Nanowires for Biomolecule Detection

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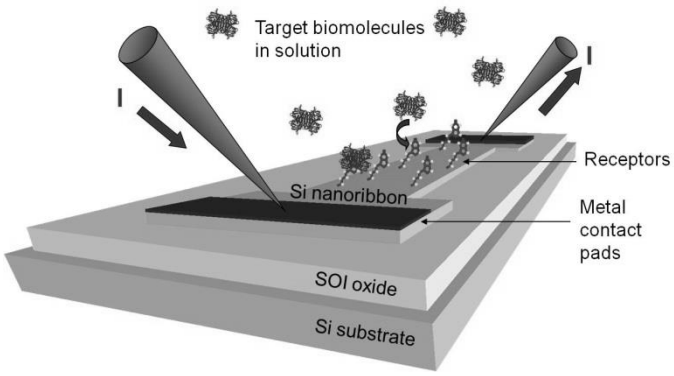
There is an increasing demand for portable sensor systems in health care that enable on-site analyses e.g. at local medicare centers, in ambulances or even at home. Semiconductor nanowires offer a highly sensitive and label free detection principle for biochemical applications that makes it possible to scale down the size of complete analysis systems. In particular silicon nanowires, making use of current CMOS technology, offer multiple parallel detection of a large number of different biomolecules such as proteins or DNA strands. Thus, silicon nanowire devices show great potential in effectively providing rapid on-site detection to avoid costly laboratory analyses.

The mechanism for sensing can be explained by charging effects when target molecules hybridize with antibodies/probes bound to the nanowire surface. This induces a depletion or an accumulation of carriers in the nanowire resulting in a change in current which can be detected. The nanowire then, in principle, works as a MOS transistor with an open gate in close proximity to the functionalized surface. This provides an internal gain mechanism that allows even small changes of the surface to be sensed. As a result, very high sensitivity can be achieved approaching the femto-molar (10^{-15} M) range. Indeed, for a model system (biotin/streptavidin) with high affinity, we have demonstrated a sensitivity approaching ~20 target molecules (Elfström et al., Nano Letters 8, 945, 2008). This sensitivity may possibly be extended to the single molecule level.

In this talk I will review the progress in the field towards biomolecule electrical sensing using nanowires. I will also describe our own work towards a multiple detection biochip using CMOS technology in combination with on-chip microfluidics. Finally, I will point out the many hurdles to overcome requiring a detailed understanding both of the physics involved as well as of the chemistry, electrochemistry and biochemistry. Examples are various types of instabilities, the screening of molecule charges by the charges of the ionic buffer solution, the electrochemistry of the oxide surface in combination with the counter electrode etc. These difficulties need to be overcome and have so far delayed commercialization of nanowire sensors.



Schematic of a silicon nanowire, defined from the top silicon layer of an SOI wafer, functionalized with a receptor molecule for sensing of a specific target molecule

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