BME680

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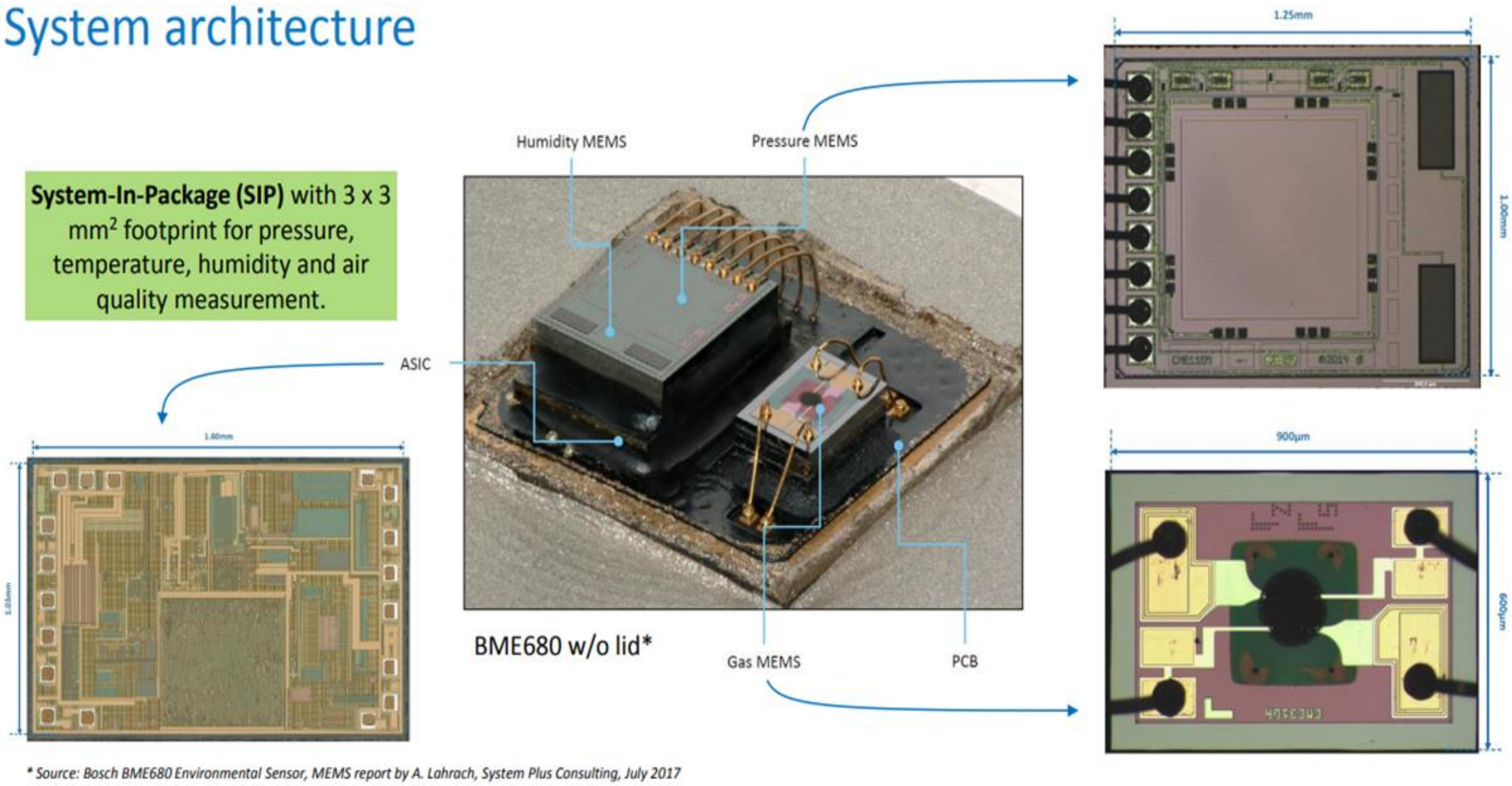
4-1 sensor measuring gas, pressure, temperature, humidity



Key Feature

- High performance gas, pressure, temperature and humidity sensors
- Very low power consumption
- Very small 3.0 x 3.0 mm^2 footprint, height 1.0 mm
- Wide power supply range: 1.71 V - 3.6 V
- Flexible digital interface to connect to host over I2C or SPI

Physics

- Temperature – by the voltage change of a silicon diode
- Pressure – by the resistance change due to the elongation of a thin membrane
- Humidity – by the relative permittivity change of a polymer-based capacitor
- Gas – by the conductivity change of a metal oxide due chemisorption of gas species

