LTCC thermal gas viscometer
-
Heater module

Thomas Maeder, Caroline Jacq, Giancarlo Corradini, Sigfrid Strässler, Hansu Birol and Peter Ryser

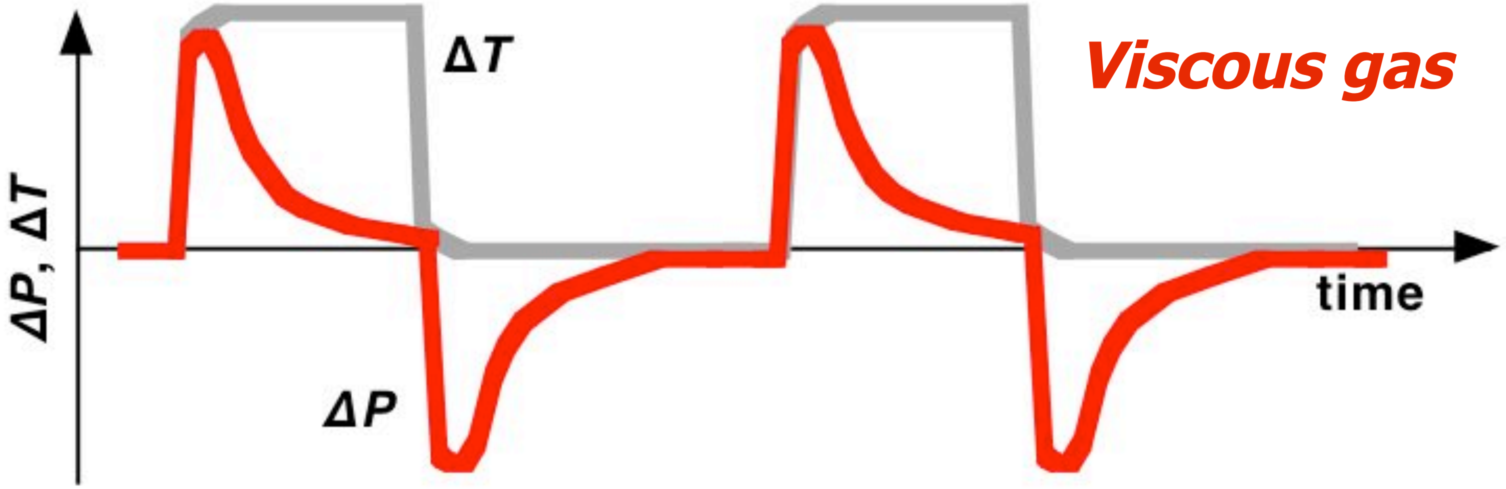
EPFL-LPM, Lausanne, Switzerland

thomas.maeder@epfl.ch

lpm.epfl.ch

Determination of gas viscosity

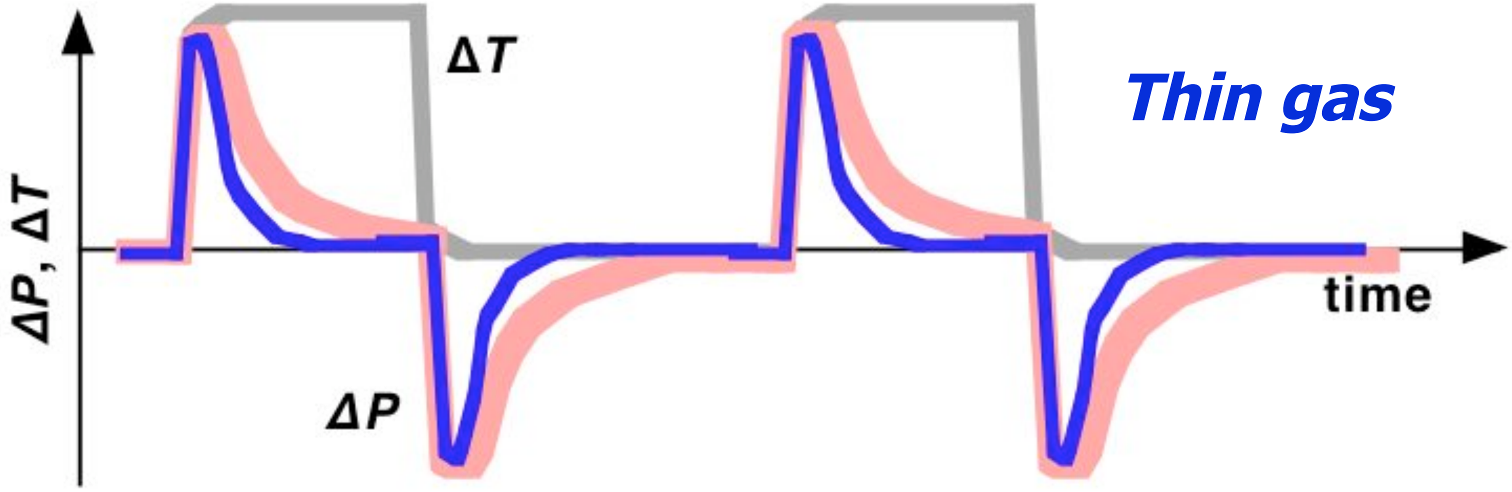
- Purpose: identification of gas mixtures
- Simple sensor principle: time relaxation



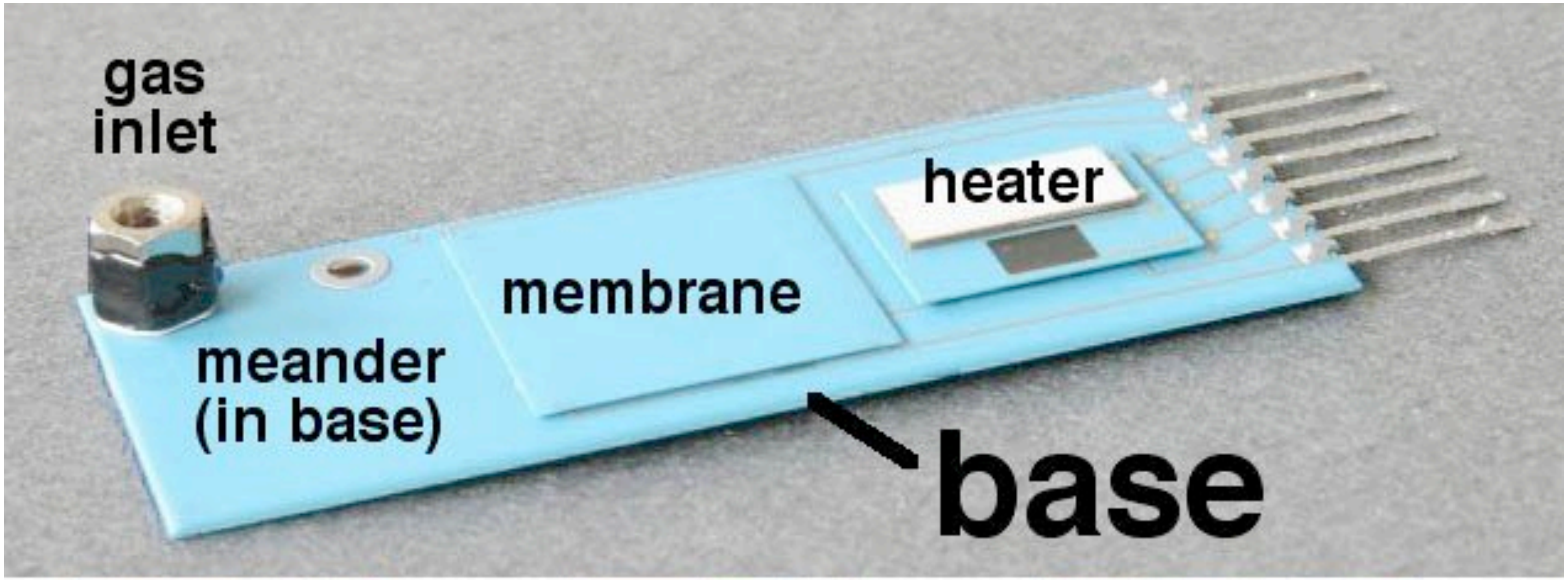
Viscous gas

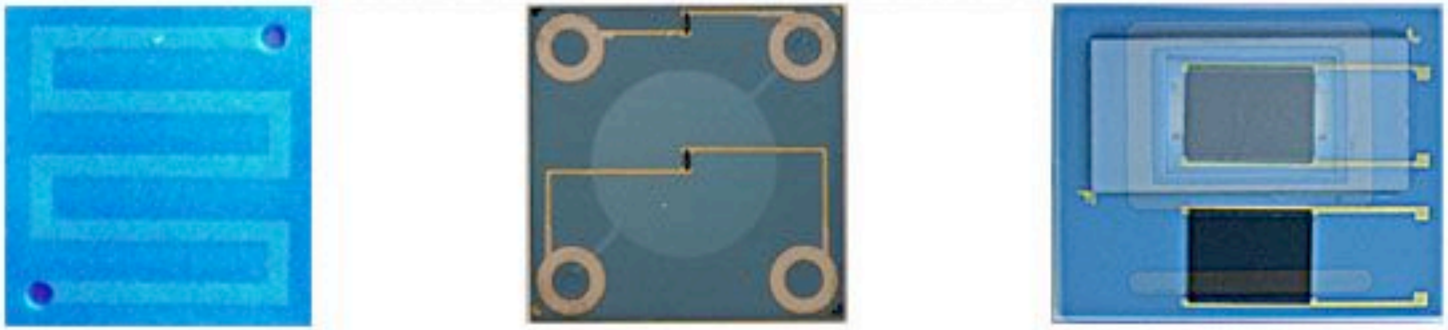
Determination of gas viscosity

- Purpose: identification of gas mixtures
- Simple sensor principle: time relaxation

