



**European Network on New Sensing Technologies for Air Pollution  
Control and Environmental Sustainability - *EuNetAir*  
COST Action TD1105**

**INTERNATIONAL WG1-WG4 MEETING on**

***New Sensing Technologies and Methods for Air-Pollution Monitoring***

**European Environment Agency - EEA**

**Copenhagen, Denmark, 3 - 4 October 2013**

Action Start date: 01/07/2012 - Action End date: 30/06/2016 - Year 2: 2013-2014 (*Ongoing Action*)

**Low Power and Portable Sensor Systems  
for Air Monitoring**



**Rob van Schaijk**

**Function in the Action:** Invited Expert

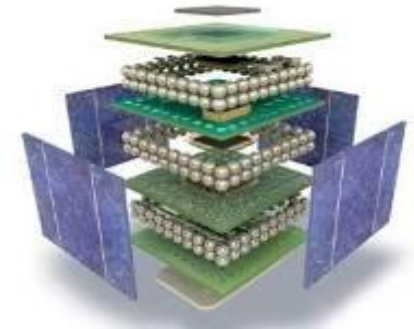
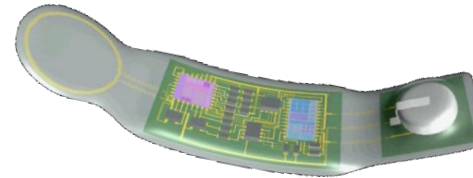
**Imec / Holst Centre, The Netherlands**

**Rob.vanSchaijk@imec-nl.nl**

# Wireless Autonomous Transducer Solutions

## Cover all basic building blocks of a wireless sensor node

- Digital signal processing
- Wireless communication
- Micro-power generation and storage
- Sensor and actuator technology
- Analog IC design

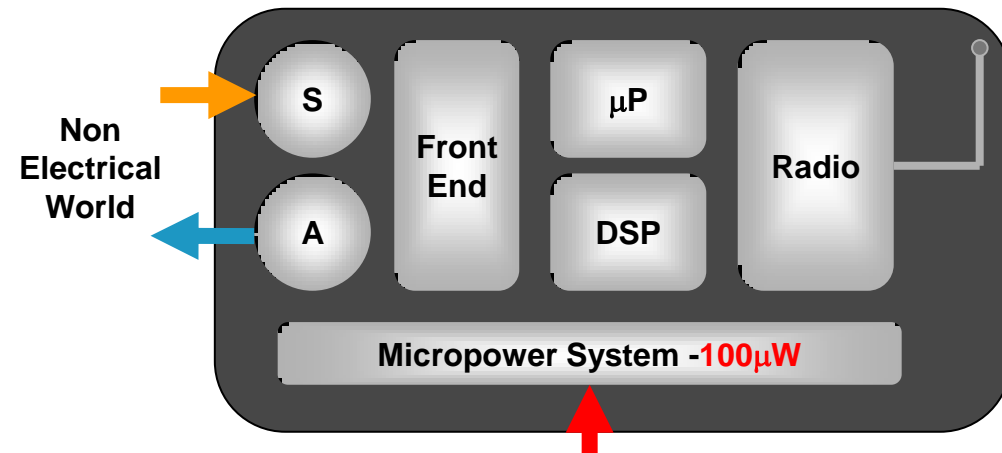


## Integration in various form factors

- 3D stack
- Flexible / stretchable

## Technology drivers

- Ultra-low power
- Miniaturization
- Low cost processes



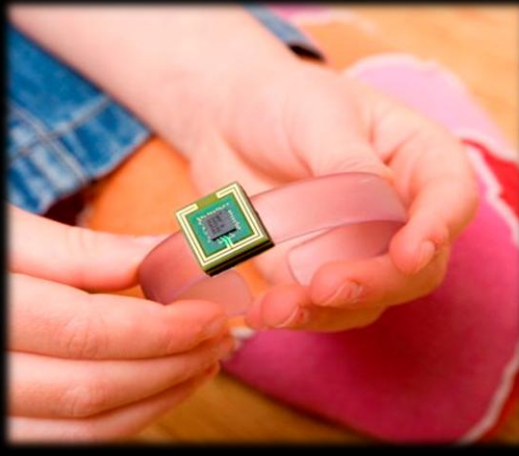
Thermal, Vibrational, RF, Light, Bio-chemical

