European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs & MC Meeting at SOFIA (BG), 16-18 December 2015

New Sensing Technologies for Indoor Air Quality Monitoring: Trends and Challenges

Action Start date: 01/07/2012 - Action End date: 30/04/2016 - Year 4: 1 July 2015 - 30 April 2016

FUNCTIONAL PACKAGING OF GAS AND PARTICLE SENSORS USING LOW TEMPERATURE CO-FIRED CERAMIC, LTCC

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Action Vice-Chair

COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

Toxic substances needed to be measured:

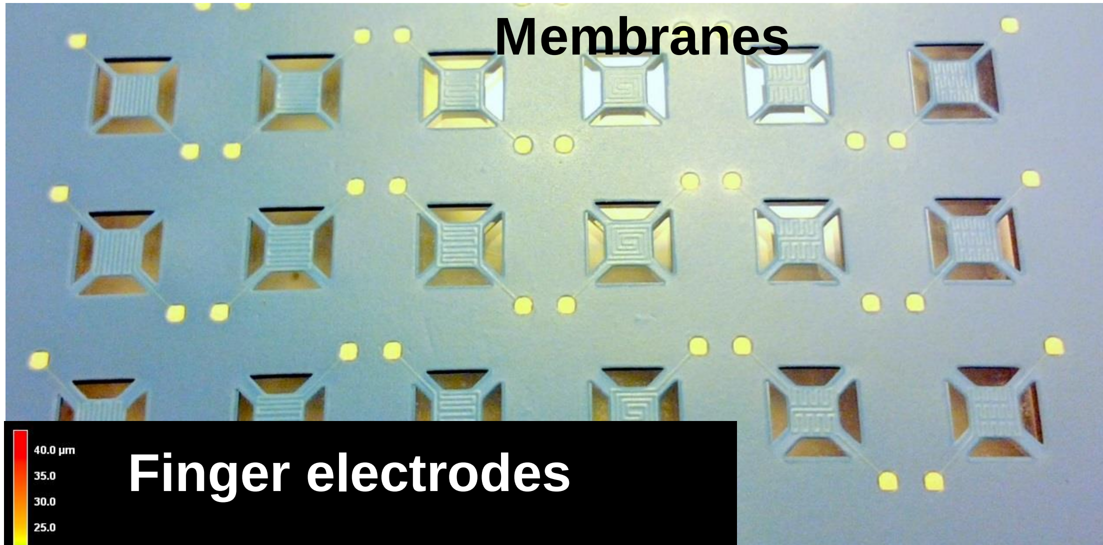
NO_x, NH_3, SO_2, CO, O_3, PAH/VOC, PM_{10}, $PM_{2.5}$, PM_1

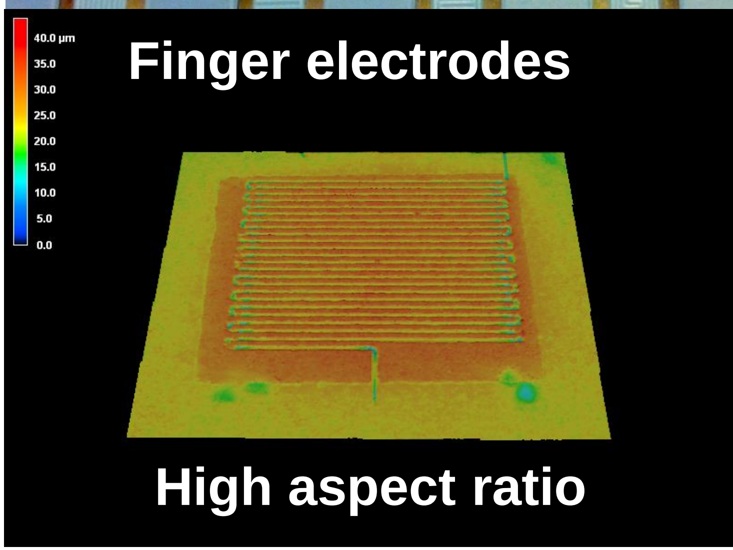
EuNetAir provide a diversity of sensor technologies, knowledge and important experience

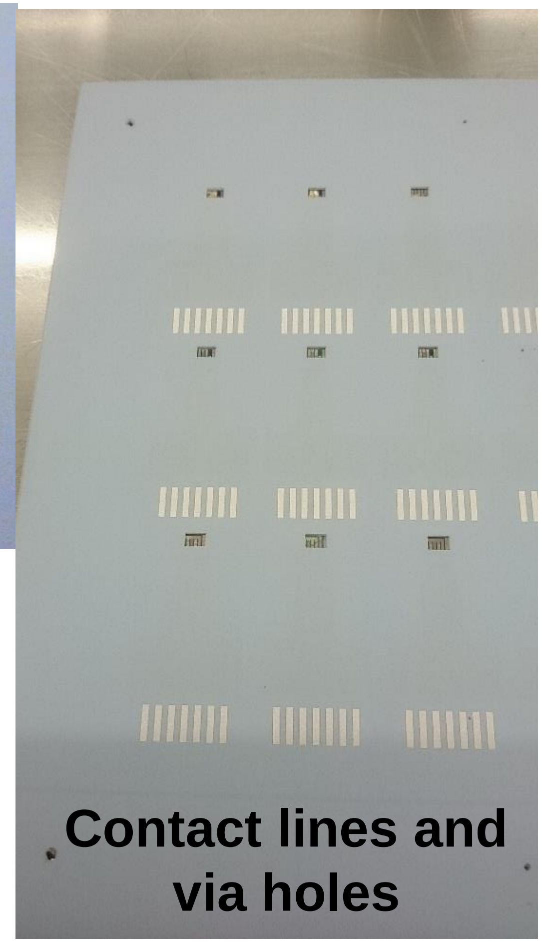
Outline

- LTCC technology:
  - Smart packaging of
    - chemical gas sensors
    - Portable particle detectors
    - The Cell clinic

LTCC processing of different structures





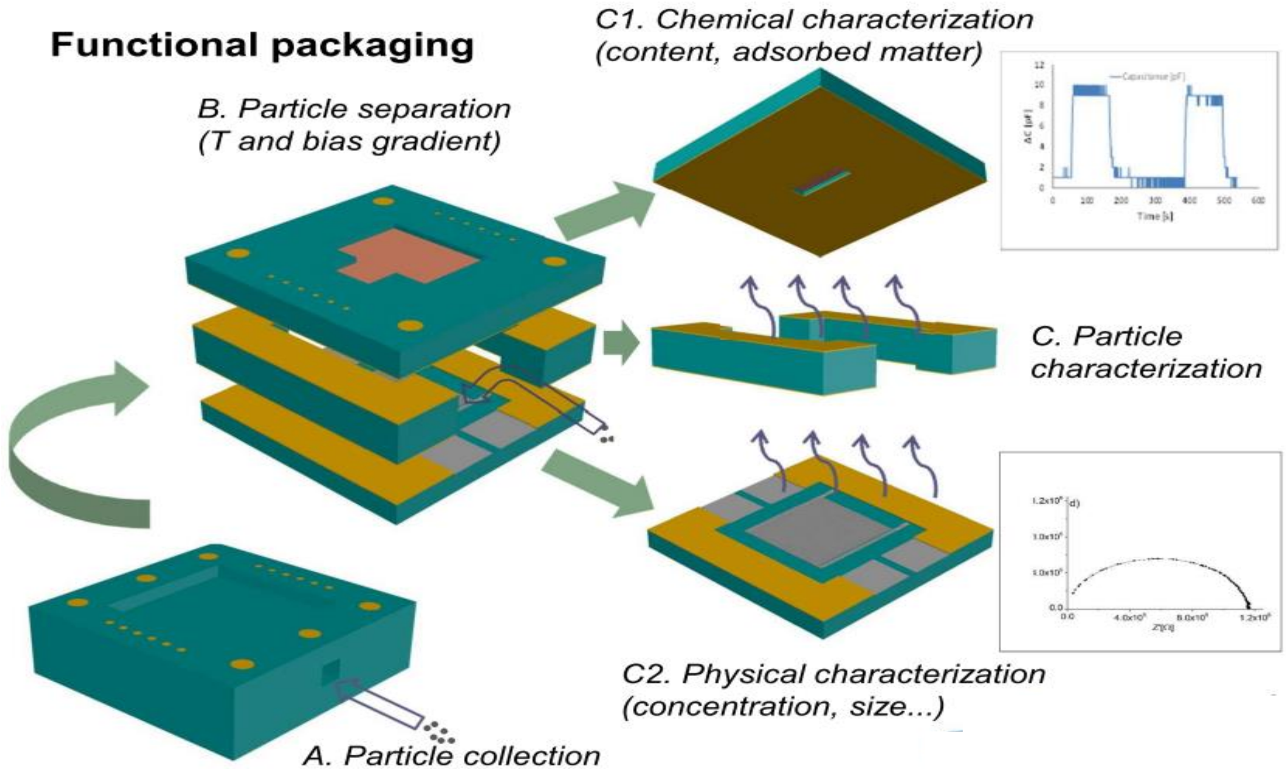


Processing on green sheets (typically 10 x 10 cm)
Stacking and firing in one (fast) step possible

LTCC platform for sensor devices

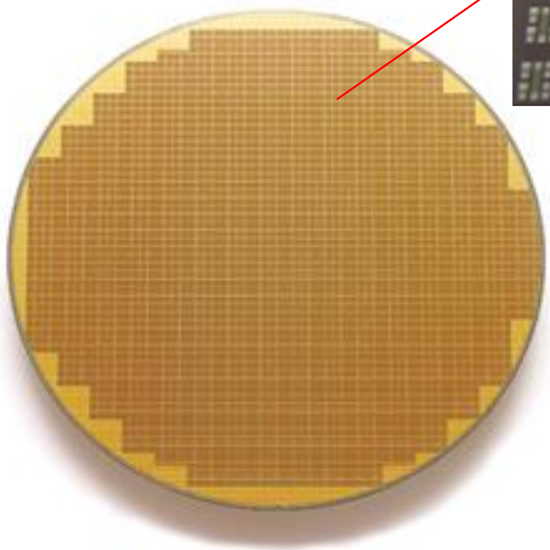
Benefits of LTCC (Low Temperature Co-fired Ceramics)

- ✓ Fast processing
- ✓ Durable, hermetic, resistant in high temperature and corrosive environment
- ✓ Relatively cheap

