**
  - ➢ **Flow control elements**
  - ➢ **Control of fluid flow in binary or continuous fashion**
  - ➢ Binary „switch“
    - Open and close position
  - ➢ Continuous control
    - Continuous adjustment of flow rate between open and close

closed



port 1 port 2

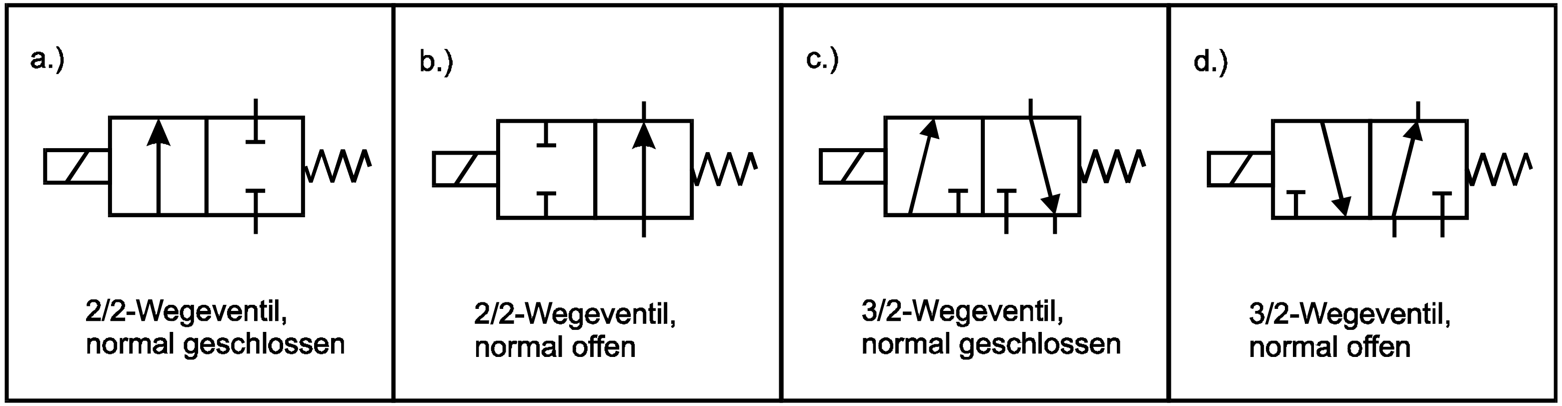
open



port 1 port 2

5.4.1. Definition and Nomenclature

- **2- and 3-way valves**
  - Switching between different inlet and outlet ports
  - Categorization according to number of ports
- Two idle modes
  - **Normally open**
  - **Normally closed**



5.4.1. Definition and Nomenclature

- Miniature valves:
  - Miniaturized conventional valves
  - Precision machining
  - Conventional driving mechanism
    - Overwhelmingly electromagnetic

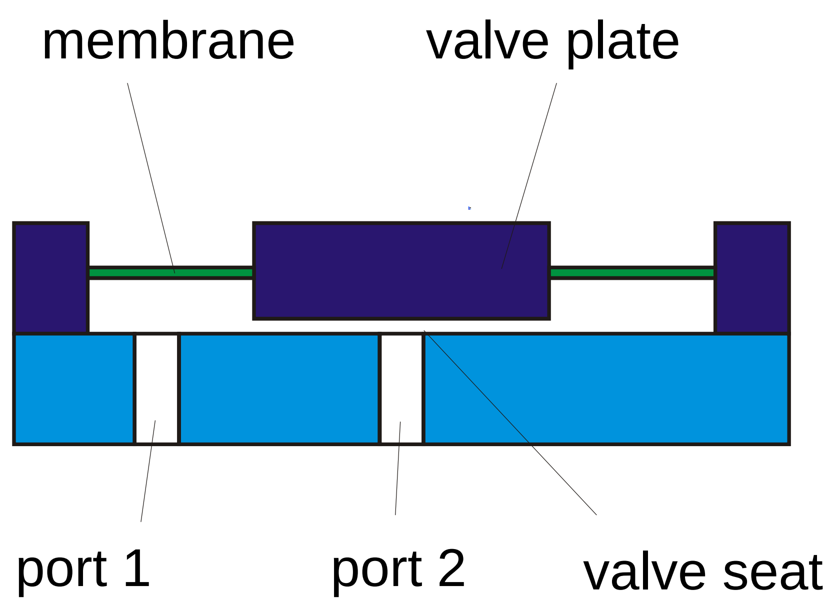
- Microvalves:
  - Microfabrication
  - Implementation of microactuators
  - Miniaturized size
  - Minimized power requirements

5.4. Active Microvalves

1. Definition and Concepts
2. Design Principles
3. Microvalve Actuation
4. 2-Way Microvalves
5. Microvalves for Pneumatic Systems
6. 3-Way Microvalves
7. Modeling of Flow in Microvalves

5.4.2. Construction Principles

Typical design of 2-way microvalve:



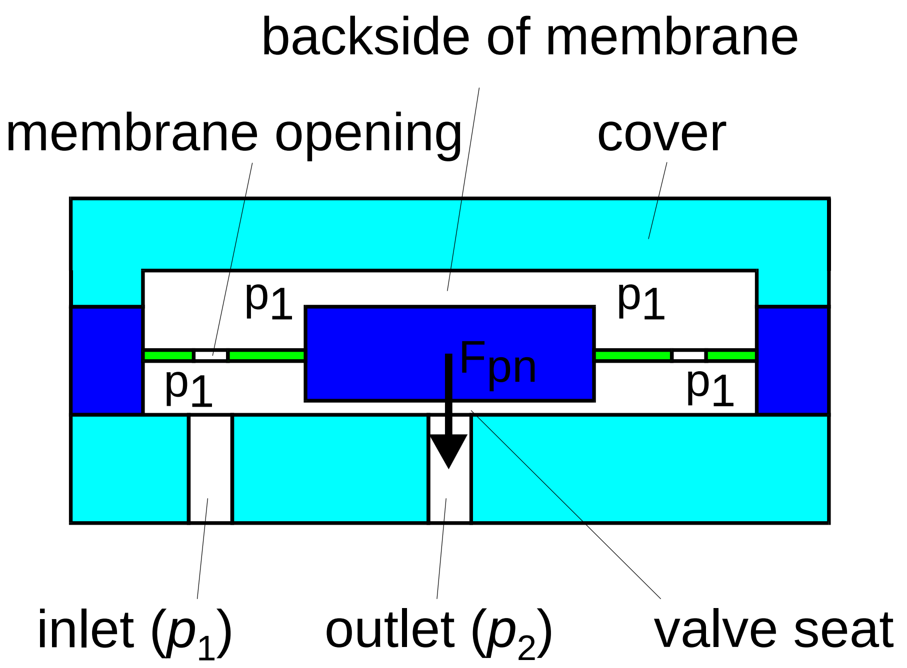
5.4.2. Construction Principles

Equilibration of pressure for valve plate:

- Minimized effective area for pneumatic force

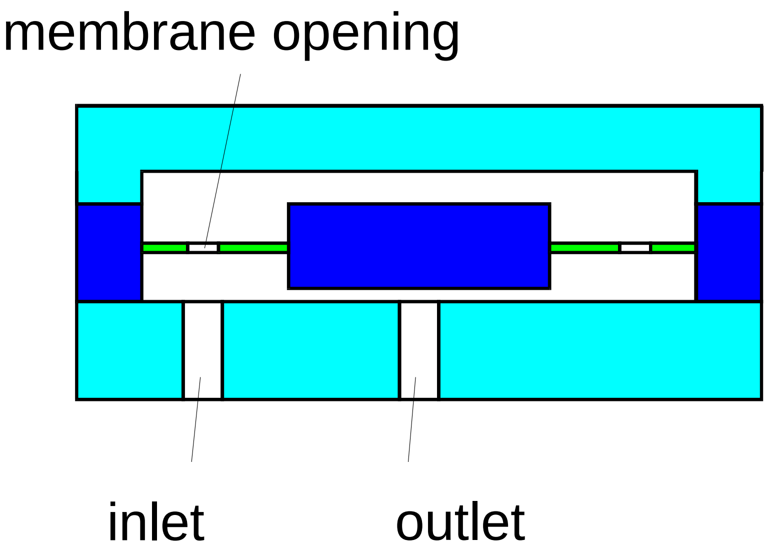
pneumatic force:

$$F_{pn} = (p_1 - p_2) \cdot A_{pn}$$

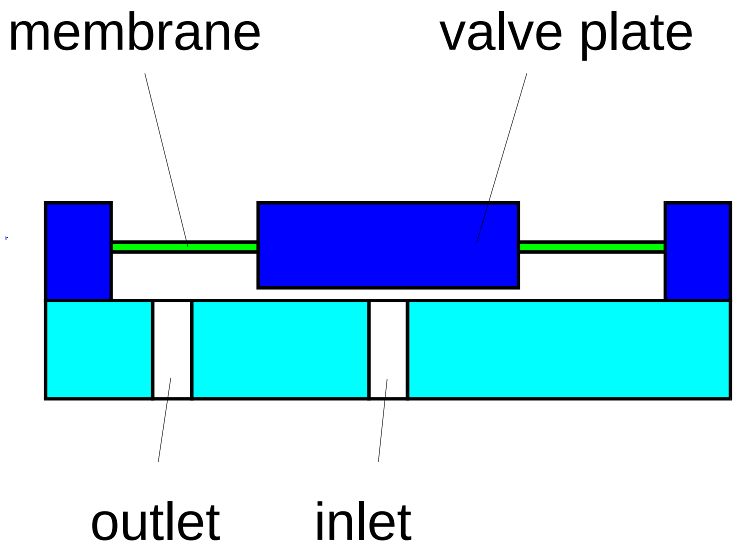


5.4.2. Construction Principles

Normally-open 2-way valve:



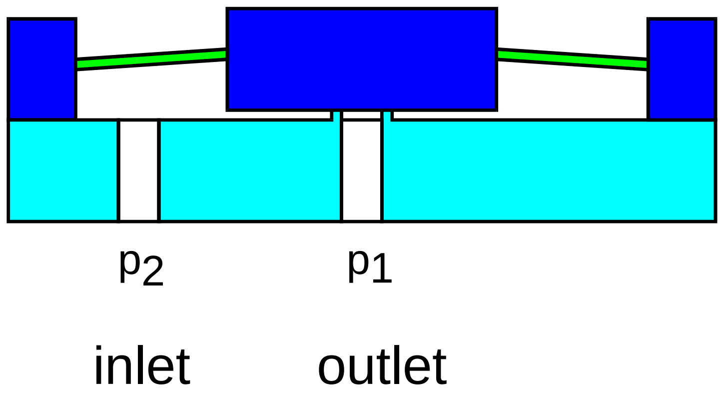
a.) equilibrated



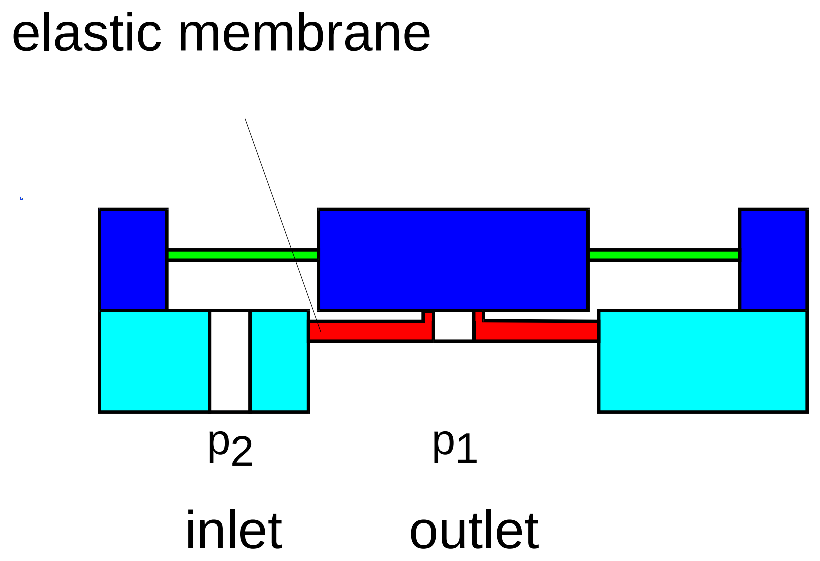
b.) non-equilibrated

5.4.2. Construction Principles

Normally closed 2-way valves:



a.) pretension on membrane



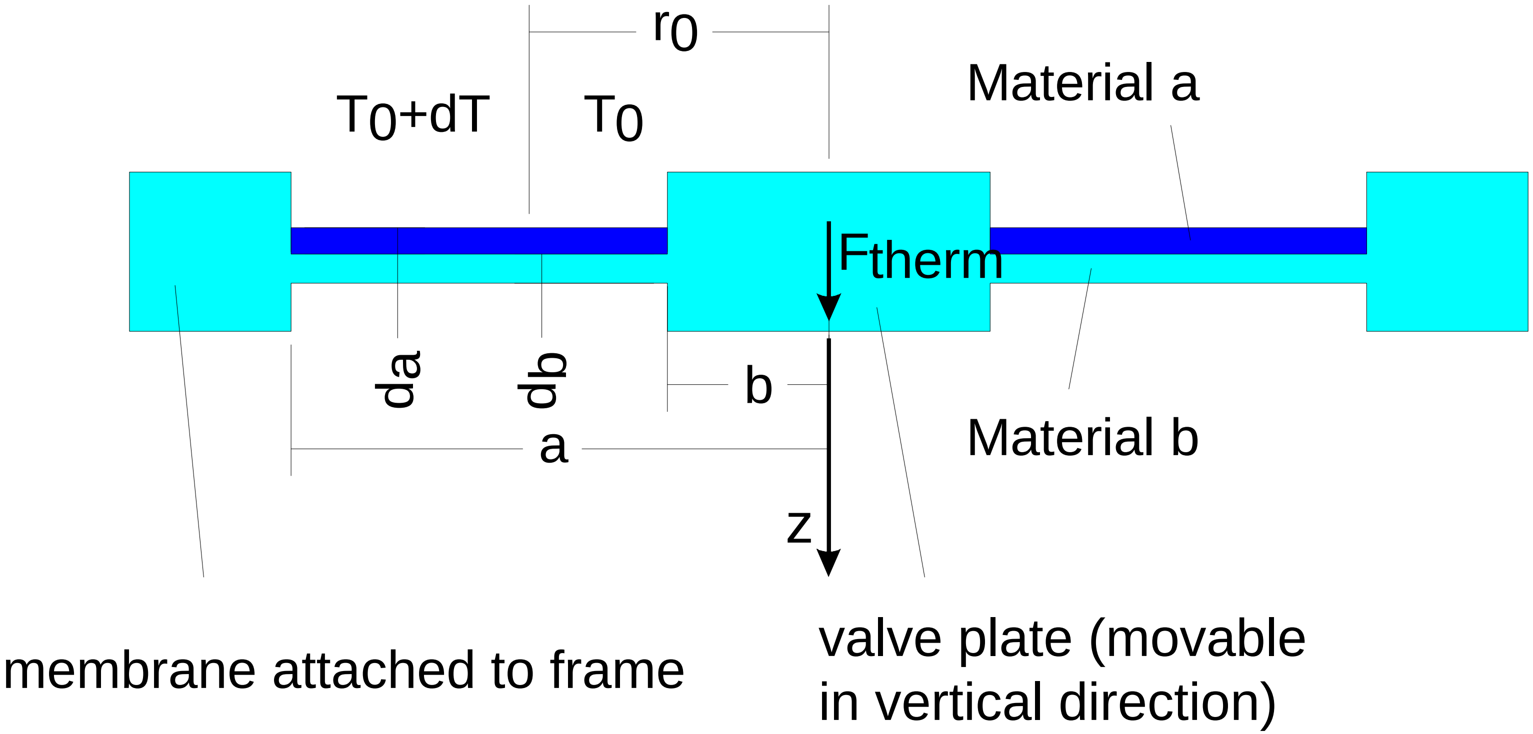
b.) elastic valve-seat membrane

5.4. Active Microvalves

1. Definition and Concepts
2. Design Principles
3. Microvalve Actuation
4. 2-Way Microvalves
5. Microvalves for Pneumatic Systems
6. 3-Way Microvalves
7. Modeling of Flow in Microvalves

