Gas and Particle Sensors for Air Quality Monitoring

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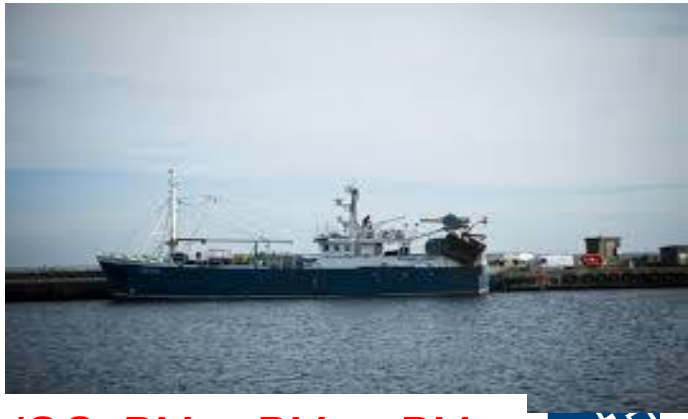
Allowed levels of emissons of toxic gas molecules and particles are today very low

Sensors systems for control are needed

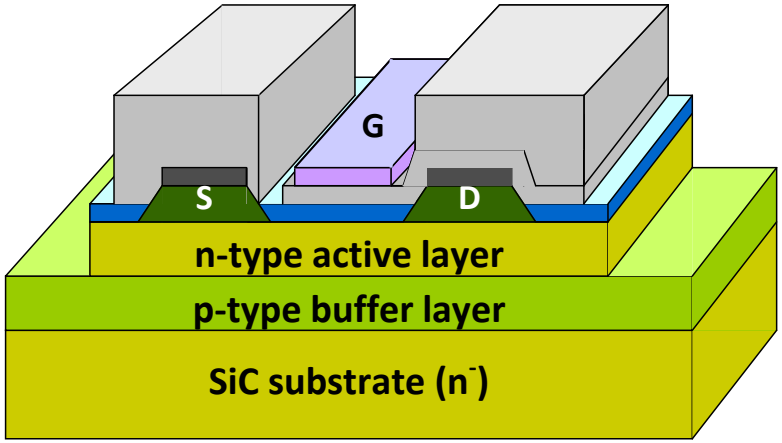


Toxic substances include: NO_x, SO_2, CO, O_3, PAH/VOC, PM_{10}, $PM_{2.5}$, PM_1

Outline

- SiC-FET improved sensor devices
  - commercialization
  - monitoring SO_2 in power plants
- Monitoring of particles by
  - Heating and detection of emissions
  - Integration of funtionality in LTCC packaging
  - The cell clinic, toxic effect of particles

SiC-FET new transducer platform for gas sensors



Cross section of depletion SiC-FET
Gate sensing layer:
porous catalytic metal, Pt, Ir

A new design of the SiC-FETs, a hybrid between a MESFET and a depletion type MOSFET, performed by SenSiC AB in collaboration with ASCATRON AB /ACREO:

- Optimized gate length increases the sensitivity
- The design allows gate bias control of selectivity and sensitivity

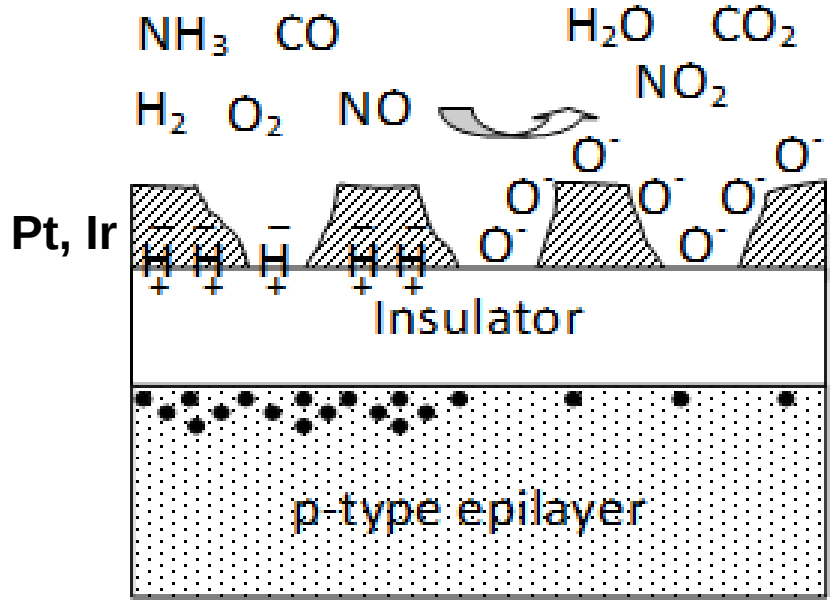
Mike Andersson

SiC-FET new transducer platform for gas sensors

SiC-FET sensor with
Improved selectivity:
NH_3 also in environments with high CO and low O_2 concentration
Applications:SCR control in trucks and stationary engines

Improved sensitivity
VOCs ppb concentrations
Application Indoor air quality control
SENSIndoor EU project

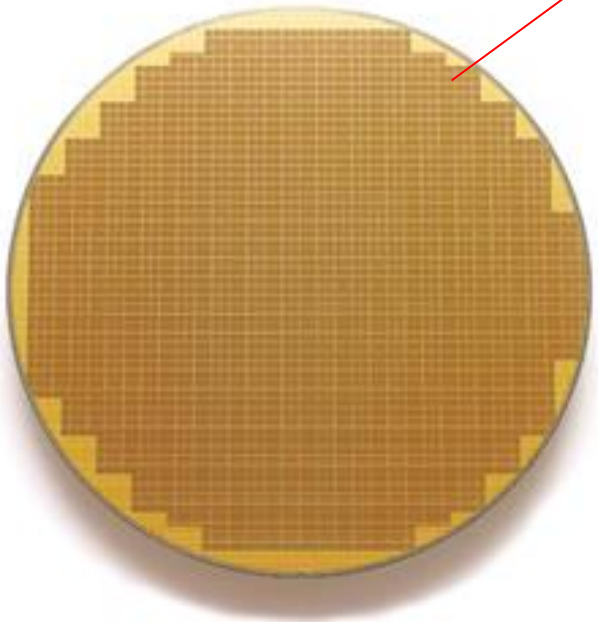
Smart sensing
SO_2 monitoring
Application: control of desulfurization unit in power plants

