Chemical sensor systems for emission control from combustions

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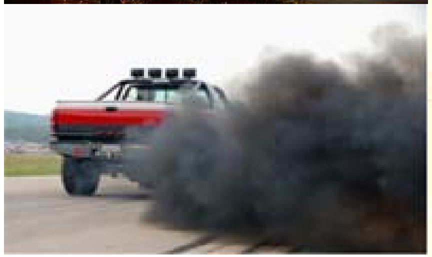
Clean environment through air quality control by sensor systems



Lucia performance (1963)

A clean environment should belong to human rights.

Sensor systems are needed for emission monitoring and control.

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

Sources of emissions: e.g. industry, vehicles and candles (soot)

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

COST
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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

COST ACTION TD1105
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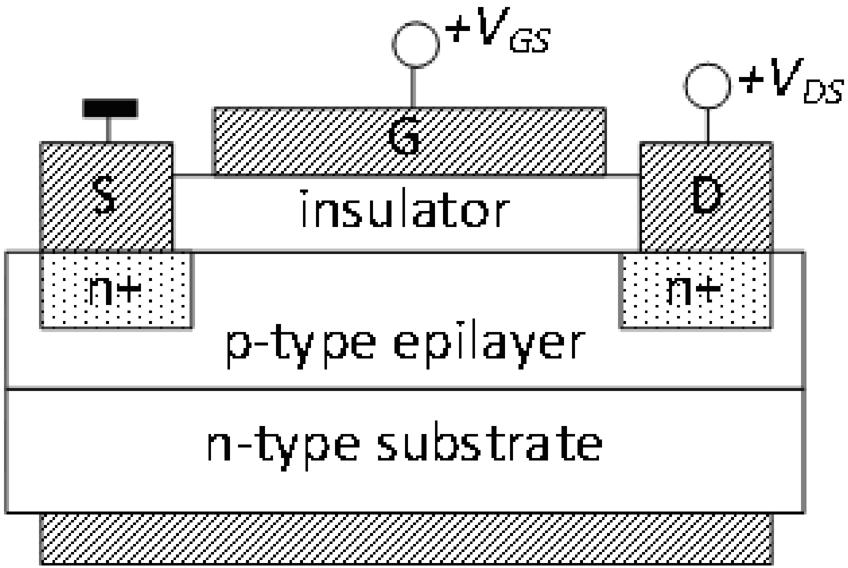
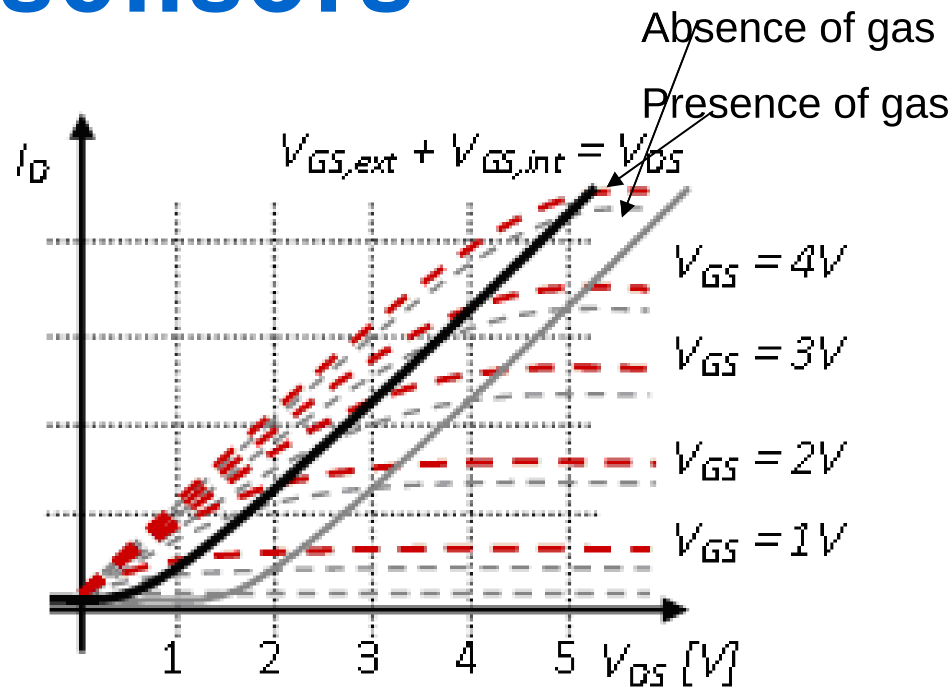
Sensors for emission control
Outline

- SiC-FET improved devices
  - ➢SiC-FET devices for selective monitoring
  - ➢SiC-FET devices, commercialization
- Monitoring of particles by
  - ➢Impedance spectroscopy
  - ➢Heating and detection of desorbing products
  - ➢SiC-FET, future technology

SiC-FET transducer platform for gas sensors



Cross section of SiC-FET
Gate composed by sensing layer
e.g. a porous catalytic metal, Pt, Ir



I/V characteristics SiC-FET: presence (red dashed line) of a gas - internal voltage drop at the gate metal/ insulator interface - a shift in the I/V-curve

