Miniaturized Sensors for Explosives Detection in Air

Jan Larsen

DTU Informatics

A Strategic Network

Total Budget: 29.200.000 DKK

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Program Commission on Nanoscience, Biotechnology and IT (NABIIT):
14.990.200 DKK

Project Coordinator: Professor Anja Boisen, DTU Nanotech

slides based on Mogens Havsteen Jakobsen's presentation at the NDRF workshop on Molecular and Odour Detection 05.03.2008

Project Partners

DTU Informatics
Department of Informatics and Mathematical Modeling

DTU Nanotech
Department of Micro- and Nanotechnology

OAK RIDGE National Laboratory

UNIVERSITY OF SOUTHERN DENMARK

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TOMORROW'S TECHNOLOGY AVAILABLE TODAY

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Motivation

In the future development of sensor based explosives detectors we find that the key challenges to address are:

reliability, selectivity, stability and cost.

Our hypothesis is that only by combining several independent and sensitive measuring principles can the reliability be improved.

We will do this by creating a strategic research network with significant pre-existing know-how and strong competences in:

miniaturized sensors, synthetic chemistry,
surface functionalization, data processing and validation.

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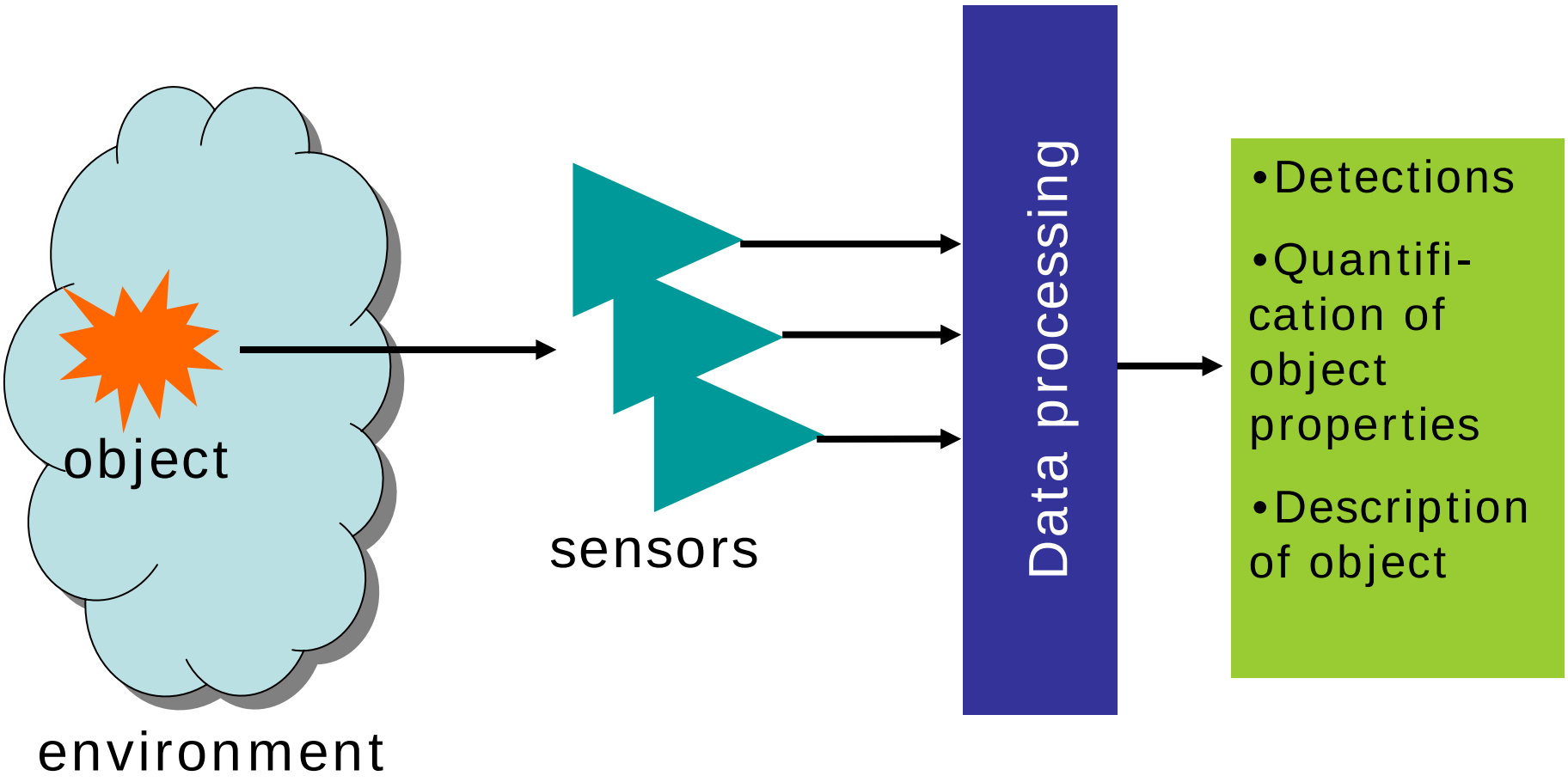
object
environment
sensors
Data processing
•Detections
•Quantifi-cation of object properties
•Description of object

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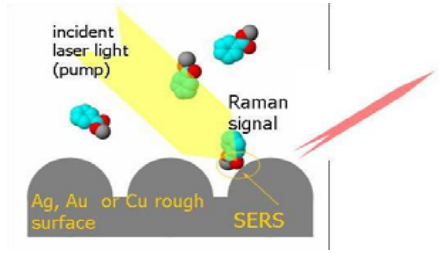
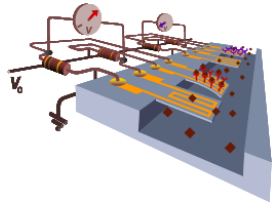
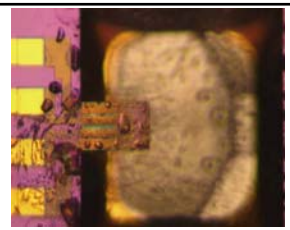
Sensor Technologies

Surface Enhanced Raman Spectroscopy (SERS)	
Cantilever Sensors	
Micro Calorimetric Sensors	
Colorimetric Censor Arrays	