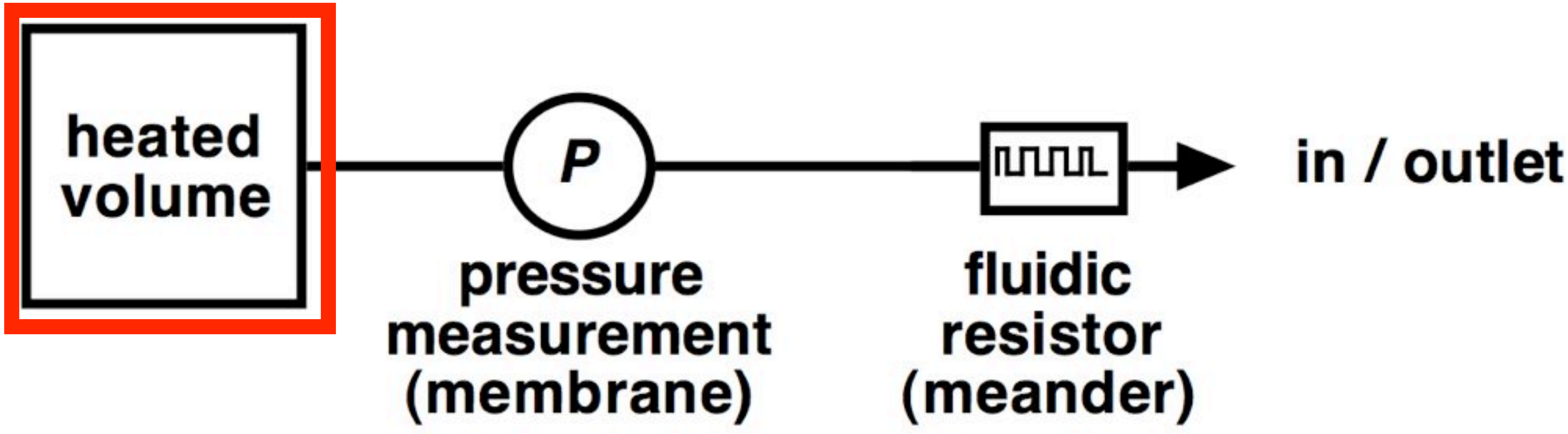


Modular LTCC sensor



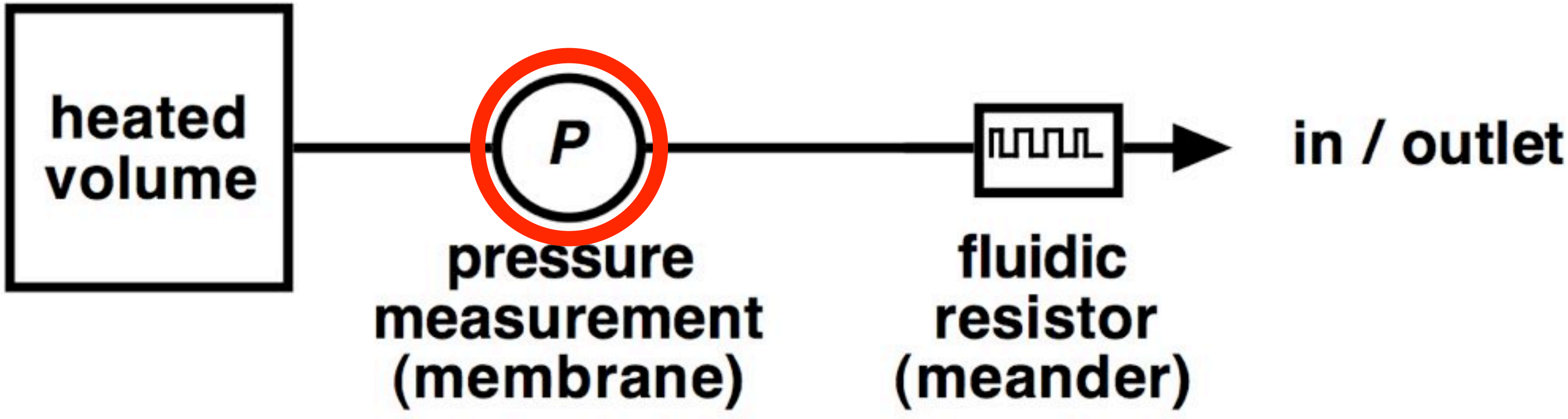


Sensor principle



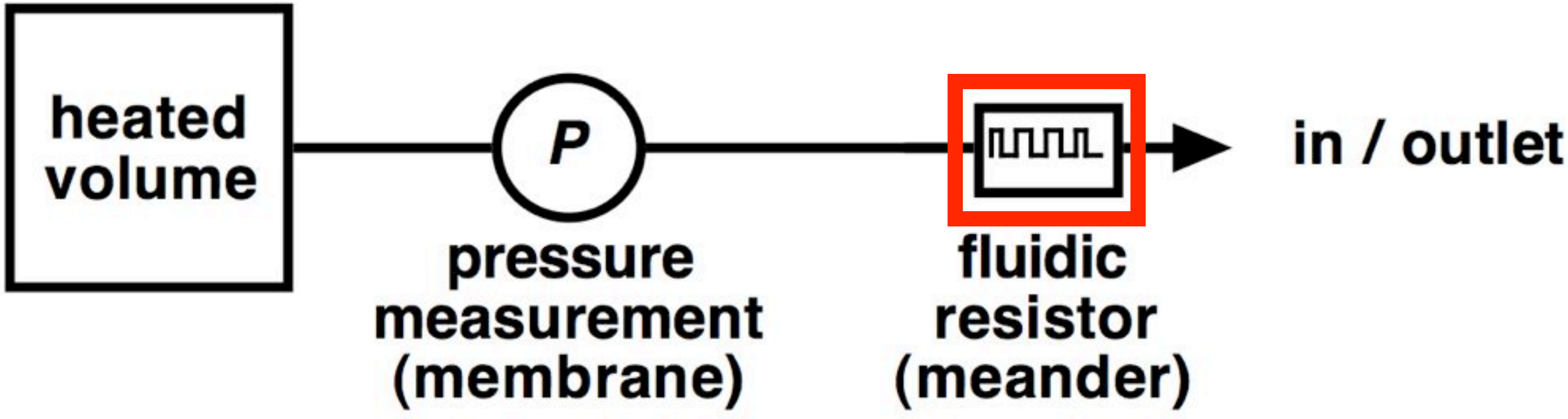
- Pressure differential generated by heating / cooling

Sensor principle



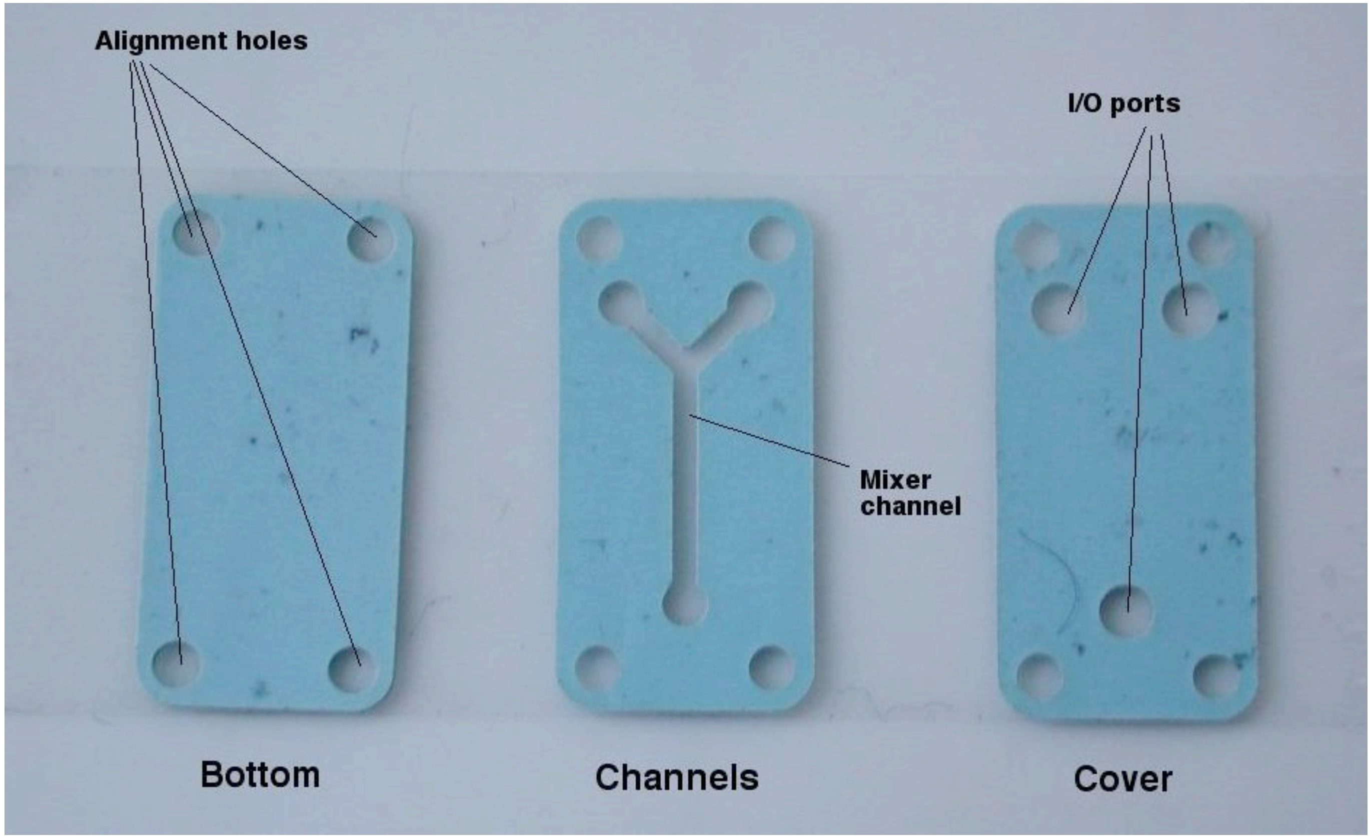
- Pressure differential generated by heating / cooling
- Pressure measured by membrane sensor