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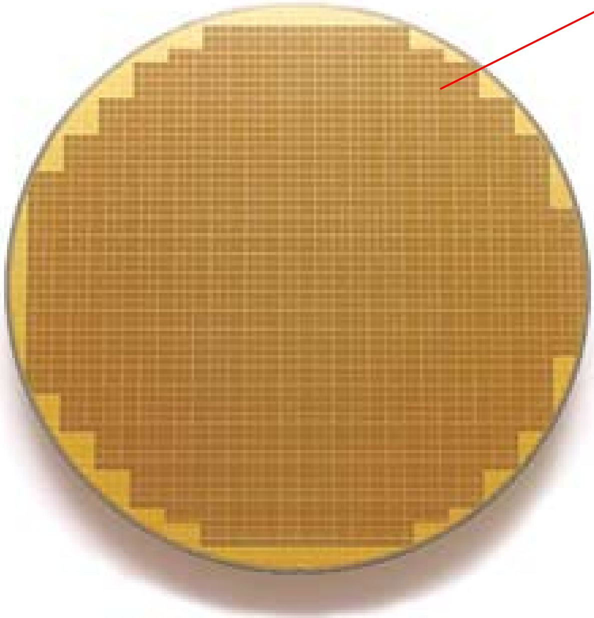
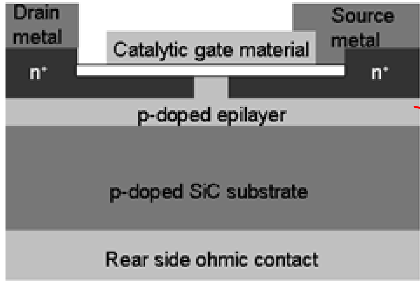
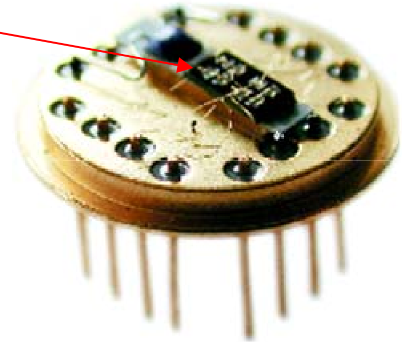
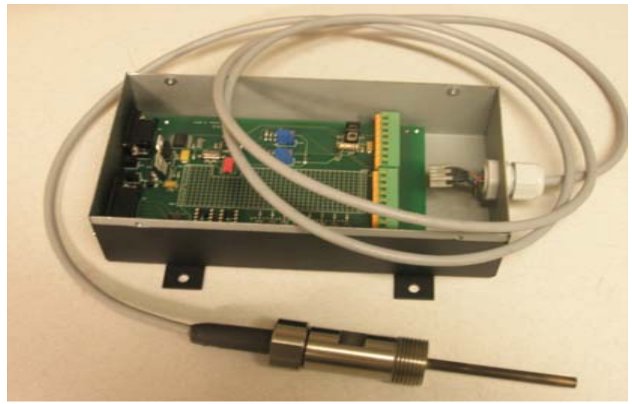
SiC-FET sensors, wafer and mounting



4” wafer, ~2000 chip







Mounting of SiC-FET sensors

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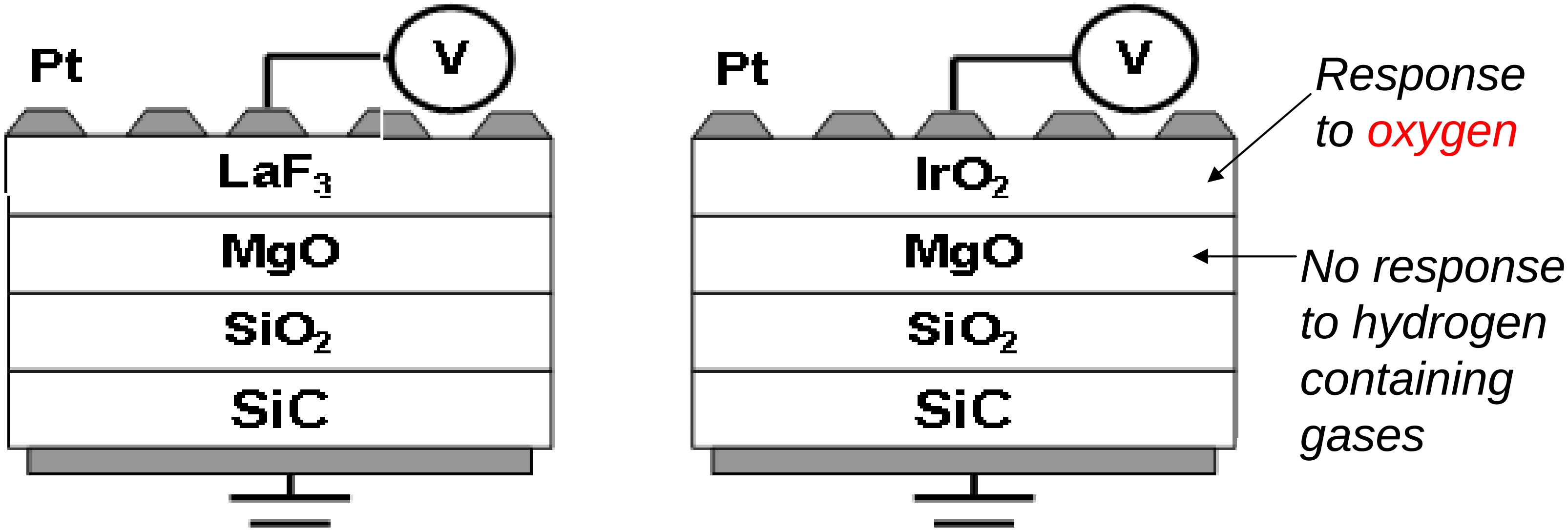
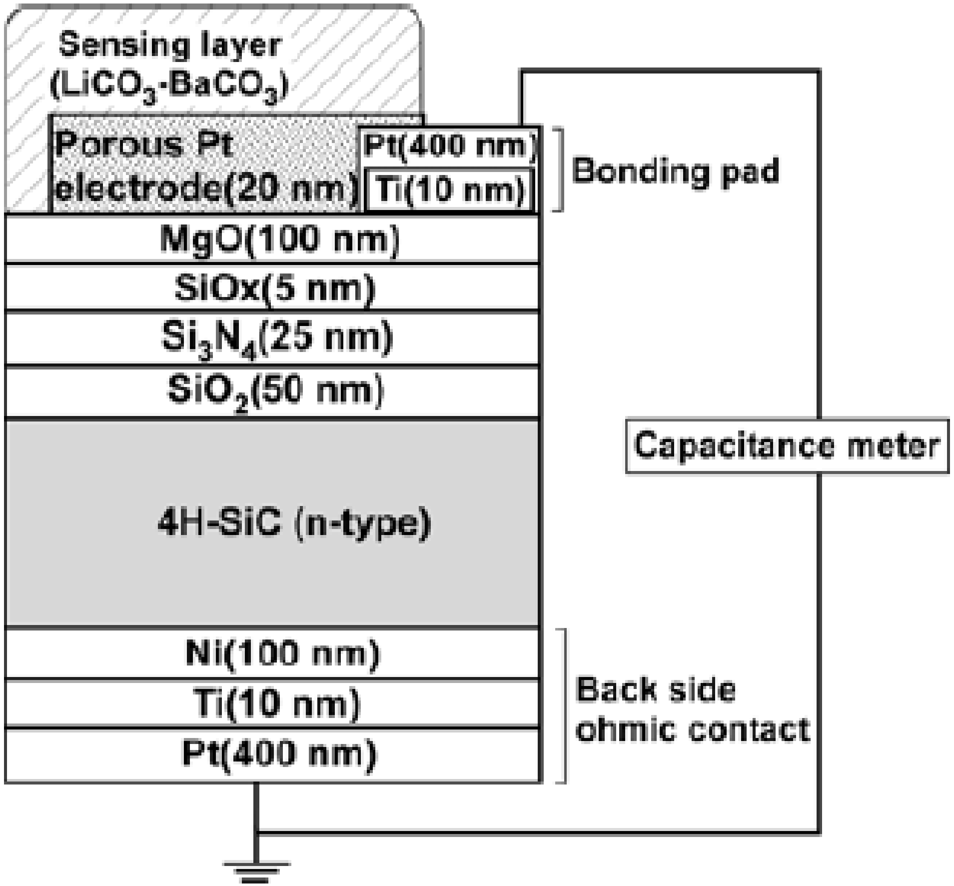
Tailoring of SiC based field effect sensors for O_2 monitoring



