P524: Survey of Instrumentation and Laboratory Techniques Week 12

11/10/2026

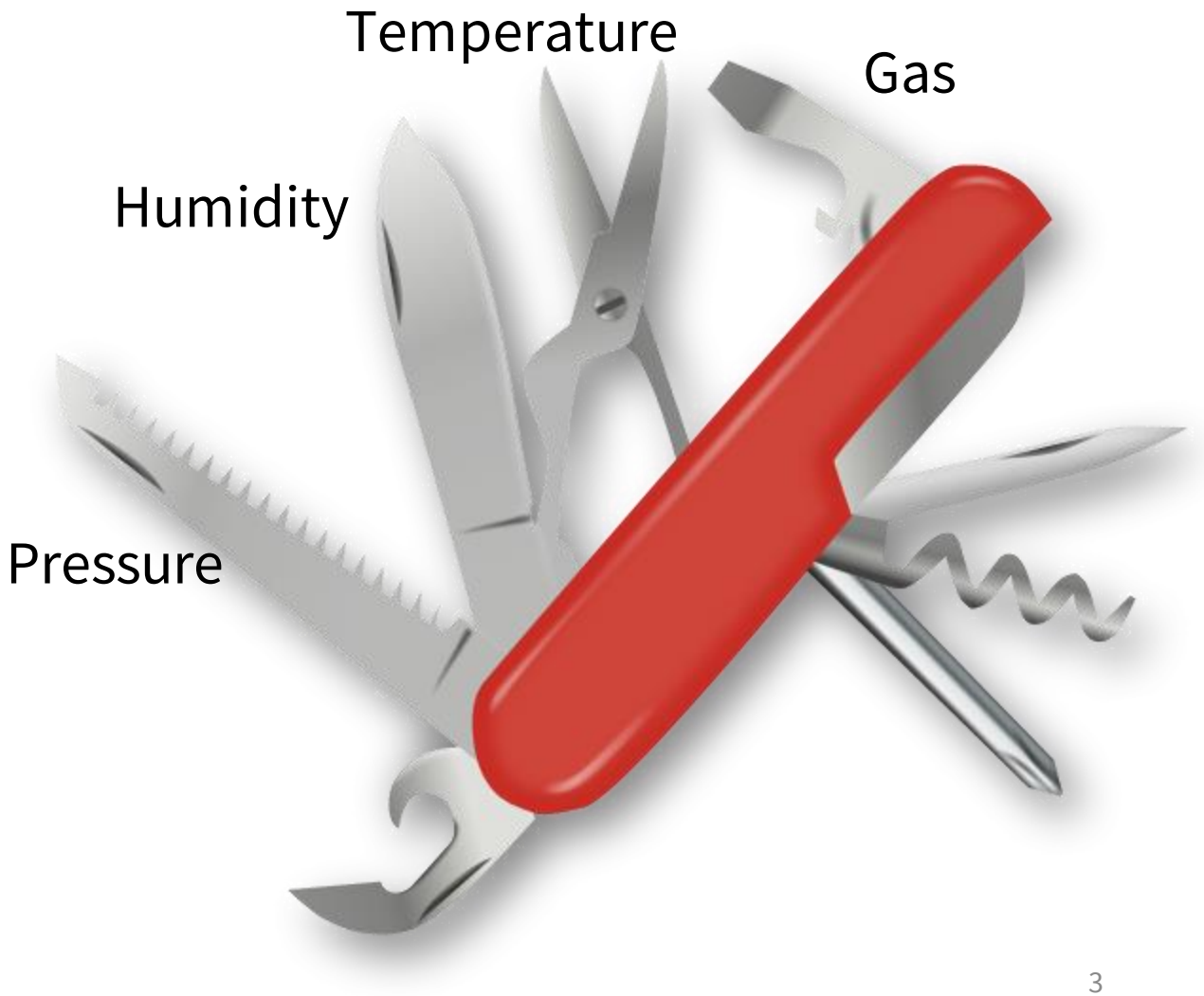
Week 12 - Sensors 6:

Atmospheric Sensors (BME680)