Temperature

- Operational Range: -40 to 85°C
- Accuracy: 0-60 °C, ±1°C

- Voltage change of a silicon diode

$$V=f(T)+ \; kT/q \; \ln(I_c/I_{c0})$$

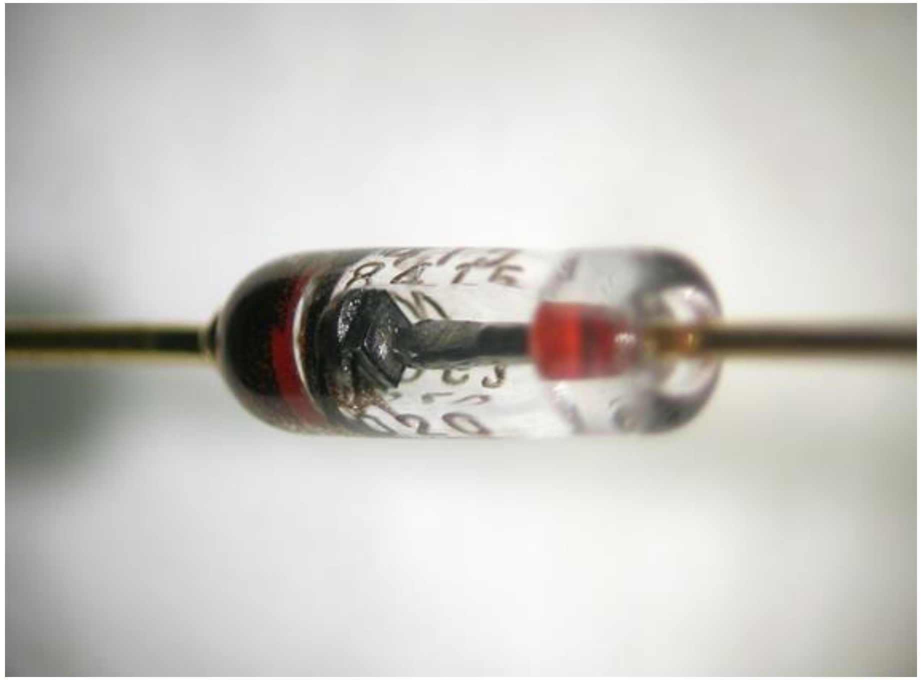


Diagram for a silicon diode
https://en.wikipedia.org/wiki/Diode#/media/File:Diode-closeup.jpg

- T=temperature, q=charge of an electron

  I_c=current, I_{c0}=reference current

- Two junctions at same temperature but different current:

$$\Delta V= kT/q \; \ln(I_{c1}/I_{c2}) \quad \rightarrow \; T=q/k \; \Delta V \ln[I_{c2}/I_{c1}]$$

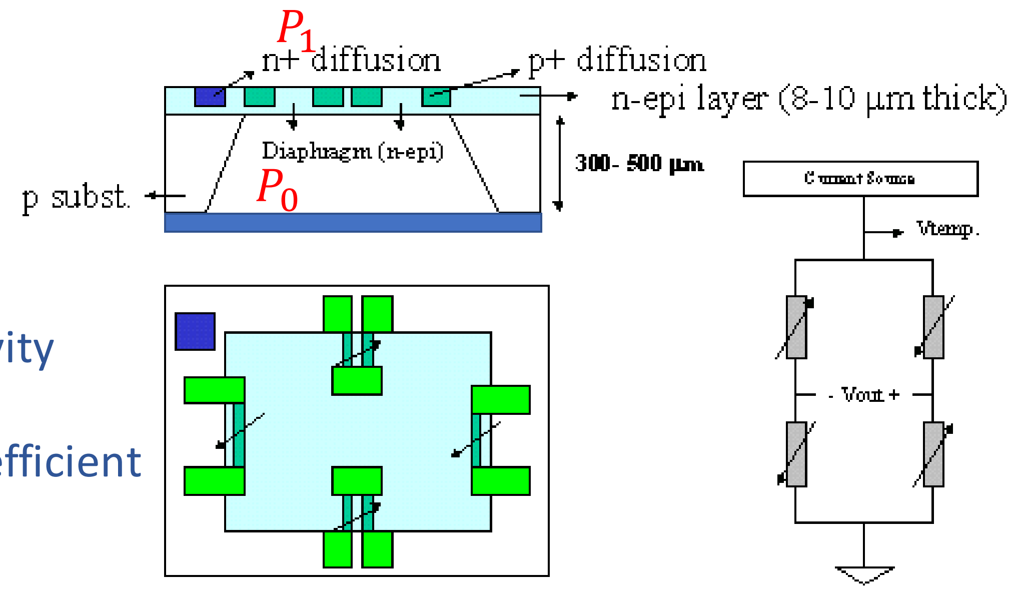
Piezoresistive pressure sensors

- Piezoresistive effect
  - The electrical resistivity ρ of a semi-conductor or metal can change when mechanical strain is applied.