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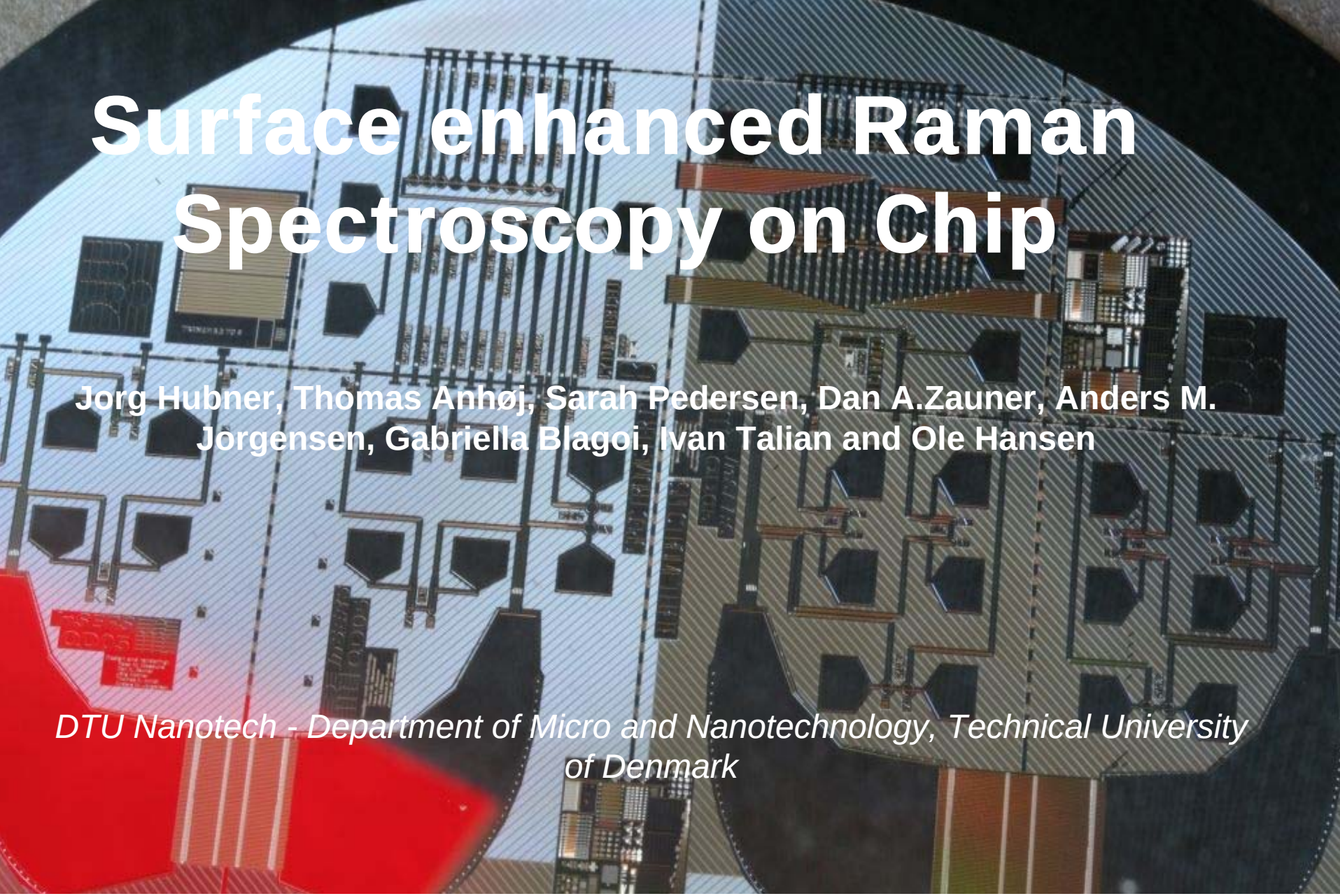
Other Major Activities

- **Sample Preparation / Pre-Concentration**
- **Data Processing and Sensor Networks**

Not considered
•Environment models
•Modeling of explosive transportation and degradation



Surface enhanced Raman Spectroscopy on Chip

Jorg Hubner, Thomas Anhøj, Sarah Pedersen, Dan A.Zauner, Anders M. Jorgensen, Gabriella Blagoi, Ivan Talian and Ole Hansen

DTU Nanotech - Department of Micro and Nanotechnology, Technical University of Denmark

Principles of Raman Spectroscopy

Raman effect:

- Weak interaction between molecule vibrations and light.

- By exposing a molecule or molecules to specific light the molecules starts vibrate and emits a spectrum of light.

fingerprint of a molecule.

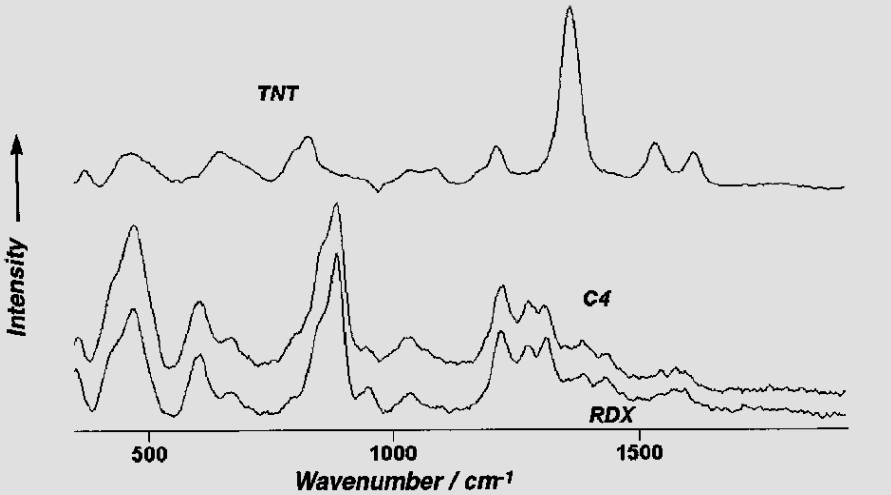
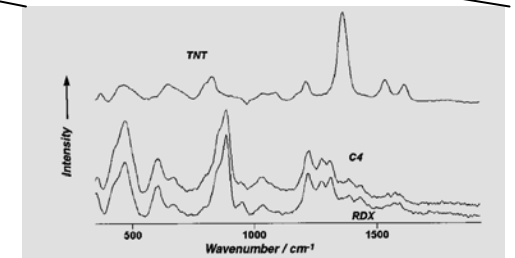


Figure 10. Raman spectra for common explosives TNT and the moldable plastic C4 and for RDX, the explosive ingredient in C4.



