Change of the paradigm: chemical sensors with additional integrated functions

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Running projects:

1. FP7 - NANODETECTOR “Ultrasensitive plasmonic detection of single nanoparticles” (EC, 10 EU partners, Coordinator)

2. Network - POLYCON “New materials and devices on the basis of conducting polymers and composites” (German Ministry for Science and Education, 7 EU partners, Coordinator)

3. New principle for SPR-transducers (Brandenburg Ministry for Science, Culture and Education)

In preparation / evaluation: H2020 and national projects on further development of NANODETECTOR-technology, new chemosensitive conducting polymers, chemosensitive electrochemical transistors

Main directions of our scientific work:

1. Development of **transducing principles** for chemical sensors and biosensors: optical (*SPR, SPR-imaging*), electrochemical / impedometric (*capacitive, electrochemical chemotransistors*)

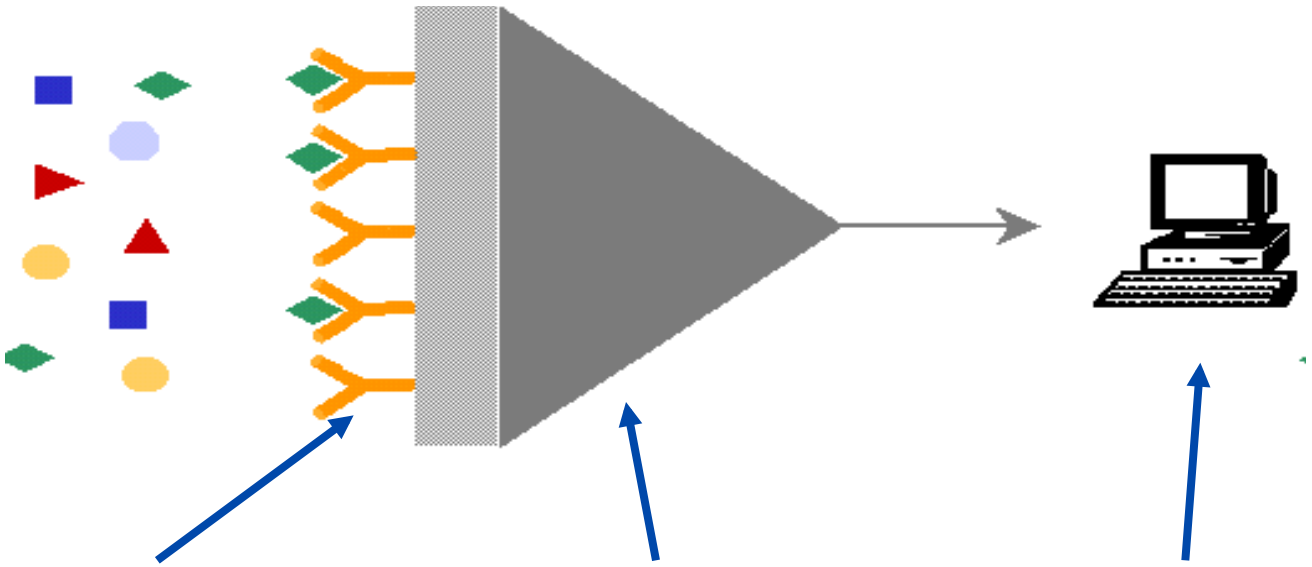
Recent results:

- SPR-sensors with integrated self-referencing
- Chemosensors with ajustable afinity
- Direct (real-time) observation of adsorption of single nanoparticles

2. Sensor-relevant surface technologies: immobilization of biomolecules and nanoparticles (*covalent, Layer-by-Layer deposition, self assembly, microstructured receptor layers, …*), artificial receptors (*MIP, nanostructured surfaces*)

3. Numerous applications

General structure of chemosensors:



Receptor → Transducer → Signal processing

Note: well defined distribution of functions

Examples of additional functions which were / can be introduced into the transducer

- Internal integrity control
- Boolean logics
- Affinity control
- Integrating referencing
- Combination with other analytical techniques (Raman or FTIR, electrochemistry, …)
- Visualization of analyte – receptor interaction