$$\frac{\Delta\rho}{\rho} = \rho_\sigma \varepsilon$$

$\Delta\rho$ - change in resistivity
ρ - original resistivity
ρ_σ - piezoresistive coefficient
ε- strain

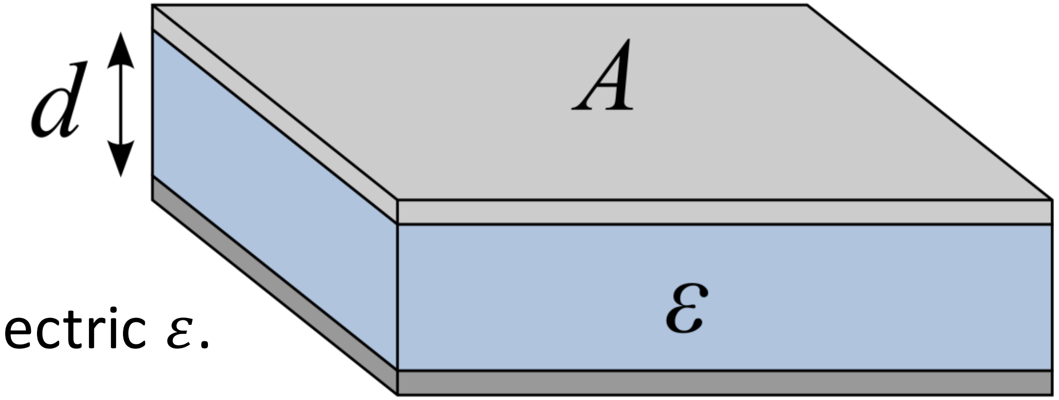
- Wheatstone bridge
  - used to amplify and measure the resistance change



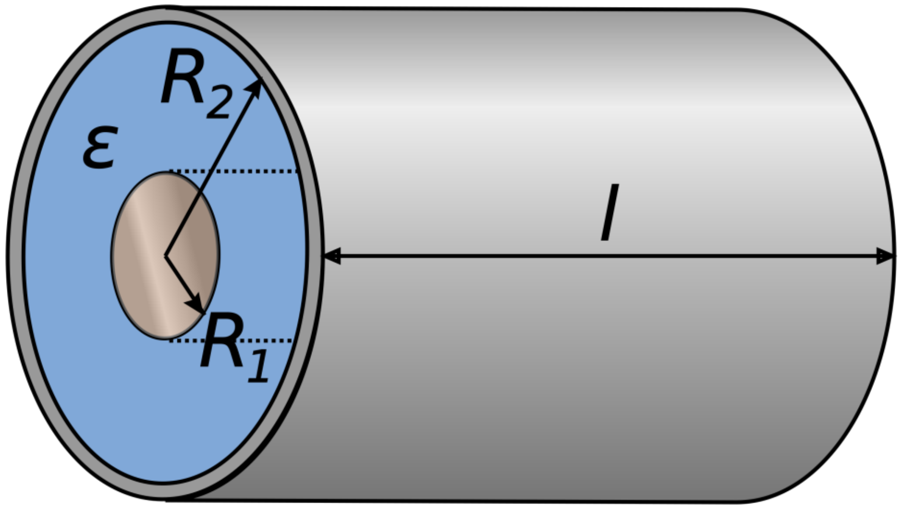
Wheatstone bridge

Diagram for a typical piezoresistive pressure sensor, http://www.microsystems.metu.edu.tr/piezops/piezops.html

Humidity



- Humidity affects the electric permittivity of the dielectric ε.
- Capacitance proportional to electric permittivity.
- $C = \frac{\varepsilon A}{d}$ for parallel-plate capacitors.
- $C = \frac{2\pi\varepsilon l}{\ln(R_2/R_1)}$ for concentric-cylinder capacitors.



