

# Pressure Sensors

*Grace Kim*

*EPFL*

**11.03.2025**

# History and actual status

- **Early Development of MEMS Pressure Sensors**

- 1957: **Mason and Thurston** – first to report silicon strain gauges for measuring displacement, force, and torque
- 1958: **Kulite Semiconductor** – The first commercial piezoresistive silicon strain gauges and pressure sensors
- 1962: **Honeywell Research** – The first to integrate diffused piezoresistive elements with a silicon force collecting element

- **Evolution and Current Trends**

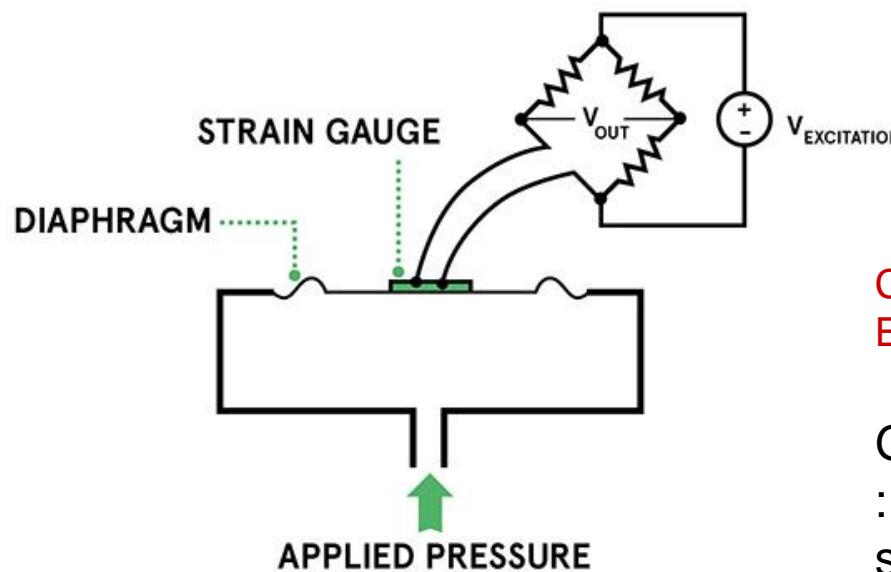
- Widely adopted in automotive, industrial, and consumer applications as production scaled up
- Continuous improvements in miniaturization, low power consumption, precision, and reliability
- Major players include Bosch, Honeywell, STMicroelectronics, etc.

# MEMS operation principle

- Basic Operating Principles

- Piezoresistive Type

- “Piezoresistive” effect: change in the electrical resistivity of a material when mechanical strain is applied



$$\frac{\Delta R}{R} = G \frac{\Delta L}{L} = G\epsilon$$

Change in  
Electrical Resistivity

Mechanical Strain

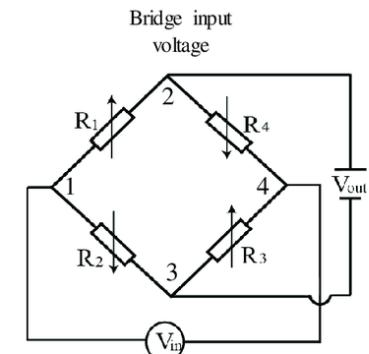
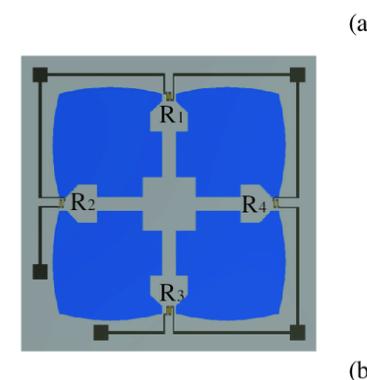
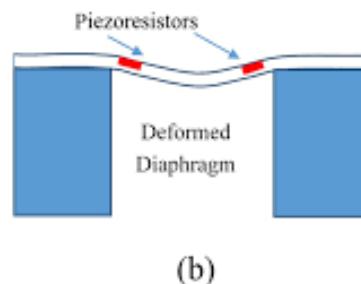
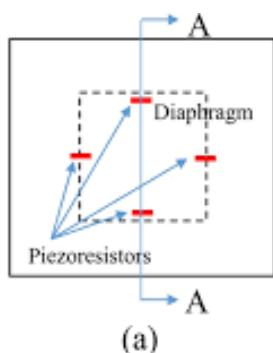
Gauge Factor  
: the amplification factor between  
strain and resistance change

