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UNI BASEL

A Biochemical Sensor Based on an ISFET Platform

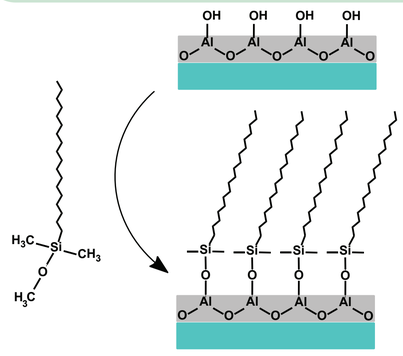
M. Wipf, R.L. Stoop, G. Navarra[a], A. Tarasov, K. Bedner[b], W. Fu, M. Calame, C. Schönenberger
Department of Physics, University of Basel, Switzerland, [a]Pharmazentrum, University of Basel, Switzerland, [b]Paul Scherrer Institut, Villigen, Switzerland

nanowire sensor

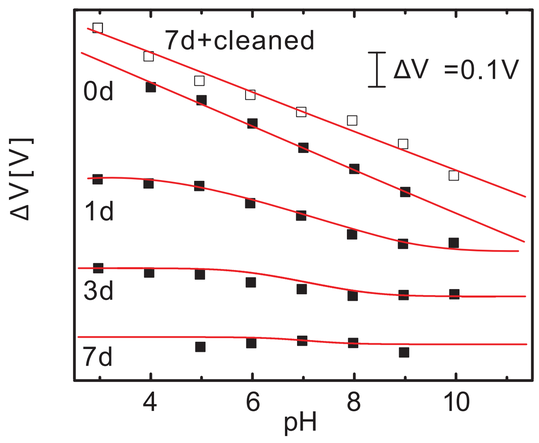
Abstract

Ion-sensitive field-effect transistors (ISFETs) based on silicon nanowires (SiNW) have attracted substantial interest for various chemical and biochemical sensing applications. [1-3] High dielectric constant gate oxide materials such as Al_2O_3 and HfO_2 are known to display surface hydroxyl groups at a high density leading to a high response to pH variations. [4-5] However, for chemical and biochemical sensing, the density of surface hydroxyl groups needs to be reduced, since their non-selective response to anions as well as the competing surface reactions with protons greatly complicate the selective sensing of other species than protons. [6] Using gold as surface material we have developed a versatile sensing platform. We demonstrate its potential by implementing arrays for the selective sensing of various ions such as Na^+, Ca^{2+}, F^- as well as FimH proteins.

Surface Passivation [5,†]



Vapor deposition of a silane with a long alkyl chain (C18) was used to passivate the Al_2O_3 surface and make it insensitive to protons.



A fully passivated NW could be used as pH reference electrode

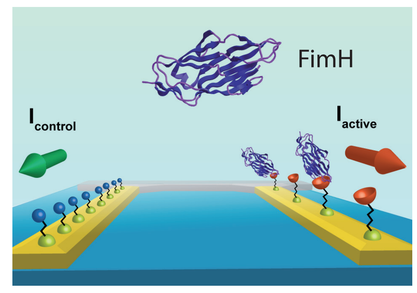
The pH response of several samples was tested, showing a decreasing pH sensitivity with increasing surface coverage.

The site-binding model was used to fit the data. The number of hydroxyl surface sites N_s was extracted from the fits.

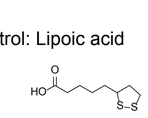
A reduction of N_s by three orders of magnitude is achieved after a reaction time of 7 days, resulting in a pH insensitive surface.

Biosensing: FimH Protein [‡]

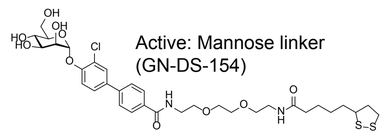
Detection and quantification of biological species are central to many areas in healthcare.
We use gold-coated nanowires functionalized with a Mannose linker to detect FimH lectin, a protein involved in urinary tract infections. FimH enables bacterial adhesion to epitelian cells as the initial step of infection.