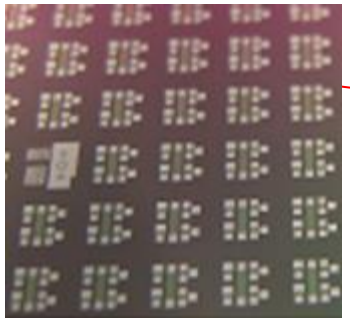


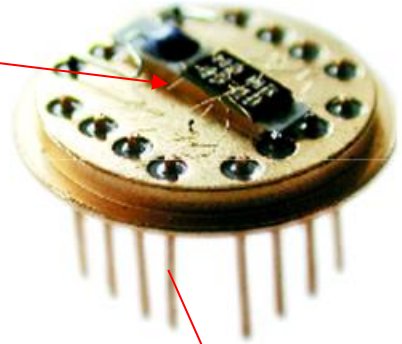
Molecule decomposition and reactions on the catatlytic metal – charging of the gate area - a change in the current through the transistor

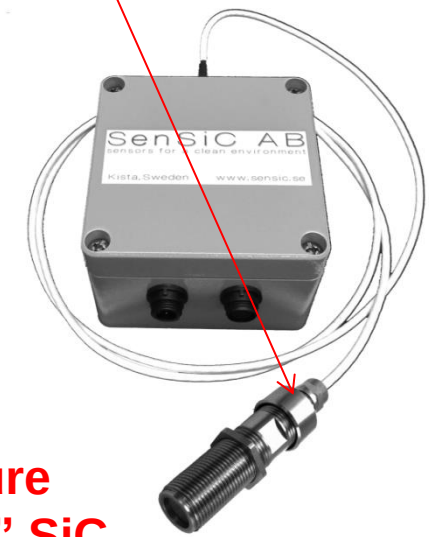
Mike Andersson

SiC-FET sensors, wafer and mounting









SiC-FET
sensor system

4” SiC wafer, ~2000 chip

Technology especially suitable for high temperature devices and power components. Processing on 4” SiC wafers using standard methods. Price of chip far less than cost for mounting and electronics.

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OULUN YLIOPISTO

SiC-FET gas sensors

A SiC-FET sensor system is being commercialized for control of the inlet air to small and medium sized wood fuelled power plants:

Increased efficiency

of the combustion

and lower emissions

SENSIC
Sensors for cleaner air

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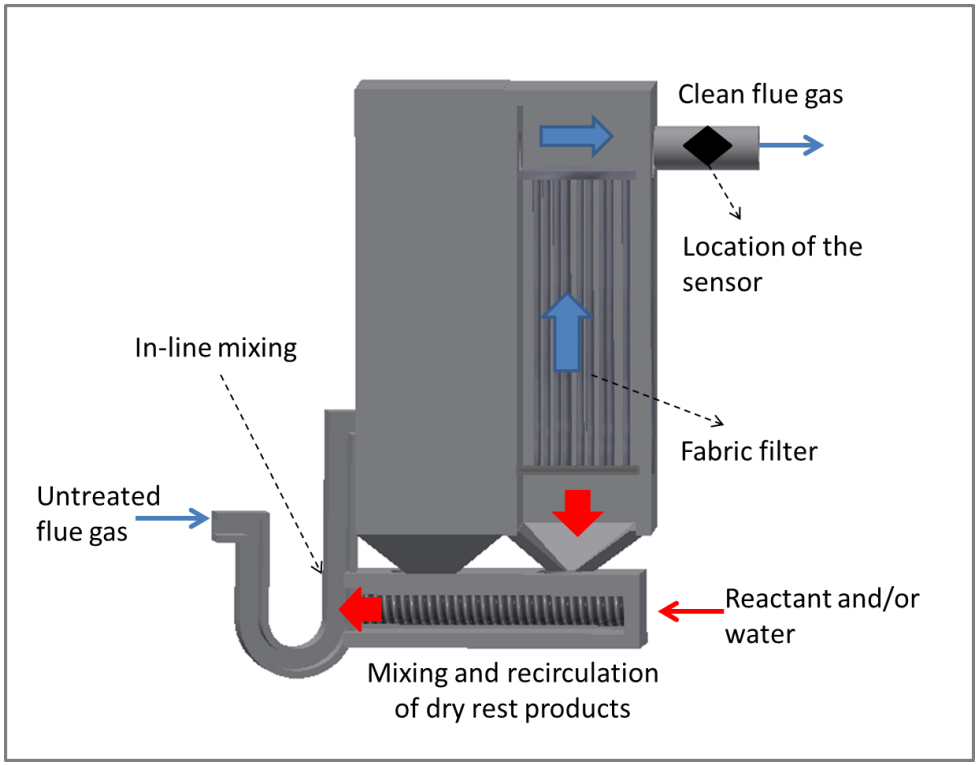
SiC-FETs for detection of SO_2

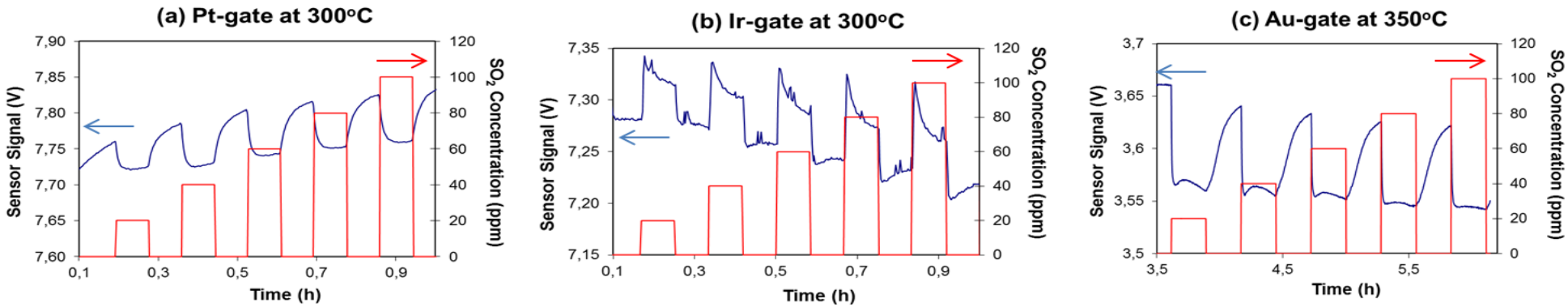


Desulpherization unit in pilot plant: calciumhydroxide + sand is blown in and absorbs the sulphur, then removed in a filter and reused