# BODY AREA NETWORKS

## Personal Healthcare & Lifestyle Solutions



Necklaces/patches



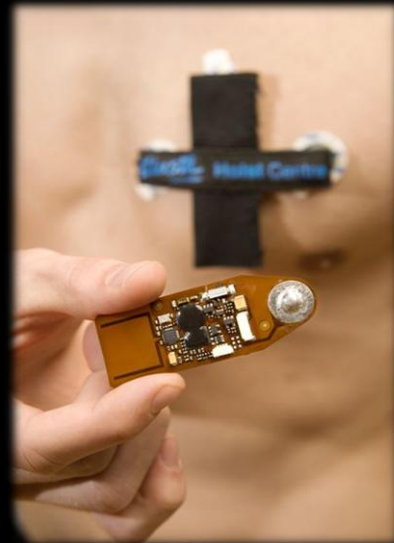
Watch-type



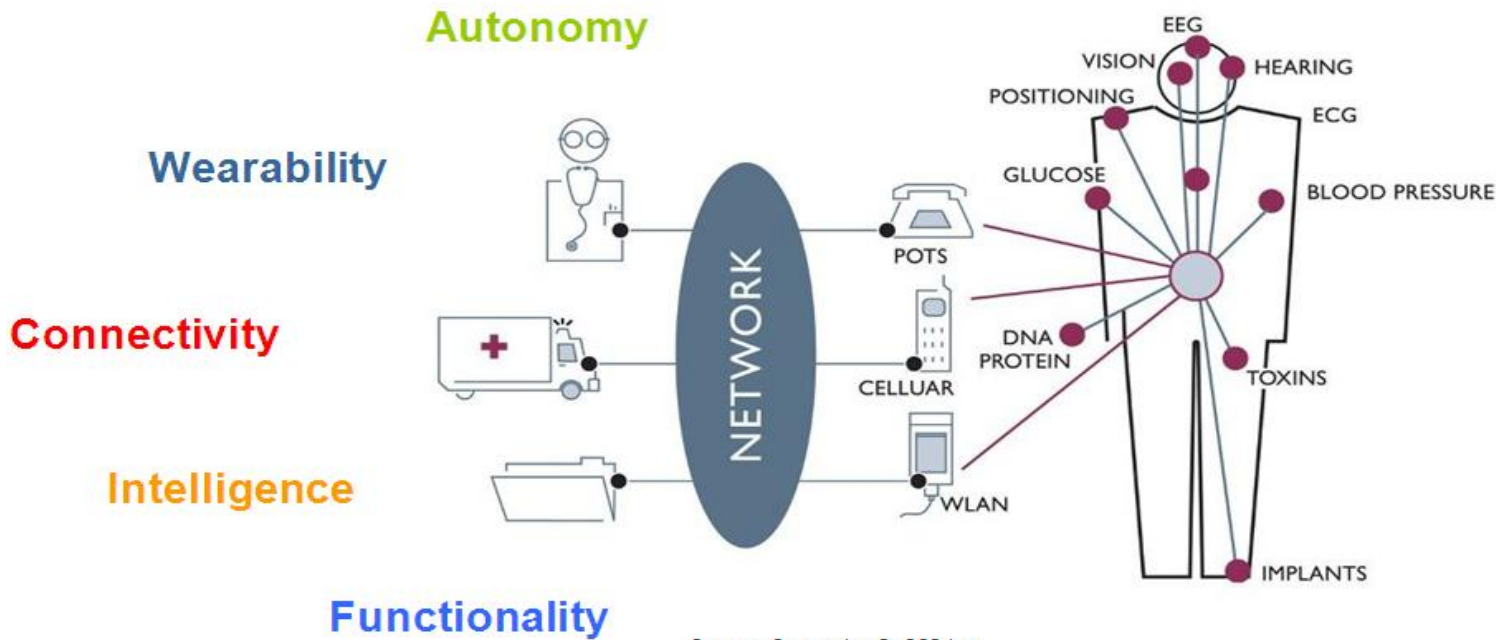
Headsets



Base Stations



# From *Body* Area Network to *Personal* Area Network



*Vehicles*



*Living spaces*



*Open spaces*



*Industry*



*Implantability*

*Office buildings*



*Working environment*



# Extend with Compact chemical Sensors



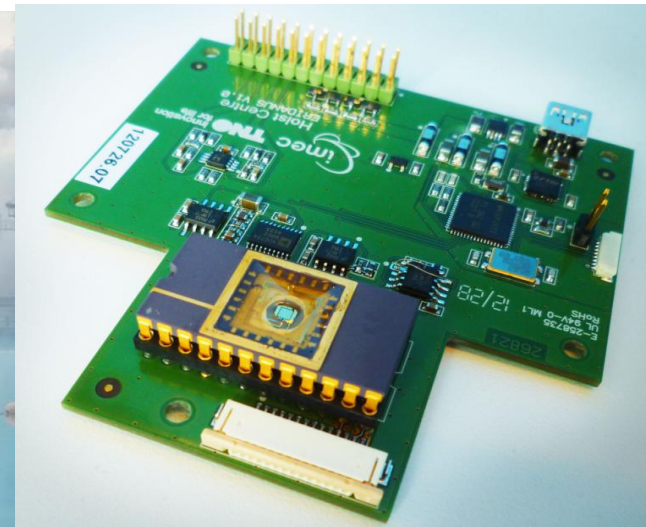
# IMEC Sensor platforms



**Ion sensor**  
**'Sweat patch'**  
**Dehydration**  
**Hypertension**



**GaN sensor:**  
**NO<sub>2</sub>, NO,..**  
**Environmental**

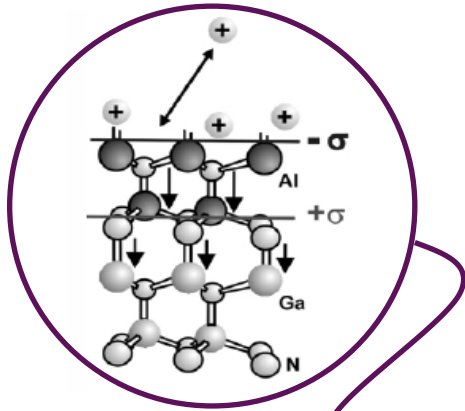


