# PANEL

# Sensing Everything: Challenges in Current Environments

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Venice, Italy

# A key challenge is…

- …deciding which sensor project/system to design and build

# Some criteria for judging opportunities and performance

- Accuracy
- Initial cost
- Operation cost
- Total lifetime cost
- Power requirements
- Sensitivity
- Size
- Stability
- Application-specific versus general-purpose
- Ability to integrate with existing sensors or other systems
- Market size
- Competition from alternative sensing methods
- Adoption risk
- Technology “push” versus market “pull”

# Conceptual filters for finding R&D projects (including sensing projects): CARTFOVEA

- **C**onfluences
- **A**nomalies
- **R**egulations (or Standards)
- **T**rends
- **F**rustrations
- **O**rthodoxies
- **V**oyages
- **E**xtremalities
- **A**nalogies

# Physical, chemical, and biological sensors in the era of Industrial Internet


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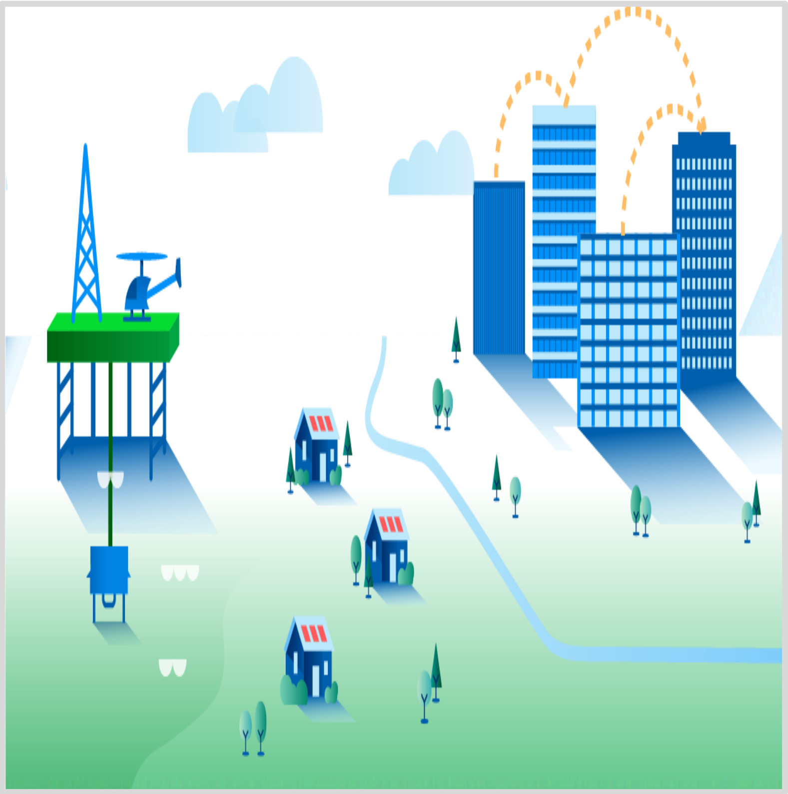
Niskayuna, NY


## Panel Discussion:

Sensing Everything: Challenges in Current Environments


The Sixth International Conference on
Sensor Device Technologies and Applications
SENSORDEVICES 2015, August 23 - 28, 2015 - Venice, Italy

# Top attributes of an ideal sensor system



## Top 10 general sensor system requirements

- Accuracy
- Cross-sensitivity
- Dynamic range
- Initial cost
- Operation cost
- Power consumption
- Response time
- Sensitivity
- Size
- Stability

Potyrailo et al., *Chem. Rev.* 2011
Potyrailo, Naik, *Annu. Rev. Mater. Res.* 2013