Zhafira Darmastuti and Peter Möller

FunMat

SO_2 sensitivity of SiC-FETs



Poor resolution of the sensor response to different concentrations of SO_2

Zhafira Darmastuti

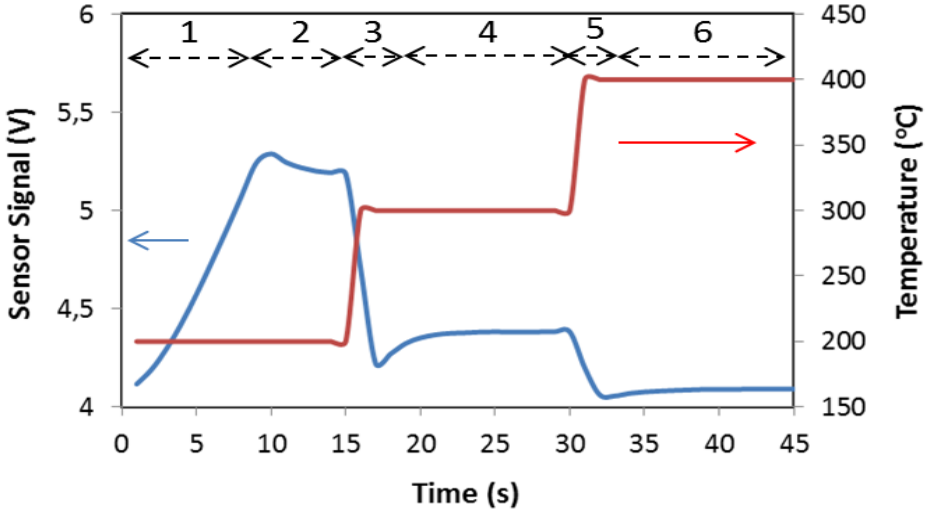
Dynamic Operation and smart data processing

Virtual multisensors:

- Temperature cycling operation mode
- single sensor producing multidimensional signal patterns

Advantages:

- Noise reduction
- Less influenced by background gases
- Cleaning of the sensor surface (high T)

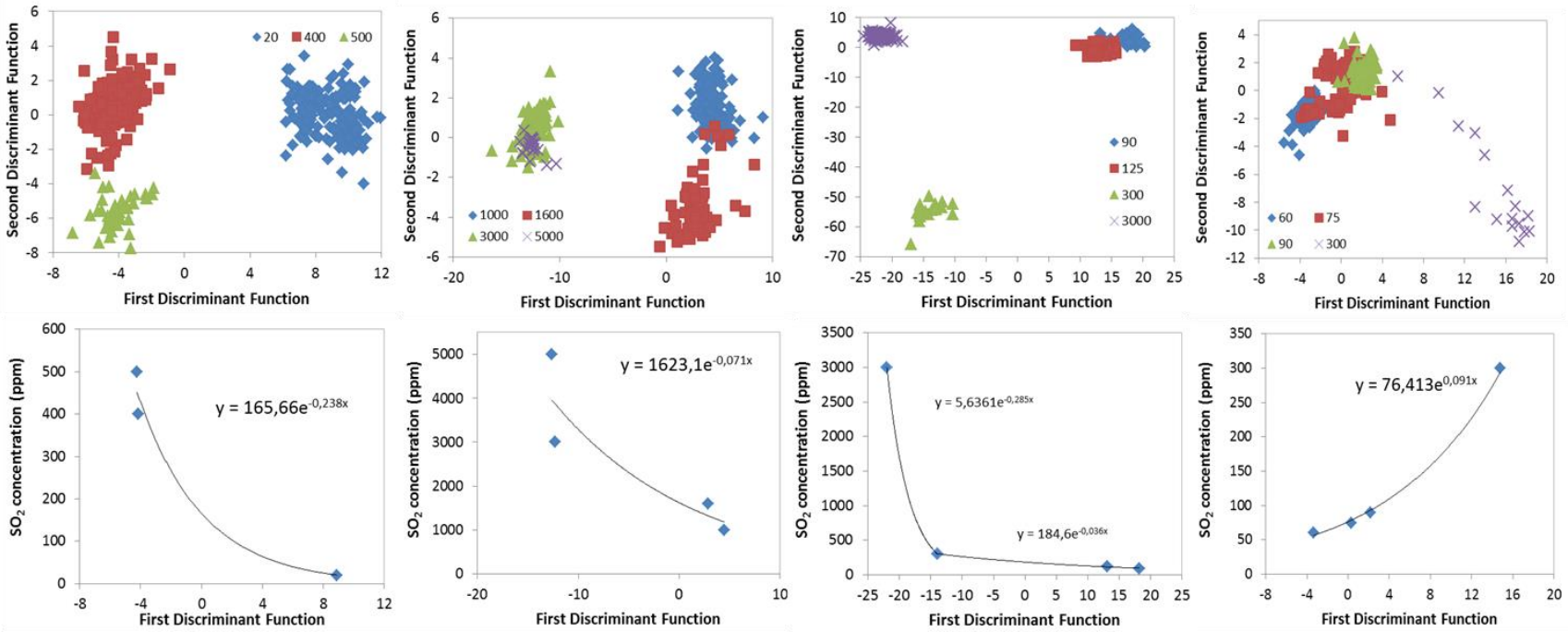


Temperature cycle and *sensor signal*

Temperature cycling operation developed together with Saarland University, Andreas Schütze and Christian Bur (talk on Tuesday, B1L-A02)

*

SO_2 detection by temperature cycled operation



Second step LDA for SO_2 quantification
The plot to correlate SO_2 concentrations to the first discriminant functions in every background group