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Clarke et al., J. Raman Spectr. 30, 827-832 (1999)

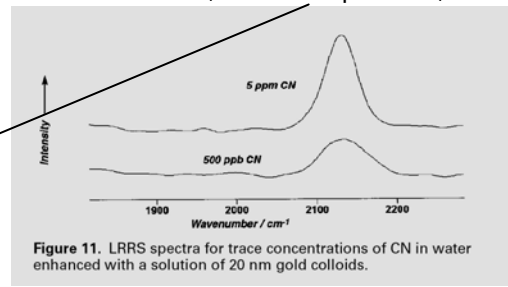


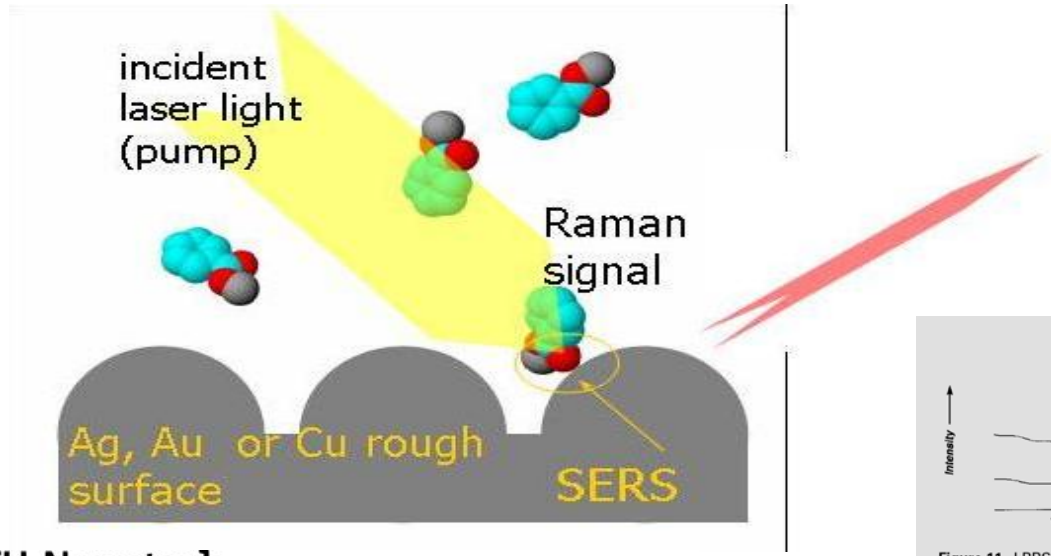
Figure 11. LRRS spectra for trace concentrations of CN in water enhanced with a solution of 20 nm gold colloids.

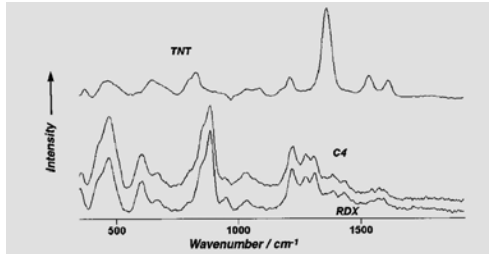
Principles of SERS

Surface Enhanced Raman Spectroscopy:

- To enhance emitted light from a molecule it can be attached to a surface.

- Enhancement of the interaction between molecules and light up to a factor 1.000.000.000 (or more in special cases) can be achieved utilizing a nano structured metal surface.





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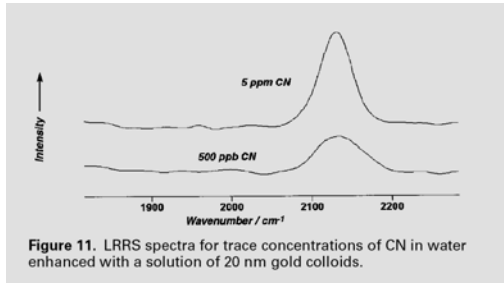

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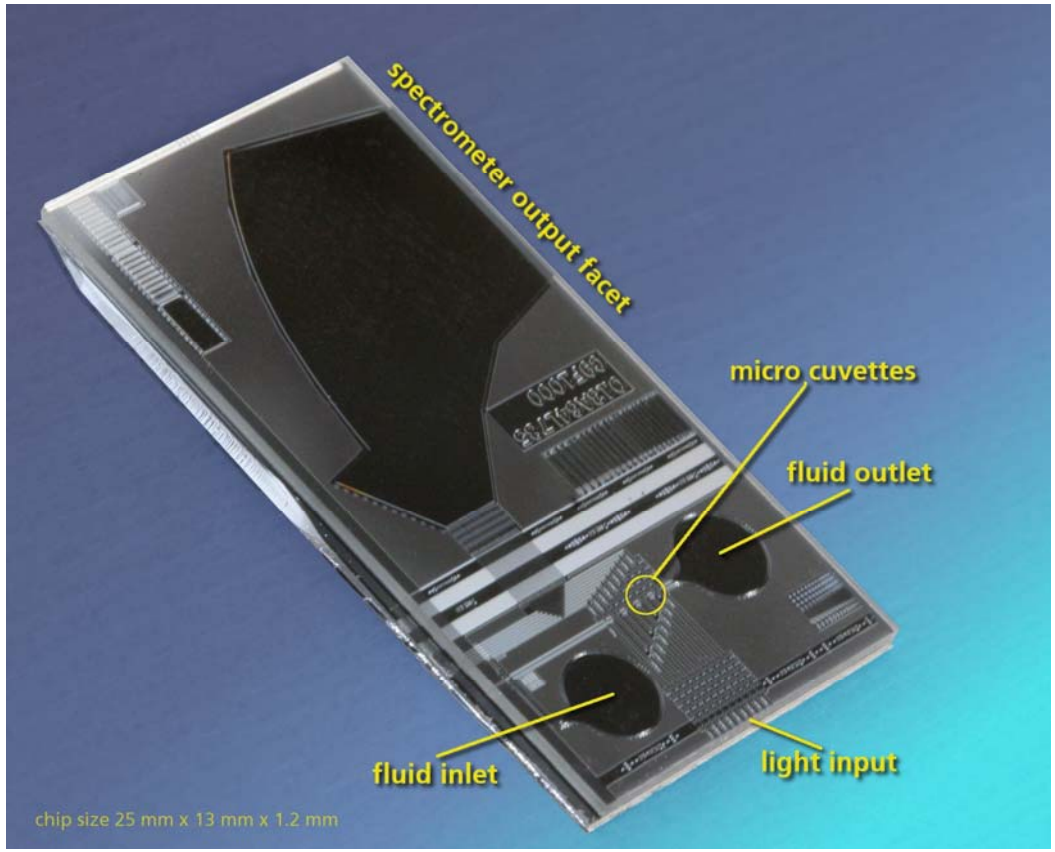
The Spectrometer Chip with Optic and Fluidic Circuitry