Diagrams of different capacitors.
https://en.wikipedia.org/wiki/Capacitance#/media/File:Plate_CapacitorII.svg
https://upload.wikimedia.org/wikipedia/commons/b/b8/Cylindrical_CapacitorII.svg

Humidity Specification

- Oparating range: -40°C (-40°F) to 85°C (185°F), 0% r.H. to 100% r.H.
- Full accuracy range: 0°C (32°F) to 65°C (149°F), 10% r.H. to 90% r.H.
- Absolute accuracy: ±3% r.H. within 20-80% r.H. at 25°C (77°F)
- Resolution: 0.008 % r.H.
- Noise in humidity (RMS): 0.01 % r.H.
- Long-term stability 0.5 % r.H./year within 10-90% r.H. at 25°C (77°F)

Organic Gas Sensor

- Metal oxide semiconductor (MOS) sensor utilizes the property of metal oxides that their conductivity changes as chemical vapor is absorbed
- The interaction between active sensing layer and target analytes at an elevated temperature lead to modulations in the energy barriers for free charge carriers, thus leading to a change in the conductivity of the sensing material

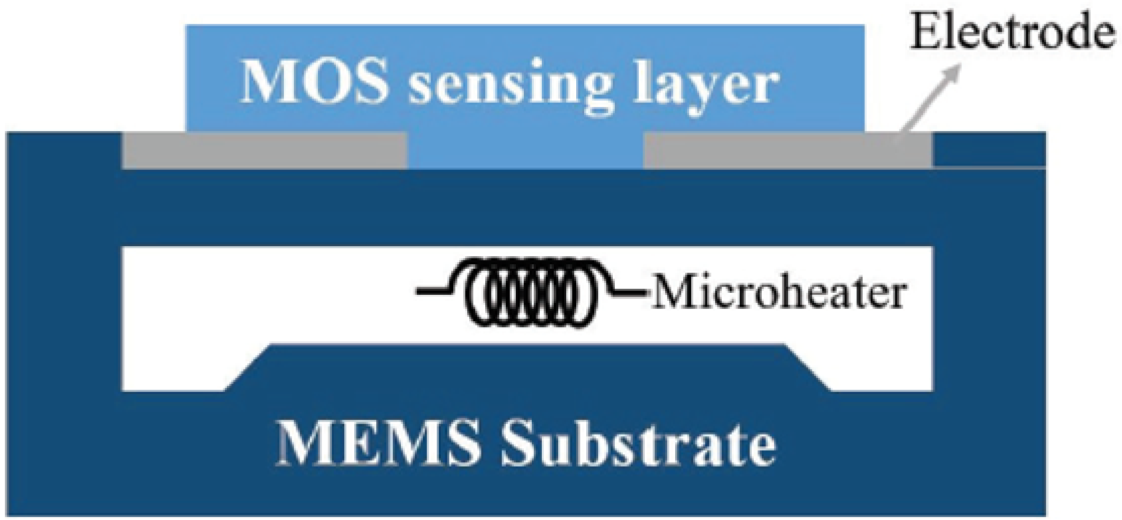


Figure from Ref. [1]

Parameter	Min	Max
Temperature	-40°C	85°C
IAQ range	0	500
Supply current	15 [mA]	18[mA]

Indoor Air Quality (IAQ)

IAQ Index	Air Quality
0 – 50	good[10]
51 – 100	average
101 – 150	little bad
151 – 200	bad
201 – 300	worse[2]
301 – 500	very bad

Figure from Ref. [1]

Conclusion

- The BME680 is a digital 4-in-1 sensor with gas, humidity, pressure and temperature measurement based on proven sensing principles.
- Its small dimensions and its low power consumption enable the integration in battery-powered or frequency-coupled devices, such as handsets or wearables.
- Potential applications in internet of things, indoor/outdoor navigation, weather forecast, and smart home control.

Reference

- BME680 Datasheet https://cdn-shop.adafruit.com/product-files/3660/BME680.pdf
- Nazemi, Haleh & Joseph, Aashish & Park, Jaewoo & Emadi, Arezoo. (2019). Advanced Micro- and Nano-Gas Sensor Technology: A Review. Sensors. 19. 1285. 10.3390/s19061285.
- Bosch Sensortec's BME680 - Nordic DevZone, https://devzone.nordicsemi.com/cfs-file/__key/communityserver-discussions-components-files/4/Bosch-Sensortec_1920_s-BME680_2C00_-a-4_2D00_in_2D00_1-integrated-environmental-sensor.pdf
- Piezoresistive Pressure and Temperature Sensor Cluste, http://www.microsystems.metu.edu.tr/piezops/piezops.html