**Accuracy** ↑
- Glucose levels in bodily fluids
- Car cabin air quality

**Cross-sensitivity** ↑
- Gas leak detection
- Biomarkers in breath

**Cost** ↑
- Subsea sensors < $10K (initial)
- Food safety label < $0.01

**Power consumption** ↑
- Wired sensors mW
- Unattended sensor nodes 0

**Stability** ↑
- Air quality years
- Bed-side medical days

**Dynamic range** ↑
- pH in pharmaceutical production
- pH of physiological liquids

Diversity of sensor designs
to meet specific application requirements

# Largest impact and market opportunities

**Top 5**

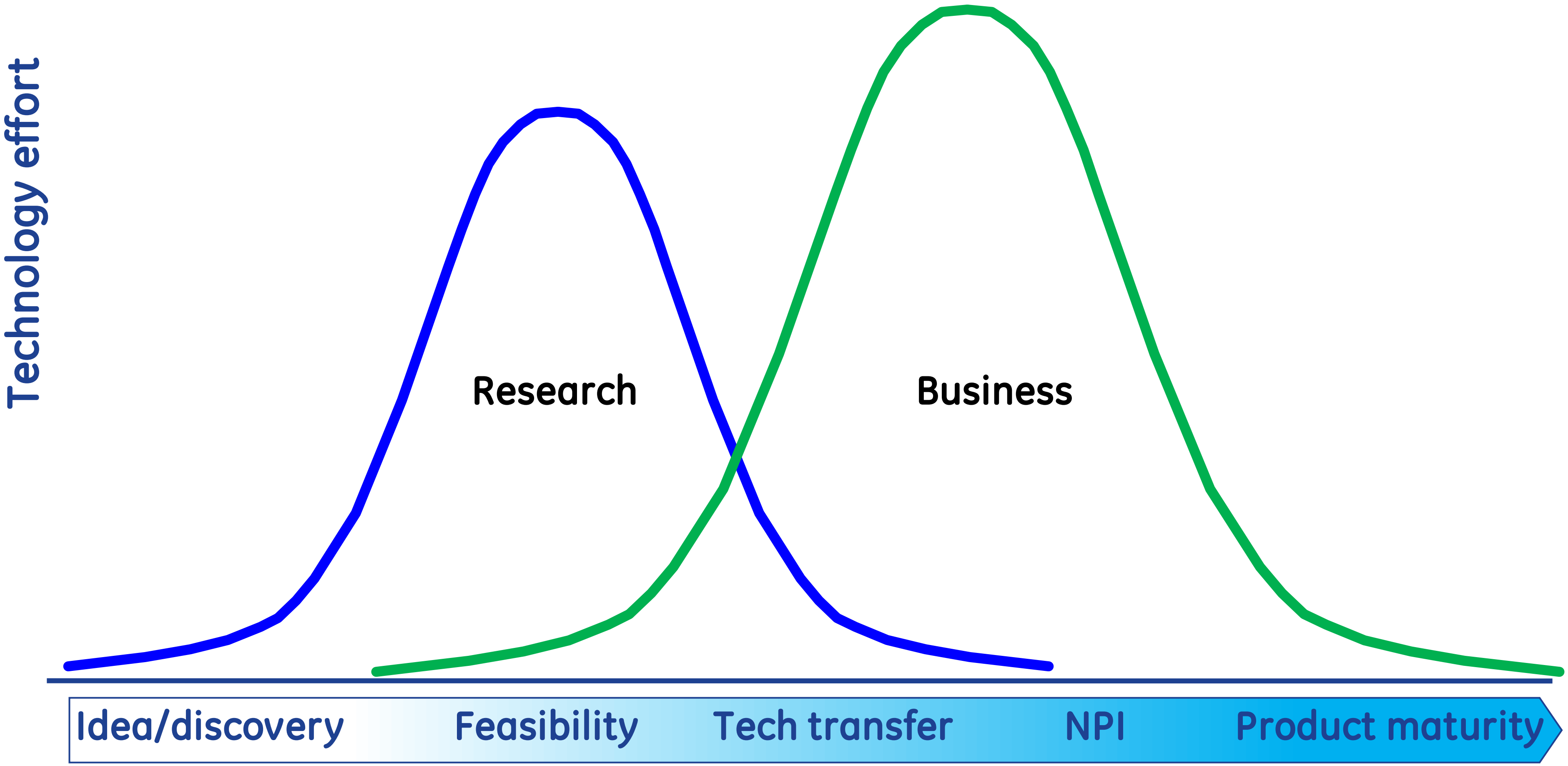
*Internet of Things, Industrial Internet* sensor system requirements

- Low cost
- Low power
- Reliability
- Communication
- Security

*Markets for Sensors in the Industrial Internet*, 2014

Our focus: enhanced sensors reliability
by development new transduction methodologies and data analytics