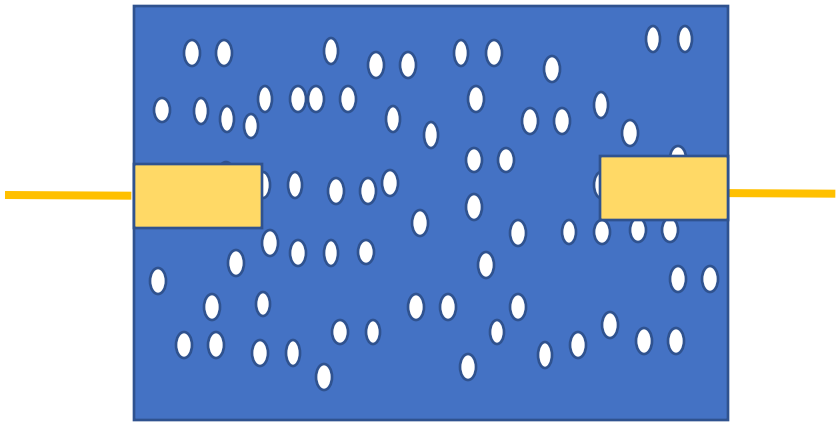
from I. Velkovsky

BME680 – the atmospheric Swiss army knife





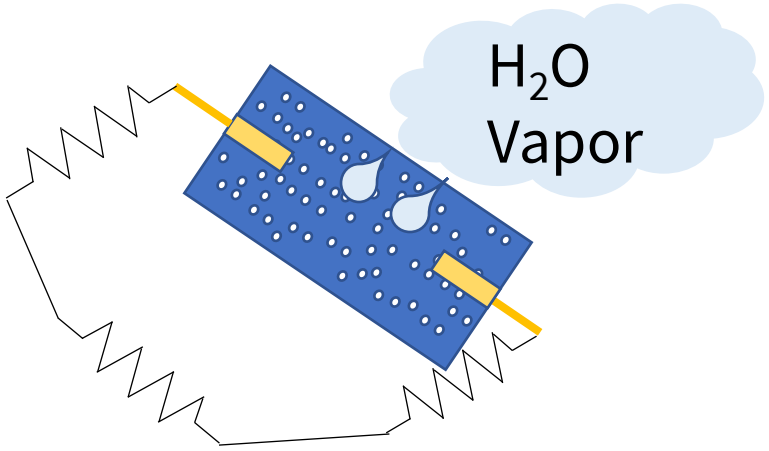
Pressure and temperature: Porous Silicon Membrane



- Sensor is a porous membrane in an internal cavity
- Porous silicon is *piezoresistive* – resistivity changes with strain
- 2 different sources of strain: temperature variation (differences in thermal expansion of different materials) and pressure change.
- Device converts change in resistivity to change in temperature and pressure

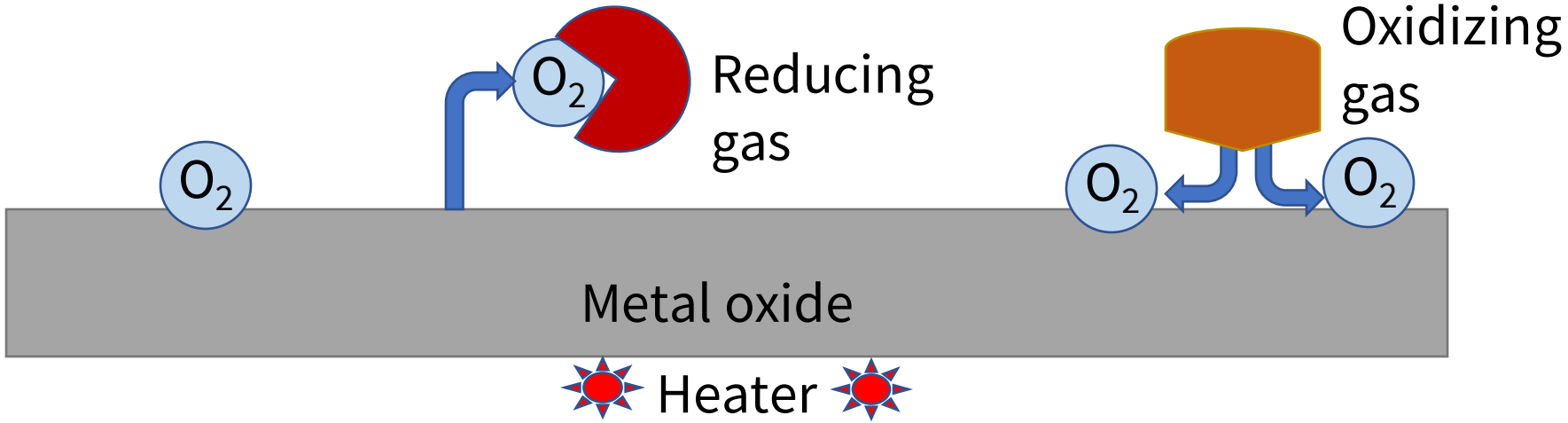
Relative humidity – porous silicon

- Same membrane technology can be used to measure relative humidity
- Water adsorption onto a specially-designed surface changes the capacitance/resistivity of the device
- Measuring that gives the % relative humidity.



Something slightly different – VOCs & Metal-Oxide gas sensors

- VOC – volatile organic compound, harmful for air quality (ex: solvent fumes)
- Metal oxide adsorbs oxygen molecules to its surface when heated, reducing electron mobility -> increasing resistivity
- Reducing/oxidizing gases change surface oxygen level
- Change in resistivity thus gives gas concentration.