M. Andersson, A. Lloyd Spetz, Tailoring of SiC based field effect gas sensors for improved selectivity to non-hydrogen containing species, IMCS13, Perth, Australia, July 12-14, 2010, 369.

Tailoring of SiC based field effect sensors for CO_2 monitoring



SiC based CO_2 sensor

Li_2CO_3-$BaCO_3$ sensing layer

MgO prevents response to hydrogen containing gases

H. Inoue, M. Andersson, M. Yuasa, T. Kida, A. Lloyd Spetz, and K. Shimanoe: CO_2 sensor combining an MISiC capacitor and a binary carbonate, Electrochemical and Solid-State Letters, 14 (1) (2011) J4-J7.

Control of urea injection in power plants

SNCR – Selective Non-Catalytic Reduction of NO/ NO_2 by NH_3 through urea injection in the flue gas

Control of urea injection by an NH_3 sensor

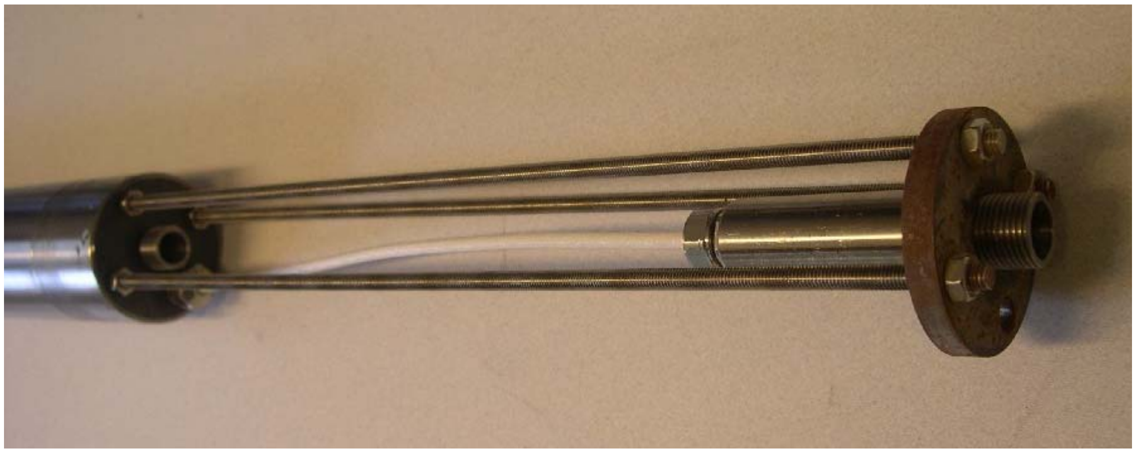
SCR-Selectiv Catalytic Reduction of NO/NO_2 in a catalytic converter by NH_3

NH_3 sensor mounting for urea control in boilers

Värmeforsk projects:

A08-828 and P08-823

Partners: SenSiC AB, Alstom Sweden AB, Tekniska Verken, Vattenfall



Two position sensor mounting ~ 40 cm apart

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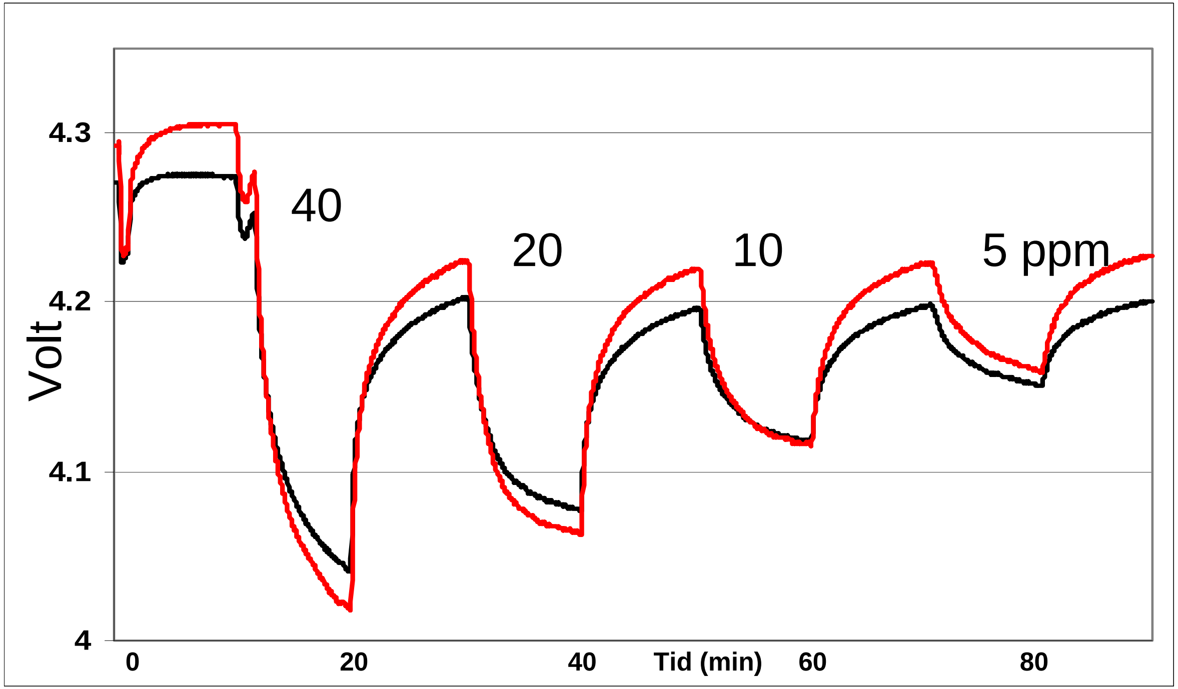
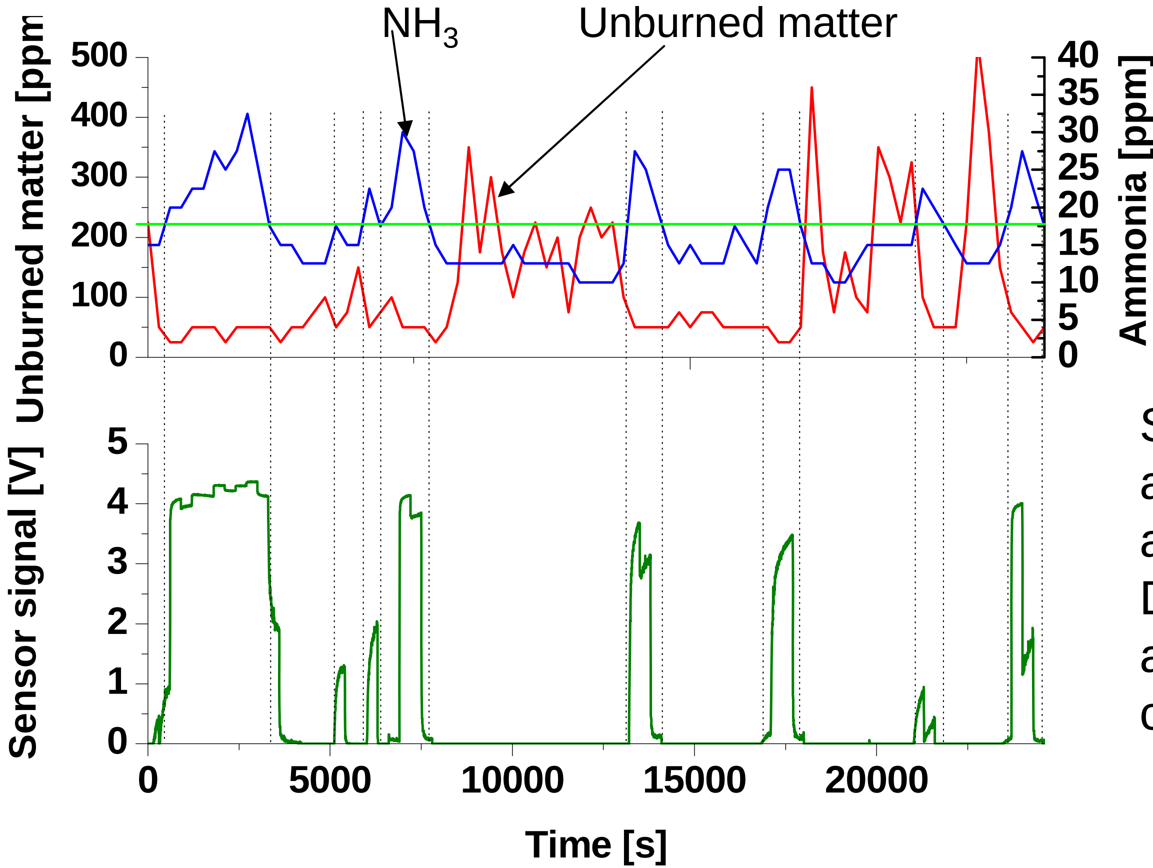
NH_3 Lab measurements



SiC-FET sensor signal to ammonia versus time for two transistors. Detection limit below 5 ppm in 10% O_2 / N_2.