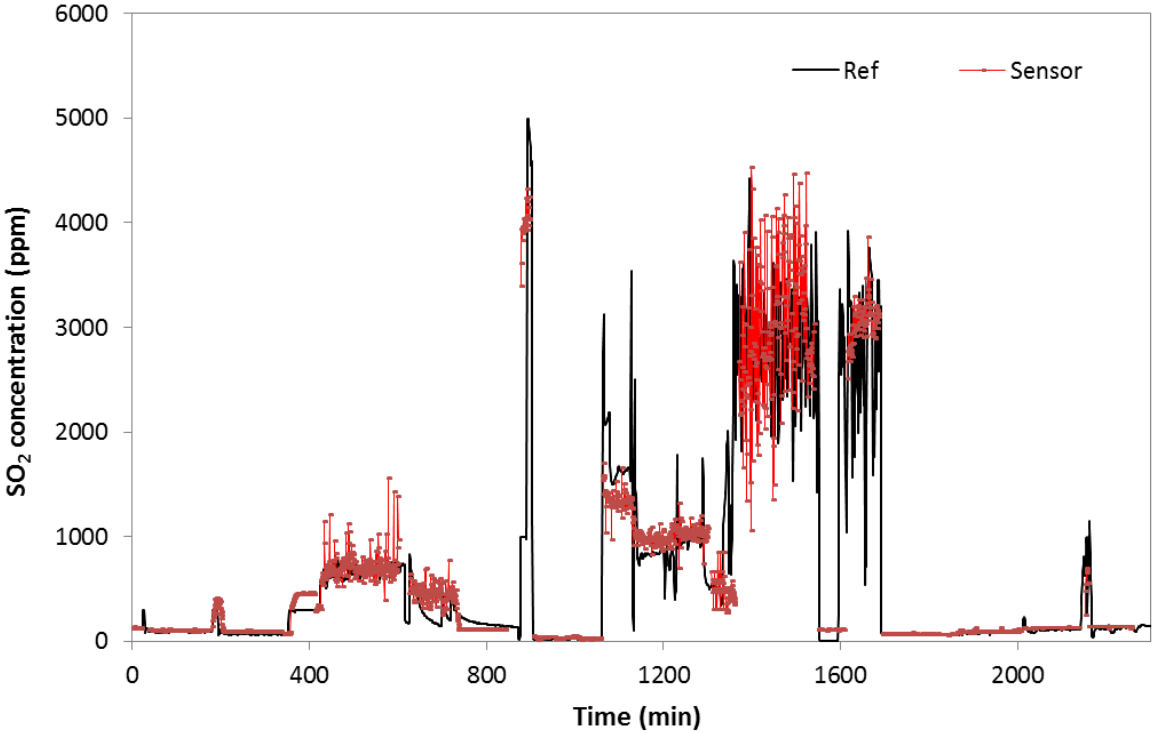
Z. Darmastuti, C. Bur, P. Möller, R. Rahlin, N. Lindqvist, M. Andersson, A. Schütze, and A. Lloyd Spetz, Sensors and Actuators B, 194 (2014) 511-520.

SO_2 detection by temperature cycled operation and 2-step LDA

Pilot unit testing at Alstom

Zhafira Darmastuti
Christian Bur

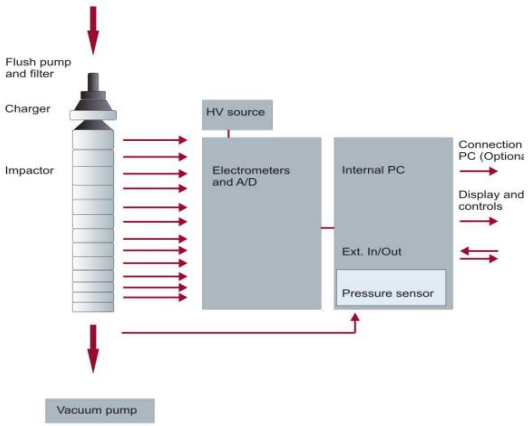
Collaboration with Saarland University, Germany



SO_2 concentration in the pilot plant measurements.
The sensor signal processed by exponential fit from the 2- step LDA (red dotted line).(different algorithms for each background))
FTIR reference instrument (black solid line)

Present commercial particle detectors

DEKATI ELPI (Electrical Low Pressure Impactor (6 nm – 10 µm)



Nano-ID™ NPS500 based on DMA (Differential Mobility Analyzer) technology, portable particle measurement device (5-500nm)

Vision

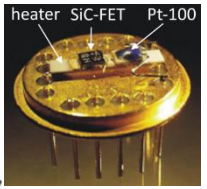
Miniaturized device for the on-line monitoring of particles for

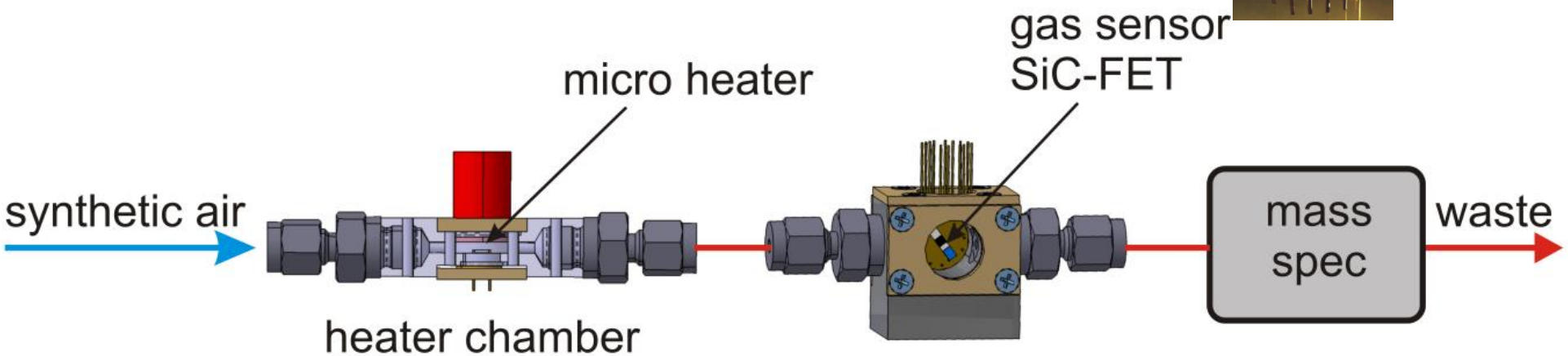
- Work places (specific)

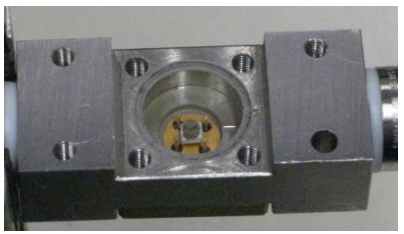
- Public use (general)

Giving information about particle number (concentration), size, “shape”, and content since these parameters influence the adverse health effect of particles