**Electrochemical sensor**  
**(Ionic Liquid): Ethylene,**  
**CO<sub>2</sub>, H<sub>2</sub>S..**  
**Environmental**  
**Food waste**

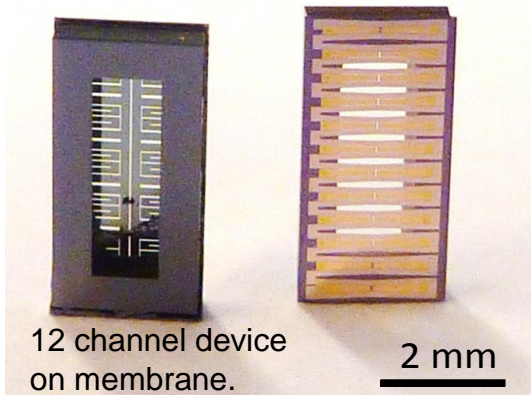
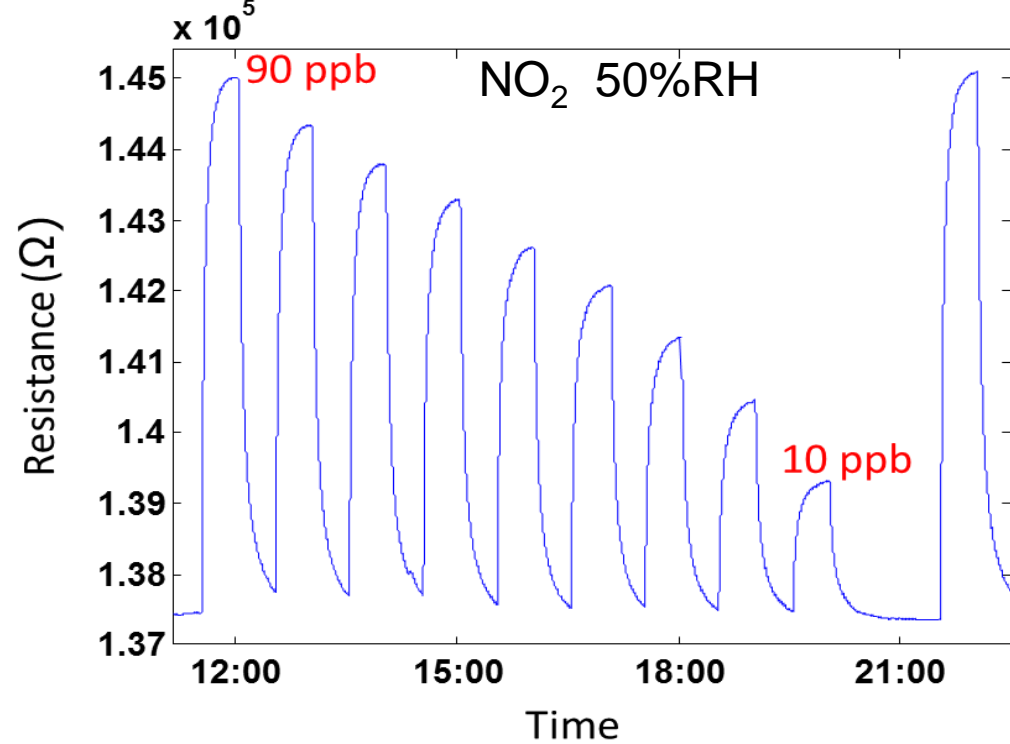
# Achieved **RESULTS** and future activities

- **AlGaN/GaN :**
- Developed environmental sensor for NO<sub>2</sub>
- Extend to different gasses: NO, CO..
  - Functionalization (polymers, metal oxides)
- **Electrochemical sensors:**
- Based on ionic liquids
  - First sensor developed for ethylene
- Extend to different gasses: CO<sub>2</sub>, H<sub>2</sub>S,..