# MEMS operation principle

- **Basic Operating Principles**

- **Piezoresistive Type**

- “Piezoresistive” effect: change in the electrical resistivity of a material when mechanical strain is applied
  - Use a Strain Gauge, that changes its electrical resistance when it is stretched.



# MEMS operation principle

- **Honeywell Pressure Sensors**
- four piezoresistors on a chemically-etched silicon diaphragm
- heavy-duty pressure sensors
  - various range of choices of ports, connectors, outputs, and pressure ranges



MIP Series



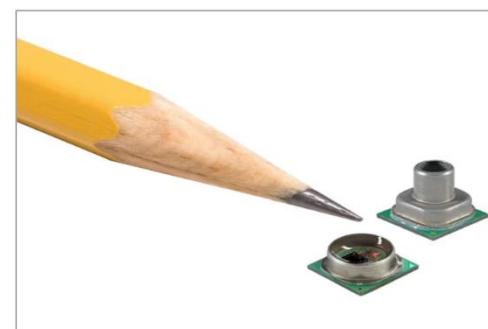
MLH Series



19 mm Series



13 mm Series



MicroPressure MPR Series



24PC Series

# MEMS operation principle

- Honeywell Pressure Sensors – TruStability Series

## PRESSURE SENSORS

### TruStability™ RSC Series

Compensated. As low as  $\pm 0.25\%$  FSS TEB. Ultra-low (differential, gage), low (absolute, diff., gage). 24-bit Digital SPI-Compatible output. DIP, SMT

#### Overview

#### Resources

#### Part Number



[Save this page as PDF](#)



[SUPPORT](#)

[WHERE TO BUY](#)

[CONTACT US](#)

#### Distributor Inventory

#### Pressure Ranges

- $\pm 1.6$  mbar to  $\pm 10$  bar -  $\pm 160$  Pa to  $\pm 1$  MPa -  $\pm 0.5$  inH<sub>2</sub>O to  $\pm 150$  psi

The TruStability™ RSC Series is a piezoresistive silicon pressure sensor offering a digital output for reading pressure over the specified full scale pressure span and temperature range. It is calibrated and temperature compensated for sensor offset, sensitivity, temperature effects, and non-linearity using a 24-bit analog-to digital converter with integrated EEPROM.

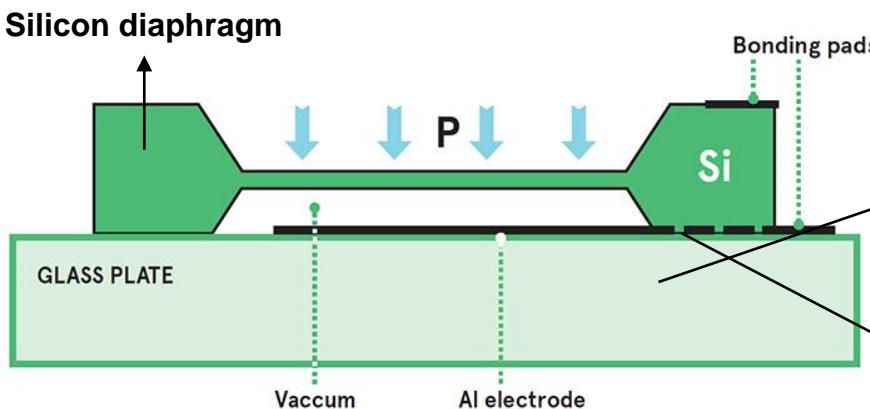
Pressure data may be acquired at rates between 20 and 2000 samples per second over an SPI interface. It is intended for use with non-corrosive, non-ionic gases, such as air and other dry gases, designed and manufactured according to ISO 9001 standards, and is REACH and RoHS compliant.

