

# MEMS Flow Sensors

*Konrad Schaefermeier*

*EPFL*

**15.04.2025**

# History and actual status

**1974:** First flow sensors were developed

**1990s:** Flow sensors began to be developed in response to need of more compact, accurate and cost-effective flow measurement systems

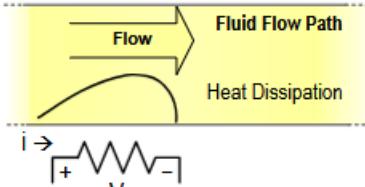
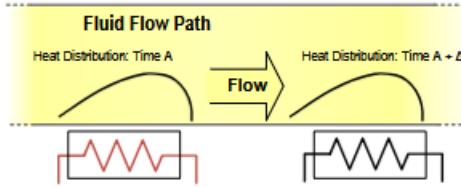
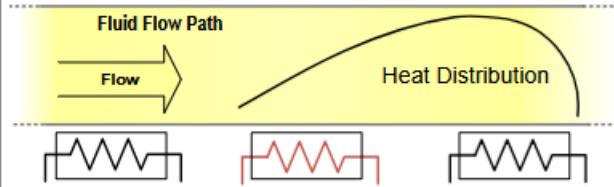
**2000s:** Commercialization, improvements in fabrication and integration

**2010s:** Multi-sensing capabilities, ongoing improvements

**Actual status:** MEMS flow sensors are becoming more and more accurate, efficient, compact and cost-effective - suitable for wider applications

# MEMS operation principle

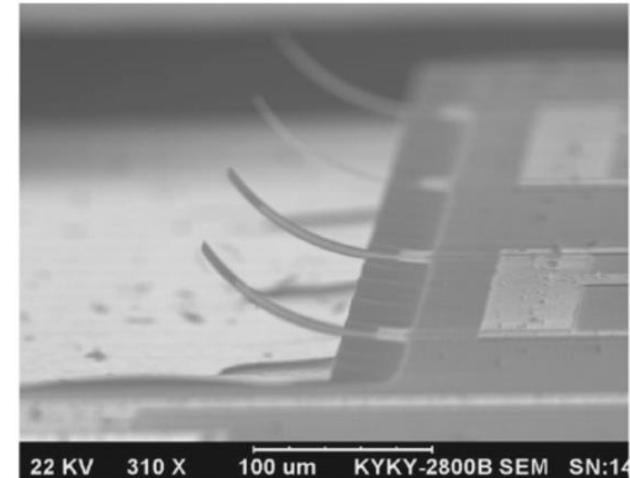
## 1. Thermal

Parameter	Hot-Wire / Hot-Film	Time-of-Flight (TOF)	Calorimetric
Measurement Principle	Resistance	Time	Voltage
Design Model			

- Hot-Wire / Hot-Film and Calorimetric are dependent of medium parameters
- TOF much more independent of medium parameters

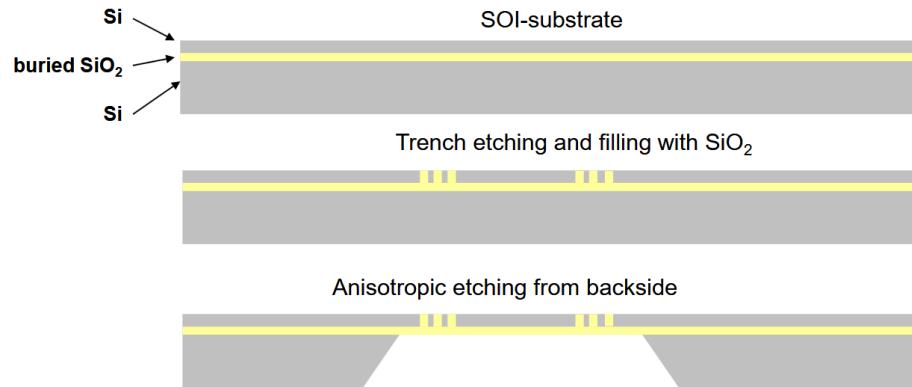
## 2. Non-thermal

- Cantilever-type sensor

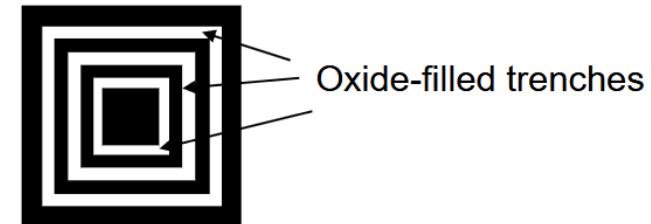


# MEMS implementation

Design criteria: Low thermal mass, low thermal conductivity, CMOS compatibility



Top view of membrane



- Trench etching using DRIE
- Deposition of  $SiO_2$  using LPCVD or PECVD
- Anisotropic KOH etching from backside

