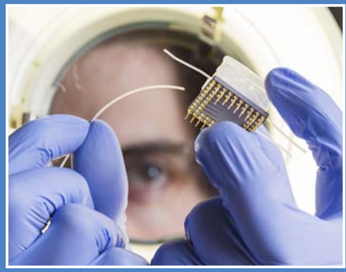
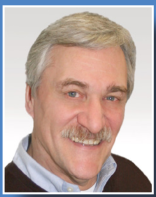
NanowireSensor

INTEGRATEABLE SILICON NANOWIRE SENSOR PLATFORM



Prof. Christian Schönenberger, Uni Basel



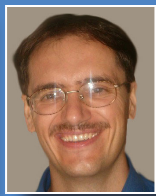
Prof. Beat Ernst, Uni Basel

Prof. Jens Gobrecht, PSI

Prof. Andreas Hierlemann, ETHZ

Prof. Adrian Ionescu, EPFL

Prof. Uwe Pieles, FHNW



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What it's about…

Exploiting the potential of electronic components, similar to the ones used in state-of-the-art integrated circuits, for biochemical sensing.

Context and project goals

Today electronics provides the means for complex computing and drives the communication society. The availability of electronics has been enabled to a large extent by integration technology. In analogy to electronics the same concept of integration is today pursued in analytics and chemical synthesis. These "labs on chips", as they are called, will enable better and faster medical diagnosis. Silicon-based electronic components for biochemical sensing, as they are developed in this project, are crucial elements for such chips.

How the project differentiates from similar competition in the field

The NANOWIRE SENSOR team is a highly interdisciplinary group of researcher working in physics, system biology, pharmacy, engineering, nanotechnology and surface chemistry. The projects covers all elements from basic science to system integration.

Quick summary of the project status and key results

In the NANOWIRE SENSOR project arrays of silicon nanowire (NW) field-effect transistors (FETs) were fabricated on a wafer scale. They are realized as double-gated SOI (silicon on insulator) FETs and FinFETs. The NW-FETs are of high quality displaying reproducible threshold voltages, low sub-threshold swing and low noise. Si-NWs were passivated with an ALD-deposited top-oxide made of Al_2O_3 or HfO_2 for their use in electrolytes. They passivated NWs display low leakage current and high gain in pH measurements with sensitivities close to the Nernst limit. A CMOS readout chip has been realized and electrically validated by reading an array of 16 wires in parallel. The fully integrated system provides a measured resolution of 12 bits and a response time of less than 0.2s in pH test experiments. The consortium has greatly expanded the knowledge on the NW liquid interface by studying the surface potential as a function of ion concentration. A milestone is the successful demonstration of differential measurements with NWs on the same chip that are functionalized differently, as well as the combination of NW-FETs for amplification. The differential measurement greatly increases the long term stability. The sensing experiments were also expanded to lectin proteins.

Success stories

Awards

S. Rigante, P. Scarbolo, D. Bouvet, M. Wipf, A. Tarasov, K. Bedner, and A.M. Ionescu, "High-k dielectric FinFETs towards Sensing Integrated Circuits", oral presentation at International Conference on ULTIMATE INTEGRATION ON SILICON, ULIS 2013, Warwick, United Kingdom, awarded as Best Paper (talk).

The consortium continued on the successful demonstration of differential measurements with an array of nanowire (NW) sensors with different functionalization. Building on potassium sensing demonstrated earlier in the project, the team has now realized a sodium ion sensor using the same platform.

The NANOWIRE SENSOR team has early on stressed on the importance of the low frequency noise determining the resolution limit of the sensor. Recently, the team could prove that the 1/f noise in silicon NW ion-sensitive FETs with ALD top-oxide layers originates from trap state fluctuations within this layer and is not caused by dielectric polarization noise. Most recently, it could be shown that the quaility of this oxide layer can further be improved by using a multilayer stack yielding devices with less noise and higher resolution. In this area, but also with the differential and integrated sensing mentioned before, the NANOWIRE SENSOR project has defined the state-of-the art worldwide.

During the whole period the project was monitored by the company Sensirion whose success in their sensing business in the area of mass flow and humidity builds on the capability of integration using CMOS components. Although Sensirion's market is not in ion-sensing, the company could profit from the insight gained within this project, and vice versa, all academic partners and the project gained immensely from the industrial input. Sensirion views this project a scientific success. However, the project has not yet matured to a product, but it has the potential to do so in the near future if research could be continued. The highest potential is in the simultaneous measurements of different ions for chemical and biochemical applications.

Main publications

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