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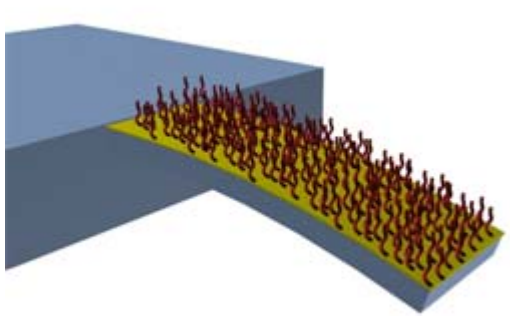
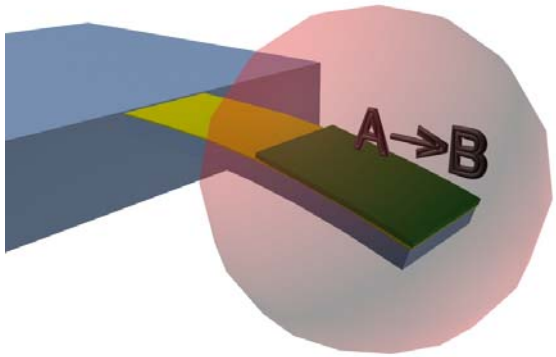
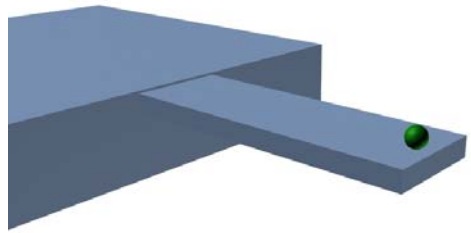
Cantilever Sensors



Change of surface stress



Change of temperature



Change of mass

Gene/Protein detection

Antigen/antibody recognition

Gas detection

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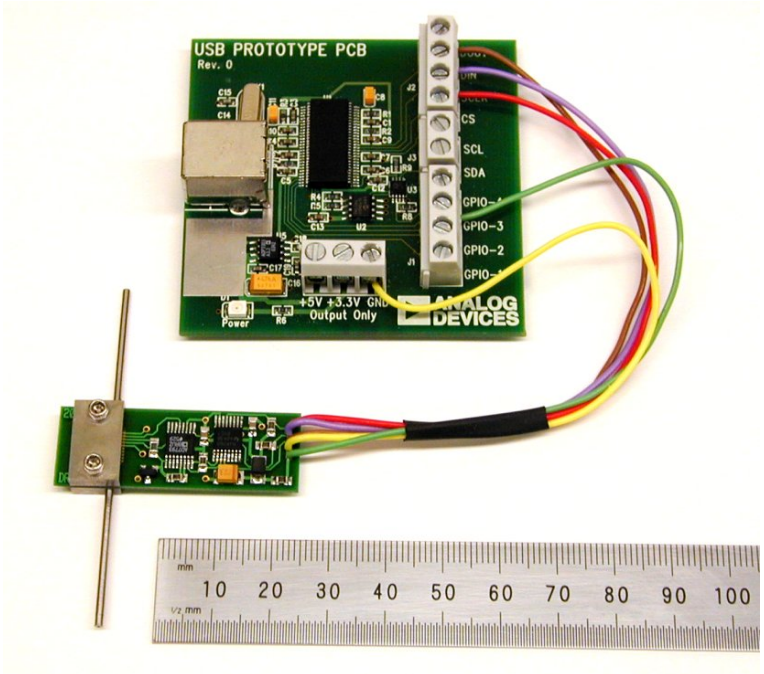
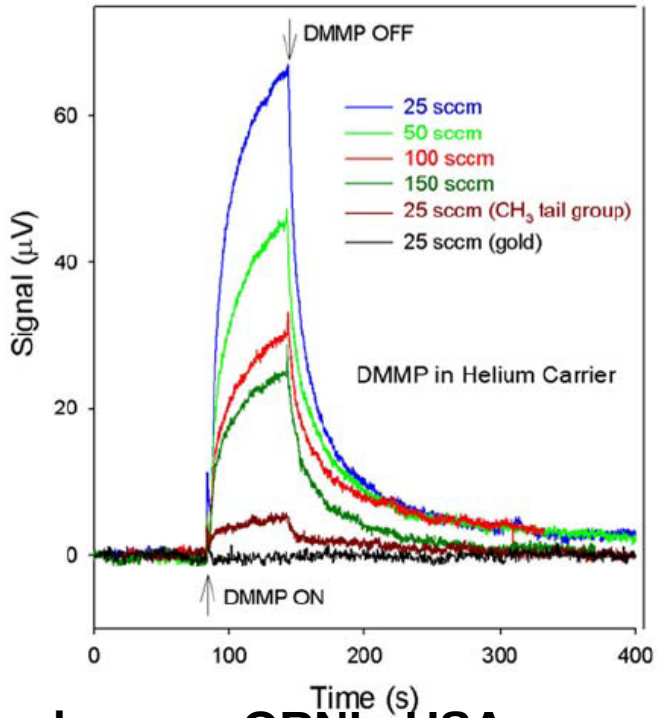
Cantilever Sensors
Detection of Nerve Gas



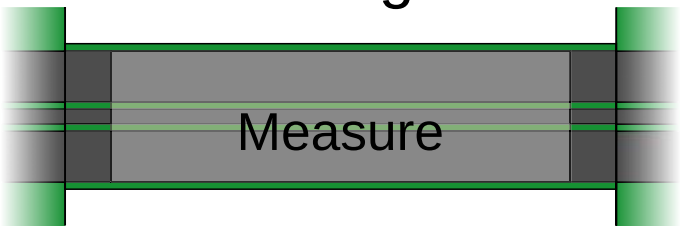


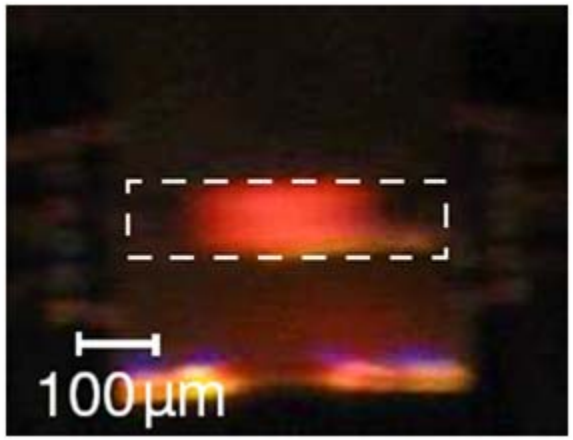
In collaboration with Lal Pinnaduwage, ORNL, USA
The cantilever is coated with 4-mercaptobenzoic acid (4-MBA) SAM

L.A. Pinnaduwage et al, Rev. Sci. Instrum. 78 (2007) 055101.