# From R&D to manufacturing

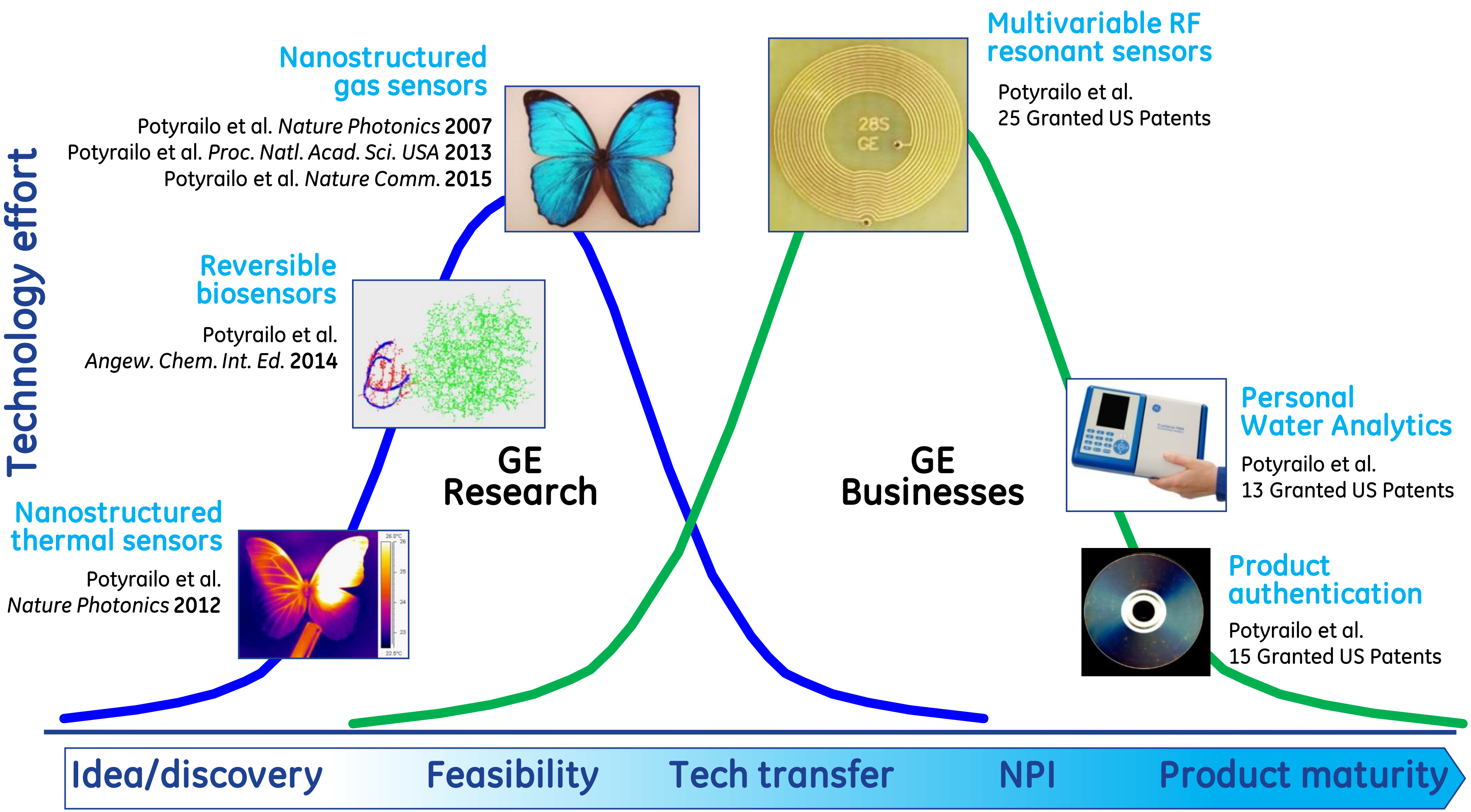




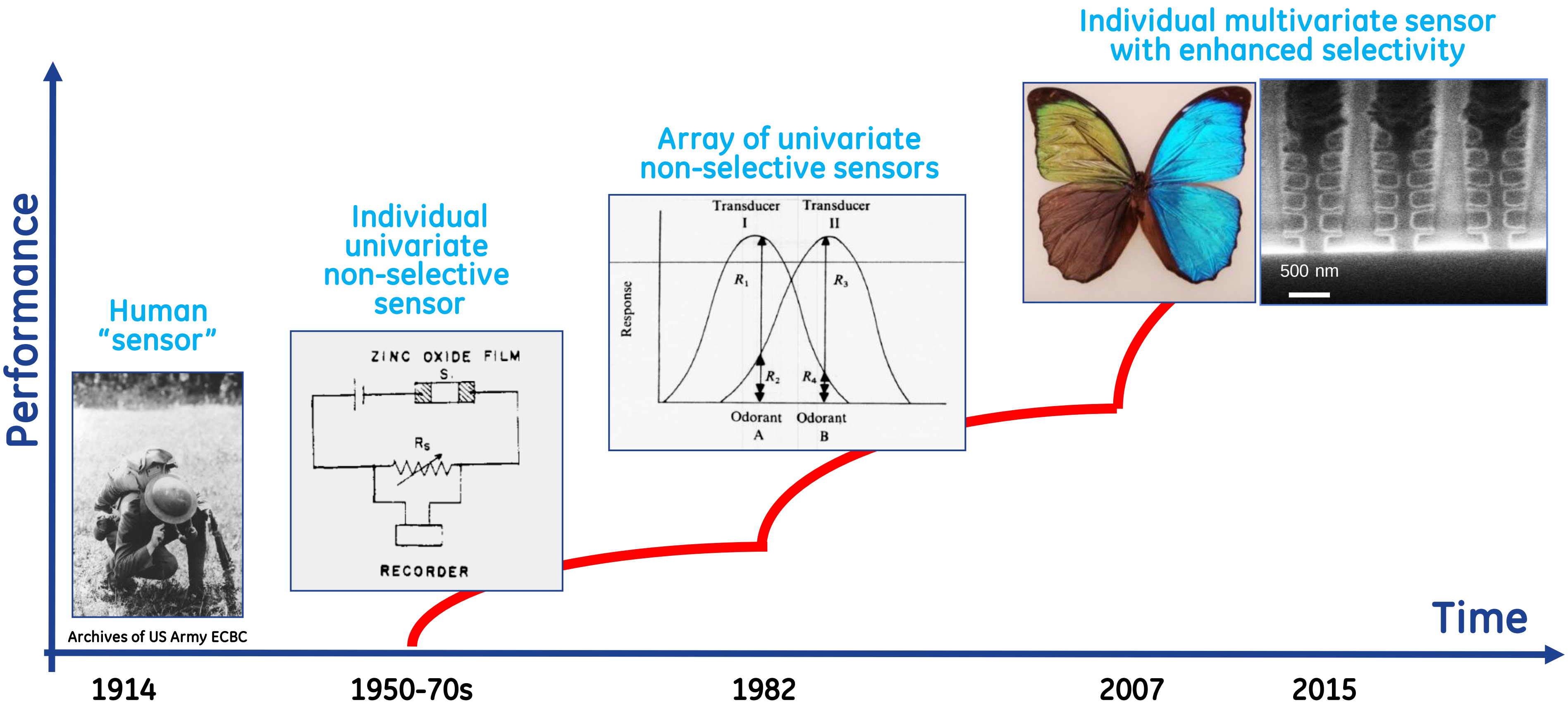



NPI = new product introduction

# From R&D to manufacturing



# Performance improvements in gas sensors




Bielanski et al.
Electric conductivity and catalytic activity of semiconducting oxide catalysts,
*Nature* **1957**, *179*, 668-669

Persaud et al.
Analysis of discrimination mechanisms in the mammalian olfactory system using a model nose,
*Nature* **1982**, *299*, 352-355