5.4.3. Microvalve Actuation

Thermomechanical actuation:
(„bimetallic“ membrane)



5.4.3. Microvalve Actuation

Thermomechanical actuation:
(„bimetallic“ membrane)

Maximum deflection of membrane:

$$z = \frac{3}{4}\frac{(\alpha_2 - \alpha_1)(d_1 + d_2)\Delta T}{d_2^2 K_{\mathrm{beam},1}} l^2$$

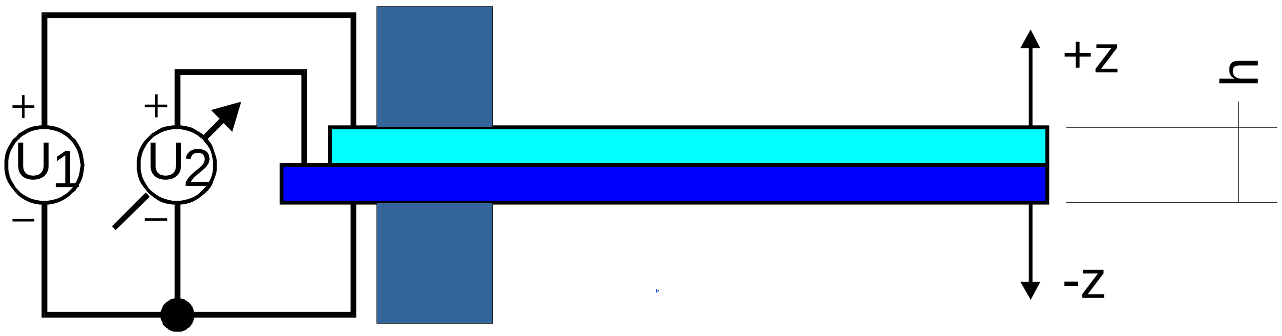
Maximum blocking force:

$$F_T = 12\pi \frac{d_2}{d_1}\frac{(\alpha_1 - \alpha_2)(d_1 + d_2)(1 + \nu_{\mathrm{aux}})\Delta T}{d_2^2 K_{\mathrm{memb},1}} D_{\mathrm{equiv}} K_{\mathrm{geom},2}$$

(W. C. Young; Roark´s Formulas for Stress & Strain; McGraw-Hill; 6. Auflage, New York, USA, 1989.)

5.4.3. Microvalve Actuation

Piezoelectric actuation:
(piezo-bimorph)



Idle amplitude:

$$z = 9 \times 10^{-10} \left[\frac{\mathrm{m}}{\mathrm{V}}\right] \frac{l^2}{h^2}(U_1 - U_2)$$

Blocking force:

$$F_{\text{piezo}} = 10 \left[\frac{\mathrm{N}}{\mathrm{Vm}}\right] \frac{hw}{l}(U_1 - U_2)$$

Valvo Unternehmensbereich Bauelemente der Philips GmbH; Piezooxide (PXE) Eigenschaften und Anwendungen; Dr. Alfred Hüthig Verlag GmbH, Heidelberg, 1988

5.4.3. Piezo-Electric Actuation

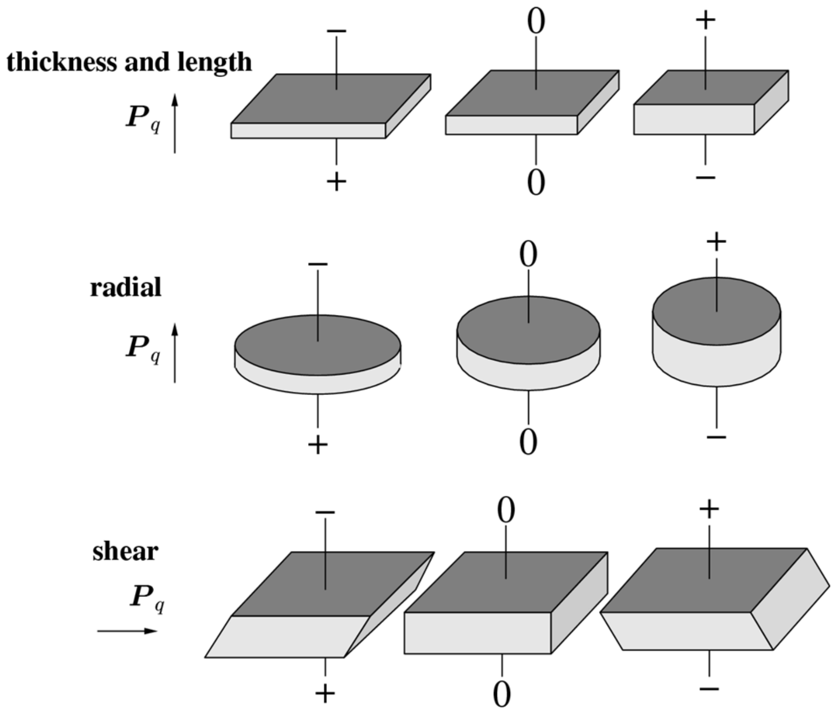


Fig. 5.20. Basic deformation modes of piezo-actuators

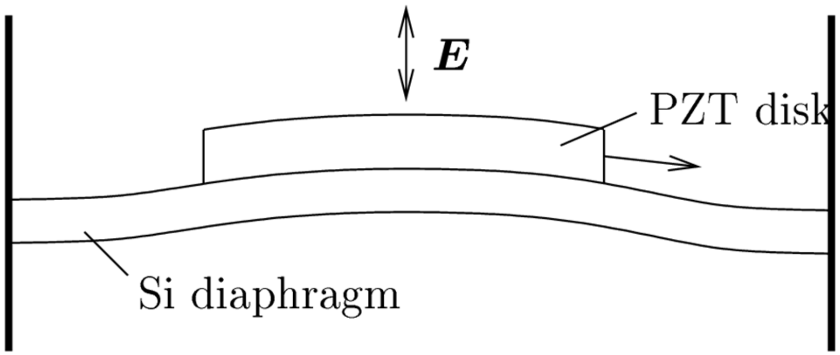


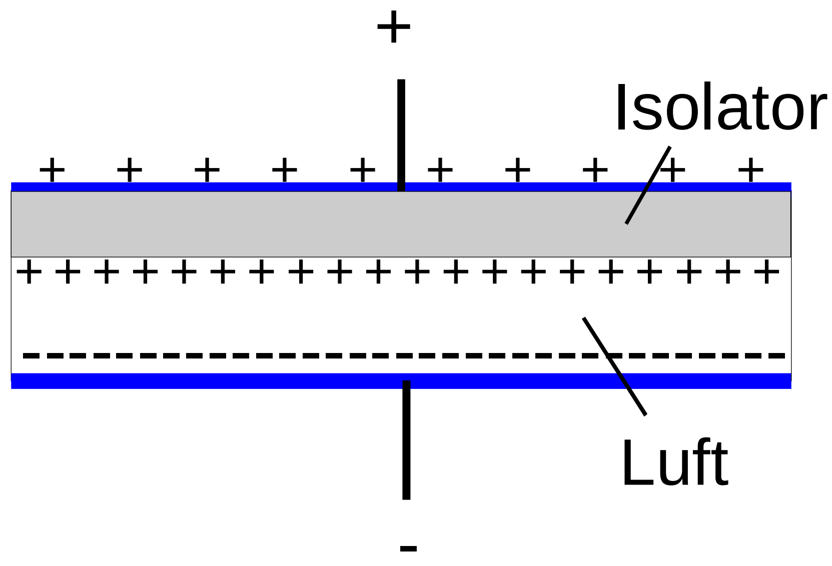
Fig. 5.21. PZT-Si bridge

5.4.3. Microvalve Actuation

Electrostatic actuation:

<u>Working principle</u>

- Oppositely charged parallel plates
- *E*-field between plates
- One plate movable
- Plates attract



<u>Electrostatic force</u>

$$F_E = \frac{1}{2}\frac{\varepsilon_0}{\varepsilon_{\mathrm{air}}} A \frac{U^2}{\left(\frac{d_{\mathrm{insul}}}{\varepsilon_{\mathrm{insul}}} + \frac{s}{\varepsilon_0}\right)^2}$$

5.4.3. Microvalve Actuation

Electrostatic actuation:

Balance of forces

$$z^3 - 2s_{\text{eff}} z^2 + s_{\text{eff}}^2 z - \frac{1}{2}\frac{\varepsilon_0 A}{k} U^2 = 0$$

Snapping voltage

$$U_{\text{snap}} = \sqrt{\frac{8}{27}\frac{k s_{\text{eff}}^3}{\varepsilon_0 A}}$$

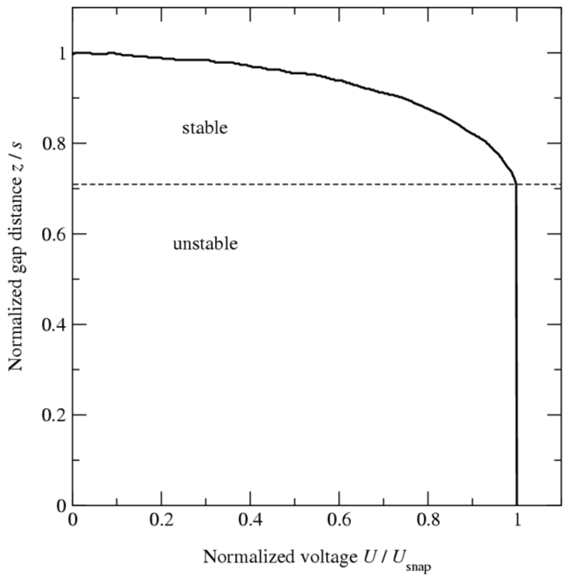


Fig. 5.24. Normalized gap distance z/s as a function of the applied voltage normalized to U_{snap}. Above the snapping threshold U_{snap}, the electrode becomes unstable and the gap closes

5.4.3. Microvalve Actuation

Paschen curve

$$E_{\mathrm{air}} = U/\varepsilon_{\mathrm{air}} \left(\frac{d_{\mathrm{insul}}}{\varepsilon_{\mathrm{insul}}} + \frac{s}{\varepsilon_{\mathrm{air}}} \right)$$

$$E_{\mathrm{insul}} = U/\varepsilon_{\mathrm{insul}} \left(\frac{d_{\mathrm{insul}}}{\varepsilon_{\mathrm{insul}}} + \frac{s}{\varepsilon_{\mathrm{air}}} \right) = \frac{\varepsilon_{\mathrm{air}}}{\varepsilon_{\mathrm{insul}}} E_{\mathrm{air}}$$

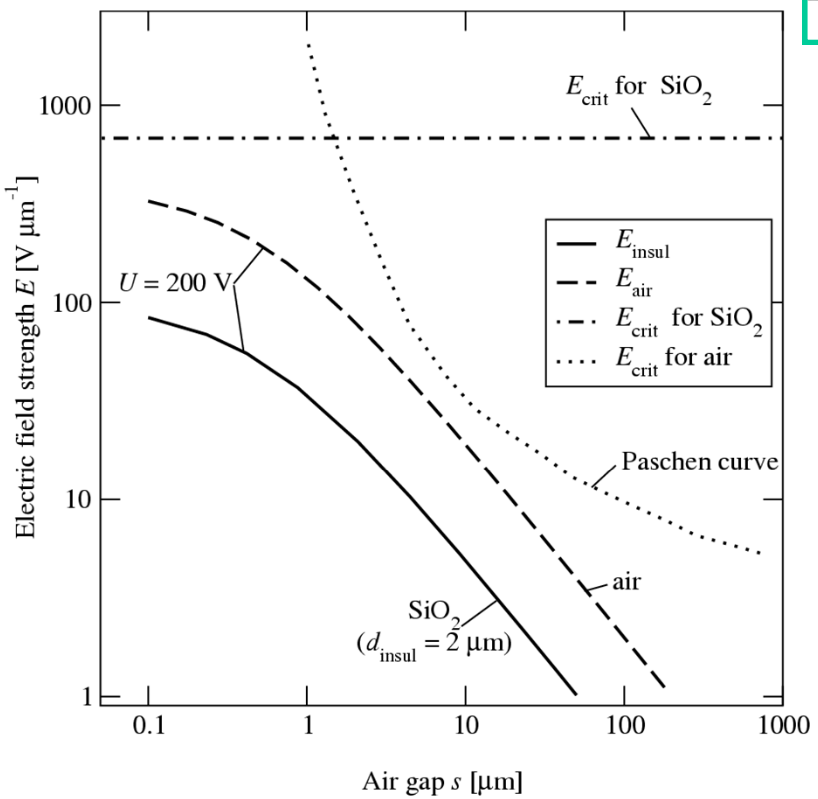


Fig. 5.25. Paschen curve representing the critical breakthrough electric field strength E^* in air. Field strengths E within air and the 2-µm insulating layer (SiO_2), cf. (**??**), remain below their respective breakthrough curves