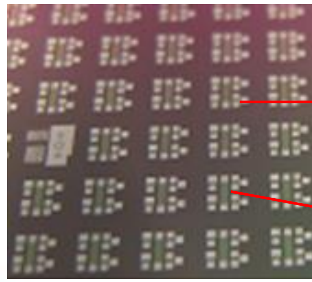


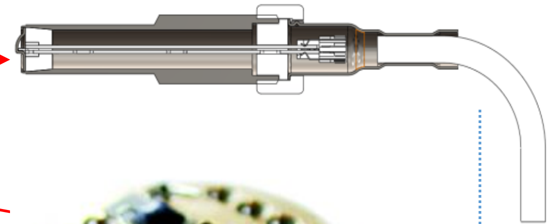
The different layers in one LTCC module

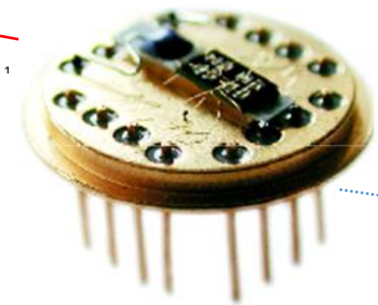
SiC-FET sensors wafer and mounting



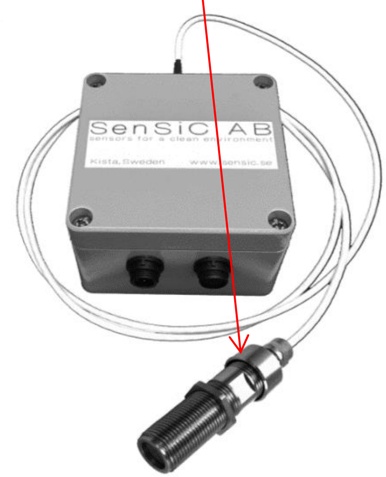
4” SiC wafer up to 2000 chips
Design and processing,
SenSiC AB/ (Ascatron AB)







SiC-FET sensor system Traditional mounting

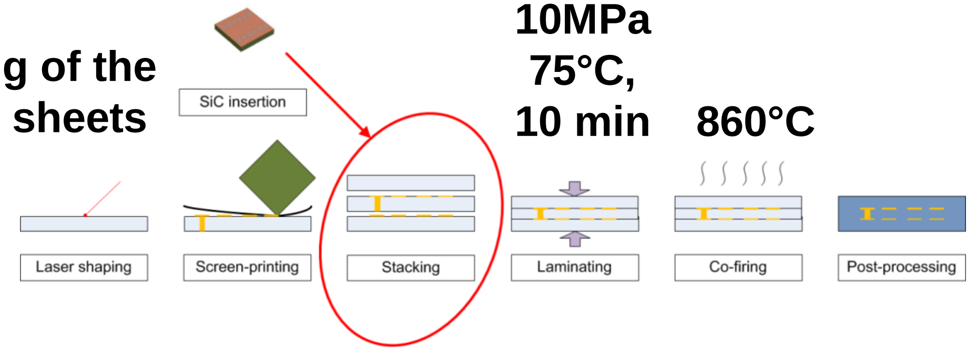


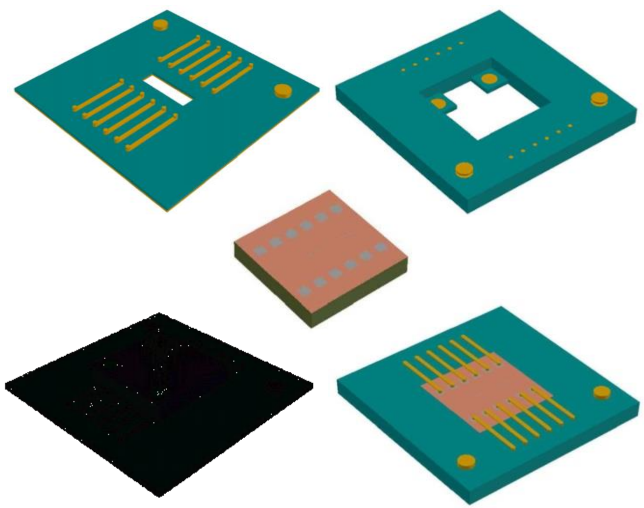
LTCC platform for SiC–FET sensors

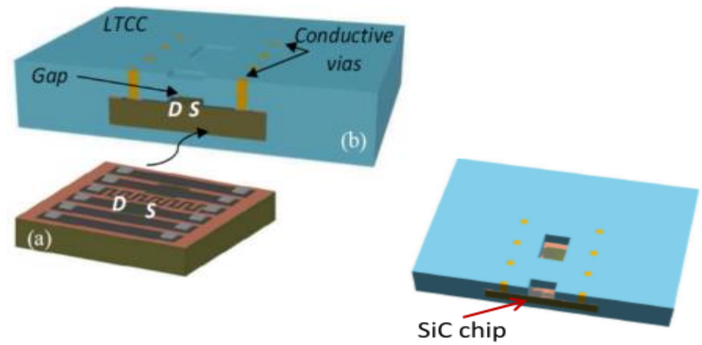
SiC FET chip inserted during stacking of the printed sheets

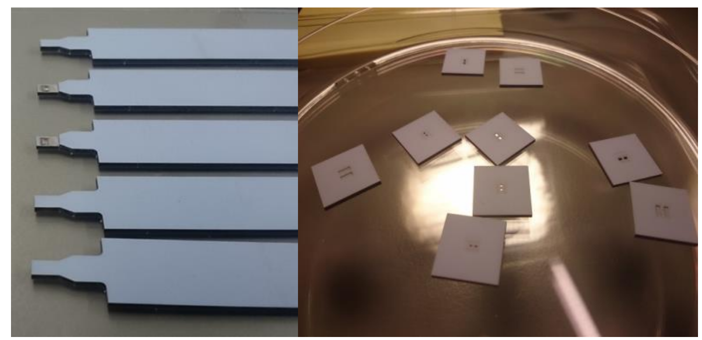
10MPa 75°C, 10 min

860°C







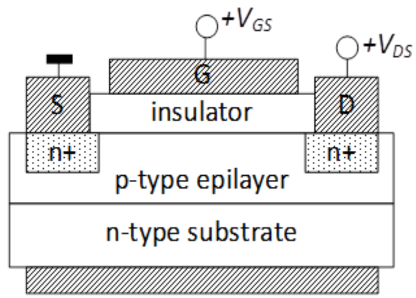


The chip/LTCC module forms one solid object which hermetically protects the sensor **no die attachment, no bonding, no post-seal**

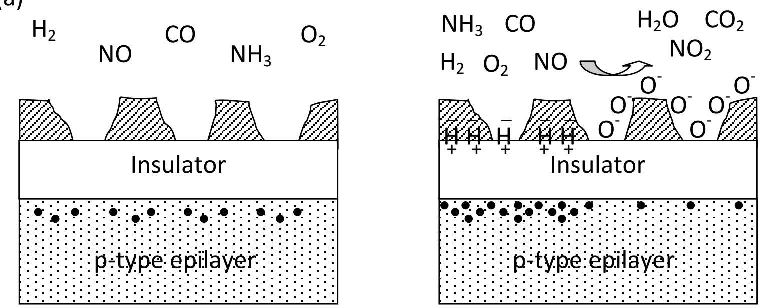
M. Sobocinski and M. Andersson , et al,, Procedia Engineering, 120 (2015) 253-256

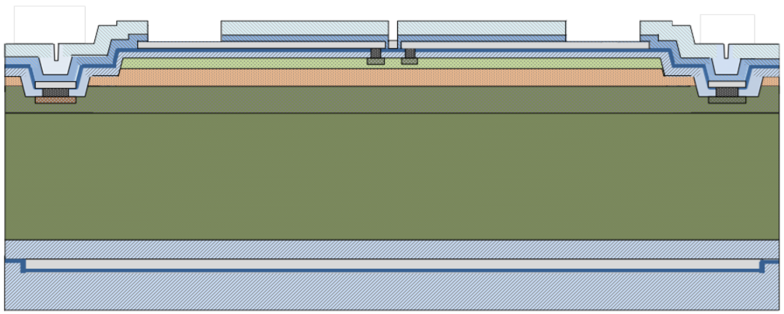
SiC-FET gas sensor technology

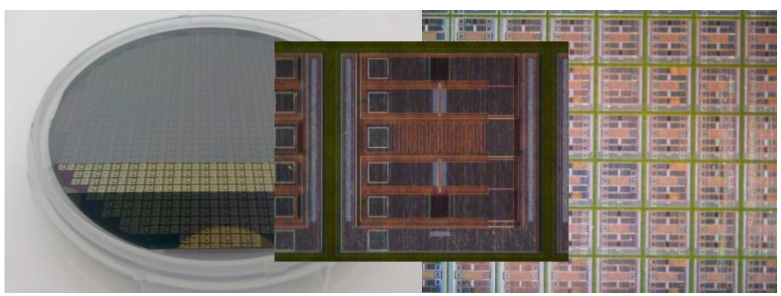
SiC based FET platform
Gate metal: porous Ir or Pt



(a)

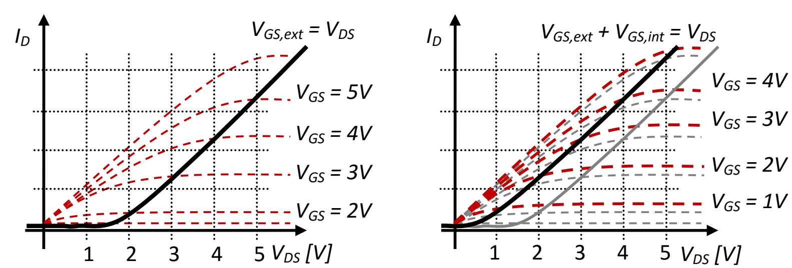






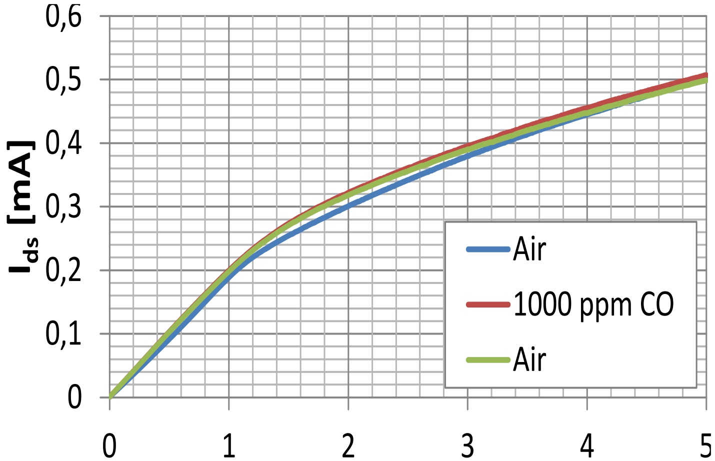
Decomposition and reactions of molecules on the catalytic metal – spill over to the oxide - charging of the gate area - a change in the current through the transistor