Sensor principle



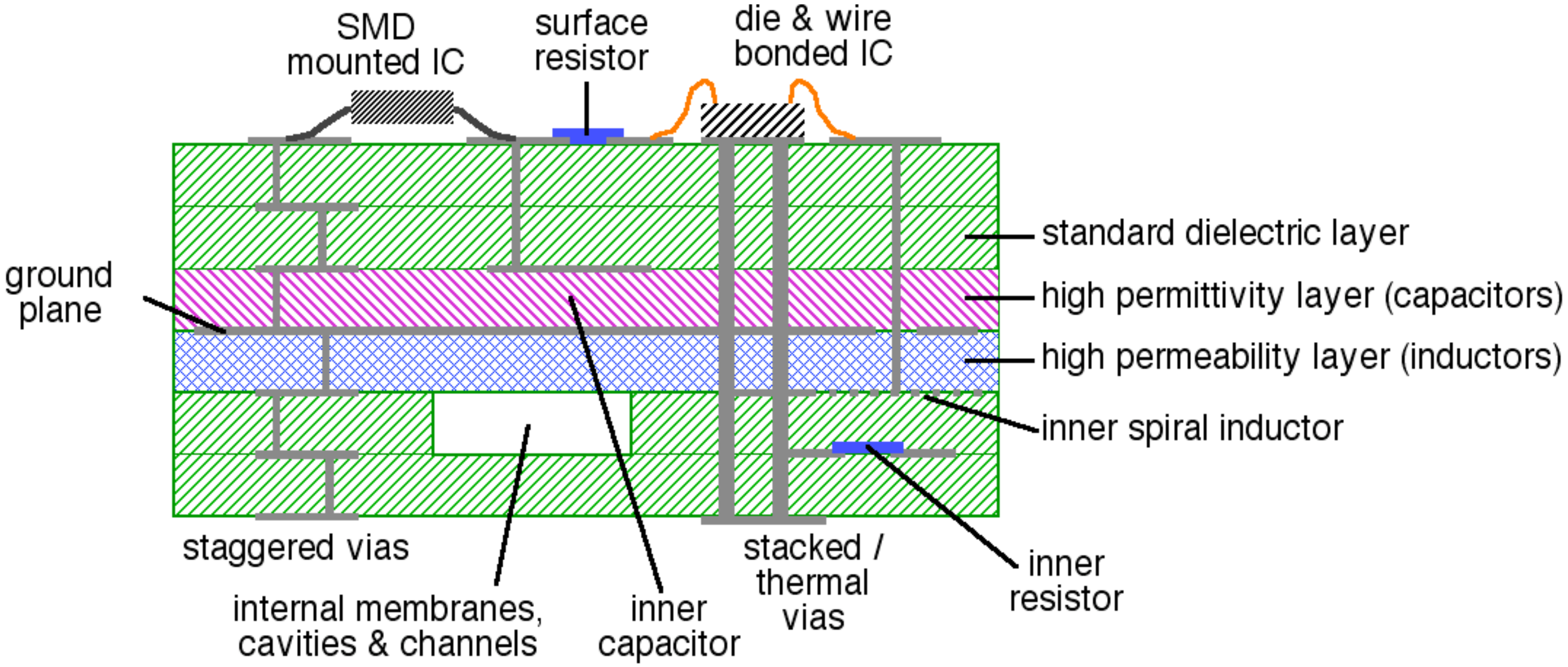
- Pressure differential generated by heating / cooling
- Pressure measured by membrane sensor
- Pressure relaxation through meander

Why LTCC (1) ?



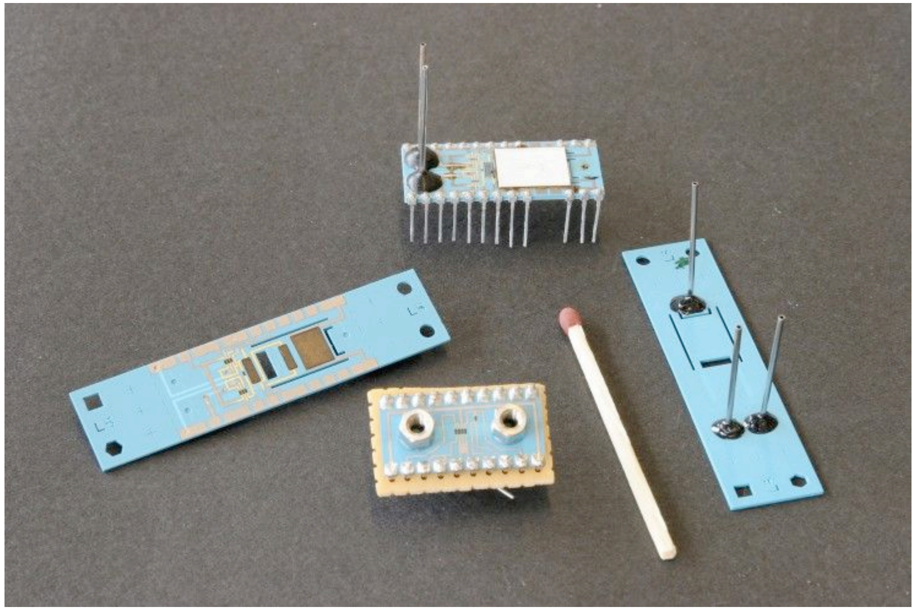
- Ease of structuration

Why LTCC (2) ?



- Integration of many functions

Why LTCC (3) ?

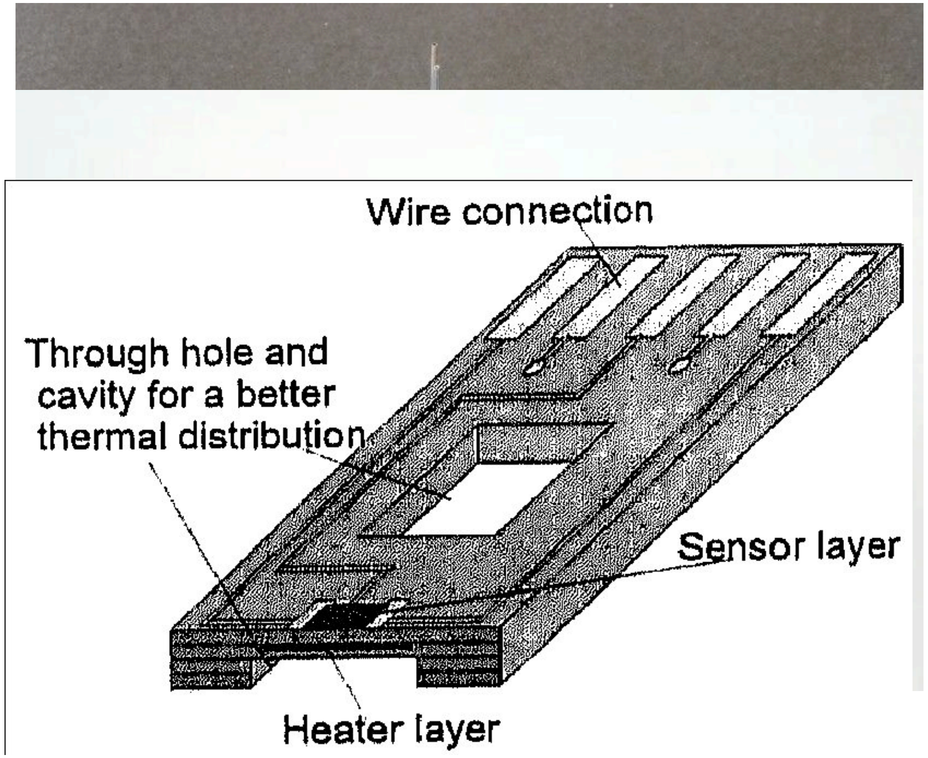


- Microreactor & flow sensor

Why LTCC (3) ?

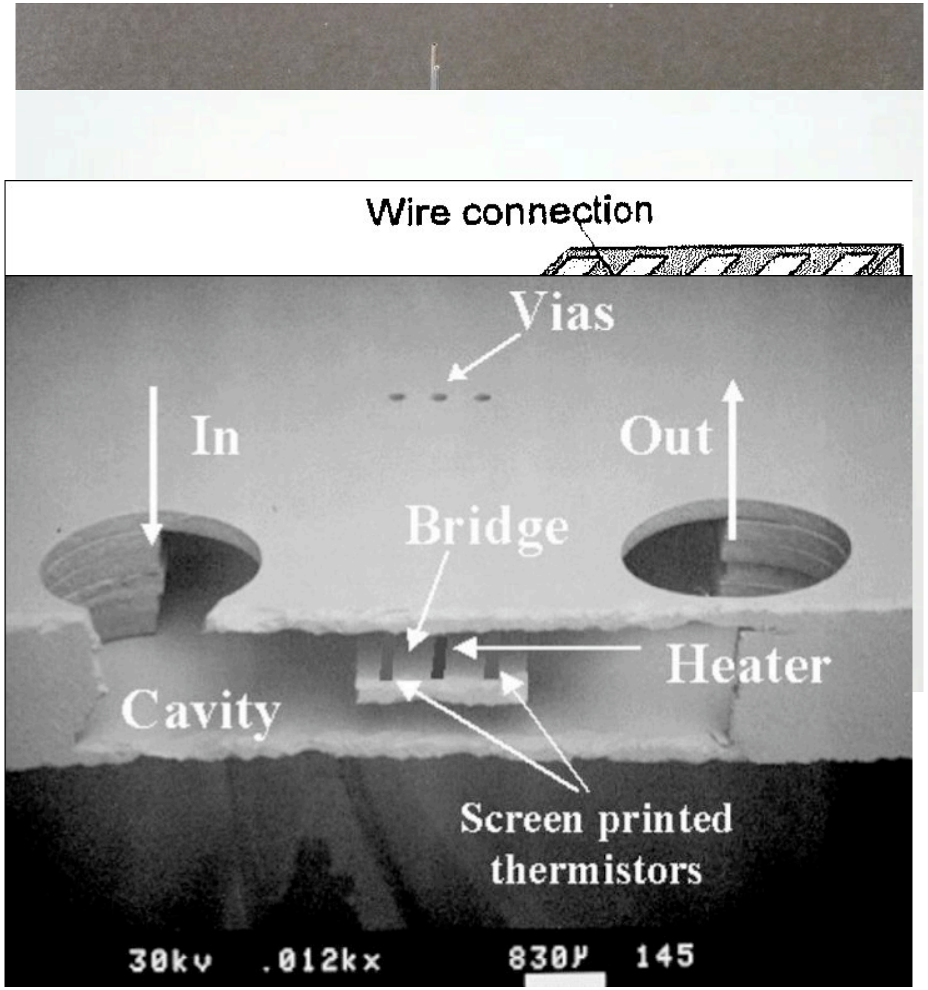
- Microreactor & flow sensor
- Inclination sensor

Why LTCC (3) ?