# MEMS operation principle

- **Basic Operating Principles**

- **Capacitive Type**

- Measures capacitance changes between a fixed electrode and a moveable diaphragm
    - Converts small deflections into electrical signals



Silicon diaphragm: pushed downwards as external pressure  $P$  is applied

Glass Substrate + Al Electrode  
: glass substrate holds the Al electrode with a vacuum gap above it

Bonding Pads: Connect the sensor's internal electrodes to external circuits for signal transmission

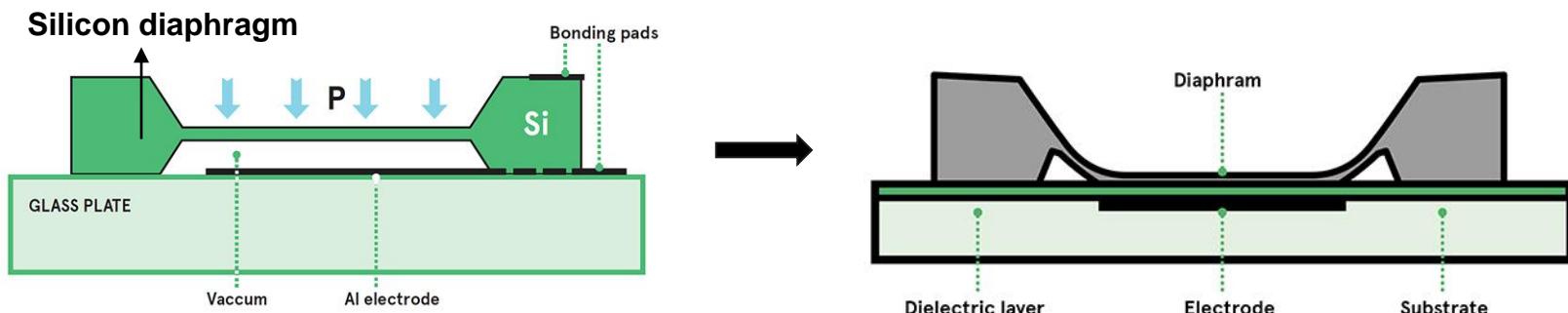
<https://my.avnet.com/abacus/solutions/technologies/sensors/pressure-sensors/core-technologies/mems/>

# MEMS operation principle

- **Basic Operating Principles**

- **Capacitive Type**

- Measures capacitance changes between a fixed electrode and a moveable diaphragm
    - Converts small deflections into electrical signals



<https://my.avnet.com/abacus/solutions/technologies/sensors/pressure-sensors/core-technologies/mems/>

## External pressure changes

- diaphragm moves toward the vacuum gap
- the distance between electrodes change
- results in change in electrical conductivity
- an external circuit detects and translates it to a signal corresponding to the applied pressure

# MEMS operation principle

- **BOSCH BMP series**

## Small and precise: barometric pressure sensors

Bosch Sensortec's barometric pressure sensors enable a variety of smartphones, wearables and smart home applications. Our very small and low-power barometric pressure sensors stabilize the altitude of drones, enable accurate indoor navigation and improve precise calorie counting in wearables. The pressure sensors work with the piezo resistive principle or the capacitive principle.



BMP585

With BMP585, customers don't need to sacrifice performance to achieve robustness – there's no compromise necessary. With its extreme accuracy, the sensor measures a change in height of just a few centimeters. At the same time, users do not have to worry about environmental conditions – thanks to its ruggedness.

- Low power consumption
- Low noise
- High robustness

[More information >](#)



BMP581

The BMP581 is the new benchmark in the field of barometric pressure sensors and is ideally suited for a wide range of altitude tracking applications like GPS modules, wearables, hearables, smart home and industrial products. This sensor is available via our distribution partners.