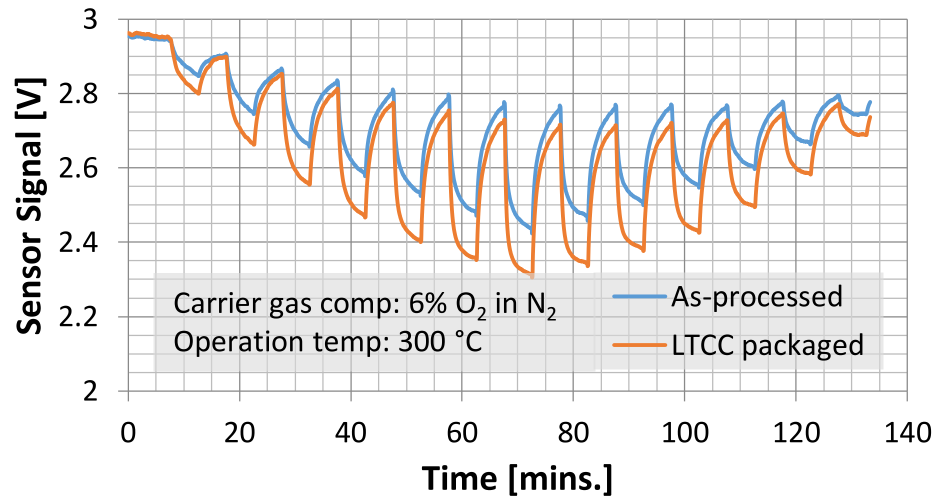
(c)

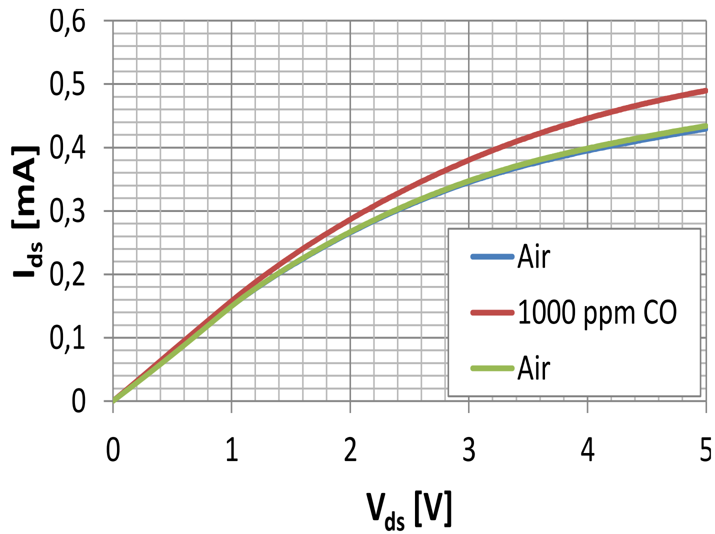


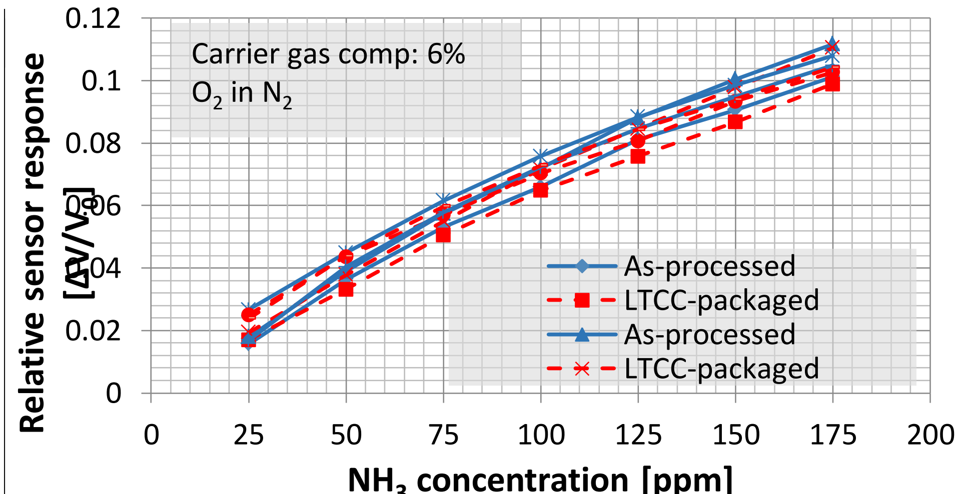
Temperature modulation and tailor made sensing layer enhances selectivity and sensitivity:
H_2, CO, NH_3, SO_2, NO_x, VOC

SiC-FET in LTCC module
Gas sensing characteristics

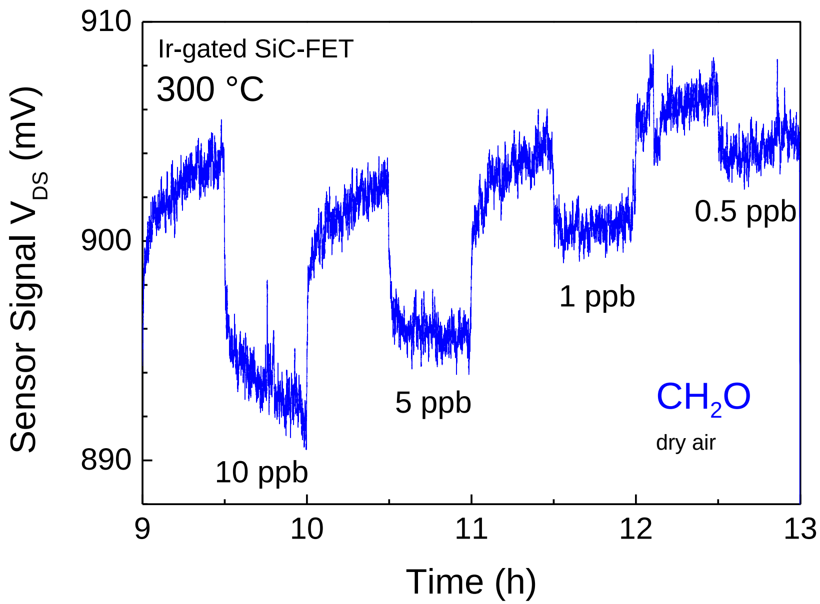


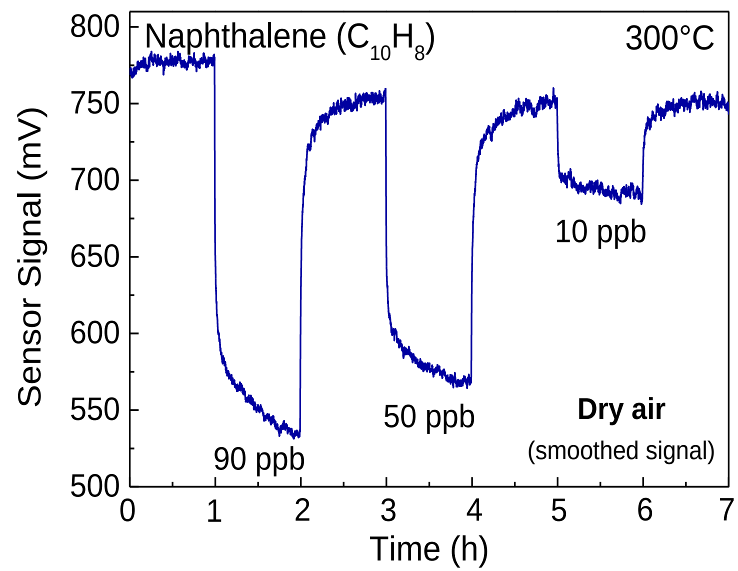






VOC detection by SiC-FET sensors



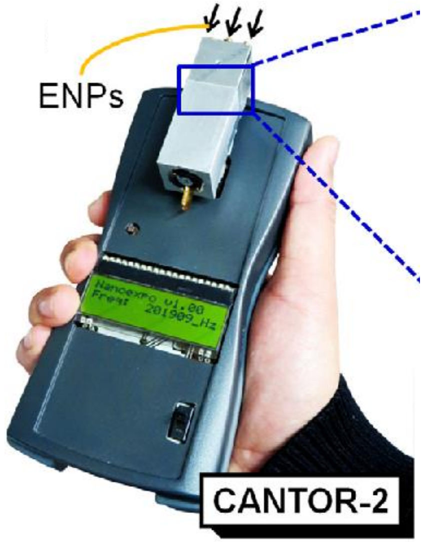


Measurements performed by Donatella Puglisi, Linköping University at Saarland University in an STSM activity within the EuNetAir