“Old” sensor batch failed to detect ammonia in low oxygen and high CO background.

NH3 detection using SiC-FET sensor as an alarm system



Sensor signal set to alarm level of 15-20ppm ammonia.
Detection in low oxygen and high CO concentration

Sensor system for control of small and medium sized power plants

SenSiC AB

sensors for a clean environment

www.sensic.se

Mike Andersson and Magnus Palm: installation of a sensor system for control of a domestic boiler) at Ariterm Sweden AB (key partner)

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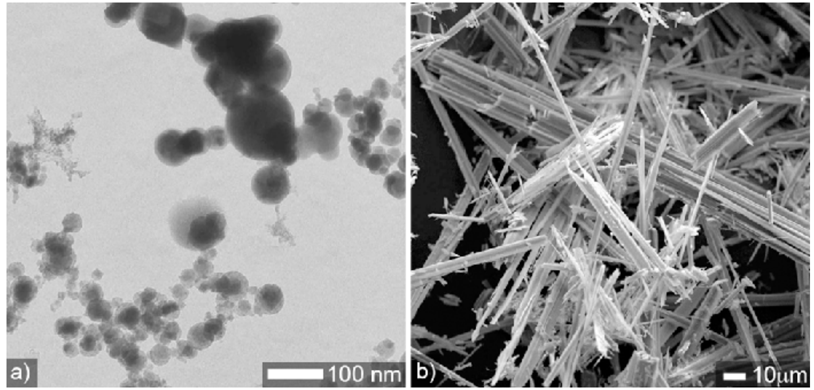
Nanoparticle sensors

- Nanoparticles show adverse health effect according to
  - Size
  - Shape
  - Content
  - Concentration
- Nanoparticles damage cells:
  - oxidative effect on cells

CHEMPACK project (2011-2014)
FiDiPro position
Oulu University i Finland



Welding nanoparticles (courtesy of Pam Drake, National Institute for Occupational Safety and Health NIOSH).

Asbestos fibers (courtesy of the US Geological Survey).

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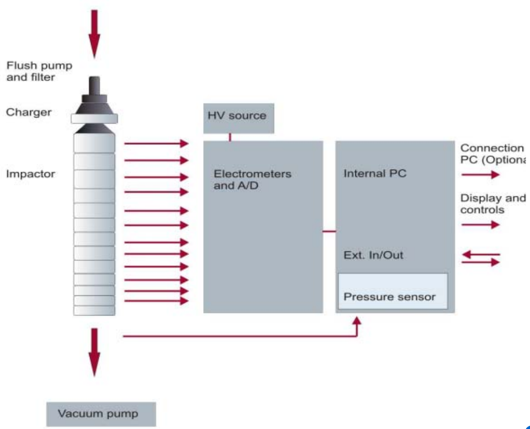
Present commercial particle detectors

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)

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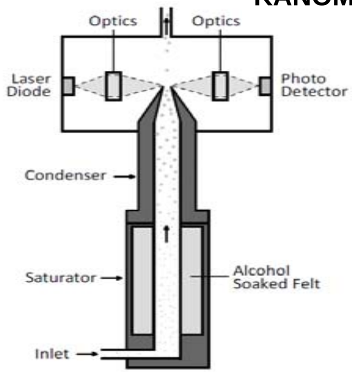
Present commercial particle detectors

- **NANOSIGHT**
  - optical method to measure size
  - laser light source
  - typical range 10 nm - 1000 nm
- **BECKMAN COULTER**
  - particle size of fluid with nanoparticles
  - laser light
  - for size analysis: electrophoretic light scattering (ELS)
- **LIGHTHOUSE WORLDWIDE SOLUTIONS**
  - handheld and portable particle counters
  - minimum sensitivity: 200 nm
- **AIRMODUS**
  - condensation to grow 1 nm diameter nanoparticles to optically detectable sizes
- **KANOMAX**
  - condensation to grow 15 nm diameter nanoparticles to optically detectable sizes
- **PEGASOR**
  - Portable real time measuring instrument
  - Detection of total surface area, mass, number of particles