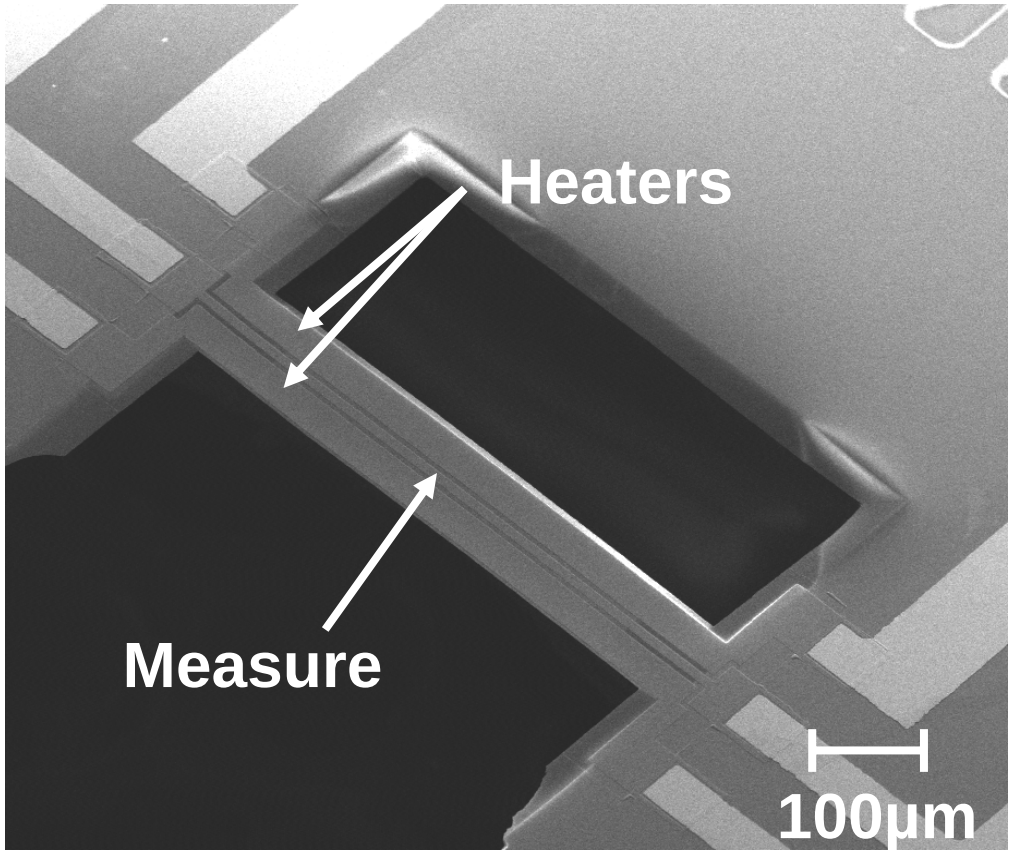
Micro Calorimetric Sensors

Bridge

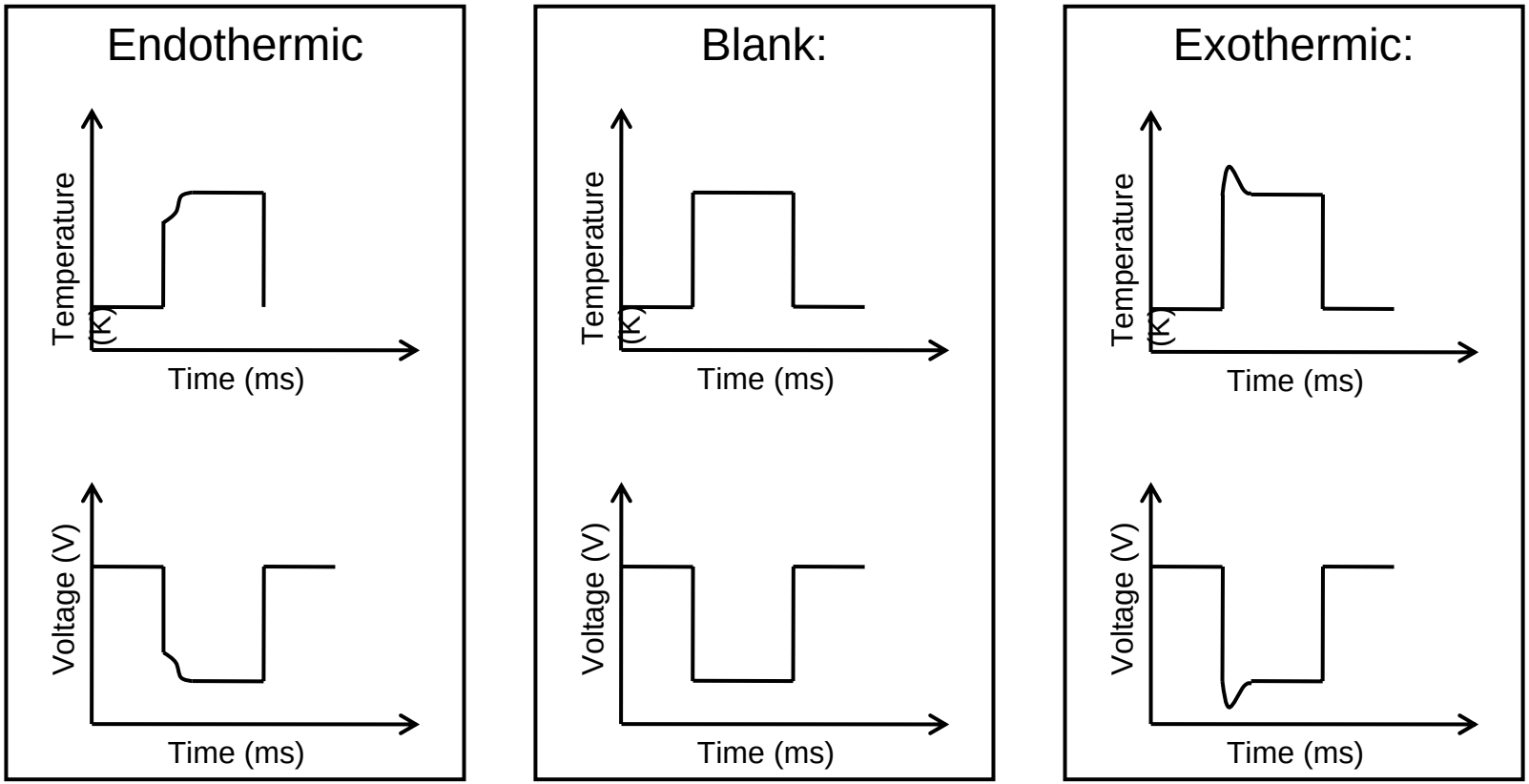




SEM image:

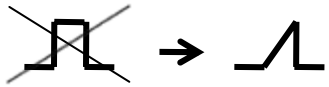


Micro Calorimetric Sensors

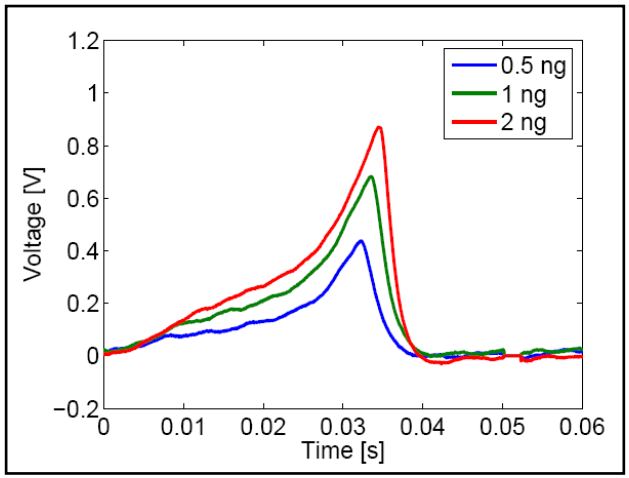


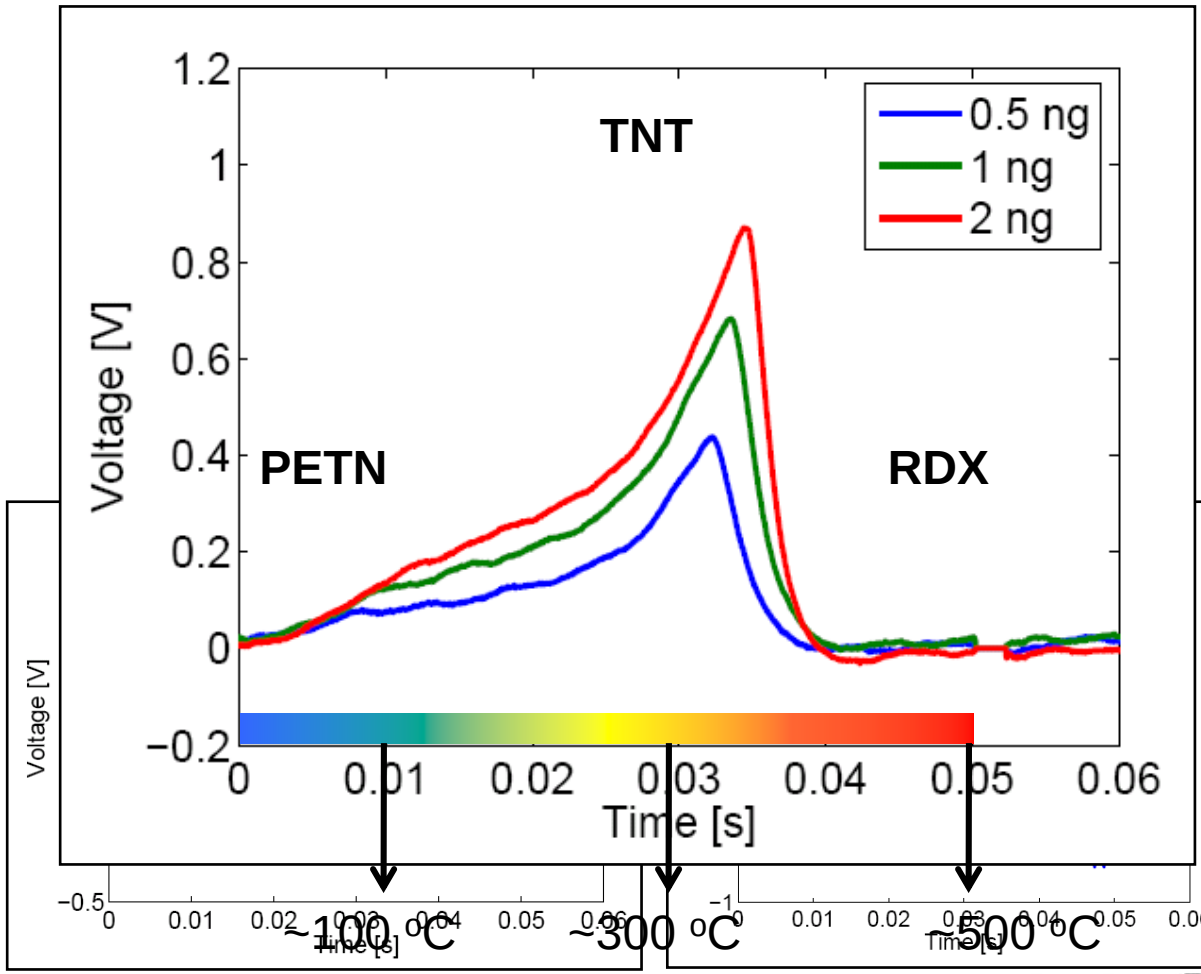
Micro Calorimetric Sensors

Using a ramping pulse instead of a square heating pulse



TNT





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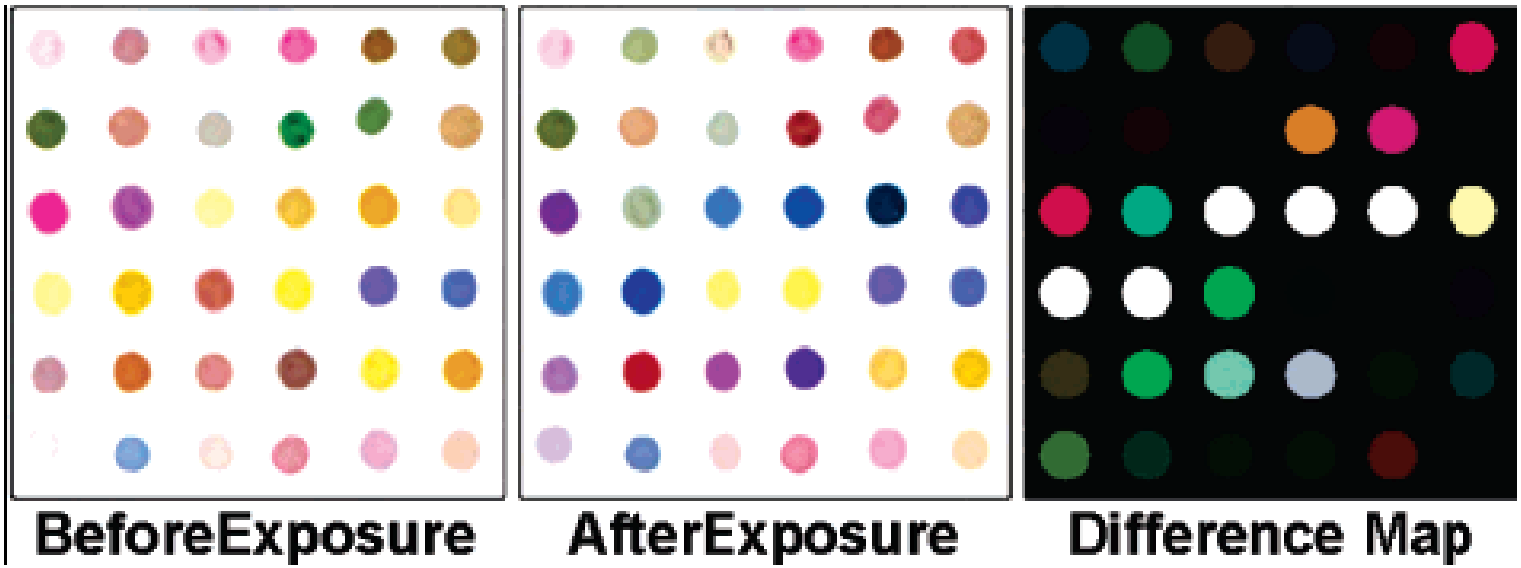
Colorimetric Sensor Arrays