Portable particle detectors

Miniaturized devices for the on-line monitoring of particles for

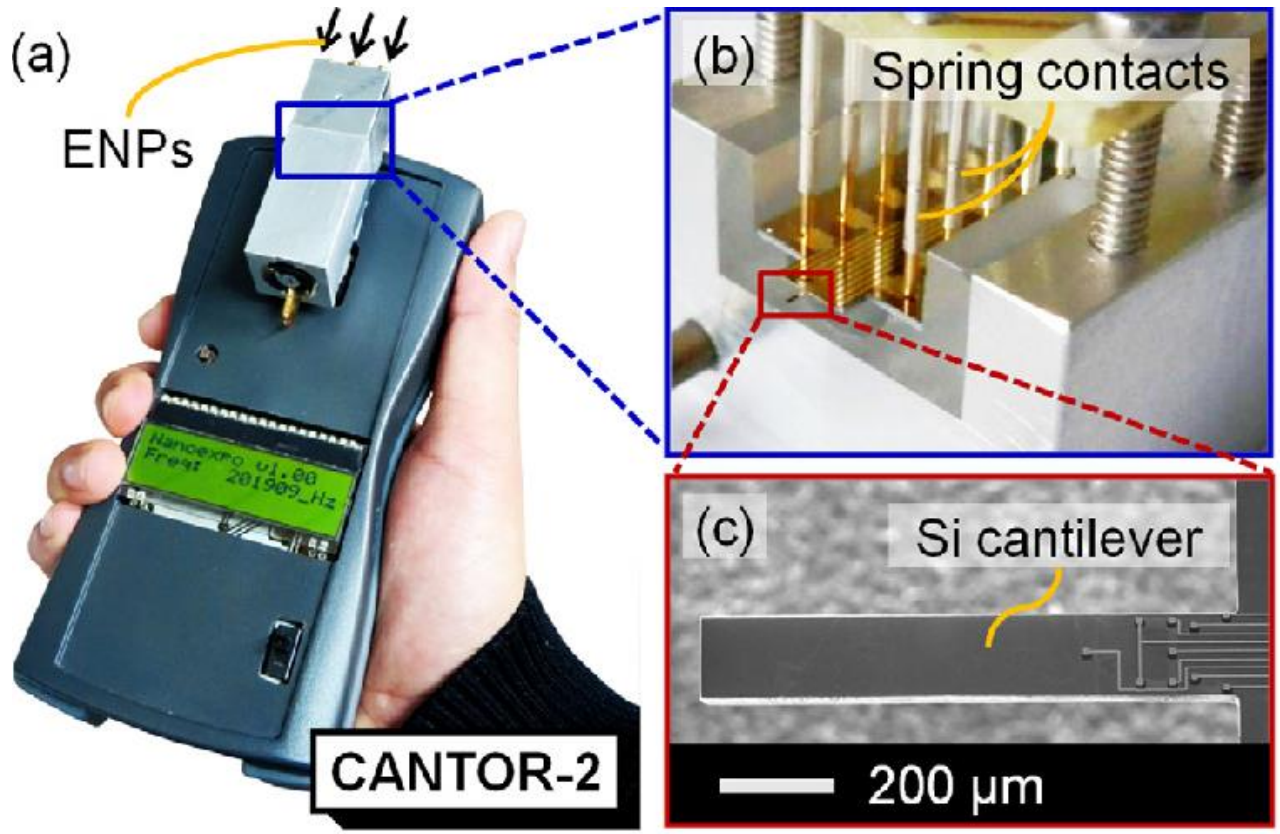
- Work places
- Public use



Giving information about particle
number (concentration)
Size
Shape (needle like, asbestos like (branched needles)
Content (CNTs containing Ni, Fe, Co has shown adverse effect in animal studies)

Since these parameters influence the adverse health effect of particles

Portable black carbon detector for work places

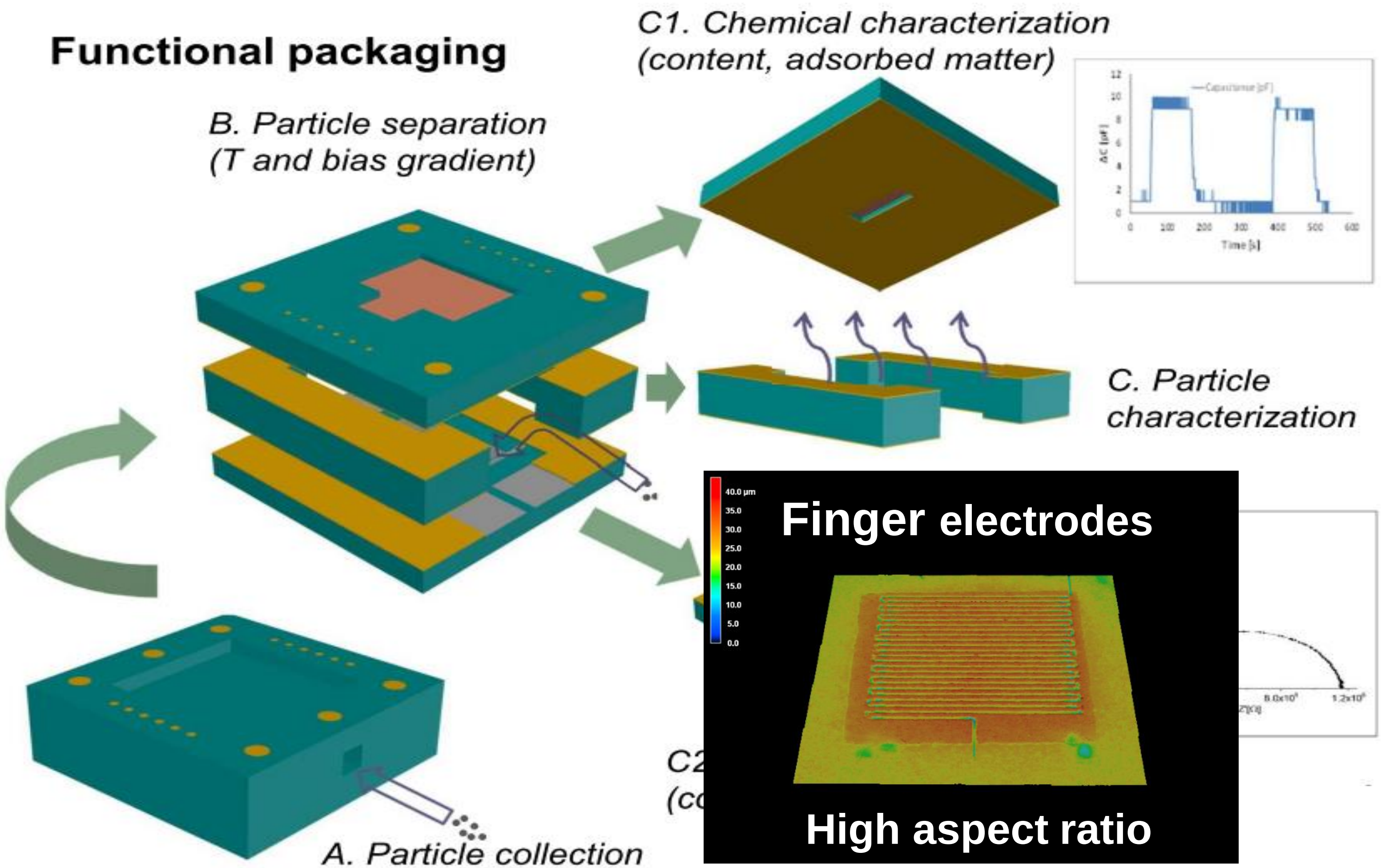


H.S. Wasisto et al, Handheld personal airborne nanoparticle detector based on microelectromechanical silicon resonant cantilever, Microelectronic Engineering, 145 (2015) 96-103. (Braunschweig Germany)

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOG

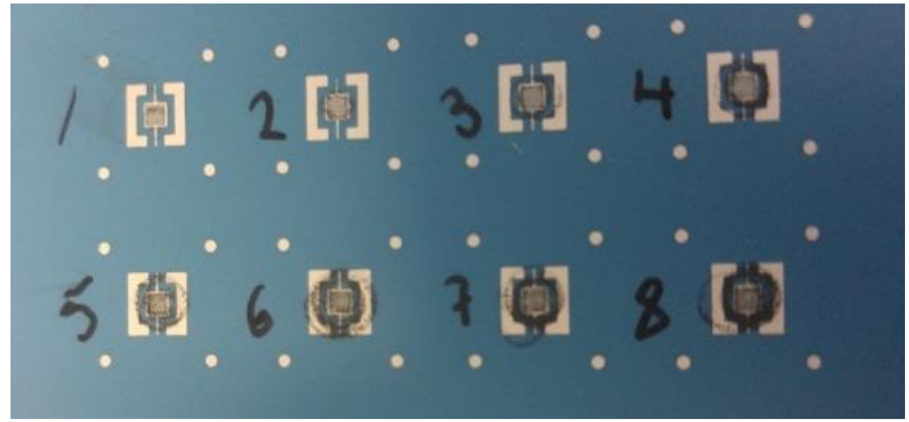
Gunter Hagen et al. Capacitive soot sensor, Eurosensors 2015 (Bayreuth)

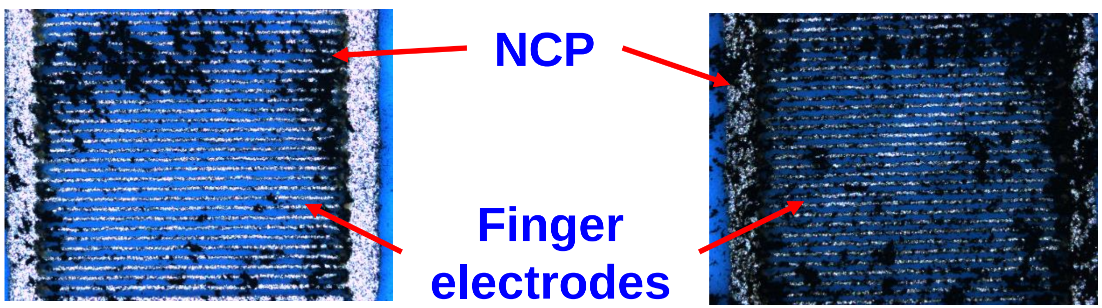
LTCC platform for Portable particle detectors



Drip-casted NCP (Nano-cobalt particles)

- 8 similar structures with different concentration of NCP
- Drip casted with a pipet from unstable, constantly sonicated solution
- Very high concertation (visible with naked eye)
- Finger width 20 µm, gap 30 µm