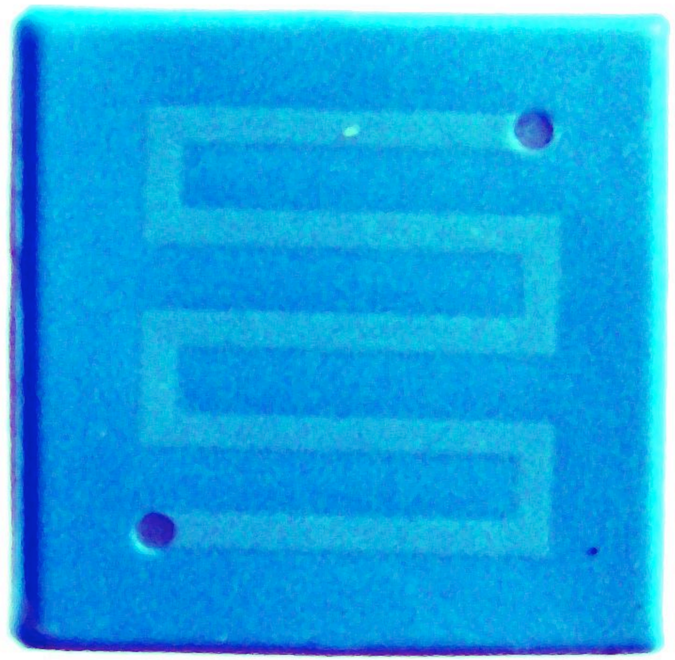
- Microreactor & flow sensor
- Inclination sensor
- Gas sensor (Golonka et al., 1998)

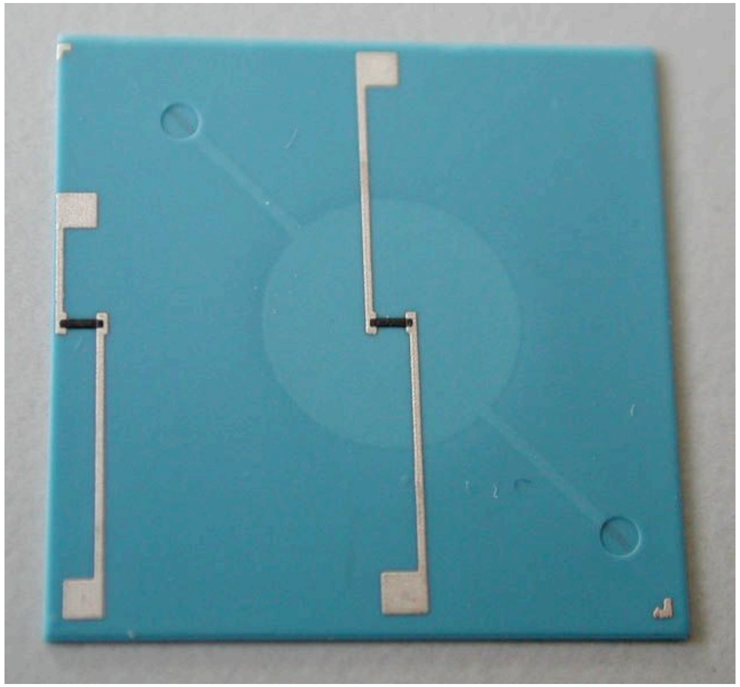
Why LTCC (3) ?



- Microreactor & flow sensor
- Inclination sensor
- Gas sensor (Golonka et al., 1998)
- Flow sensor (Gongora et al., 2001)