- Low-power consumption
- Low noise
- Small size

[More Information >](#)



BMP580

The BMP580 is the new benchmark in the field of barometric pressure sensors and impresses with its enormous accuracy. This enables endless and new use cases such as fitness tracking where accurate altitude change is key. This sensor is available for our direct customers only.

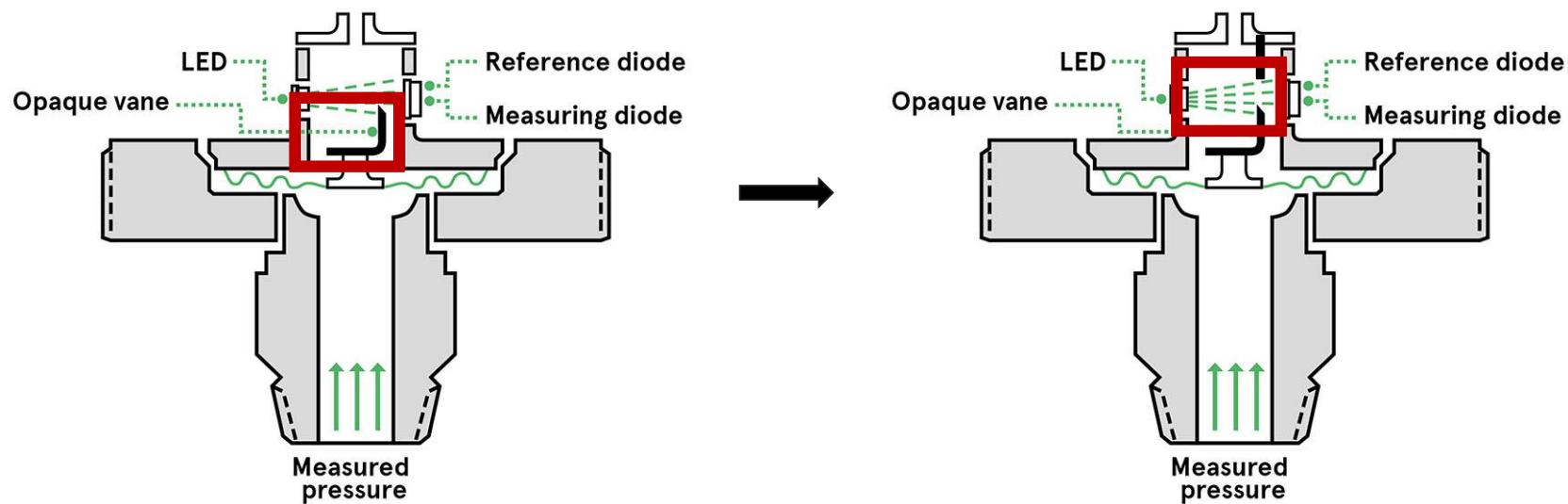
- Low-power consumption
- Low noise
- Small size

[More information >](#)

**Barometric Pressure Sensors**  
detect atmospheric pressure values and height changes  
Used in smartphones, smartwatches, drones, etc.

# MEMS operation principle

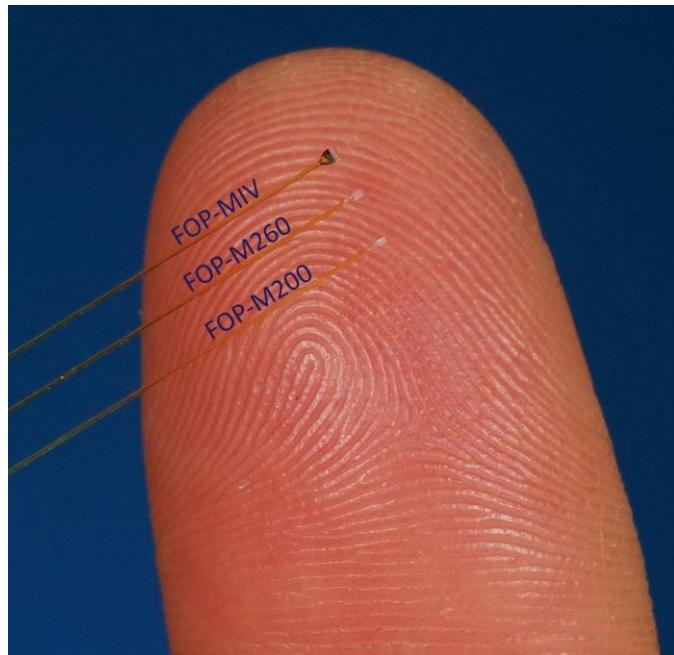
- Other Operating Principles
  - Optical Pressure Sensors
    - Detects pressure change through an effect of light