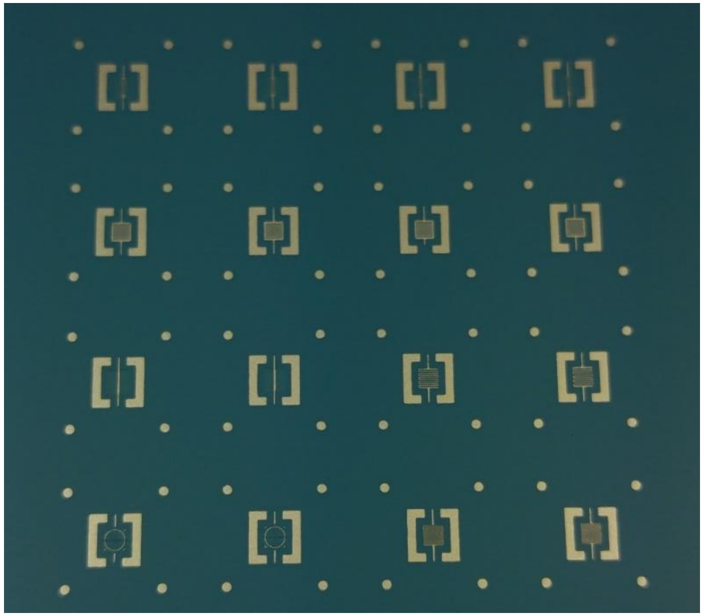


Structure 1

Structure 8

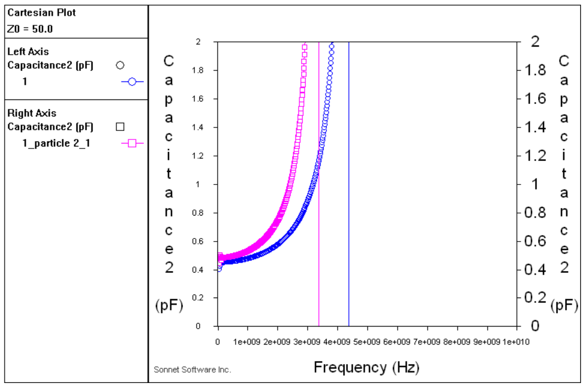
Ink-jet printed NCuP

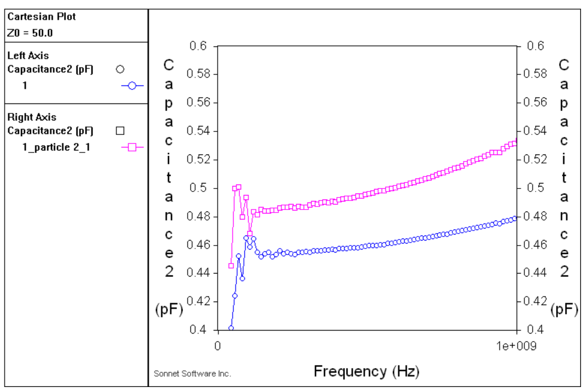
- Resolution of print: 500dpi
- 5 layers printed on every component
- Heated substrate (50 C)
- 0.1 % solution



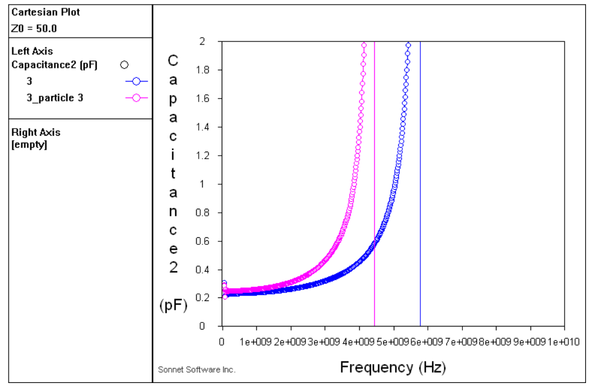
Impedance spectroscopy investigation

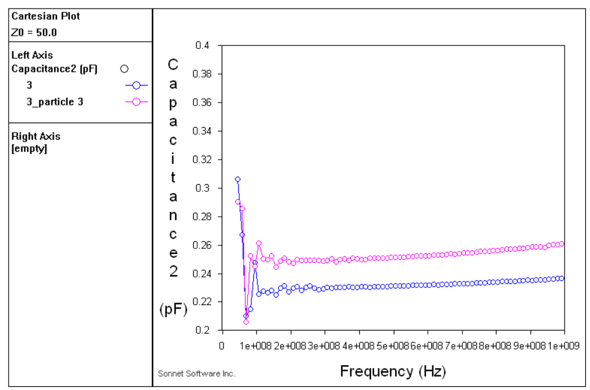
10 fingers





5 fingers

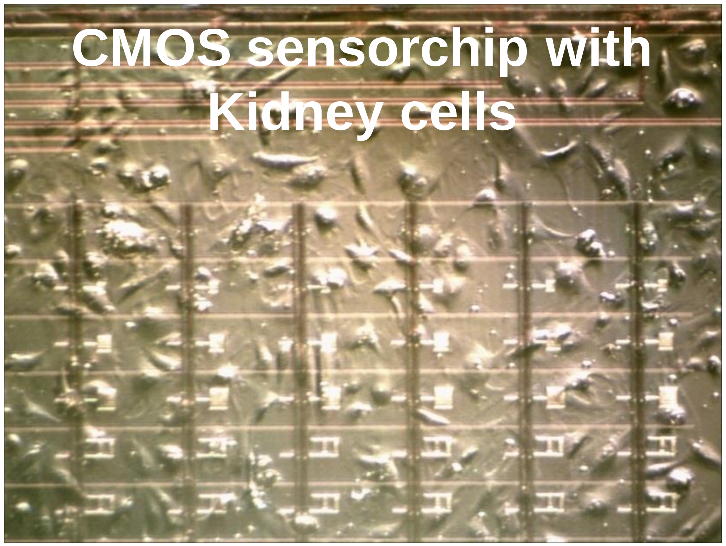


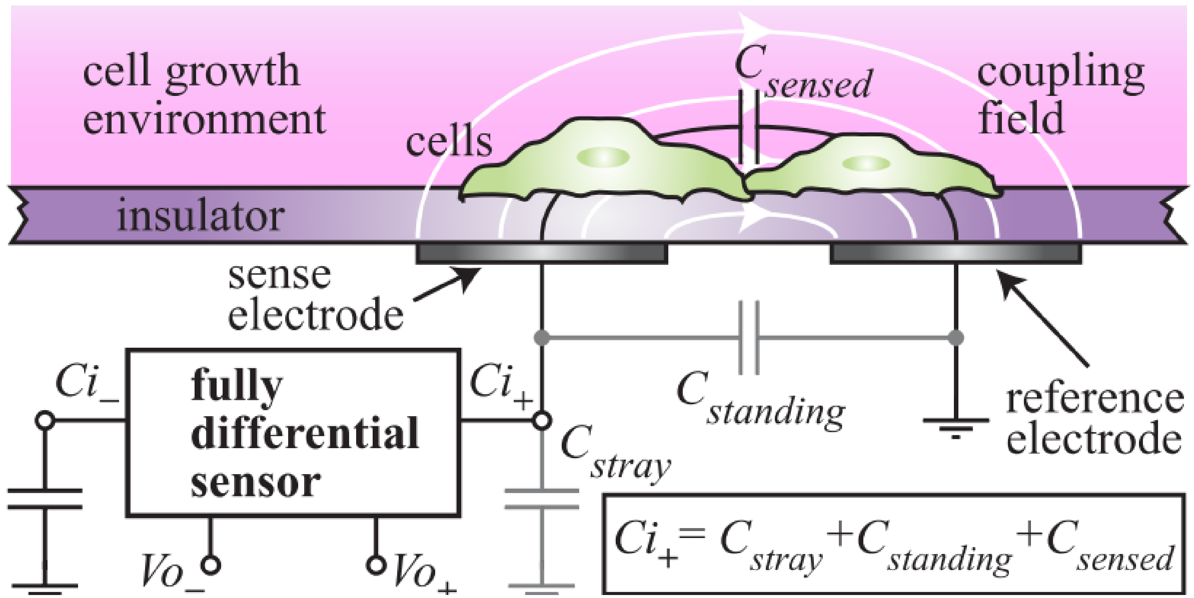


- 5 and 10 finger capacitors work ok
- Visible response to NCuP – increasing capacitance

- Blue shows clean sensor
- Pink shows exposed sensor
- 1-10 GHz

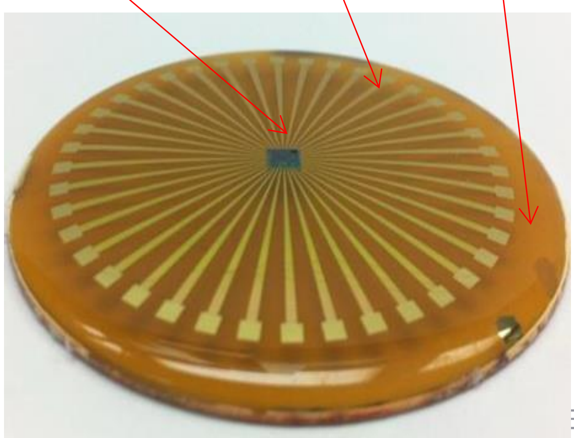
Cell Clinic: Measurement of Toxic effect of particles on cells