# ENVIRONMENTAL SENSING: ALGAN/GAN 2DEG BASED

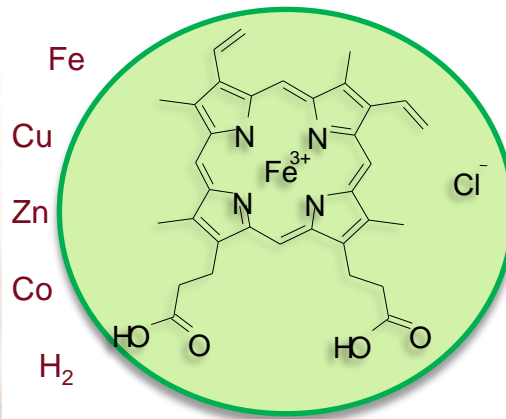


2DEG conductance modulation by gas induced charge trapping at surface



12 channel device on membrane.

2DEG membranes enable low-power heating



Surface functionalization

## Challenges and outlook

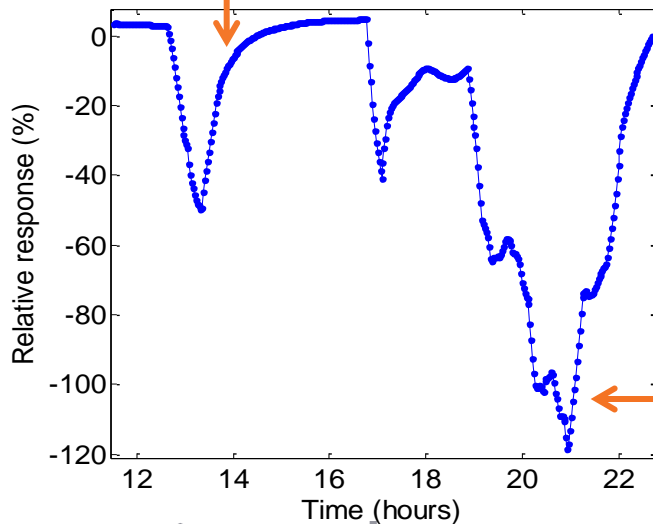
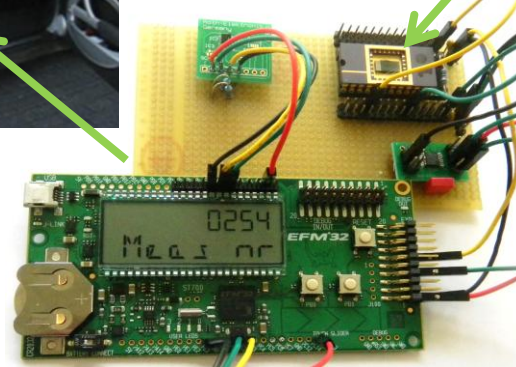
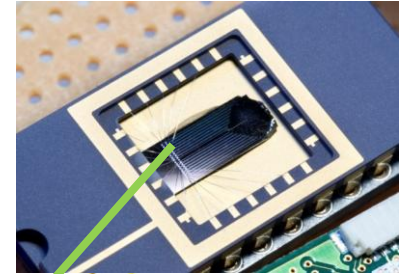
- Sensing layers for detection of other gases, NO, CO<sub>2</sub>, VOC
- Humidity regulating layer
- Smart packaging solutions for mobile applications