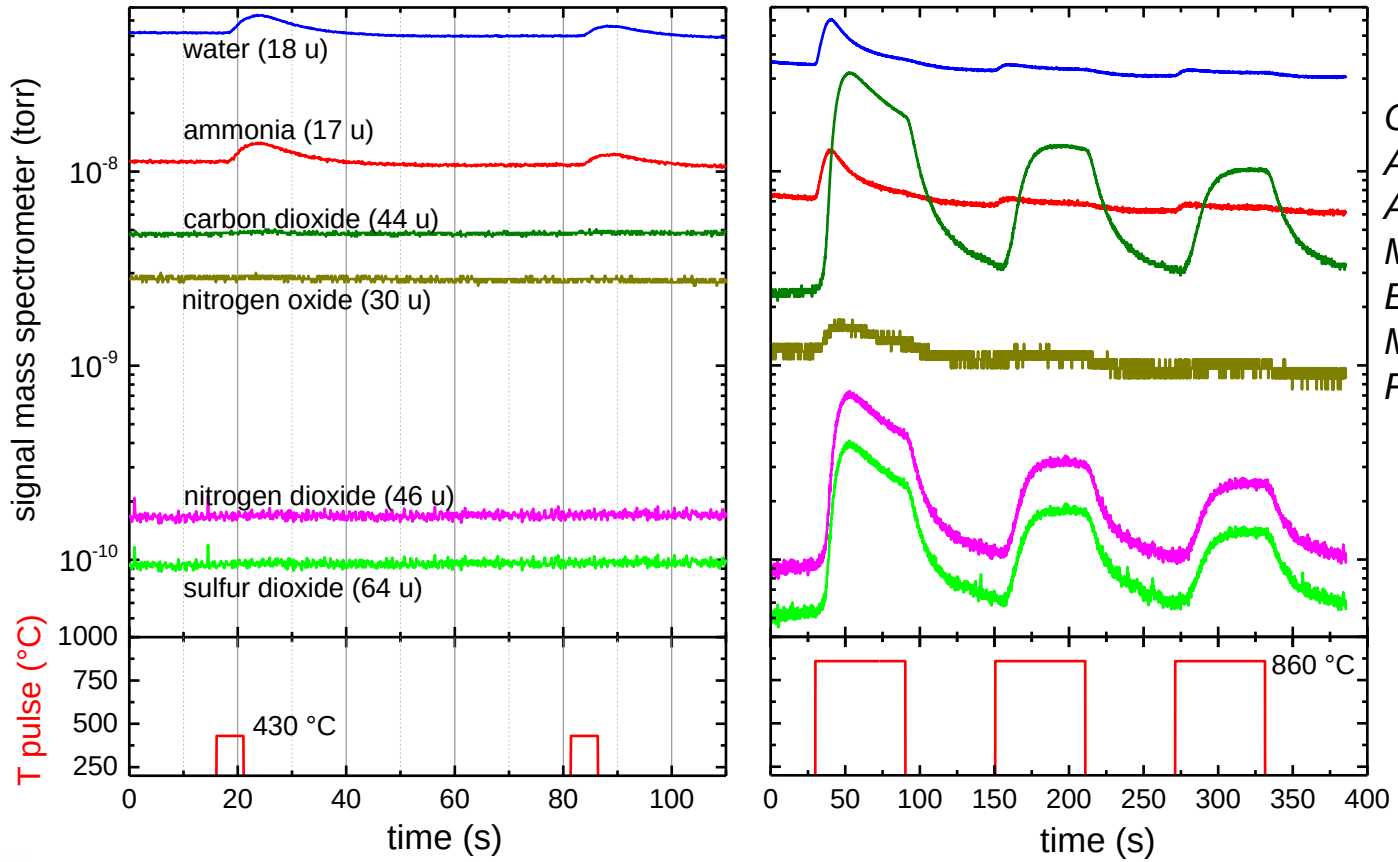
Particle content meausurment set up







Detection of particle content

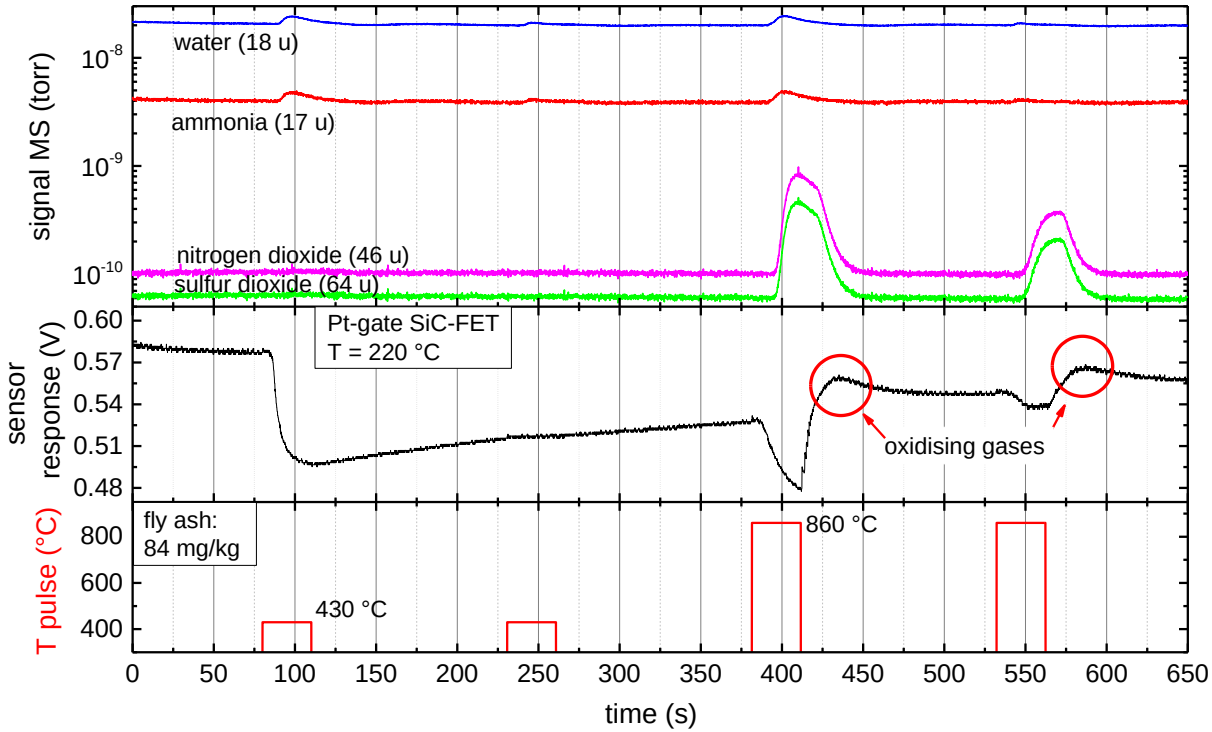


C. Bur, M. Bastuck, A. Schütze, J. Juuti, A. Lloyd Spetz, M. Andersson, E-MRS 2014, May 26-30, Lille, France, poster.

Mass spectra of fly ash with 84 mg/kg ammonia when heated to 430 °C (left) and 860 °C (right).