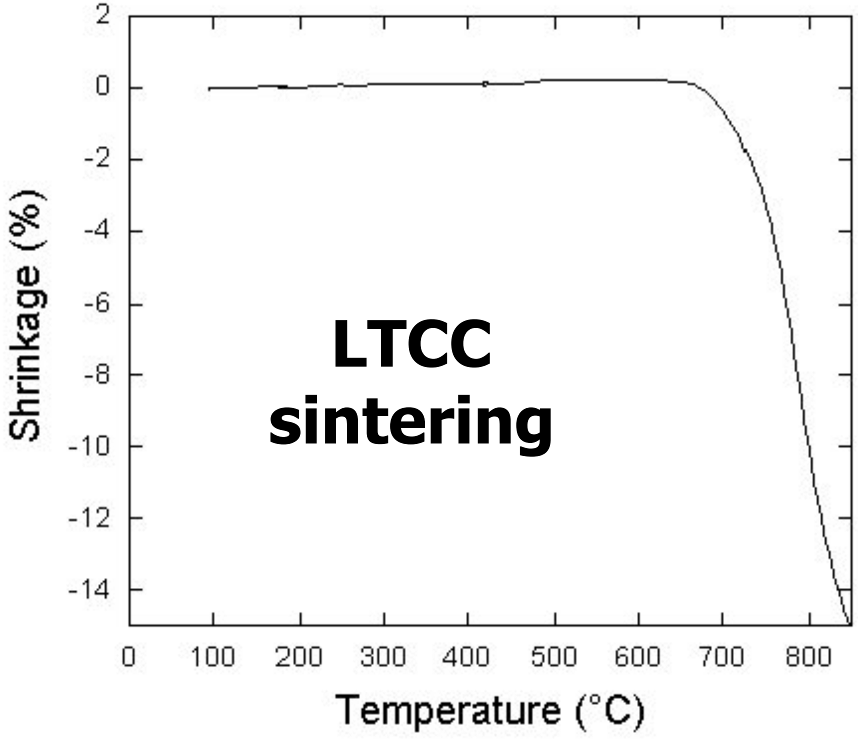
LTCC for membranes & meanders

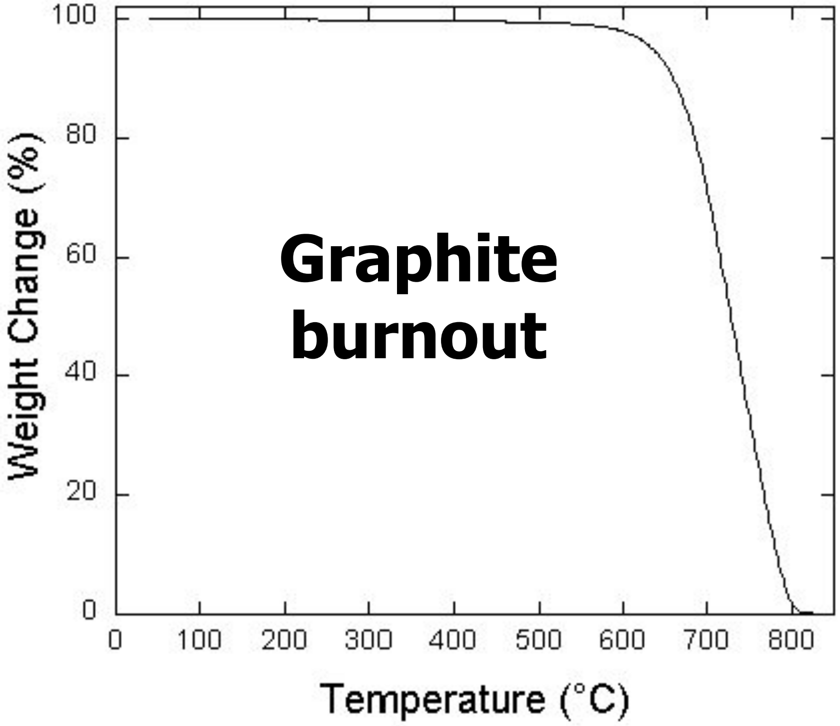




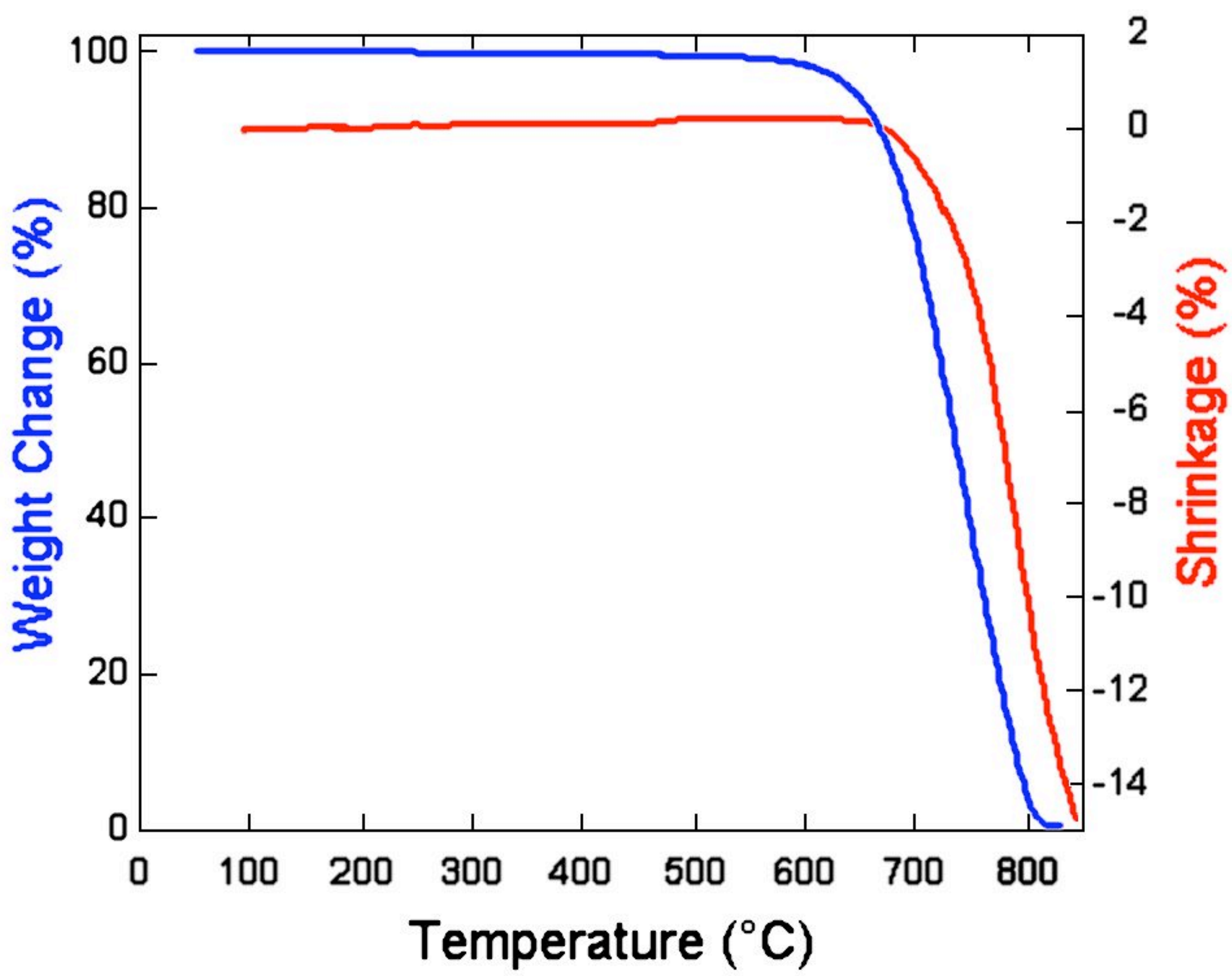
- Small spacings
- Intricate layout

Cavities by graphite fugitive phase

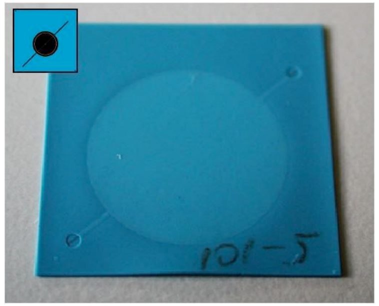




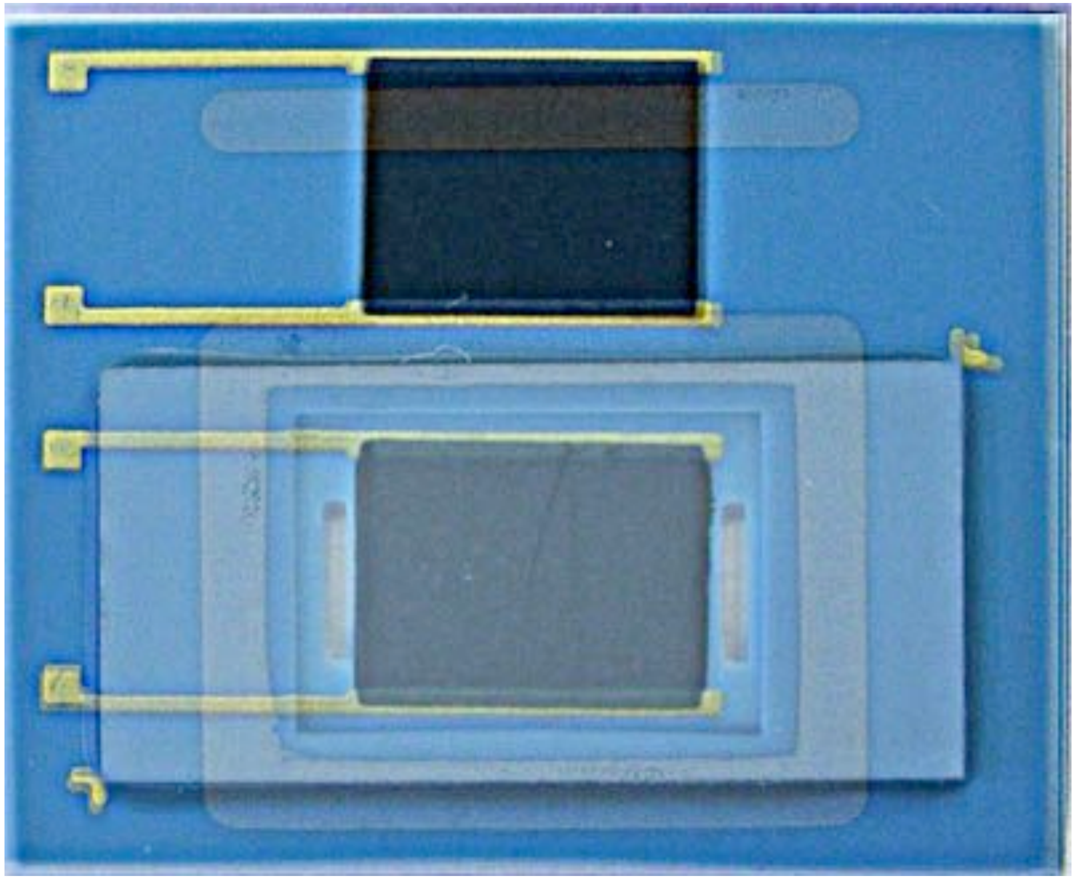
Cavities by graphite fugitive phase



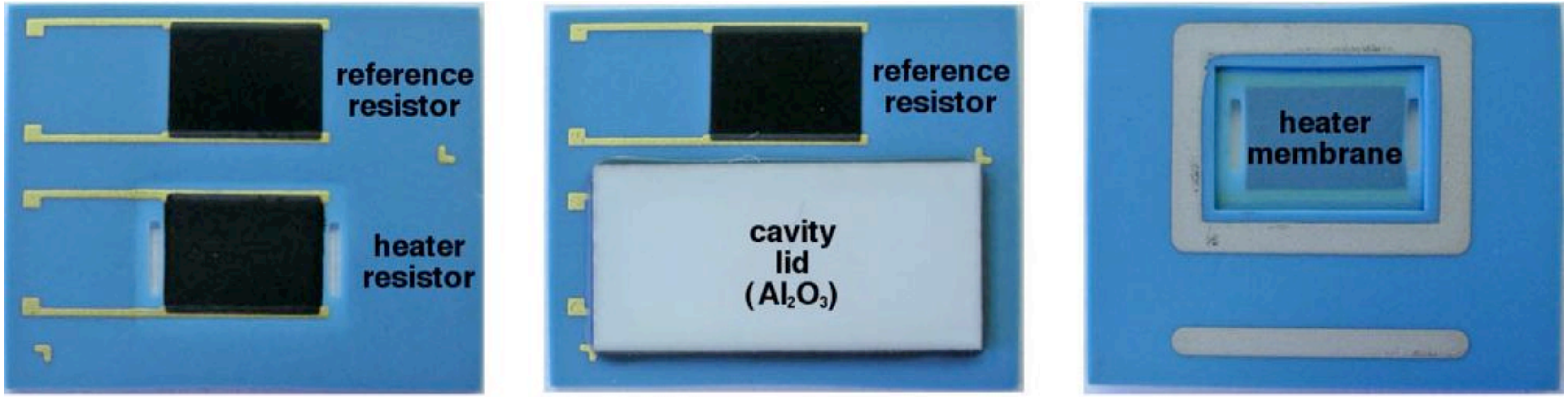
- Graphite burns out **shortly before** LTCC densifies.
- Spacing can be controlled by **heating rate**.

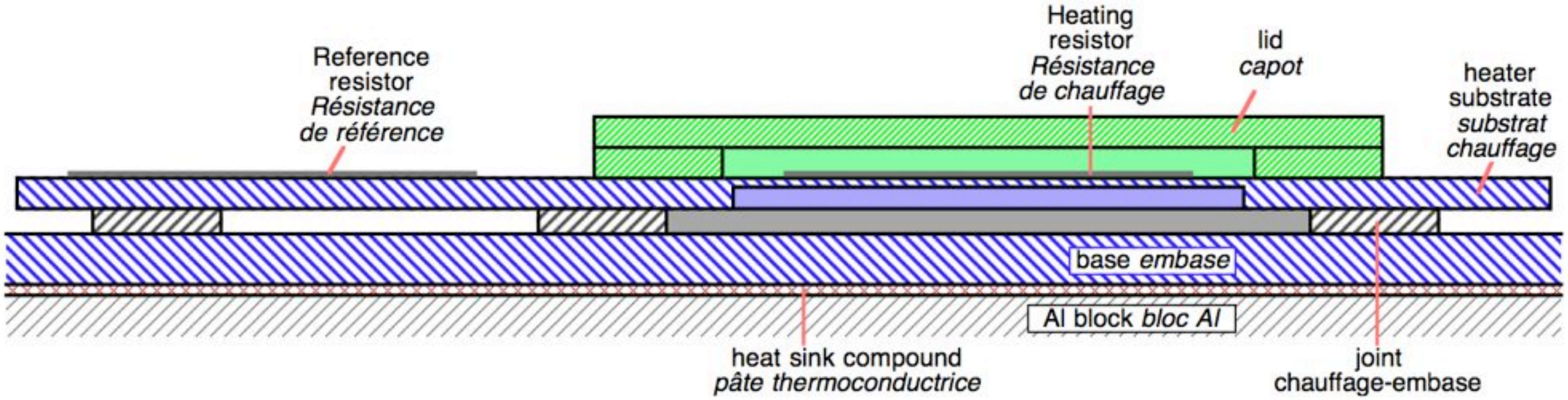


Heater module (1)