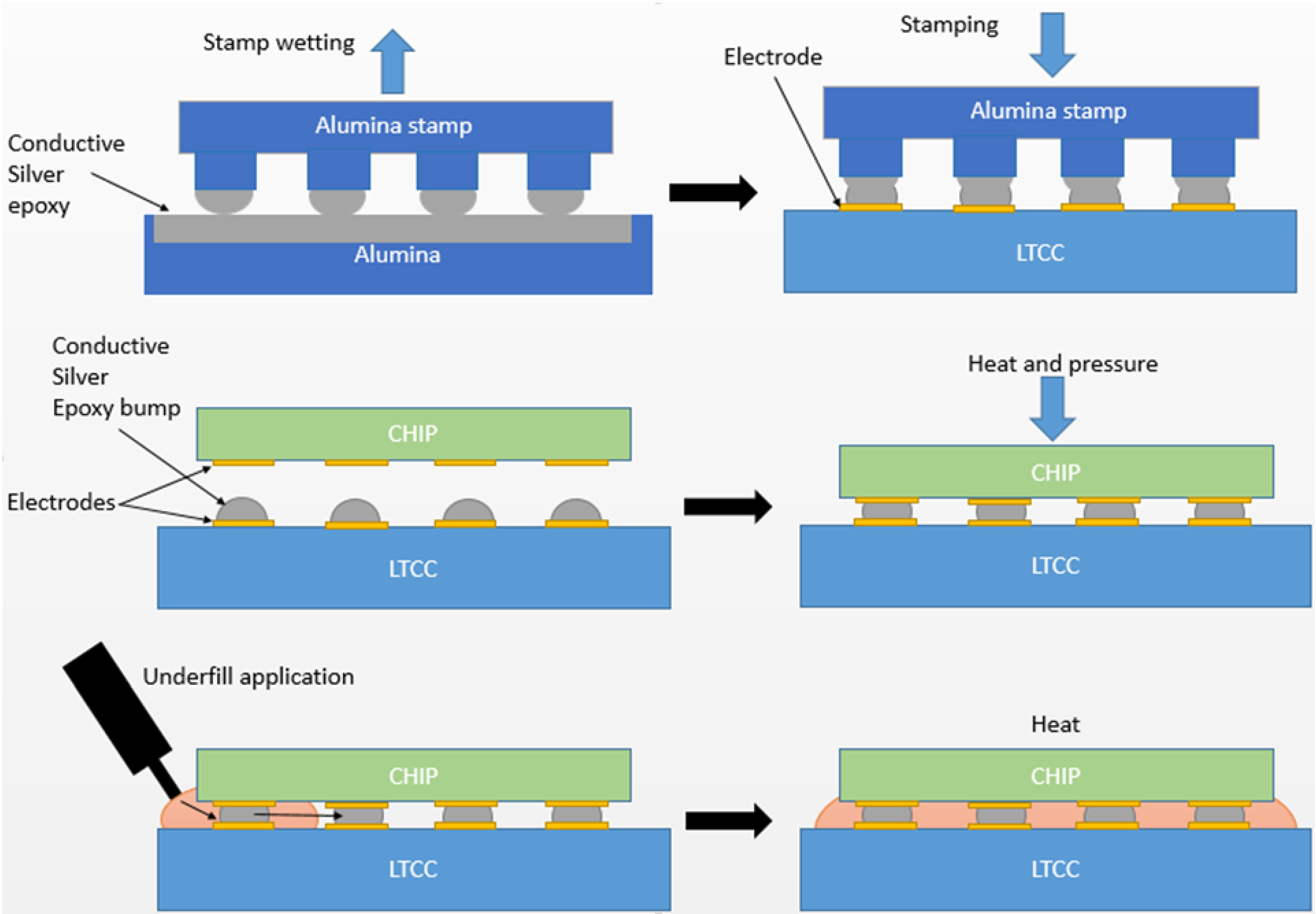
Capacitive measurement principle

Sensor chip, Cu leads, epoxy



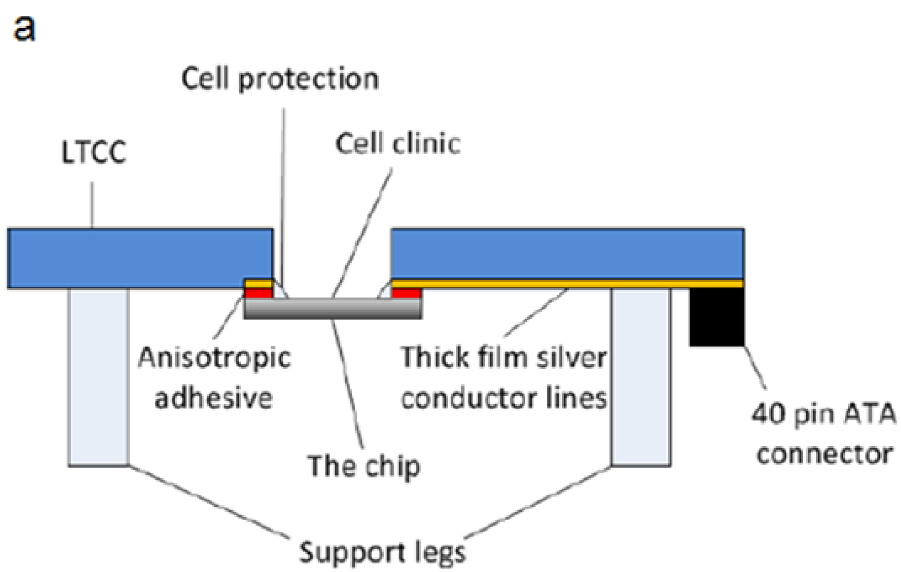
Packaged chip by epoxy molding

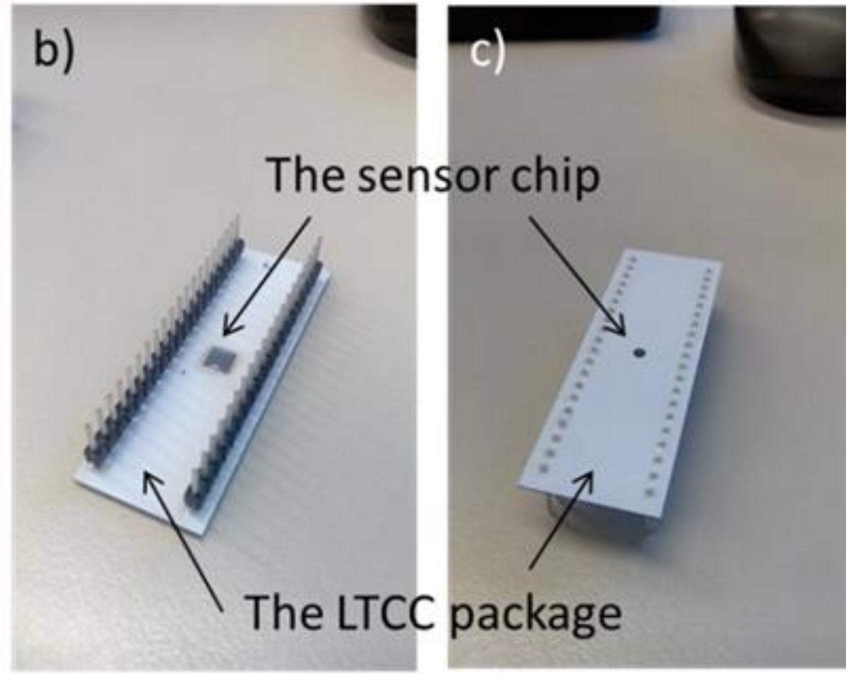
LTCC packaging for the cell clinic

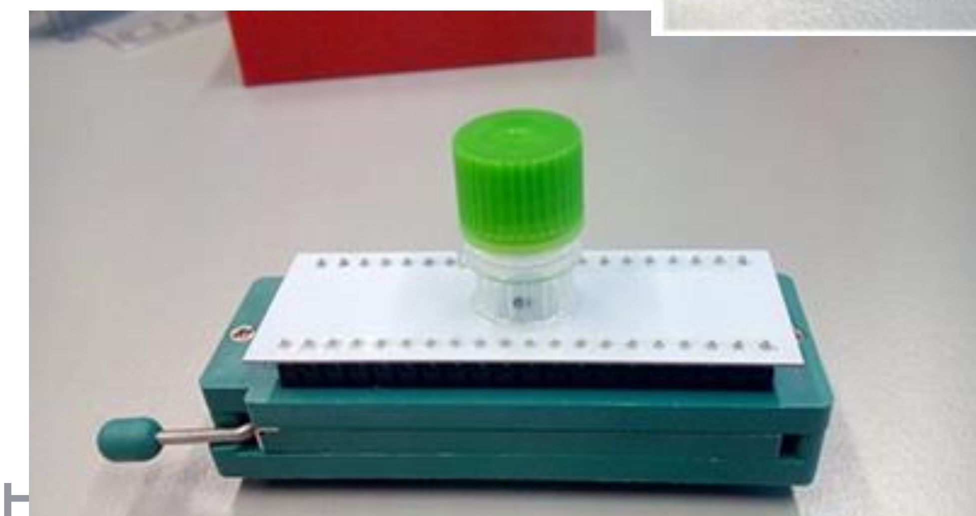


Niina Halonen, et al, Procedia Engineering, 120 (2015) 1079-1082

LTCC packaging for the cell clinic



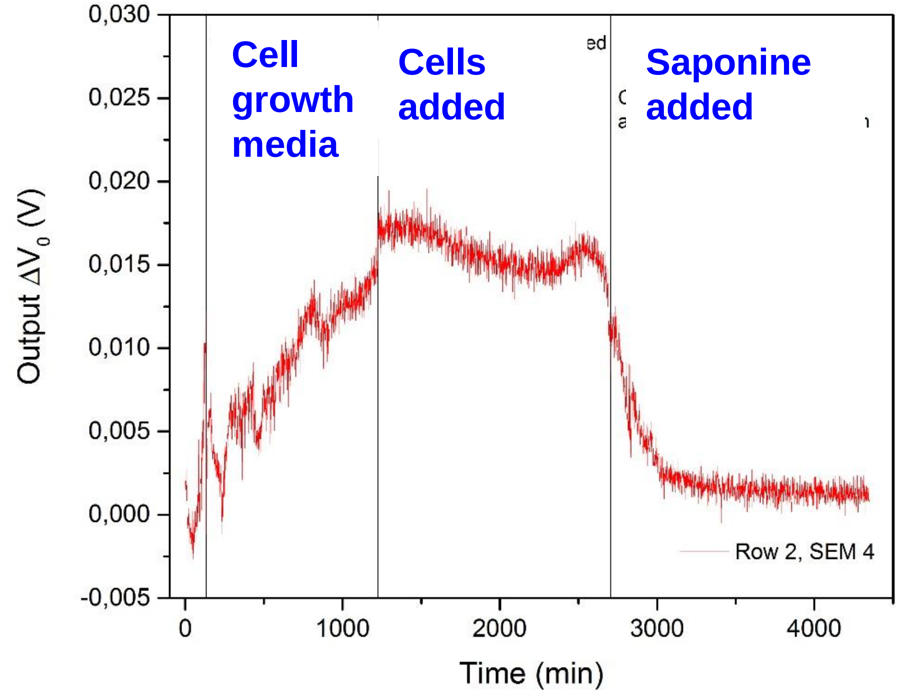




Zero insertion force (ZIF) connector

Development of microincubator

Preliminary testing



- The saponine test: BEAS2B cells were cultivated on the chip and
- After 24 h of the cell deposition they were killed with saponine
- Microincubator liquid flue system possible to include in the LTCC technology

Conclusions

The LTCC (Low Temperature Co-fired Ceramic) facilitates as sensor platform for

- SiC-FET Gas sensors
- Portable nanoparticle detector
- The cell clinic/ microincubator

Collaborators

Applied Sensor Science at Linköping University

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Lida Khavalezadeh, PhD student
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Prof. Krisztian Kordas
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Ass. Prof. Mike Andersson
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Joni Kilpijärvi, Master student