<https://my.avnet.com/abacus/solutions/technologies/sensors/pressure-sensors/core-technologies/optical/>

# MEMS operation principle

- **FISO Technologies – FOP Series**



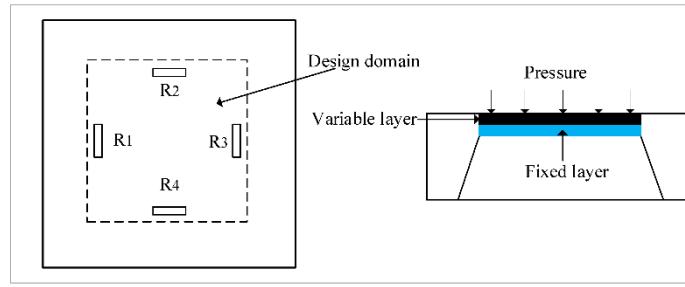
## Miniature Fiber Optic Pressure Transducers

Optical signal measurement of fiber end diaphragm deformation.  
Electromagnetic noise (EMI) independent.  
Used in medical or MRI environments.

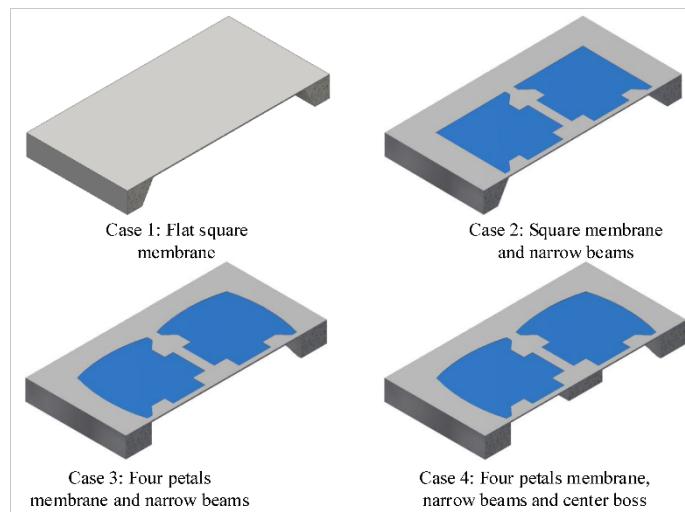
<https://fiso.com/en/service/medical/>

# MEMS implementation

- Design Considerations



(a)



(b)

<https://www.mdpi.com/1424-8220/18/7/2023>

- Manufacturing Processes

- Start with a **pure silicon wafer**.
- Use **etching** (selectively removing material), **deposition** (adding thin layers) to build structures on the wafer.
- After building these structures, each wafer is **cut** into many dies (individual chips)

**a. bulk micromachining**

isotropic etching

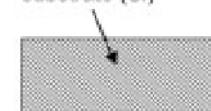


anisotropic etching



**b. surface micromachining**

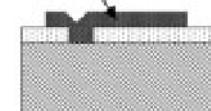
substrate (Si)



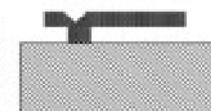
sacrificial layer



structural layer



microstructure



[https://www.researchgate.net/figure/Micromachining-techniques-a-bulk-micromachining-anisotropic-and-isotropic-etching\\_fig3\\_229877992](https://www.researchgate.net/figure/Micromachining-techniques-a-bulk-micromachining-anisotropic-and-isotropic-etching_fig3_229877992).