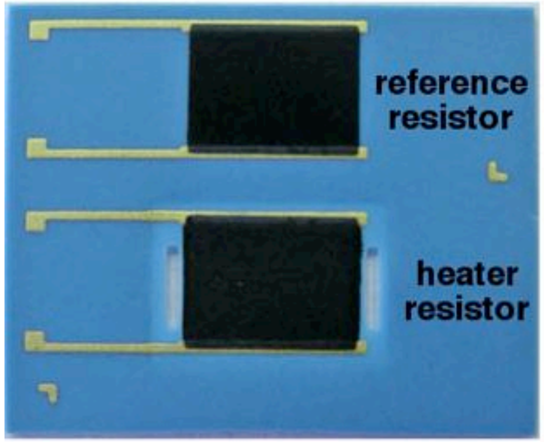


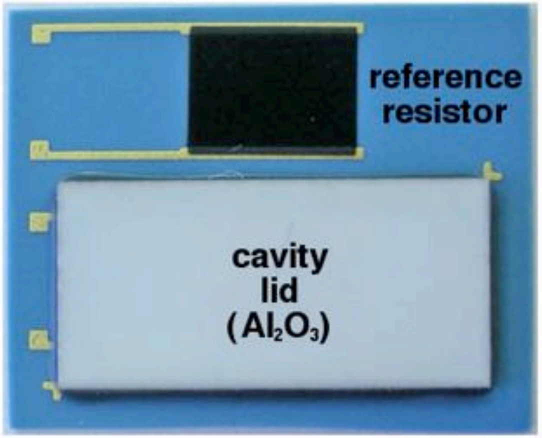
Heater module (2)

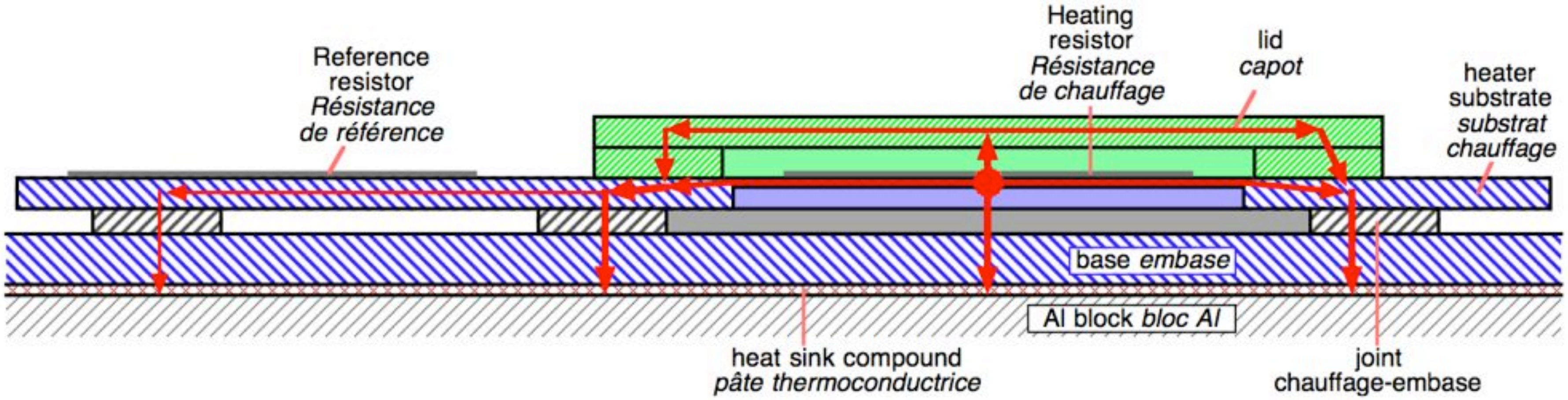




Heater module (2)







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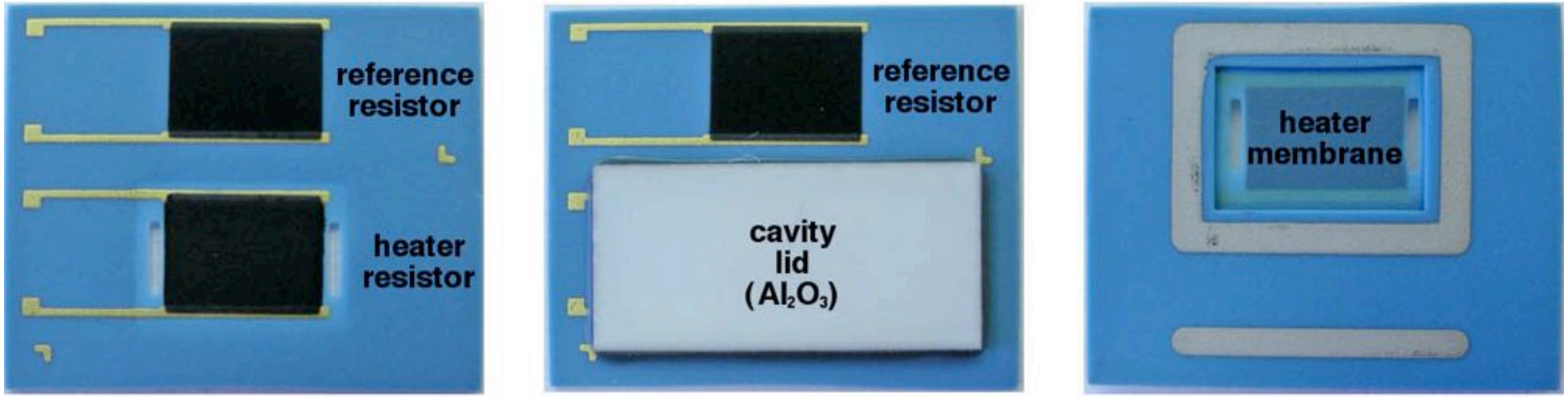
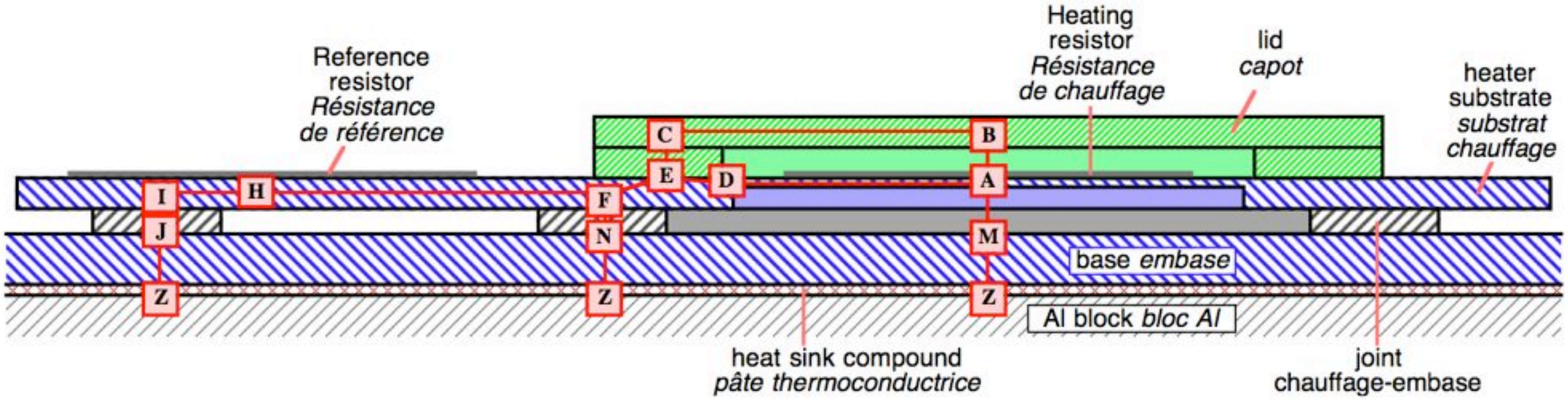
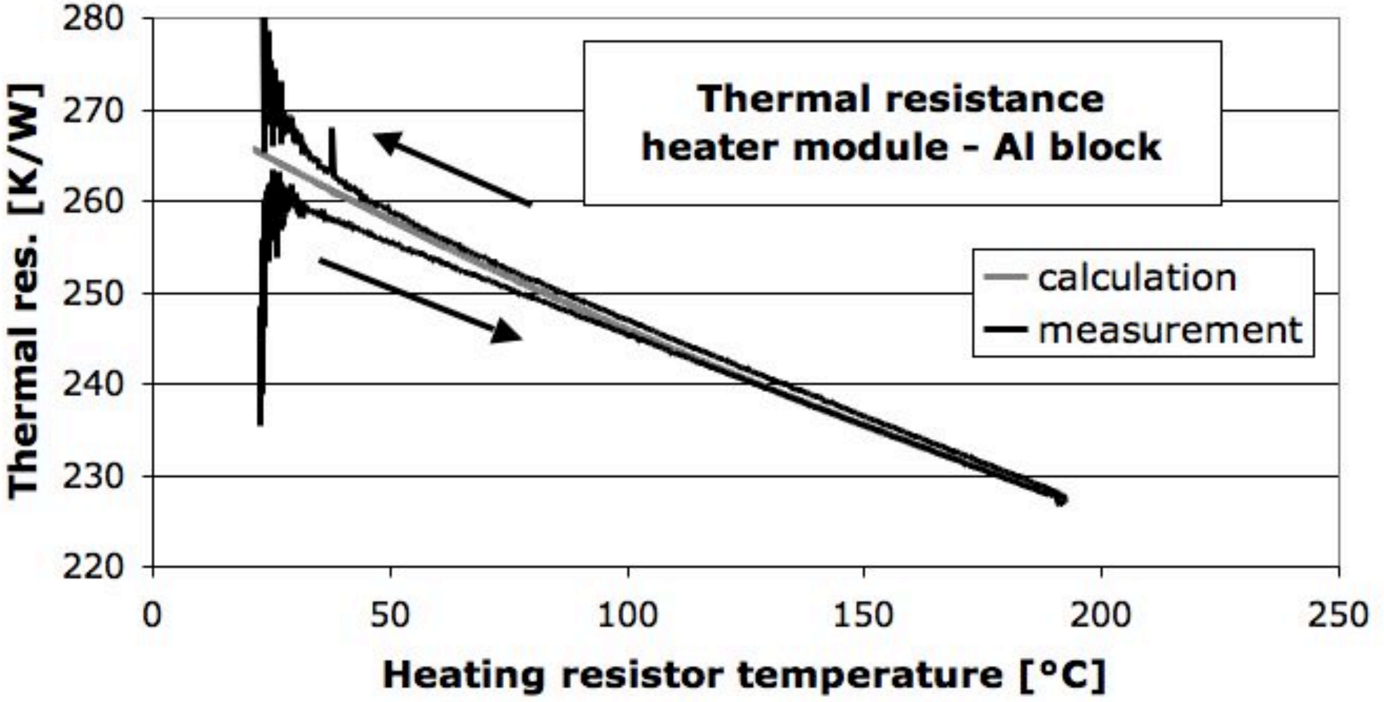