Potyrailo et al.
*Morpho* butterfly wing scales demonstrate highly selective vapour response,
*Nature Photonics*, **2007**, *1*, 123-128

Potyrailo et al.
Towards outperforming conventional sensor arrays with fabricated individual photonic vapour sensors inspired by *Morpho* butterflies,
*Nature Communications* **2015**, 6, 7959

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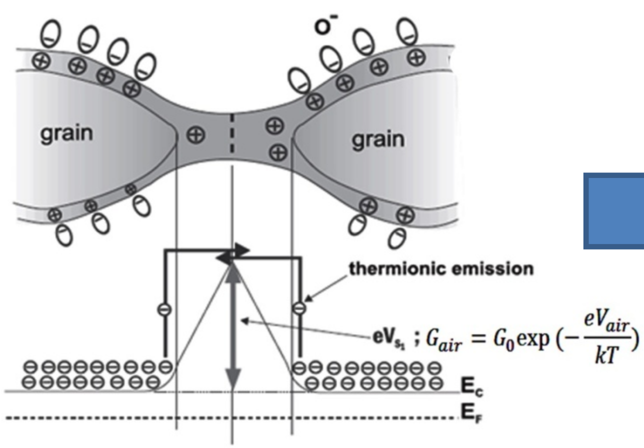
# High Temperature Gas Sensors for Process Control and Field Analysis Purposes