Maryland University, USA

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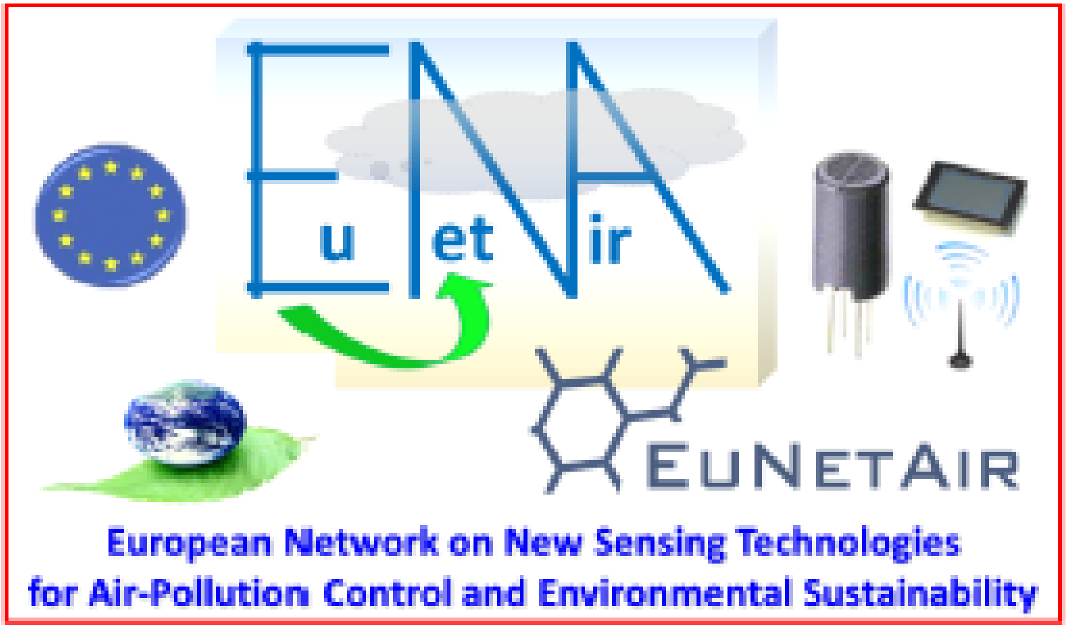
COST ACTION EuNetAir TD1105 (STSM)

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir

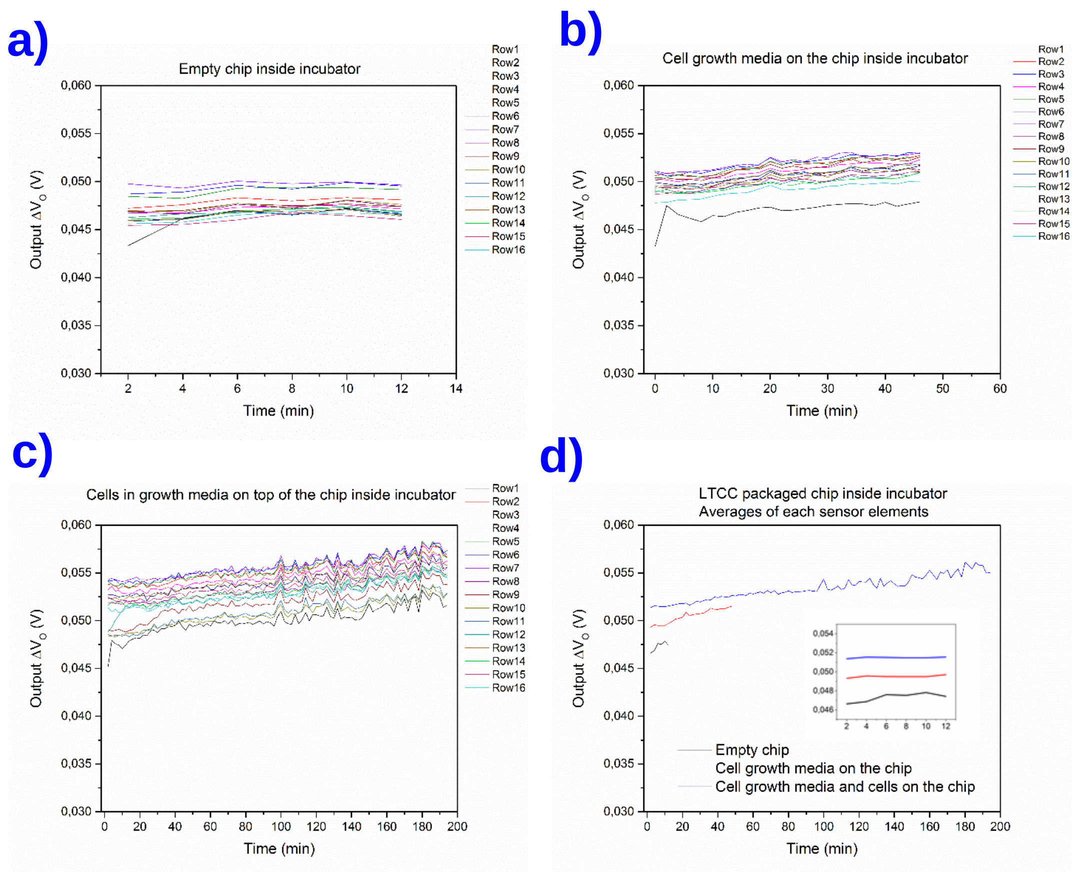
Bake-up Slides

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir



2. STATUS OF CELL MEASUREMENTS

- The LTCC packaged chip has been tested with BEAS2B cells (human lung epithelial cells) to study the response of the chip



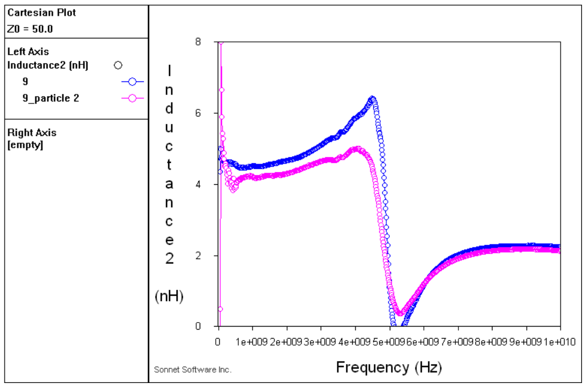
- **About 2 mV increase in the output signal as cell growth media or media with cells is added.**

Figure 2: The LTCC packaged sensor chip inside incubator (a) empty; (b) with cell growth media; (d) with BEAS2B cells in growth media. Values for each sensor row are averages of the 5 SEMS; (d) Average output values of 80 sensors of the chip as the chip is empty, with cell growth media and with the BEAS2B cells in media. In the inset is the magnification of the first recorded 12 minutes.

2.2 Inductors

Line inductor

9



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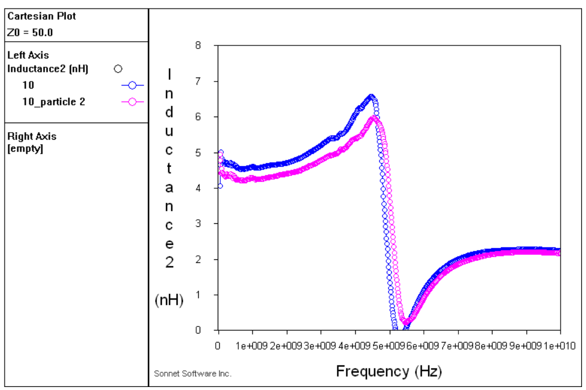
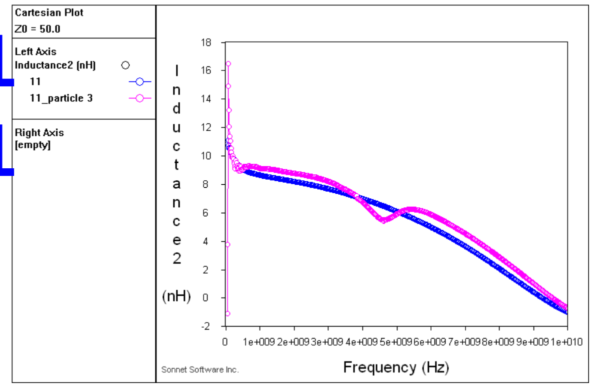


5 meander inductor

11



- Line and 5 turn meander ok.
- NCuP decrease inductance
- Maybe thicker lines?

- Blue shows clean sensor
- Red shows exposed sensor

2. STATUS OF CELL MEASUREMENTS

- The saponine test: BEAS2B cells were cultivated on the chip and after 24 h of the cell deposition they were killed with saponine; clear drop in the signal as expected.
- More detailed data analyzis under process