5.4. Active Microvalves

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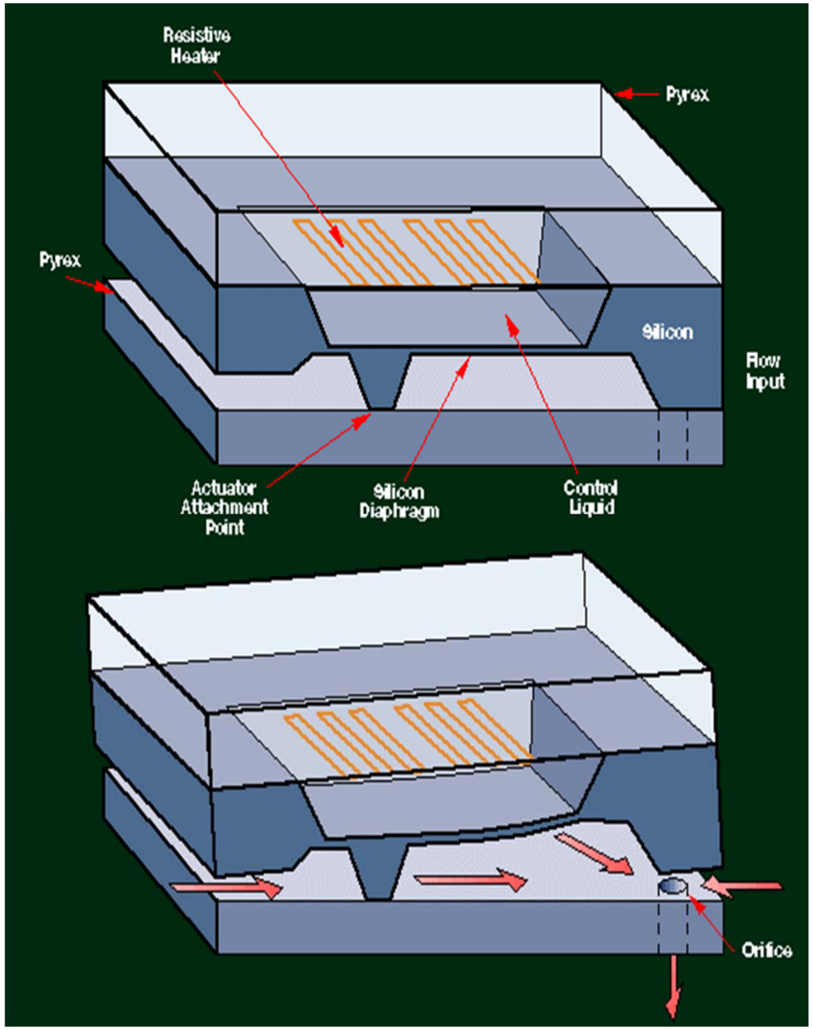
5.4.4. Redwood Microsystems

Redwood Microsystems NC-1500

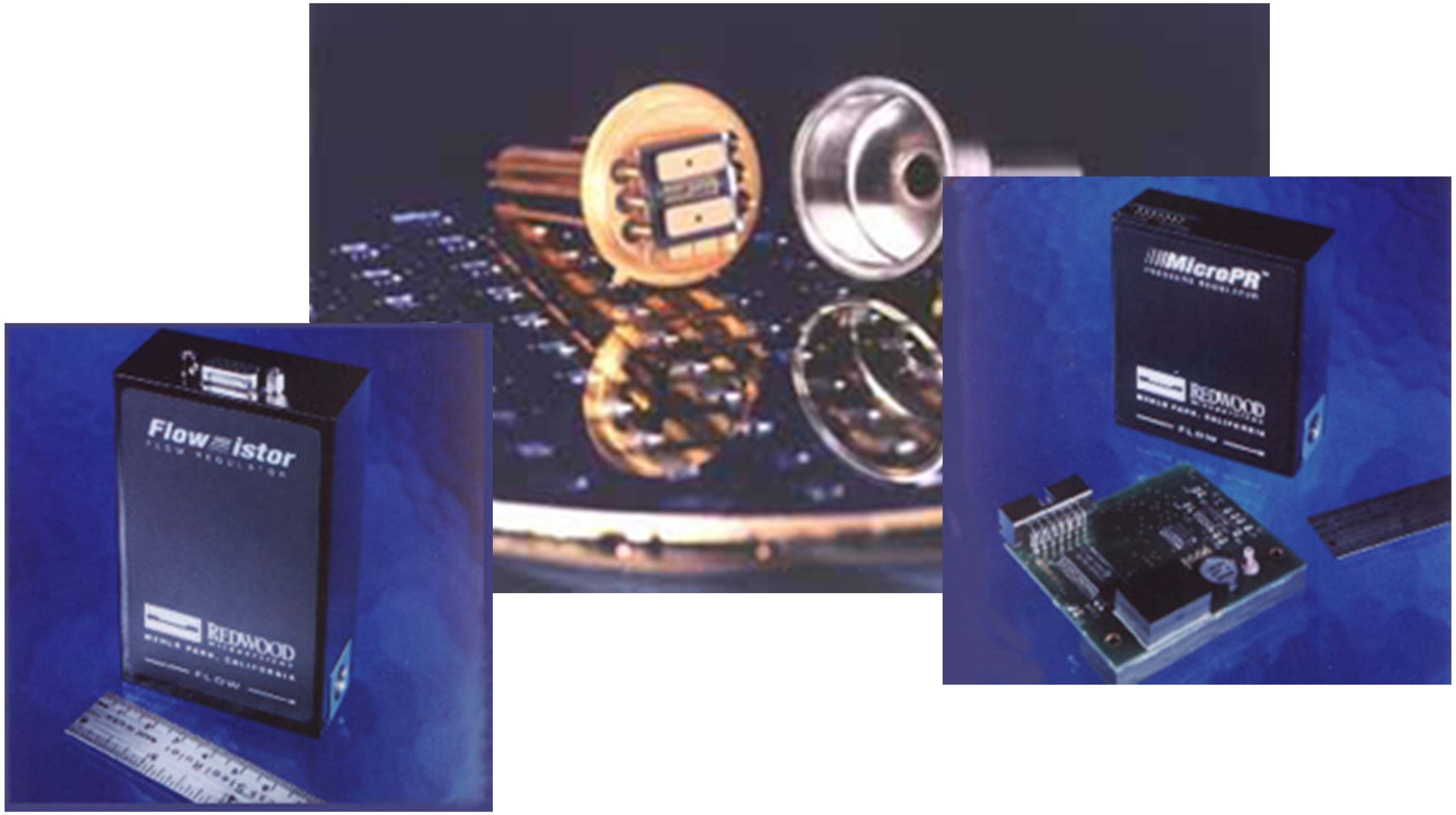
- Valve type: 2-way normally-closed
- Actuation: thermopneumatic
- Media: Gases
- Maximum pressure: 7 bar
- Flow rates:

  0.1 ml / min – 1.500 ml / min
- Response time: 1 s
- Power: 1.5 W
- Temperature range: 0 – 55°C
- Tolerable particle size: 1 µm
- Internal volume: 0,6 ml
- Dimensions 6x6x2mm³
- Operating voltage: 0-15 V
- Proportional mode possible



5.4.4. Redwood Microsystems

www.redwoodmicro.com



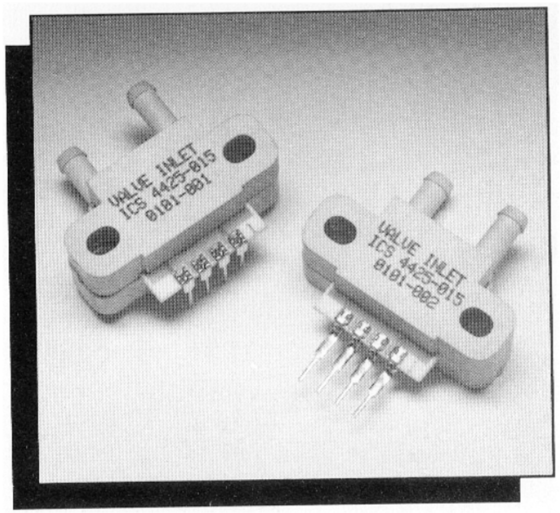
Flow controller

Druckregler

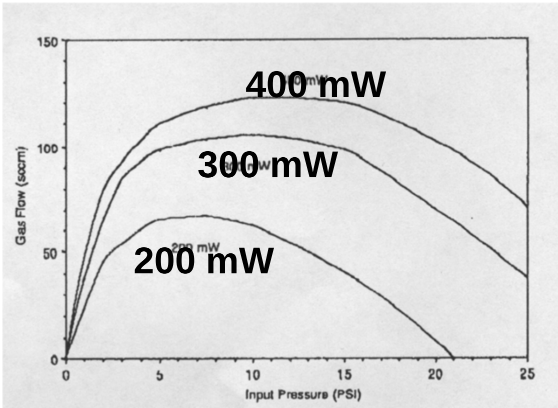
5.4.4. IC-Sensors

<u>IC-Sensors (USA)</u>

- Valve type: 2-way normally-closed
- Actuation: Thermomechanical
- Media: Gases
- Maximum pressure: 1 bar
- Flow rate: 0.15 l / min
- Response time: 50 ms
- Power: 0.4 W
- Temperature range: -20 – 70°C
- Tolerable particle size: 25 µm
- Operating voltage: 5 V



Gas flow (sccm)

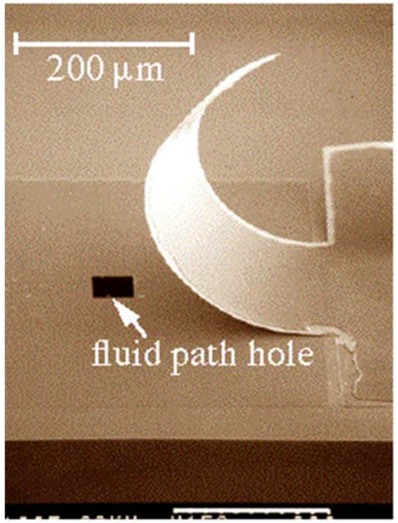


Input pressure (PSI)

5.4.4. Lawrence Livermore National Laboratory

Lawrence Livermore
National Laboratory:

- Valve type: 2-way normally-open
- Actuation:
  - electrostatic
  - with 1-µm polyimide cantilever

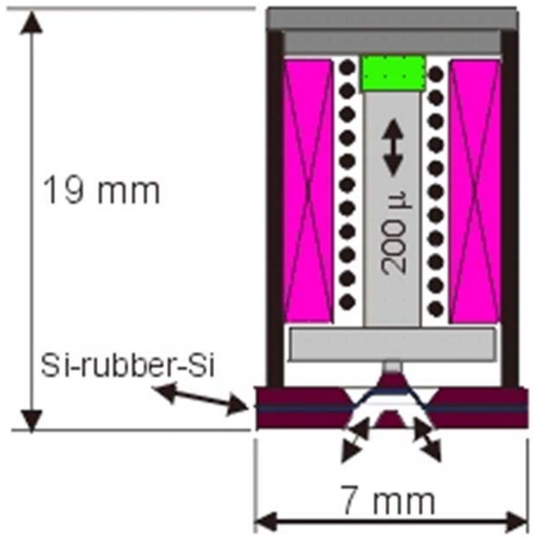


- Valve amplitude:200 µm
- Media: Gases
- Maximum pressure: 0.2 bar
- Flow rate: ?
- Response time: ?
- Power: 10 µW
- Temperature range: ?
- Size ?

5.4.4. Twente Microproducts

Twente Microproducts:

- Valve type: 2-way
  - Bistable (NO / NC)
  - Rubber-membrane
- Actuation: electromagnetic
  - Combination of permanent magnet and electromagnet



Cross-section of a silicon microvalve with miniature magnetic actuator

5.4.4. Electromagnetic Actuation

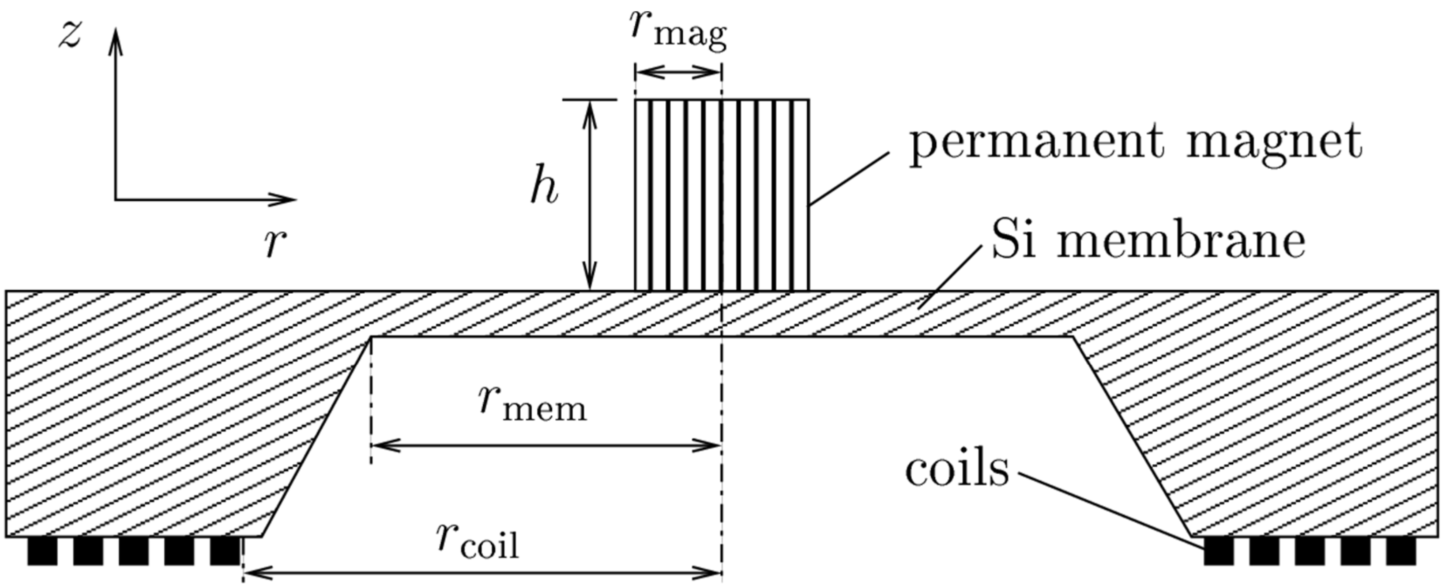


Fig. 5.26. Electromagnetic actuation by a membrane-mounted permanent magnet which translates according to the magnetic field generated by the coils

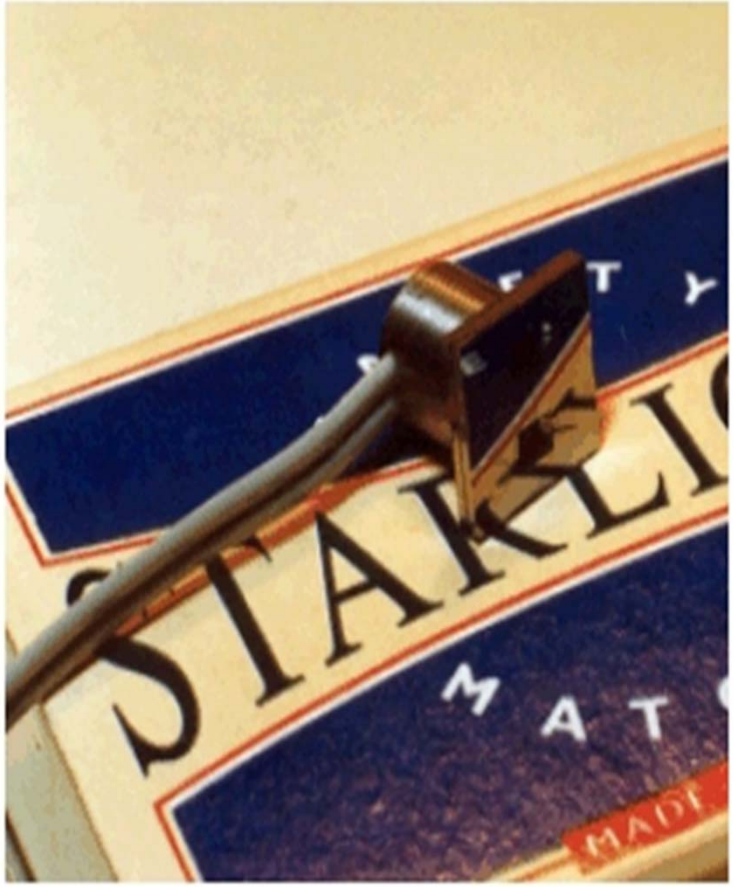
$$F_z = B_r A \int_0^h \frac{\mathrm{d}H_z}{\mathrm{d}z} \mathrm{d}z$$

$$H(z) = \frac{N I_{coil} r_{coil}}{2(r_{coil}^2 + z^2)^{3/2}}$$

5.4.4. Twente Microproducts

Twente Microproducts:

- Media: Gases, Liquids
- Maximum pressure: 2 bar
- Gap diameter: 0.2 mm
- Response time: ?
- Operating current: 0.5 A
- Power: no blocking power
- Dead volume: < 5 µl
- Dimensions: 6 x 6 x 6 mm³

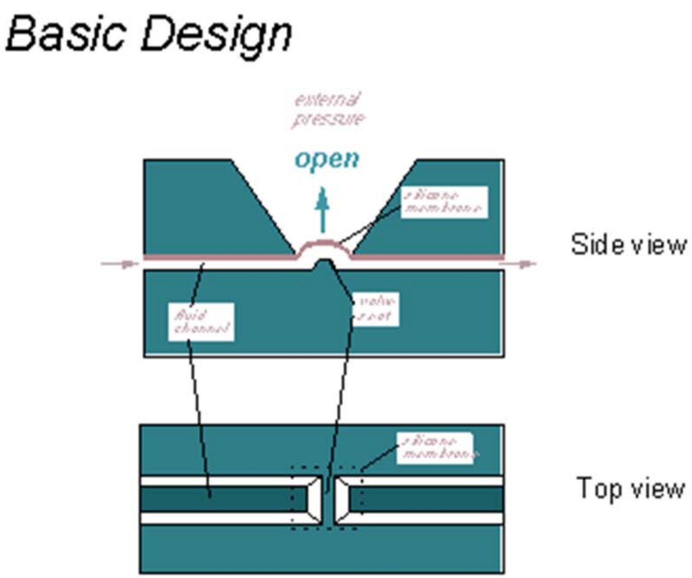


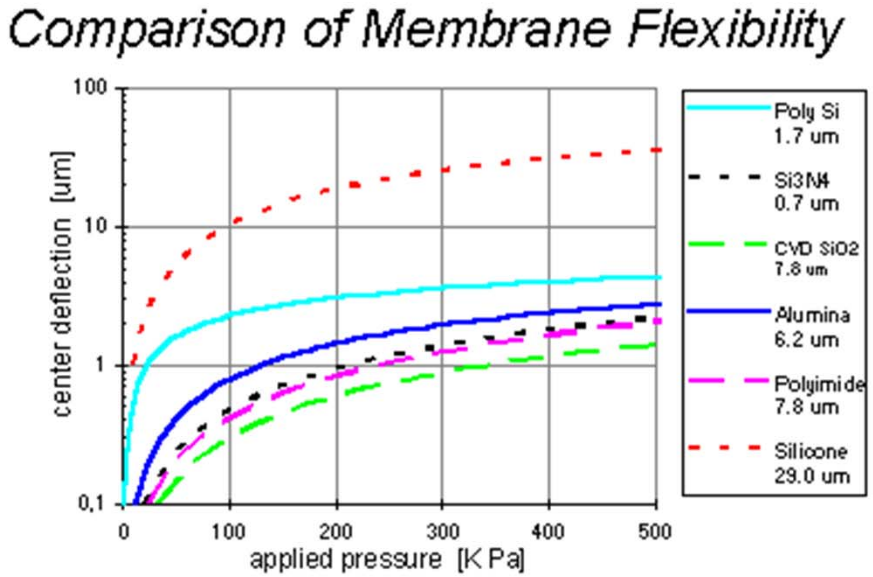
Bi-stable magnetically actuated microvalve (dimensions 6x6x6 mm)

5.4.4. Industrial Microelectronics Center (IMC)

IMC (Sweden):

- Valve type: 2-way normally-open
- Actuation:
  - Pneumatic
  - Silicone membrane





Comparison of deflections of 0.2 x 0.2 mm membrane made of different materials.
(Thickness adapted for maximum pressure head of 5 bars)

5.4.4. Industrial Microelectronics Center (IMC)

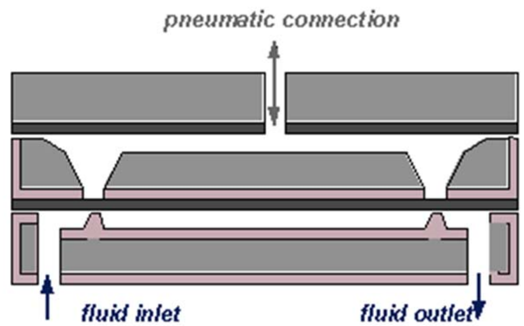
IMC (Sweden):

- Valve type: 2-way normally-open
- Actuation: pneumatic

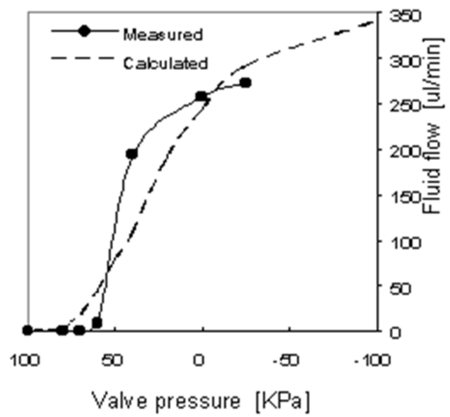
- Media: Gases or liquids

- Actuation pressure depends on hydrodynamic pressure of flow to be switched

Valve System



Water flow at 100 KPa inlet pressure



5.4. Active Microvalves

1. Definition and Concepts
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5.4.5. Miniature Valves – State of the Art

Trends in Automation Technology:

- Intelligent, decentralized subsystems
- Communicating over common data bus
- Miniaturization
- Integration of electronics

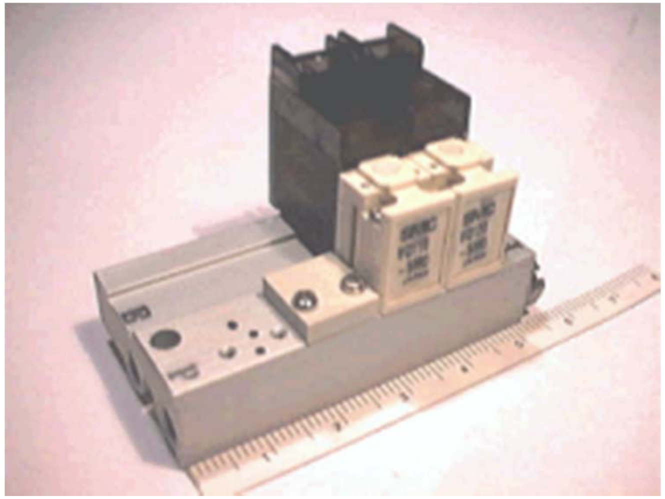
Present Situation:

- Reduction of electric power consumption
- electromagnetic and piezoelectric actuation
- Typical power consumption 0.5 – 1 W
- Various miniaturized valves already feature power consumption below 10 mW which can be controlled by bus system

5.4.5. Miniature Valves – State of the Art

Electromagnetically actuated miniature valve:

Manufacturer:	SMC
Type:	3-way, normally-closed
Pressure range:	0 – 7 bar
Flow rate:	8 l / min
Media:	filtered, compressed air
Temperature range:	< 50°C
Power:	500 mW
Response time:	< 10 ms
Width of housing:	10 mm



Quelle: Fa. SMC

5.4.5. Miniature Valves – State of the Art

Electromagnetically actuated miniature valve:

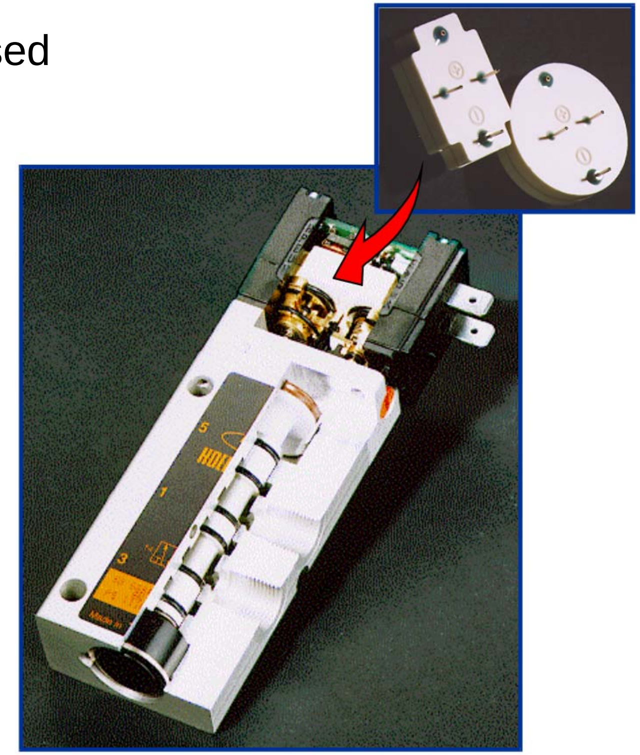
Manufacturer:	Bürkert
Type:	3-way, normally closed
Pressure range:	0 – 10 bar
Flow:	4 l / min
Media:	dry, filtered air
Temperature range:	-25°C - 80°C
Power:	10 mW
Response time:	20 ms

Source: Fa. Bürkert

5.4.5. Miniature Valves – State of the Art

Piezoelectrically actuated miniature valve:

Manufacturer:	Hoerbiger-Origa
Type:	3-way, normally closed
Pressure range:	0 – 2 bar
Flow:	1.5 l / min
Media:	dry, filtered compressed air
Temperature range:	-10°C - 60°C
Power:	6 mW
Response time:	2 ms
Housing:	∅19 mm



Source: Hoerbiger-Origa

5.4. Active Microvalves

1. Definition and Concepts
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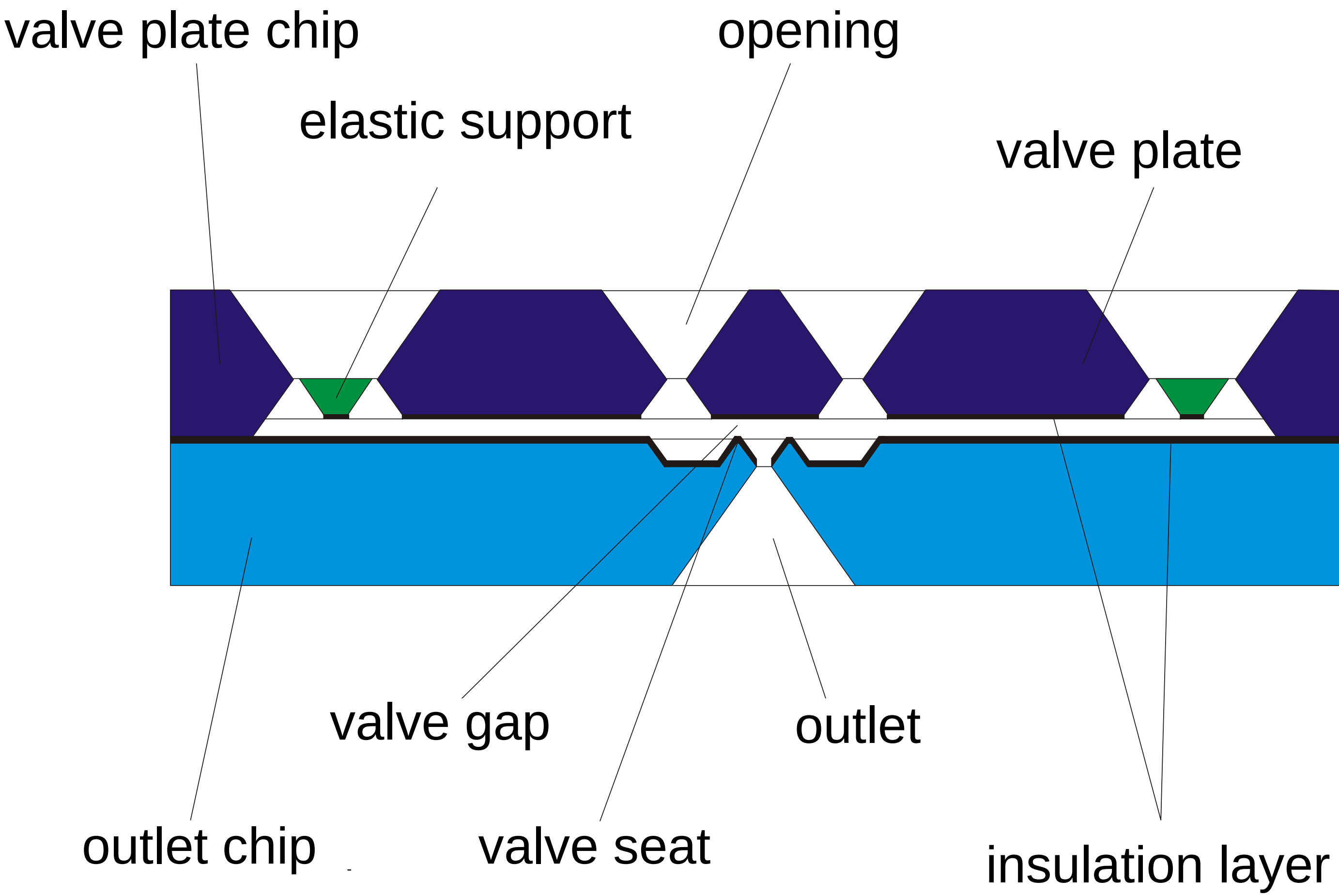
5.4.6. MegaMic Valve Series of HSG-IMIT