# Characteristics

- **Main Performance Parameters**
  - **Pressure Range:** From a few mmHg up to hundreds of bars (depending on application)
  - **Accuracy:** Typically  $\pm 0.1\%$  to  $\pm 1\%$  Full Scale (FS)
  - **Resolution:** Can be  $<0.01\%$  FS for high-end products
  - **Temperature Range:** Some devices operate from  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  or wider
- **Example Products**
  - **Bosch BMP388:** 300 to 1250 hPa range,  $\pm 0.5$  hPa accuracy
  - **Honeywell ABP Series:**  $\pm 1\%$  FS accuracy, multiple pressure ranges

# Characteristics

- Bosch BMP388

## Technical data

Parameter	Technical data
Operation range	Pressure: 300... 1250 hPa
Supply voltage VDDIO	1.2 V ... 3.6 V
Supply voltage VDD	1.65 V ... 3.6 V
Interface	I <sup>2</sup> C and SPI
Average typical current consumption (1 Hz data rate)	3.4 $\mu$ A @ 1Hz
Absolute accuracy pressure (typ.) P=900 ...1100 hPa (T=25 ... 40°C)	$\pm$ 0.5 hPa
Relative accuracy pressure (typ.) P=900...1100 hPa (T=25 ... 40°C)	$\pm$ 0.08 hPa
Noise in pressure (lowest bandwidth, highest resolution)	0.03 Pa
Temperature coefficient offset (-20°...65°C @ 700 hPa to 1100 hPa)	$\pm$ 0.75 Pa/K
Long-term stability (12 months)	$\pm$ 0.33 hPa
Solder drift	< $\pm$ 1.0 hPa
Maximum sampling rate	200 Hz
Package dimensions	10-pin LGA with metal lid 2.0 x 2.0 x 0.75 mm <sup>3</sup>

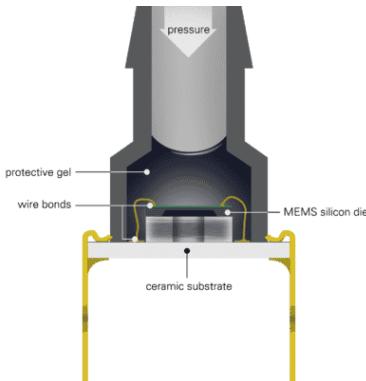
# Packaging and systems integration

- Packaging

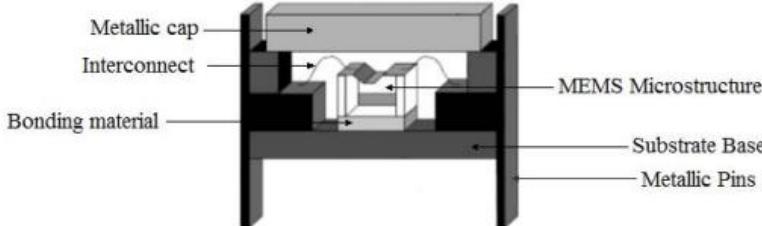
1. Ceramic

2. Plastic

3. Metal



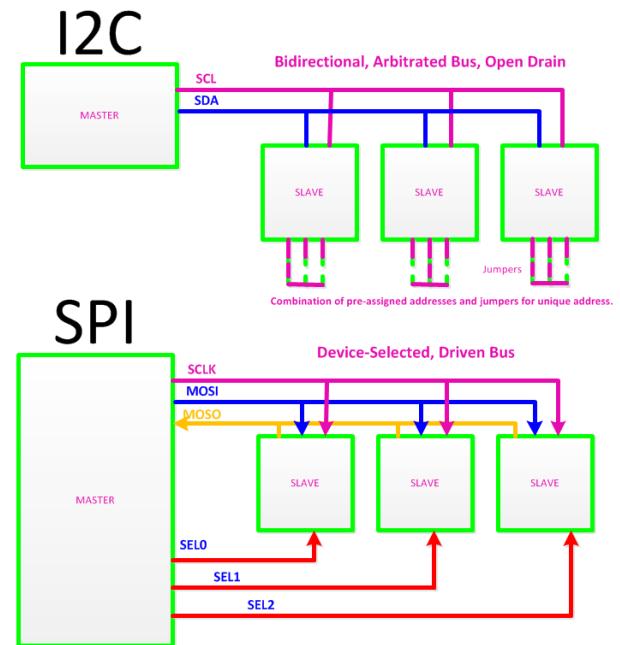
<https://infoteh.etf.ues.rs.ba/zbornik/2014/radovi/ELS/ELS-1.pdf>