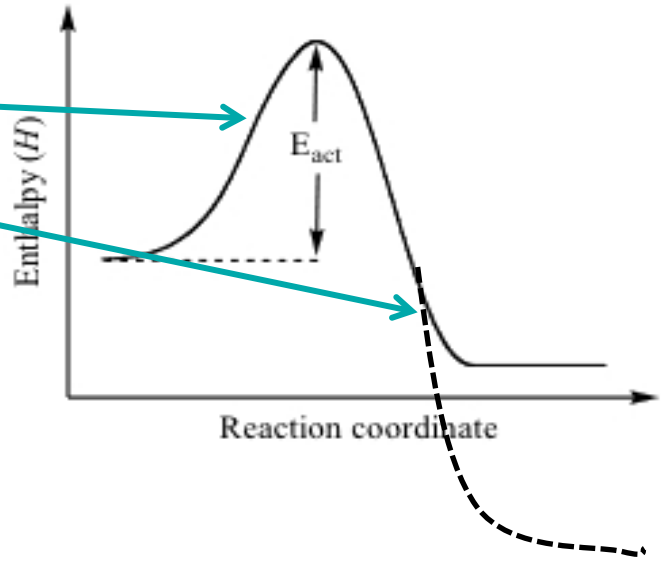
Example 1. Motivation and realization of integration of affinity control

Motivation:

1. Minimization of a physical number of sensor elements in sensor arrays

2. Improvement of sensor recovery

$$K_{binding} = \frac{k_{ads}}{k_{des}}$$



High sensor sensitivity and selectivity require

a receptor with a high value of $K_{binding}$

It is a rather seldom case when both k_{ads} and k_{des} are large

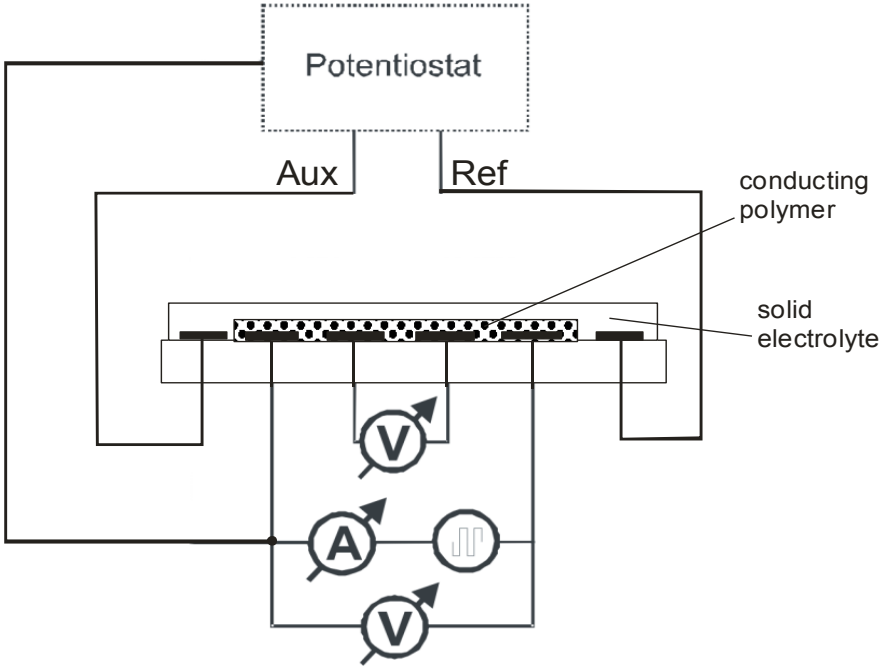
Therefore, high value of $K_{binding}$ correlates usually with low k_{des}

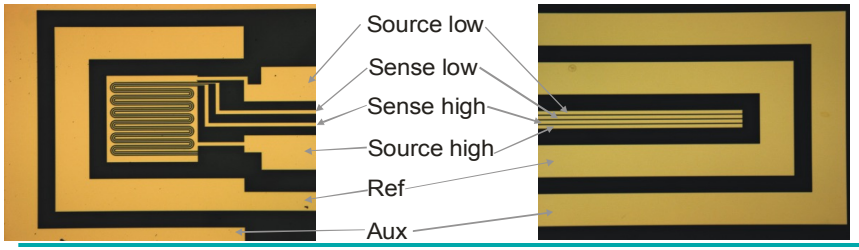
The consequence: poor sensor recovery

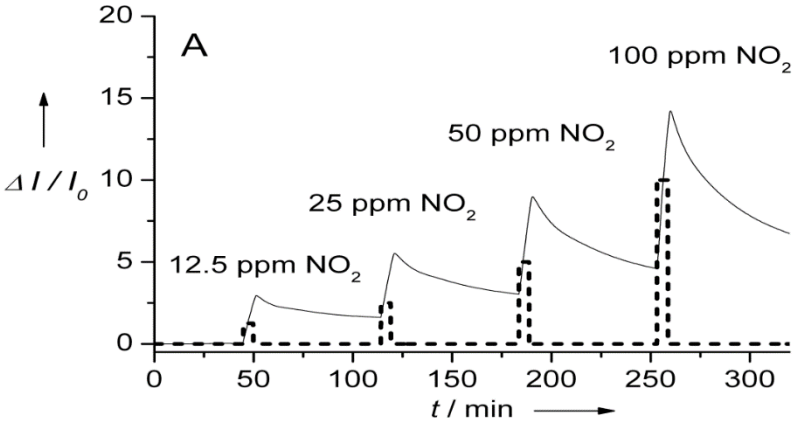
Example 1. Motivation and realization of integration of affinity control