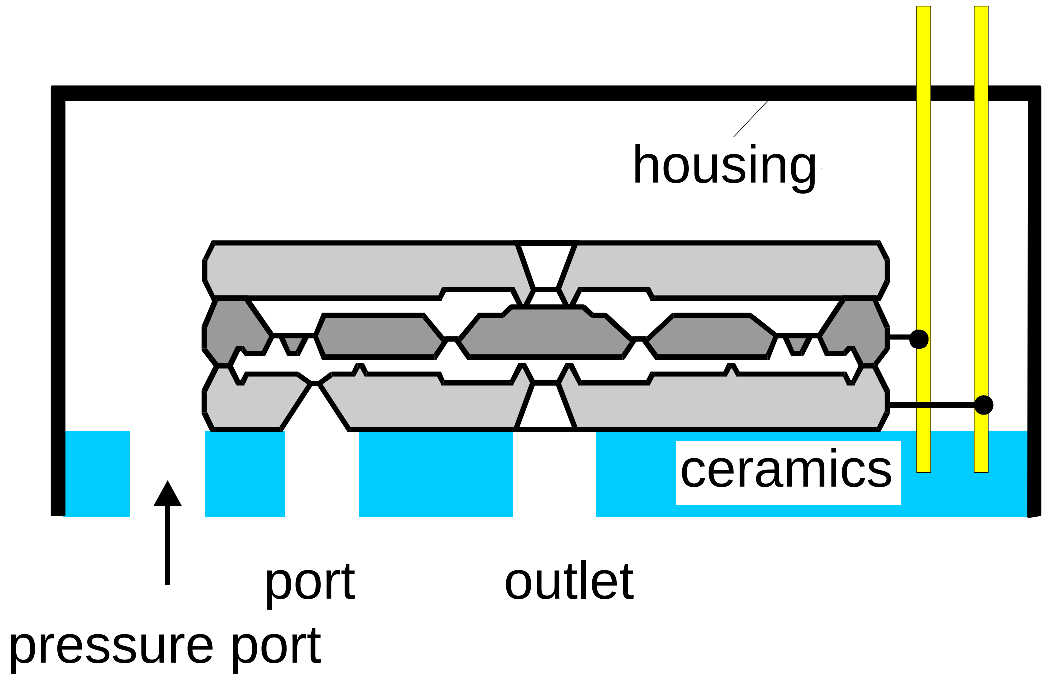
Normally-open, electrostatically actuated 2-way valve

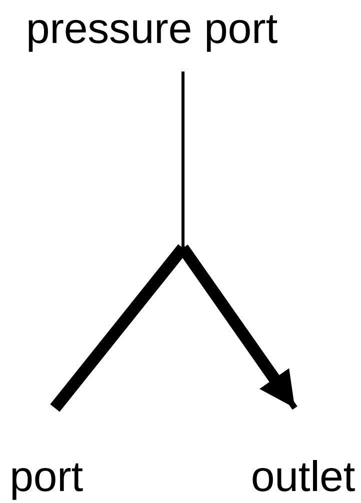


5.4.6. Microvalves for Gases

System concept

- 3-way valve (switch)
- Electrostatic actuation
- Normally-closed by mechanical pretension

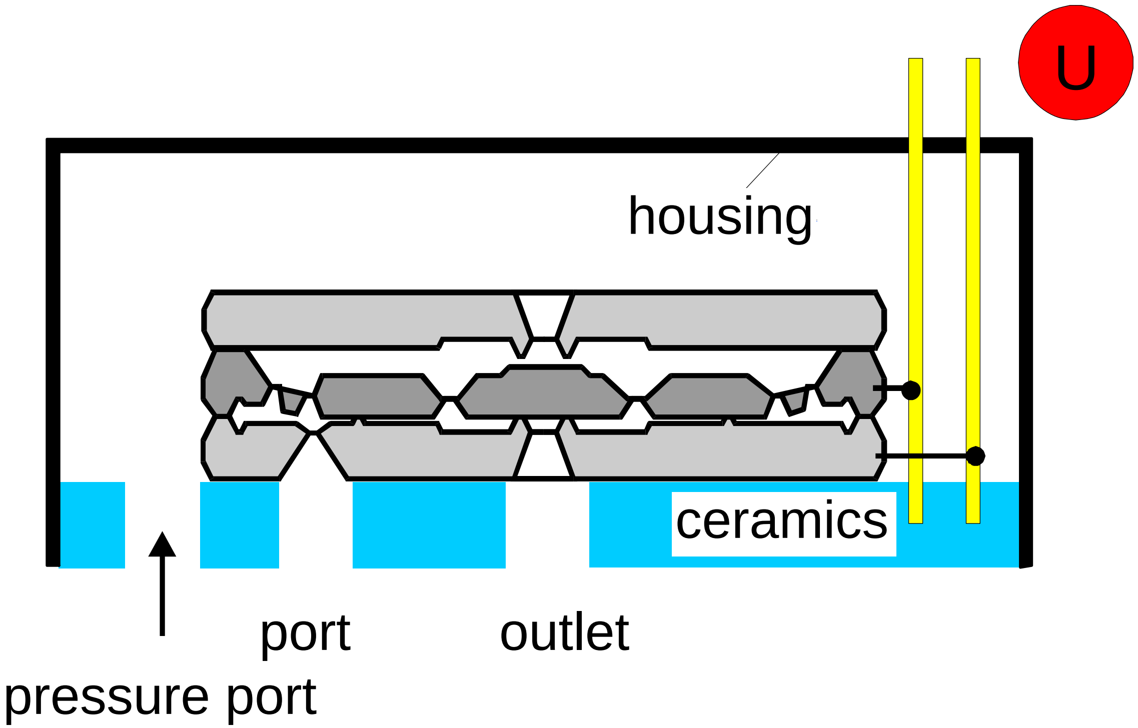


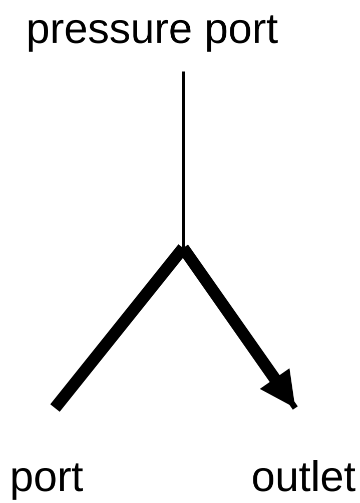


5.4.6. Microvalves for Gases

System concept

- 3-way valve (switch)
- Electrostatic actuation
- Normally-closed by mechanical pretension





5.4.6 Microvalves

Characteristics:

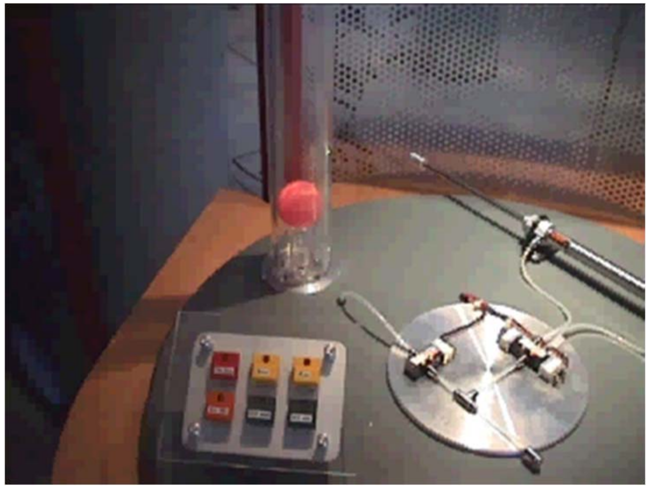
Housing: 7 x 10 x 16 mm^3

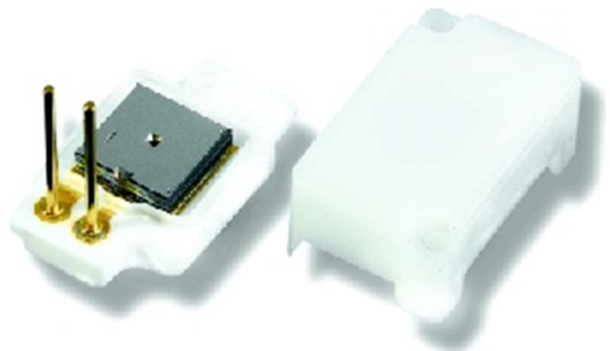
Response time: < 1 ms

Power: 3 mW

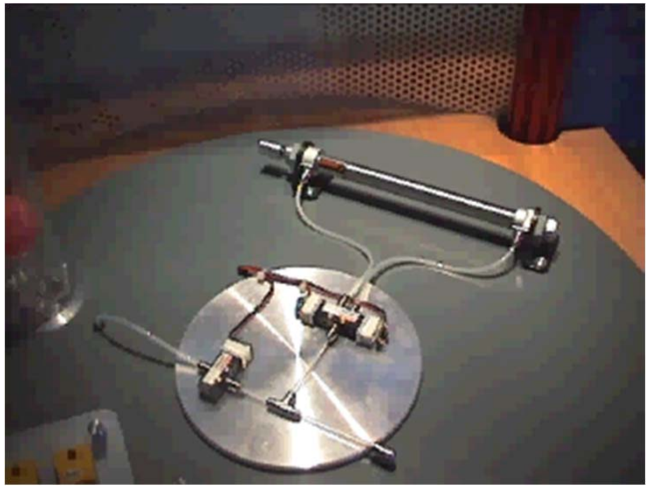
Pressure range: 10 bar (16 bar)

Max. flow: 1 l / min



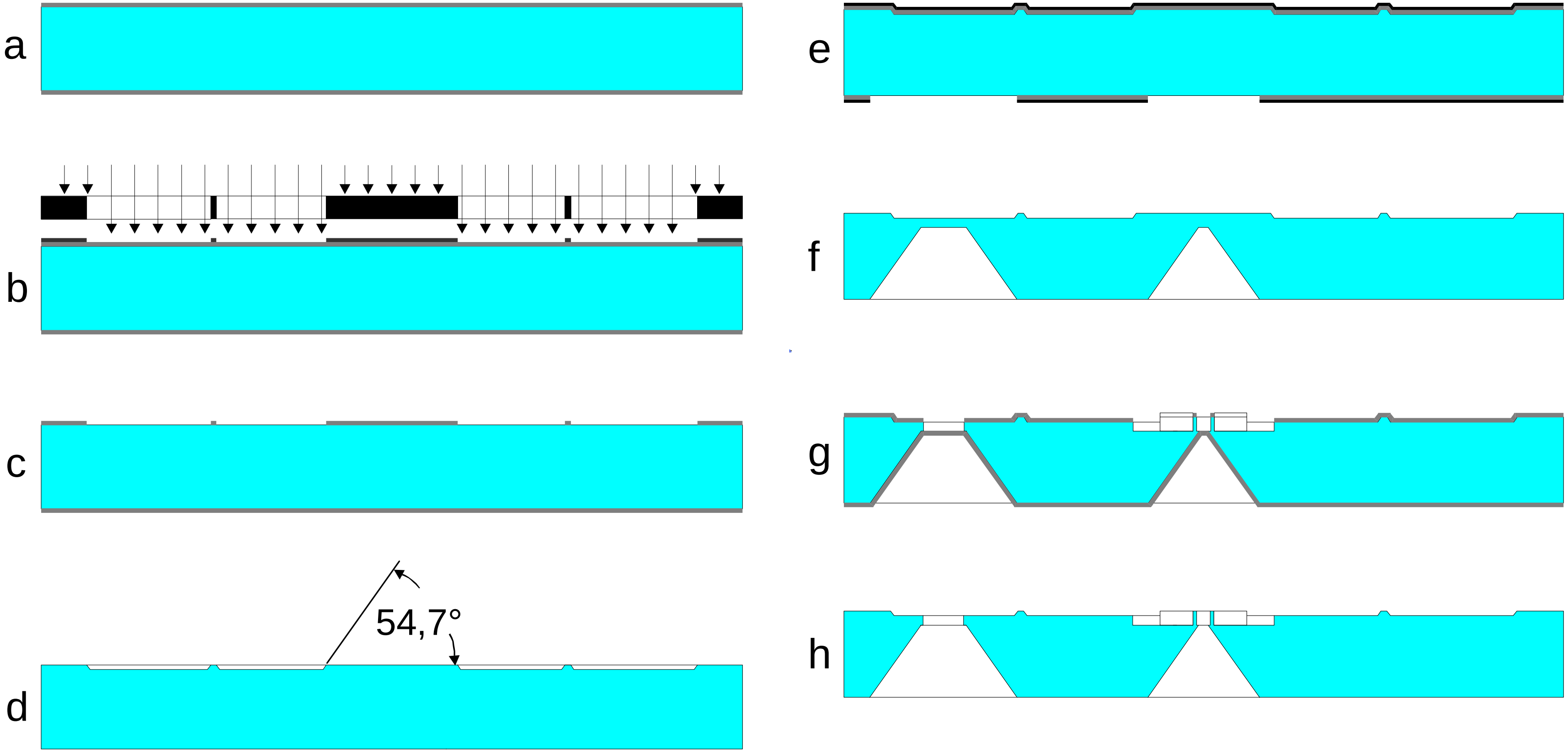


Pneumatics (10 bar)