AIRMODUS

BECKMAN COULTER

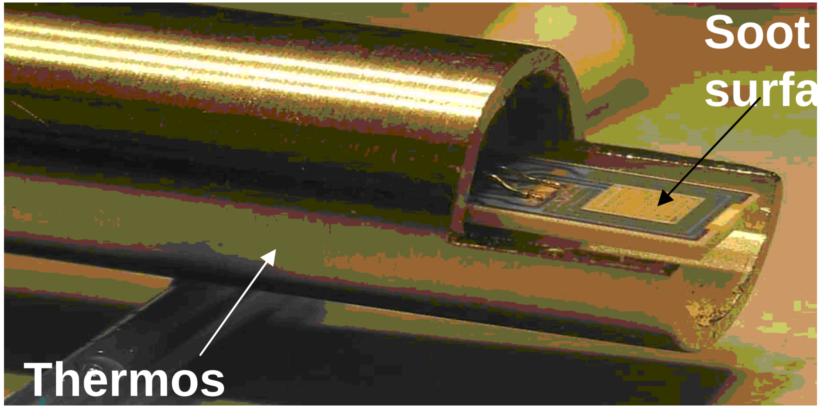
KANOMAX MODEL 3800

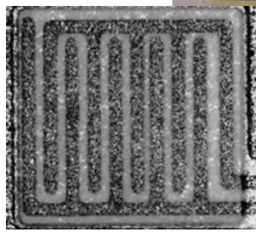


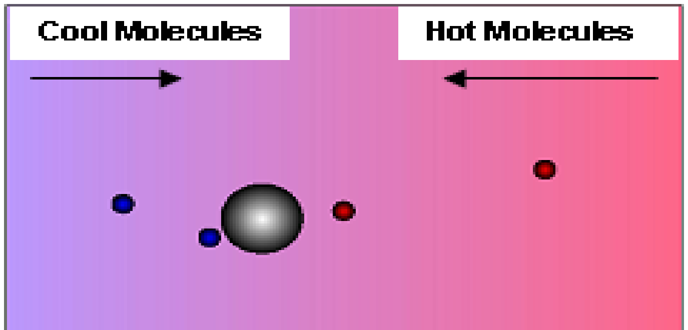
NANOSIGHT LM10

LIGHTHOUSE HANDHELD 2016

Soot sensor based on Thermophoresis







Thermophoresis:

A force acting on particles in a temperature gradient →

Soot is deposited on the coldest surface

Thermos packaging to decrease temperature on the sensor surface

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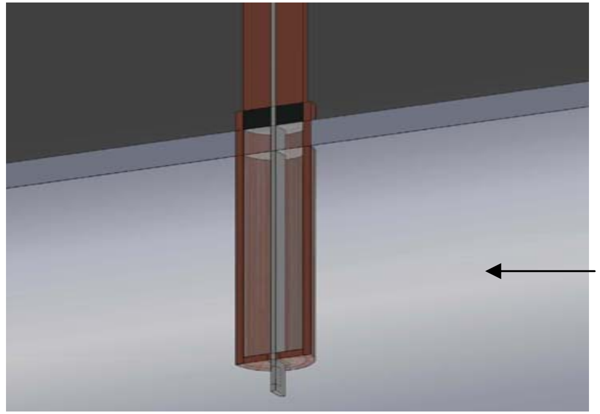
MD13 Heavy duty truck engine



Exhaust pipe

Robert Bjorklund, Linköing University and Ann Grant, Volvo Technology

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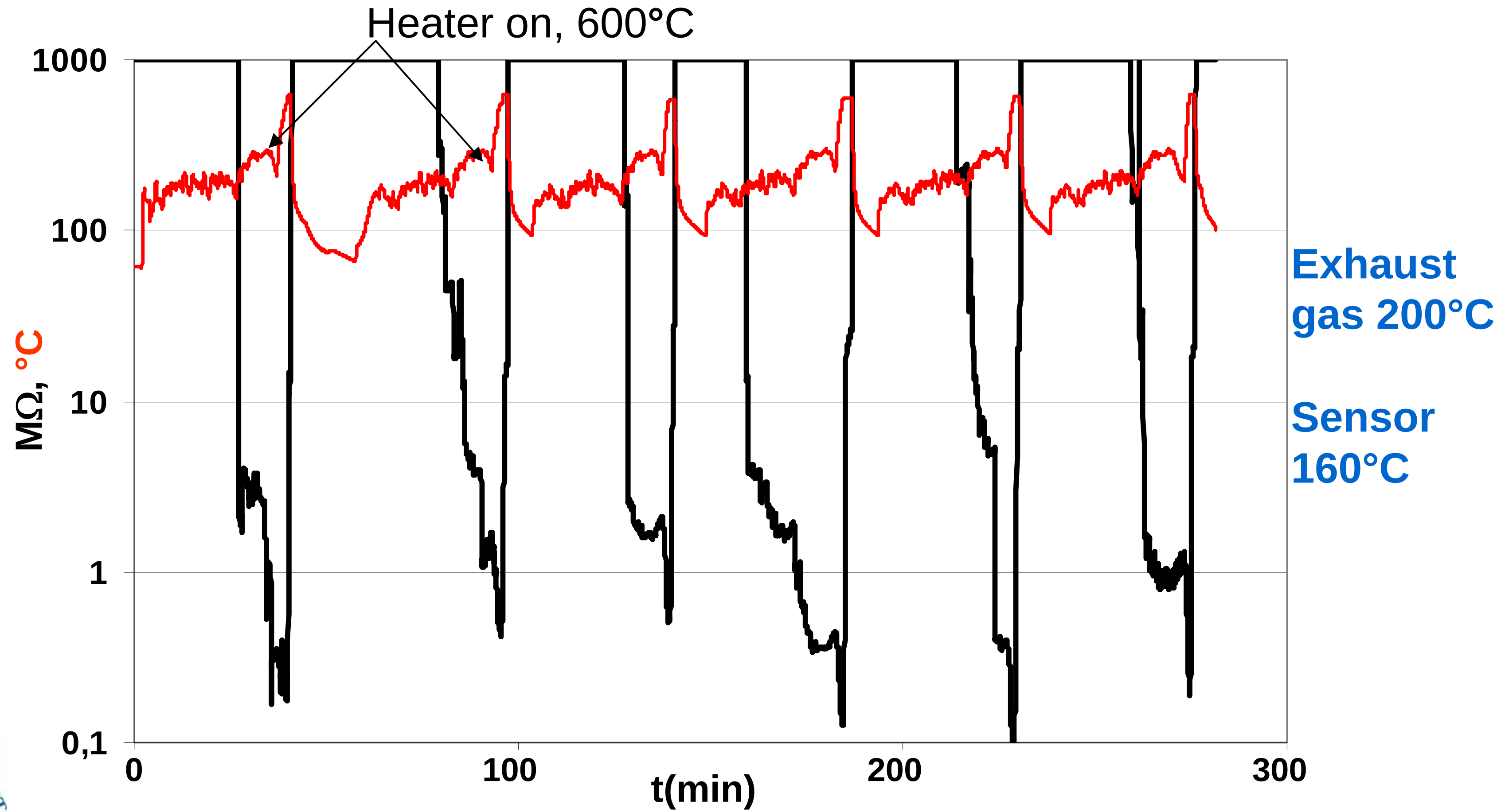
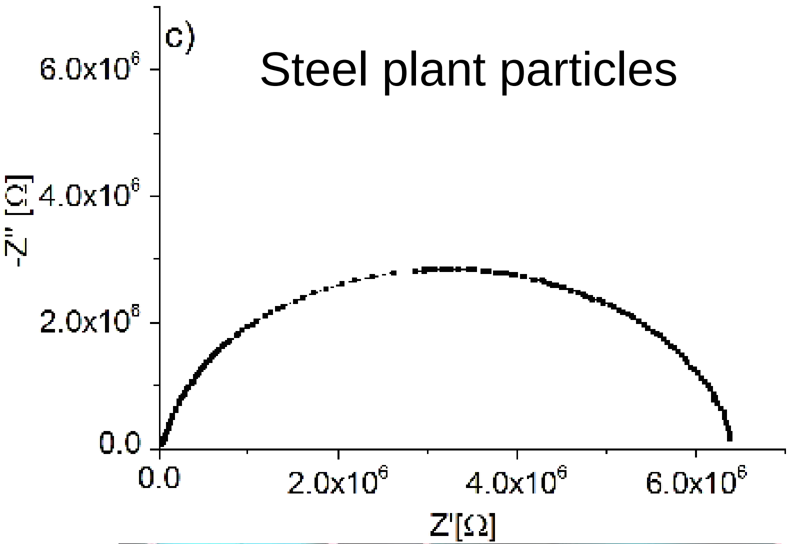
6 World Harmonized Transient Cycles