Detecting particle content

C. Bur, M. Bastuck, A. Schütze, J. Juuti, A. Lloyd Spetz, M. Andersson, E-MRS 2014, May 26-30, Lille, France.



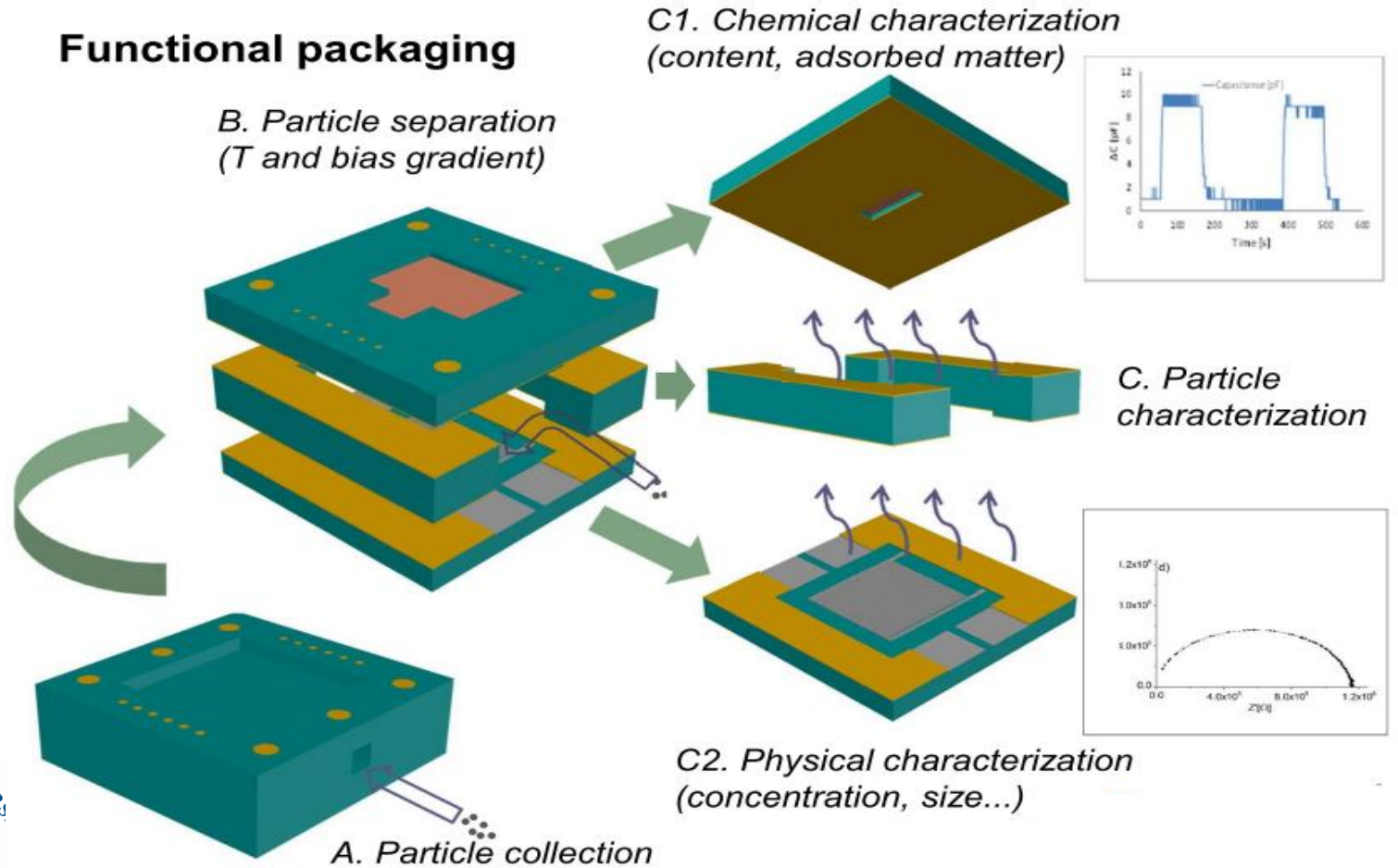
Mass spectra

Sensor signal

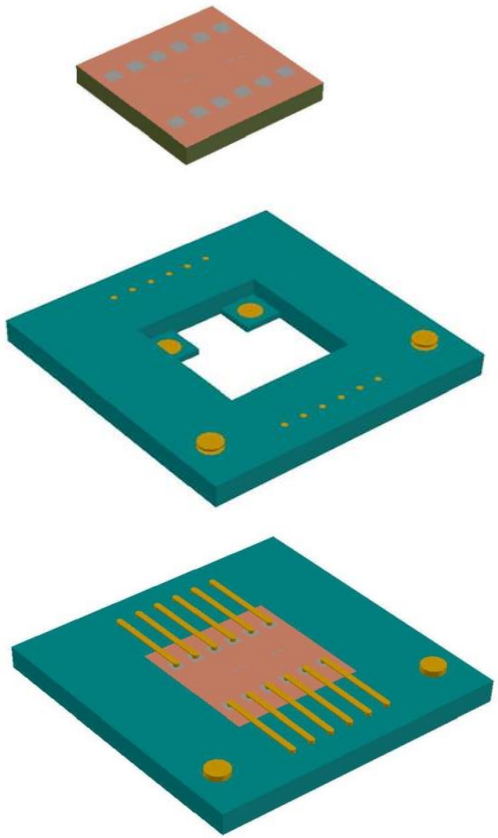
Heating pulses

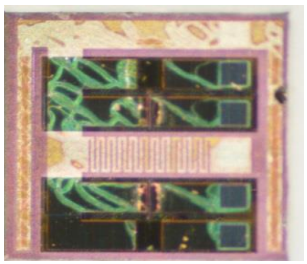
Sensor response (middle) and mass spectra (top) for heated NH_3 contaminated fly ash (84 mg/kg).
carrier gas: synthetic air

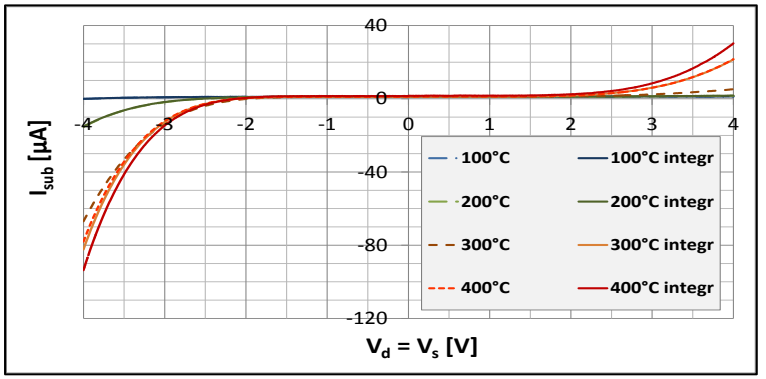
Nanoparticle detector LTCC platform - overview