# Low-ppb environmental monitoring



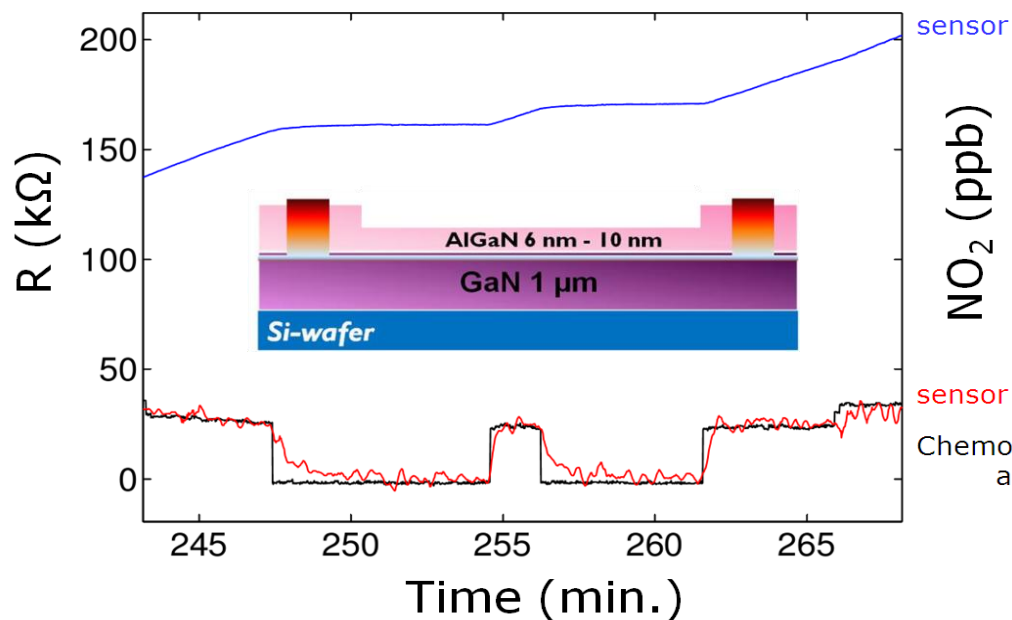
Parking garage



Clean air in nature

- ✓ Battery operated
- ✓ On-chip data storage
- ✓ Humidity and temperature
- ✓ Simple resistive readout
- ✓ Reversible
- ✓ Sub-ppb detection limit
- ✓ Very low cross-sensitive to e.g.  $\text{SO}_2$ ,  $\text{CO}_2$ ,  $\text{NH}_3$

# Combine physiology with environmental data



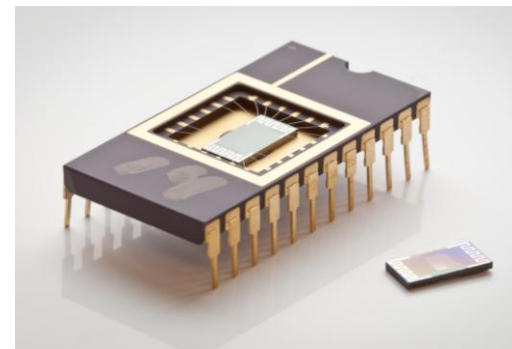
sensor

NO<sub>2</sub> (ppb)

sensor slope (a.u.)

Chemo-luminescent analyzer

In collaboration with



## My Air My Health

U.S. Department of Health and Human Services  
U.S. Environmental Protection Agency

**Fast response with slope based detection:**

**20 sec response for 25 ppb NO<sub>2</sub>**

# And also: Asthma & Personal Environment

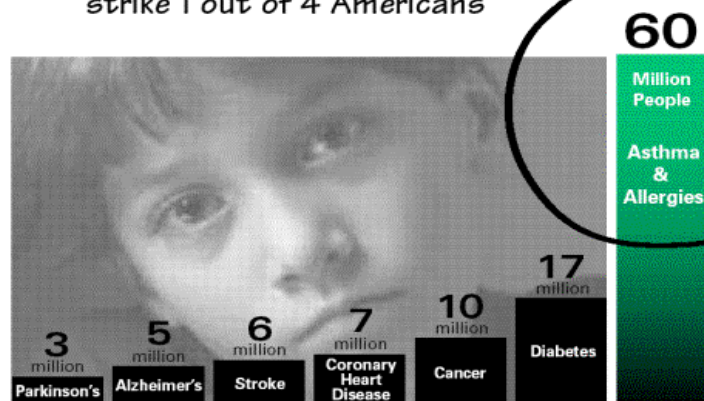


20 million Americans suffer from asthma (1 in 15 Americans) !!

Asthma accounts for one-quarter of all emergency room visits in the U.S.