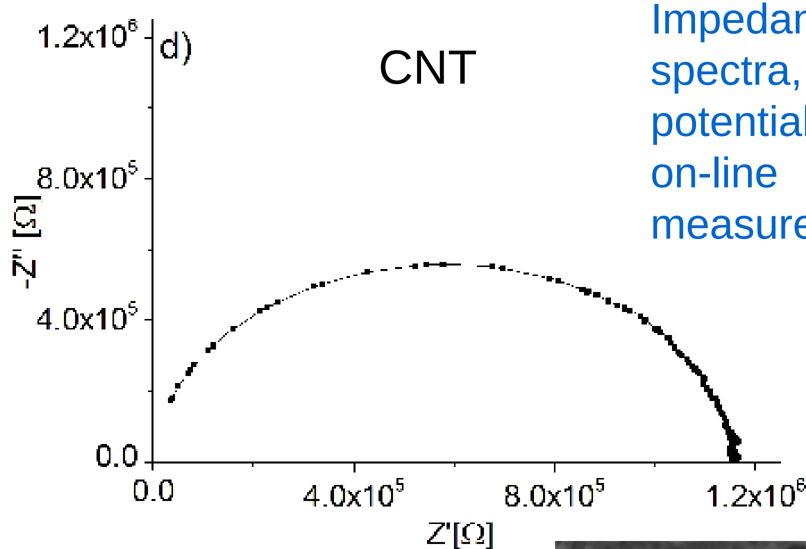


30 min/cycle, 18 min response time, 1370 mg/cycle, 40 mg/kWh)