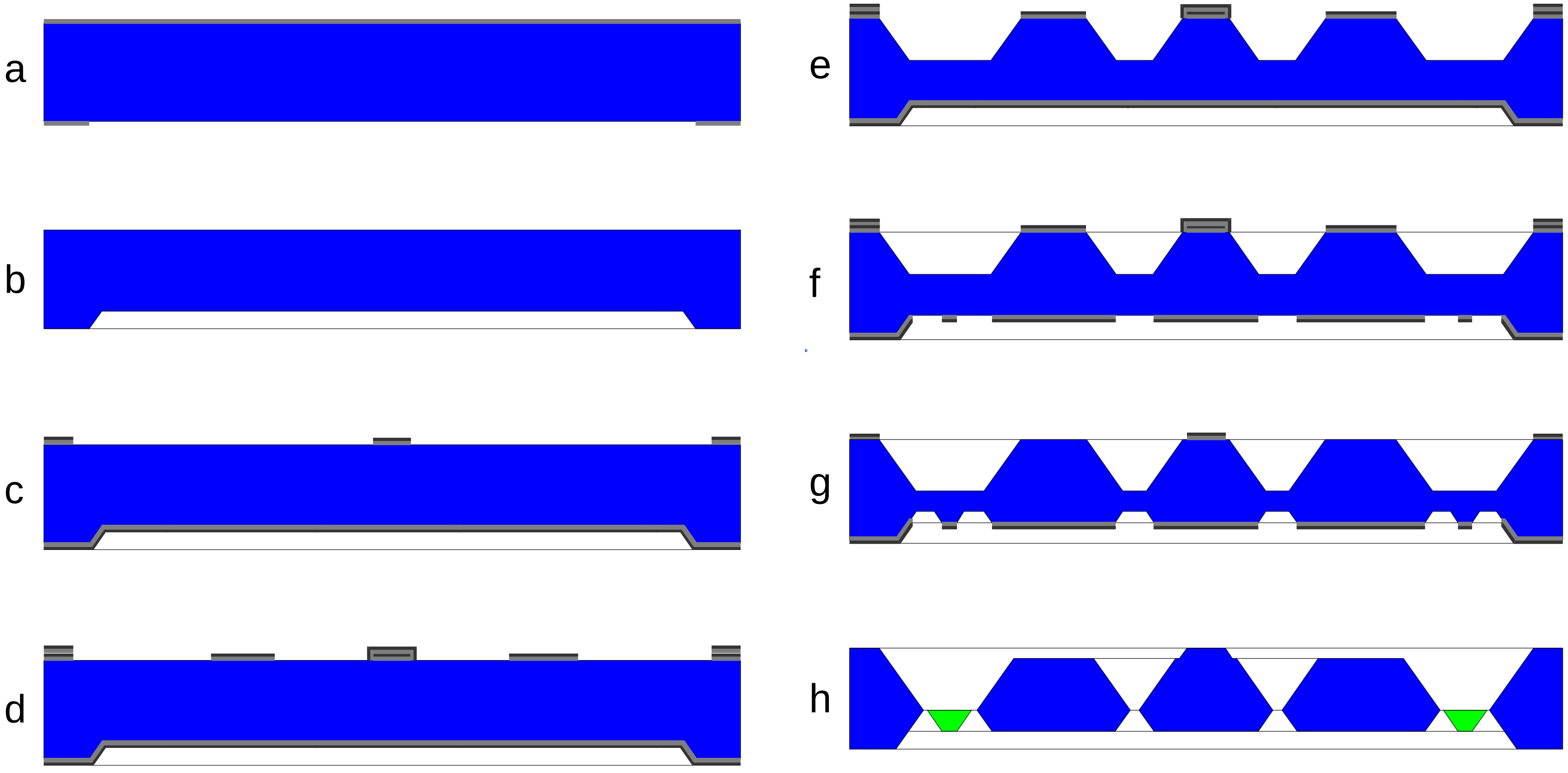
5.4.6 MegaMic-Valve Series of HSG-IMIT

manufacturing of outlet wafer



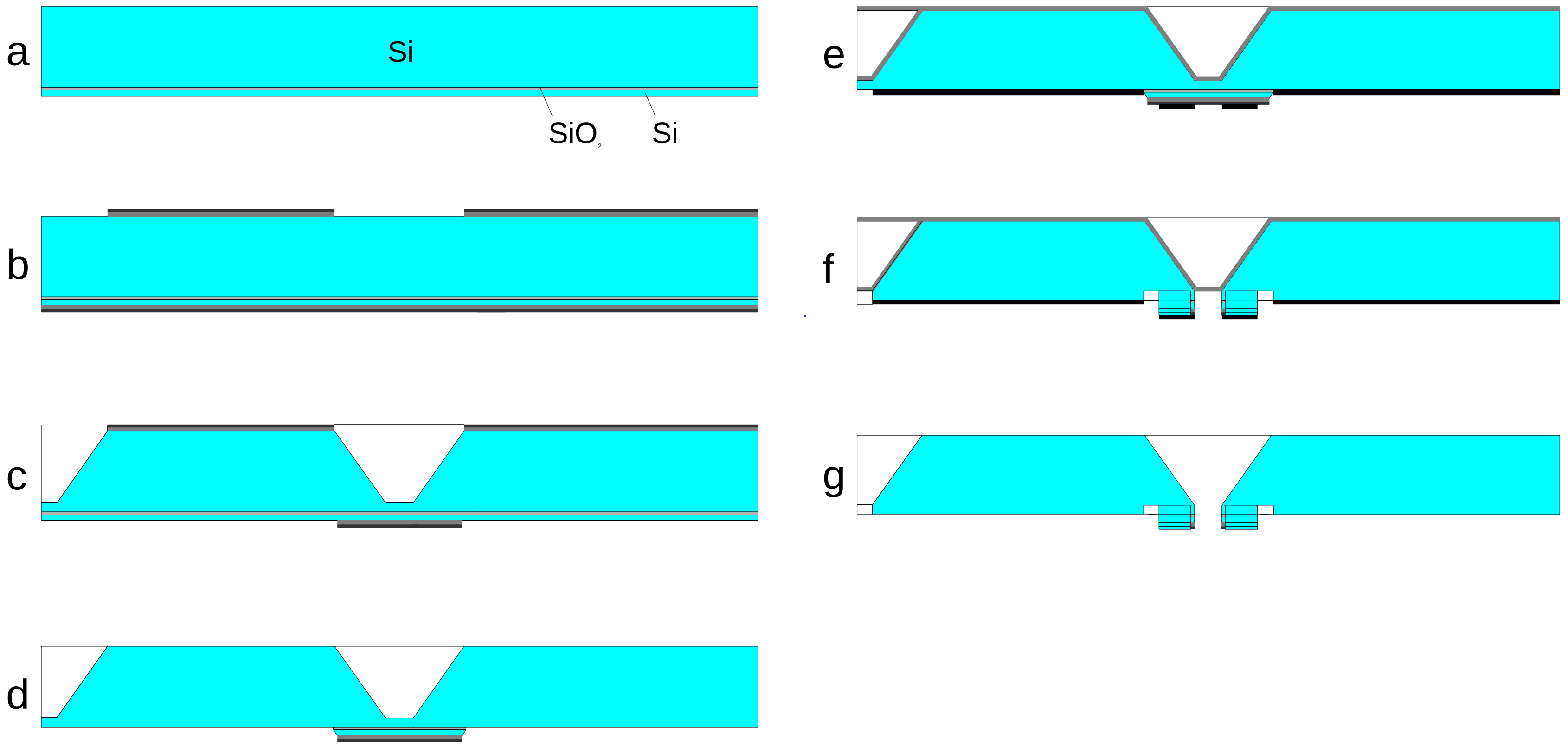
5.4.6 MegaMic-Valve Series of HSG-IMIT

manufacturing process of valve plate chip



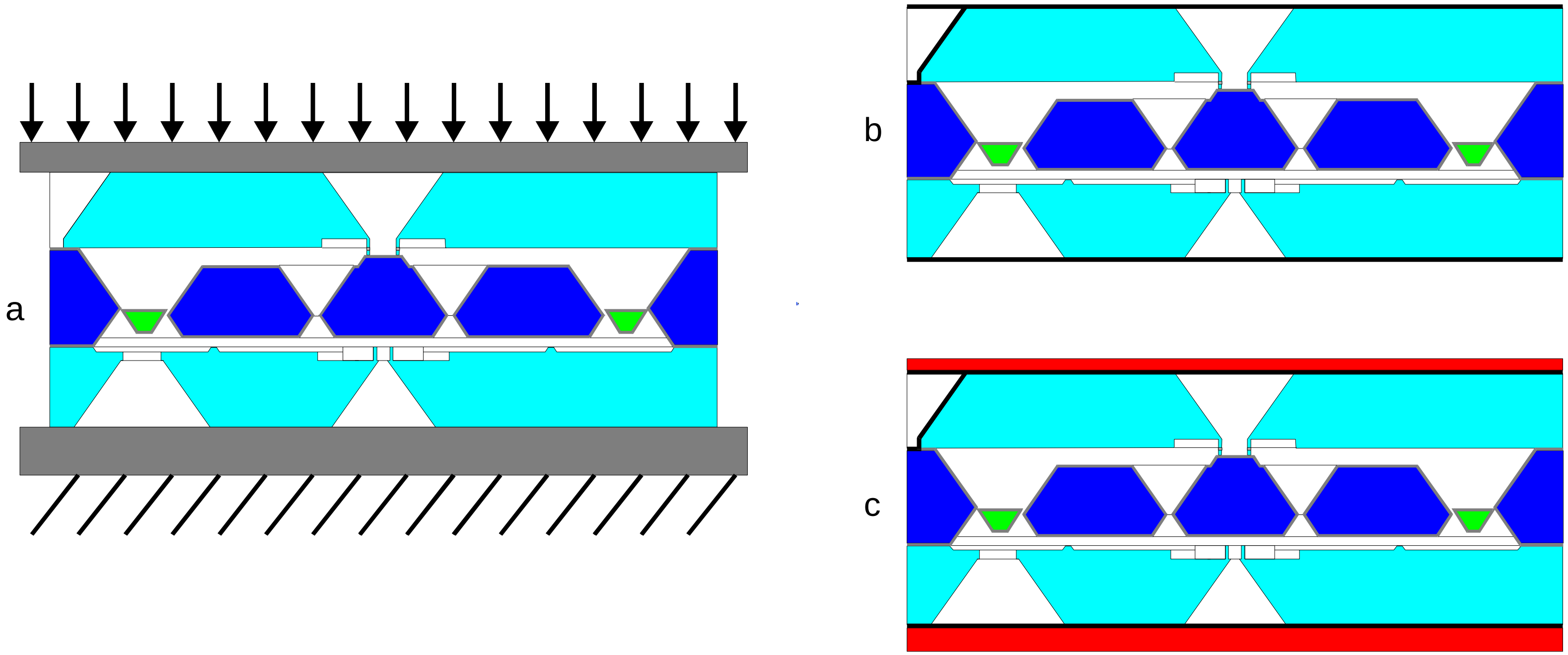
5.4.6 MegaMic-Valve Series of HSG-IMIT

manufacturing of cover chip



5.4.6 MegaMic-Valve Series of HSG-IMIT

full-wafer bonding and dicing of valve chip

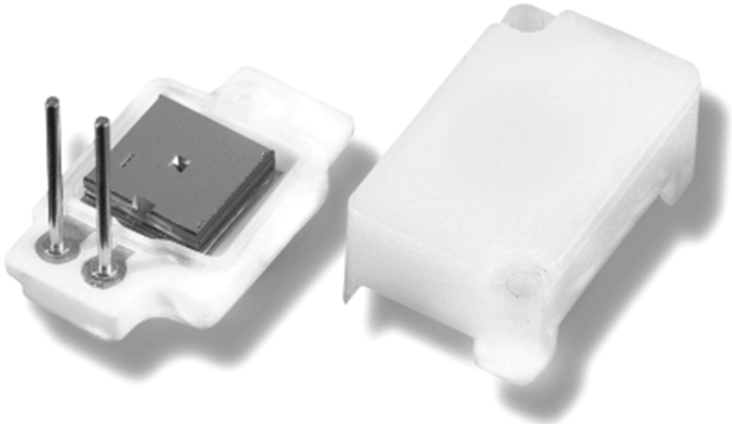


5.4.6 MegaMic-Valve Series of HSG-IMIT

packaging and assembly

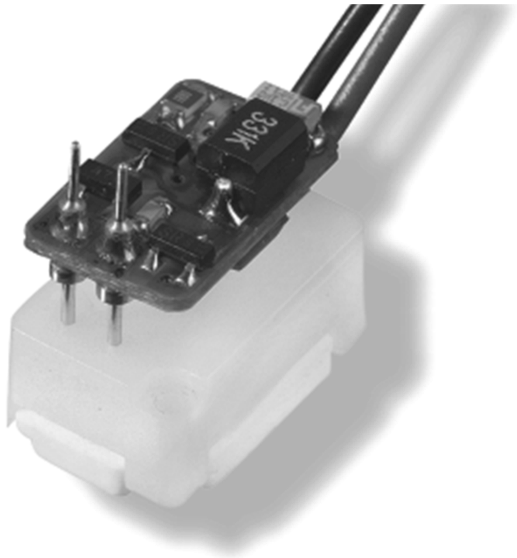
5.4.6 MegaMic-Valve Series of HSG-IMIT

Electrostatically actuated 3-way microvalve MegaMic



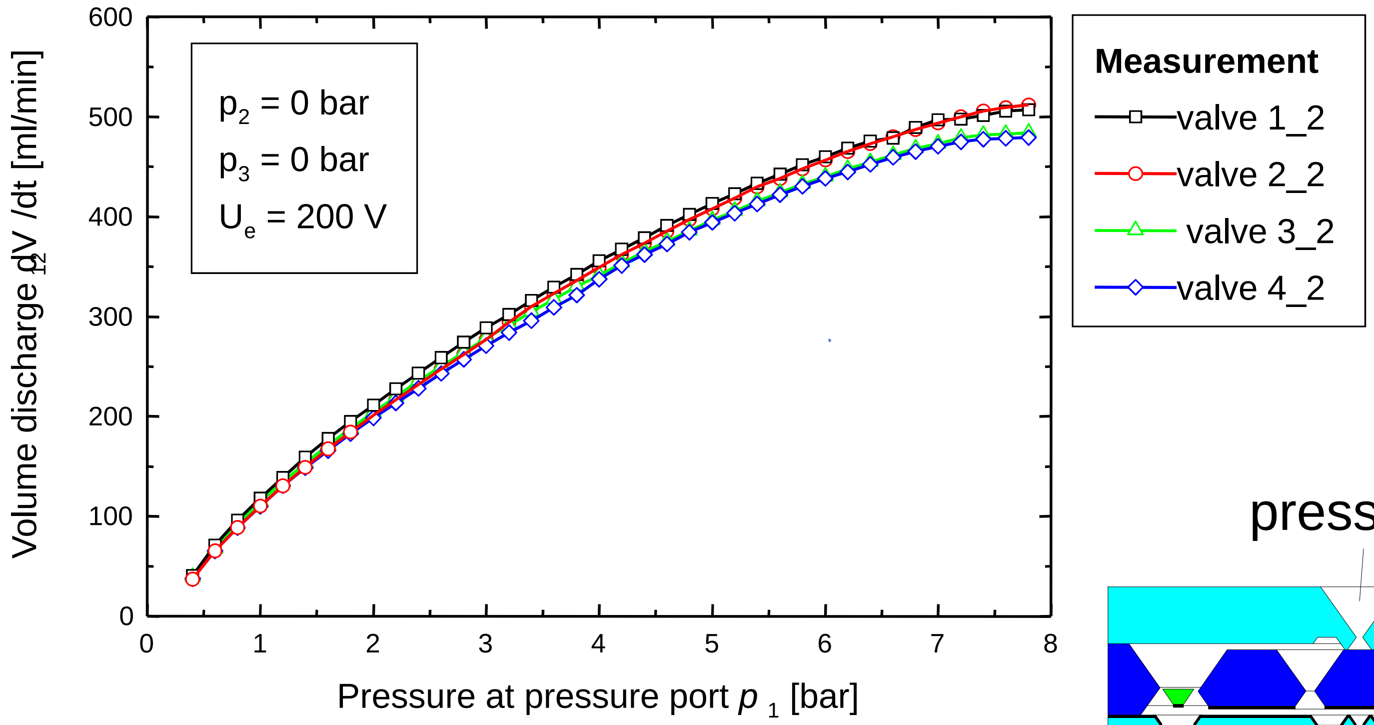
Characteristics:

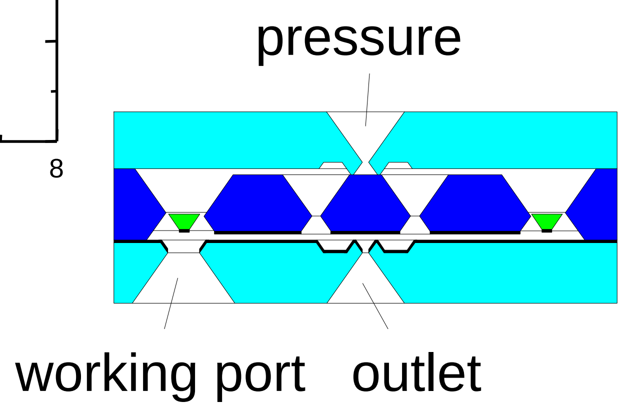
-Pressure range:	10 bar
-Flow rate:	typ. 0.5 l / min
-Response time:	< 1 ms
-Power:	3 mW
-Temperature range:	-40°C – 80°C