A colorimetric sensor array of chemoresponsive dyes

1. **Before exposure to volatile organic compound (VOC)**
2. **After exposure**
3. **Color difference map**

Anal. Chem. 2006, 78, 3591-3600

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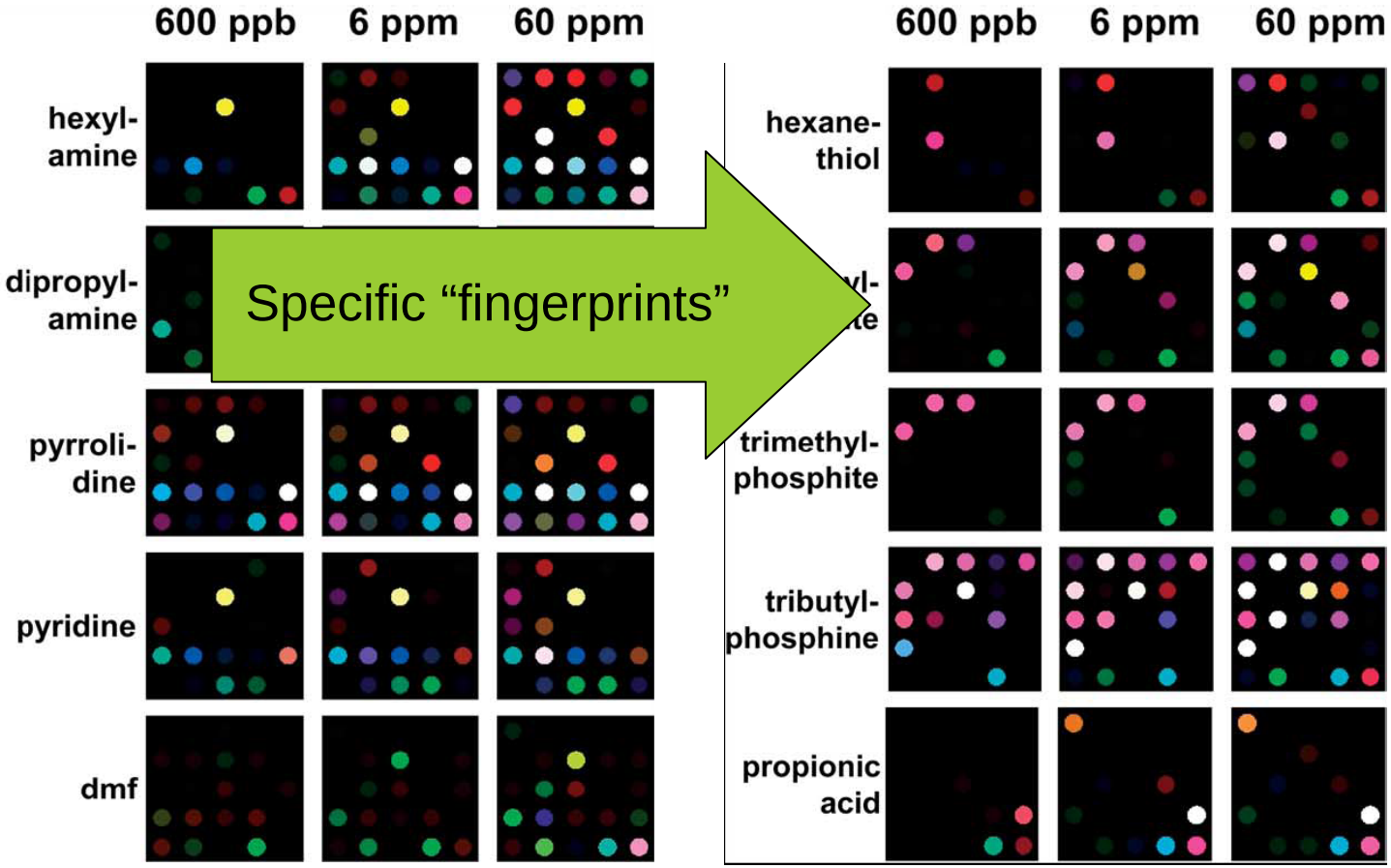
Colorimetric Sensor Arrays