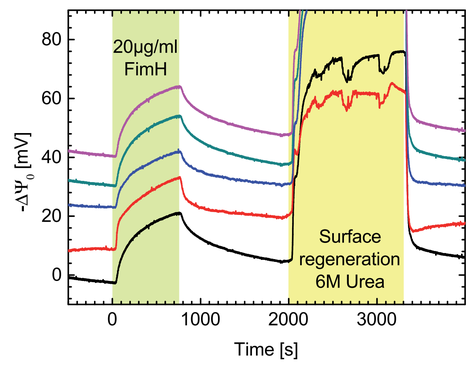


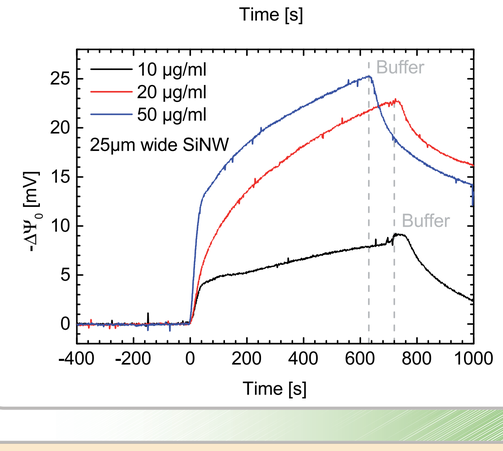
Control: Lipoic acid



Active: Mannose linker (GN-DS-154)

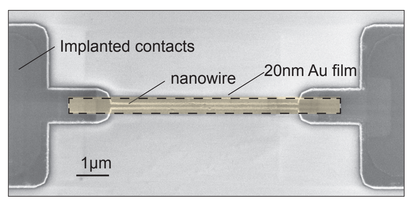


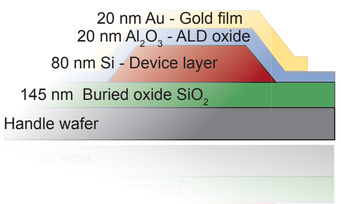




Differential Measurement [7,¶]

The intrinsic non-selective sensitivity of oxide surfaces greatly complicates the selective sensing of ionic species other than protons. Hence, we modify individual nanowires with thin gold films as a novel approach to surface functionalization for the detection of specific analytes.



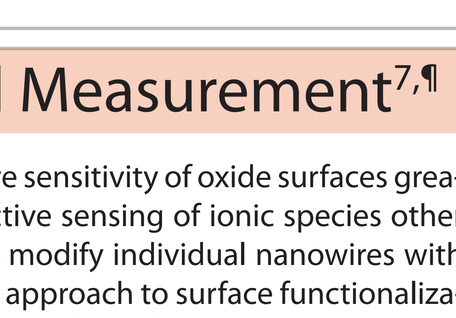


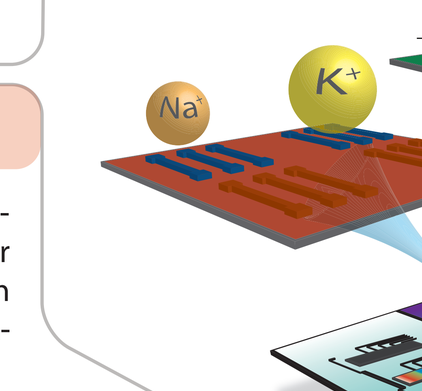
Similar to oxides, gold surfaces show a response to background ionic species, but are only slightly sensitive to protons.

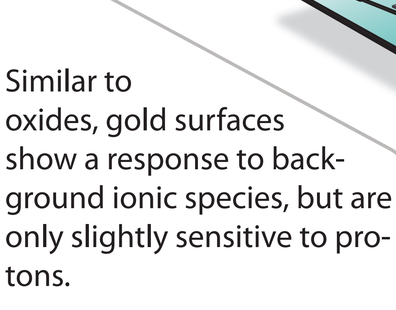
With the site-binding model we estimate the number of hydroxylated gold surface atoms to be only ≈1%.

We demonstrate Na^+ sensing by a self-assembled monolayer of thiol-modified crown ethers in a differential measurement setup. A sensitivity of ≈-44mV per decade in a NaCl solution is achieved by measuring the difference between a functionalized nanowire and a nanowire with a bare gold surface.