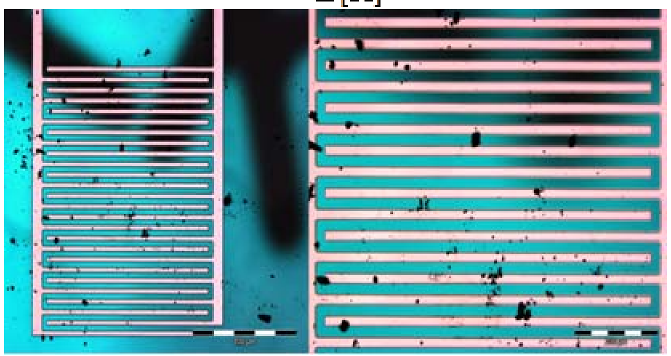
Robert Bjorklund and Ann Grant

Impedance spectra of particles from steel plant and CNTs



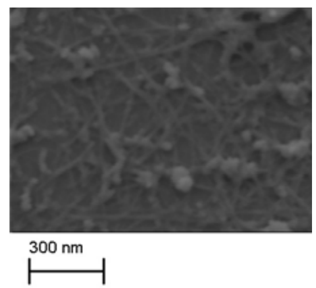


Impedance spectra, potential for on-line measurements



Optical image, airborne particles from steel plant

SEM: CNTs deposited on IDEs



Joni Huotari

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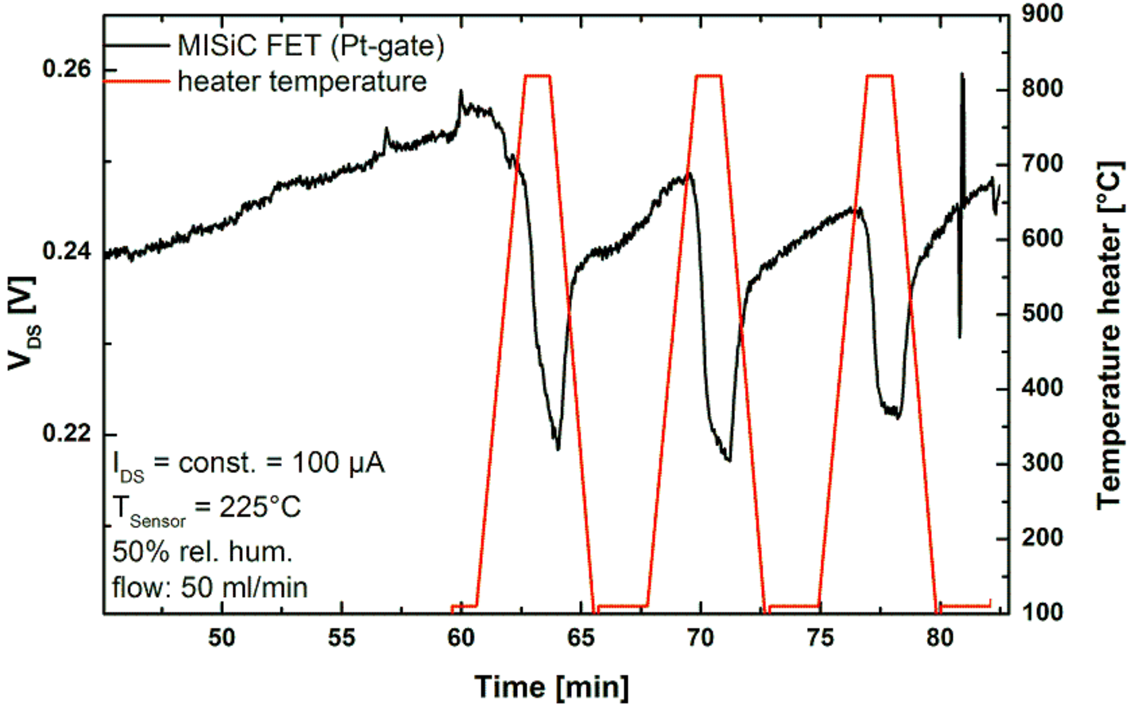
Detection of particle content

Workplace and Indoor Aerosol conference in Lund:

Detection of Pd in particles by the catalytic CO conversion efficiency



Christian Bur

First results, detection of ammonia containing fly ash particles.
Particles are heated repeatedly to ~ 800°C.
A small gas flow brings emissions from heater to SiC-FET sensors.

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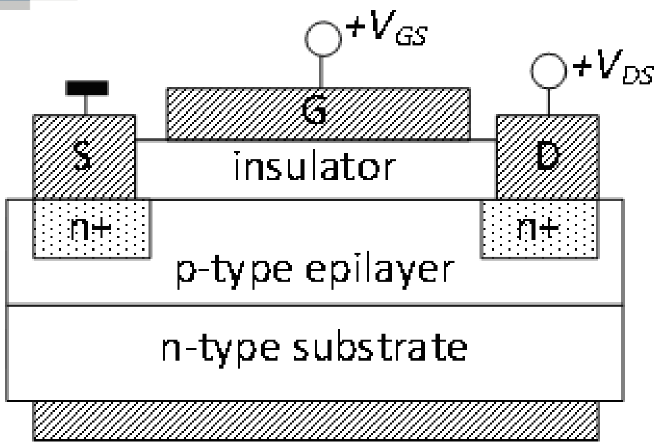
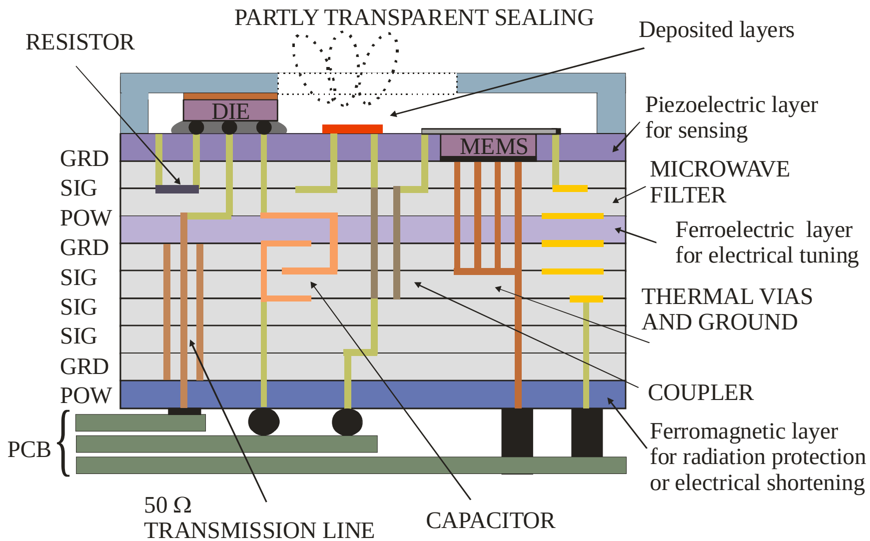
Future development



Particles are charged, SiC- FET device a possibility

Source and drain contacts need protection by over glass, but also bond wires must be protected



Additional functionality by smart packaging, LTCC packaging (Docent Jari Juuti):

Collection of particles by thermophoresis (cold sensor surface), applied voltage, magnetic field

Detection of content of particles by heating at a hot spot and detection of emissions by a sensor array, smart operation and data evaluation

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Conclusions

- Toxic gases and airborne nanoparticles need to be monitored for emisson control
- The new generation SiC-FETs provide a powerful sensor platform for detection of gases and potentially nanoparticles
- The content of nanoparticles is important to measure. Our present approach is based on impedance spectroscopy and heating particles and subsequent detection of the emissions

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Hossein Fashandi, PhD student
Peter Möller, research engineer

Microelectronics and Material Science Laboratories, Oulu University

Prof. Heli Jantunen
Prof. Jyrki Lappalainen
Prof. Anita Lloyd Spetz
Joni Huotari, PhD student

Laboratory for Measurement Technology, Saarland University

Prof. Andreas Schütze
Christian Bur, PhD student

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