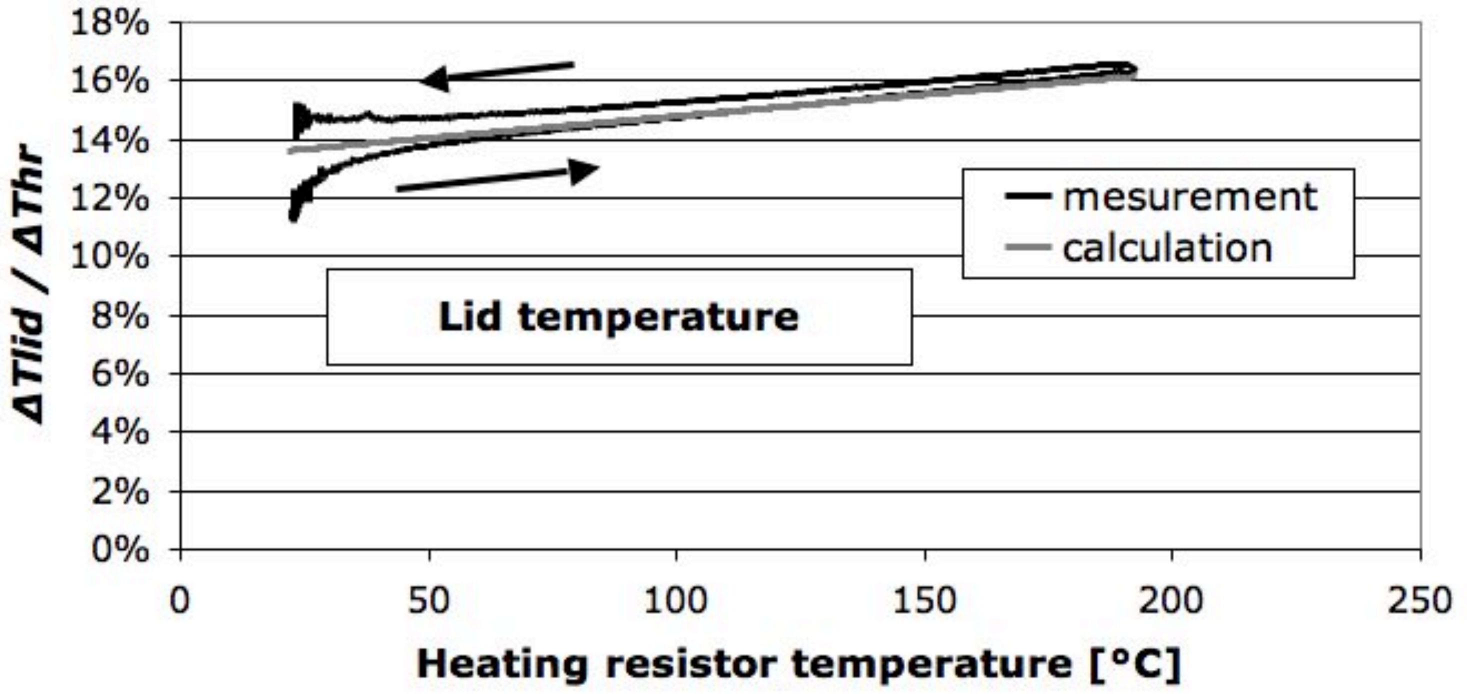


Results (1/3): thermal resistance



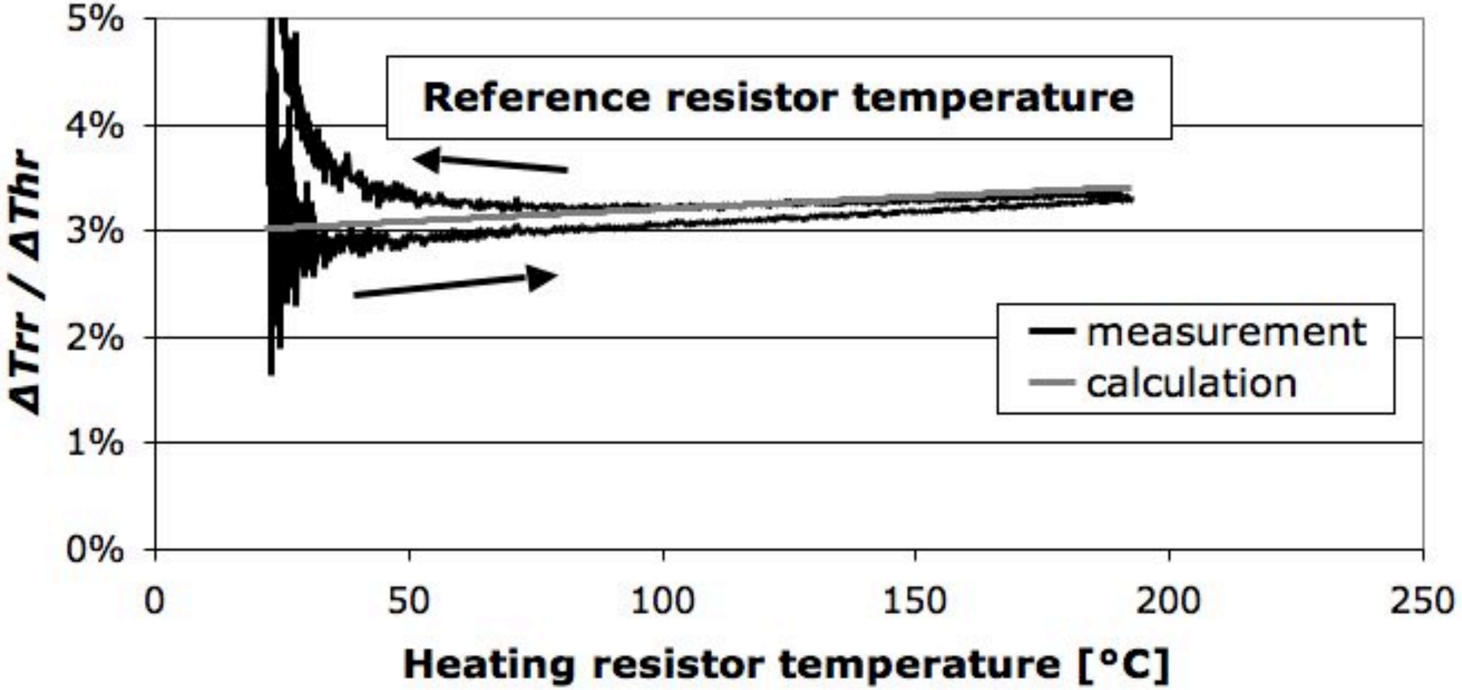
- Good correspondance with model
- Change = increase of air conductivity with temperature
- Some positive temperature drift at low power