Annual cost (USA):  
\$18 billion

Asthma and allergies strike 1 out of 4 Americans

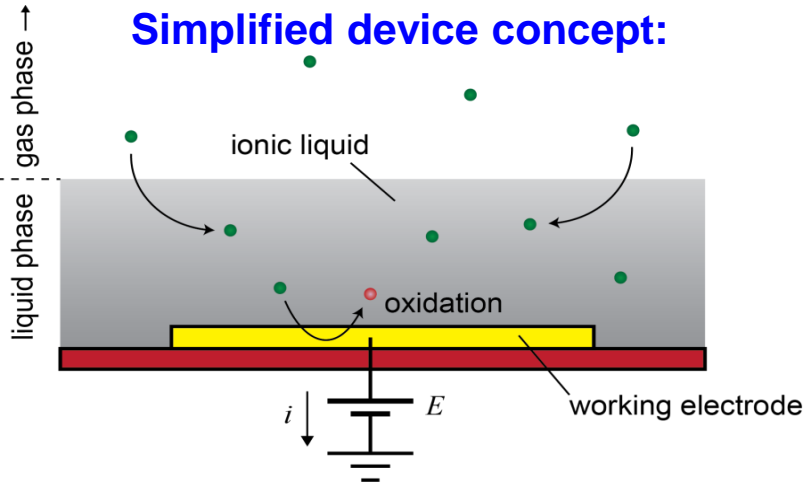


\* Annual U.S. Prevalence Statistics for Chronic Diseases

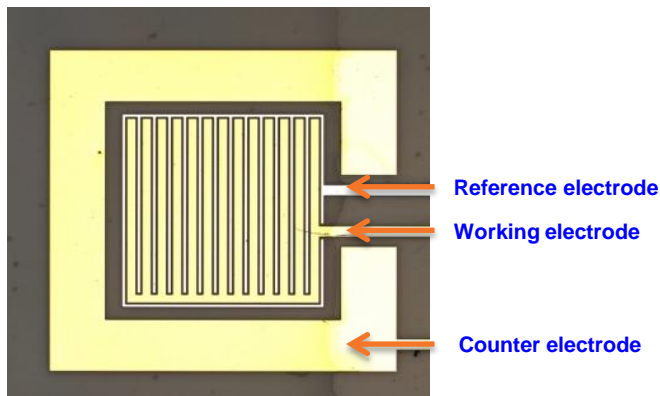
- On January 22, 2010 EPA strengthened ambient air quality standard NO<sub>2</sub> to increase protection of public health
- EPA also is making changes to the NO<sub>2</sub> air quality monitoring network requirements
- Limit short-term exposures to peak NO<sub>2</sub> which often occur near major roads and could worsen asthma symptoms
- Maintain NO<sub>2</sub> below levels associated with respiratory related emergency department visits and hospital admissions