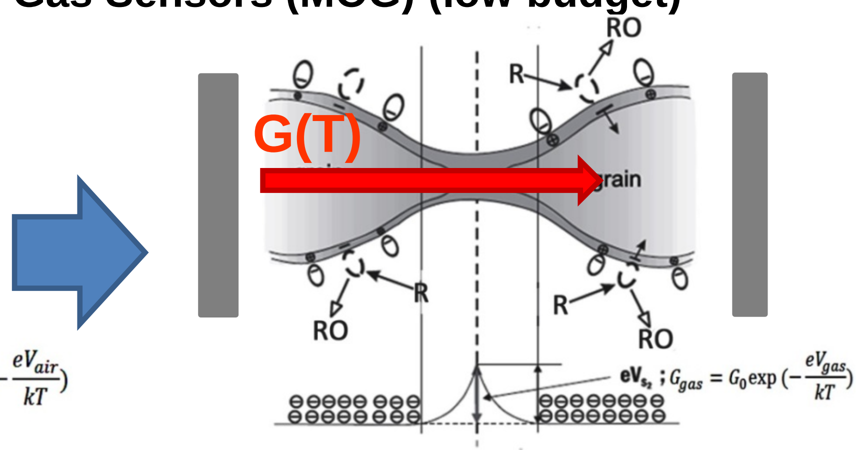
## HT-Gas Sensing in harsh environments:

- Optical principles (complex in installation and costly)
- Electrochemical, zirconia-based devices (low budget)

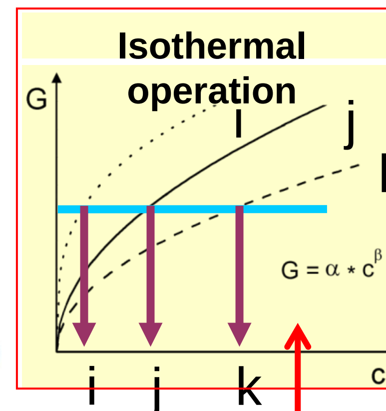
- **Resistive Metal Oxide Gas Sensors (MOG) (low budget)**




$$e^- + \tfrac{1}{2}O_2(g) \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} O^-_{ads}$$




$$R(g) + O^-_{ads} \xrightarrow{k_2} RO(g) + e^-$$

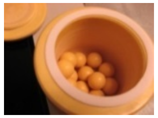



Influenced by T and additives !

B. LicznerskI, Bul. Polish Academy of Sciences, 52 (2004) 37

# MOG Technology – Gas Analysis

Prep. of gas sensing materials



Paste

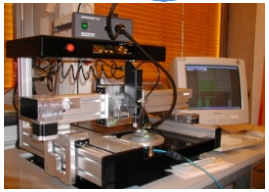
IDE, heater

Metalization

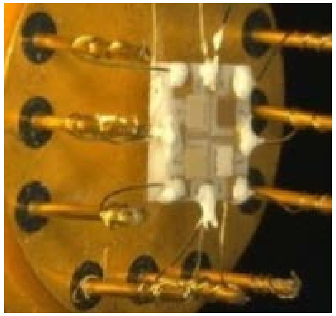
Photolithography

Plasma-Etching (Pt, Au)

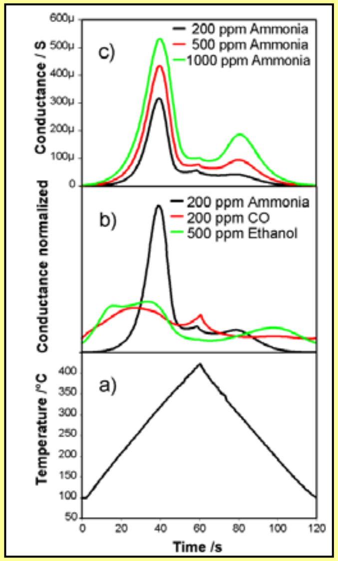
Substrate



Micro-Dispensing on IDE



**Four gas sensing layers and a T-sensor on a chip**




## Operation of four diff. $SnO_2$/additive – layers in dynamic temperature mode

- **Characteristic conductance profile signatures ↔ surface reactions**
- **Gas identification, chemical analysis (SimSens) → monitoring, alarm**