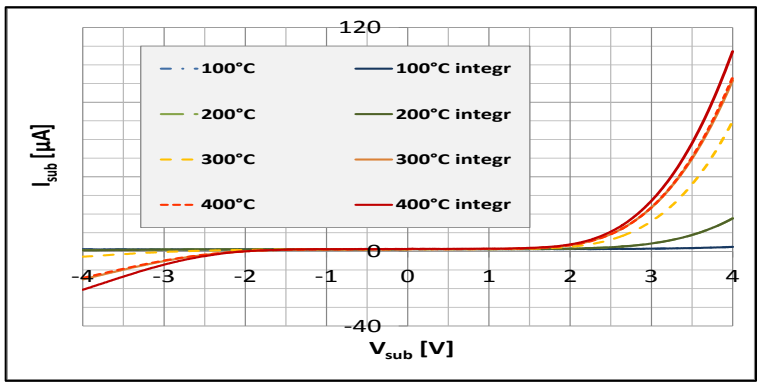


Characterization of particle content



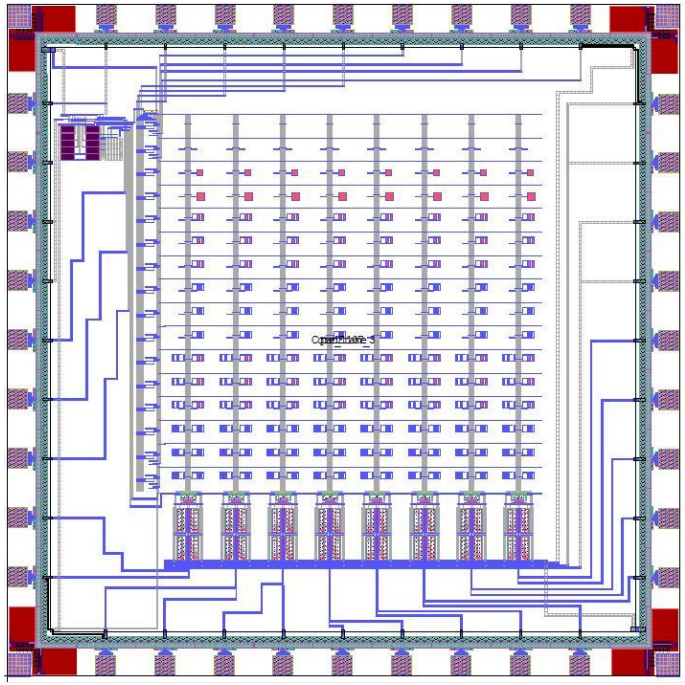




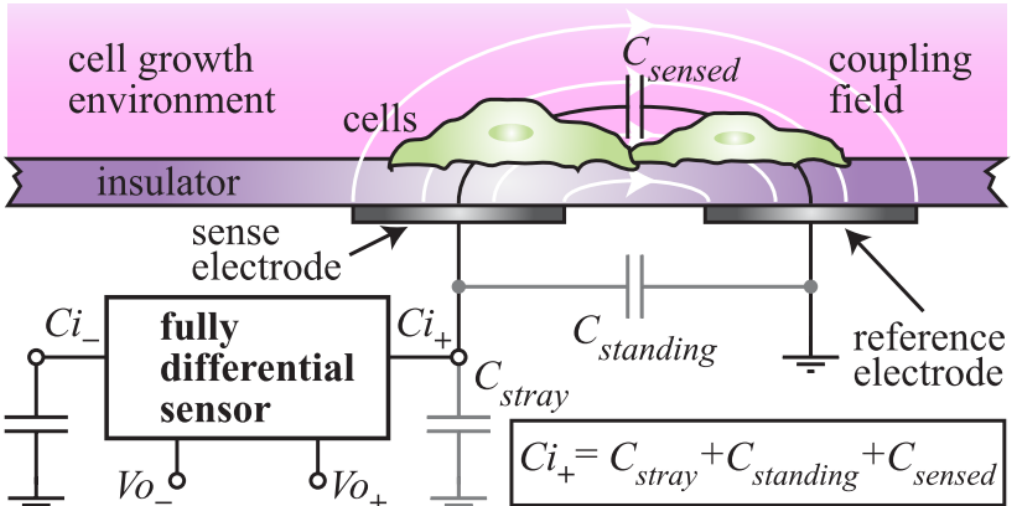


Direct, hermetic sensor integration

Cell Clinic: Measurement of Toxic effect of particles



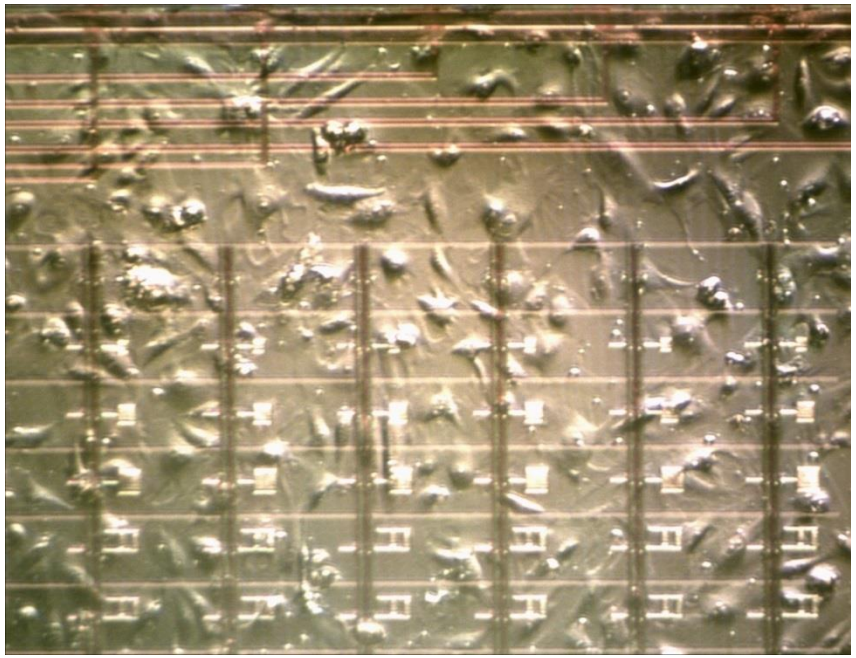
Sensor chip layout.