# Imec miniaturized electrochemical sensors

## Simplified device concept:

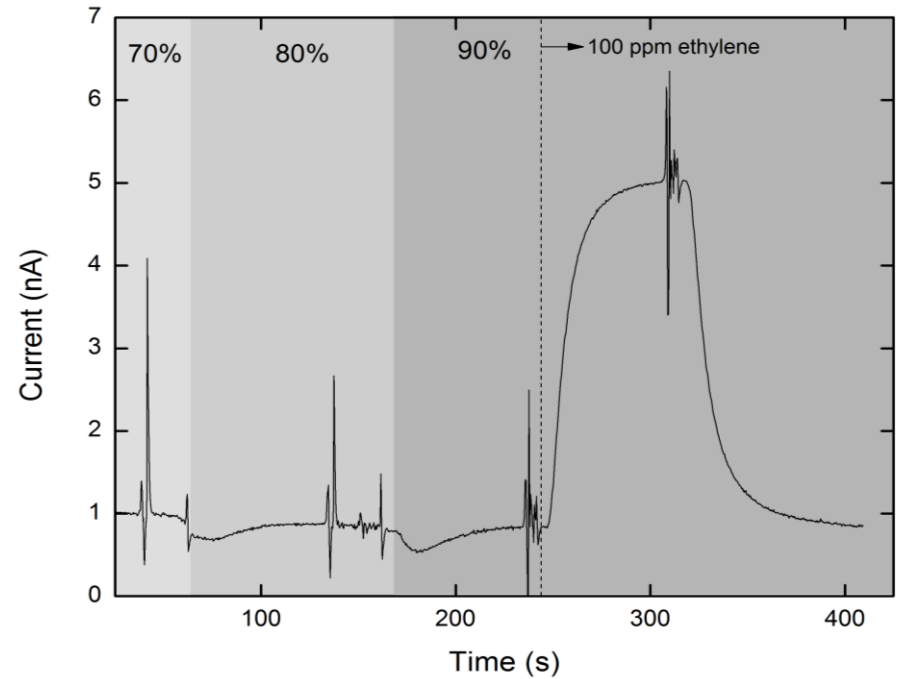
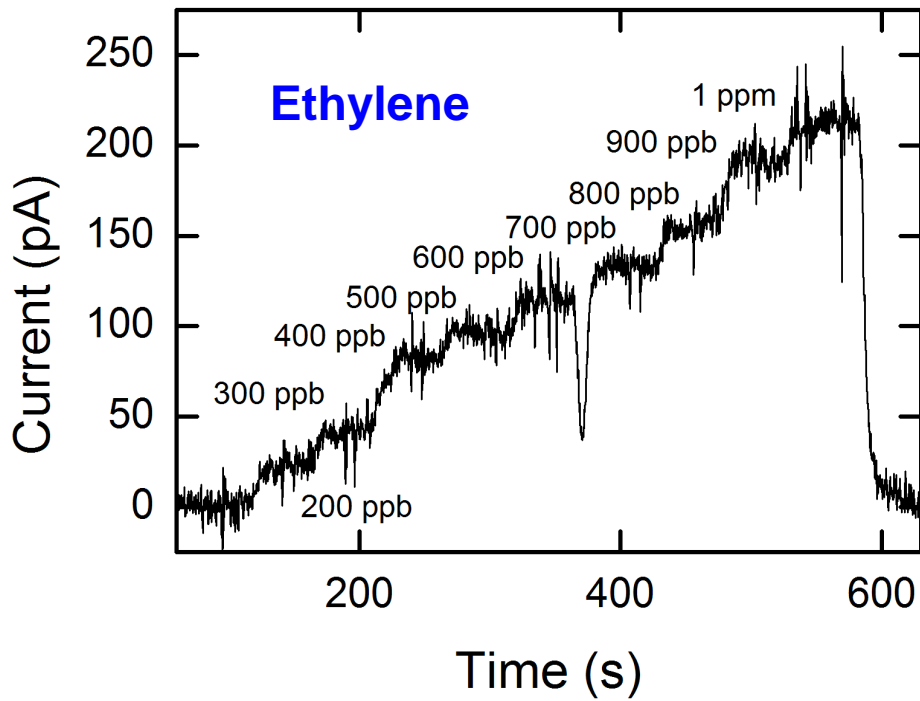
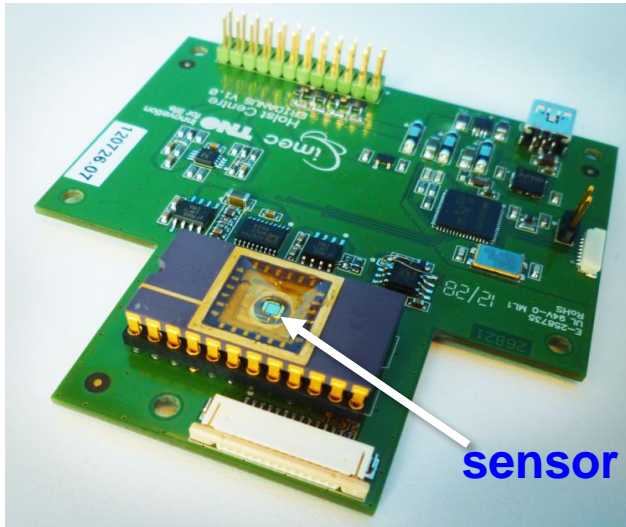


~2,5 mm



- Ionic liquid as electrolyte
  - non-volatile (negligible vapor pressure)
  - no electrolyte reservoir / porous electrodes (smaller)
  - higher gas solubility, smaller Henry's constant
  - wide electrochemical window
- Amperometric sensor development for different gasses ( $\text{CO}_2$ ,  $\text{NH}_3$ ,  $\text{H}_2\text{S}$ ..)
  - variables
    - ionic liquid screening
    - electrode materials
- First miniaturized ethylene sensor
  - Plant hormone responsible for ripening
  - Smoldering fires





**No cross-sensitivity with humidity**

# Future planned **Activities**

- **Activities directions as future ACTIVITIES:**
- Further develop gas sensor platforms based on AlGa<sub>N</sub>/Ga<sub>N</sub> and electrochemical principle:
  - AlGa<sub>N</sub>/Ga<sub>N</sub> :
    - Extend to different gasses: NO, CO..
    - Functionalization (polymers, metal oxides)
  - Electrochemical sensors:
    - Based on ionic liquids
    - Extend to different gasses: CO<sub>2</sub>, H<sub>2</sub>S,..
- Develop the gas sensor systems in a small form factor
  - Integrate read-out electronics
  - System in package
  - Application: integrate gas sensors in personal area network (PAN)