5.4.6 MegaMic-Valve Series of HSG-IMIT

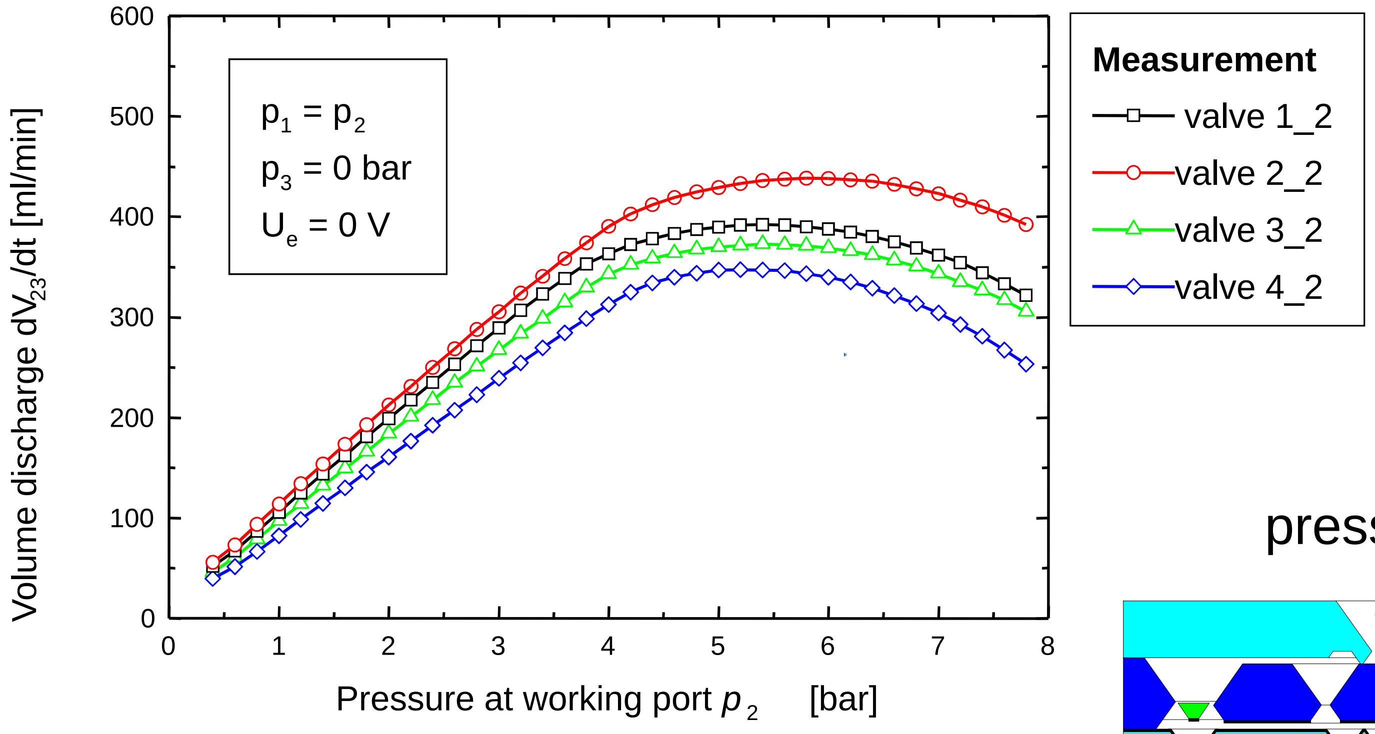
Measurement of volume flow from pressure to working port

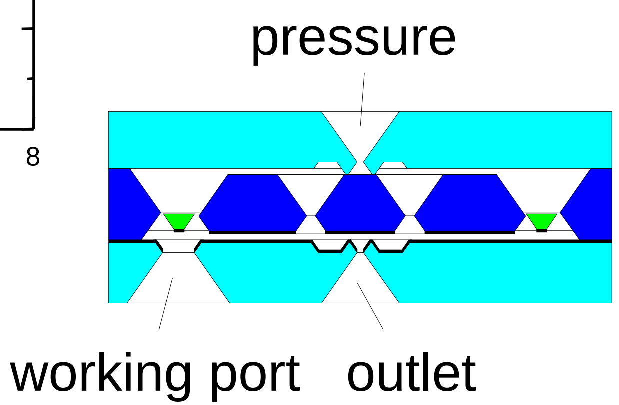




5.4.6 MegaMic-Valve Series of HSG-IMIT

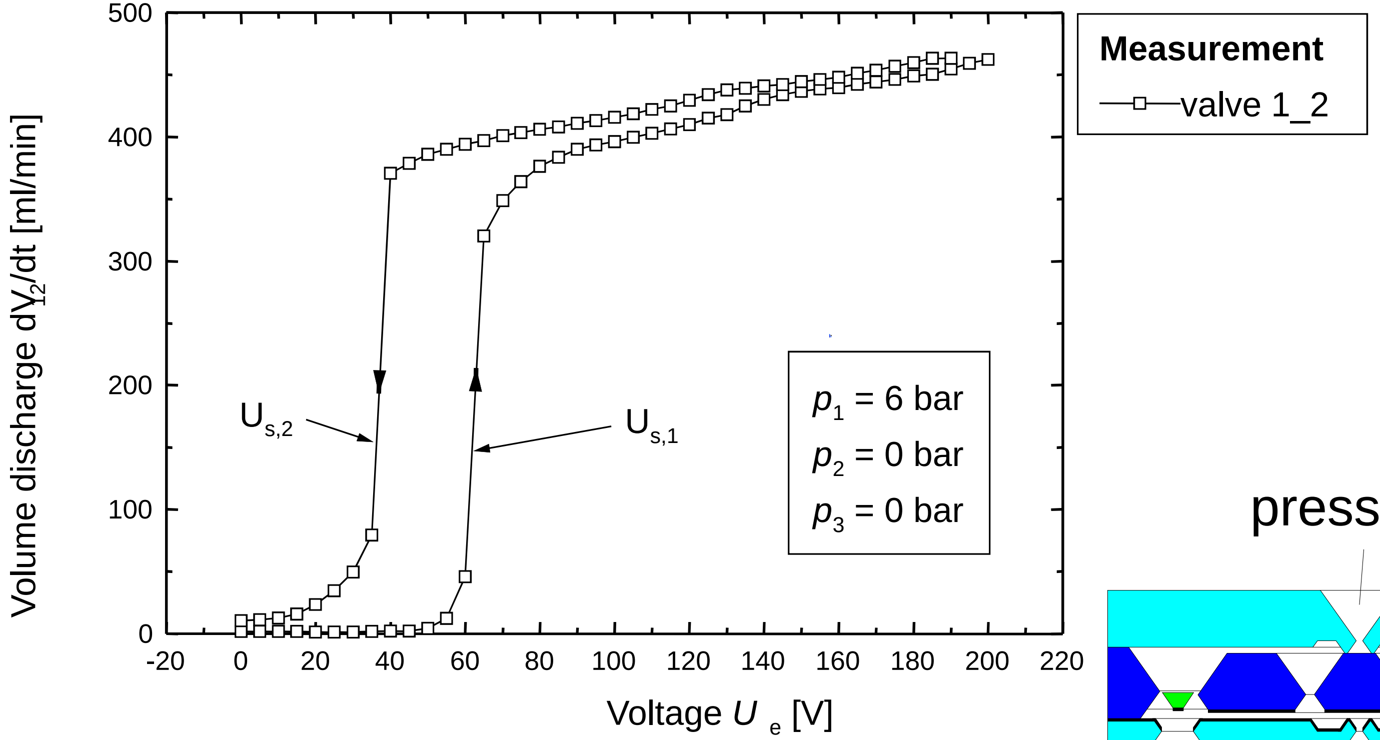
Measurement of volume flow from pressure to outlet

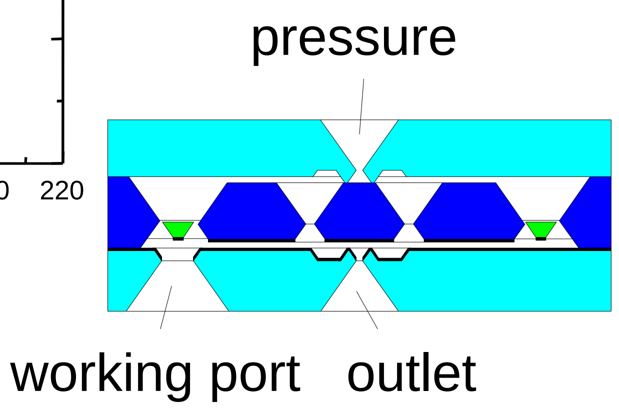




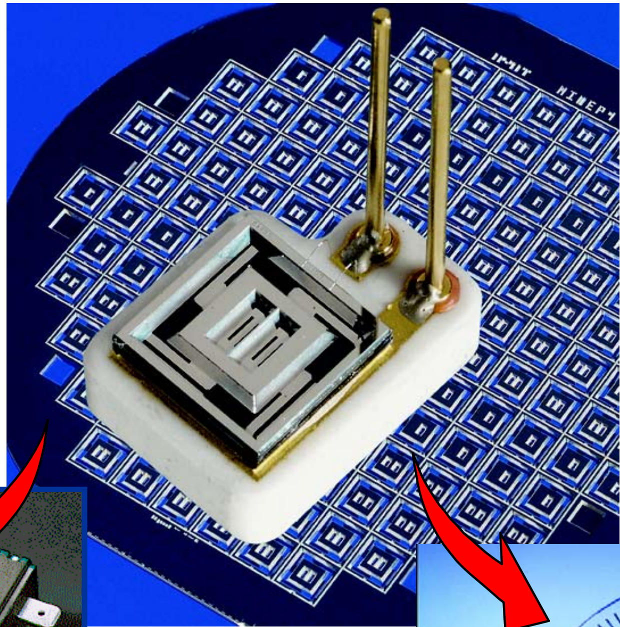
5.4.6 MegaMic-Valve Series of HSG-IMIT

Measurement of electric switching characteristics



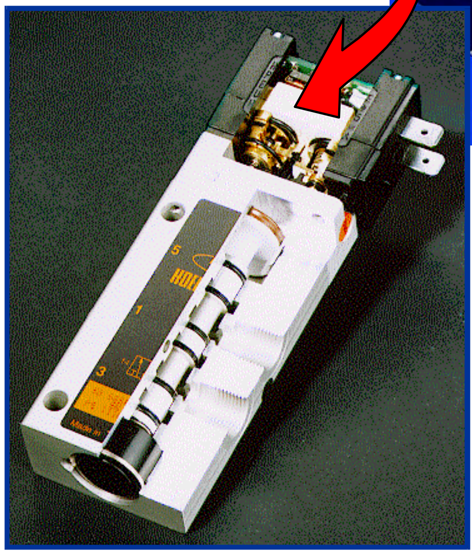


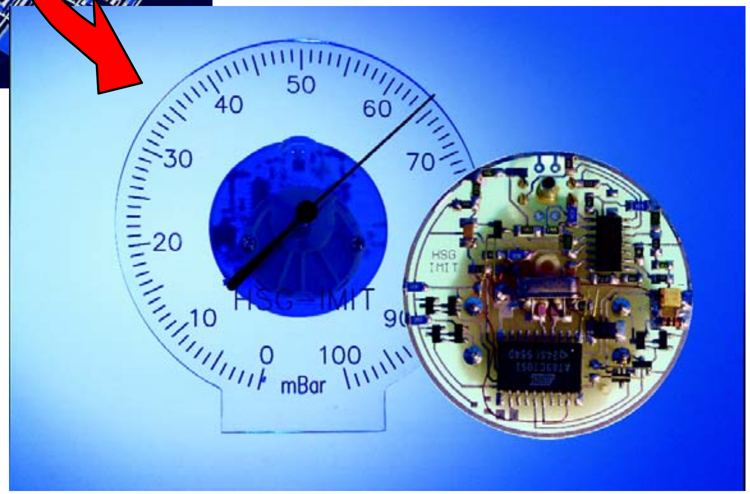
5.4.6. Applications for MegaMic



MEGA MIC

Kooperation mit HOERBIGER-ORIGA

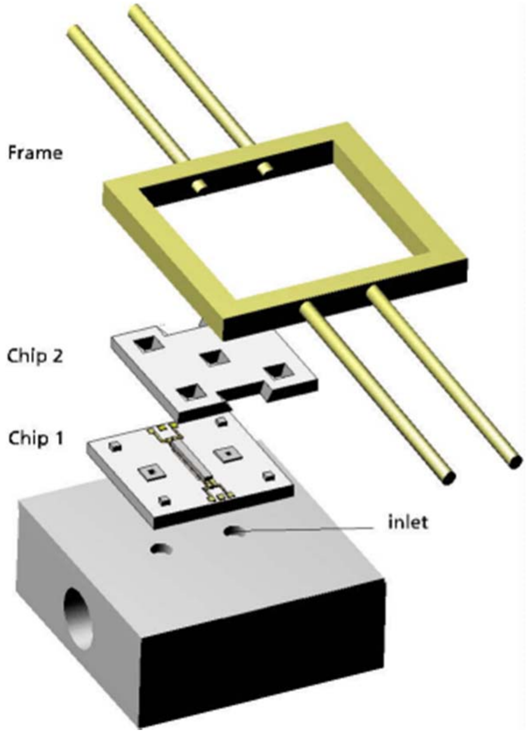




5.4.6. FhG-Institut für Siliziumtechnologie

- Valve type: 3-way normally-open
- Pressure distribution principle
  - Nozzle / collision plate

- Actuation: thermomechanical
- Gap opening: 60 µm
- Media: Gases
- Maximum pressure: 9 bar
- Flow rate: 1.5 l / min
- Response time: 35 ms
- Power: 600 mW
- Temperature range: ?
- Dimensions 6x6x2 mm³



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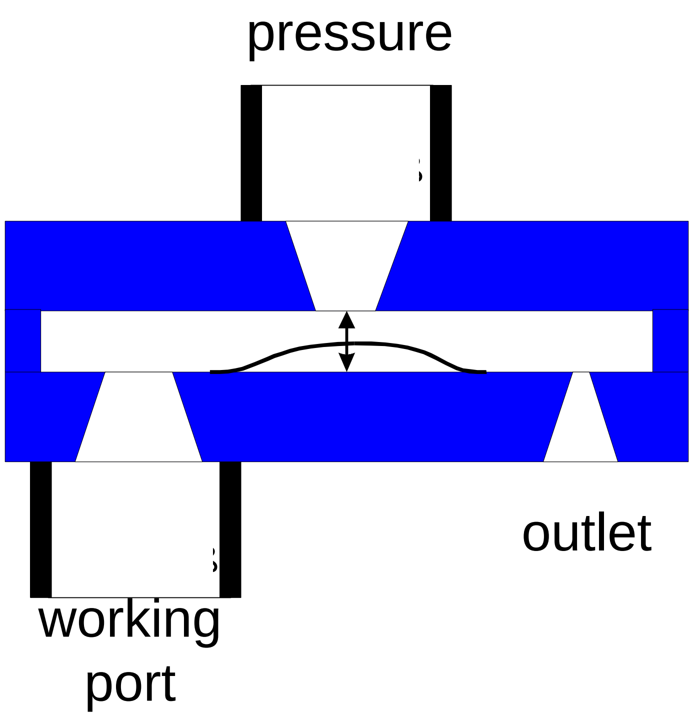
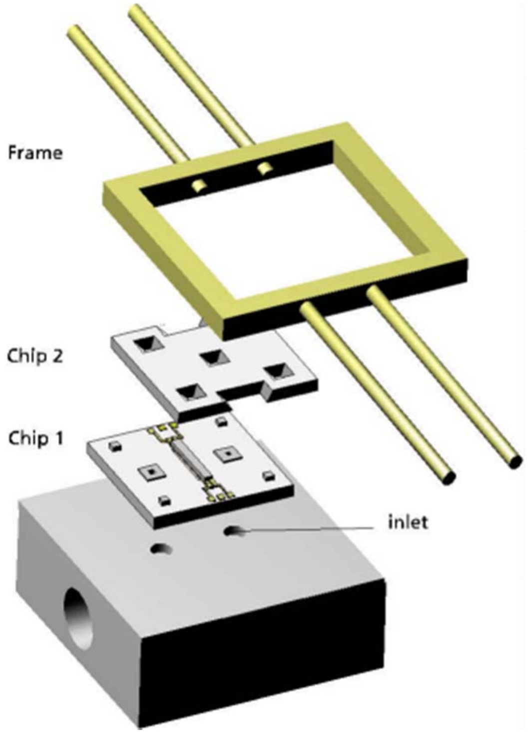
- Pressure distribution principle
  - Nozzle / collision plate