Results (2/3): lid temperature



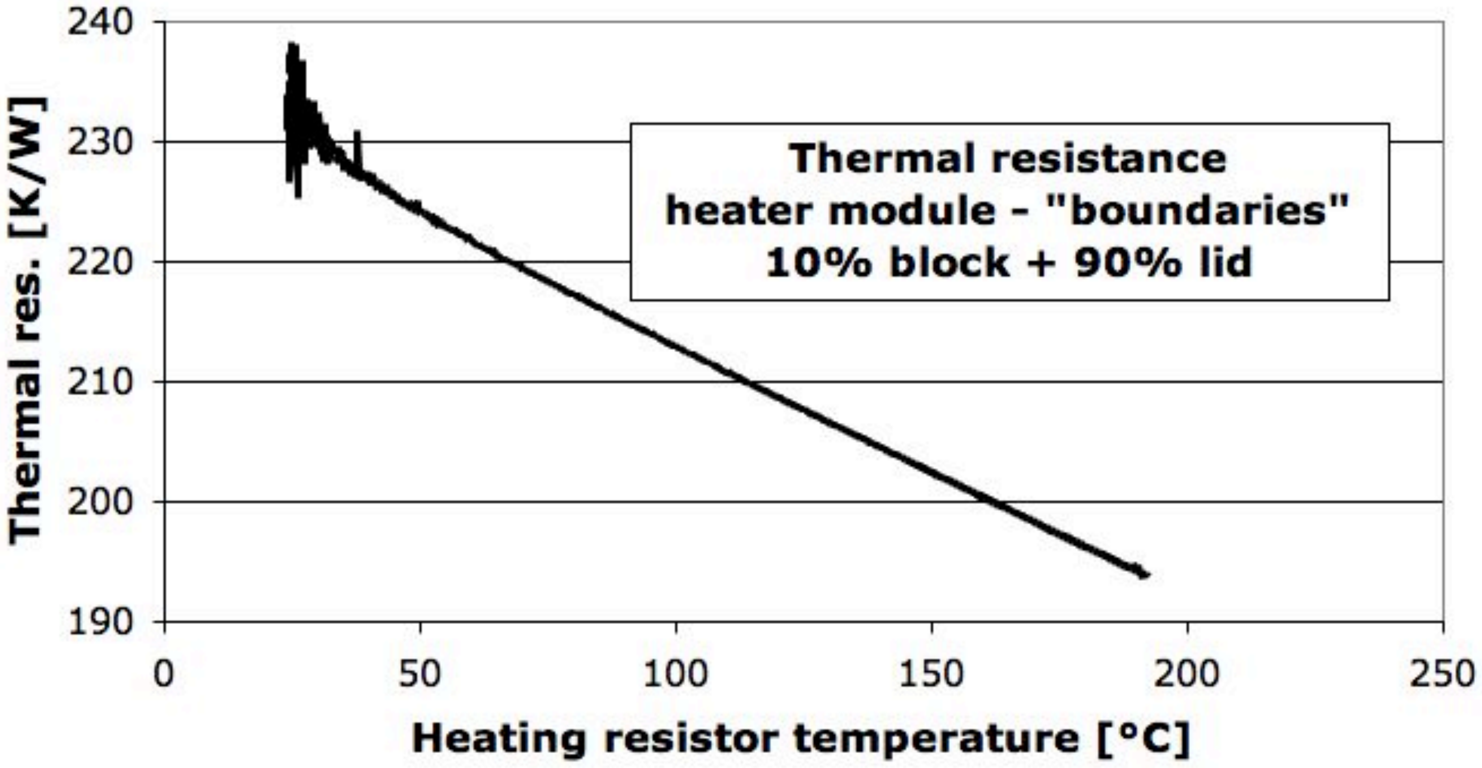
- Fractional lid temperature rise (rel. to heating resistor)
- Air conductivity rises with increasing temperature.
- Lid (Al_2O_3) conductivity drops with increasing temp.

Results (3/3): reference resistor



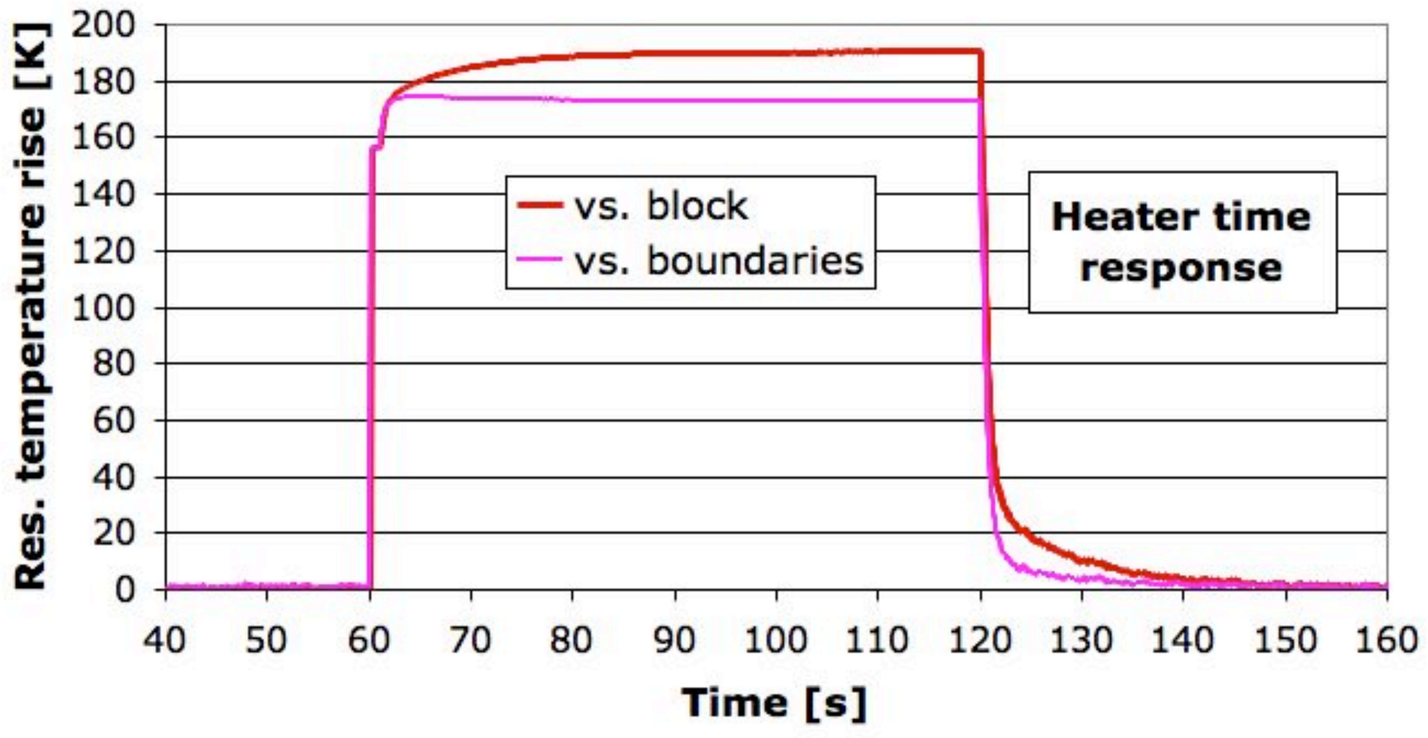
- Fractional reference resistor temperature rise
- Slight rise with increasing temperature, due to proportionally hotter lid

Origin of thermal drift



- Thermal resistance vs. weighted reference (block+lid)
- No hysterisis with these boundary conditions

Transient behaviour



- Very fast resistor response time (≈1 s)
- Heating faster than cooling due to TCR
- Additional delayed response due to lid, etc.

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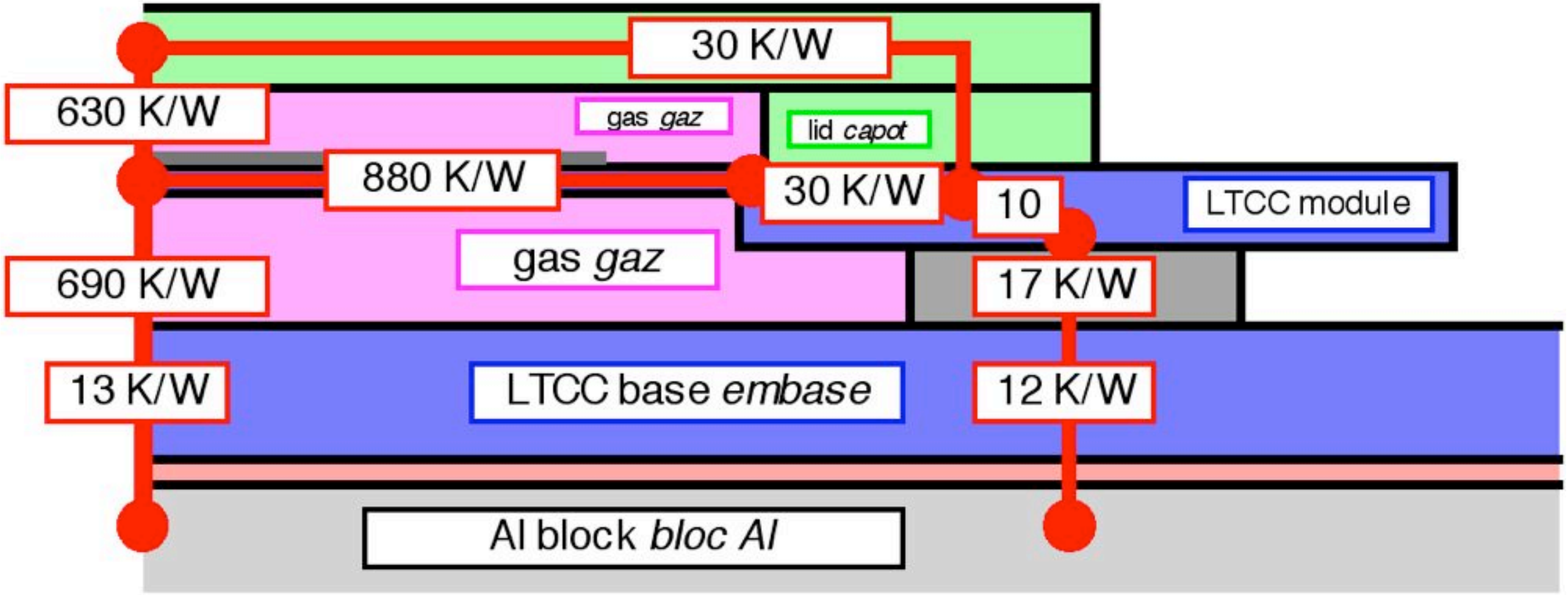
Thermal resistances



- Res. of base & heat sink compound: ca. 3% of total
- Average « parasitic » resistances: ca. 12%
- Lid + module: large resistances, slow equilibration

Materials (& better alternatives)

Part / layer	**Material**	**Conductivity** [W/m/K]
Module	LTCC	3
	LTCC+Ag	*6*
Lid	Alumina 96%	24
	Al, Al-Si	*150*
Joints	Silicone glue	0.2
	Sn-Ag-Cu solder	*60*
Heat sink comp.	Grease + Al_2O_3	0.6
Cavity	Air	0.026

Conclusions

- High thermal resistance (≈ 250 K/W)
- Average cavity ΔT @ 0.5 W: ca. +60K
- Generated pressure peak: ca. ±0.2 bar
- High speed (≈ 1s)
- Boundary conditions not yet optimal
- Improvement by using better materials

Merci / Danke / Grazie / Hvala

THANK

YOU !