# Imagine gas sensors in your PAN !



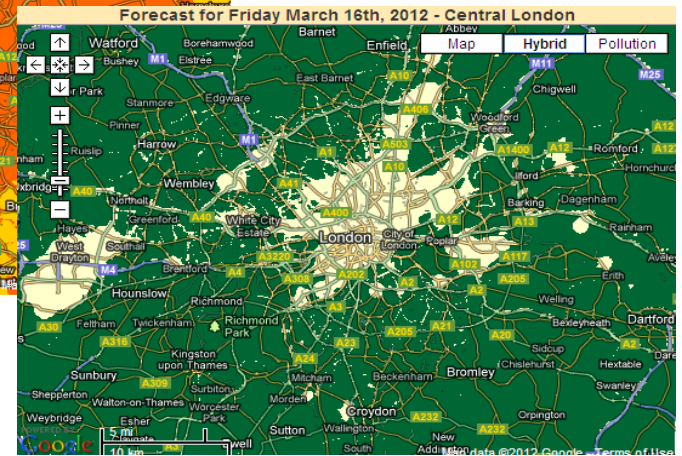
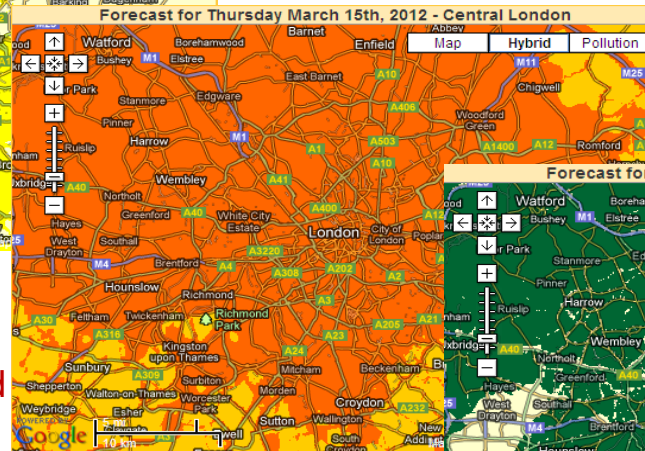
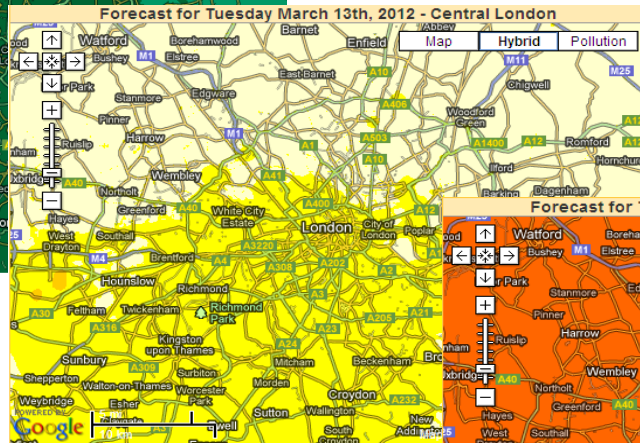
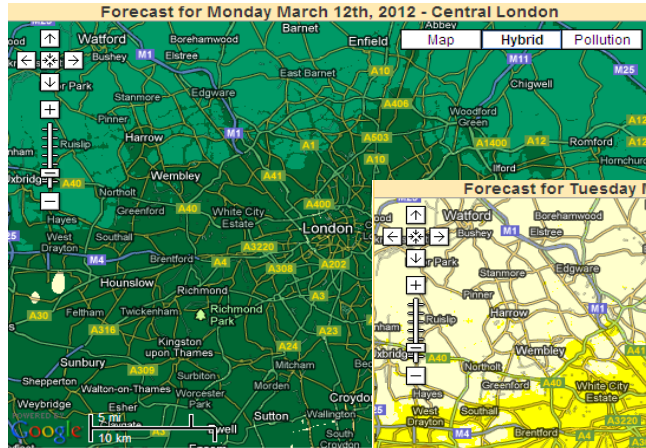
# Personal pollutant exposure



Main sources: traffic,  
domestic boilers,  
industry.

Main limitations: expensive  
low sensitivity  
form factor  
limited distribution

*A need for personalized air quality*



The City of London has been declared an Air Quality Management Area. Levels of PM<sub>10</sub> and NO<sub>2</sub> in the City consistently exceed health-based national objectives.

# CITY OF LONDON



# The future is coming...!



NASA adapt **iPhone**  
to *smell* chemicals  
(Nov 17, 2009)



**NTT DoCoMo**  
A Cell Phone that  
spots *Bad Breath*



**Nokia EcoSensor Concept**  
Wearable sensor unit to sense  
(environment, health..), and a  
dedicated mobile phone (not an e-nose yet)



Other concepts:  
*Health conscious phone*  
that *smells* food properties

**Nokia Scentsory Concept**  
e-nose samples the odor of  
caller environment and transmit  
to recipient electronically