Datasheet info:

- https://www.bosch-sensortec.com/media/boschsensortec/downloads/datasheets/bst-bme680-ds001.pdf

1.5 Temperature sensor specification

Table 8: Temperature parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating temperature range	T_A	operational	-40	25	85	°C
Supply current	$I_{DD,T}$	1 Hz forced mode, temperature measurement only		1.0		µA
Absolute accuracy temperature[15]	$A_{T,25}$	25 °C		±0.5		°C
	$A_{T,full}$	0–65 °C		±1.0		°C
Output resolution	R_T	API output resolution		0.01		°C
RMS noise	N_T	Lowest oversampling		0.005		°C

1.4 Pressure sensor specification

Table 7: Pressure parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating temperature range	T_A	operational	-40	25	85	°C
		full accuracy	0		65	
Operating pressure range	P	full accuracy	300		1100	hPa
Supply current	$I_{DD,LP}$	1 Hz forced mode, pressure and temperature, lowest power		3.1	4.2	µA
Temperature coefficient of offset[13]	TCO_P	25–40 °C, 900 hPa		±1.3		Pa/K
				±10.9		cm/K
Absolute accuracy pressure	$A_{p,\ full}$	300–1100 hPa 0–65°C		±0.6		hPa
Relative accuracy pressure	A_{rel}	700–900hPa, 25–40 °C, at constant humidity		±0.12		hPa
	A_{rel}	900–1100hPa 25–40 °C, at constant humidity		±0.12		hPa
Resolution of pressure output data	R_P	Highest oversampling		0.18		Pa
Noise in pressure	$N_{P,fullBW}$	Full bandwidth, highest oversampling		1.4		Pa
				11		cm
		Reduced bandwidth, highest oversampling		0.2		Pa
				1.7		cm
Solder drift		Minimum solder height 50µm	-0.5	1.2	+2.0	hPa
Long-term stability[14]	P_{stab}	per year		±1.0		hPa
Possible sampling rate	f_{sample_P}	Lowest oversampling, see chapter 3.3.2	157	182		Hz

1.3 Humidity sensor specification

Table 6: Humidity parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating Range[10]			-40	25	85	°C
			0		100	% r.H.
Full accuracy range			0		65	°C
			10		90	% r.H.
Supply Current	$I_{DD,H}$	1 Hz forced mode, temperature and humidity measurement		2.1	2.8	µA
Absolute Accuracy	A_H	20–80 % r.H., 25 °C, including hysteresis		±3		% r.H.
Hysteresis[11]	H_H	10→90→10 % r.H., 25°C		±1.5		% r.H.
Nonlinearity	NL_H	10→90 % r.H., 25°C		1.7		% r.H.
Response time to complete 63% of step[12]	$\tau_{0.63\%}$	N_2 (dry) → 90 % r.H., 25°C		8		s
Resolution	R_H			0.008		% r.H.
Noise in humidity (RMS)	N_H	Highest oversampling		0.01		% r.H.
Long-term stability	ΔH_{stab}	10–90 % r.H., 25°C		0.5		% r.H./ year

Table 2: Gas sensor parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operational range[1]			-40		85	°C
			10		95	% r.H.
Supply Current during heater operation	I_{DD}	Heater target temperature 320 °C, constant operation (V_{DD} ≤ 1.8 V, 25°C)	9	12	13	mA
Peak Supply Current	I_{Peak}	Occurs within first ms of switching on the hotplate	15	17	18	mA
Average Supply Current (V_{DD} ≤ 1.8 V, 25°C)	$I_{DD,IAQ}$	Ultra-low power mode		0.09		mA
		Low power mode		0.9		mA
		Continuous mode		12		mA
Response time[2] (brand-new sensors)	$\tau_{33\text{-}63\%}$	Ultra-low power mode		92		s
	$\tau_{33\text{-}63\%}$	Low power mode		1.4		s
	$\tau_{33\text{-}63\%}$	Continuous mode		0.75		s
Resolution of gas sensor resistance measurement			0.05	0.08	0.11	%
Noise in gas sensor resistance (RMS)	N_R			1.5		%

In-class activity: VOC output under different conditions

- Connect (or re-connect) a BME680 sensor (I2C or SPI interface, Adalogger or Mega)
- Using the example code, test that the BME680 is working, including the VOC sensor
- Obtain ethanol, dropper, solvent-resistant plate (e.g., Adafruit coaster), and soldering fan
- Align fan, plate, and running BME circuit on benchtop
- Drip solvent on plate to evaporate
- Measure VOC output as function of plate distance and amount of solvent evaporated
    - Is there a clear dependence?
    - Does the sensor saturate under some conditions?
    - Is there a solvent dependence (try acetone*)?

Suggestions

- Work in SEPARATE PARTS OF ROOM and use solvent SPARINGLY (contamination easy and long-lasting)
- Modify program to display VOC readings only, about 1/second
- Use the Serial Plotter
- Align fan, plate, and BME circuit carefully: use markings on benchtop
- Start with fan, plate, BME equally spaced ~ 50 cm, and one drop ethanol
- Then increase drops (2, 5, …), decrease plate-BME distance

*ONLY after ethanol, time permitting