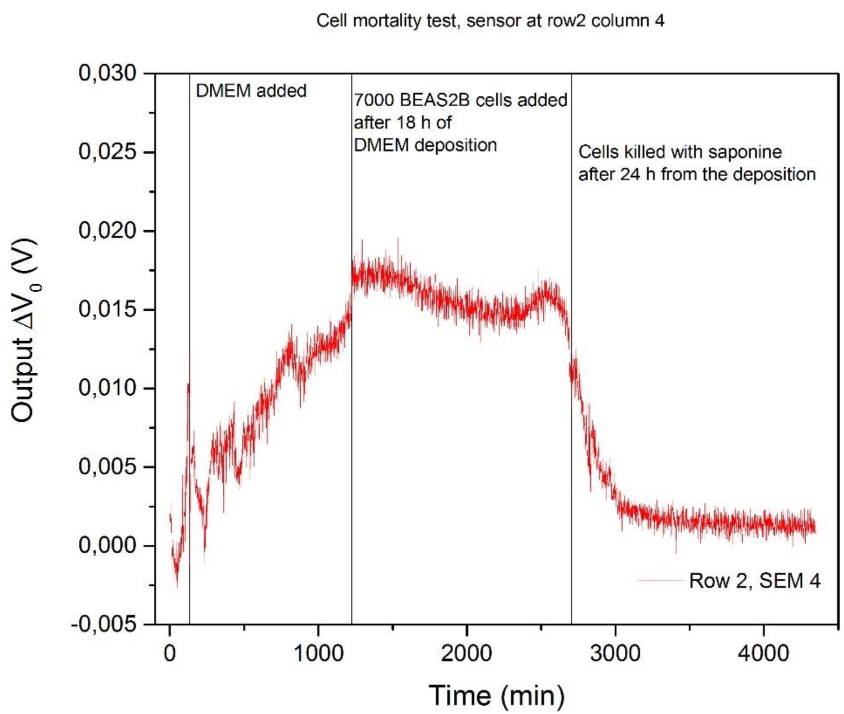
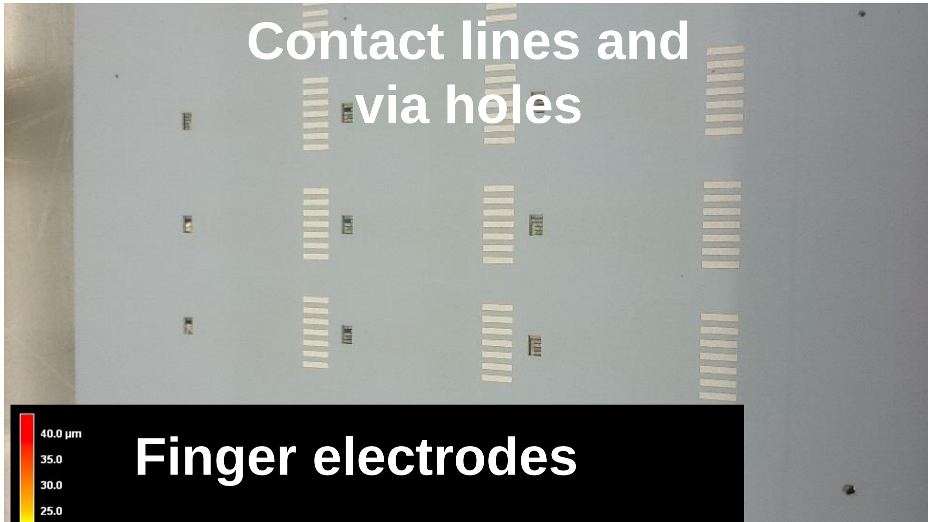
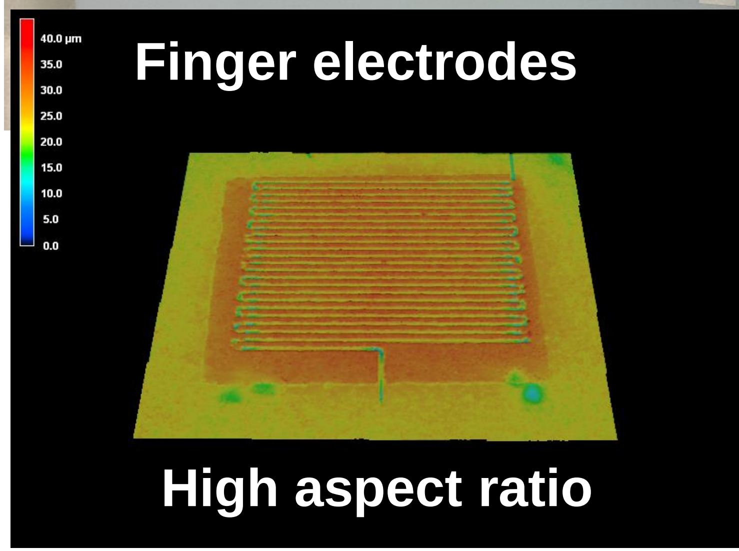


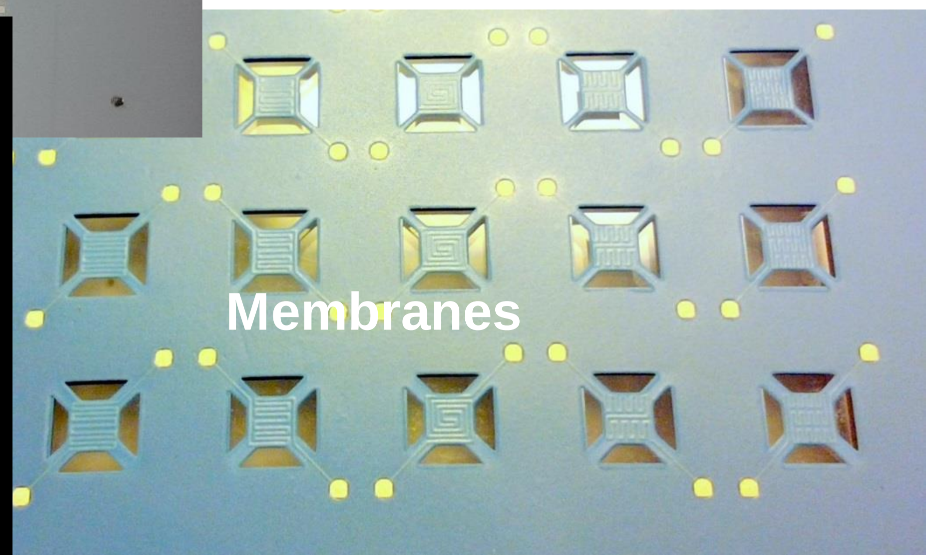
Figure 3: Sensor response (from the row2 column 4) to cell growth media, the cells and killing of the cells.

LTCC processing of dedicated structures for particle detectors



Membranes: heating collected particles, detecting emitted gases for content /adsorbent analysis



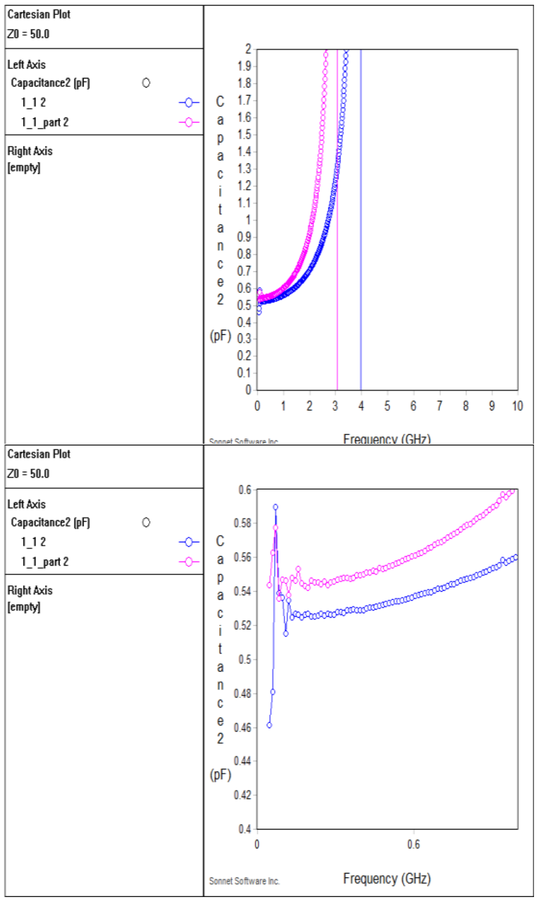


Finger electrodes, high aspect ratio: concentration size, content

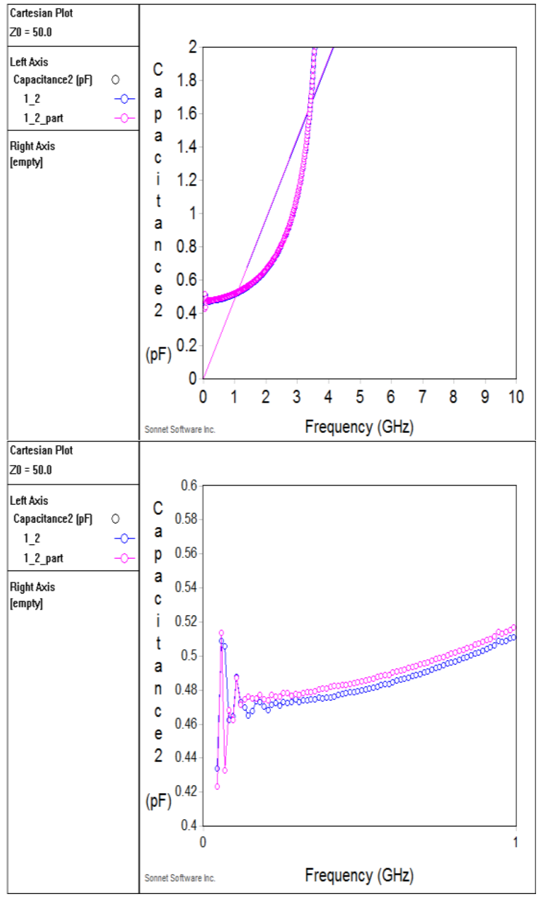
Nicole Neubauer et al, Functionality based detection of airborne engineered nanoparticles in quasi real time: A new type of detector and a new metric, Ann. Occup. Hyg. 57 (2013) 842-852 (Karlsruhe)

Carbon black (soot) measurements

1

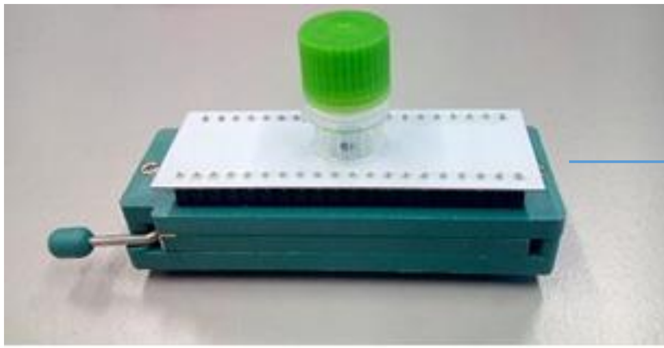


2



- Particle size 45 nm
- 0.01 wt% concentration
- Small amount of surfactant 0.0005 wt%
- Drip cast 1 µl on 100 °C substrates
- Used 10 finger capacitor structures

Development of microincubator



LTCC packaging of the chip potential as microincubator

LTCC packaged chip with electronics in the incubator

Particle detector, commercial device

Particle Sense P600

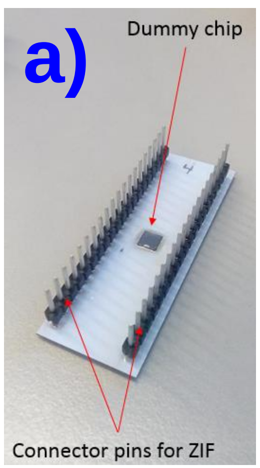
Measures PM1, PM2.5 and PM10

1. Status of sensor chip Package

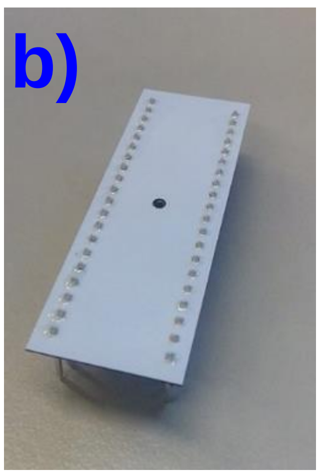
- 1st generation LTCC package is ready and found biocompatible and durable for the cell clinic application
- 2nd generation package will include also a microfluidic system

Figure 1: The LTCC package at different stages

Package backside



Package topside



Package connected to ZIF connector with cell well