5.4. Active Microvalves

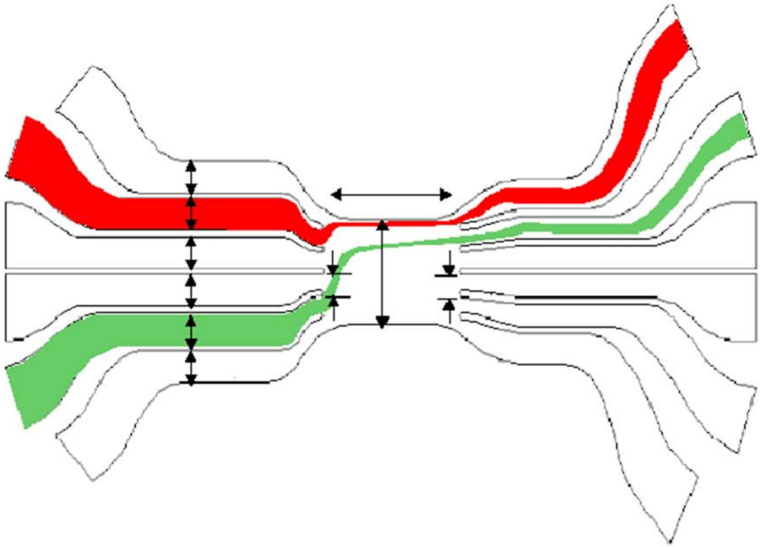
5. Flow Control

1. Check Valves
2. Fixed-Geometry Valves
3. Actuation Principles
4. Active Micro-Valves
5. Fluerics

5.5. Flow Switches

1. Hydrodynamic Flow Switches
2. Microfluidic Flip-Flop
3. Hydrodynamic Oscillator
4. Microfluidic Proportional Amplifier

5.5.1. Hydrodynamic Flow Switch



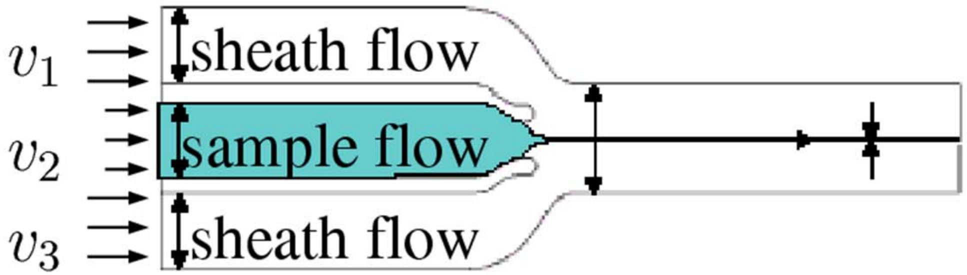


Fig. 5.38. Hydrodynamic $M \times N$ flow switch with hydrodynamic focusing by laminar sheath flow

5.5.2. Microfluidic Flip-Flop

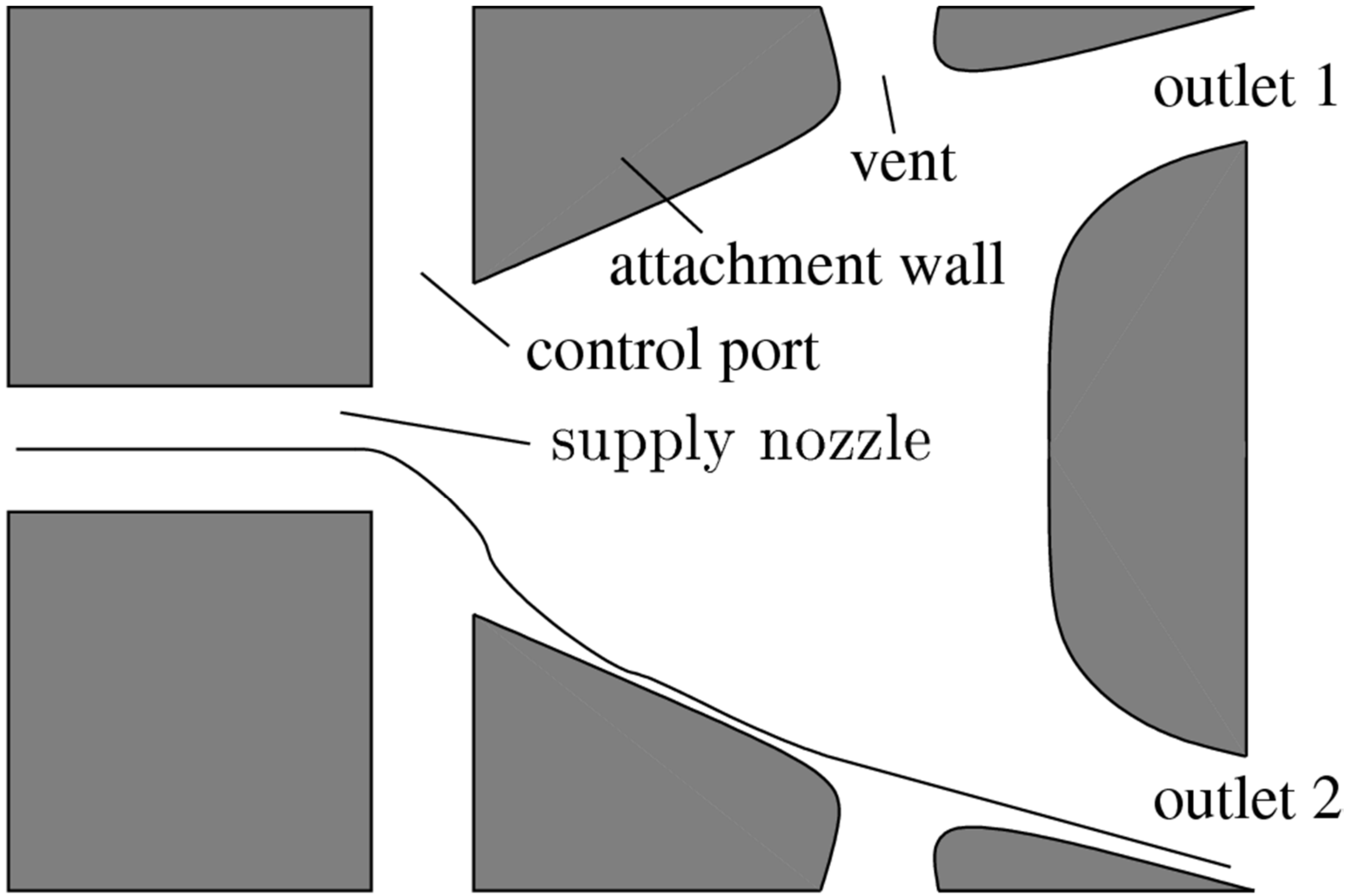


Fig. 5.39. Fluidic amplifier based on the Coanda effect (not to scale)

5.5.3. Microfluidic Oscillator

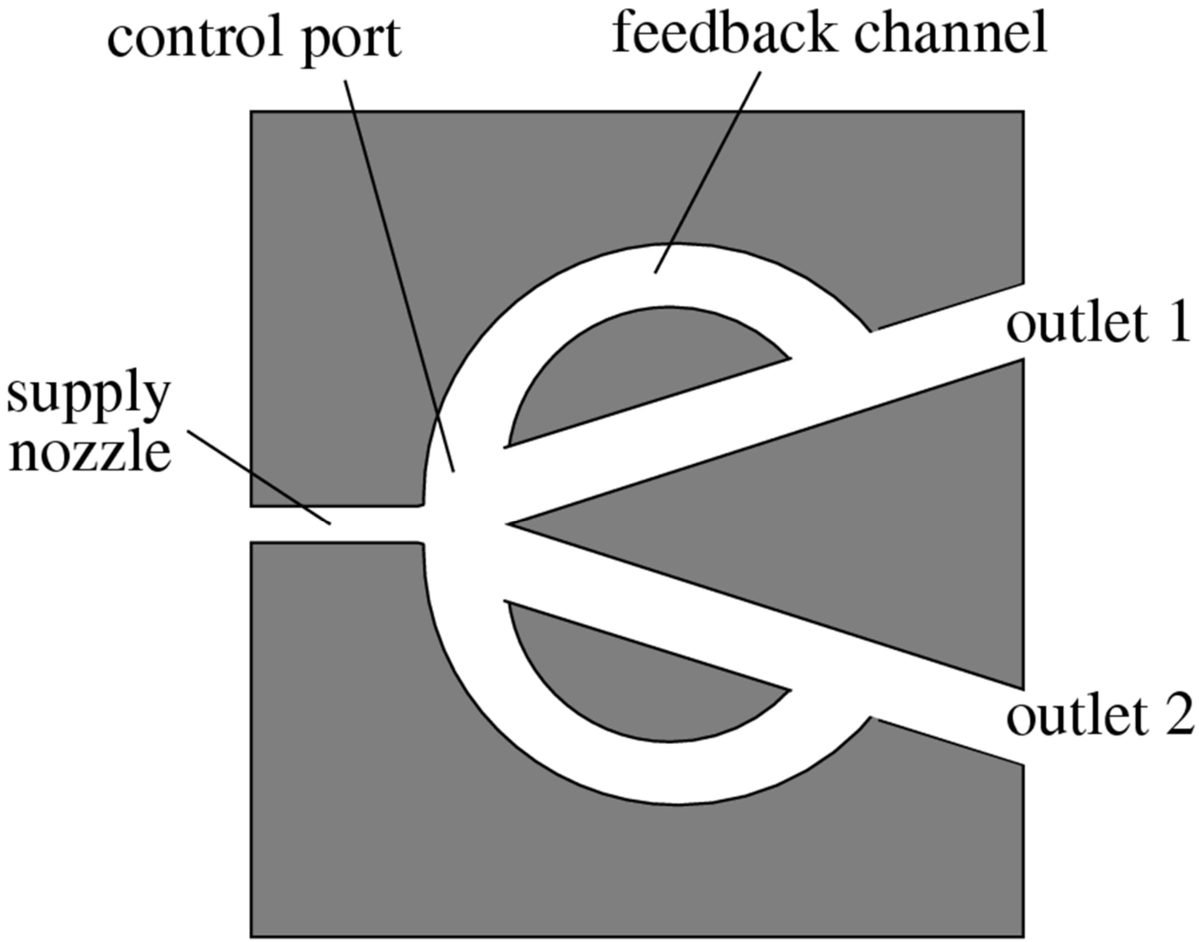


Fig. 5.40. Fluidic micro-oscillator with a feedback channel

5.5.4. Microfluidic Proportional Amplifier

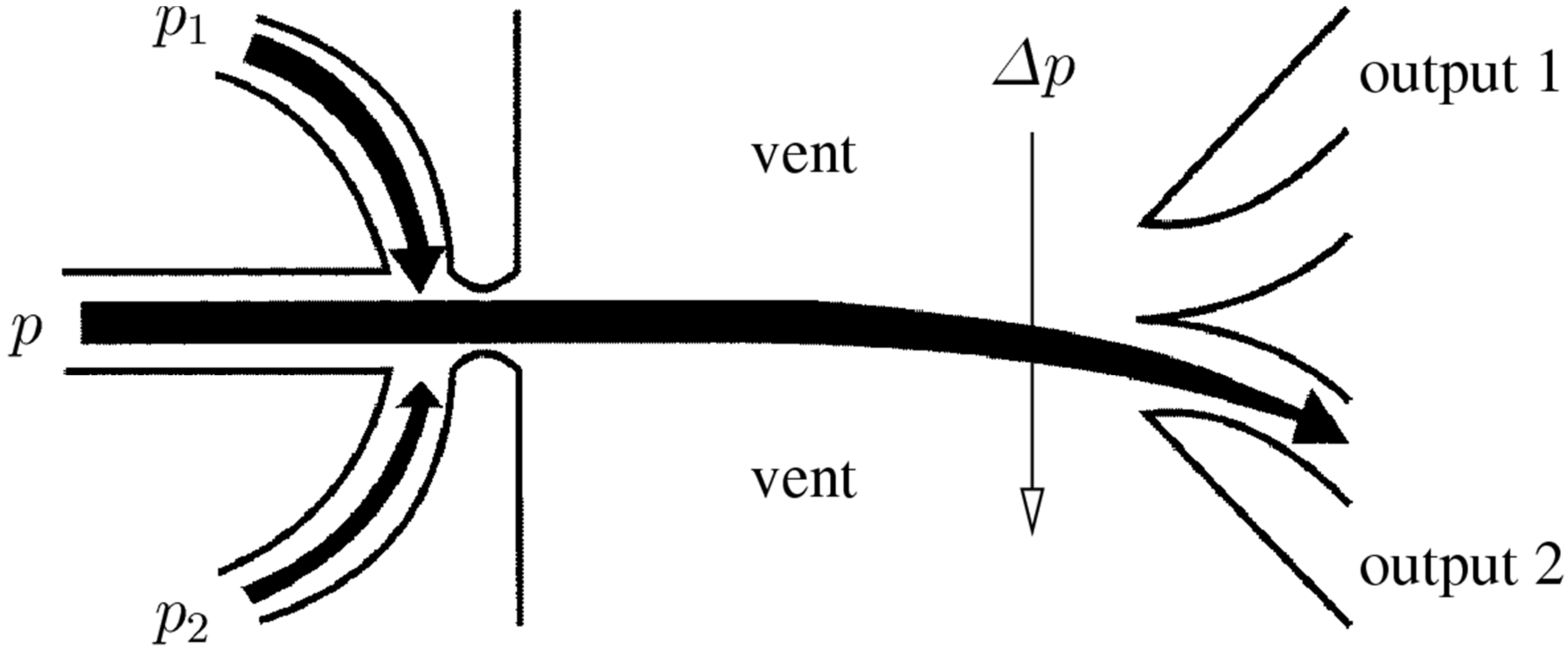


Fig. 5.41. Schematic of a proportional fluidic amplifier