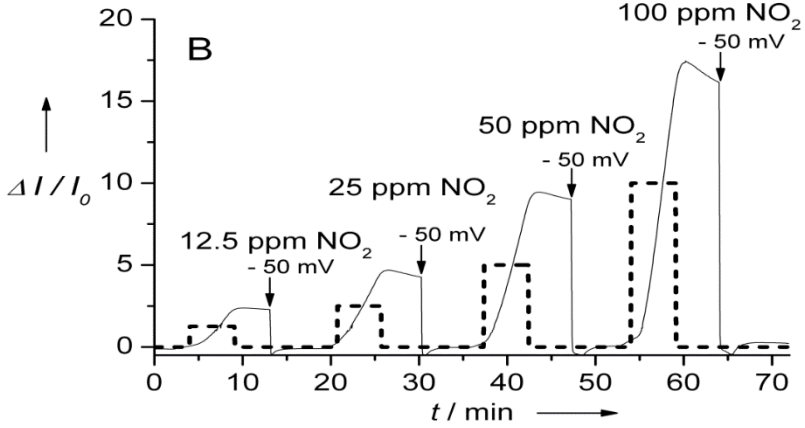
Realization:

Chemosensitive electrochemical chemotransistor









Example 2. Visualization of analyte – receptor binding

SPR detection of single nanoparticles on the receptor surface

Why?

- extremely high sensitivity (single nanoparticles)
- direct detection, almost no freedom (=no doubts) in data interpretation
- a possibility to integrate with other techniques

movie

There is strong discrepancy between scientific development of chemical sensors and their acceptance in industry

- Science:
  - thousands of publications
  - dozen of journals
  - sensors for almost all possible analytes

- Industry (incl. medicine, environmental monitoring, etc.)
  - sensors for very few analytes are used (glucose, lactate, O_2, CO_2, Hg and few more)
  - no commercial sensors even for some practically important analytes (TCP, HCl)

- Why?
  - In the most publication a sensor principle rather than a sensor as a device is presented
  - Non-unified and not-compatible sensing platforms
  - In many cases - poor quality (low sensitivity, low life-time stability)
  - There is a high risk to use a single parameter for a decision

Why within Horizon-2020 and at European level?

- A development of new sensors is a multidisciplinary task and includes a number of task which are wide out of the direct topic of sensor preparation. For example, it may include:
  - complicated organic synthesis (i.e., synthesis of new receptors)
  - preparation of transducers using photolithography (in some cases - electron beam lithography)
  - sophisticated image analysis
  - development of software
  - advanced optical techniques
  - surface chemistry
  - surface characterization
  - microfluidics
  - commercialization

It is typically impossible to find this competence in one country.

- Development of new sensors belongs to the high-tec field of science => indirect positive effect of this cooperation on the fields of science which are essentially wider than the particular tasks of collaborative projects.

- The program mechanisms allows to include industry and to follow industrial needs

Few examples of the most needed sensors

- sensors for detection of single nanoparticles allowing chemical identification (Nanosafety!)
- sensors for fast detection of single viruses or spores in liquids and in air
- sensors for cabin toxins (TCP and others) for airplanes
- general ultrasensitive platforms for bioanalytics (express methods to replace ELISA)
- sensors for epigenetic applications (analysis of DNA- methylation)
- …

Suggestions for EC-support

- Comparison, critical analysis and unification of sensing platforms (CA or NoE)
- Analysis of the discrepancy between industrial needs and science and actions to minimize it (CA)
- Particular calls on sensors for the most important analytes (Collaborative projects)
- Organization of European infrastructure for sensor developments (labs working on organic synthesis, microfluidics, microsystem technique, …)
- Organization of a [sub]-cluster „Sensors“ to coordinate this activity. Today we need:
  - Definition of the field (only chemo/biosensors or also physical sensors?)
  - Definition of possible tasks
  - Distribution of responsibility
  - Planning of the next action

Thank you for attention!