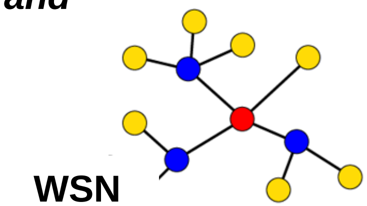
In collaboration with: R. Seifert, H.-B. Keller, Institute of Applied Informatics, Karlsruhe Institute of Technology (KIT), Germany

# Gas Analysis for …

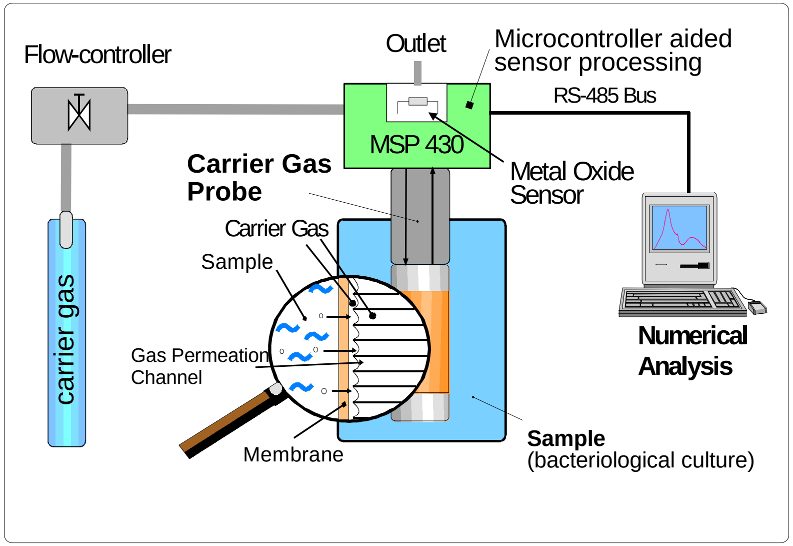
**Detection of hazards** (SensorDevices V, Gas Sensors II)

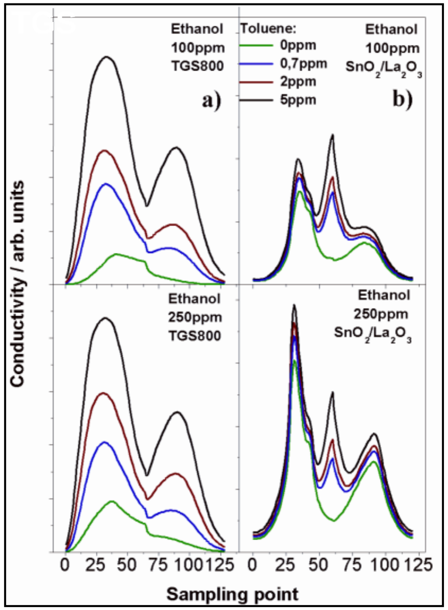
Analysis of gases and vapours at ambient air

***Multisensor-Platform for Early Fire Detection and Identification***




Analysis of volatile substances diss. in water



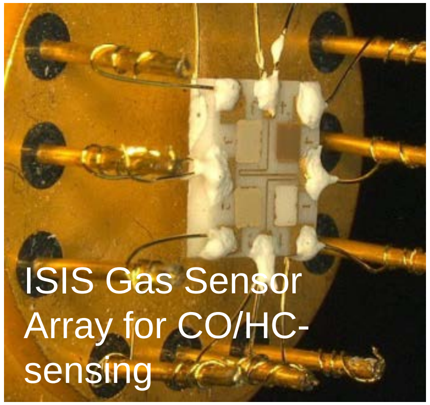
## Wood/biomass combustion control

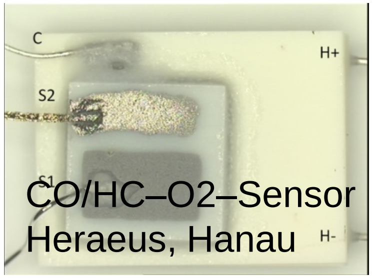
- Optimization of the combustion process
- Reduction of emissions (toxic gases, particulate matter)
- More energy efficiency

especially for low-power fireplaces.