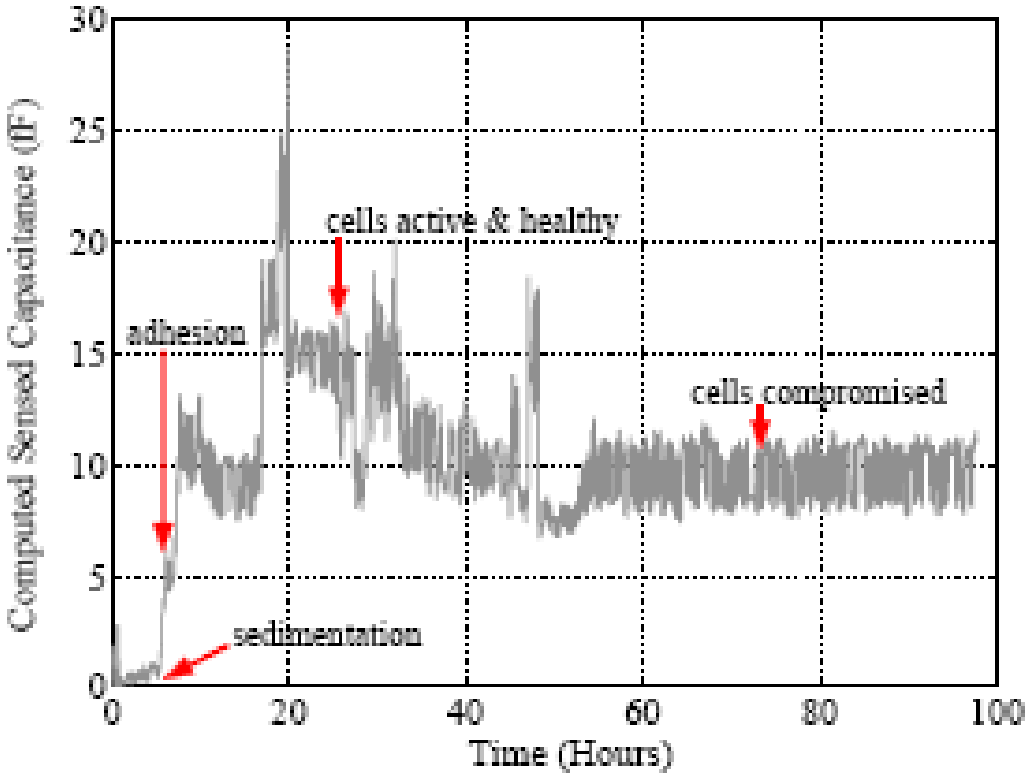
Schematic picture of capacitive signal monitoring from cell adhesion on the CMOS chip. Healthy cells spread out, dead cells curl up.

Niina Halonen et al A4P-G20

Cell clinic, sensor chip

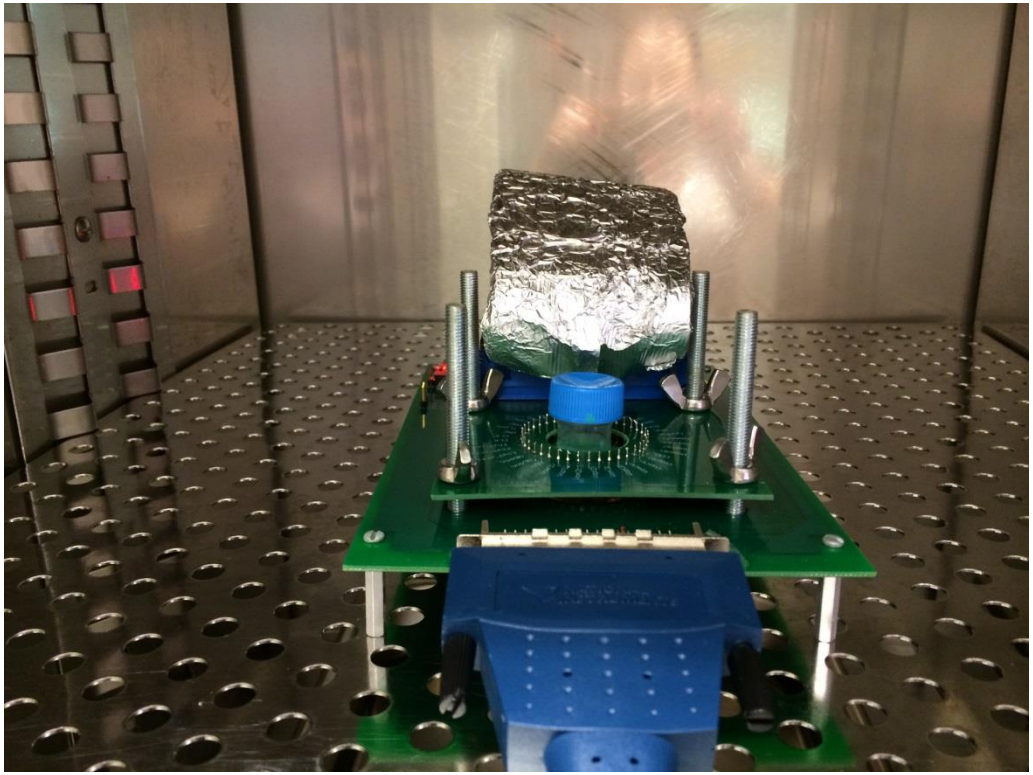


Microscope image of viable adherent kidney cells of on the surface of the IC chip.



The capacitance measured with healthy or dead cells on the sensor surface

Cell clinic, in incubator



Niina Halonen, Timir Datta-Chaudhury, Antti Hassinen, Somashekar Bangalore Prakash, Peter Möller, Pamela Abshire, Elisabeth Smela, Sakari Kellokumpu, Anita Lloyd Spetz,
Cell clinic, CMOS chip measuring capacitance as indication of cell adhesion applied in evaluating the cytotoxicity of nanomaterials
Poster A4P_G20

Conclusions

- Toxic gases and airborne nanoparticles need to be monitored for environmental control
- The new generation SiC-FETs provide a powerful sensor platform for detection of gases with improved sensitivity and selectivity
- The content of nanoparticles is important to measure. Our present approach is based on LTCC technology housing with integrated devices and measurement capability like impedance spectroscopy or heating particles and subsequent detection of the emissions
- A cell clinic is under development: electrical monitoring of health status of cells adherant to a CMOS chip, during nanoparticle exposure

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Hossein Fashandi, PhD student
Peter Möller, research engineer

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