Thermal conductivity @100°C in W/(m\*K):

$$\lambda_{Si} \approx 108$$
$$\lambda_{SiO_2} \approx 1.48$$

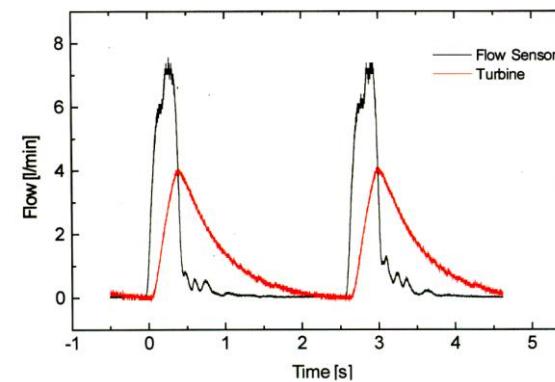
# Characteristics

## Example: Sensirion SLF3S-1300F (Liquid medium)

Parameter	SLF3S-1300F	Unit
H <sub>2</sub> O Full scale flow rate	±40	ml/min
H <sub>2</sub> O Sensor output limit <sup>1</sup>	±65	ml/min
Accuracy <sup>2</sup> (whichever error is larger)	±5 0.05	% of measured value ml/min
Repeatability <sup>2</sup> (whichever error is larger)	±0.5 0.01	% of measured value ml/min
Temperature coefficient <sup>3</sup> (additional error / °C; whichever is larger)	0.2 0.002	% measured value / °C ml/min / °C
Mounting orientation sensitivity <sup>4</sup>	<0.02	ml/min

**Table 1:** Specifications for liquid flow sensor SLF3S-1300F (all data for medium H<sub>2</sub>O, at 23 °C, and for VDD 3.5 V)

- Additional characteristics like **Sensitivity, Response time and Pressure drop** are important



<https://sensirion.com/products/catalog/SLF3S-1300F>

Lecture Notes "Physical Sensors in Silicon Technology", RWTH Aachen University,  
Dr. rer. nat. Xuan Thang Vu, 2024

# Packaging and systems integration

## Packaging

- Protects sensor from dust, moisture, and shock.
- Uses plastics, ceramics, or metals depending on application.
- Encapsulation allows gas/liquid contact while shielding sensitive parts.

## Integration

- **Electrical:** Standard interfaces (I2C, SPI, Analog) for easy connection.
- **Mechanical:** Mounted into flow channels or tubes; designed for low pressure drop.
- **Product Integration:** Embedded in ventilators, medical, automotive, and industrial devices.



<https://sensirion.com/company/news/press-releases-and-news/article/release-slf3s-4000b>

<https://sensirion.com/de/produkte/katalog/LPG10-1000>

# Products and current applications

## Sensirion AG

E.g. SFM for gas, SLF3S for liquid



Sensirion SFM3300-D,  
used for respiratory devices

## Renesas Electronics

FS2012 for liquid

**Winsen FR03H**

**Aceinna MFC2030**



Source: Bruce Blaus, Blausen Medical Communications Inc.

## **Applications:**

Medical Devices (Infusion Pumps, Blood Flow),  
Industrial Application (HVAC systems, Process Control),  
Environmental Monitoring (Air Quality Monitoring),  
Consumer Electronics, ...

<https://sensirion.com/products/catalog/SFM3300-D>

# References

- Whitepaper – MEMS Mass Flow Sensor: <https://www.renesas.com/en/document/whp/whitepaper-mems-mass-flow-sensor?r=344051>
- Sensirion Liquid Flow Meters Product Brochure:  
[https://www.mouser.com/pdfDocs/Sensirion\\_Liquid\\_Flow\\_Meters\\_Product\\_Brochure.pdf](https://www.mouser.com/pdfDocs/Sensirion_Liquid_Flow_Meters_Product_Brochure.pdf)
- Lecture Notes “Physical Sensors in Silicon Technology“, Dr. rer. nat. Xuan Thang Vu, RWTH Aachen University, 2024
- Sensirion SFM3000: <https://www.sensirion.com/en/flow-sensors/gas-flow-sensors/sfm3000/>
- Winsen FR03H: <https://www.winsen-sensor.com/sensors/gas-flow-sensor/fr03h-flow-sensor.html>
- Aceina MFC2030: <https://www.aceinna.com/flow-sensors/MFC2030>