LSU 4.9, Bosch


CarboSen, Lamtec

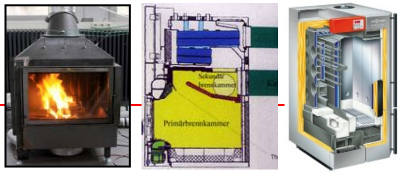

ISIS Gas Sensor Array for CO/HC-sensing



CO/HC–O2–Sensor Heraeus, Hanau

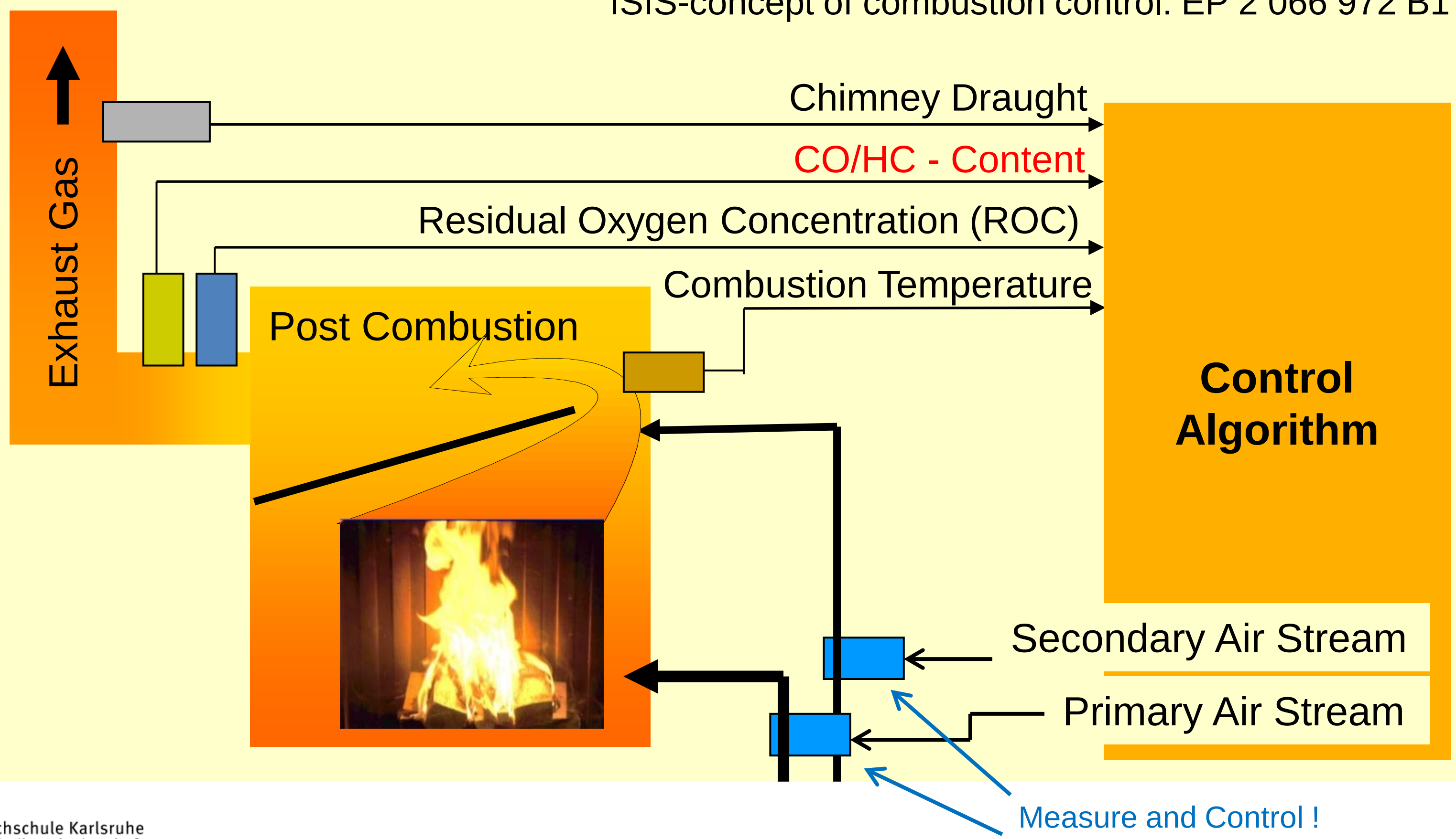
**High Temperature Gas Sensors for combustion process control.**