<https://meritsensor.com/three-common-types-of-pressure-sensor-packages/>

- Systems Integration

## I2C, SPI digital interfaces



<https://learn.circuit.rocks/spi-vs-i2c>

# Products and current applications

- **Piezoresistive Pressure Sensors**

- Products: HoneyWell – TruStability Series, NXP – MPX Series, TE Connectivity – M3200 Series

- Applications

- Automotive: Manifold Absolute Pressure (MAP) sensors

- Medical: Blood pressure monitors, respiratory devices.

- Industrial: Process control, hydraulic systems, pneumatic equipment.

- Consumer Electronics: Home appliances, micro-pumps.

- **Conductive Pressure Sensors**

- Products: BOSCH – BMP series, Tekscan – FlexiForce® A201

- Interlink Electronics FSR™ (Force-Sensing Resistor) 402 & 400 Series,

- Applications:

- Consumer Electronics & Wearables: Button/force sensing

- Automotive & Transport: Seat occupancy detection, tactile feedback system

- Medical & Healthcare: Bed monitoring, patient posture tracking.

- Sports Equipment: Force mapping, tennis rackets, training aids.

# Products and current applications

- **Optical Pressure Sensors**

- Products: FISO Technologies – FOP Series, Opsens – OPP Series

- Applications:

- Medical: Invasive blood pressure measurement in high-EMI environments

- Industrial & Process Control: Monitoring in corrosive or high-voltage environments (no electronic interference).

- Energy Sector: Oil & gas monitoring under high temperatures/pressures.

- Research & Lab: Experiments in radiation or strong electromagnetic fields.

# References

- M. Madou, "Fundamentals of Microfabrication and Nanotechnology," CRC Press.
- Boser, B. E., Howe, R. T., et al., "Surface Micromachined Capacitive Pressure Sensor," IEEE Journal of Solid-State Circuits.
- Bosch Sensortec ([www.bosch-sensortec.com](http://www.bosch-sensortec.com)) – BMP Series Datasheet
- Honeywell (sensing.honeywell.com) – ABP, TruStability Series Datasheets
- TE Connectivity ([www.te.com](http://www.te.com)) – Various Industrial Pressure Sensor Specifications
- M. Mokhtari and S. Darbani, "Material selection for optimum design of MEMS pressure sensors," *ResearchGate*, 2019. [Online]. Available: [https://www.researchgate.net/publication/336906109\\_Material\\_selection\\_for\\_optimum\\_design\\_of\\_MEMS\\_pressure\\_sensors](https://www.researchgate.net/publication/336906109_Material_selection_for_optimum_design_of_MEMS_pressure_sensors).
- Ivanka Stanimirović, Zdravko Stanimirović, "MEMS Packaging: Material Requirements and Reliabilit," in *Proceedings of INFOTEH 2014*, 2014. [Online]. Available: <https://infoteh.etf.ues.rs.ba/zbornik/2014/radovi/ELS/ELS-1.pdf>.
- Circuitrocks, "SPI vs I2C," Circuitrocks, n.d. [Online]. Available: <https://learn.circuit.rocks/spi-vs-i2c>. [Accessed: Mar. 11, 2025].
- A. V. Tran, X. Zhang, and B. Zhu, "Mechanical structural design of a piezoresistive pressure sensor for low-pressure measurement: A computational analysis by increases in the sensor sensitivity," *Sensors*, vol. 18, no. 7, p. 2023, Jun. 2018. [Online]. Available: <https://doi.org/10.3390/s18072023>.