K. S. Suslick et al. / Tetrahedron 60 (2004) 11133–11138

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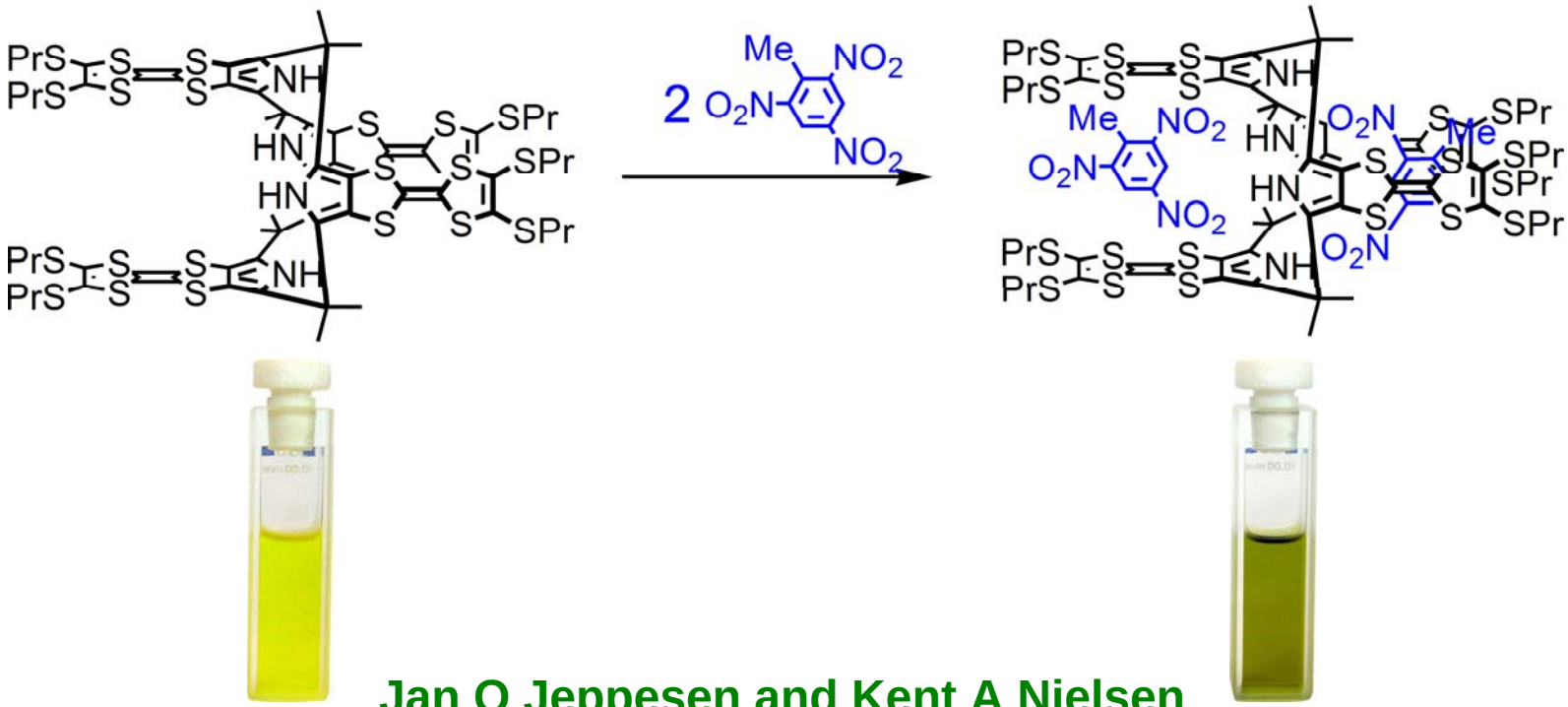
Colorimetric Sensor Arrays



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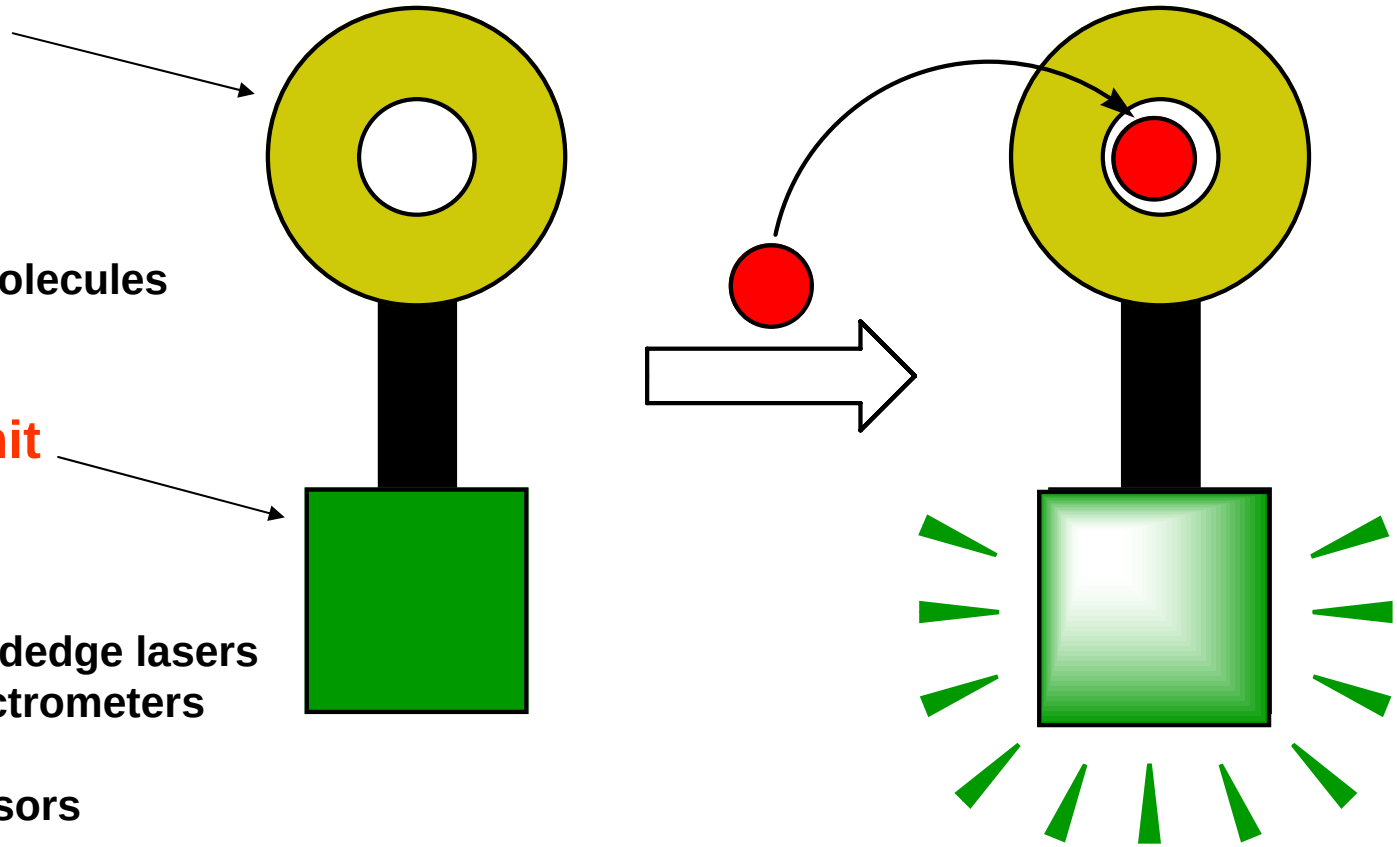
Sensor Functionalization

A Receptor Unit

- Antibodies
- Proteins
- Enzymes
- Peptides
- Chemoresponsive molecules
- Polymers

A Transducer Unit

- Cantilevers
- Flappers
- Disc resonators
- Photonic crystal bandedge lasers
- Optical sensors/spectrometers
- SERS surfaces
- Electrochemical sensors
- Magnetic sensors



Change in Physical Properties

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Data Processing

- Signal processing: optimal preprocessing of individual sensor data
  - noise reduction
  - feature extraction
  - feature selection
- Data and sensor fusion
  - Learning based optimal nonlinear combination of sensor data
  - Outlier detection
  - Robustness against environment changes
  - Integration of context info
  - Time integration

Increased sensitivity

Increased specificity (lower false positive) and robustness/reliability

Thank you for your attention