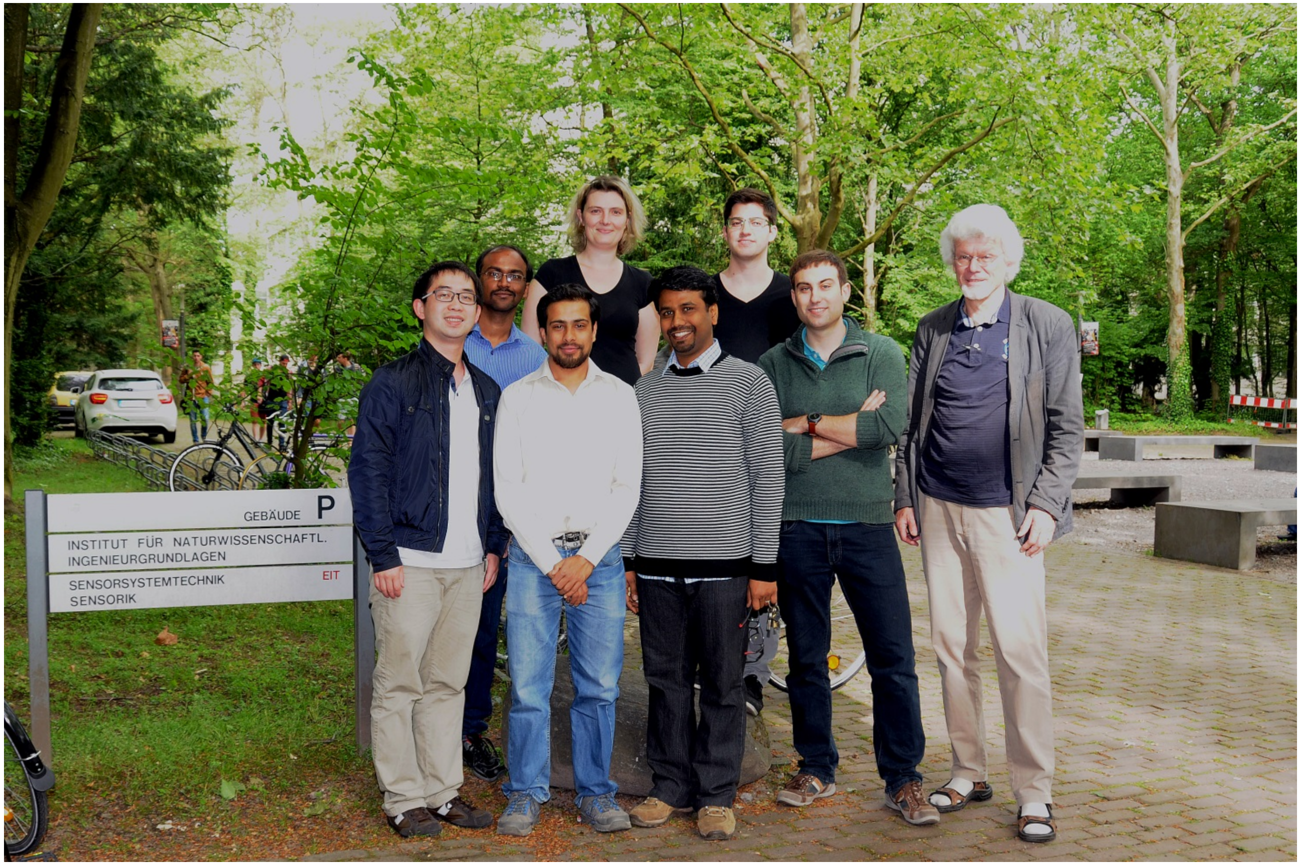
# HT-Gas Sensors for Combustion Process Control



Combustion of Log-Wood / Wood-Pellets / Biomass-Pellets → • Sensors • Air-Stream Control → • Low Emissions • High Efficiency

ISIS-concept of combustion control: EP 2 066 972 B1






ISIS Sensor Group (June 2015)