The SAM does not affect the unspecific response of gold to pH and background ionic species. This makes it an ideal system for differential measurements.

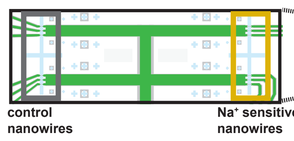


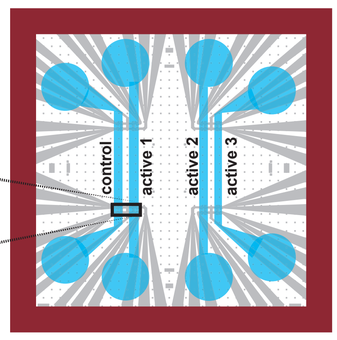


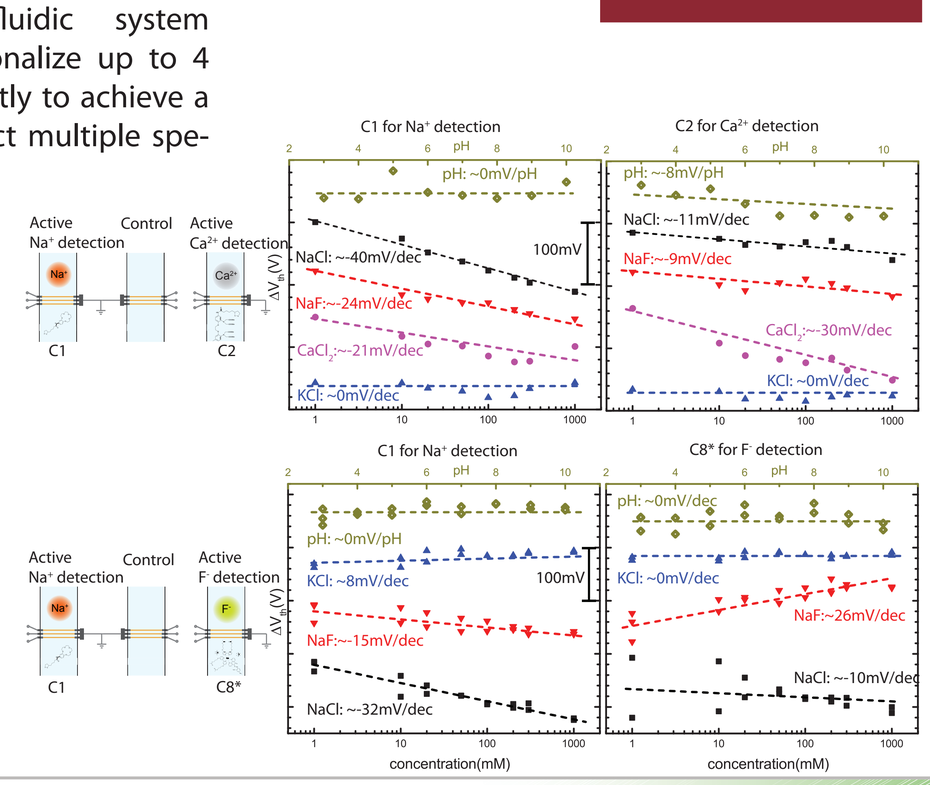


Multi Ion Detection [¶]

Using the differential approach, successfull sodium (Na^+), calcium (Ca^{2+}) and fluoride (F^-) detection has been demonstrated. The developed microfluidic system allows to functionalize up to 4 channels differently to achieve a platform to detect multiple species.







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[6] A. Tarasov et al., ACS nano 6, 9291-9298 (2012).
[7] M. Wipf et al., ACS nano 7, 5978-5983 (2013).
[†] In collaboration with: J. Kurz, J. Grognux, U. Pieles, FHNW
[‡] In collaboration with: G. Navarra, A. Odedra, B. Ernst, Pharmazentrum
[¶] In collaboration with: I. A. Wright, C. J. Martin, E. C. Constable, Dep. of Chemistry, Basel