Laboratory for Chemical Sensors and Biosensors, University of Applied Sciences Aachen, Jülich Campus (in collaboration with Research Centre Jülich, FZJ)

The Laboratory for Chemical Sensors and Biosensors has been founded about seven years ago by Prof. Dr. Michael J. Schöning and has acquired a well-established international reputation in sensor sciences and technologies. The research activity of the Laboratory covers a broad range of scientific, engineering and technological topics of semiconductor-based (bio-)chemical sensors at macro-, micro- and nanoscale level, employing multi-disciplinary approaches to their development and application. The main research activities are focusing on the development of semiconductor field-effect-based (bio-)chemical sensors sensitive towards various ions and analytes by applying different transducer platforms, like capacitive EIS (electrolyte-insulator-semiconductor) structure, ISFET (ion-sensitive field-effect transistor) and LAPS (light-addressable potentiometric sensor). Some examples of recent key developments and current topics of the research activities are listed below. For more detailed information, see also: www.fh-juelich.de/biosensorik.html.

<u>1) (Bio-)chemical sensors for environmental, food industry and medical applications:</u>

- catheter-type ISFETs for determination of pH in rain droplets and in urine probes,
- a cleaning-in-place (CIP)-suitable EIS pH-sensor,
- heavy metal (Pb^{2+}, Cd^{2+}, Cu^{2+}, Tl^{+}, etc.) single sensors and sensor arrays based on thin-film chalcogenide glass materials prepared by pulsed laser deposition technique,
- a highly sensitive, low detection limit and long lifetime (>250 days) penicillin-sensitive ISFET and EIS sensor, a capacitive EIS sensor for monitoring organophosphorous pesticides in aqueous solutions, and enzyme-modified EIS sensors sensitive to alliin and cyanide,
- a handheld 16 channel pen-shaped “chip-card” LAPS with integrated signal processing unit for multi-sensor and chemical imaging applications,
- EIS sensors and ISFETs for the label-free detection of charged biomolecules, and biosensors based on intact chemoreceptors (beetle/chip sensor).

<u>2) Integration of field-effect sensors with microfluidic platforms for multi-parameter detection:</u>

- a modular concept and so-called “(bio-)chemical and physical sensing using the same transducer” approach has been applied to develop an ISFET-based multi-parameter sensor-system for the detection of three (bio-)chemical (pH, K^{+} and penicillin) and five physical quantities (temperature, flow velocity, flow direction, diffusion coefficient of ions and liquid level) using only four ISFETs and an ion generator; here, the ISFET, which is known as a (bio-)chemical sensor, also serves as a physical sensor,
- capacitive EIS sensors and a thin-film ion-generator have been integrated on wafer level together with a micromachined flow-through microcell by combining Si and SU-8 technologies; the microcell with the integrated EIS sensor has been tested in flow-through and FIA (flow-injection analysis) modes for multi-parameter detection as well as in LAPS configuration for visualisation of test samples injected into the microchannel; in addition, a thick-film miniaturised reference electrode was integrated together with a thin-film pH sensor on one single chip.

Advanced technologies for (bio-)chemical sensor preparation:

- the PLD (pulsed laser deposition) technique has been successfully applied for the fabrication of long-term stable pH-sensitive Al_2O_3- and Ta_2O_5-gate EIS sensors as well as for thin-film chalcogenide-glass heavy-metal microsensors and sensor arrays; besides the compatibility with silicon planar technology, the main advantage of this method is the controlled deposition of multi-component compositions in a defined stoichiometry,
- porous silicon has been applied as biocompatible substrate material for pH-sensitive and enzyme-modified capacitive EIS sensors and LAPS as well as for the study of the interface living cells/Si; in addition, the increase of the sensor surface provides an increased capacitance value that is essential for a further miniaturisation down to the µm scale,
- nanostructuring using conventional photolithography and layer-expansion technique combines a strategy for the fabrication of different nanostructures and nano-sensors (nano-gaps, nano-electrodes, nano-channels, etc.); this technique is based on the conversion of a photolithographically patterned metal layer to its metal oxide; nanometer-scaled structures (even <10 nm) with different layouts at both the laboratory and mass-production level can be achieved.